AN INVESTIGATION OF THE INCREASE IN VARIABILITY OF STANDARD PENETRATION TEST RESULTS FOR GRAVELLY SOILS

A THESIS SUBMITTED TO

THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

OF

MIDDLE EAST TECHNICAL UNIVERSITY

BY

ALPER PEHLIVAN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR

THE DEGREE OF MASTER OF SCIENCE

IN

ENGINEERING SCIENCES

SEPTEMBER 2019

Approval of the thesis:

AN INVESTIGATION OF THE INCREASE IN VARIABILITY OF STANDARD PENETRATION TEST RESULTS FOR GRAVELLY SOILS

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ABSTRACT

AN INVESTIGATION OF THE INCREASE IN VARIABILITY OF STANDARD PENETRATION TEST RESULTS FOR GRAVELLY SOILS

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September 2019, 107 pages

Variability in the results of standard penetration tests (SPT) due to nonuniformity of particle size distribution in soil layers is a known issue in geotechnical applications. Such phenomenon may result in artificial increase in penetration resistance in silts, clays and sands due to encountering large particles. An analysis of SPT variability in such cases can be conducted by dividing the total penetration distance into two smaller segments. In this study, the difference between number of blow counts for the second 15 cm penetration and that for the third 15 cm blow counts is used for analyzing the variance. Furthermore, possible statistical limits for the range of reasonable differences are derived to enable the detection of any artificial increase in SPT blow counts due to the existence of gravel or larger sized particles. Determination of such limits allows a correction for the SPT blow count to be used for estimation of geotechnical parameters. In order to ensure that the analyses conducted on the SPT results are not biased by the possible errors due to equipment and procedural variabilities, all the samples investigated in this study are based on a dataset of tests conducted by the same equipment and operators.

Keywords: SPT, Variability, Gravel, Correction, Plugging

ÖZ

ÇAKILLI ZEMİNLERDE STANDART PENETRASYON TESTİ SONUÇLARININ DEĞİŞKENLİĞİNDEKİ ARTIŞIN BİR İNCELEMESİ

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Tez Danışmanı: Doç. Dr. Mustafa Tolga Yılmaz

Eylül 2019, 107 sayfa

Zemin katmanlarındaki dane büyüklüğü dağılımının çeşitliliği nedeniyle standart penetrasyon testleri (SPT) sonuçlarındaki değişkenlik, geoteknik uygulamalarda bilinen bir sorundur. Bu olay, siltlerde, killerde ve kumlarda, büyük daneli parçacıklar ile karşılaşılıp penetrasyon direncinde yapay bir artışa neden olabilir. Bu gibi durumlarda SPT değişkenliğinin bir analizi, toplam penetrasyon mesafesini iki küçük parçaya bölerek yapılabilir. Bu çalışmada, ikinci 15 cm'lik penetrasyon için darbe sayısı ile üçüncü 15 cm'lik darbe sayısı arasındaki fark, varyansı analiz etmek için kullanılmıştır. Ayrıca, çakıl veya daha büyük boyutlu partiküllerin varlığından dolayı SPT darbe sayılarındaki herhangi bir yapay artışın tespitini mümkün kılmak için olası istatistiksel sınırlamalar türetilmiştir. Bu tür sınırların belirlenmesi, geoteknik parametrelerin belirlenmesinde kullanılacak SPT darbe sayısının düzeltilmesine izin verir. SPT sonuçları üzerinde yapılan analizlerin ekipman ve işlemsel değişkenliklerden kaynaklanan muhtemel hatalardan etkilenmediğinden emin olmak için, bu çalışmada incelenen tüm örnekler aynı ekipman ve operatörler tarafından yapılan test veri setine dayanmaktadır.

Anahtar Kelimeler: SPT, Değişkenlik, Çakıl, Düzeltme, Tıkanma

To My Family and Friends

ACKNOWLEDGEMENTS

I am grateful to my advisor Assoc. Prof. Dr. M. Tolga Yılmaz for his never-ceasing guidance, backed by his understanding and expertise in the field. His belief in me made it possible for me to reach to the next step in this journey.

I will always be indebted to Prof. Dr. Kağan Tuncay for mentoring me in every subject that I sought his guidance. I will always feel a gratitude for all the advices you have shared.

I would also like to thank to my mother Ayşegül Yılmaz, my father Kenan Pehlivan, my sister Eda Pehlivan and my brother Kerem Pehlivan for always being there for me. Knowing I can always count on you makes it possible for me to move forward.

I also wish to express my deepest gratitude to MİTAŞ family, especially to my director Kıvanç Canbaloğlu, and my former general manager Sezgin Üstün for never expecting me to prioritize my responsibilities in work before any of my academic goals. You are a paragon of an administrator, and I am fortunate to have worked with you.

Finally, I would like to thank all the instructors in METU. I learned much throughout my undergraduate and graduate studies.

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LIST OF ABBREVIATIONS

ABBREVIATIONS

ANOVA	Analysis of Variance
ASTM	American Society for Testing and Materials
CH	Inorganic clays or high plasticity, fat clays
CIUC	Consolidated-isotropically undrained, triaxial compression
CL	Inorganic clays of low to medium plasticity, gravelly/sandy/silty/lean clays
COV	Coefficient of Variation
CPT	Cone Penetration Test
DEM	Distinct Element Method
DMT	Dilatometric Test
fs	Fourth Spread
G1	Group of material consisting of smaller particles
G2	Group of material consisting of larger particles
GC	Clayey gravels, gravel-sand-clay mixtures
GM	Silty gravels, gravel-sand-silt mixtures
GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
GW	Well-graded gravels and gravel-sand mixtures, little or no fines
IQR	Interquartile Range
LCL	Lower Control Limit
MC	Monte Carlo simulations
MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts
ML	Inorganic silts, very fine sands, rock four, silty or clayey fine sands

N2	Number of blows taken for second 150 mm penetration of SPT
N3	Number of blows taken for third 150 mm penetration of SPT
NAVFAC	Naval Facilities Engineering Command
OH	Organic clays of medium to high plasticity
OL	Organic silts and organic silty clays of low plasticity
PMT	Pressuremeter Test
PT	Peat, muck, and other highly organic soils
SC	Clayey sands, sand-clay mixtures
SD	Standard Deviation
SM	Silty sands, sand-silt mixtures
SP	Poorly graded sands and gravelly sands, little or no fines
SPT	Standard Penetration Test
SW	Well-graded sands and gravelly sands, little or no fines
UC	Undrained Consolidated Strength
UCL	Upper Control Limit
USCS	Unified Soil Classification System
UU	Undrained Unconsolidated Strength
Vs	The shear wave velocity
VST	Vane Shear Test

LIST OF SYMBOLS

SYMBOLS

μ	Mean value
χ^2	Chi square

CHAPTER 1

INTRODUCTION

1.1. General

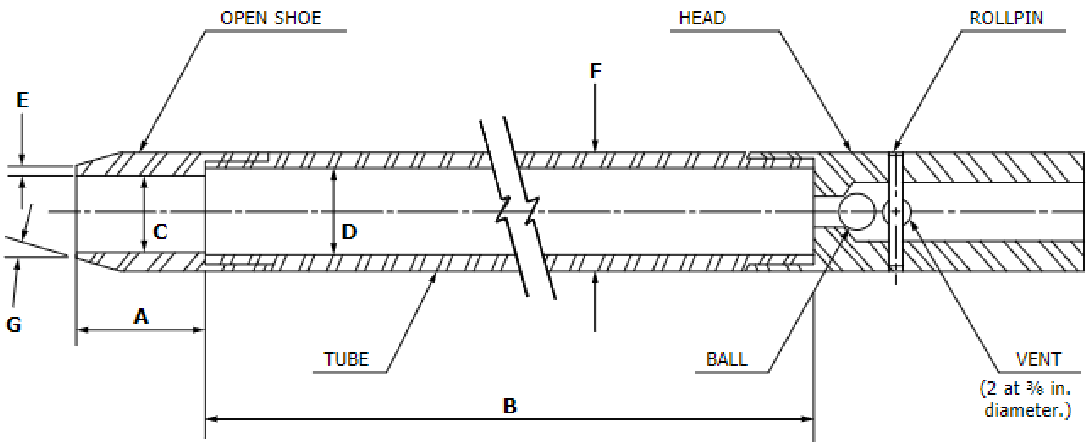
Standard penetration test (SPT) is one of the oldest in-situ field test that is used for soil classification and estimation of its mechanical properties. The test is designed to provide disturbed samples and penetration resistance of the soil by penetrating the ground at the bottom of borehole. While the test is initially developed in United States, the testing procedure varies in different parts of the world. Therefore, standardization of the testing procedure was vital in order to be able to compare the results from different parts of the world. To provide a standardized test method, ASTM (2018) released the code of practice D1586M-18, which describes the testing equipment and procedures thoroughly. Although SPT is a widely used and simple test, it suffers from a number of factors that hinders its reliability by causing an excessive variability in the test results. The variability can be caused by the equipment errors or procedures followed during the test as well as the uncertain nature of the soil that is being tested. In this study, the artificial increase in penetration resistance in soils due to relatively large-sized particles is investigated.

1.2. Literature Survey

The testing procedure of SPT consists of driving a thick walled sample tube shown in Figure 1.1 into the ground. The tube is driven into the ground by the drops of a slide hammer that weights 63.5kg. The structure of the slide hammer is shown in Figure 1.2. Each blow of the slide hammer drops from a distance of 760 mm. The number of blows required to drive the sample tube through a penetration length of 150 mm is recorded. This procedure is repeated 3 times, such that the total length of penetration reaches to 450 mm in the tested soil layer. Each of the 150 mm interval is named as N1, N2 and N3 respectively. The sum of blows required for the second and third 150 mm penetration length is defined as standard penetration resistance or SPT N value.

The test is terminated and expressed as a refusal if any of the following three conditions are met during a test (ASTM, 2018).

1- A total of 50 blows is reached during any one of the three 150 mm intervals.
2- A total of 100 blows is reached.
3- There is no observed advance of the sampler during the application of 10 successive blows of the hammer.



A = 1.0 to 2.0 in. (25 to 50 mm)
B = 18.0 to 30.0 in. (0.457 to 0.762 m)
C = 1.375± 0.005 in. (34.93 ± 0.13 mm)
D = 1.50 ± 0.05 - 0.00 in. (38.1 ± 1.3 - 0.0 mm)
E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
F = 2.00 ± 0.05 - 0.00 in. (50.8 ± 1.3 - 0.0 mm)
G = 16.0° to 23.0°

Figure 1.1. Split-barrel sampler (ASTM, 2018).

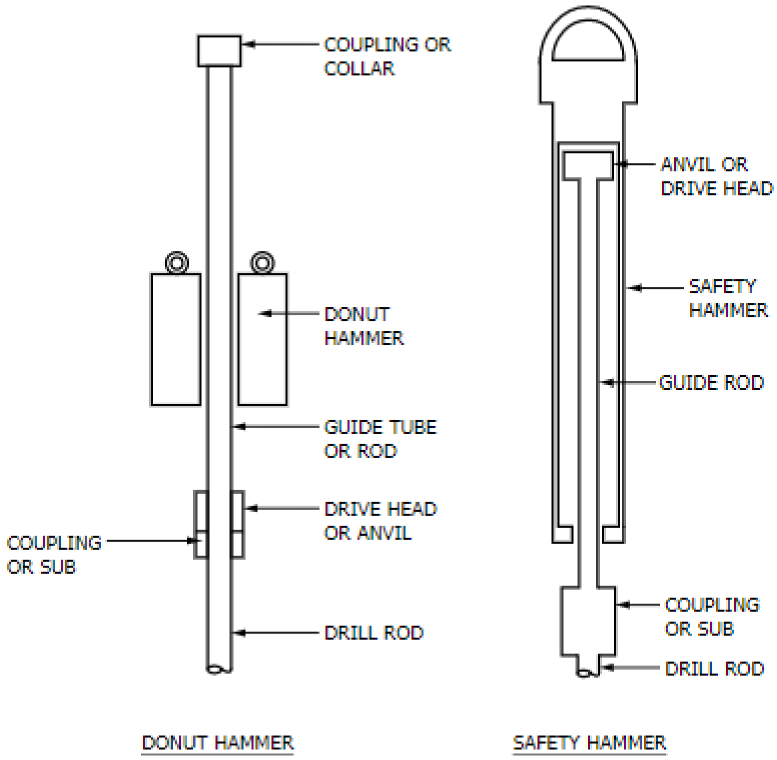


Figure 1.2. Schematic drawing of the donut hammer and safety hammer (ASTM, 2018).

Due to its several advantages such as relatively low cost and ease of operation, it is one of the most widely used in situ tests for soil exploration in geotechnical applications. In their studies, stated that SPT is widely used in Australia, South Africa, India, Portugal, Israel, Britannia, and Japan (Nixon 1982, Décourt 1990, as cited in Sivrikaya and Togrol, 2007). It has been noted that in North America, SPT has been the basis of soil exploration practice and is most likely to remain so (Horn and Selig, 1979). Furthermore Mori stated that in Japan, more than 90% of initial soil explorations are carried out by SPT (as cited in Sivrikaya and Togrol, 2007). SPT is frequently used in geotechnical exploration practices in Turkey as well.

Since SPT is among the oldest and most frequently used in-situ tests, there has been many studies about how to utilize the test results for the needs of soil exploration and geotechnical applications. Various important parameters for foundation design such as friction angle, undrained shear strength, soil density can be estimated from the SPT results (Kulhawy and Mayne, 1990). Furthermore, settlement of the foundations resting on coarse-grained soils can be approximated based on the in-situ testing results (Burland and Burbidge, 1985). The shear wave velocity (V_s) of the soil, which is important for seismic analyses may be empirically estimated using SPT-N (Tan et al. 2012). The liquefaction susceptibility can also be assessed using SPT, since the penetration resistance is related to relative density of soil, which is related to the liquefaction resistance of soil (Liao et al. 1988). However, for the very same reason, many researches have been conducted about the reliability and the variability problems of SPT.

Although SPT might appear as a reliable tool to obtain the needed parameters for a geotechnical application, many factors may increase variability in the results of SPT. Particularly the procedures followed and the equipment used during the test may yield a bias in SPT-N (Sivrikaya and Togrol, 2007). Even ASTM D1586M-18, an internationally known standard of practice for SPT, allows numerous factors that may affect the SPT-N value. The drill stem length, the type of anvil, the blow rate, the alignment of the hammer, the use of liners or borehole fluid and the type of hammer are some of the known factors (Aggour and Rose, 2001). Due to those reasons, SPT-N can vary for 100% or more if a different test apparatus and drillers are used in the same soil formation (ASTM, 2018). Furthermore, a number of operational procedures that influences the SPT-N are shown in the Table 1.1.

Table 1.1. *Procedures that may affect the N value (NAVFAC, 1986).*

Inadequate cleaning of the borehole
Not seating the sampler spoon on undisturbed material
Driving of the sample spoon above the bottom of casing
Failure to maintain sufficient hydrostatic head in boring
Attitude of operators
Overdrive sampler
Sampler plugged by gravel
Plugged casing
Over washing ahead of casing
Drilling method
Free fall of the drive weigh is not attained
Not using correct weight
Weight does not strike drive cap concentrically
Not using a guide rod
Not using a good tip on the sampling spoon
Use of drill rods heavier than standard
Not recording blow counts and penetration accurately
Incorrect drilling procedures
Using drill holes that are too large
Inadequate supervision
Improper logging of soils
Using too large a pump

While any of the operational procedures mentioned in Table 1.1 may yield significantly biased test results, a sampler impeded by gravels or cobbles is one of the most critical factors listed. Rollins et al. (1998) states that such an impedition caused by gravels due to the plugging of the sampler may artificially increase the SPT blow count. Furthermore, it is also reported that the blow counts for the same soil using the same rig can vary depending on the attitude of the operator. It is also possible for a sampler to be impeded by gravels or cobbles, causing a sudden increase in blow count, which should be recognized by the observer. Hence, the experience of the supervisor is also one of the factors that may introduce a variability in the SPT reports.

Geotechnical variability had been investigated by Phoon and Kulhawy (1999). In their study, they denoted three primary sources of geotechnical uncertainty shown in Figure 1.3, namely the inherent soil variability, measurement error, and transformation uncertainty. The combined contribution of these three uncertainties may yield a biased estimation of the soil property.

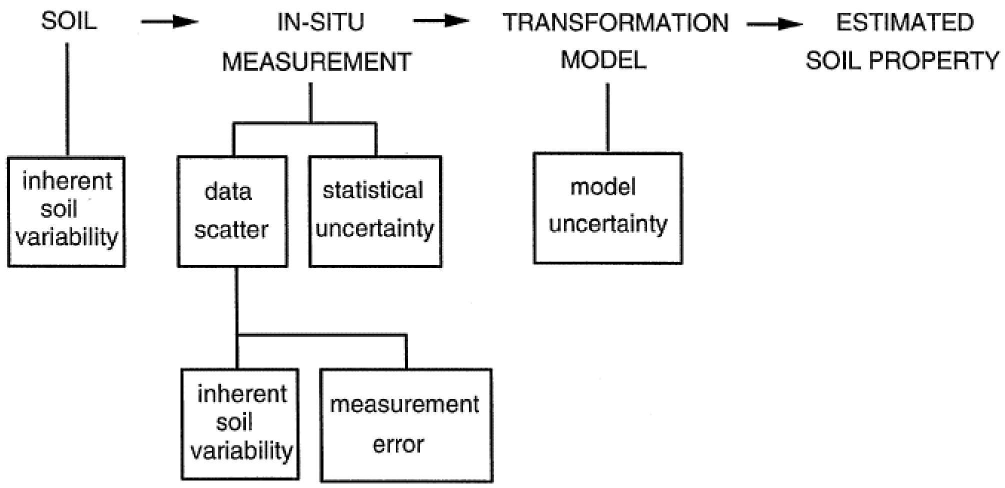


Figure 1.3. Types of uncertainty (Phoon and Kulhawy, 1999).

Inherent soil variability is the uncertainty introduced by the natural geological processes. Due to natural geologic processes that continually modify the soil mass in-situ, all soil properties are expected to vary both horizontally and vertically. Coefficient of variation (COV) is a measure of relative variability of the data defined as the ratio of the data's standard deviation (SD) to its mean (μ). According to Phoon et al. (1995) a COV due to inherent soil variability is to be expected in the results of the field tests, and for SPT, the expected COV is in the range of 25-50% on a sand or clay layer as shown in Table 1.2. Similar high ranges of COV can be observed for other in-situ tests such as Cone Penetration Test (CPT) and Dilatometric Test (DMT) as well. However, the relatively high COV observed in other test methods can be explained by certain soil types not suggested for the corresponding in-situ test methods. For SPT on the other hand, a relatively high COV is to be expected regardless of the soil type.

Table 1.2. *Approximate guidelines for inherent soil variability (Phoon et al. 1995)*

Test type	Property	Soil type	Mean	COV(%)
Lab strength	s_u(UC)	Clay	10–400 kN/m^2	20–55
	s_u(UU)	Clay	10–350 kN/m^2	10–30
	s_u(CIUC)	Clay	150–700 kN/m^2	20–40
	$\overline{\phi}$	Clay and sand	20–40°	5–15
CPT	q_T	Clay	0.5–2.5 MN/m^2	<20
	q_c	Clay	0.5–2.0 MN/m^2	20–40
	q_c	Sand	0.5–30.0 MN/m^2	20–60
VST	s_u(VST)	Clay	5–400 kN/m^2	10–40
SPT	N	Clay and sand	10–70 blows/ft	25–50
DMT	A	Clay	100–450 kN/m^2	10–35
	A	Sand	60–1300 kN/m^2	20–50
	B	Clay	500–880 kN/m^2	10–35
	B	Sand	350–2400 kN/m^2	20–50
	I_D	Sand	1–8	20–60
	K_D	Sand	2–30	20–60
	E_D	Sand	10–50 MN/m^2	15–65
PMT	p_L	Clay	400–2800 kN/m^2	10–35
	p_L	Sand	1600–3500 kN/m^2	20–50
	E_{PMT}	Sand	5–15 MN/m^2	15–65
Lab index	w_n	Clay and silt	13–100%	8–30
	w_L	Clay and silt	30–90%	6–30
	w_P	Clay and silt	15–25%	6–30
	PI	Clay and silt	10–40%	—[a]
	LI	Clay and silt	10%	—[a]
	γ, γ_d	Clay and silt	13–20 kN/m^3	<10
	D_r	Sand	30–70%	10–40; 50–70[b]

Measurement error is the uncertainty introduced by equipment, procedural-operator, and random testing effects. Kulhawy and Trautmann (1996) noted a COV range of 15-45 due to measurement errors for an SPT as shown in Table 1.3. The table shows that among the other common in-situ tests, SPT has the highest COV for the measurement errors. This is largely related to equipment and procedure variability.

Table 1.3. *Summary of measurement error of common in situ tests (Kulhawy and Trautmann, 1996)*

Test	Coefficient of variation, COV (%) Equipment	Procedure	Random	Total[a]	Range[b]
Standard penetration test (SPT)	5–75[c]	5–75[c]	12–15	14–100[c]	15–45
Mechanical cone penetration test (MCPT)	5	10–15[d]	10–15[d]	15–22[d]	15–25
Electric cone penetration test (ECPT)	3	5	5–10[d]	7–12[d]	5–15
Vane shear test (VST)	5	8	10	14	10–20
Dilatometer test (DMT)	5	5	8	11	5–15
Pressuremeter test, prebored (PMT)	5	12	10	16	10–20[e]
Self-boring pressuremeter test (SBPMT)	8	15	8	19	15–25[e]

a - COV(Total) = [COV(Equipment)^2 + COV(Procedure)^2 + COV(Random)^2]$^{0.5}$.
b - Because of limited data and judgment involved in estimating COVs, ranges represent probable magnitudes of field test measurement error.
c - Best to worst case scenarios, respectively, for SPT.
d - Tip and side resistances, respectively, for CPT.
e - It is likely that results may differ for pressuremeter seating stress, pressuremeter yield stress, and pressuremeter limit stress, but the data are insufficient to clarify this issue.

Transformation uncertainty shown in Figure 1.3 is the variability introduced when the design soil parameters are transformed by the use of field or laboratory measurements through empirical approaches. Errors due to such an uncertainty are not an interest of this study.

The variability of SPT-N may be related to grain-size distribution as well. While fine grained sands yields the most reliable results, the presence of large particles can increase the SPT-N artificially (Daniel et al. 2004). The reason behind the increase of blow counts is that the gravel particles can clog or block the sampler and prevent its advancement. Such an artificial increase in penetration resistance may pose a risk in geotechnical designs because it yields overestimation of soil density or of parameters related to soil density.

An approach to the effects of gravel influence on penetration tests is investigated using the Distinct Element Method (DEM) by Daniel et al. (2004). In their study, Daniel et al. performed computer generated two-dimensional simulations with five different cases of two parallel platens whose distance in between are 25.4, 50.8, 76.2, 102 and 127 mm. While 50.8 mm distance is generated to simulate the SPT sampler, the other four are generated to investigate the ratio of platen spacing to the mean grain size. A particle assemblage consisting of 28,712 spherical particles whose combined mass retained on above sieves with 4.75 mm and 5.60 mm opening would be 50% was generated. Afterwards each of the platens are driven with a constant rate into the particle field, similar to the advancement of the SPT sampler as shown in Figure 1.4a and Figure 1.4b. Simulation results indicates that the gravel particles creates an arching effect as shown in Figure 1.4c and Figure 1.4d. The arching effect prevents the advancement of the soil into the platens, which leads to an artificial increase in soil's shear strength due to the plugging of the spacing. It is also noted that the plugging occurs earlier in platens with smaller spaces; hence, they would have less particle recovery percentage. Figure 1.5 shows the increase in recovery percentage as platen distance increases.

