FINAL REPORT

INVESTIGATION OF SHRINK AND SWELL FACTORS FOR SOILS USED IN FDOT CONSTRUCTION

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by

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ABSTRACT

The shrinkage and bulkage factors for soils used in typical FDOT construction projects influence the initial and final estimate of earth needed as borrow or excess material. Variations from initial estimates and final in-place quantities frequently occur. The differences result in cost overruns, construction claims, disputes, budget waste and added administrative costs. Changes in actual shrink and swell numbers during the construction process are often cited as a basis for any changes from estimated to final in-place quantities.

This project investigates these shrinkage and bulkage factors of Florida soils used in earthwork estimation by the Florida Department of Transportation (FDOT). The shrinkage factor indicates the reduction in volume of soil from the borrow pit stage to the final compacted stage, while the bulkage factor accounts for the increase in volume of the soil between the pit and the loose state in the truck. A methodology for predicting these factors is formulated based on density changes of the soil as it is excavated, transported, and compacted. Soil densities at the three different stages are used to calculate shrinkage and bulkage factors, and have been determined from seven field projects throughout the state of Florida. Laboratory testing, such as sieve analyses and standard proctor tests, and field testing using nuclear density and speedy moisture tests, cone penetration tests, dilatometer tests, drive sleeve tests, and unit volume box tests, have been used to determine the soil densities at the three stages of earthwork. Statistical analyses of past projects are conducted to illustrate the frequency of deviations from the current shrinkage factors based on planned and borrow excavation quantities. This justifies the use of a more detailed field investigation.

A method is developed to correlate the results of the cone penetration testing (CPT) to in-situ dry density of sandy soils using the uniformity coefficient from grain size analysis. Dilatometer test results are also utilized to estimate the dry density of the soil but are found to over-predict the values in most cases. A unit volume box test is used to simulate the density of a soil while in a loose state, while compacted density values are obtained from the field logs or using standard proctor test in the laboratory.

Based upon the results of all the laboratory and field tests, average values of shrinkage and bulkage factors are evaluated. Shrinkage factors of 15 to 20% and a bulkage factor of 25% are found to be typical for all projects monitored and are recommended for future use. The shrinkage factors obtained are significantly lower than the currently used FDOT shrinkage factors (30-35%), while the bulkage factor obtained agrees well with the FDOT value of 25%.

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CHAPTER 1
SCOPE OF THE PRESENT STUDY

1.1 Introduction

Shrinkage and bulkage factors for soils are used in typical FDOT construction projects to compensate for changes in the volume of the soil as it is excavated and placed into a fill or embankment. The current practice is to adopt an arbitrary shrinkage factor of 30-35% for adjustment of fill as it is placed and compacted. In addition, a bulkage factor of 25% is used to account for any loss of soil during transportation or stockpiling. These randomly assigned factors often lead to significant variations between initial estimates and final in-place quantities resulting in cost overruns, construction claims, disputes, budget waste and added administrative costs.

1.2 Summary of Project Objectives

The objectives of this project are:

1. To examine past projects where the shrinkage and bulkage factors did not correlate with actual earthwork calculations and measurements.

2. To investigate the factors such as soil types and local conditions, which may have caused these errors to take place and may have a significant influence on the shrink and bulkage factors.

3. To determine the relationship between densities of borrow soil obtained from (a) Cone Penetration, Dilatometer Tests and in-situ Nuclear Density tests, (b) Nuclear

Density tests in trucks or stockpiles and densities from a unit box, and (c) the maximum compaction densities from Proctor tests and minimum-maximum density Tests.

4. To establish more accurate guidelines for shrinkage and bulkage factors used in statewide FDOT earthwork. Make recommendations for the use of shrinkage and bulkage factors based upon soil type and field tests.

The overall work plan consists of the following tasks:

1. Define shrinkage and bulkage factors on the basis of initial and final state properties, for instance, soil dry densities.

2. Evaluate past FDOT project data to determine cost differences due to earthwork changes, and analyze the data based on theoretical and actual shrinkage factors.

3. Select and monitor on-going projects for a detailed field study to assess soil classification, moisture and dry density at each stage of the earthwork. Collect soil samples for further laboratory analysis. Perform cone and dilatometer soundings and nuclear density tests for borrow materials and in-place fills.

4. Perform laboratory tests on soil samples from the field projects to obtain correlation between shrink and bulkage factors and soil properties.