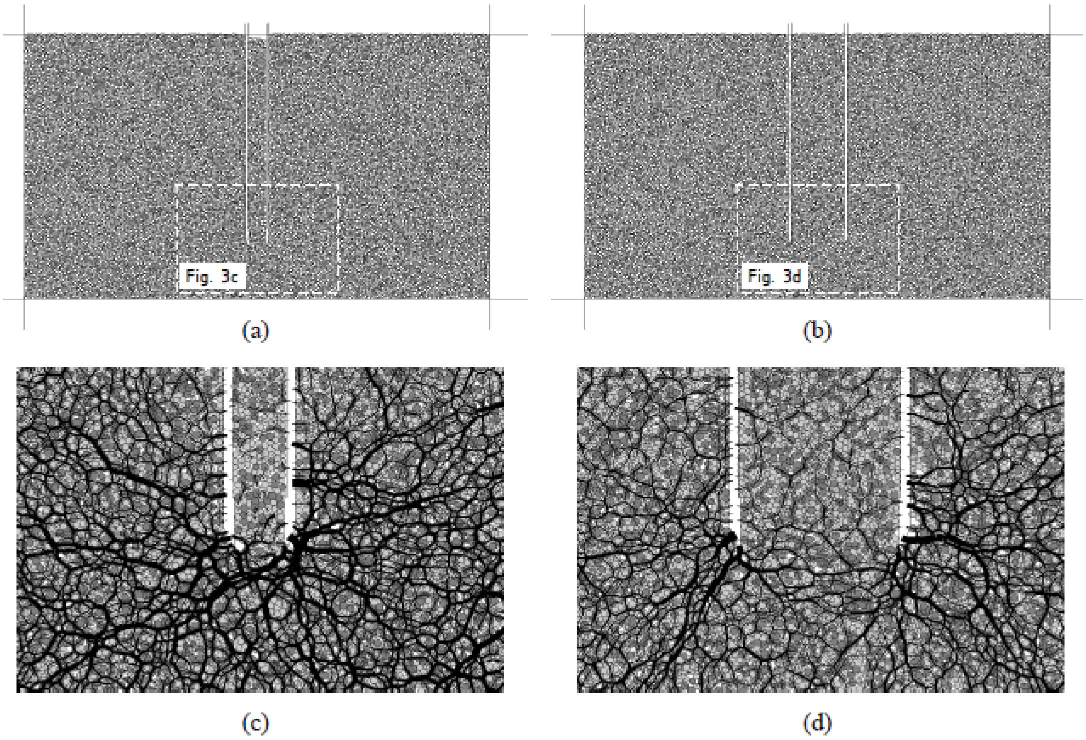


Figure 1.4. DEM sampler penetration simulations for (a, c) 50.8 mm (2") and (b, d) 127 mm (5") samplers. The superimposed black lines in (c) and (d) are proportional in thickness to the magnitude of the interparticle forces. (Daniel et al. 2004)

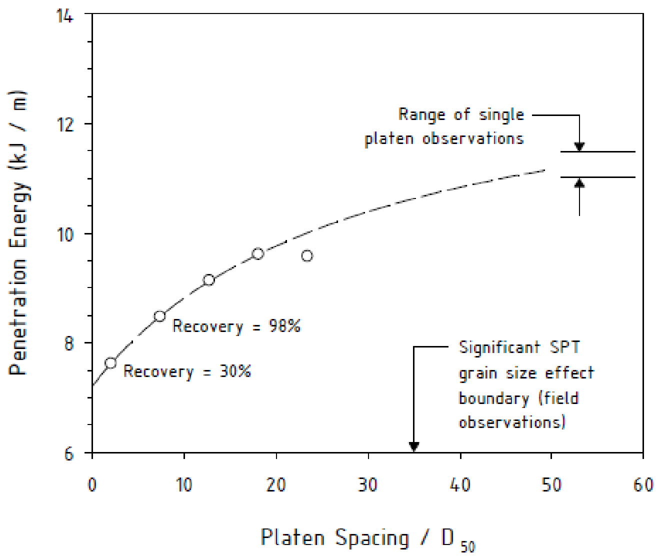


Figure 1.5. DEM modeling results demonstrating effect of platen spacing on required penetration energy. Recovery was 100% unless otherwise indicated. (Daniel et al. 2004)

Ghafgazi et al. (2017) introduced a screening framework for evaluating the gravel influence that can be applied during the early stages of the site investigation. A brief summary of the screening process is that blow count per inch (2.5cm) of penetration is taken into consideration, in addition to physical evidences obtained at site. Physical evidences are the gradation of the samples retrieved in the sampler and the photographs of the samples. If possible, samples obtained by sonic cores can also increase the reliability of the process. Ghafgazi et al. suggested that the SPT-N data is to be indexed from I to V according to the physical evidence and the blow count per inch data. Definitions of the indexes are presented in Table 1.4.

Table 1.4. *Rubric developed for assigning gravel influence indices to SPT data (Ghafgazi et al. 2017)*

	Per-inch SPT blow counts		Physical Evidence (a)	
Index	Is there a sign of gravel influence?	Can a reliable correction be applied?	Are gravels present based on the physical evidence SPT (or Sonic)?	Is the gravel present influential gravels? (b)
I	No	-	No	-
	No	-	Yes	No
II	No	-	Yes	Yes
III	Yes	Yes	Yes	No
	Yes	Yes	No	-
IV	Yes	Yes	Yes	Yes
V	Yes	No	Yes	Yes

a - Physical evidence refers to soil gradations, sample photos and field logs from SPT split spoon samples and/or Sonic cores in the vicinity of the SPT sample.
b - An influential gravel is one of sufficient size and abundance to have plausibly affected SPT penetration measurement.

The indices I and II implies that no gravel were present in the per-inch blow counts and there were either no influential gravel in the vicinity of sampler (I) or the influential gravel was present but did not have any effect on the per-inch SPT blow counts (II). In the sites where dense sand seams or only non-influential gravels are present, it is possible to observe a sign of gravel influence in per-inch SPT blow counts, whether there is a sign of gravels in the physical evidences or not. Such cases are indexed as III. Indices IV and V are the cases where the presence of gravel is certain in both per-inch SPT blow counts and the physical evidences. In those cases, if the influence of the gravel on per-inch SPT blow counts is negligible or can be corrected index IV is chosen, otherwise index V is chosen. However, it should be noted that Ghafgazi et al. (2017) omitted all samples with gravel content more than 20%. This omission was developed considering the guidance from Mejia, (as cited by Dejong et al. 2016) regarding that the gravel content above 20% is likely to influence the SPT-N.

Indices I and II are considered independent from the gravel influence. Index III either can be free or made free from gravel influence by manually removing the spikes from the blow per inch profile. The gravel presence in SPT samples classified as Index IV are virtually certain but that influence may either be negligible or can be corrected similar to Index III. Index V is considered as influenced by gravel to the extent that a reliable correction cannot be applied. Cases of the per-inch SPT blow count for all five indexes and their possible corrections are shown in Figure 1.6.

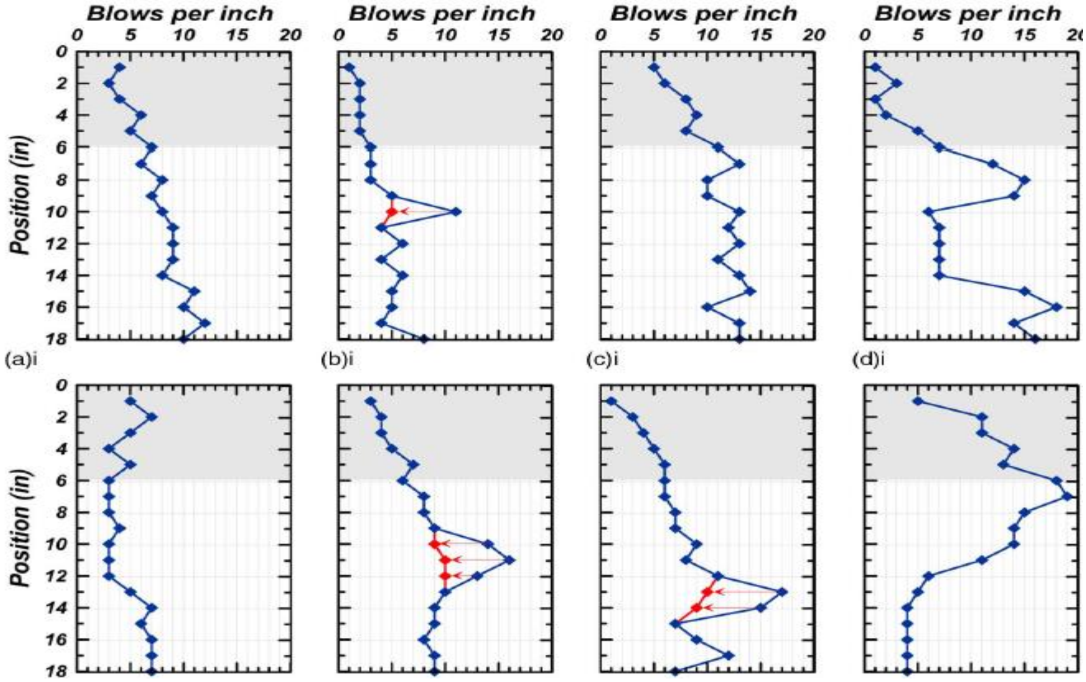


Figure 1.6. Per-inch SPT blow counts used to evaluate gravel influence: (a) no influence (Indices I and II); (b) potential influence with reliable correction (Index III); (c) influence with reasonable trend or reliable correction (Index IV); (d) influence, not correctable (Index V) (Ghafgazi et al. 2017)

While the screening framework is a useful tool to determine the gravel influence, such a process is applicable only if the gravel influence is expected prior to the site investigation and cannot be used for tests that have already been conducted. Although the procedure of Ghafgazi et al. (2017) can be very useful to determine the artificial increase in penetration resistance due to gravel influence, additional studies on the physical evidence and recording blow counts after every 2.5 cm penetration of sampler will be necessary. This takes away the simplicity and time efficiency of SPT, and usually is not recorded in practical applications following the standards such as ASTM D1586. The layering of soil deposits may reduce the applicability of this procedure as well. It also should be noted that in the study of Ghafgazi et al. (2017), the samples with gravel content higher than 20% were omitted since they are likely to elevate the blow count. However, how soil sample behaves at gravel contents higher than 20% and whether SPT-N is increased due to the gravel content or not are not investigated thoroughly.

1.3. Scope

The variability in SPT results, originating from the uncertainty of the soil due to the natural geological processes, is unavoidable. An analysis of SPT variability, particularly the results showing higher penetration results than the actual figures, can be investigated by dividing the total penetration distance of 30 cm into smaller segments. Because the standard application yields penetration resistance for each 15 cm penetration length separately, an analysis of variability (or an artificial increase in penetration resistance) may be investigated by considering the difference between the penetration resistance measured for the second 15 cm length of penetration (N2) and that for the third (N3). In this study, a statistical analysis of this difference is presented to derive conclusions for the likely variability in SPT in different types of soil (clay, silt, sand and gravel), and to determine possible statistical limits for this difference so that any artificial increase in SPT result in standard applications can be detected before selection of parameters for a particular geotechnical problem. Particular emphasize is put on soils involving a significant percentage of gravel-sized particles by weight.

An outline of this study is given in the following:

- Chapter 1 summarizes the literature on the variability of SPT, and presents the scope of this study.
- Chapter 2 presents the analysis procedures and the details of the data in study.
- Chapter 3 consists of statistical tests and analyses conducted on the data.
- Chapter 4 shows the determination of outlier limits.
- Chapter 5 summarizes the research done in this study.

CHAPTER 2

METHODOLOGY

2.1. Data

In 2006, General Directorate of Disaster Affairs of Turkey had initiated a geotechnical site-survey program for 153 strong-motion accelerometers distributed on Turkey. The geotechnical investigation involved SPT sampling and laboratory tests on soil classification (Sandıkkaya et al., 2010). The borelogs are accessible at the site http://khydata.deprem.gov.tr/2K/khydata-v4.php (on the link "stations") The links between borelog codes and pertinent station codes are presented on Table A.1 of Sandıkkaya (2008), which is accessible on the web. All of the SPTs were conducted by the same operators and the same equipment. For that reason, up to 100% variance due to in-situ measurement error caused by equipment and operator difference as noted in ASTM D1586 (2018) is expected to be limited in this dataset.

SPTs conducted in 153 sites initially provided a sample size of 2182. However, not all of the samples were complete with the necessary information required in this study. Investigation of the remaining data revealed a number of test refusals. However when this refusal occurs at the third 150 mm increment, an empirical SPT-N may be estimated by extrapolating the advancement of hammer at the time of refusal. 679 of the 2182 samples are eliminated from the data due to having a refusal at first or second 150 mm interval. Samples whose blow count at third 150 mm increment is extrapolated. The SPT-N, N3 and N2 of the extrapolated data can be found in Appendix A.

It is found that 49 of the remaining 1503 samples are from an artificial soil fill. Artificial fills are eliminated from the sample due to their unnatural depositional process, which may have caused a significant bias in variability. Furthermore, the soil type of 39 of the remaining 1454 samples were not classified in the lab due to lack of sample recovery during SPT. No additional data, such as the properties of specimens recovered in the same layer was available to eliminate the uncertainty for these samples. They are eliminated from the data to avoid any biased estimation. Which left 1415 specimens to conduct the analyses. Full list of the remaining specimen are given in Appendix B

Before conducting the statistical investigation, the remaining data is investigated of any classification error that may have been introduced in field tests. Each sample's field description is compared with their laboratory classification and corresponding grain size curves. By inspecting remaining sample's percent of mass retained on No 4 and passed through No 200 US Standard sieves (4.76 mm and 0.075 mm sieve opening respectively according to ASTM D6913, 2017), each sample's soil classification is determined according to the unified soil classification system, USCS as per ASTM D2487 (2017) shown in Table 2.1. It is found that the site description of 44 specimens are not consistent with USCS. In those cases where USCS and field descriptions are contradicting, data is corrected according to USCS. The list of these specimens, their site descriptions and their corrected soil classes are provided in Appendix C.

Table 2.1. *Basic reference for the Unified Soil Classification System (ASTM, 2017)*

Major Divisions		**Group Symbol**	**Typical Names**
Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels	GW	Well-graded gravels and gravel-sand mixtures, little or no fines
		GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
	Gravels with Fines	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands	SW	Well-graded sands and gravelly sands, little or no fines
		SP	Poorly graded sands and gravelly sands, little or no fines
	Sands with Fines	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
Silts and Clays Liquid Limit less than 50		ML	Inorganic silts, very fine sands, rock four, silty or clayey fine sands
		CL	Inorganic clays of low to medium plasticity, gravelly/sandy/silty/lean clays
		OL	Organic silts and organic silty clays of low plasticity
Silts and Clays Liquid limit 50 or more		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts
		CH	Inorganic clays or high plasticity, fat clays
		OH	Organic clays of medium to high plasticity
Highly Organic Soils		PT	Peat, muck, and other highly organic soils

While the specimen is classified according to USCS, it is not the only soil classification method in practice. Various soil classification systems define a sample's classification different from USCS. According to ASTM D3282 (2015) for instance, given that the plasticity index is less than 6, a sample can be considered as gravel as long as the percent passing through sieve No 40 (0.425 mm) is less than 35. As mentioned by Punmia et al. (2005), M.I.T. soil classification system defines particles retained on or above No 10 (2 mm) sieve as gravel, and classifies the sample's group as gravel if the particles retained on or above sieve No 10 is greater than 35%.

To determine a factor that can be used to differentiate the effect of gravel particles on SPT, the data is divided into two groups. Group one (G1) specimens, whose percent of mass retained on No 4 is less than or equal to 50. Group two (G2) specimens, whose mass retained on No 4 is greater than 50. The initial limit of 50 had been chosen since it is the limit of gravel class according to USCS (ASTM D2487, 2017). However, all three of the given soil classification systems have a different criterion on the classification of gravel. Therefore, considering specimen with mass retained above sieve No 4 greater than 50% as the only threshold to classify as gravel when the definition of gravelly soil is not universally agreed on may not be statistically meaningful for a change in the penetration resistance due to gravel-sized particles. Consequently, different percentage limits of mass retained on No 4 (such as 40%, 30% and 20%) are also considered for a reclassification of gravelly soils as well.

2.2. The Methods Used for Statistical Analyses

For statistical analyses, a normalized variable related to SPT blow counts has to be chosen. Initially five different variables were chosen as shown in the Table 2.2. These variables were constructed to investigate the variation among the groups G1 and G2. In order to investigate the potential difference between the two groups, Analysis of Variance (ANOVA) will be used. However, before testing the groups using ANOVA, each of these variables will be examined whether they meet the basic assumptions of the test. The ones that do not meet the basic assumptions of ANOVA will be discarded.

Table 2.2. *SPT blow count related factors.*

Variable	Formula
V1	$N3 - N2$
V2	$N3/N2$
V3	$(N3 - N2)/(N3 + N2)$
V4	$((N3 - N2)/(N3 + N2))^2$
V5	$(N3 - N2)/(N3 \, . \, N2)$

2.2.1. Analysis of Variance

A one-way ANOVA is a statistical test that examines whether there is any significant difference between the means of groups or treatments. There can be more than two groups in a one-way ANOVA, and the test investigates the potential difference of a single variable amongst the groups. The ANOVA calculates an F-statistic, the ratio of the variance calculated between the groups (deviation of each group mean from the overall mean) to the variance calculated within the groups (the total deviation of each sample's mean from their corresponding group mean). If the group means are drawn from populations with the same means, the variance between the group means should be lower than the variance of the samples. Hence, a higher F-statistic means that the samples were drawn from populations with different mean values. If k is the number of groups that are being investigated, the hypotheses of interest of an ANOVA test will be as follows (Devore, 2011).

- H_0: $\mu_1 = \mu_2 = \mu_3 ... = \mu_k$
- H_a: At least two group means are different.

where μ_j is the mean of group j

While ANOVA can statistically determine whether at least two groups have significantly different means, it is an omnibus test; hence, it cannot designate the group that shows the difference. Nonetheless, further analyses of data can yield determination of the group with a different group mean. At first, ANOVA will be used to investigate if the soil types within G1 could be considered as a united class. In order to be able to consider them as one group the statistical parameters of all three soil classes within the group G1 should be similar. After confirming that the components within G1 are identical, an ANOVA test between gravelly soils (G2) and other soil types (G1) will be conducted. A failure to reject the null hypothesis of ANOVA test conducted on G1 and G2 could imply three reasons:

i While the mass retained above sieve No4 in samples grouped in G1 is less than 50%, there are some large particles present in some of those samples. Those samples could be causing the mean of G1 to be similar to that of G2.

ii The sample size of G2 may not be sufficient for a statistically strong conclusion.

iii Effect of gravel particles within G2 group soils on SPT is not as significant as necessary to cause a statistical difference between the two groups

Second, in the case of a failure to reject the null hypothesis that the means of G1 and G2 are equal, a lower limit for proportion of particles passing No4 sieve was considered to transfer some of the large particles to gravelly soils (G2) from finer soils (G1). By doing so the large particle content within G1 will be reduced to suppress the first reason (i). Furthermore, the sample size of G2 will be increased, which will improve the strength of statistical conclusion (ii). Suppression of the first two reasons i & ii will increase the significance of third reason, which will indicate whether gravel effect on the SPT-N is distinguishable.

Third, the effect of very small SPT-N values on statistical parameters will be investigated because the discrete distribution of SPT-N reported as integers may yield in significant truncation error in estimation of statistical parameters. This will be done by removing samples with an SPT-N less than 5 and 10 consecutively and investigating the change in the sample mean and variance as well as the results of ANOVA.

ANOVA is based on the assumption that the populations are normally distributed. Nonetheless, its susceptibility to normality is investigated by various researchers. Whether the plausible violations of the ANOVA assumptions has a serious consequences on the validity of probability statements of the test was investigated by Glass et al. (1972). They found that skewness (the degree of distortion from the symmetrical bell curve) of the population would have very little effect on either the significance level or the power of the test, unless the sample size is small. They also found that although the effect is very slight, actual significance level would be less than the nominal significance level when the population has a negative kurtosis (a measure of the dispersion of the variable around mean and standard deviation) value and actual significance level will exceed the nominal significance level when the population has a positive kurtosis value if the sample sizes are unequal. One other important conclusion of their research was that significance levels beyond 0.1% could distort the results while significance level of 1% is sufficient for robustness of the ANOVA. Harwell et al. (1992) conducted a meta-analysis of some of the ANOVA alternatives on literature. He based his research on the empirical studies that are often referred as Monte Carlo (MC) simulation studies. MC simulation is a technique that generates a range of possible outcomes for a given event. In a MC simulation, random sets of numbers sampled from populations with known characteristics are generated. Harwell et al. evaluated the data generated in these simulations, and found that for unequal sample sizes, significance levels are only slightly affected by non-normality. It was noted that this inflation of significance level is due to skewness of the distribution more than the kurtosis. Lix et al. (1996) also investigated the consequences of violation of the normality assumption of ANOVA. They noted that non-normality of variable do not tend to result in inflated error rates when the distribution is symmetric. They also noted that probability of having an incorrect rejection of H_0 is only slightly inflated when the group sizes were unequal and the distributions are skewed.

For normality of a test with unequal sample sizes, the findings of Lix et al. (1996) and those of Harwell et al (1992) agree that skewness can cause a minor inflation in the error while kurtosis is a much smaller cause of error. Findings of Glass et al. (1972) note that skewness has a very little effect on the significance level of the test unless the sample size is very small, and that kurtosis can cause a slight difference on the nominal significance level of the test.

While simulation studies, using a variety of non-normal distributions, have shown that violation of normality assumption of ANOVA will have very little effect on error rates if sample sizes are large (Glass et al. 1972, Harwell et al. 1992, Lix et al. 1996); it is preferable for sample to resemble normal probabilistic distribution. For that reason, all five variables shown in Table 2.2 will be investigated for normality before conducting ANOVA so that the variable more consistent with a normal distribution will be preferred for further analyses.

2.2.2. χ^2 Goodness of Fit Test For Normality

Normality of the data will be tested using χ^2 goodness of fit test (Navidi, 2015). The hypotheses of interest in a χ^2 goodness of fit test are as follows:

- H_0: There is no significant difference between the observed and the expected distribution.
- H_a: There is a significant difference between the observed and the expected distribution.

Where the observed distribution is the variables shown in Table 2.2 and the expected distribution is a normal distribution. If the test fails to reject H_0, data may be considered normally distributed (i.e., the sample cannot strongly reject normality), and ANOVA can be used to compare the groups. If the test rejects H_0, then G1 and G2 can be concluded non-normally distributed for the variable in study. In case that normality of all five variables are rejected, the variable as close as possible to a normal probabilistic distribution will be chosen.

2.2.3. Outlier Analysis

Afterwards, the remaining data will be investigated whether it is influenced by the outliers. An outlier is an observation that is not in an agreement with the overall pattern of a distribution (Moore and McCabe, 1999). One convenient way to observe an outlier is to examine the histogram of sample, so that the likely limits for sample can be seen. These limits will be estimated by using interquartile range (IQR) method or 3-standard deviations method (3-SD) method. The data located out of those limits will be accepted as outlier and will be eliminated. ANOVA will be used again to see if the removal of outliers causes an improvement in the similarity of data groups.

IQR is a horizontal measurement scale in which the data is sorted from its smallest to its largest, and the divided to two halves. The lower fourth and the upper fourth, which are the median of smaller and larger halves respectively, are determined. The difference between the upper and lower fourth is the fourth spread (f_s). Any observation that is farther than 1.5 f_s from the closest fourth is named as an outlier and should be removed (Devore, 2011). This method is applied to both G1 and G2 separately. Once this analysis removes some of the outliers, it is repeatedly applied until it can no longer determine any other outliers.

In the 3-SD method, the limits for sample are determined by adding and subtracting the sample standard deviation multiplied by three to the sample mean (Pearson, 2002). Similar to IQR application, all the data that is not within these limits is considered as outlier. Once this test removes some of the samples as outliers, it is repeatedly applied until no other outlier data is found.

CHAPTER 3

STATISTICAL ANALYSIS OF SAMPLE

3.1. Summary of the Statistical Variability

A total sample size of 1415 was available for statistical analyses after eliminations presented in chapter 3. For each soil class, sample mean (μ) and coefficient of variation (COV) of the variables defined in Table 2.2 is shown in Table 3.1. Gravel type soils usually have a noticeably different variability than the rest of the sample. For variables V4 and V5, COV is noticeably less than the rest of the sample, and COV is slightly greater than that for the other sample types for variables V2 and V3. For V1 on the other hand, both Gravel and Silt classes has a lower COV than the rest of the data. Gravel type soils has a noticeably different mean as well. From V1 to V4, the mean for gravels is higher than the rest of the sample. For V5 however, the means of gravels are similar to that of silts, which is much less than the rest of sample.

Table 3.1. *COV and SD of soil types after the expelled specimens.*

		μ					COV				
	Size	V1	V2	V3	V4	V5	V1	V2	V3	V4	V5
Clay	610	6.167	1.384	0.134	0.032	0.023	3.061	0.487	0.901	1.928	2.505
Silt	57	5.662	1.422	0.130	0.042	0.013	1.544	0.571	1.236	1.930	6.872
Sand	694	8.085	1.430	0.137	0.042	0.020	2.376	0.508	1.118	1.911	3.071
Gravel	54	14.726	1.637	0.159	0.073	0.013	1.721	0.705	1.387	1.612	2.097
Total Data	1415	7.414	1.418	0.136	0.039	0.021	2.578	0.515	1.055	1.923	2.937

Since gravel class soils have noticeably different statistical parameters than the rest of the soil classes, the groups G1 and G2 are formed in a way to separate gravel class from the rest of the soil types. The soil classes other than gravels are regrouped as one class (G1) for the initial examination of the statistical difference of gravel class soils (G2) from other soils as follows. Soils are classified as gravel, in case proportion of particles by weight is greater than 50%. This proportion limit is later reduced to see the sensitivity of results.

Sample size, μ and COV for both of the groups G1 and G2 is reported in Table 3.2 by considering all 5 variables. Out of 1415 samples, 1361 are in the group G1 while only 54 are in the group G2. Hence, the sample size for the group G1 is sufficient for precise estimation of its parameters, provided that the particle sizes do not affect the variables. However, the sample size for G2 is relatively limited. For V1, V4 and V5, COV is higher for G2 than G1, and for V2 and V3 it is less than G1. These differences in statistical parameters imply possible bias in penetration resistance of gravelly soils, regardless of the selection among the variables in Table 2.2. However, the statistical significance of these differences should be investigated by using statistical tests.

Table 3.2. *COV and μ of G1 and G2 after the expelled specimens.*

		μ					COV				
	Size	V1	V2	V3	V4	V5	V1	V2	V3	V4	V5
G1	1361	7.124	1.409	0.135	0.038	0.021	2.634	0.501	1.033	1.926	2.938
G2	54	14.726	1.637	0.159	0.073	0.013	1.721	0.705	1.387	1.612	2.097

3.2. Selection of the Variable for Statistical Analyses

To simplify analysis results and reduce bias in conclusions, one of the five variables has to be chosen for further statistical analyses. Emphasize was put on the shape of frequency distribution for its similarity to a normal probabilistic distribution. The normality will be investigated by using both χ^2 goodness of fit test, and by examining histograms (Navidi, 2015). Number of intervals used in histograms and χ^2 tests are chosen according to rule of Sturges (1926). Sturges suggests number of intervals to be chosen as the closest integer to 1+3.3 log(n) where n is the number of observations (sample size). Since the number of observations in G1 and G2 are different, numbers of class intervals used in their respective histograms and χ^2 tests are also different.

The histogram for all five variables of the data in G1 had been plotted in Figure 3.1. The investigation of five histograms reveals that V1, V4 and V5 have skewed distributions that are significantly different from symmetric bell curve of a normal distribution. However, V2 and V3 have distributions sharing similarity to a normal distribution with the exception of possible outliers at ends of variable ranges. In order to have a better insight on the similarity to a normal distribution, χ^2 goodness of fit tests is also conducted on all variables. Width of each interval is determined in a way to have equal expected probability for each interval. A summary of the calculating for χ^2 goodness of fit tests are given in Table 3.3.

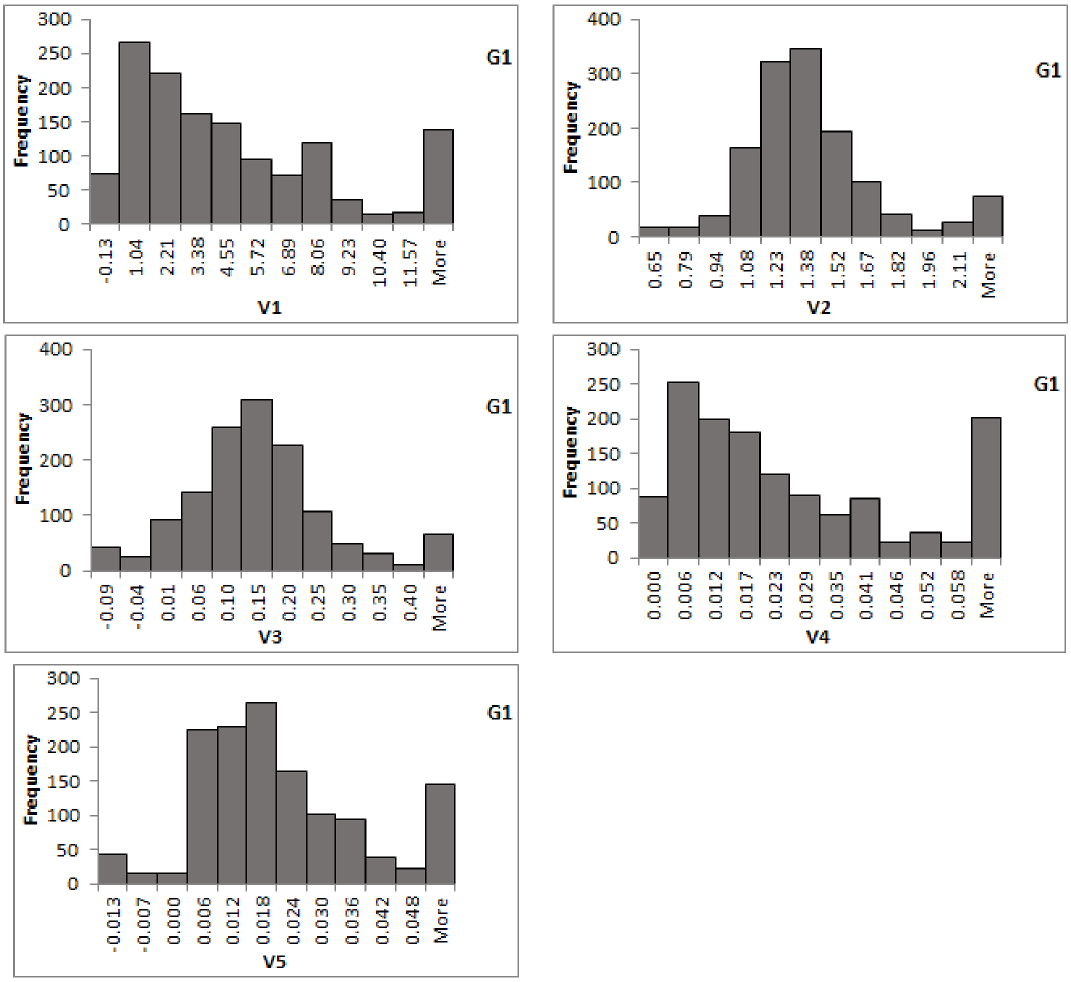


Figure 3.1. Histogram of G1 for each variable.

Table 3.3. χ^2 goodness of fit test for G1

V1				
I	Class	Expected	Observed	χ2
1	X1<-18.83	113.42	0	113.417
2	-18.83<X2<-11.03	113.42	3	107.496
3	-11.03<X3<-5.53	113.42	10	94.298
4	-5.53<X4<-0.96	113.42	61	24.225
5	-0.96<X5<3.17	113.42	650	2538.619
6	3.17<X6<7.12	113.42	368	571.456
7	7.12<X7<11.07	113.42	131	2.726
8	11.07<X8<15.20	113.42	58	27.077
9	15.20<X9<19.78	113.42	17	81.965
10	19.78<X10<25.28	113.42	7	99.849
11	25.28<X11<33.08	113.42	2	109.452
12	33.08<X12	113.42	54	31.127
			Σχ2	3801.707
			Degree of Freedom	9
			p-value	~0

V2				
I	Class	Expected	Observed	χ2
1	X1<0.43	113.42	0	113.417
2	0.43<X2<0.72	113.42	28	64.329
3	0.72<X3<0.93	113.42	44	42.486
4	0.93<X4<1.1	113.42	205	73.953
5	1.10<X5<1.26	113.42	370	580.470
6	1.26<X6<1.40	113.42	307	330.414
7	1.40<X7<1.55	113.42	173	31.302
8	1.55<X8<1.71	113.42	82	8.702
9	1.71<X9<1.88	113.42	45	41.271
10	1.88<X10<2.09	113.42	31	59.890
11	2.09<X11<2.38	113.42	15	85.401
12	2.38<X12	113.42	61	24.225
			Σχ2	1455.861
			Degree of Freedom	9
			p-value	~0

V3				
I	Class	Expected	Observed	χ2
1	X1<-0.05	113.42	60	25.158
2	0.05<X2<0.00	113.42	101	1.359
3	0.00<X3<0.04	113.42	77	11.693
4	0.04<X4<0.07	113.42	154	14.522
5	0.07<X5<0.10	113.42	181	40.272
6	0.10<X6<0.13	113.42	200	66.099
7	0.13<X7<0.16	113.42	145	8.795
8	0.16<X8<0.19	113.42	121	0.507
9	0.19<X9<0.23	113.42	113	0.002
10	0.23<X10<0.27	113.42	68	18.187
11	0.27<X11<0.32	113.42	43	43.719
12	0.32<X12	113.42	98	2.096
			Σχ2	232.408
			Degree of Freedom	9
			p-value	5.12E-45

V4				
I	Class	Expected	Observed	χ2
1	X1<-0.06	113.42	0	113.417
2	-0.06<X2<-0.03	113.42	0	113.417
3	-0.03<X3<-0.01	113.42	0	113.417
4	-0.01<X4<0.01	113.42	392	684.279
5	0.01<X5<0.02	113.42	438	928.914
6	0.02<X6<0.04	113.42	186	46.451
7	0.04<X7<0.05	113.42	120	0.382
8	0.05<X8<0.07	113.42	61	24.225
9	0.07<X9<0.09	113.42	43	43.719
10	0.09<X10<0.11	113.42	14	87.145
11	0.11<X11<0.14	113.42	36	52.844
12	0.14<X12	113.42	71	15.863
			Σχ2	2224.073
			Degree of Freedom	9
			p-value	~0

V5				
I	Class	Expected	Observed	χ2
1	X1<-0.06	113.42	16	83.674
2	-0.06<X2<-0.04	113.42	3	107.496
3	-0.04<X3<-0.02	113.42	17	81.965
4	-0.02<X4<-0.01	113.42	28	64.329
5	-0.01<X5<0.01	113.42	316	361.852
6	0.01<X6<0.02	113.42	513	1407.790
7	0.02<X7<0.03	113.42	231	121.903
8	0.03<X8<0.05	113.42	85	7.120
9	0.05<X9<0.06	113.42	64	21.531
10	0.06<X10<0.08	113.42	19	78.600
11	0.08<X11<0.11	113.42	27	65.844
12	0.11<X12	113.42	42	44.970
			Σχ2	2447.073
			Degree of Freedom	9
			p-value	~0

Similar to results observed in histograms, V1, V4 and V5 have the highest χ^2 scores, resulting in the lowest p-values. P-value is the probability of having extreme values when null hypothesis is true, hence as the p-value gets lower, the rejection of null hypothesis gets stronger. However, despite having a significantly lower χ^2 score, V2 and V3 still have p-values much lower than 1% as well. Hence, G1 cannot be assumed to be normally distributed for any of the five variables.

However, since ANOVA is not very sensitive to violation of normality assumption for large sample sizes such as G1, one of the variables can be chosen for further analyses. V3 has a histogram similar to normal distribution and the highest p-value. Hence, the analysis for G1 supports the selection of this variable for ANOVA analyses.

The histogram for all five variables of the data in G2 had been plotted in Figure 3.2. The investigation of all five histograms for group G2 reveals that V1, V2 and V4 have a distribution significantly different from a symmetric bell shaped distribution of a normal variable. However, V3 and V5 has a frequency distribution similar to that of a normal distribution. Compared to standard normal distribution V3 appears slightly skewed towards left side with some outliers at the right end. V5 on the other hand has a leptokurtic distribution with possibly a higher kurtosis than standard normal distribution. This observation is considered to be due to limited sample size.

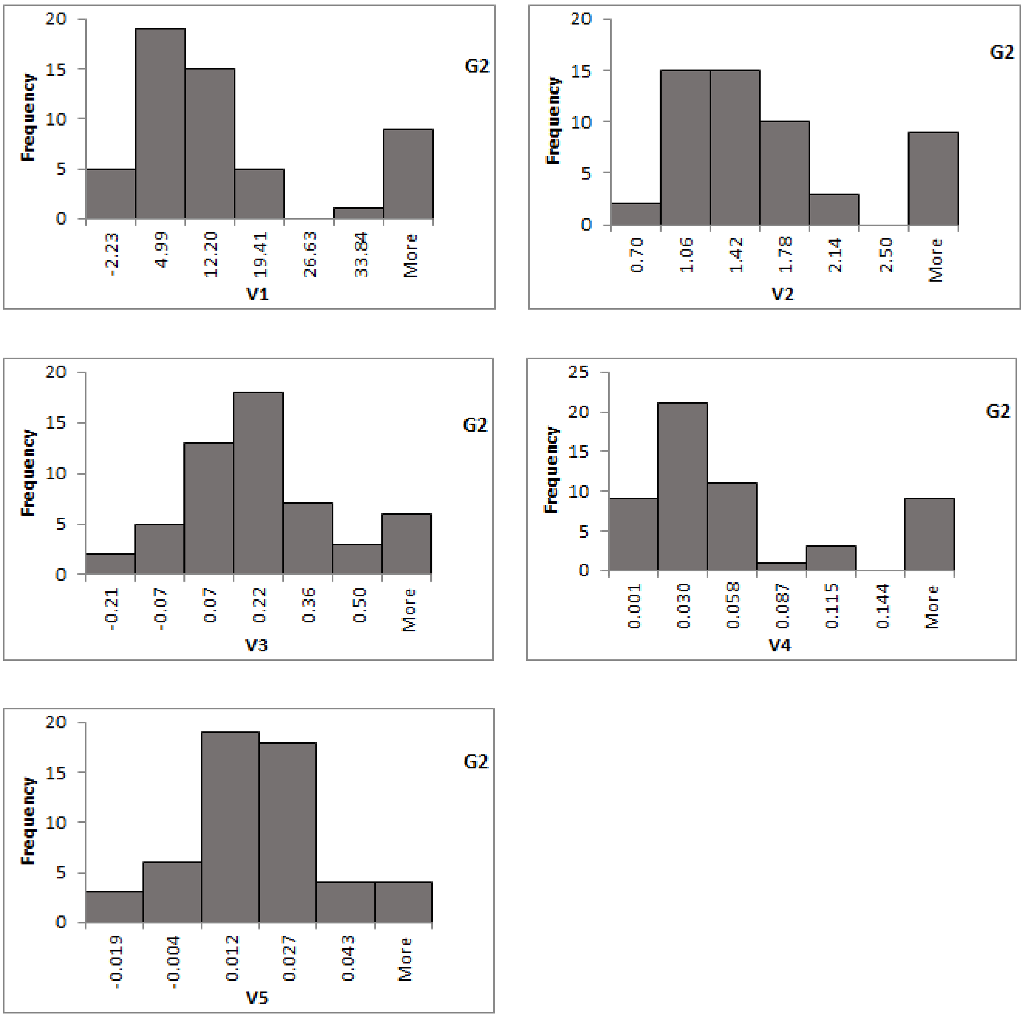


Figure 3.2. Histogram of G2 for every variable

A summary of the χ^2 goodness of fit tests are given in Table 3.4.

Table 3.4. *χ^2 goodness of fit test for G2*

V1				
I	Class	Expected	Observed	χ2
1	X1<-12.58	7.71	0	7.714
2	-12.58<X2<0.25	7.71	15	6.881
3	0.25<X3<10.12	7.71	21	22.881
4	10.12<X4<19.33	7.71	8	0.011
5	19.33<X5<29.20	7.71	0	7.714
6	29.20<X6<42.03	7.71	3	2.881
7	42.03<X7	7.71	7	0.066
			Σχ2	48.148
			Degree of Freedom	4
			p-value	8.79E-10

V2				
I	Class	Expected	Observed	χ2
1	X1<0.40	7.71	0	7.714
2	0.40<X2<0.98	7.71	12	2.381
3	0.98<X3<1.43	7.71	20	19.566
4	1.43<X4<1.84	7.71	10	0.677
5	1.84<X5<2.29	7.71	3	2.881
6	2.29<X6<2.87	7.71	2	4.233
7	2.87<X7	7.71	7	0.066
			Σχ2	37.519
			Degree of Freedom	4
			p-value	1.41E-07

V3				
I	Class	Expected	Observed	χ2
1	X1<-0.08	7.71	7	0.066
2	-0.08<X2<0.03	7.71	10	0.677
3	0.03<X3<0.12	7.71	7	0.066
4	0.12<X4<0.20	7.71	9	0.214
5	0.20<X5<0.28	7.71	9	0.214
6	0.28<X6<0.39	7.71	3	2.881
7	0.39<X7	7.71	9	0.214
			Σχ2	4.333
			Degree of Freedom	4
			p-value	0.363

V4				
I	Class	Expected	Observed	χ2
1	X1<-0.05	7.71	0	7.714
2	-0.05<X2<0.01	7.71	15	6.881
3	0.01<X3<0.05	7.71	25	38.733
4	0.05<X4<0.09	7.71	2	4.233
5	0.09<X5<0.14	7.71	3	2.881
6	0.14<X6<0.20	7.71	1	5.844
7	0.20<X7	7.71	8	0.011
			Σχ2	66.296
			Degree of Freedom	4
			p-value	1.37E-13

V5				
I	Class	Expected	Observed	χ2
1	X1<-0.02	7.71	4	1.788
2	-0.02<X2<0.00	7.71	6	0.381
3	0.00<X3<0.01	7.71	13	3.622
4	0.01<X4<0.02	7.71	15	6.881
5	0.02<X5<0.03	7.71	9	0.214
6	0.03<X6<0.04	7.71	2	4.233
7	0.04<X7	7.71	5	0.955
			Σχ2	18.074
			Degree of Freedom	4
			p-value	0.001

Similar to results observed in histograms, V1, V2 and V4 have the highest $\Sigma\chi^2$ scores, resulting in the lowest p-values. While V5 has a distribution that appeared similar to standard normal distribution, it has a p-value of 0.1%; hence, the normality assumption for V5 can be rejected as well. However, having a significantly lower $\Sigma\chi^2$ score, V3 has a p-value of 36.3%; hence, the normality assumption for V3 cannot be strongly rejected for this sample size. Since violation of normality assumption for ANOVA can only be acceptable for large sample sizes, G2 must be normally distributed. Only variable whose normality assumption for G2 cannot be strongly rejected is V3.

Test results and histograms for both G1 and G2 show that the variable V3 yields the sample frequency distribution closest to probabilistic normal distribution. Hence, further statistical investigations will be carried out only for V3.

3.3. Investigation of Effects of Gravel on SPT Variability

The presence of gravel influence on G1, which consists of soils whose proportion of gravel-sized particles is less than or equal to 50% by weight, will be statistically investigated by using ANOVA test between G1 and the G2. G2 consists of soils whose proportion of gravel-sized particles is greater than 50% by weight. The variable V3 ((N3-N2)/(N3+N2)) is used as variable of analysis to compare the two soil groups G1 and G2.

3.3.1. Similarity Between Soil Classes in G1

Statistical similarities between the three soil types, clays, silts and sands is investigated using ANOVA to justify the assumption that they can be considered as a single class. The test result of ANOVA for V3 of three soil types are presented in Table 3.5. Similarity of V3 for means between three soil types results in a significantly large p-value, so that the test cannot strongly reject the statistical similarity between SPT results for clay silt and sand. Therefore, these soil types can be considered to constitute a unique population.

Table 3.5. *ANOVA test results between clay, silt and sand materials*

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Clay	610	81.589	0.134	0.015
Silt	57	7.411	0.130	0.026
Sand	694	94.736	0.137	0.023

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00	2	0.00	0.10	0.90	2.31
Within Groups	26.45	1358	0.02			
Total	26.46	1360				

3.3.2. Investigation of Consistence Between G1 and G2

Statistical differences between the gravels (G2) and other soil types (G1) are investigated using ANOVA. The test results are presented in Table 3.6. P-value of 24% implies that the test cannot strongly reject the similarity of means of two soil groups. However, the sample size for G2 may not be sufficient for a strong statistical inference. By reconsidering the limits for proportion of gravel sized particles in soil specimens for soil classification, the similarity between two soil groups will be reassessed.

Table 3.6. *ANOVA results between G1 and G2*

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
G1	1361	183.74	0.135	0.019
G2	54	8.57	0.159	0.048

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.03	1	0.03	1.41	0.24	2.71
Within Groups	29.02	1413	0.02			
Total	29.05	1414				

N3 and N2 are reported as integers. This results in truncation error when penetration through 15cm is considered only. Besides, the truncation error in SPT results (N2+N3) is more significant when N2+N3 is lower. Expelling the data whose N2+N3 is relatively small is considered for possible improvement in statistics. Consequently, ANOVA was applied after removing data whose SPT-N is less than or equal to 5 and 10 to investigate the effects of small SPT-N on the test results. 28 specimens have SPT-N less than 5, and 101 have SPT-N less than 10. SPT-N of the samples belonging to G2 are all greater than 5, and only one specimen is less than 10. Results of ANOVA for groups G1 and G2 when the samples less than 5 and 10 are removed are given in Table 3.7 and Table 3.8 respectively.

Table 3.7. *ANOVA test results between G1 and G2 when N less than 5 are removed.*

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
G1	1333	185.24	0.139	0.018
G2	54	8.57	0.159	0.048

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.02	1	0.02	1.03	0.31	2.71
Within Groups	26.95	1385	0.02			
Total	26.97	1386				

Table 3.8. *ANOVA test results between G1 and G2 when N less than 10 are removed.*

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
G1	1260	176.50	0.140	0.018
G2	53	8.68	0.164	0.048

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.03	1	0.03	1.47	0.23	3.85
Within Groups	25.28	1311	0.02			
Total	25.31	1312				

The results when SPT-N less than 5 removed shows that the increase in mean value of G1 results in a relatively increase in p-value of the test. When SPT-N less than 10 are removed, the mean value of G1 increased by only 0.001, the mean value of G2 increased by 0.006, which results in a decrease of p-value. Hence, the data for SPT-N less than 5 is possibly introducing bias in V3. The similarity between groups G1 and G2 is increasing when this possible bias is eliminated. The differences in means, variances and ANOVA p-values due to removing SPT-N lower than 5, and 10 are summarized in Table 3.9.

Table 3.9. *Differences in descriptive statistics and ANOVA p-values*

All N	N≥5 Data	N≥10 Data

	G1	G2	G1	G2	G1	G2
Sample Size	1361	54	1333	54	1260	53
Mean	0.135	0.159	0.139	0.159	0.140	0.164
Variance	0.019	0.048	0.018	0.048	0.018	0.048
P-Value	0.24		0.31		0.23	

To further investigate whether the groups involving smaller ranges of SPT-N are significantly different from the groups whose small range are expelled, an ANOVA test is conducted as seen in Table 3.10. A p-value of 0.60 implies that the removal of small SPT-N made no significant difference, and expelling these specimens is not very necessary.

Table 3.10. *ANOVA test results between initial G1, and the G1 data with small SPT-N removed.*

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Initial G1	1361	183.74	0.135	0.019
G1 with N>4	1333	185.24	0.139	0.018
G1 with N>9	1260	176.50	0.140	0.018

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.02	2	0.01	0.51	0.60	2.30
Within Groups	73.63	3951	0.02			
Total	73.64	3953				

ANOVA test between two groups separated as more than 50 percent of mass passing through sieve No 4 (G1) and retained above sieve No 4 (G2) revealed that the group means are similar. The similarity between two groups could be due to truncation errors, relatively small sample size of G2 or the effect of gravel-sized particles within G1 despite being less than 50% by mass. In order to investigate the effects of truncation errors, samples whose SPT-N is relatively small are removed from both of the groups and ANOVA test is repeated. Furthermore, an ANOVA test between the initial G1 and the G1 whose specimen with small SPT-N removed is also carried out. It is found that expelling specimen with small SPT-N made no noticeable difference in the test results. Therefore, an investigation of the effects of gravel-sized particles within G1 is necessary.

3.4. Investigation of Effects of Gravel-Sized Particles on SPT Variability

It is possible that the effect of gravel-sized particles retained above No4 sieve can appear when the proportion of gravel-sized particles is less than 50% by weight. As mentioned in Chapter 1, Mejia, (as cited by Dejong et al 2016) states that any gravel content above 20% is likely to cause an elevation in the SPT-N. Furthermore, Ghafgazi et al (2017) states that their method to eliminate the gravel induced artificial increase in SPT-N cannot be used on some soil layers unless their gravel-sized particles are less than 20% by weight. Therefore, soil groups are redefined such that the groups will be separated by considering increments of 10%, from 20% to up until 50% by mass retained at sieve No 4. These gravelly soils are classified as $G2_X$ such that, subscript X denotes the minimum proportion of particles remaining on No.4 sieve by weight. Similarly, soils with proportion of particles (passing sieve No 4) less than X are grouped as $G1_X$.

Table 3.11 shows the statistics for the sample that is considered as gravel ($G2_X$) due to their gravel content. $G1_{50}$ has a mean of 0.135 and a variance of 0.019 while $G2_{50}$ has a mean of 0.159 and a variance of 0.048. Table 3.11 shows that the sample with mass retained above sieve No4 between 40 and 50 has a mean of 0.146, which is a value in between of both $G1_{50}$ (0.135) and $G2_{50}$ (0.159). Samples with mass retained above sieve No4 in between 30-50 has a mean of 0.155, which is similar to that of $G2_{50}$. Samples with mass retained above sieve No4 in between 20-50 on the other hand has statistical parameters between $G1_{50}$ and $G2_{50}$. Therefore, the sample size for gravelly soils is increased by considering all specimens with mass proportion referencing on No4 sieve greater than 30%.

Table 3.11. *Specimen moved from $G1_{50}$ to $G2_{50}$ when separated at No4 of 40, 30 and 20.*

Sample with No4 Between	Sample Size	Mean V3	Variance V3
40-50	39	0.146	0.042
30-50	116	0.155	0.044
20-50	205	0.142	0.038

Before conducting ANOVA test on $G1_{30}$ and $G2_{30}$, it should be ensured that samples in each group could still be considered statistically identical within the groups they were assigned. While the soil types of sand, clay and silt within $G1_{50}$ were found statistically identical, the of the sample size after changing $G1_{50}$ to $G1_{30}$ could cause the remaining soil types within $G1_{30}$ to be statistically different particularly because the gravelly soils that were shifted from $G1_{50}$ to $G2_{50}$ have a different group mean than those of $G1_{30}$. Similarly, now that non-gravel soil types (according to USCS) are included within $G2_{30}$, a statistical difference may have been caused in between the different soil types. In order to ensure that the reduction in sample size did not cause a statistical difference between the soil types in $G1_{30}$, ANOVA is used on the remaining sand, clay and silt types as shown in Table 3.12. For $G2_{30}$, ANOVA is used on the specimen shifted from $G1_{50}$ to $G2_{30}$ against the initial $G2_{50}$ as shown in Table 3.13.

Table 3.12. *ANOVA test results for soil groups within $G1_{30}$*

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Clay	608	81.49	0.134	0.015
Silt	57	7.41	0.130	0.026
Sand	580	76.89	0.133	0.019

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00	2	0.00	0.04	0.96	2.31
Within Groups	21.33	1242	0.02			
Total	21.33	1244				

Table 3.13. *ANOVA between G2 and soils with 30% <No4 <50%*

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Gravels	54	8.57	0.159	0.048
30% <+No4 <50%	116	17.94	0.155	0.044

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00	1	0.00	0.01	0.91	2.74
Within Groups	7.65	168	0.05			
Total	7.65	169				

Tables 3.12 and 3.13 shows that both of the groups investigated using ANOVA test has a large p-value, implying that the null hypothesis cannot be rejected. The tests are also carried out for $G1_{40}$ and $G1_{20}$ and the p-values are obtained as 0.94 and 0.88 respectively. However, for $G2_{40}$ and $G2_{20}$, p-values of 0.78 and 0.60 are obtained. It is worth noting that the greatest p-values for both G1 and G2 are obtained when the groups are separated +No4 > 30% and smallest ones are obtained when the groups are separated at +No4 > 20%.