In summary, this report describes the theory and definitions of shrinkage and bulkage factors, presents data on past projects that reflects a definite need for this research, and summarizes field investigations of the selected projects in the Central Florida area. Associated findings concerning laboratory testing of soils to correlate soil properties with the shrink and bulkage factors are also included in this report.

CHAPTER 2

REVIEW OF SHRINKAGE AND BULKAGE FACTORS

2.1 Introductory Remarks

The use of shrinkage and bulkage factors in earthwork applications is a common practice in most construction and estimating codes. Values of shrinkage and bulkage factors are often generated based upon local engineering experience, general information in construction estimating handbooks and texts, or recommendations from governmental offices or private industry. For example, shrinkage values for the Florida Department of Transportation (FDOT) range from 30 to 35% while a bulkage factor of 25% is adopted for most construction projects. The NAVFAC Design Manual (1982), published by the U.S. Navy, recommends a shrinkage factor of 10 - 15%, and the British Columbia Forestry Service (1995) offers shrinkage and bulkage factors for different material types as shown in Table 2.1. The Georgia Department of Transportation (GDOT) (Scruggs, 1990) conducted research in this area to help establish more accurate sets of shrinkage factors for each district within the state. In addition, the "Caterpillar Performance Handbook" (1995), published by Caterpillar, Inc., offers insightful definitions for shrinkage and bulkage and the proper calculations of these factors.

Estimating textbooks, such as those by Helton (1992) and Lewis (1983), suggest using 10 -20% bulkage factors and shrinkage factors from 10-15% for sand and gravel. It is pointed out in these publications that the shrinkage properties will vary with compaction method, moisture content, grain size, and in-situ weight density. However, the present methods of estimating shrink and bulkage potential of soils are not very accurate and quite often either over-predict or under-predict the quantity of fill or borrow materials.

Table 2.1 Example of Shrinkage and Bulkage Factors (BCFS, [1995])

Material Type	Shrinkage Factor	Bulkage Factor
Clean Sand	5%	12%
Common Sand	10%	25%
Hard Pan	0%	25%
Clayey Silt or Clay	9%	30%

2.2 Current FDOT Practice - Shrinkage and Bulkage Factors

Current practice of the Florida Department of Transportation (1991) classifies earthwork items on highway projects into three broad categories:

(i) Classified Excavation - consisting of Regular (Roadway or Borrow), Subsoil, Lateral Ditch and Channel.

(ii) Unclassified Excavation

(iii) Embankment - consisting of compacted fill including backfill.

Roadway excavation is the net volume of the material excavated between the original ground surface and the bottom of the proposed roadway template. Retention and detention areas are a part of Roadway excavation as well. Interestingly, Roadway excavation pay item is often called Regular Excavation (Pay Item 120-1) in several FDOT publications and roadway designs. Hence, Regular excavation will be used in this report to indicate Roadway excavation as opposed to Borrow Excavation (Pay Item 120-2-2). Borrow excavation is the net volume of material that the contractor must furnish from areas generally outside the project boundaries. If available, borrow materials may also be obtained from within the right of way of the project.

Borrow excavation is measured using two methods - Pit measure or Truck Measure. In each case, the FDOT designer has to apply certain adjustment factors to the net total fill volume calculated from the roadwork plans to account for reduction in soil volume or losses due to handling from one stage to another. These factors are known as shrinkage and truck adjustment (or bulkage) factors. The shrinkage adjustment factor is applied to the net volume of the design fill in all cases while the bulkage adjustment factor is applied to the in-place volume when the pay item is based on truck measure. In summary, it may be stated that earthwork volumes occupy three different stages,

(1) Truck measure or loose state, (Borrow Excavation only)
(2) Pit measure or in-place state which consists of volume of soil obtained locally as Regular excavation and volume of soil borrowed and reduced for bulkage,
(3) Design Fill or compacted state.

Figure 2.1 describes the three stages of the earthwork in order to clarify the nomenclature used for the various items.

Currently, the practice of computing these factors is based on the Roadways Plans Preparation Manual of FDOT (1989) where typical values are assigned based upon the recommendations of the District offices. Typical values of the shrinkage factors range from 30 to 35 % while a bulkage factor of 25 % is adopted for most projects. An example earthwork calculation from an actual FDOT project is reproduced from the Plans Preparation Manual in Table 2.2 below.