Finally, the similarity between the groups $G1_{30}$ and $G2_{30}$ are investigated using ANOVA tests. Descriptive statistics and ANOVA results for $G1_{30}$ and $G2_{30}$ are given in Table 3.14. It is shown in Table 3.14 that ANOVA test conducted on $G1_{30}$ and $G2_{30}$ has a p-value of 5%. The null hypothesis of ANOVA can be rejected. The alternate hypothesis states that there is a statistically significant difference between the means of the groups. Therefore, when the groups are separated at No4 = 30, the SPT-N related variable V3 is statistically different for finer soils in $G1_{30}$ and gravelly soils in $G2_{30}$. Consequently, a gravel induced artificial variability can be observed by considering all specimens with a gravel content above 30% by weight.

Table 3.14. *ANOVA test results between $G1_{30}$ and $G2_{30}$*

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
$G1_{30}$	1245	165.79	0.133	0.017
$G2_{30}$	170	26.51	0.156	0.045

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.08	1	0.08	3.78	0.05	2.71
Within Groups	28.97	1413	0.02			
Total	29.05	1414				

The ANOVA test is also carried out for groups that are separated at No4 of 40% and 20% and p-values of 0.23 and 0.22 are obtained respectively, which are given in Appendix D. In either cases, the null hypothesis cannot be strongly rejected. Failure to reject the null hypothesis for the initial one could be explained by relatively small sample size (93) and by the possibility of the presence of large particles whose proportion of gravel-sized particles by mass is in between 30-40%. Failure to reject the null hypothesis for the latter could be due to that the specimen with the proportion of gravel-sized particles in between 20 and 30 are free from the gravel induced artificial increase in SPT-N. Therefore, adding a relatively large number of specimen free from gravel influence into a relatively small number of gravels could cause $G2_{20}$ to be statistically similar to $G1_{20}$.

CHAPTER 4

OUTLIER ANALYSIS

4.1. Determination of Outlier Limits Using IQR and 3-SD Methods

While the ANOVA test on groups $G1_{30}$ and $G2_{30}$ shows that the two groups are statistically different, the effects of outliers in this outcome was not rigorously investigated. Furthermore, some of the SPT refusals were extrapolated according to the advancement of the sampler during the field test, so this may introduce some unexpected bias in results. Any outliers within the soil groups due to involving such refusals must also be detected and removed. Both IQR and 3-SD methods will be used to detect the outliers within groups $G1_{30}$ and $G2_{30}$ for the variable V3. The histograms of $G1_{30}$ and $G2_{30}$ for V3 before the removal of outliers are given in Figure 4.1. Histogram of both $G1_{30}$ and $G2_{30}$ suggests presence of outliers in the range $V3 > 0.37$. Furthermore, histogram of $G1_{30}$ suggests that any V3 lower than -0.08 may also be an outlier.

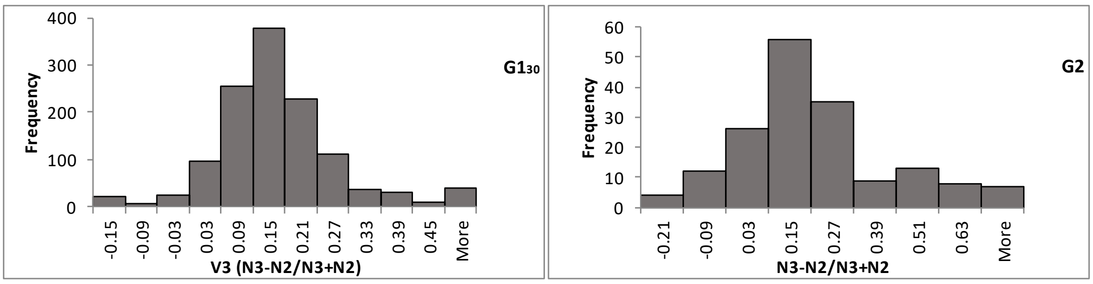


Figure 4.1. Histograms of $G1_{30}$ and $G2_{30}$ for variable V3

The two methods used to determine the outliers are to use 3-SD method around the mean, which is a tool used to set upper and lower limits, and the IQR method. Once these methods removes some of the specimen as outliers, new outlier limits are determined for the remaining specimen once again until they can no longer determine any other outliers. When IQR method is used, two iterations for $G1_{30}$ and five iterations for $G2_{30}$ had been conducted until the method can no longer determine any outlier. Then the upper and lower limits for 3-SD is used. Four iterations for $G1_{30}$ is made, but the method failed to mark any outlier specimen for $G2_{30}$. The summary of outlier data according to IQR is presented in Table 4.1. That according to 3-SD is presented in Table 4.2.

Table 4.1. *Outlier limits according to IQR*

	Sample Size	Upper Limit	Lower Limit	% of Outliers	Non Outliers
$G1_{30}$	1245	0.341	-0.098	7.149	1156
$G2_{30}$	170	0.389	-0.203	18.824	138

Table 4.2. *Outlier limits according to 3-SD*

	Sample Size	Upper Limit	Lower Limit	% of Outliers	Non Outliers
$G1_{30}$	1245	0.381	-0.132	6.024	1170
$G2_{30}$	170	0.794	-0.482	0.000	170

While both of the methods removes some outliers, the outliers removed by IQR method includes all the outliers removed by 3-SD method. The upper and lower limits defined by the 3-SD limit consists of a wider range, as expected. Therefore, the method 3-SD removed a limited number of outliers for $G1_{30}$, and none for $G2_{30}$. Histograms of $G1_{30}$, and $G2_{30}$ after expelling outliers by IQR and 3-SD are given in Figure 4.2 and Figure 4.3 respectively. Histograms shows that both of the methods removes the apparent outliers in $G1_{30}$. Furthermore, histogram of $G2_{30}$ also shows more similarity to a normal bell shape after the removal of outliers using IQR method. However, since 3-SD method removed no outliers in $G2_{30}$, corresponding histogram did not change.

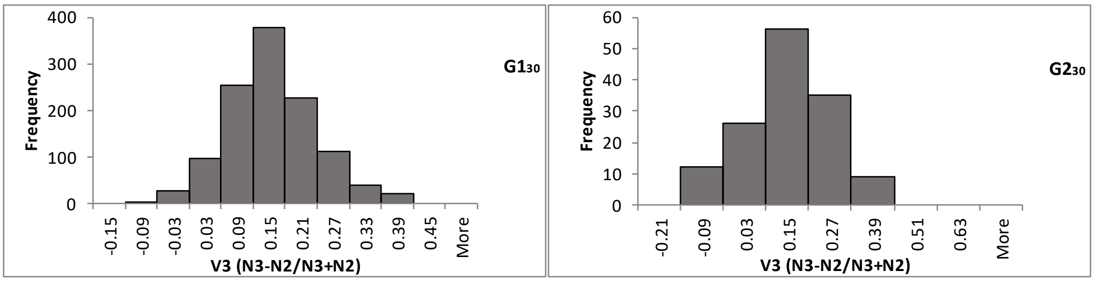


Figure 4.2. Histograms of $G1_{30}$ and $G2_{30}$ for variable V3 after IQR

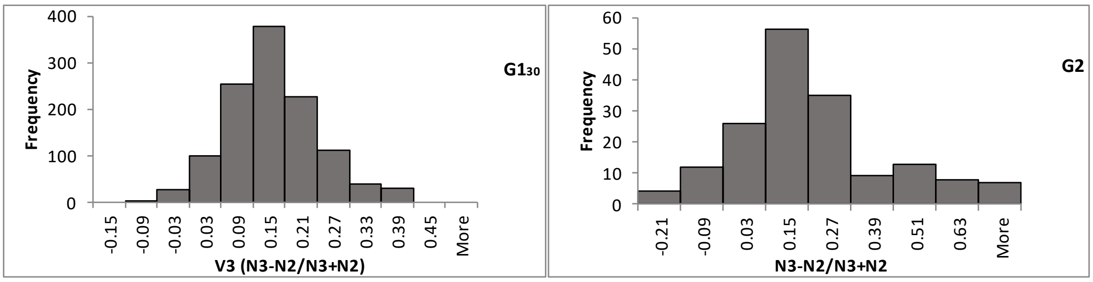


Figure 4.3. Histograms of $G1_{30}$ and $G2_{30}$ for variable V3 after 3-SD

An ANOVA test had been conducted after both of the methods. ANOVA test results for IQR and 3-SD are given in Table 4.3 and Table 4.4 respectively. P-values are reduced from 0.05 to 3.39E-05 and 5.01E-4 after IQR and 3-SD respectively. Both of the p-values are small enough to refuse the null hypothesis. The ANOVA test results shows that after IQR, the $G2_{30}$ particles have a mean V3 of 0.09, while those of $G1_{30}$ is 0.12. This is caused by having a much smaller lower limit for $G2_{30}$ than the lower limit of $G1_{30}$. Hence, consideration of two groups $G1_{30}$ and $G2_{30}$ separately in outlier analysis does not yield coherent results. A unique criterion for outlier limits should be determined.

Table 4.3. *ANOVA test results between $G1_{30}$ and $G2_{30}$ after IQR method.*

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
G1 IQR	1156	141.96	0.12	0.007
G2 IQR	138	12.48	0.09	0.014

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.13	1	0.13	17.31	3.39E-05	3.85
Within Groups	9.65	1292	0.01			
Total	9.78	1293				

Table 4.4. *ANOVA test results between $G1_{30}$ and $G2_{30}$ after 3-SD method.*

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
G1 3-SD	1170	145.60	0.12	0.007
G2 3-SD	170	26.51	0.16	0.045

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.15	1	0.15	12.17	5.01E-04	3.85
Within Groups	16.18	1338	0.01			
Total	16.33	1339				

Since variable V3 gets higher as the difference between second and third 150 mm advancement of the SPT sampler increases, specimens with larger particles usually has a higher V3. It is expected to have similar group means for both $G1_{30}$ and $G2_{30}$ after expelling the outliers. However, outlier limits determined by IQR method are resulting in a smaller group mean for $G2_{30}$, which implies that method may be distorting the data by determining some specimen as outliers while they may not be one. Therefore, outliers determined by IQR are not reliable. Furthermore, 3-SD limits removed no outliers from $G2_{30}$, which caused to group to have a higher mean, so the limit of 3-SD may not be the ideal outlier determination method as well. Instead of determining new outliers by using different limits such as 2 or 2.5 SD, an estimation based on the limits already determined by both of the methods for groups $G1_{30}$ and

$G2_{30}$ can be made. Moreover, having different outlier limits for each group is not only results in different group means, but also hinders the practical use of such limits in engineering applications. Consequently, the determined upper and lower outlier limits are preferable to be same for both of the groups.

4.2. Determination of Outlier Limits Based On Estimations

It is shown in Table 4.1 and Table 4.2 that a lower limit similar to that of IQR and 3-SD and suitable for both $G1_{30}$ and $G2_{30}$ must be within the range of -0.2 to -0.1. Similarly, a reasonable upper limit for V3 can be between 0.3 and 0.4. The three limits to be investigated and the corresponding data mean after expelling outliers are shown in Table 4.5. Cases 1, 2 and 3 have upper and lower outlier limits at a similar distance from the mean of V3.

Table 4.5. *Outlier limits determined by multipliers of SD*

Case	Upper Limit	Lower Limit	Average V3	% of Outliers	Non Outliers
1	0.4	-0.2	0.119	6.64%	1321
2	0.4	-0.1	0.124	8.34%	1297
3	0.3	-0.1	0.116	11.59%	1251

ANOVA test between the two groups $G1_{30}$ and $G2_{30}$ after expelling the outliers according to limits specified in cases 1, 2 and 3 is conducted. Highest p-value is obtained in case 2 as 0.12 as shown in Table 4.6. P-values obtained from ANOVA tests for cases 1 and 3 are 4.27E-4 and 0.028 respectively and the test results are given in Appendix E. Since p-values for cases 1 and 3 are very small, null hypothesis for those cases are rejected. However, for case 2, when the specimens with V3 higher than 0.4, or lower than -0.1 are expelled, similarity of V3 for means between the two soil groups results in a large p-value. Therefore, the test cannot strongly reject the statistical similarity between SPT results of the group with very little content of large soil particles, and the one with a high content, whereas such statistical similarity was not present before the removal of outliers.

Table 4.6. *ANOVA test results between $G1_{30}$ and $G2_{30}$ after outlier removals based on estimation 2.*

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*

G1 case 2	1169	146.73	0.13	0.007
G2 case 2	128	14.45	0.11	0.011

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.02	1	0.02	2.42	0.12	2.71
Within Groups	9.84	1295	0.01			

4.3. A Suggested Method for SPT-N Correction Due To Extreme Variability

The possible effect of gravels plugging the sampler on SPT-N can be partially eliminated by applying the limits determined in the previous section. Once the difference between N2 and N3 exceeds the limits for V3, specifying the range for outliers, the data can be corrected to be consistent with these limits. This is possible by decreasing N2 or N3 such that the condition -0.1 < V3 < 0.4 can be satisfied. Hence, the conditions

$$0.4 > \frac{N3 - N2}{N3 + N2}, or\ N3 < \frac{7}{3}N2 \qquad (1.a)$$

$$-0.1 < \frac{N3 - N2}{N3 + N2}, or\ N2 < \frac{11}{9}N3 \qquad (1.b)$$

Can be satisfied after reducing either N3 or N2 to the closest integer satisfying the above inequalities. When the specimen has a V3 above, N2 can be kept as it is recorded in field, and N3 can be reduced to the closest integer that is smaller than 7/3 of N2. Similarly, when the specimen has a V3 below the allowable limit of -0.1, N3 can be kept as it is recorded in field and N2 can be reduced to the closest integer that is smaller than 11/9 of N3. Some of the corrections applied to N3 due to having a V3 higher than the outlier limit are given in Table 4.7 while the full list of the corrected SPT-N data are available in Appendix F. Similarly, some corrections applied to N2 due to having a V3 lower than the outlier limit are given in Table 4.8 while the full list is in Appendix G.

Table 4.7. *N3 corrections on specimen with V3 > 0.4*

Log	Depth (m)	N2	N3	V3	SPT-N	Corrected N3	Corrected SPT-N	Corrected V3
AI-003-IZN	22.5	4	27	0.742	31	9	13	0.385

AI-010-BOL	10.5	9	26	0.486	35	21	30	0.400
AI-015-GRD	6.0	21	107	0.672	128	49	70	0.400
AI-026-MAT06-MIM	13.5	14	35	0.429	49	32	46	0.391
AI-029-MAT02	7.5	35	107	0.508	142	81	116	0.397

Table 4.8. *N2 corrections on specimen with V3 < -0.1*

Log	Depth (m)	N2	N3	V3	SPT-N	Corrected N2	Corrected SPT-N	Corrected V3
AI-006-AKY	7.5	35	25	-0.167	60	30	55	-0.091
AI-030-MAT04	16.5	18	14	-0.125	32	17	31	-0.097
AI-057-DBY	12.0	29	16	-0.289	45	19	35	-0.086
AI-071-TKT	6.0	25	20	-0.111	45	24	44	-0.091
AI-103-SMV	10.5	17	11	-0.214	28	13	24	-0.083

It should be noted that SPT log Al-015-GRD at the depth of 6.0m and Al-029-MAT02 at the depth of 7.5m shown in Table 4.7 were initially refusals due to having their SPT sampler failing to penetrate 15cm in 50 blows. Despite that the correction is also applied on them, such specimens are involved in this study because of the lack of gravelly specimen in the data. Utilizing such refusals in practice is not allowed by ASTM D1586 (2018).

The sample for corrected SPT-N is investigated by comparisons with SPT-N obtained in the closest depth in the same soil layer. The comparisons are shown in Table 4.9. Reduction in the SPT-N using the suggested method usually brought the SPT-N of the specimen down to a similar SPT-N of the specimen in the same soil layer that is 1.5m above or below. However, in some cases where the SPT-N of the specimen was already very small before the reduction, the change in SPT-N caused the difference between the specimen and the other soils in the same layer to be even greater. Engineering judgement is certainly necessary for such conditions. Nonetheless, the corrections for refused SPT are usually not sufficient to bring the test results to a value reported by a closest test result. Although very significant reductions in SPT-N are possible. This observation is supporting that SPT may not be a reliable test for parameter estimation in case either N2 or N3 exceeds the number 50 for 15cm penetration.

Table 4.9. *SPT-N comparison with the specimen in the same soil layer*

log	Depth (m)	Soil Type	SPT-N	Reduced SPT-N	SPT-N at +1.5m	SPT-N at -1.5m
AI-003-IZN	16.5	Clay	7	6	none	7
AI-003-IZN	22.5	Silt	31	13	none	12
AI-007-GYN-B	3.0	Sand	17	13	40	10
AI-007-GYN-B	4.5	Sand	10	3	17	12
AI-007-GYN-B	6.0	Sand	12	10	10	26
AI-008-GYN-D	7.5	Sand	3	2	8	8
AI-010-BOL	10.5	Sand	35	30	22	refusal
AI-011-DZC	24.0	Sand	160	116	72	refusal
AI-012-MEN	24.0	Clay	412	123	refusal	44
AI-015-GRD	6.0	Sand	128	70	56	none
AI-021-CYH-PTT	27.0	Clay	27	26	24	25
AI-023-MAT17	10.5	Sand	135	93	53	63
AI-026-MAT06-MIM	13.5	Gravel	49	46	39	none
AI-029-MAT02	7.5	Clay	142	116	46	refusal
AI-030-MAT04	16.5	Clay	32	31	none	52
AI-032-MAT07	3.0	Sand	10	8	none	13
AI-037-MAT13	16.5	Gravel	23	22	27	24
AI-040-ELB	25.5	Sand	143	120	40	refusal
AI-041-MAT11	21.0	Clay	105	73	35	refusal
AI-047-MLT	12.0	Clay	149	140	25	refusal

Table 4.10. (Continued) SPT-N comparison with the specimen in the same soil layer

log	Depth (m)	Soil Type	SPT-N	Reduced SPT-N	SPT-N at +1.5m	SPT-N at -1.5m
AI-052-MUS	18.0	Sand	24	22	refusal	24
AI-057-DBY	12.0	Sand	45	35	none	33
AI-063-TER-PTT	6.0	Gravel	52	48	refusal	37
AI-064-TER-MET	4.5	Clay	3	2	11	none
AI-066-ZAR	3.0	Clay	9	6	none	22
AI-074-AMS-BAY	4.5	Sand	190	133	56	67
AI-075-MRZ	12.0	Gravel	56	53	34	none
AI-081-IZN-KY	15.0	Silt	6	4	none	3

AI-081-IZN-KY	16.5	Silt	3	2	6	4
AI-081-IZN-KY	25.5	Clay	3	2	2	2
AI-081-IZN-KY	30.0	Clay	3	2	5	2
AI-082-CEK	3.0	Clay	38	35	11	39
AI-086-SRK	9.0	Sand	35	30	21	49
AI-086-SRK	12.0	Sand	125	103	49	49
AI-088-CNK	3.0	Sand	4	3	none	6
AI-095-EZN	3.0	Sand	66	60	none	71
AI-103-SMV	10.5	Sand	28	24	none	16
AI-107-DNZ-MET	19.5	Sand	228	133	57	none
AI-111-ODM	12.0	Sand	32	26	none	27
AI-115-BRN-BAY	6.0	Sand	3	2	2	none
AI-116-BRN-EU	13.5	Sand	36	35	none	51
AI-116-BRN-EU	19.5	Sand	40	33	refusal	27
AI-120-AYD-DSİ	1.5	Sand	20	16	none	53
AI-126-KOY	3.0	Gravel	31	26	none	49
AI-136-CRD	10.5	Gravel	105	100	none	64
AI-137-DIN	3.0	Clay	5	4	11	11
AI-137-DIN	10.5	Clay	16	13	7	none
AI-137-DIN	18.0	Sand	130	120	none	13
AI-139-AFY	1.5	Clay	5	4	none	6
AI-141-KUT-BAY	1.5	Clay	3	2	none	2
AI-142-KUT-SS	7.5	Sand	17	15	4	none
AI-147-BGD	3.0	Clay	34	28	refusal	19
AI-148-SNG	13.5	Sand	21	15	none	14

Table 4.11. (Continued) SPT-N comparison with the specimen in the same soil layer

log	Depth (m)	Soil Type	SPT-N	Reduced SPT-N	SPT-N at +1.5m	SPT-N at -1.5m
AI-148-SNG	16.5	Sand	17	15	14	30
AI-148-SNG	6.0	Sand	33	30	23	21
AI-150-BND-TDM	10.5	Clay	115	106	71	none

CHAPTER 5

CONCLUSIONS

In this study, the variability of SPT-N due to the plugging of SPT sampler by large particles were statistically investigated. Typically, such phenomena can be observed and noted during the field tests. However, failure to notice the extreme variability in SPT blow counts, possibly due to plugging of larger particles in the sample tube could cause an overestimation of representative penetration resistance of soil, which may pose a risk in geotechnical designs. Therefore, determining and understanding the effects of large particles, particularly those of gravels, on the SPT-N blow count after the field tests is vital.

Although there exists a screening framework for evaluating the gravel influence on the soil parameters (Ghafgazi et al., 2017) in the literature, a rigorous field work such as recording blow counts after every 2.5 cm penetration of sampler and obtaining physical evidences such as photographs and soil gradations of the samples are necessary to utilize that method. Such procedures not only takes away the simplicity of the SPT, but also are required to be executed during the field tests, which makes the method unavailable for the tests that have already been conducted. Therefore, a statistical method to reduce the artificial increase in penetration resistance due to gravel-sized particles is investigated in this study. To provide reliable limits for when to expect an artificial increase in the SPT-N, statistical tests had been conducted on SPT results conducted on 153 sites. By investigating the difference between the penetration resistance measured for the second 15 cm length of penetration (N2) and for the third (N3), possible limits to detect an artificial increase in SPT-N is statistically obtained. A database of standard penetration tests, conducted by the same testing equipment and operator was used to limit the variability due to equipment and procedures.

The data was cleared of any specimen that is not providing reliable information, such as those from landfills and from unclassified layers, as well as those from the refused SPT within the first 30cm interval of the penetration. However, to ensure that a sufficient number of gravelly samples are left for analyses, refusals within the last 15 cm interval are included by extrapolating their advancements. At later phases of the study, an outlier analysis is conducted to ensure that including such refusals caused no discrepancy within the data.

- Five variables related with the advancement of the SPT sampler's second and third 15cm intervals has been constructed. Data was separated into two groups according to their proportion of gravel-sized particles by weight. The variable V3=(N3-N2)/(N3+N2) was chosen for further statistical analyses since it was the one that yielded the sample frequency distribution closest to a normal distribution. The statistical test ANOVA has been conducted between the three soil types (clays, silts and sands) in group G1 defined as the soil specimens with proportions of gravel-sized particles by weight less than 50% to justify the assumption that they can be considered as a single class. Afterwards, an ANOVA test on groups G1 and G2 defined as the specimens with proportion of gravel-sized particles by weight move than 50% has been conducted to investigate their statistical differences. It was found that the groups separated at a proportion of gravel-sized particles at 50% were not statistically significantly different for the chosen variable V3. Therefore different groups separated at various proportions of gravel-sized particles were formed. It is found that samples whose mass proportion is greater than 30% have a noticeably different SPT blow count pattern than the samples with the smaller particle sizes. Therefore, the data for SPT-N for specimens whose mass proportion of gravel-sized soils is greater than 30% ($G2_{30}$) shows a significant statistical deviation from the distributions for finer materials ($G1_{30}$).

- Whether the differences between the group means of $G1_{30}$ and $G2_{30}$ was caused by the presence of outliers is investigated by using two different outlier removal methods. Three different sets of limits for variability of V3 are derived. Remaining three cases are investigated using ANOVA test, and it is found that after expelling the sample with a V3 greater than 0.4, or less than -0.1, similarity of statistical means for the groups $G1_{30}$ and $G2_{30}$ cannot be strongly rejected.

- Based on the determined outlier limits, a method for correcting the specimens that had their SPT results influenced by the presence of large particles was derived. The method is to reduce N3 to the closest integer that is smaller than 7/3 of N2 if V3>0.4, or to reduce N2 to the closest integer that is smaller than 11/9 of N3 if V3<-0.1 in case these thresholds are exceed. Using this method reduces V3 to a more reasonable range as well as reduces the SPT-N of the specimen, which is expected to yield a safer estimation for representative penetration resistance for soil considered in geotechnical design.

5.1. Possible Future Study Topics

- The sample for gravelly soils were limited. Therefore, a larger data set for gravels may be gathered for further assessment of statistical conclusions, but the variability due to differences between operators (testing procedures) and equipment needs attention.

- In this study, soil particles retained above sieve No 4 are considered as large particles, and the tests only considered the proportion of mass of the large particles when separating the data into two groups. However, no consideration was given into the actual sizes of these particles. The effect of size of particles passing No.4 sieve can be investigated by new sampling studies.

- SPT can be repeated in soils where excessive differences between N2 and N3 were observed for further justification of the criterion developed in this study.

REFERENCES

Aggour, M. S., & Rose, R. W. (2001). Standard Penetration Test (SPT) Correction. *Maryland Department of Transportation State Highway Administration*, (September), 1–93.

ASTM D3282-15 (2015). Standard Practice for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes. *ASTM Standard Test Method*. https://doi.org/10.1520/D3282-09.

ASTM D2487-17 (2017). Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System). *ASTM Standard Guide, D5521-05*, 1–5. https://doi.org/10.1520/D2487-11.

ASTM D6913-17 (2017). Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis. *ASTM International, West Conshohocken, PA, 04*(Reapproved 2009), 1–35. https://doi.org/10.1520/D6913-04R09.2

ASTM D1586-18 (2018). Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils. *ASTM Standard Test Method*, *D1586-08a*, 1–9. https://doi.org/10.1520/D1586-11.2

Burland, J. B., & Burbidge, M. C. (1985). Settlement of foundations on sand and gravel. *Proceedings of the Institution of Civil Engineers*, *78*(6), 1325–1381.

Daniel, C. G., Howie, J., & Sy, A. (2004). Characterization of SPT grain size effects in gravels, (1), 299–306.

DeJong, J. T., Sturm, A. P., & Ghafghazi, M. (2016). Characterization of gravelly alluvium. *Soil Dynamics and Earthquake Engineering*, *91*(September), 104–115. https://doi.org/10.1016/j.soildyn.2016.09.032

Devore, J. L. (2011). *Probability and Statistics for Engineering and the Sciences*.

Glass, G. V., Peckman, P. D., & Sanders, J. R. (1972). Consequences of Failure to Meet Assumptions Underlying the Fixed Effects Analyses of Variance and Covariance. *Review of Educational Research*, *42*(3), 237–288.

Ghafghazi, M., DeJong, J. T., Sturm, A. P., & Temple, C. E. (2017). Instrumented Becker Penetration Test. II: iBPT-SPT Correlation for Characterization and Liquefaction Assessment of Gravelly Soils. *Journal of Geotechnical and Geoenvironmental Engineering*, *143*(9), 04017063. https://doi.org/10.1061/(ASCE)GT.1943-5606.0001718

Horn, H. M. (1979). North American Experience in Sampling and Laboratory Dynamic Testing. *Geotechnical Testing Journal*, *GTJODJ*, *2*(2), 84-87.

Kulhawy, F. H., & Mayne, P. W. (1990). Manual on estimating soil properties for foundation design. Electric Power Research Institute, Palo Alto, Calif., Report EL-6800

Kulhawy, F. H., & Trautmann, C. H. (1996). Estimation of in situ test uncertainty. In Uncertainty in the geologic environment (GSP 58). Edited by C.D. Shackelford, P.P. Nelson, and M.J.S. Roth. American Society of Civil Engineers, New York, pp. 269– 286.

Liao, S. S. C., Veneziano, D., & Whitman, R. V. (1988). Regression Models For Evaluating Liquefaction Probability. *Journal of Geotechnical Engineering*, *114*(4), 389–411. https://doi.org/10.1061/(ASCE)0733-9410(1988)114:4(389)

Lix, M. L. Keselman, J. C., & Keselman H. J. (1996). Consequences of Assumption Violations Revisited : A Quantitative Review of Alternatives to the One-Way Analysis of Variance " F " Test. *Review of Educational Research*, *66*(4), 579–619.

Harwell, M. R., Rubinstein, E.N., Hayes, W. S., & Olds, C. C. (1992). Summarizing Monte Carlo Results in Methodological Research : The One- and Two-Factor Fixed Effects ANOVA Cases. *Journal of Educational Statistics*, *17*(4), 315–339.

Moore, D. S., & McCabe, G. P. (1999). *Introduction to the Practice of Statistics*.

NAVFAC DM-7.1. (1986). Soil Mechanics Design Manual 7.1. *Department of the Navy*

Navidi, W. (2015). *Statistics for Engineers and Scientists*.

Pearson, R. K. (2002). Outliers in Process Modelling and Identification, *IEEE Transactions on Control Systems Technology, 10(1)*

Phoon, K. K., & Kulhawy, F. H. (1999). Characterization of geotechnical variability. *Canadian Geotechnical Journal*, *36*(4), 612–624. https://doi.org/10.1139/t99-038

Phoon, K. K., Kulhawy, F. H., & Grigoriu, M. D. (1995). Reliability-Based Design of Foundations for Transmission Line Structures. *Electrical Power Research Institute, Palo Alto, Report TR-105000*.

Punmia, B. C., Jain, A. K., & Jain, A. K. (2005). *Soil Mechanics and Foundations*.

Rollins, K. M., Diehl, N. B., & Weaver, T. J. (1998). Implications of Vs—BPT $(N_1)_{60}$ correlations for liquefaction assessment in gravels. *Geotechnical earthquake engineering and soil dynamics III*, Vol. 1, ASCE, Reston, VA, 506–507.

Sandıkkaya, M. A. (2008). Site Classification of Turkish National Strong-Motion Recording Sites (Unpublished master's thesis). Middle East Technical University, Ankara, Turkey

Sandıkkaya, M. A., Yılmaz, M. T., Bakır, B. S., & Yılmaz, Ö. (2010). Site Classification of Turkish National Strong-Motion Stations. *Journal of Seismology*, *14*(3), 543-563. https://doi.org/10.1007/s10950-009-9182-y

Sivrikaya, O., & Togrol, E. (2007). Relationships between SPT-N value and Undrained Shear Strength of Fine-grained Soils in Turkey. *Teknik Dergi*, *18*(89), 4229–4246.

Sturges, H. A. (1926). The Choice of a Class Interval. *Journal of the American Statistical Association*, *21*(153), 65–66. Retrieved from http://www.jstor.org/stable/2965501

Tan, C. G., Majid, T. A., Ariffin, K. S., & Bunnori, N. M. (2012). Site-specific empirical correlation between shear wave velocity and standard penetration resistance using MASW method. *CHUSER 2012 - 2012 IEEE Colloquium on Humanities, Science and Engineering Research*, (Chuser), 94–97. https://doi.org/10.1109/CHUSER.2012.6504288

APPENDICES

A. List of extrapolated SPT-N due to test refusal

Boring Log	Depth (m)	SPT No	N1	N2	Extrapolated N3	N3/distance (1/cm)
AI-006-AKY	18.0	SPT12	16	30	107	50/7
AI-011-DZC	4.5	SPT-3	20	32	68	50/11
AI-011-DZC	12.0	SPT-8	12	38	107	50/7
AI-011-DZC	15.0	SPT-10	21	38	75	50/10
AI-011-DZC	24.0	SPT-16	18	35	125	50/6
AI-012-MEN	21.0	SPT-14	17	26	150	50/5
AI-012-MEN	24.0	SPT-16	18	37	375	50/2
AI-015-GRD	6.0	SPT-4	12	21	107	50/7
AI-016-BEY	22.5	SPT-15	19	47	83	50/9
AI-016-BEY	24.0	SPT-16	28	32	125	50/6
AI-019-MRS	12.0	SPT-8	17	30	58	50/13
AI-023-MAT17	10.5	SPT-7	17	28	107	50/7
AI-023-MAT17	25.5	SPT-17	19	32	125	50/6
AI-026-MAT06-MIM	7.5	SPT-5	18	43	58	50/13
AI-029-MAT02	7.5	SPT-5	22	35	107	50/7
AI-029-MAT02	9.0	SPT-6	26	39	150	50/5
AI-032-MAT07	24.0	SPT-16	19	26	150	50/5
AI-038_MAT14	18.0	SPT-10	25	40	150	50/5
AI-038_MAT14	24.0	SPT-13	8	17	188	50/4
AI-040-ELB	15.0	SPT-10	24	38	75	50/10
AI-040-ELB	16.5	SPT-11	22	34	68	50/11
AI-040-ELB	25.5	SPT-17	30	36	107	50/7
AI-041-MAT11	21.0	SPT-14	22	22	83	50/9
AI-041-MAT11	25.5	SPT-17	21	32	125	50/6
AI-047-MLT	12.0	SPT-8	37	42	107	50/7
AI-049-BNG	7.5	SPT-5	29	29	75	50/10
AI-049-BNG	12.0	SPT-8	29	35	83	50/9
AI-049-BNG	18.0	SPT-12	22	38	125	50/6
AI-049-BNG	28.5	SPT-19	32	42	83	50/9
AI-062-ERZ	6.0	SPT-4	25	40	94	50/8
AI-062-ERZ	9.0	SPT-6	27	39	107	50/7
AI-062-ERZ	15.0	SPT-10	22	38	125	50/6
AI-064-TER-MET	6.0	SPT-4	22	38	75	50/10
AI-070-RES	19.5	SPT-13	16	32	125	50/6
Boring Log	Depth (m)	SPT No	N1	N2	Extrapolated N3	N3/distance (cm)
AI-071-TKT	16.5	SPT-11	22	32	150	50/5
AI-071-TKT	30.0	SPT-20	19	32	107	50/7
AI-072-ERB	16.5	SPT-11	20	36	188	50/4
AI-072-ERB	24.0	SPT-16	22	37	75	50/10

AI-074-AMS-BAY	4.5	SPT-3	18	40	150	50/5
AI-078-KRG	3.0	SPT-2	4	12	94	50/8
AI-079-TOS	19.5	SPT-13	30	41	150	50/5
AI-086-SRK	12.0	SPT-8	15	31	94	50/8
AI-087-GL-1	3.0	SPT-2	15	37	75	50/10
AI-087-GL-1	10.5	SPT-7	27	38	75	50/10
AI-087-GL-1	12.0	SPT-8	35	43	94	50/8
AI-087-GL-1	13.5	SPT-9	23	36	83	50/9
AI-087-GL-1	27.0	SPT-18	28	43	125	50/6
AI-087-GL-1	28.5	SPT-19	33	46	125	50/6
AI-090-BGA	10.5	SPT-7	23	41	125	50/6
AI-097-AYV	3.0	SPT-2	16	45	125	50/6
AI-098-DKL	28.5	SPT-19	31	42	75	50/10
AI-099-KNK	16.5	SPT-9	17	40	94	50/8
AI-106-BLD	4.5	SPT-3	23	44	150	50/5
AI-107-DNZ-MET	3.0	SPT-2	26	35	94	50/8
AI-107-DNZ-MET	19.5	SPT-13	16	40	188	50/4
AI-126-KOY	25.5	SPT-17	26	32	150	50/5
AI-136-CRD	10.5	SPT-7	11	30	75	50/10
AI-137-DIN	18.0	SPT-12	11	36	94	50/8
AI-138-SDL	15.0	SPT-10	38	45	75	50/10
AI-140-STG	6.0	SPT-3	17	29	107	50/7
AI-147-BGD	24.0	SPT-18	18	37	107	50/7
AI-147-BGD	25.5	SPT-17	13	21	125	50/6
AI-147-BGD	27.0	SPT-18	21	27	150	50/5
AI-147-BGD	28.5	SPT-19	18	28	125	50/6
AI-150-BND-TDM	10.5	SPT-7	28	32	83	50/9
AI-150-BND-TDM	25.5	SPT-17	26	34	75	50/10
AI-152-BRS	3.0	SPT-2	14	30	94	50/8

B. The sample for statistical analyses

Boring Log	depth (m)	N1	N2	N3	USCS
AI-003-IZN	6	2	7	4	SP/SM
AI-003-IZN	7.5	4	5	7	CL
AI-003-IZN	9	7	10	12	SC
AI-003-IZN	10.5	9	11	11	SP/SM
AI-003-IZN	12	12	12	14	SM
AI-003-IZN	13.5	10	10	18	SP/SM
AI-003-IZN	15	10	11	11	ML
AI-003-IZN	16.5	4	4	3	CL
AI-003-IZN	18	2	3	4	CL
AI-003-IZN	19.5	2	3	3	CL
AI-003-IZN	21	2	2	3	CL/ML
AI-003-IZN	22.5	2	4	27	ML
AI-003-IZN	24	8	6	8	SM
AI-003-IZN	25.5	8	11	13	ML
AI-003-IZN	27	6	7	6	SM
AI-003-IZN	28.5	6	8	8	CL/ML
AI-003-IZN	30	7	8	8	CL/ML
AI-003-IZN	31.5	7	7	9	ML
AI-003-IZN	33	8	8	8	CL
AI-003-IZN	34.5	3	5	7	CL/ML
AI-003-IZN	36	2	4	6	ML
AI-003-IZN	37.5	13	15	25	SM
AI-003-IZN	39	19	24	28	SP/SM
AI-005-SKR	1.5	3	6	7	CL
AI-005-SKR	3	7	12	17	CL
AI-005-SKR	4.5	12	14	17	CL
AI-005-SKR	9	19	22	31	CL
AI-006-AKY	1.5	2	2	3	CL
AI-006-AKY	3	2	3	4	CL/ML
AI-006-AKY	4.5	3	4	5	CL/ML
AI-006-AKY	7.5	26	35	25	GW/GM
AI-006-AKY	12	12	7	6	CL
AI-006-AKY	13.5	7	7	8	CL/ML
AI-006-AKY	15	8	9	10	CL/ML
AI-006-AKY	16.5	7	8	7	CL/ML
AI-006-AKY	18	16	30	107	SM
AI-006-AKY	21	16	22	25	SW/SM
AI-006-AKY	24	16	28	31	SW/SM
AI-006-AKY	30	17	33	35	SW
AI-007-GYN-B	1.5	15	20	20	SM
AI-007-GYN-B	3	3	4	13	SW/SM

Boring Log	depth (m)	N1	N2	N3	USCS
AI-007-GYN-B	4.5	3	1	9	SW/SM
AI-007-GYN-B	6	7	3	9	SM
AI-007-GYN-B	7.5	10	10	16	SM
AI-007-GYN-B	9	4	6	12	SM
AI-007-GYN-B	15	8	14	32	ML
AI-008-GYN-D	4.5	3	3	4	CL
AI-008-GYN-D	6	3	4	4	SC
AI-008-GYN-D	7.5	3	2	1	SC
AI-008-GYN-D	9	3	3	5	SC
AI-009-MDR	3	2	9	14	SC
AI-009-MDR	6	14	19	21	SC
AI-009-MDR	7.5	13	19	17	SC
AI-009-MDR	10.5	14	20	16	SC
AI-009-MDR	18	9	9	10	SC
AI-009-MDR	19.5	17	19	24	SC
AI-010-BOL	1.5	2	5	9	CH
AI-010-BOL	3	5	11	14	CH
AI-010-BOL	4.5	7	10	13	CH
AI-010-BOL	6	5	9	13	CH
AI-010-BOL	7.5	7	10	12	CH
AI-010-BOL	9	4	8	14	CL
AI-010-BOL	10.5	6	9	26	SC
AI-010-BOL	13.5	7	9	11	CL/ML
AI-010-BOL	15	13	17	25	CL
AI-010-BOL	18	14	11	18	CL
AI-010-BOL	19.5	8	12	16	CL
AI-010-BOL	21	8	13	24	CH
AI-010-BOL	22.5	9	17	25	CL
AI-010-BOL	27	10	15	21	CL
AI-010-BOL	28.5	8	16	23	CH
AI-010-BOL	30	9	17	21	CH
AI-011-DZC	1.5	1	2	4	CL
AI-011-DZC	3	2	3	4	CL
AI-011-DZC	4.5	20	32	68	SW/SC
AI-011-DZC	6	5	7	11	CL
AI-011-DZC	7.5	4	7	12	CL/ML
AI-011-DZC	9	5	9	14	CL
AI-011-DZC	10.5	6	10	17	CL/ML
AI-011-DZC	12	12	38	107	SM
AI-011-DZC	15	21	38	75	SP/SM
AI-011-DZC	18	24	36	45	SM
AI-011-DZC	22.5	16	28	44	SP
AI-011-DZC	24	18	35	125	SP

Boring Log	depth (m)	N1	N2	N3	USCS
AI-012-MEN	1.5	2	3	4	CL/ML
AI-012-MEN	3	1	1	1	CL/ML
AI-012-MEN	4.5	8	14	9	GW
AI-012-MEN	7.5	6	16	24	CL
AI-012-MEN	9	14	18	26	CL
AI-012-MEN	10.5	14	22	30	CL
AI-012-MEN	12	10	17	24	CL
AI-012-MEN	13.5	9	18	25	CL
AI-012-MEN	21	17	26	150	CL
AI-012-MEN	24	18	37	375	CL
AI-012-MEN	25.5	10	19	25	CL
AI-012-MEN	27	9	22	30	CL
AI-012-MEN	28.5	13	25	38	CL
AI-013-CER	4.5	9	29	40	GC
AI-013-CER	6	4	8	10	CH
AI-013-CER	7.5	7	10	12	CH
AI-013-CER	9	7	11	13	CH
AI-013-CER	10.5	8	10	14	CH
AI-013-CER	12	7	13	13	CH
AI-013-CER	13.5	8	12	14	CH
AI-015-GRD	1.5	17	21	22	GW/GC
AI-015-GRD	3	5	10	11	SW/SC
AI-015-GRD	6	12	21	107	SW/SC
AI-016-BEY	1.5	8	11	18	CH
AI-016-BEY	3	7	9	9	SC
AI-016-BEY	4.5	8	10	13	GM
AI-016-BEY	6	11	13	14	CH
AI-016-BEY	7.5	10	14	26	CH
AI-016-BEY	9	27	38	40	CH
AI-016-BEY	10.5	16	24	38	CH
AI-016-BEY	12	17	22	35	CH
AI-016-BEY	13.5	31	35	40	CH
AI-016-BEY	15	28	34	41	CH
AI-016-BEY	16.5	15	26	34	CH
AI-016-BEY	18	17	23	35	CH
AI-016-BEY	19.5	31	37	41	CH
AI-016-BEY	22.5	19	47	83	SC
AI-016-BEY	24	28	32	125	CH
AI-018-CMR	2	7	18	15	SM
AI-018-CMR	3	6	6	7	GP
AI-018-CMR	4.5	7	8	8	SC
AI-018-CMR	6	5	9	12	SC
AI-018-CMR	7.5	8	11	17	SC

Boring Log	depth (m)	N1	N2	N3	USCS
AI-019-MRS	1.5	2	2	4	CL
AI-019-MRS	4.5	5	2	2	CL
AI-019-MRS	6	3	4	5	CH
AI-019-MRS	7.5	5	9	14	CL
AI-019-MRS	9	5	12	14	CL
AI-019-MRS	12	17	30	58	SC
AI-019-MRS	22.5	13	20	26	SC
AI-019-MRS	25.5	18	26	32	SP
AI-019-MRS	27	20	30	38	SP/SM
AI_020_KRT	1.5	14	22	38	CL
AI-021-CYH-PTT	1.5	4	4	6	CL
AI-021-CYH-PTT	3	5	7	9	CL
AI-021-CYH-PTT	4.5	3	5	7	CL
AI-021-CYH-PTT	6	4	4	5	CH
AI-021-CYH-PTT	7.5	9	10	13	ML
AI-021-CYH-PTT	9	11	12	14	ML
AI-021-CYH-PTT	10.5	7	9	13	CH
AI-021-CYH-PTT	12	5	8	14	CH
AI-021-CYH-PTT	13.5	4	5	7	CH
AI-021-CYH-PTT	15	4	5	6	CH
AI-021-CYH-PTT	16.5	5	6	8	CH
AI-021-CYH-PTT	18	4	5	7	CL
AI-021-CYH-PTT	19.5	6	8	10	CH
AI-021-CYH-PTT	21	7	9	13	CH
AI-021-CYH-PTT	22.5	7	8	11	CL
AI-021-CYH-PTT	24	7	10	12	CH
AI-021-CYH-PTT	25.5	6	9	15	CL
AI-021-CYH-PTT	27	6	8	19	CL
AI-021-CYH-PTT	28.5	7	10	15	CL
AI-021-CYH-PTT	30	7	11	16	CH
AI-022-CYH-TIM	1.5	3	5	6	CL
AI-022-CYH-TIM	3	6	9	11	CL/ML
AI-022-CYH-TIM	4.5	9	9	9	CL/ML
AI-022-CYH-TIM	6	2	4	4	CH
AI-022-CYH-TIM	7.5	6	7	10	CL
AI-022-CYH-TIM	9	5	7	9	CH
AI-022-CYH-TIM	10.5	4	5	7	CL
AI-022-CYH-TIM	12	9	10	11	ML
AI-022-CYH-TIM	13.5	4	6	9	CH
AI-022-CYH-TIM	15	6	8	9	CH
AI-022-CYH-TIM	16.5	7	8	10	CH
AI-022-CYH-TIM	18	5	7	8	CH
AI-022-CYH-TIM	19.5	4	5	8	CH

Boring Log	depth (m)	N1	N2	N3	USCS
AI-022-CYH-TIM	21	5	6	8	CH
AI-022-CYH-TIM	22.5	3	5	6	CH
AI-022-CYH-TIM	24	9	13	15	CL
AI-022-CYH-TIM	25.5	7	11	14	CH
AI-022-CYH-TIM	27	11	16	16	CH
AI-022-CYH-TIM	28.5	10	15	17	CH
AI-022-CYH-TIM	30	10	16	16	CH
AI-023-MAT17	3	4	6	7	SM
AI-023-MAT17	4.5	4	6	11	SM
AI-023-MAT17	9	26	19	34	SP/SM
AI-023-MAT17	10.5	17	28	107	SM
AI-023-MAT17	12	19	27	36	SP
AI-023-MAT17	13.5	13	24	35	GP
AI-023-MAT17	15	18	25	31	SP
AI-023-MAT17	18	21	28	39	GM
AI-023-MAT17	19.5	14	27	33	GP
AI-023-MAT17	21	19	23	31	GP
AI-023-MAT17	22.5	10	17	26	SP
AI-023-MAT17	25.5	19	32	125	GW
AI-025-MAT06-MET	6	10	16	16	SP
AI-025-MAT06-MET	7.5	10	16	18	SM
AI-025-MAT06-MET	9	11	17	22	SM
AI-025-MAT06-MET	10.5	4	6	9	SP
AI-025-MAT06-MET	12	4	8	11	SP/SM
AI-025-MAT06-MET	13.5	5	7	10	SP
AI-025-MAT06-MET	15	5	8	13	SP
AI-025-MAT06-MET	16.5	7	9	16	SP/SM
AI-025-MAT06-MET	18	7	10	18	SP
AI-025-MAT06-MET	19.5	11	13	17	SP/SM
AI-025-MAT06-MET	21	8	9	18	SP/SM
AI-025-MAT06-MET	22.5	7	11	18	SP/SM
AI-025-MAT06-MET	24	6	10	13	SP/SC
AI-025-MAT06-MET	25.5	11	16	20	SP/SM
AI-025-MAT06-MET	27	10	16	22	SP/SM
AI-025-MAT06-MET	28.5	12	16	21	SP/SM
AI-025-MAT06-MET	30	11	16	22	SP/SM
AI-026-MAT06-MIM	1.5	4	6	9	CL
AI-026-MAT06-MIM	3	3	4	7	CL
AI-026-MAT06-MIM	4.5	6	8	11	CH
AI-026-MAT06-MIM	6	4	20	30	GM
AI-026-MAT06-MIM	7.5	18	43	58	SW/SM
AI-026-MAT06-MIM	10.5	10	20	24	SM
AI-026-MAT06-MIM	12	10	15	24	SP/SM

Boring Log	depth (m)	N1	N2	N3	USCS
AI-026-MAT06-MIM	13.5	13	14	35	GP/GM
AI-026-MAT06-MIM	15	12	15	23	SM
AI-026-MAT06-MIM	16.5	10	14	23	SP/SM
AI-026-MAT06-MIM	19.5	22	30	42	SP/SM
AI-027-MAT01	1.5	3	3	3	CL
AI-027-MAT01	3	8	11	17	CL/ML
AI-027-MAT01	4.5	11	17	25	SP
AI-027-MAT01	6	14	17	24	SP
AI-027-MAT01	7.5	12	18	21	SP
AI-027-MAT01	9	10	13	24	SP/SM
AI-027-MAT01	10.5	7	11	19	SM
AI-027-MAT01	12	8	14	21	SM
AI-027-MAT01	13.5	7	14	20	SM
AI-027-MAT01	15	8	11	16	SM
AI-027-MAT01	16.5	7	11	16	SM
AI-027-MAT01	18	11	16	20	SM
AI-027-MAT01	19.5	9	18	21	SM
AI-027-MAT01	21	15	18	20	SP/SM
AI-027-MAT01	22.5	11	13	16	SM
AI-027-MAT01	24	9	15	20	SM
AI-027-MAT01	25.5	7	17	21	SM
AI-027-MAT01	27	10	15	24	SM
AI-027-MAT01	28.5	8	18	23	SM
AI-027-MAT01	30	9	17	25	SM
AI-028-MAT03	1.5	5	9	13	CH
AI-028-MAT03	3	18	22	35	GC/M
AI-029-MAT02	1.5	8	11	14	CH
AI-029-MAT02	3	5	7	8	CH
AI-029-MAT02	6	10	18	28	CH
AI-029-MAT02	7.5	22	35	107	CH
AI-029-MAT02	9	26	39	150	CH
AI-030-MAT04	1.5	14	14	15	GM
AI-030-MAT04	4.5	9	14	14	GW/GM
AI-030-MAT04	6	12	11	19	SC
AI-030-MAT04	7.5	12	13	16	SC
AI-030-MAT04	9	7	10	13	SC
AI-030-MAT04	10.5	8	25	38	CH
AI-030-MAT04	12	10	13	15	CH
AI-030-MAT04	13.5	8	10	12	CH
AI-030-MAT04	15	8	11	13	SC/M
AI-030-MAT04	16.5	13	18	14	CL
AI-030-MAT04	18	14	17	35	CL
AI-030-MAT04	19.5	10	18	43	SM