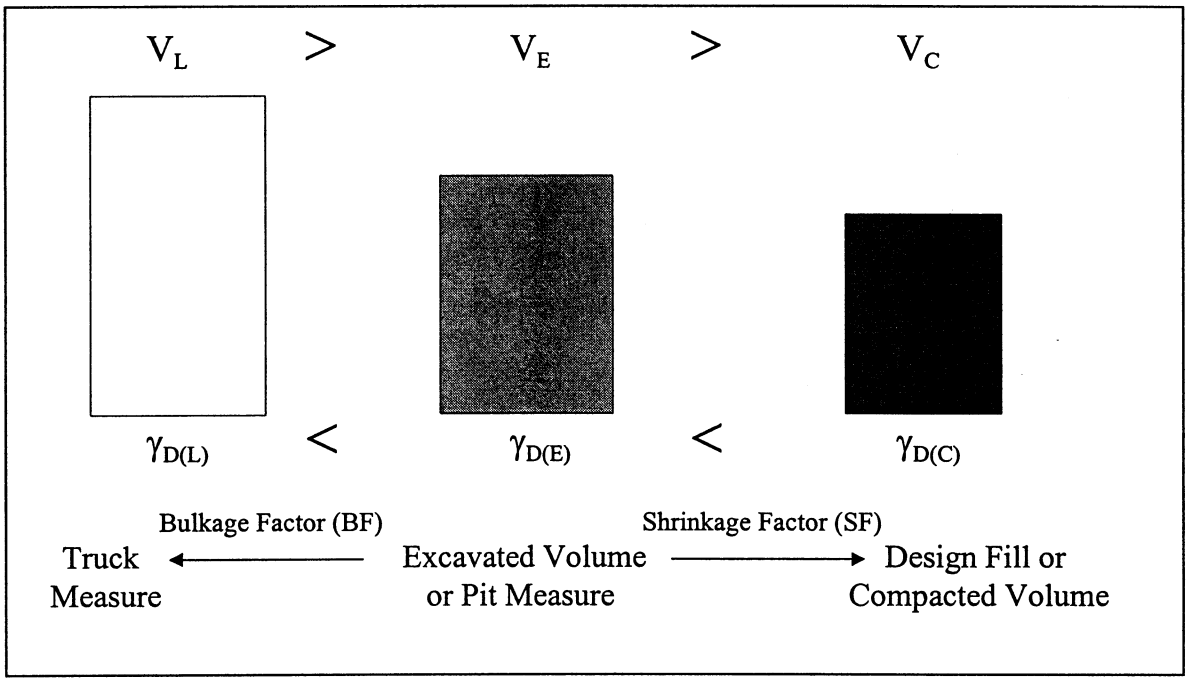

Figure 2.1 Different stages of Earthwork Quantities and the Associated Factors

Table 2.2 Earthwork Calculation Example (FDOT, 1989)

Fill (from cross-sections)	18,838 m^3 (24,639 CY)
Shrinkage factor (30%)	5,651 m^3 (7,392 CY)
Total Fill	24,489 m^3 (32,031 CY)
Roadway Excavation (deduct)	1859 m^3 (2,426 CY)
Borrow Excavation (Pit)	22,634 m^3 (29,605 CY)
Bulkage factor (25%)	5,659 m^3 (7,401 CY)
Borrow Excavation (Truck)	28,293 m^3 (37,006 CY)

However, according to the impact study conducted by Mehta (1997), the shrinkage and bulkage factors presently used by the FDOT are not consistent with the universal equations published in other sources. The FDOT shrinkage factor is expressed as the difference of the excavated and compacted volumes as a percentage of the compacted volume rather than as a percentage of the excavated volume, or expressed mathematically,

$$SF_{(FDOT)} = \frac{V_E - V_C}{V_C} \tag{2.1}$$

This equation can also be written in relationship to the corresponding dry densities as

$$SF_{(FDOT)} = \frac{(\gamma_d)_C}{(\gamma_d)_E} - 1 \tag{2.2}$$

The bulkage factor, defined by the FDOT, is also different from the universal equations. The bulkage factor is defined in the FDOT Roadway Plans Preparation Manual (1989) as the ratio of the volume of the soil in the truck to the excavated soil volume, which can be expressed as follows,

$$BF_{(FDOT)} = \frac{V_T}{V_E} \tag{2.3}$$

Or, in terms of the soil dry densities, the bulkage factor is expressed as

$$BF_{(FDOT)} = \frac{(\gamma_d)_E}{(\gamma_d)_T} \tag{2.4}$$

However, an example problem illustrated in the Plans Preparations Manual (1989) showed that the usage of the bulkage factor and its definition are inconsistent. The adjustment of borrow fill material in the example of earthwork calculations from the FDOT manual is defined by the following relationship,

$$V_T = \left[\frac{1}{1+SF_{(FDOT)}}\right]\left[\frac{V_C}{\left(1+BF_{(FDOT)}\right)}+V_{regular}\right] \quad (2.5)$$