Boring Log	depth (m)	N1	N2	N3	USCS
AI-032-MAT07	3	12	6	4	SC
AI-032-MAT07	4.5	9	7	6	SC
AI-032-MAT07	6	5	6	7	CL
AI-032-MAT07	7.5	1	3	4	CL
AI-032-MAT07	9	3	6	10	CL
AI-032-MAT07	10.5	6	11	14	CL
AI-032-MAT07	12	7	12	15	CL
AI-032-MAT07	13.5	7	16	33	CL
AI-032-MAT07	15	8	12	16	CL
AI-032-MAT07	16.5	11	21	25	SC
AI-032-MAT07	18	9	11	14	SM
AI-032-MAT07	19.5	8	12	16	CL
AI-032-MAT07	24	19	26	150	SW/SM
AI-035-MAT15	1.5	17	25	38	CH
AI-036-MAT16	4.5	19	34	31	SC
AI-036-MAT16	24	20	17	34	SM
AI-037-MAT13	6	4	8	12	GC/M
AI-037-MAT13	7.5	16	24	34	GP
AI-037-MAT13	9	4	13	13	GC
AI-037-MAT13	10.5	4	5	8	SC
AI-037-MAT13	12	8	11	12	GC
AI-037-MAT13	13.5	8	8	10	SC
AI-037-MAT13	15	8	14	13	GP/GC
AI-037-MAT13	16.5	12	13	10	GC
AI-037-MAT13	18	15	12	12	GC
AI-037-MAT13	19.5	9	12	14	GP
AI-037-MAT13	24	11	15	18	SC
AI-037-MAT13	27	13	20	24	SC/M
AI-038_MAT14	18	25	40	150	SC/M
AI-038_MAT14	24	8	17	188	CL/ML
AI-040-ELB	1.5	18	27	34	CL
AI-040-ELB	3	4	6	8	CL
AI-040-ELB	4.5	10	13	20	GC/M
AI-040-ELB	6	10	14	20	SC/M
AI-040-ELB	7.5	3	4	6	CH
AI-040-ELB	9	7	9	15	CH
AI-040-ELB	10.5	8	10	14	CH
AI-040-ELB	12	9	10	11	CL
AI-040-ELB	13.5	8	11	12	CL
AI-040-ELB	15	24	38	75	GP/GC/M
AI-040-ELB	16.5	22	34	68	SC
AI-040-ELB	18	11	15	16	CL
AI-040-ELB	19.5	14	22	22	SP

Boring Log	depth (m)	N1	N2	N3	USCS
AI-040-ELB	21	19	24	32	SW/SC/M
AI-040-ELB	24	11	16	24	SW
AI-040-ELB	25.5	30	36	107	SC/M
AI-041-MAT11	1.5	8	14	34	SC
AI-041-MAT11	4.5	12	18	26	SC
AI-041-MAT11	6	10	17	23	GC
AI-041-MAT11	7.5	13	23	29	SC
AI-041-MAT11	9	10	17	17	CL
AI-041-MAT11	10.5	11	20	29	SC
AI-041-MAT11	12	13	24	31	SC
AI-041-MAT11	13.5	10	19	26	SC
AI-041-MAT11	18	7	12	17	CL
AI-041-MAT11	19.5	8	15	20	CL
AI-041-MAT11	21	22	22	83	CL/ML
AI-041-MAT11	25.5	21	32	125	SC/M
AI-042-MAT12-MET	1.5	8	12	17	CL
AI-042-MAT12-MET	3	16	20	25	CH
AI-042-MAT12-MET	4.5	9	17	21	CH
AI-042-MAT12-MET	6	11	13	17	CH
AI-042-MAT12-MET	7.5	14	15	16	CL
AI-042-MAT12-MET	9	13	17	26	CH
AI-042-MAT12-MET	10.5	15	20	23	CH
AI-042-MAT12-MET	12	14	18	27	CH
AI-042-MAT12-MET	13.5	13	19	30	CH/CL
AI-042-MAT12-MET	15	10	12	18	CH
AI-042-MAT12-MET	16.5	7	10	21	CH
AI-042-MAT12-MET	18	7	13	19	CH
AI-042-MAT12-MET	19.5	10	16	18	CH
AI-042-MAT12-MET	21	13	17	25	CH
AI-042-MAT12-MET	22.5	13	18	20	CH
AI-042-MAT12-MET	25.5	10	13	19	CH
AI-042-MAT12-MET	27	9	12	20	CH
AI-042-MAT12-MET	28.5	11	17	18	CH
AI-042-MAT12-MET	30	12	15	21	CH
AI-043-KMR	3	8	5	10	CL
AI-047-MLT	6	9	10	12	CL
AI-047-MLT	7.5	7	10	19	CL
AI-047-MLT	9	8	12	13	GC
AI-047-MLT	10.5	7	11	14	CL
AI-047-MLT	12	37	42	107	CH
AI-048-ELZ	1.5	4	13	13	CL
AI-048-ELZ	3	23	29	31	CL
AI-048-ELZ	4.5	22	28	32	CL

Boring Log	depth (m)	N1	N2	N3	USCS
AI-049-BNG	7.5	29	29	75	GC/M
AI-049-BNG	12	29	35	83	GC/M
AI-049-BNG	18	22	38	125	GC/M
AI-049-BNG	28.5	32	42	83	GC/M
AI-050-SLH-OE	3	9	13	18	CL
AI-050-SLH-OE	4.5	8	16	15	CL
AI-050-SLH-OE	6	8	11	12	SC
AI-050-SLH-OE	7.5	9	10	13	SC
AI-050-SLH-OE	9	10	12	15	SC
AI-050-SLH-OE	10.5	9	11	17	SC
AI-050-SLH-OE	12	12	16	20	SC
AI-050-SLH-OE	13.5	10	14	18	SC
AI-050-SLH-OE	15	20	26	24	GC/M
AI-51-SLH-MET	3	8	13	16	CL
AI-51-SLH-MET	4.5	10	12	18	CL
AI-51-SLH-MET	6	18	11	16	SC
AI-51-SLH-MET	7.5	9	10	21	SC
AI-51-SLH-MET	10.5	16	20	32	SC
AI-51-SLH-MET	12	10	12	19	GC
AI-51-SLH-MET	13.5	8	15	17	CL
AI-052-MUS	1.5	8	6	9	SC
AI-052-MUS	3	6	8	11	SC
AI-052-MUS	4.5	4	9	12	GC
AI-052-MUS	6	6	9	13	SC
AI-052-MUS	7.5	5	7	9	SC
AI-052-MUS	9	5	5	7	GC
AI-052-MUS	10.5	6	5	7	CL
AI-052-MUS	12	8	10	12	CL
AI-052-MUS	15	8	3	13	SC/M
AI-052-MUS	18	15	14	10	SC/M
AI-052-MUS	19.5	7	12	12	SC
AI-052-MUS	21	7	13	15	CL
AI-052-MUS	22.5	8	14	13	SC
AI-052-MUS	24	8	12	17	SC
AI-052-MUS	25.5	10	13	15	SC
AI-052-MUS	27	10	14	17	SC
AI-052-MUS	28.5	12	16	18	SC
AI-052-MUS	30	12	17	18	SC
AI-053-MLZ	1.5	3	5	7	CH
AI-053-MLZ	3	10	21	30	CL
AI-053-MLZ	4.5	11	16	23	SC
AI-053-MLZ	6	8	13	17	SC
AI-053-MLZ	7.5	9	14	17	CL/ML

Boring Log	depth (m)	N1	N2	N3	USCS
AI-053-MLZ	9	10	16	18	CL/ML
AI-053-MLZ	10.5	11	12	15	CH
AI-053-MLZ	12	9	12	17	CH
AI-053-MLZ	13.5	8	16	18	CH
AI-053-MLZ	15	9	16	18	CH
AI-053-MLZ	16.5	8	16	18	CH
AI-053-MLZ	18	8	16	18	CH
AI-053-MLZ	19.5	10	15	18	CH
AI-053-MLZ	21	8	13	19	CH
AI-053-MLZ	22.5	11	16	19	CH
AI-053-MLZ	24	8	12	20	CH
AI-053-MLZ	25.5	9	14	21	CH
AI-053-MLZ	27	11	16	19	CH
AI-053-MLZ	28.5	12	16	20	CH
AI-053-MLZ	30	13	18	21	CH
AI-054-TAT	1.5	6	5	7	SC/M
AI-054-TAT	3	3	5	6	SC/M
AI-054-TAT	4.5	6	9	15	SC/M
AI-054-TAT	6	9	10	10	SP/SC/M
AI-054-TAT	7.5	8	11	12	SP/SC/M
AI-054-TAT	9	7	10	13	SW
AI-054-TAT	10.5	15	27	40	SC/M
AI-055-VAN	1.5	2	9	17	CL
AI-055-VAN	3	6	11	32	SC/M
AI-055-VAN	7.5	5	9	13	CL/ML
AI-055-VAN	10.5	10	12	14	SC/M
AI-055-VAN	12	9	14	14	CL
AI-055-VAN	13.5	9	12	13	CH
AI-055-VAN	15	9	13	18	CL
AI-055-VAN	16.5	8	10	20	CL
AI-055-VAN	18	8	14	18	CL/ML
AI-055-VAN	21	14	14	24	SC/M
AI-055-VAN	22.5	13	17	26	CL/ML
AI-055-VAN	24	11	12	21	CL/ML
AI-055-VAN	25.5	14	15	24	SC/M
AI-055-VAN	27	10	16	25	CL/ML
AI-055-VAN	28.5	15	18	27	CL
AI-055-VAN	30	12	15	26	CL/ML
AI-056-MUR	3	7	8	8	SP/SC/M
AI-056-MUR	4.5	3	6	6	CL/ML
AI-056-MUR	6	3	5	6	SC/M
AI-056-MUR	7.5	3	5	7	SC/M
AI-056-MUR	9	4	6	7	SC/M

Boring Log	depth (m)	N1	N2	N3	USCS
AI-056-MUR	10.5	2	4	8	SC/M
AI-056-MUR	12	3	6	7	CL/ML
AI-056-MUR	13.5	7	10	15	ML/CL
AI-056-MUR	15	8	12	14	ML/CL
AI-056-MUR	16.5	5	5	9	CL
AI-056-MUR	18	6	7	8	ML
AI-056-MUR	19.5	2	4	4	ML
AI-056-MUR	21	4	7	9	CL
AI-057-DBY	4.5	6	7	8	CL
AI-057-DBY	6	4	5	6	CL
AI-057-DBY	7.5	3	4	7	CL
AI-057-DBY	9	5	7	6	SC
AI-057-DBY	10.5	6	7	8	CL
AI-057-DBY	12	29	29	16	SW/SM
AI-057-DBY	13.5	10	12	21	SM
AI-057-DBY	15	12	18	21	SM
AI-057-DBY	16.5	14	15	27	SM
AI-057-DBY	18	13	15	26	SW/SM
AI-057-DBY	19.5	11	13	12	SM
AI-057-DBY	21	15	17	19	SC/SM
AI-057-DBY	22.5	8	12	16	SC/SM
AI-057-DBY	24	7	12	15	GC/GM
AI-057-DBY	25.5	9	10	18	SC/SM
AI-057-DBY	27	8	13	13	SC
AI-057-DBY	28.5	11	11	16	SC
AI-057-DBY	30	10	14	19	SC
AI-058-AGR	9	3	4	11	CL
AI-058-AGR	10.5	7	7	15	SP/SC/M
AI-058-AGR	12	6	8	12	CH
AI-058-AGR	13.5	6	10	13	CH
AI-058-AGR	15	14	17	21	CL
AI-058-AGR	16.5	11	15	20	CH
AI-058-AGR	18	10	16	18	CL
AI-058-AGR	19.5	13	16	20	CL
AI-058-AGR	21	14	17	19	CL
AI-058-AGR	22.5	12	15	19	CL
AI-058-AGR	24	12	17	23	CL
AI-058-AGR	25.5	11	16	21	CL
AI-058-AGR	27	13	16	22	CL
AI-058-AGR	28.5	11	18	22	CL
AI-058-AGR	30	13	18	22	CL
AI-059-HRS	1.5	3	5	6	CL/ML
AI-059-HRS	3	14	17	17	GW/GC/M

Boring Log	depth (m)	N1	N2	N3	USCS
AI-059-HRS	6	16	26	34	CL
AI-059-HRS	7.5	15	26	35	CL
AI-059-HRS	9	15	24	40	CL
AI-059-HRS	10.5	14	24	38	CL
AI-059-HRS	12	12	21	38	CL
AI-059-HRS	13.5	13	22	34	CL
AI-059-HRS	15	13	23	26	CL
AI-059-HRS	16.5	13	24	28	CL
AI-059-HRS	18	16	30	45	CL
AI-059-HRS	19.5	15	28	40	CL
AI-059-HRS	21	13	25	38	CH
AI-059-HRS	22.5	14	24	36	CL
AI-059-HRS	24	15	26	34	CH
AI-059-HRS	25.5	16	28	38	CH
AI-059-HRS	27	15	30	39	CH
AI-059-HRS	28.5	14	28	40	CL
AI-059-HRS	30	14	31	40	CL
AI-060-KRS	4.5	5	2	3	SC/M
AI-060-KRS	6	10	14	17	SP/SC/M
AI-060-KRS	9	20	22	17	SP/SC/M
AI-060-KRS	12	4	6	10	CH
AI-060-KRS	13.5	7	10	13	CH
AI-060-KRS	15	8	17	23	CH
AI-060-KRS	16.5	8	15	21	CH
AI-060-KRS	18	7	14	14	CH
AI-060-KRS	19.5	15	20	28	ML
AI-060-KRS	21	14	18	28	CH
AI-060-KRS	22.5	7	15	18	ML
AI-060-KRS	24	8	16	20	CH
AI-060-KRS	25.5	7	14	21	CH
AI-060-KRS	27	9	16	18	CH
AI-060-KRS	28.5	7	18	22	CH
AI-060-KRS	30	8	18	20	CH
AI-062-ERZ	3	12	17	25	SC/M
AI-062-ERZ	6	25	40	94	SP/SC/M
AI-062-ERZ	9	27	39	107	SW/SC/M
AI-062-ERZ	15	22	38	125	SW/SM/C
AI-063-TER-PTT	3	18	22	25	SC/M
AI-063-TER-PTT	6	25	30	22	GP/GC/M
AI-063-TER-PTT	7.5	18	16	21	GC/M
AI-063-TER-PTT	10.5	12	19	19	GC/M
AI-064-TER-MET	3	4	5	6	CL
AI-064-TER-MET	4.5	2	2	1	CL

Boring Log	depth (m)	N1	N2	N3	USCS
AI-064-TER-MET	6	22	38	75	SP/SC/M
AI-064-TER-MET	9	4	5	7	CH
AI-064-TER-MET	10.5	7	14	17	CL
AI-064-TER-MET	12	8	13	16	CH
AI-064-TER-MET	13.5	7	12	18	CH
AI-064-TER-MET	15	8	13	27	CH
AI-064-TER-MET	19.5	22	22	35	SC/M
AI-064-TER-MET	21	20	31	33	CH
AI-064-TER-MET	22.5	23	33	35	CL
AI-064-TER-MET	24	21	30	34	CL
AI-065-ERC	1.5	2	2	4	CL
AI-065-ERC	3	4	4	7	SC/M
AI-065-ERC	4.5	5	5	8	SC/M
AI-065-ERC	6	5	6	7	CL
AI-065-ERC	7.5	6	8	9	CL
AI-065-ERC	9	4	7	7	CL
AI-065-ERC	10.5	5	7	8	CL
AI-065-ERC	12	7	8	11	SC
AI-065-ERC	13.5	6	9	11	SC
AI-065-ERC	15	21	23	22	SW/SC
AI-065-ERC	16.5	16	20	22	SC
AI-065-ERC	18	7	8	9	CL
AI-065-ERC	19.5	8	8	9	SC
AI-065-ERC	21	8	8	9	SC
AI-065-ERC	22.5	6	8	9	SC
AI-065-ERC	24	8	12	20	SC
AI-065-ERC	25.5	8	14	19	SC
AI-065-ERC	27	9	13	20	CL
AI-065-ERC	28.5	8	13	19	CL
AI-065-ERC	30	8	12	20	SC
AI-066-ZAR	3	2	2	7	CL
AI-066-ZAR	4.5	5	10	12	CL
AI-066-ZAR	6	7	11	14	CL
AI-066-ZAR	7.5	6	6	8	CL
AI-066-ZAR	9	6	7	9	CL
AI-066-ZAR	10.5	4	5	6	CL
AI-066-ZAR	12	6	9	9	CH
AI-066-ZAR	13.5	5	7	10	CL
AI-066-ZAR	15	6	8	11	CH
AI-066-ZAR	16.5	7	8	10	CH
AI-066-ZAR	18	10	11	15	SC/M
AI-066-ZAR	19.5	9	12	16	CH
AI-066-ZAR	21	7	11	13	CH

Boring Log	depth (m)	N1	N2	N3	USCS
AI-066-ZAR	22.5	7	11	13	SC/M
AI-066-ZAR	24	9	10	14	SC/M
AI-066-ZAR	25.5	8	12	14	SC/M
AI-066-ZAR	27	9	13	16	SW/SC/M
AI-066-ZAR	28.5	7	10	14	SW/SC/M
AI-066-ZAR	30	8	11	16	SC/M
AI-067-REF-HK	9	14	24	31	SC
AI-068-REF-KM	1.5	6	7	9	CH
AI-068-REF-KM	4.5	7	9	12	SC/M
AI-068-REF-KM	6	6	7	10	SC/M
AI-068-REF-KM	9	27	25	33	SC/M
AI-069-SSH	1.5	6	8	10	CL
AI-070-RES	1.5	6	6	20	GC/M
AI-070-RES	6	27	25	30	GW/GC/M
AI-070-RES	12	18	29	17	SW/SC/M
AI-070-RES	19.5	16	32	125	SP/SC/M
AI-071-TKT	1.5	4	7	11	CL
AI-071-TKT	3	6	10	12	CL
AI-071-TKT	4.5	5	7	10	SC/M
AI-071-TKT	6	20	25	20	GW/GC/M
AI-071-TKT	9	15	20	26	GW/GC/M
AI-071-TKT	12	20	33	25	GP/GC/M
AI-071-TKT	16.5	22	32	150	SP
AI-071-TKT	22.5	20	26	38	SP
AI-071-TKT	27	26	40	46	SW
AI-071-TKT	30	19	32	107	GP
AI-072-ERB	1.5	5	6	7	SP
AI-072-ERB	3	13	15	16	SP/SC
AI-072-ERB	4.5	17	20	21	SC
AI-072-ERB	6	20	16	18	GC
AI-072-ERB	7.5	27	23	19	SC
AI-072-ERB	9	12	32	30	GW/GC
AI-072-ERB	16.5	20	36	188	GP/GC
AI-072-ERB	22.5	18	26	40	SP/SC
AI-072-ERB	24	22	37	75	GP
AI-072-ERB	28.5	21	30	38	SW/SC
AI-073-AMS-MZFL	4.5	16	18	16	SW/SC
AI-073-AMS-MZFL	6	10	8	11	SW
AI-073-AMS-MZFL	10.5	12	15	18	SW/SC
AI-073-AMS-MZFL	12	16	24	28	SP
AI-073-AMS-MZFL	13.5	14	21	22	SW/SC
AI-073-AMS-MZFL	15	10	21	26	SP
AI-073-AMS-MZFL	16.5	17	21	23	SP

Boring Log	depth (m)	N1	N2	N3	USCS
AI-073-AMS-MZFL	18	20	23	26	SC
AI-073-AMS-MZFL	19.5	21	22	23	SW/SC
AI-073-AMS-MZFL	21	17	20	24	SP
AI-073-AMS-MZFL	22.5	18	21	25	SP
AI-073-AMS-MZFL	24	15	20	24	SC
AI-073-AMS-MZFL	25.5	17	22	26	SP
AI-073-AMS-MZFL	27	20	24	26	SP
AI-073-AMS-MZFL	28.5	21	23	26	SP
AI-073-AMS-MZFL	30	20	24	28	SC
AI-074-AMS-BAY	3	12	24	32	SC
AI-074-AMS-BAY	4.5	18	40	150	SC
AI-074-AMS-BAY	6	13	29	38	SC
AI-074-AMS-BAY	7.5	11	23	36	SC
AI-074-AMS-BAY	9	14	18	32	SC
AI-075-MRZ	3	12	29	38	SC
AI-075-MRZ	4.5	10	17	18	SC
AI-075-MRZ	6	11	19	22	CL
AI-075-MRZ	7.5	13	20	25	SC
AI-075-MRZ	9	14	24	32	SC
AI-075-MRZ	10.5	14	15	19	GC
AI-075-MRZ	12	10	16	40	GC
AI-075-MRZ	13.5	8	13	19	SC
AI-075-MRZ	15	5	7	10	SC
AI-075-MRZ	16.5	6	8	10	SW/SC
AI-075-MRZ	21	10	14	17	SP/SC
AI-075-MRZ	22.5	11	14	17	SW/SC
AI-075-MRZ	24	13	15	18	SC
AI-075-MRZ	28.5	25	35	41	SW/SC
AI-075-MRZ	30	25	33	45	SC
AI-076-OSM	1.5	6	6	6	CL/ML
AI-076-OSM	3	4	6	9	SM
AI-076-OSM	9	15	19	24	SW/SC
AI-076-OSM	10.5	15	19	20	SW/SC
AI-076-OSM	12	19	36	40	GW/GC
AI-076-OSM	13.5	14	33	30	SW/SC
AI-076-OSM	19.5	15	25	38	GW/GC
AI-076-OSM	21	17	20	24	SW/SC
AI-076-OSM	22.5	14	22	33	SP/SC
AI-076-OSM	25.5	18	21	33	SP
AI-076-OSM	27	16	23	35	SW
AI-076-OSM	28.5	17	25	36	SW
AI-076-OSM	30	18	26	34	SP
AI-077-OSM-EHK	3	3	4	5	CL

Boring Log	depth (m)	N1	N2	N3	USCS
AI-077-OSM-EHK	4.5	5	9	17	CL
AI-077-OSM-EHK	6	3	4	5	CL
AI-077-OSM-EHK	7.5	3	4	5	CL
AI-077-OSM-EHK	9	4	6	8	CL
AI-077-OSM-EHK	10.5	2	5	7	CL
AI-077-OSM-EHK	12	4	6	8	CL
AI-077-OSM-EHK	13.5	5	9	11	CL
AI-077-OSM-EHK	15	9	14	17	CL
AI-077-OSM-EHK	16.5	4	9	10	CL
AI-077-OSM-EHK	18	6	9	12	CL
AI-077-OSM-EHK	19.5	6	8	10	CL
AI-077-OSM-EHK	21	8	10	15	CL
AI-077-OSM-EHK	22.5	6	9	12	CL
AI-077-OSM-EHK	24	6	8	11	CL
AI-077-OSM-EHK	25.5	7	10	14	CL
AI-077-OSM-EHK	27	8	9	12	CL
AI-077-OSM-EHK	28.5	7	10	14	CL
AI-077-OSM-EHK	30	9	15	16	SM
AI-078-KRG	3	4	12	94	GP/GC
AI-079-TOS	1.5	4	17	29	CL
AI-079-TOS	3	20	35	41	CL
AI-079-TOS	4.5	13	25	40	SC
AI-079-TOS	6	12	24	36	CL
AI-079-TOS	7.5	7	14	16	SC
AI-079-TOS	9	12	21	24	CL
AI-079-TOS	19.5	30	41	150	SC
AI-080-YLV	1.5	10	10	12	SP/SM
AI-080-YLV	3	8	11	16	SM
AI-080-YLV	4.5	7	9	9	SM
AI-080-YLV	6	7	7	8	SP/SM
AI-080-YLV	7.5	3	3	5	CL
AI-080-YLV	9	15	18	24	GP
AI-080-YLV	10.5	3	4	4	CH
AI-081-IZN-KY	1.5	1	1	1	SM
AI-081-IZN-KY	3	2	4	5	SM
AI-081-IZN-KY	4.5	15	17	18	SP/SM
AI-081-IZN-KY	6	3	13	19	SM
AI-081-IZN-KY	7.5	8	10	13	ML
AI-081-IZN-KY	9	5	9	11	SM
AI-081-IZN-KY	10.5	3	5	7	SM
AI-081-IZN-KY	12	3	4	3	CL
AI-081-IZN-KY	13.5	2	3	2	SC
AI-081-IZN-KY	15	2	4	2	ML

Boring Log	depth (m)	N1	N2	N3	USCS
AI-081-IZN-KY	16.5	2	2	1	ML
AI-081-IZN-KY	18	1	2	2	ML
AI-081-IZN-KY	19.5	1	2	3	CL
AI-081-IZN-KY	24	1	1	1	CL
AI-081-IZN-KY	25.5	1	2	1	CL
AI-081-IZN-KY	27	1	1	1	CL
AI-081-IZN-KY	28.5	2	2	3	CL
AI-081-IZN-KY	30	2	2	1	CH
AI-081-IZN-KY	31.5	0	1	1	CL
AI-081-IZN-KY	36	1	1	1	CL
AI-081-IZN-KY	37.5	13	25	27	SM
AI-082-CEK	1.5	3	5	6	CH
AI-082-CEK	3	24	22	16	CH
AI-082-CEK	4.5	12	18	21	CH
AI-082-CEK	6	7	9	13	CH
AI-082-CEK	7.5	7	11	14	CL
AI-082-CEK	9	8	15	16	CH
AI-082-CEK	10.5	11	17	19	CL
AI-082-CEK	12	17	21	18	CH
AI-082-CEK	13.5	10	14	21	CH
AI-082-CEK	15	11	17	25	CH
AI-082-CEK	16.5	7	13	16	CH
AI-082-CEK	18	9	15	19	CH
AI-082-CEK	19.5	12	17	23	CL
AI-082-CEK	21	10	16	20	CH
AI-082-CEK	22.5	16	21	27	CL
AI-082-CEK	24	15	23	25	CH
AI-082-CEK	25.5	16	22	25	CH
AI-082-CEK	27	17	25	26	CL
AI-082-CEK	28.5	17	24	26	CH
AI-082-CEK	30	16	22	27	CH
AI-083-ERG	4.5	8	5	5	ML
AI-083-ERG	6	6	7	8	SP/SM
AI-084-TKR-MET	4.5	16	30	41	SP/SM
AI-086-SRK	1.5	1	1	2	SM
AI-086-SRK	3	3	3	4	SM
AI-086-SRK	4.5	2	5	7	SP/SM
AI-086-SRK	7.5	8	10	11	SM
AI-086-SRK	9	17	9	26	SP/SM
AI-086-SRK	10.5	17	21	28	SM
AI-086-SRK	12	15	31	94	SM
AI-086-SRK	13.5	16	24	25	SM
AI-086-SRK	15	13	19	26	SM

Boring Log	depth (m)	N1	N2	N3	USCS
AI-086-SRK	16.5	20	22	20	SP/SM
AI-086-SRK	18	17	19	26	SP/SM
AI-086-SRK	19.5	11	15	28	SM
AI-086-SRK	21	13	17	24	SM
AI-086-SRK	22.5	13	18	27	SM
AI-086-SRK	24	16	21	23	SP/SM
AI-086-SRK	25.5	12	19	21	SP/SM
AI-086-SRK	27	11	17	26	SM
AI-086-SRK	30	18	20	22	SP/SM
AI-087-GL-1	1.5	20	27	39	ML
AI-087-GL-1	3	15	37	75	ML
AI-087-GL-1	4.5	18	29	46	CL
AI-087-GL-1	6	9	18	19	CH
AI-087-GL-1	7.5	13	24	31	ML
AI-087-GL-1	9	15	27	31	CL
AI-087-GL-1	10.5	27	38	75	CL
AI-087-GL-1	12	35	43	94	ML
AI-087-GL-1	13.5	23	36	83	CL
AI-087-GL-1	15	18	28	45	CH
AI-087-GL-1	27	28	43	125	CL
AI-087-GL-1	28.5	33	46	125	CL
AI-088-CNK	1.5	3	8	8	SW/SC/M
AI-088-CNK	3	1	1	3	SM
AI-088-CNK	4.5	1	3	3	SP/SM
AI-088-CNK	6	13	14	15	SW/SM
AI-088-CNK	7.5	11	13	15	SM
AI-088-CNK	9	14	15	16	SW/SM
AI-088-CNK	10.5	13	15	15	SP
AI-088-CNK	12	11	13	13	SP
AI-088-CNK	13.5	10	12	16	SP
AI-088-CNK	15	13	16	18	SP
AI-088-CNK	16.5	12	14	15	SP/SM
AI-088-CNK	18	13	13	16	SP
AI-088-CNK	19.5	12	15	16	SP
AI-088-CNK	21	13	14	16	SP/SM
AI-088-CNK	22.5	9	11	15	SP
AI-088-CNK	24	9	10	13	SP
AI-088-CNK	25.5	11	12	14	SP
AI-088-CNK	27	10	12	15	SP
AI-088-CNK	28.5	13	13	17	SP
AI-088-CNK	30	11	15	16	SP
AI-090-BGA	1.5	4	6	7	CL
AI-090-BGA	3	5	7	12	ML

Boring Log	depth (m)	N1	N2	N3	USCS
AI-090-BGA	4.5	5	8	12	SC
AI-090-BGA	7.5	8	11	16	CH
AI-090-BGA	9	10	12	18	CH
AI-090-BGA	10.5	23	41	125	SC
AI-090-BGA	16.5	17	24	43	SC
AI-090-BGA	18	16	27	40	SC
AI-090-BGA	21	18	29	36	SC
AI-090-BGA	30	23	36	43	SC
AI-091-GNN	1.5	4	7	22	GM
AI-091-GNN	3	29	37	46	SM
AI-092-EDN-SO	1.5	11	16	21	SC
AI-092-EDN-SO	3	11	21	23	SC
AI-092-EDN-SO	4.5	17	28	36	SC
AI-092-EDN-SO	6	19	23	27	SC
AI-092-EDN-SO	7.5	13	26	28	SC
AI-092-EDN-SO	9	15	20	26	SC
AI-092-EDN-SO	10.5	10	18	35	SC
AI-092-EDN-SO	12	14	21	23	SM
AI-092-EDN-SO	13.5	21	28	34	SC
AI-092-EDN-SO	15	22	26	38	SC
AI-092-EDN-SO	19.5	15	18	25	CL
AI-092-EDN-SO	21	13	19	23	CL
AI-092-EDN-SO	25.5	16	18	22	SC
AI-092-EDN-SO	27	14	19	21	SC
AI-092-EDN-SO	28.5	13	16	24	SC
AI-092-EDN-SO	30	17	19	24	SC
AI-094-YNC	6	14	8	11	SC/SM
AI-094-YNC	7.5	19	21	25	CL
AI-094-YNC	9	12	16	21	SC
AI-094-YNC	10.5	15	19	24	SC
AI-094-YNC	12	10	12	14	SC
AI-094-YNC	13.5	9	13	15	CL
AI-094-YNC	15	21	29	38	ML
AI-094-YNC	16.5	18	37	40	CL
AI-094-YNC	19.5	18	21	26	SC/SM
AI-094-YNC	22.5	24	29	32	SC
AI-094-YNC	24	19	23	30	SC
AI-094-YNC	25.5	21	26	33	SM
AI-094-YNC	27	18	22	29	SC
AI-094-YNC	28.5	23	25	33	CL
AI-094-YNC	30	25	29	38	SC
AI-095-EZN	1.5	11	14	16	SC
AI-095-EZN	3	24	39	27	SC

Boring Log	depth (m)	N1	N2	N3	USCS
AI-095-EZN	4.5	22	34	37	SC
AI-095-EZN	6	26	33	38	SC
AI-095-EZN	7.5	30	35	42	SC
AI-095-EZN	9	31	36	45	SM
AI-096-EDR	3	3	3	8	ML
AI-096-EDR	4.5	2	4	4	SC
AI-096-EDR	6	4	7	9	CL/ML
AI-096-EDR	10.5	17	24	38	SW/SM
AI-096-EDR	12	22	40	48	SM
AI-097-AYV	3	16	45	125	SC
AI-097-AYV	4.5	10	25	39	CH
AI-098-DKL	1.5	5	8	8	SW/SM
AI-098-DKL	3	6	7	8	SW/SM
AI-098-DKL	4.5	5	7	9	SM
AI-098-DKL	6	7	8	10	SP/SM
AI-098-DKL	7.5	5	6	8	SP
AI-098-DKL	9	3	4	6	SM
AI-098-DKL	10.5	3	5	6	SP/SM
AI-098-DKL	12	1	2	2	CH
AI-098-DKL	13.5	2	3	4	CH
AI-098-DKL	15	2	3	3	CH
AI-098-DKL	16.5	2	3	3	CH
AI-098-DKL	18	2	2	3	CH
AI-098-DKL	19.5	2	3	3	CH
AI-098-DKL	21	2	3	4	CH
AI-098-DKL	22.5	14	9	14	CH
AI-098-DKL	24	15	19	24	CH
AI-098-DKL	25.5	18	28	38	CH
AI-098-DKL	27	21	32	40	CH
AI-098-DKL	28.5	31	42	75	CH
AI-099-KNK	6	17	21	21	GC
AI-099-KNK	12	8	12	15	GC
AI-099-KNK	13.5	7	8	8	SC
AI-099-KNK	16.5	17	40	94	CL
AI-100-AKS	1.5	6	10	11	CL
AI-100-AKS	3	15	32	42	GP/GM
AI-100-AKS	4.5	4	4	6	CL
AI-100-AKS	6	3	4	4	CL
AI-100-AKS	7.5	8	13	15	CL/ML
AI-100-AKS	9	15	7	6	SC
AI-100-AKS	10.5	3	4	5	CL/ML
AI-100-AKS	12	3	5	5	SC
AI-100-AKS	13.5	20	35	39	SM

Boring Log	depth (m)	N1	N2	N3	USCS
AI-100-AKS	16.5	6	7	9	CL
AI-100-AKS	18	8	10	12	CH
AI-100-AKS	19.5	8	9	11	SM
AI-100-AKS	21	8	12	13	SM
AI-100-AKS	22.5	8	13	15	SW/SM
AI-100-AKS	24	7	10	13	CH
AI-100-AKS	25.5	10	11	12	CH
AI-100-AKS	27	7	10	15	CL/ML
AI-100-AKS	28.5	11	12	16	SM
AI-100-AKS	30	10	13	15	CL
AI-103-SMV	1.5	6	13	22	SC/SM
AI-103-SMV	3	9	11	11	SC/SM
AI-103-SMV	4.5	4	8	8	SC
AI-103-SMV	6	3	3	3	SC/SM
AI-103-SMV	7.5	3	3	6	CL
AI-103-SMV	9	4	5	6	CL
AI-103-SMV	10.5	16	17	11	SM
AI-103-SMV	12	4	6	10	SC
AI-103-SMV	13.5	4	7	9	SC
AI-103-SMV	15	16	24	24	SM
AI-103-SMV	16.5	9	12	15	SC
AI-103-SMV	18	6	8	11	SC
AI-103-SMV	19.5	5	6	10	SC/SM
AI-103-SMV	21	7	8	10	CL
AI-103-SMV	22.5	12	22	29	GM
AI-103-SMV	24	14	18	23	SW/SC/M
AI-103-SMV	25.5	9	18	26	SM
AI-103-SMV	27	11	16	21	SC/M
AI-103-SMV	28.5	13	19	27	SC
AI-103-SMV	30	16	20	28	SC/M
AI-104-GDZ	3	13	16	16	CL
AI-104-GDZ	4.5	13	27	17	SC
AI-104-GDZ	6	13	18	15	CL
AI-104-GDZ	7.5	11	13	14	CH
AI-104-GDZ	9	17	24	38	CH
AI-105-USK	4.5	6	9	12	CL
AI-105-USK	6	7	9	13	CL
AI-105-USK	7.5	6	10	12	CH
AI-105-USK	9	8	10	13	CH
AI-105-USK	10.5	9	11	13	CH
AI-105-USK	12	9	11	14	CL
AI-105-USK	13.5	8	12	13	CL
AI-105-USK	15	10	11	15	CH

Boring Log	depth (m)	N1	N2	N3	USCS
AI-105-USK	16.5	10	12	14	CL
AI-105-USK	18	9	11	13	CH
AI-105-USK	19.5	10	12	15	CL
AI-105-USK	21	7	8	13	CL
AI-105-USK	22.5	8	10	13	CL
AI-105-USK	24	6	9	14	CL
AI-105-USK	25.5	7	10	13	CL
AI-105-USK	27	9	12	14	CL
AI-105-USK	28.5	10	12	15	CL
AI-105-USK	30	9	11	16	CL
AI-106-BLD	1.5	11	10	11	SM
AI-106-BLD	4.5	23	44	150	GW
AI-107-DNZ-MET	3	26	35	94	SM
AI-107-DNZ-MET	4.5	4	5	7	SC/SM
AI-107-DNZ-MET	6	9	10	12	ML
AI-107-DNZ-MET	7.5	9	11	12	SM
AI-107-DNZ-MET	9	8	12	14	SM
AI-107-DNZ-MET	10.5	16	11	13	ML
AI-107-DNZ-MET	12	13	15	17	SP/SM
AI-107-DNZ-MET	13.5	27	14	16	SM
AI-107-DNZ-MET	15	13	15	18	CL/ML
AI-107-DNZ-MET	16.5	9	16	16	SC/SM
AI-107-DNZ-MET	18	13	20	37	SC/SM
AI-107-DNZ-MET	19.5	16	40	188	SM
AI-107-DNZ-MET	21	15	18	22	CL/ML
AI-107-DNZ-MET	22.5	20	19	20	CL
AI-107-DNZ-MET	24	15	18	19	CL
AI-107-DNZ-MET	25.5	16	17	21	CL
AI-107-DNZ-MET	27	14	18	21	CL
AI-107-DNZ-MET	28.5	17	19	21	CL
AI-107-DNZ-MET	30	18	21	22	CL
AI-108-DNZ-BAY	3	17	22	25	CL
AI-108-DNZ-BAY	4.5	17	30	30	CL
AI-109-ALA	1.5	5	7	11	CL
AI-109-ALA	3	7	4	7	SM
AI-109-ALA	4.5	9	7	9	SW
AI-109-ALA	6	7	8	11	SC
AI-109-ALA	7.5	5	8	11	SC
AI-109-ALA	9	16	23	26	SW/SM
AI-110-SAL	3	13	10	10	SM
AI-110-SAL	4.5	7	7	9	CL/ML
AI-110-SAL	6	8	8	10	SM
AI-110-SAL	7.5	10	10	9	SP/SM

Boring Log	depth (m)	N1	N2	N3	USCS
AI-110-SAL	9	17	20	28	SM
AI-110-SAL	10.5	18	19	25	SM
AI-110-SAL	12	13	23	28	SM
AI-110-SAL	13.5	24	24	27	SM
AI-110-SAL	15	18	28	28	GM
AI-110-SAL	16.5	18	20	25	SW/SM
AI-110-SAL	18	12	12	17	SM
AI-110-SAL	19.5	13	16	20	SM
AI-110-SAL	21	8	10	16	SM
AI-110-SAL	22.5	10	13	14	SM
AI-110-SAL	24	13	15	20	SM
AI-110-SAL	25.5	10	14	15	ML
AI-110-SAL	27	11	13	17	CL
AI-110-SAL	28.5	13	16	17	CL
AI-110-SAL	30	13	17	18	CL
AI-111-ODM	1.5	2	4	6	SM
AI-111-ODM	3	9	14	16	SM
AI-111-ODM	4.5	7	11	15	SM
AI-111-ODM	6	9	12	14	SM
AI-111-ODM	7.5	10	12	16	SM
AI-111-ODM	9	11	15	22	SC
AI-111-ODM	10.5	11	14	22	SC
AI-111-ODM	12	16	20	12	SP/SM
AI-111-ODM	13.5	10	12	15	SM
AI-111-ODM	15	3	5	8	SC
AI-111-ODM	16.5	5	7	11	SC
AI-111-ODM	18	9	14	12	SM
AI-111-ODM	19.5	8	13	16	SC
AI-111-ODM	21	7	14	20	SM
AI-111-ODM	22.5	9	12	18	SC
AI-111-ODM	24	10	14	16	CL
AI-111-ODM	25.5	11	14	18	SM
AI-111-ODM	27	11	16	20	SM
AI-111-ODM	28.5	13	16	21	SM
AI-111-ODM	30	14	19	24	SM
AI-112-MNS	3	15	19	17	SM
AI-112-MNS	4.5	7	3	7	SC
AI-112-MNS	6	8	8	7	SC
AI-112-MNS	7.5	7	11	10	GM
AI-112-MNS	9	12	20	16	SM
AI-115-BRN-BAY	4.5	3	1	1	SM
AI-115-BRN-BAY	6	2	2	1	SM
AI-115-BRN-BAY	7.5	1	1	1	CL

Boring Log	depth (m)	N1	N2	N3	USCS
AI-115-BRN-BAY	9	1	1	1	CH
AI-115-BRN-BAY	10.5	3	4	5	SC
AI-115-BRN-BAY	12	6	7	11	SM
AI-115-BRN-BAY	13.5	5	8	9	SM
AI-115-BRN-BAY	15	7	5	4	GP/GC
AI-115-BRN-BAY	16.5	7	10	11	SM
AI-115-BRN-BAY	18	3	3	4	CL
AI-115-BRN-BAY	19.5	8	10	14	SP/SM
AI-115-BRN-BAY	21	11	18	20	SW/SM
AI-115-BRN-BAY	22.5	16	19	24	SP/SM
AI-115-BRN-BAY	24	20	22	30	SM
AI-115-BRN-BAY	25.5	21	21	29	SP/SM
AI-115-BRN-BAY	27	22	24	33	SP/SM
AI-115-BRN-BAY	28.5	19	22	28	SP/SM
AI-115-BRN-BAY	30	22	26	33	SP
AI-116-BRN-EU	1.5	9	21	24	CL
AI-116-BRN-EU	3	4	9	14	SM
AI-116-BRN-EU	4.5	9	10	11	SC
AI-116-BRN-EU	6	9	13	17	SM
AI-116-BRN-EU	7.5	9	17	23	SM
AI-116-BRN-EU	9	10	13	21	SC
AI-116-BRN-EU	10.5	15	12	15	CL
AI-116-BRN-EU	12	13	17	17	CL
AI-116-BRN-EU	13.5	16	20	16	SM
AI-116-BRN-EU	15	19	24	27	SC
AI-116-BRN-EU	16.5	23	21	28	SC
AI-116-BRN-EU	19.5	19	25	15	SC
AI-116-BRN-EU	21	10	12	15	CL
AI-116-BRN-EU	22.5	11	13	17	CL
AI-116-BRN-EU	24	10	12	18	CH
AI-116-BRN-EU	25.5	14	15	16	CH
AI-116-BRN-EU	27	12	14	18	CH
AI-116-BRN-EU	28.5	15	17	18	CH
AI-116-BRN-EU	30	15	17	23	CH
AI-118-KUS-HSL	6	1	2	4	SM
AI-118-KUS-HSL	7.5	3	3	4	CL
AI-118-KUS-HSL	9	2	3	4	SM
AI-118-KUS-HSL	10.5	3	3	5	SM
AI-118-KUS-HSL	12	1	3	5	CL
AI-118-KUS-HSL	13.5	1	2	3	SM
AI-118-KUS-HSL	15	1	5	7	SM
AI-118-KUS-HSL	16.5	4	6	7	SM
AI-118-KUS-HSL	18	6	5	11	SM

Boring Log	depth (m)	N1	N2	N3	USCS
AI-118-KUS-HSL	19.5	4	6	10	SM
AI-118-KUS-HSL	21	10	13	20	CL
AI-118-KUS-HSL	22.5	24	30	48	CL
AI-119-AYD-HH	4.5	17	15	19	GP/GM
AI-119-AYD-HH	6	10	16	28	SM
AI-119-AYD-HH	7.5	16	26	33	SM
AI-119-AYD-HH	9	14	19	25	SP/SM
AI-119-AYD-HH	10.5	11	17	21	SM
AI-119-AYD-HH	13.5	10	12	19	SM
AI-119-AYD-HH	15	8	11	19	ML
AI-119-AYD-HH	16.5	6	12	23	ML
AI-119-AYD-HH	18	9	12	20	SM
AI-119-AYD-HH	19.5	10	13	21	SM
AI-119-AYD-HH	21	15	27	28	SM
AI-119-AYD-HH	22.5	16	24	27	ML
AI-119-AYD-HH	24	13	21	28	ML
AI-119-AYD-HH	25.5	16	25	29	ML
AI-119-AYD-HH	27	15	25	30	ML
AI-119-AYD-HH	28.5	16	27	31	ML
AI-119-AYD-HH	30	17	26	31	ML
AI-120-AYD-DSİ	1.5	3	5	15	SM
AI-120-AYD-DSİ	3	14	22	31	SM
AI-120-AYD-DSİ	4.5	13	24	31	SP
AI-120-AYD-DSİ	6	22	30	33	SM
AI-120-AYD-DSİ	7.5	8	13	14	SP
AI-120-AYD-DSİ	9	6	11	15	SM
AI-120-AYD-DSİ	10.5	15	21	19	SP
AI-120-AYD-DSİ	12	24	34	37	SM
AI-120-AYD-DSİ	13.5	20	29	30	SP
AI-120-AYD-DSİ	15	12	14	18	SM
AI-120-AYD-DSİ	16.5	9	10	12	SM
AI-120-AYD-DSİ	18	7	9	12	SC
AI-120-AYD-DSİ	19.5	12	14	17	SC/SM
AI-120-AYD-DSİ	21	13	23	37	ML
AI-120-AYD-DSİ	22.5	11	15	30	CL
AI-120-AYD-DSİ	24	17	24	36	CL
AI-120-AYD-DSİ	25.5	12	21	34	SM
AI-120-AYD-DSİ	27	15	19	32	CL
AI-120-AYD-DSİ	28.5	14	23	36	SC
AI-120-AYD-DSİ	30	13	20	35	CL/ML
AI-122-MLS	1.5	8	12	13	CL
AI-122-MLS	3	6	20	30	CL
AI-122-MLS	4.5	16	28	33	SC

Boring Log	depth (m)	N1	N2	N3	USCS
AI-122-MLS	6	18	30	47	SC
AI-122-MLS	7.5	14	17	21	CH
AI-122-MLS	9	13	15	22	CL
AI-122-MLS	10.5	12	16	20	CL
AI-122-MLS	12	10	13	18	CL
AI-122-MLS	13.5	11	14	19	CH
AI-122-MLS	15	11	16	20	CH
AI-122-MLS	16.5	12	13	16	ML
AI-122-MLS	18	10	14	17	ML
AI-122-MLS	19.5	6	8	12	SM
AI-122-MLS	21	6	10	18	ML
AI-122-MLS	22.5	7	9	11	SM
AI-122-MLS	24	6	8	12	SC
AI-122-MLS	25.5	10	13	18	SC
AI-122-MLS	27	9	11	14	CL/ML
AI-122-MLS	28.5	12	14	16	SC
AI-122-MLS	30	14	16	20	SC
AI-125-MAR	3	8	16	17	SM
AI-125-MAR	4.5	14	20	26	CL
AI-125-MAR	6	22	25	30	SC
AI-125-MAR	7.5	14	17	20	SC
AI-125-MAR	10.5	12	16	20	SC
AI-125-MAR	15	16	28	30	CL
AI-125-MAR	16.5	14	17	22	SC
AI-125-MAR	18	12	12	14	SM
AI-125-MAR	19.5	13	18	20	CL
AI-125-MAR	21	12	22	23	CL
AI-125-MAR	22.5	15	20	22	CL
AI-125-MAR	25.5	17	21	29	CL
AI-126-KOY	1.5	12	10	10	SM
AI-126-KOY	3	23	19	12	GW/GM
AI-126-KOY	4.5	18	26	23	GM
AI-126-KOY	6	5	8	10	SC/SM
AI-126-KOY	7.5	7	9	8	GC/GM
AI-126-KOY	9	25	24	23	GM
AI-126-KOY	12	8	11	19	SM
AI-126-KOY	13.5	4	9	8	CL/ML
AI-126-KOY	15	5	6	7	CL
AI-126-KOY	16.5	8	4	4	SM
AI-126-KOY	18	4	7	8	CL/ML
AI-126-KOY	19.5	5	6	10	SC/SM
AI-126-KOY	21	6	8	11	CL
AI-126-KOY	22.5	18	26	24	SP/SM

Boring Log	depth (m)	N1	N2	N3	USCS
AI-126-KOY	25.5	26	32	150	SP
AI-127-FTH	1.5	4	4	6	CL
AI-127-FTH	3	4	6	10	CH
AI-127-FTH	4.5	2	2	3	CH
AI-127-FTH	6	4	5	6	CH
AI-127-FTH	7.5	4	6	7	CH
AI-127-FTH	9	6	10	13	CH
AI-127-FTH	10.5	8	10	11	SC
AI-127-FTH	12	8	14	17	ML
AI-127-FTH	13.5	9	15	19	ML
AI-127-FTH	15	11	15	20	CL
AI-127-FTH	16.5	13	17	21	CH
AI-127-FTH	19.5	10	12	22	CH
AI-127-FTH	21	10	12	15	CL
AI-127-FTH	22.5	9	13	13	CH
AI-127-FTH	24	8	12	14	CH
AI-127-FTH	25.5	9	13	15	CH
AI-127-FTH	27	10	14	15	CH
AI-127-FTH	28.5	10	15	16	CH
AI-127-FTH	30	11	15	16	CH
AI-129-FNK	1.5	1	2	3	MH
AI-129-FNK	3	8	10	15	GM
AI-129-FNK	4.5	12	15	20	SP/SM
AI-129-FNK	6	11	18	20	SP/SM
AI-129-FNK	7.5	8	15	16	SM
AI-129-FNK	9	13	16	19	SP
AI-129-FNK	10.5	8	15	27	SM
AI-129-FNK	12	9	10	12	SP/SM
AI-129-FNK	13.5	11	11	14	SM
AI-129-FNK	15	9	10	13	SM
AI-129-FNK	16.5	10	13	17	SP/SM
AI-129-FNK	18	8	17	24	ML
AI-129-FNK	19.5	12	18	26	ML
AI-129-FNK	21	8	16	25	SP/SM
AI-129-FNK	22.5	13	19	26	SP/SM
AI-129-FNK	24	15	18	30	SM
AI-129-FNK	25.5	16	20	25	SM
AI-129-FNK	27	18	21	26	SP
AI-129-FNK	28.5	17	21	29	SM
AI-129-FNK	30	19	23	26	SP/SM
AI-132-TFN	3	21	17	16	GP
AI-132-TFN	7.5	20	23	13	SW/SM
AI-132-TFN	9	10	20	21	CL