Back-calculating the bulkage factor relationship from Equation (2.5) lead to the correct equation for bulkage, shown in Equation (2.10) later. The equations for shrinkage and bulkage factors based on the theoretical definitions and those defined by the FDOT will be used in to determine shrinkage and bulkage factors. This will allow for a direct comparison of the results obtained from the field study and provide insight into the accuracy of the presently recommended FDOT shrinkage and bulkage factors.

These inconsistencies were pointed out by Gordon S. Burleson, Engineer of Construction Training in a memorandum to District Area Engineer and District Soil Engineers dated March 20, 1992. Based upon this memorandum and the widely used definitions of shrinkage and bulkage factors, the next section presents a discussion of the proper use of these factors. The present research consistently used the correct definition of these factors except when citing records of existing FDOT calculations based on the inconsistent formula. In addition, the present research also endeavored to get a better measure for these factors based upon the classification and properties of the borrow material.

2.3 Universal Definition of Shrinkage Factor

The term shrinkage is used to define the reduction in volume of the quantity of soil when it is obtained from a cut and is placed and compacted to form an embankment or backfill. Based upon the net volumes of the design fill and the excavated (pit measure) materials, a corrected theoretical shrinkage factor may be defined as

$$SF = \frac{V_E - V_C}{V_E} \tag{2.6}$$

or,

$$V_E = \frac{V_C}{(1 - SF)} \tag{2.7}$$

The shrinkage factor may also be expressed in terms of the dry unit weights of the two states of soil as follows:

$$SF = 1 - \frac{\gamma_{d(E)}}{\gamma_{d(C)}} \tag{2.8}$$

where $\gamma_{d(E)}$ is the dry unit weight of the in-place or pit measure borrow material and $\gamma_{d(C)}$ is the dry unit weight of the design fill or compacted soil at the Percent Compaction specified based upon Proctor tests. The maximum unit weight at 100-103% compaction is usually greater than the dry unit weight of loose borrow and thus the soil has a positive shrinkage factor. However, in some cases, the factor may become a swell factor if the borrow dry density exceeds the maximum density of the fill at Percent Compaction.

The bulkage factor (BF) is used for Borrow Excavation (Truck Measure) pay items and accounts for the additional volume the soil occupies when it is in loose state as in the case of being in a truck. Bulkage is defined as the difference in volume between the loose volume (truck measure) and the in-place excavated volume from a borrow pit (pit measure), expressed as a percentage of the borrow volume (pit measure). Thus, for a Truck Measure pay item, the net volume becomes the volume of the loose soil in the truck after the bulkage adjustment. The bulkage factor may be expressed mathematically as,

$$BF = \frac{V_L - V_E}{V_E} \tag{2.9}$$

or,

$$V_L = V_E(1 + BF) \tag{2.10}$$

where, V_L is the volume of the loose borrow soil in the truck. In terms of the soil density in the loose state and the pit density before placement, the bulkage factor may be written as:

$$BF = \frac{\gamma_{d(E)}}{\gamma_{d(L)}} - 1 \tag{2.11}$$

The adjustments applied to the computed earthwork quantities based on the two factors may be summarized in the following relation

$$V_L = [\frac{V_C}{(1 - SF)} - V_{regular}](1 + BF) \tag{2.12}$$

where, $V_{regular}$ is the volume of Regular excavation (Pay Item 120-1). It must be noted that in addition to inaccurate estimation of shrinkage parameter, there are numerous other parameters that influence the earthwork calculations and may cause differences in the planned and actual quantities. Some of these factors are discussed later in this report.

The example calculations shown in Table 2.2 can now be corrected using the universal definition of shrinkage factor and both calculations are shown side-by-side in Table 2.3 below.

Table 2.3 Comparison of Earthwork Calculations based on Universal and FDOT methods for defining Shrinkage Factors

Items	**Current FDOT Method**	**Universal Method**
Fill (from cross-sections)	18,838 m^3 (24,639 CY)	18,838 m^3 (24,639 CY)
Shrinkage factor (30%)	5,651 m^3 (7,392 CY)	8,073 m^3 (10,559 CY)
Total Fill	24,489 m^3 (32,031 CY)	26,911 m^3 (35,198 CY)
Roadway Excavation (deduct)	1,859 m^3 (2,426 CY)	1,859 m^3 (2,426 CY)
Borrow Excavation (Pit Measure)	22,634 m^3 (29,605 CY)	25,052 m^3 (32,772 CY)
Bulkage factor (25%)	5,659 m^3 (7,401 CY)	6,263 m^3 (8,193 CY)
Borrow Excavation (Truck Measure)	28,293 m^3 (37,006 CY)	31,315 m^3 (40,965 CY)

2.4 Conclusion

This chapter presented the current and revised definitions of the shrinkage and bulkage factors and the procedure of estimating these factors using the soil volumes at different stages of earthwork. These definitions will be utilized in the upcoming chapters to compute better estimates for these earthwork factors.

CHAPTER 3
STATISTICAL DATA AND COST ANALYSIS

3.1 Introductory Remarks

An extensive review of past FDOT projects showing significant variations of planned and final earthwork quantities is described in this chapter. This illustrates the effect of over- and under-runs in earthwork estimation. This review is broken down into three parts. The first part is a comprehensive analysis of the initial planned quantities and final quantities for a number of past FDOT projects. This exercise allows one to determine the overall effects of earthwork estimation. The second part is an in-depth review of some of the past projects, with substantial differences in estimated and actual soil quantities, to further investigate potential sources of errors and the contribution of incorrect shrinkage and bulkage factors.

The third part discusses a survey questionnaire, which was sent to each district, including the Turnpike, to gather preliminary information from the FDOT engineers. This preliminary information gathered gives a fairly subjective view of what actually takes place in a roadway project. This can also shed some light on the practicalities of moving earth. Chapters 4 and 5 will discuss the determination of improved factors based on the tracking of the soil densities in different stages at three field projects. Soil tracking can help describe what processes the soil actually undergoes through each phase of construction.

3.2 Statistical Review and Cost Analysis of Past Earthwork Data

A list of projects is compiled from FDOT records for the past five years. Appendix C lists the details of these projects consisting of the year of project, state project number, planned quantity, final in-place quantity, bid for earthwork, difference in quantities, percentage difference in quantities, estimate of shrinkage factor, and estimate of overrun or under-run. The tables are broken down into categories such as project years and earthwork pay items.

3.2.1 Cost Analysis

Table 3.1 summarizes the detailed cost analysis (see Table C-9, Appendix C) for three pay items for the period 1991 through 1996. It presents the financial implications of differences in planned and actual earthwork quantities ***due to all possible causes***. The table covers ***both over- and under-runs*** although it was observed that there were over-runs in a majority (about 60%) of the cases. It is evident the differences related to earthwork items have cost the Florida Department of Transportation an average of $2 million per year over the past 6 years with a total of about $15 million in losses. Thus, the present research on the effect of shrinkage and bulkage factors for earthwork calculations is vital in determining the portion of the error arising from these factors.

Table 3.1 Cost Analysis of Over- and Under-Runs by Pay Item and Year

Year	Pay Item			Total
	120-1 (Regular)	120-2-2 (Borrow)	120-6 (Embankment)	
1991	$143,469	$861,622	$1,044,057	$2,049,149
1992	$229,390	$1,180,692	$1,167,132	$2,577,213
1993	$542,281	$1,397,914	$597,352	$2,537,548
1994	$245,770	$989,926	$54,715	$1,290,412
1995	$504,367	$1,533,187	$593,949	$2,631,503
1996	$295,634	$1,288,790	$1,738,189	$3,322,613
Total	$1,960,913	$7,252,131	$5,195,393	$14,408,437

3.2.2 Statistical Analysis

Certain projects with identical project numbers for two pay items, such as either regular and borrow excavation or regular excavation and embankment, are selected from the database shown in Appendix C for closer scrutiny for shrinkage factors. Since only data pertaining to planned and actual borrow quantities after adjustment is available from the FDOT database, an approximate design fill quantity is back-calculated using an the existing shrinkage factor of 35% and a bulkage factor of 25 % using the following equation:

$$V_{DESIGN\ FILL} = (1 - 0.35)\left[\frac{V_{PLANNED\ BORROW}}{1.25} + V_{REGULAR\ EXCAVATION}\right] \tag{3.1}$$