Boring Log	depth (m)	N1	N2	N3	USCS
AI-132-TFN	10.5	18	22	24	SM
AI-132-TFN	12	13	23	33	CL
AI-132-TFN	13.5	21	25	32	SM
AI-133-BRD1	1.5	6	8	10	CL
AI-133-BRD1	3	7	11	15	CL
AI-133-BRD1	4.5	10	14	17	CL
AI-133-BRD1	6	11	19	21	CL
AI-133-BRD1	7.5	10	17	22	CL
AI-133-BRD1	9	11	19	20	CL
AI-133-BRD1	10.5	11	17	20	ML
AI-133-BRD1	12	10	18	20	CL
AI-133-BRD1	13.5	12	17	19	CL
AI-133-BRD1	15	13	18	22	CL
AI-134-BRD2	1.5	5	7	6	SM
AI-134-BRD2	3	3	6	8	CL
AI-134-BRD2	4.5	4	7	9	CL
AI-134-BRD2	6	7	9	11	CL
AI-134-BRD2	7.5	5	7	10	CL/ML
AI-134-BRD2	9	9	10	12	SC
AI-134-BRD2	10.5	13	15	16	SC
AI-134-BRD2	12	13	15	16	SC
AI-135-SNK	3	10	14	21	CL
AI-135-SNK	4.5	15	9	11	CL
AI-135-SNK	7.5	12	10	15	GC
AI-135-SNK	9	9	11	14	SC
AI-135-SNK	10.5	9	16	27	CH
AI-135-SNK	12	14	19	25	CH
AI-135-SNK	13.5	10	18	19	CL
AI-135-SNK	15	15	17	21	CH
AI-136-CRD	1.5	16	30	47	GP/GM
AI-136-CRD	4.5	4	9	13	CL
AI-136-CRD	6	10	11	12	CL
AI-136-CRD	7.5	11	12	10	GC/GM
AI-136-CRD	10.5	11	30	75	GC
AI-136-CRD	12	27	35	29	GC/GM
AI-137-DIN	1.5	5	5	6	CL
AI-137-DIN	3	1	3	2	CL
AI-137-DIN	4.5	3	5	6	CL
AI-137-DIN	6	4	7	9	CL
AI-137-DIN	7.5	4	7	8	CL
AI-137-DIN	9	2	3	4	CL
AI-137-DIN	10.5	3	4	12	CL
AI-137-DIN	12	15	27	28	SP

Boring Log	depth (m)	N1	N2	N3	USCS
AI-137-DIN	13.5	5	8	10	CL
AI-137-DIN	15	5	9	14	CL
AI-137-DIN	16.5	8	10	13	CL
AI-137-DIN	18	11	36	94	SC
AI-137-DIN	19.5	9	6	7	SM
AI-137-DIN	21	7	8	9	CH
AI-137-DIN	22.5	6	10	12	CH
AI-137-DIN	24	8	12	14	CH
AI-137-DIN	25.5	9	11	14	CH
AI-137-DIN	27	8	13	14	CH
AI-137-DIN	28.5	9	12	15	CL
AI-137-DIN	30	10	13	15	CL
AI-138-SDL	6	10	12	17	GW/GM
AI-138-SDL	7.5	5	7	9	CL
AI-138-SDL	9	5	6	8	CL
AI-138-SDL	10.5	7	11	22	GC
AI-138-SDL	12	6	10	11	CL
AI-138-SDL	13.5	6	12	19	GC
AI-138-SDL	15	38	45	75	GC
AI-138-SDL	24	17	26	40	GP/GM
AI-138-SDL	25.5	22	30	44	GW/GM
AI-139-AFY	1.5	2	3	2	CH
AI-139-AFY	3	1	2	4	CL
AI-139-AFY	4.5	8	9	6	SW/SM
AI-139-AFY	6	1	2	2	CL
AI-139-AFY	7.5	10	13	15	SW/SM
AI-139-AFY	9	10	10	11	SW/SM
AI-139-AFY	10.5	12	12	15	SW/SM
AI-139-AFY	12	10	13	17	SP
AI-139-AFY	13.5	6	11	12	SP/SM
AI-139-AFY	15	13	16	20	SW/SM
AI-139-AFY	16.5	18	20	24	SP/SM
AI-139-AFY	18	12	18	23	SW/SM
AI-139-AFY	19.5	11	17	21	SP
AI-139-AFY	21	13	20	22	SP
AI-139-AFY	22.5	12	18	20	SW/SM
AI-139-AFY	24	13	16	22	SP
AI-139-AFY	25.5	16	16	21	SW/SM
AI-139-AFY	27	14	17	24	SP
AI-139-AFY	28.5	14	18	24	SP
AI-139-AFY	30	15	18	24	SP
AI-140-STG	6	17	29	107	CH
AI-141-KUT-BAY	1.5	1	2	1	CL

Boring Log	depth (m)	N1	N2	N3	USCS
AI-141-KUT-BAY	3	1	1	1	CL/ML
AI-141-KUT-BAY	4.5	1	1	1	CL/ML
AI-141-KUT-BAY	6	1	1	1	ML
AI-141-KUT-BAY	7.5	2	1	1	CL
AI-141-KUT-BAY	9	6	4	5	CL/ML
AI-141-KUT-BAY	10.5	11	12	13	SM
AI-141-KUT-BAY	12	6	3	17	GC/GM
AI-141-KUT-BAY	13.5	4	9	12	CL
AI-141-KUT-BAY	15	5	8	13	ML
AI-141-KUT-BAY	16.5	6	9	14	ML
AI-141-KUT-BAY	18	6	17	30	GM
AI-141-KUT-BAY	19.5	16	20	28	SM/C
AI-141-KUT-BAY	21	21	22	32	SM
AI-141-KUT-BAY	22.5	19	23	27	SM/C
AI-141-KUT-BAY	24	6	10	12	CL
AI-141-KUT-BAY	25.5	7	11	14	GC
AI-141-KUT-BAY	27	17	25	27	SM
AI-141-KUT-BAY	28.5	22	26	33	SM
AI-141-KUT-BAY	30	16	24	34	SM
AI-142-KUT-SS	1.5	1	2	2	ML
AI-142-KUT-SS	4.5	3	6	6	ML
AI-142-KUT-SS	6	1	2	2	SM
AI-142-KUT-SS	7.5	10	10	7	SM
AI-142-KUT-SS	9	5	7	9	ML
AI-142-KUT-SS	10.5	3	10	15	ML
AI-142-KUT-SS	12	4	5	7	SM
AI-142-KUT-SS	13.5	1	2	4	CL
AI-142-KUT-SS	15	4	6	10	CL
AI-142-KUT-SS	16.5	5	7	11	CL
AI-142-KUT-SS	18	5	7	9	CL
AI-142-KUT-SS	19.5	6	8	8	CL
AI-142-KUT-SS	21	5	8	9	CL
AI-142-KUT-SS	22.5	8	11	16	CL
AI-142-KUT-SS	24	9	16	21	CL
AI-142-KUT-SS	25.5	10	15	23	CL
AI-142-KUT-SS	27	12	18	22	CL
AI-142-KUT-SS	28.5	11	17	21	CL
AI-142-KUT-SS	30	10	16	22	CL
AI-143-EMT	1.5	9	14	14	CL
AI-143-EMT	3	8	11	13	ML
AI-143-EMT	4.5	2	3	3	CH
AI-143-EMT	6	3	4	5	CH
AI-143-EMT	7.5	4	7	9	CL

Boring Log	depth (m)	N1	N2	N3	USCS
AI-143-EMT	9	6	8	10	CL
AI-143-EMT	10.5	5	7	10	CL
AI-143-EMT	12	6	7	9	CL
AI-143-EMT	13.5	6	8	9	CL
AI-143-EMT	15	9	11	12	CL
AI-143-EMT	16.5	12	10	12	GC
AI-143-EMT	18	10	10	13	CH
AI-143-EMT	19.5	8	10	13	SC/CL
AI-143-EMT	21	12	14	18	SC
AI-143-EMT	22.5	10	14	15	SC/CL
AI-143-EMT	24	8	12	16	SC
AI-143-EMT	25.5	11	13	19	SC/CL
AI-143-EMT	27	13	15	17	SC
AI-143-EMT	28.5	11	16	18	CH
AI-143-EMT	30	12	15	19	CH
AI-147-BGD	3	6	21	13	CL
AI-147-BGD	4.5	5	7	12	CH
AI-147-BGD	6	2	3	4	CL
AI-147-BGD	7.5	7	13	19	SM
AI-147-BGD	10.5	7	9	20	CL
AI-147-BGD	12	6	9	16	CH
AI-147-BGD	13.5	8	11	15	CH
AI-147-BGD	15	10	12	16	CH
AI-147-BGD	16.5	10	13	17	CH
AI-147-BGD	18	9	13	15	CH
AI-147-BGD	19.5	11	12	18	CH
AI-147-BGD	21	13	15	20	CH
AI-147-BGD	22.5	11	16	19	CH
AI-147-BGD	24	18	37	107	GC
AI-147-BGD	25.5	13	21	125	SC
AI-147-BGD	27	21	27	150	SC
AI-147-BGD	28.5	18	28	125	SM
AI-148-SNG	1.5	7	5	6	SM
AI-148-SNG	3	1	2	3	CL
AI-148-SNG	4.5	6	11	12	SC
AI-148-SNG	6	4	9	24	SC
AI-148-SNG	7.5	3	8	13	SM
AI-148-SNG	9	3	3	4	SC
AI-148-SNG	10.5	14	11	17	SM
AI-148-SNG	12	15	11	18	SC
AI-148-SNG	13.5	6	14	7	SM
AI-148-SNG	15	3	6	8	SC
AI-148-SNG	16.5	7	10	7	SC

Boring Log	depth (m)	N1	N2	N3	USCS
AI-148-SNG	18	11	13	17	SC
AI-148-SNG	19.5	13	21	23	SM
AI-148-SNG	21	16	20	24	SM
AI-148-SNG	22.5	19	22	26	SM
AI-148-SNG	24	16	18	20	SC
AI-148-SNG	25.5	14	16	23	SC
AI-148-SNG	27	17	19	21	SM
AI-148-SNG	28.5	20	20	22	GM
AI-148-SNG	30	19	22	23	SC
AI-149-BND-MET	1.5	5	12	16	CL
AI-149-BND-MET	3	17	26	38	SC
AI-149-BND-MET	4.5	16	19	27	SC/SM
AI-149-BND-MET	6	18	22	33	SC
AI-149-BND-MET	7.5	16	24	32	SC
AI-149-BND-MET	9	16	24	20	SM
AI-149-BND-MET	10.5	13	17	18	CL
AI-149-BND-MET	12	13	14	16	CL
AI-149-BND-MET	13.5	14	15	17	SC
AI-149-BND-MET	15	11	14	17	SC
AI-149-BND-MET	16.5	13	16	19	CL
AI-149-BND-MET	18	14	15	18	CL
AI-149-BND-MET	19.5	14	16	18	SM
AI-149-BND-MET	21	15	17	21	SC
AI-149-BND-MET	22.5	13	16	20	SC
AI-149-BND-MET	24	15	17	22	SM
AI-149-BND-MET	25.5	15	18	22	SM
AI-149-BND-MET	27	18	19	20	SM
AI-149-BND-MET	28.5	17	19	23	SM
AI-149-BND-MET	30	17	18	24	SM
AI-150-BND-TDM	1.5	9	13	36	CL/ML
AI-150-BND-TDM	9	25	32	39	CL
AI-150-BND-TDM	10.5	28	32	83	CL
AI-150-BND-TDM	12	25	30	32	SM
AI-150-BND-TDM	13.5	24	28	32	CH
AI-150-BND-TDM	15	24	36	32	CH
AI-150-BND-TDM	16.5	21	24	30	CH
AI-150-BND-TDM	18	20	26	34	CH
AI-150-BND-TDM	19.5	22	29	33	CH
AI-150-BND-TDM	21	25	27	38	CH
AI-150-BND-TDM	22.5	26	27	39	CH
AI-150-BND-TDM	24	30	35	48	CH
AI-150-BND-TDM	25.5	26	34	75	CH
AI-151-MKP	1.5	8	16	12	SM

Boring Log	depth (m)	N1	N2	N3	USCS
AI-151-MKP	3	8	13	15	SP
AI-151-MKP	4.5	4	4	5	CL
AI-151-MKP	6	5	9	9	CL
AI-152-BRS	3	14	30	94	SW/SM
AI-152-BRS	4.5	3	2	4	SM
AI-152-BRS	6	6	8	7	ML
AI-152-BRS	7.5	3	4	5	SP/SC
AI-152-BRS	9	6	9	12	SM
AI-152-BRS	10.5	8	14	12	SP/SM
AI-152-BRS	12	7	12	13	SM
AI-152-BRS	13.5	7	11	15	CL/ML
AI-152-BRS	15	8	12	16	SM
AI-152-BRS	16.5	7	10	14	SM
AI-152-BRS	18	6	10	13	SM
AI-152-BRS	19.5	7	11	12	SM
AI-152-BRS	21	8	14	17	SM
AI-152-BRS	22.5	10	12	15	SM
AI-152-BRS	24	7	13	14	SM
AI-152-BRS	25.5	9	12	12	SM
AI-152-BRS	27	8	13	12	SM
AI-152-BRS	28.5	11	15	16	SM
AI-152-BRS	30	12	17	18	SM
AI-153-ING	1.5	2	3	4	CH
AI-153-ING	3	2	5	6	CL
AI-153-ING	4.5	3	6	10	SM
AI-153-ING	6	7	9	12	SC
AI-153-ING	7.5	9	10	14	GM
AI-153-ING	9	12	16	22	SP/SM
AI-153-ING	10.5	15	28	29	GW/GM
AI-153-ING	12	13	20	26	SW/SM
AI-153-ING	13.5	13	8	13	SM
AI-153-ING	15	17	30	35	SM
AI-153-ING	16.5	21	41	42	SM
AI-153-ING	18	16	21	27	SM
AI-153-ING	19.5	18	22	36	SM
AI-153-ING	21	18	20	22	SM
AI-153-ING	22.5	15	18	23	SM
AI-153-ING	24	15	15	20	SM
AI-153-ING	25.5	17	19	22	SM
AI-153-ING	27	16	20	22	SM
AI-153-ING	28.5	20	22	25	SM

C. Soil Type Corrections

Boring Log, SPT No	Corrected	Initial	+No4	-No200
AI-006-AKY,SPT5	SW	Gravel	45.6	5.92
AI-011-DZC,SPT-8	GW	Silt	61.53	4.73
AI-016-BEY,SPT-3	SC	Gravel	41.94	18.66
AI-023-MAT17,SPT-12	SM	Gravel	48.29	21.2
AI-026-MAT06-MIM,SPT-9	SP	Gravel	46.74	10.27
AI-030-MAT04,SPT-1	SM	Gravel	34.67	32.69
AI-037-MAT13,SPT-6	SC	Gravel	38.27	27.56
AI-037-MAT13,SPT-8	SC	Gravel	40.32	25.23
AI-037-MAT13,SPT-11	SC	Gravel	37.36	36.03
AI-037-MAT13,SPT-12	SC	Gravel	48.78	19.78
AI-041-MAT11,SPT-4	SC	Gravel	49.78	19
AI-047-MLT,SPT-6	SC	Gravel	45.99	26.37
AI-049-BNG,SPT-5	SC	Gravel	49.47	17.36
AI-049-BNG,SPT-8	SC	Gravel	49.54	28.49
AI-049-BNG,SPT-19	SC	Gravel	45.3	19.65
AI-051-SLH-MET,SPT-8	SC	Gravel	34.74	40.86
AI-052-MUS,SPT-6	SC	Gravel	43.18	26.68
AI-057-DBY,SPT-16	SM	Gravel	41.67	19.47
AI-063-TER-PTT,SPT-2	GW	Gravel	54.63	17.66
AI-071-TKT,SPT-6	SW	Gravel	47.74	5.98
AI-072-ERB,SPT-4	SC	Gravel	45.04	24.66
AI-072-ERB,SPT-11	SW	Gravel	42.69	5.23
AI-075-MRZ,SPT-7	SC	Gravel	39.9	28.66
AI-075-MRZ,SPT-8	SC	Gravel	37.17	38.48
AI-076-OSM,SPT-13	SW	Gravel	41.94	9.22
AI-080-YLV,SPT-6	SW	Gravel	0	3.66
AI-099-KNK,SPT-4	SC	Gravel	41.99	17.33
AI-099-KNK,SPT-6	SC	Gravel	40.5	33.71
AI-106-BLD,SPT-3	SP	Gravel	45.85	4
AI-110-SAL,SPT-10	SM	Gravel	49.76	14.42
AI-112-MNS,SPT-5	SM	Gravel	42.01	13.57
AI-119-AYD-HH,SPT-3	SP	Gravel	44.58	11.45
AI-125-MAR,SPT-15	GW	Clay	99.38	61.26
AI-126-KOY,SPT-3	SM	Gravel	45.3	14.84
AI-126-KOY,SPT-5	SC	Gravel	27.7	46.1
AI-129-FNK,SPT-2	SM	Gravel	42.38	15.97
AI-136-CRD,SPT-8	SC	Gravel	37.17	34.08
Boring Log, SPT No	Corrected	Initial	+4	-200
AI-138-SDL,SPT-17	SW	Gravel	46.25	8.31
AI-141-KUT-BAY,SPT-8	SC	Gravel	45.57	29.28
AI-141-KUT-BAY,SPT-12	SM	Gravel	38.41	38.96
AI-141-KUT-BAY,SPT-17	SC	Gravel	34.34	33.38

AI-143-EMT,SPT-11	SC	Gravel	27.13	46.09
AI-148-SNG,SPT-19	SM	Gravel	47.56	18.7
AI-153-ING,SPT-5	SM	Gravel	42.29	16.05

D. ANOVA results due to change in limit for particles passing No.4 sieve

+No.4 > 40%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
$G1_{40}$	1322	178.05	0.135	0.019
$G2_{40}$	93	14.25	0.153	0.046

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.03	1	0.03	1.45	0.23	2.71
Within Groups	29.02	1413	0.02			
Total	29.05	1414				

+No.4 > At 20%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
$G1_{20}$	1156	154.56	0.134	0.016
$G2_{20}$	259	37.74	0.146	0.040

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.03	1	0.03	1.48	0.22	2.71
Within Groups	29.02	1413	0.02			
Total	29.05	1414				

E. ANOVA Test Results For Outlier Limits of Case 1 and Case 3

Case 1: -0.2 to 0.4

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
G1 Case1	1182	144.62	0.122	0.008
G2 Case1	139	12.88	0.093	0.015

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.11	1	0.11	12.48	0.00	2.71
Within Groups	11.59	1319	0.01			
Total	9.86	1296				

Case 3: -0.1 to 0.3

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
G1 Case3	1129	133.12	0.118	0.006
G2 Case3	122	12.39	0.102	0.008

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.11	1	0.11	12.48	0.00	2.71
Within Groups	11.59	1319	0.01			
Total	7.61	1250				

F. The list for corrected N3 due to upper outlier limit

Log	Depth	N2	N3	V3	SPT-N	Corrected N3	Corrected SPT-N	Corrected V3
AI-003-IZN	22.5	4	27	0.742	31	9	13	0.385
AI-010-BOL	10.5	9	26	0.486	35	21	30	0.400
AI-015-GRD	6.0	21	107	0.672	128	49	70	0.400
AI-026-MAT06-MIM	13.5	14	35	0.429	49	32	46	0.391
AI-029-MAT02	7.5	35	107	0.508	142	81	116	0.397
AI-029-MAT02	9.0	39	150	0.587	189	91	130	0.400
AI-030-MAT04	19.5	18	43	0.410	61	42	60	0.400
AI-032-MAT07	24.0	26	150	0.705	176	60	86	0.395
AI-038_MAT14	18.0	40	150	0.579	190	93	133	0.398
AI-038_MAT14	24.0	17	188	0.834	205	39	56	0.393
AI-040-ELB	25.5	36	107	0.497	143	84	120	0.400
AI-041-MAT11	1.5	14	34	0.417	48	32	46	0.391
AI-041-MAT11	21.0	22	83	0.582	105	51	73	0.397
AI-041-MAT11	25.5	32	125	0.592	157	74	106	0.396
AI-047-MLT	12.0	42	107	0.437	149	98	140	0.400
AI-049-BNG	7.5	29	75	0.442	104	67	96	0.396
AI-049-BNG	12.0	35	83	0.408	118	81	116	0.397
AI-049-BNG	18.0	38	125	0.534	163	88	126	0.397
AI-052-MUS	15.0	3	13	0.625	16	7	10	0.400
AI-055-VAN	3.0	11	32	0.488	43	25	36	0.389
AI-058-AGR	9.0	4	11	0.467	15	9	13	0.385
AI-062-ERZ	6.0	40	94	0.402	134	93	133	0.398
AI-062-ERZ	9.0	39	107	0.466	146	91	130	0.400
AI-062-ERZ	15.0	38	125	0.534	163	88	126	0.397
AI-066-ZAR	3.0	2	7	0.556	9	4	6	0.333

AI-070-RES	1.5	6	20	0.538	26	14	20	0.400
AI-070-RES	19.5	32	125	0.592	157	74	106	0.396
AI-071-TKT	16.5	32	150	0.648	182	74	106	0.396
AI-071-TKT	30.0	32	107	0.540	139	74	106	0.396
AI-072-ERB	16.5	36	188	0.678	224	84	120	0.400
AI-074-AMS-BAY	4.5	40	150	0.579	190	93	133	0.398
AI-075-MRZ	12.0	16	40	0.429	56	37	53	0.396
AI-078-KRG	3.0	12	94	0.773	106	28	40	0.400
AI-079-TOS	19.5	41	150	0.571	191	95	136	0.397
AI-086-SRK	9.0	9	26	0.486	35	21	30	0.400
Log	Depth	N2	N3	V3	SPT-N	Corrected N3	Corrected SPT-N	Corrected V3
AI-086-SRK	12.0	31	94	0.503	125	72	103	0.398
AI-087-GL-1	27.0	43	125	0.488	168	100	143	0.399
AI-087-GL-1	28.5	46	125	0.462	171	107	153	0.399
AI-088-CNK	3.0	1	3	0.500	4	2	3	0.333
AI-090-BGA	10.5	41	125	0.506	166	95	136	0.397
AI-091-GNN	1.5	7	22	0.517	29	16	23	0.391
AI-096-EDR	3.0	3	8	0.455	11	7	10	0.400
AI-097-AYV	3.0	45	125	0.471	170	105	150	0.400
AI-099-KNK	16.5	40	94	0.402	134	93	133	0.398
AI-106-BLD	4.5	44	150	0.546	194	102	146	0.397
AI-107-DNZ-MET	3.0	35	94	0.456	129	81	116	0.397
AI-107-DNZ-MET	19.5	40	188	0.648	228	93	133	0.398
AI-120-AYD-DSİ	1.5	5	15	0.500	20	11	16	0.375
AI-126-KOY	25.5	32	150	0.648	182	74	106	0.396
AI-136-CRD	10.5	30	75	0.429	105	70	100	0.400
AI-137-DIN	10.5	4	12	0.500	16	9	13	0.385

AI-137-DIN	18.0	36	94	0.445	130	84	120	0.400
AI-140-STG	6.0	29	107	0.574	136	67	96	0.396
AI-141-KUT-BAY	12.0	3	17	0.700	20	7	10	0.400
AI-147-BGD	24.0	37	107	0.487	144	86	123	0.398
AI-147-BGD	25.5	21	125	0.712	146	49	70	0.400
AI-147-BGD	27.0	27	150	0.695	177	63	90	0.400
AI-147-BGD	28.5	28	125	0.634	153	65	93	0.398
AI-148-SNG	6.0	9	24	0.455	33	21	30	0.400
AI-150-BND-TDM	1.5	13	36	0.469	49	30	43	0.395
AI-150-BND-TDM	10.5	32	83	0.445	115	74	106	0.396
AI-152-BRS	3.0	30	94	0.515	124	70	100	0.400

G. The list for corrected N2 due to lower outlier limit

Log	Depth	N2	N3	V3	SPT-N	Corrected N2	Corrected SPT-N	Corrected V3
AI-003-IZN	6.0	7	4	-0.273	11	4	8	0.000
AI-012-MEN	4.5	14	9	-0.217	23	11	20	-0.100
AI-057-DBY	12.0	29	16	-0.289	45	19	35	-0.086
AI-071-TKT	6.0	25	20	-0.111	45	24	44	-0.091
AI-071-TKT	12.0	33	25	-0.138	58	30	55	-0.091
AI-081-IZN-KY	12.0	4	3	-0.143	7	3	6	0.000
AI-081-IZN-KY	13.5	3	2	-0.200	5	2	4	0.000
AI-081-IZN-KY	15.0	4	2	-0.333	6	2	4	0.000
AI-081-IZN-KY	16.5	2	1	-0.333	3	1	2	0.000
AI-081-IZN-KY	25.5	2	1	-0.333	3	1	2	0.000
AI-081-IZN-KY	30.0	2	1	-0.333	3	1	2	0.000
AI-082-CEK	3.0	22	16	-0.158	38	19	35	-0.086
AI-095-EZN	3.0	39	27	-0.182	66	33	60	-0.100
AI-103-SMV	10.5	17	11	-0.214	28	13	24	-0.083
AI-104-GDZ	4.5	27	17	-0.227	44	20	37	-0.081
AI-111-ODM	12.0	20	12	-0.250	32	14	26	-0.077
AI-112-MNS	9.0	20	16	-0.111	36	19	35	-0.086
AI-115-BRN-BAY	6.0	2	1	-0.333	3	1	2	0.000
AI-115-BRN-BAY	15.0	5	4	-0.111	9	4	8	0.000
AI-116-BRN-EU	13.5	20	16	-0.111	36	19	35	-0.086
AI-116-BRN-EU	19.5	25	15	-0.250	40	18	33	-0.091
AI-126-KOY	3.0	19	12	-0.226	31	14	26	-0.077
AI-132-TFN	7.5	23	13	-0.278	36	15	28	-0.071
AI-137-DIN	3.0	3	2	-0.200	5	2	4	0.000
AI-139-AFY	1.5	3	2	-0.200	5	2	4	0.000
AI-139-AFY	4.5	9	6	-0.200	15	7	13	-0.077
AI-141-KUT-BAY	1.5	2	1	-0.333	3	1	2	0.000
AI-142-KUT-SS	7.5	10	7	-0.176	17	8	15	-0.067
AI-147-BGD	3.0	21	13	-0.235	34	15	28	-0.071
AI-148-SNG	13.5	14	7	-0.333	21	8	15	-0.067
AI-148-SNG	16.5	10	7	-0.176	17	8	15	-0.067
AI-151-MKP	1.5	16	12	-0.143	28	14	26	-0.077