Next, based upon this approximate fill quantity and a bulkage factor of 25% again, an actual shrinkage factor is calculated using the following relationship:

$$SF = \frac{\left[\frac{V_{ACTUAL\ BORROW}}{1.25} + V_{ACTUAL\ REGULAR} - V_{DESIGN\ FILL}\right]}{\left[\frac{V_{ACTUAL\ BORROW}}{1.25} + V_{ACTUAL\ REGULAR}\right]} \tag{3.2}$$

These computations are provided in the form of tables found in Appendix C, with the associated losses for each individual project. As discussed in Chapter 2, the method of calculation for design fill and shrinkage factor previously used by FDOT is found to be inconsistent with common practice. The calculation using the previous definitions of shrinkage and bulkage factors provide the following equations for the design fill volume and the shrinkage factors.

$$V_{DESIGN\ FILL} = \left(\frac{1}{0.35}\right)\left[\frac{V_{PLANNED\ BORROW}}{1.25} + V_{REGULAR\ EXCAVATION}\right] \tag{3.3}$$

$$SF = \left(\frac{V_{ACTUAL\ BORROW}}{1.25} + V_{REGULAR\ EXCAVATION}\right)\left(\frac{1}{V_{DESIGN\ FILL}}\right) - 1 \tag{3.4}$$

These equations are derived using the *inconsistent definition of shrinkage factor* used currently by FDOT and are included in the present analysis only for the purpose of comparing the previous and corrected methods of computing these factors and should not be adopted for any other future purpose. Table 3.2 cross-references projects with both regular excavation and borrow excavation, and shows the difference in the old design fill and new design fill calculation methods. The table also shows differences in the old shrinkage factor and the new shrinkage factor.

Table 3.2: Comparison of Old and New Shrinkage Factors for Past FDOT Projects

Project Number	Planned Borrow Quantity (Truck) (CY)	Actual Borrow Quantity (Truck) (CY)	Planned Regular Excavation 120-1 (CY)	Actual Regular Excavation 120-1 (CY)	Approx. Design Fill (OLD) (Eq 3.3)	Approx. Design Fill (NEW) (Eq 3.1)	Plan Shrinkage Factor	Old Shrinkage Factor (Eq 3.4)	New Shrinkage Factor (Eq 3.2)
162103503	23444	16738	79274	72344	72614	63719	0.35	0.18	0.26
730103521	1830	5888	1614	1428	2280	2001	0.35	1.69	0.67
740303514	2400	3251	1644	1490	2640	2317	0.35	0.55	0.43
890203503	23000	19552	5340	5865	17585	15431	0.35	0.22	0.28
978803316	1800	1059	3469	3122	3636	3191	0.35	0.09	0.20
979203340	7200	2420	9572	10113	11357	9966	0.35	0.06	0.17
110103557	4035	3659	4530	2850	5747	5043	0.35	0.01	0.13
550403530	351	247	1230	1156	1119	982	0.35	0.21	0.27
610403518	9920	10913	998	707	6618	5807	0.35	0.43	0.38
700103523	1153	1650	3776	3579	3480	3054	0.35	0.41	0.38
890503512	4134	4351	1377	2058	3470	3045	0.35	0.60	0.45

Project Number	Planned Borrow Quantity (Truck) (CY)	Actual Borrow Quantity (Truck) (CY)	Planned Regular Excavation 120-1 (CY)	Actual Regular Excavation 120-1 (CY)	Approx. Design Fill (OLD) (Eq 3.3)	Approx. Design Fill (NEW) (Eq 3.1)	Plan Shrinkage Factor	Old Shrinkage Factor (Eq 3.4)	New Shrinkage Factor (Eq 3.2)
978803313	1057	1399	738	522	1173	1029	0.35	0.40	0.37
30803518	35809	30275	6803	6431	26259	23043	0.35	0.17	0.25
120043506	1676	1898	1063	1163	1781	1562	0.35	0.51	0.42
170203560	810	1013	231	268	651	571	0.35	0.66	0.47
480993811	763	33	2599	2823	2377	2086	0.35	0.20	0.27
600203515	424	955	37605	49479	28107	24664	0.35	0.79	0.51
305303606	22031	16616	9553	8518	20132	17666	0.35	0.08	0.19
860953457	2000	2446	11655	16374	9819	8616	0.35	0.87	0.53
900603576	1550	1047	600	529	1363	1196	0.35	0.00	0.12
55303603	37736	31534	12476	10380	31604	27732	0.35	0.13	0.22
100603580	700	1616	8328	7117	6584	5777	0.35	0.28	0.31
101203519	7455	10697	28257	25015	25349	22244	0.35	0.32	0.34
160203536	448	1576	1984	2195	1735	1523	0.35	0.99	0.56
380103522	200	952	6819	7512	5170	4536	0.35	0.60	0.45
530023430	456	1804	399	1319	566	496	0.35	3.88	0.82
550003643	5103	3886	56	156	3065	2690	0.35	0.07	0.18
720703501	756	643	506	427	823	722	0.35	0.14	0.23
722903418	2756	3504	1338	1769	2624	2303	0.35	0.74	0.50
741603416	49540	70844	8033	8636	35307	30982	0.35	0.85	0.53
780503518	6574	4461	826	974	4508	3955	0.35	0.01	0.13
880603525	2006	1466	506	1752	1564	1372	0.35	0.87	0.53
940303528	5416	4964	14586	13083	14014	12297	0.35	0.22	0.28
101103566	414	864	2544	2747	2130	1869	0.35	0.61	0.46
101403502	733	1164	2848	2582	2544	2232	0.35	0.38	0.36
155603603	139	324	529	599	474	416	0.35	0.81	0.52
290703513	5204	4143	160	170	3202	2810	0.35	0.09	0.19
291803430	60499	56659	19084	17621	49988	43864	0.35	0.26	0.30
540013431	158	83	70	221	145	128	0.35	0.98	0.56
580303526	3058	3501	1628	1787	3018	2648	0.35	0.52	0.42

Project Number	Planned Borrow Quantity (Truck) (CY)	Actual Borrow Quantity (Truck) (CY)	Planned Regular Excavation 120-1 (CY)	Actual Regular Excavation 120-1 (CY)	Approx. Design Fill (OLD) (Eq 3.3)	Approx. Design Fill (NEW) (Eq 3.1)	Plan Shrinkage Factor	Old Shrinkage Factor (Eq 3.4)	New Shrinkage Factor (Eq 3.2)
610013425	186	400	224	86	276	242	0.35	0.47	0.40
730203519	659	823	651	504	873	766	0.35	0.33	0.34
750603556	627	1354	1315	1148	1346	1181	0.35	0.66	0.47
940053506	3704	2905	1054	719	2976	2611	0.35	0.02	0.14
978713321	44256	60406	3187	3429	28587	25085	0.35	0.81	0.52
305303602	56836	71042	35067	37887	59656	52348	0.35	0.59	0.45

It is evident in Table 3.2 that the new method of calculating shrinkage is much closer to the Plan Shrinkage Value of 0.35 than the old method of calculation. This difference in the calculating methods of shrinkage factors and design fill may be one factor contributing to the under and over estimation of excavation and fill. The next chapter provides more information of the actual shrinkage and bulkage factors of excavated and compacted soils through a soil density tracking method.

It must be clearly understood that the analysis in this section is approximate and is conducted only as a statistical exercise from a number of past projects. Negative values of these factors does not necessarily indicate swell factors but may be the result of other influencing parameters such as:

(i) Design alterations based on supplemental agreements to account for changes in construction. These may have been a result of changes in slopes or grades or additional areas included for work or other adjustments made. Some of these changes are often attributed to plan errors or omissions in plans.

(ii) Plan Errors with cross-sections, omissions, calculations of quantities, etc. causing over-runs or under-runs of earthwork quantities

Scruggs (1990), in a similar study in Georgia, lists a number of other factors which may affect earthwork calculations on transportation projects including the following:

(1) Stripping - the removal of the top mat of roots and other organic vegetation from the ground surface before fills are place. Removal of this material requires placing additional borrow as replacement for the stripped material.

(2) Consolidation - the process wherein the underlying foundation soils settle under the weight of new loads, such as roadway fills, which are applied to them. The time required for soils to consolidate varies greatly depending on the type of soil, gradation, and how quickly water trapped within soil particles dissipates. Soil volumes lost through the consolidation process require replacement. Often this settlement occurs during the construction of the fills, and it is difficult to determine the exact amount that is lost.

(3) Erosion of soils during the construction phase of a project can also cause losses and affect final quantities. Erosion due to the actions of water and wind are more prevalent with granular soils such as sand and non-plastic silts.

(4) Materials are occasionally encountered in construction cuts that were not found during the soil survey investigation, which the contractor cannot readily spread and compact in fill sections. This is usually due to material being very wet or very plastic, such as clays and plastic slits. These materials are often wasted and require replacement soils.

(5) Clearing and grubbing operations can also affect earthwork quantities, since some loss of soils can occur during removal or vegetation, stumps, and boulders.

All of these factors can result in significant changes in the quantity of earthwork. This change can be appreciable on projects with low fills and large amounts of stripping, clearing and grubbing. Some projects have had as much as a 100% increase in the required borrow soil.

The following sections will summarize the results of the statistical analyses of construction projects in Florida over a five-year span. The findings of the analyses will provide the basis for shrinkage factors in the state and provide insight into problem areas in the state.

3.2.3 Summary of Earthwork Data

Over four hundred projects were reviewed and used in the back-calculation of the shrinkage factors described in the previous section. The shrinkage factor was limited to all positive values (0 - 100%) assuming that the compacted density at percent compaction is always greater than in-situ, or in-place, density which is typical for Florida soils. This limitation eliminated approximately 34% of the total projects surveyed. Values within ±10% of the FDOT recommended shrinkage value of 35% were deemed acceptable, not causing significant over-runs or under-runs in earthwork calculations.

Earthwork Data Summarized on Statewide Basis

Figures 3.1 and 3.2 present the results of the statistical analyses of the projects reviewed statewide based on the theoretical definition and the FDOT definition, respectively. The figures report the calculated shrinkage factors and the frequency at which each factor appeared in the analysis. Also, *an acceptable range of 25-45% (which is within 10% of the current recommended value of 35%) for shrinkage factors is shown.* From the projects surveyed using the theoretical definition, it was found that of the 468 total projects reviewed 125 (26.7%) were either less than or equal to zero, 73 projects (15.6%) fell between the 0 to 25% range, and 106 projects (22.6%) were above the acceptable range. The remaining 164 projects (35%) were within the acceptable shrinkage factor limit. When the projects were reviewed using the FDOT definitions,

- 163 projects (34.8%) were less than or equal to zero,
- 87 projects (18.6%) were between 0 and 25%,
- 83 projects (17.7%) were between 45% and 100%,
- 59 projects (12.6%) were greater than 100%, and
- the remaining 76 projects (16%) were within the range of acceptance.

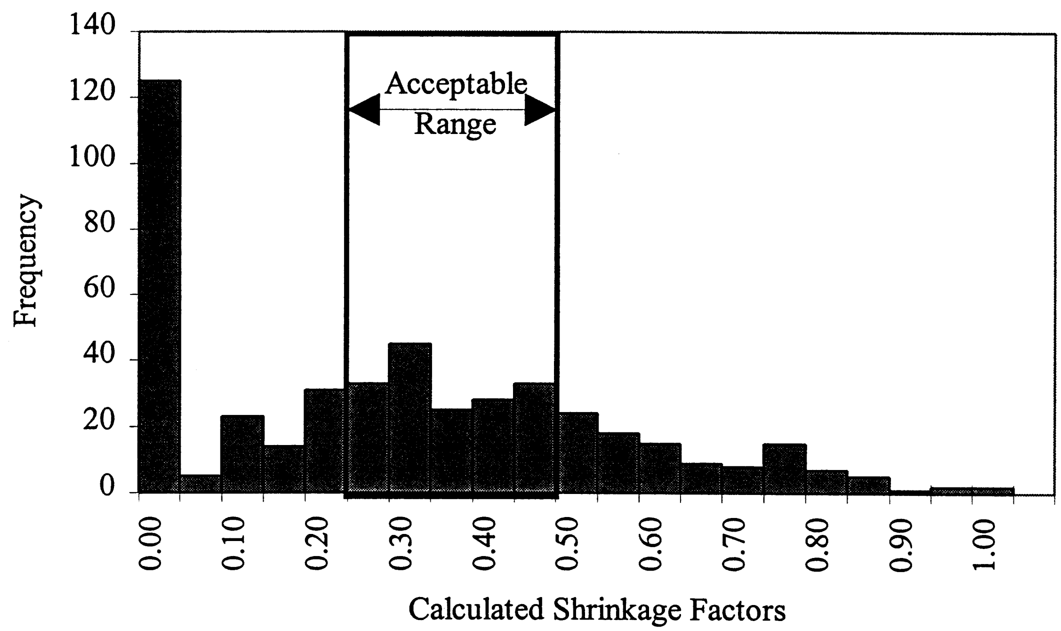

Figure 3.1. Calculated Shrinkage Factors based on Universal Definitions

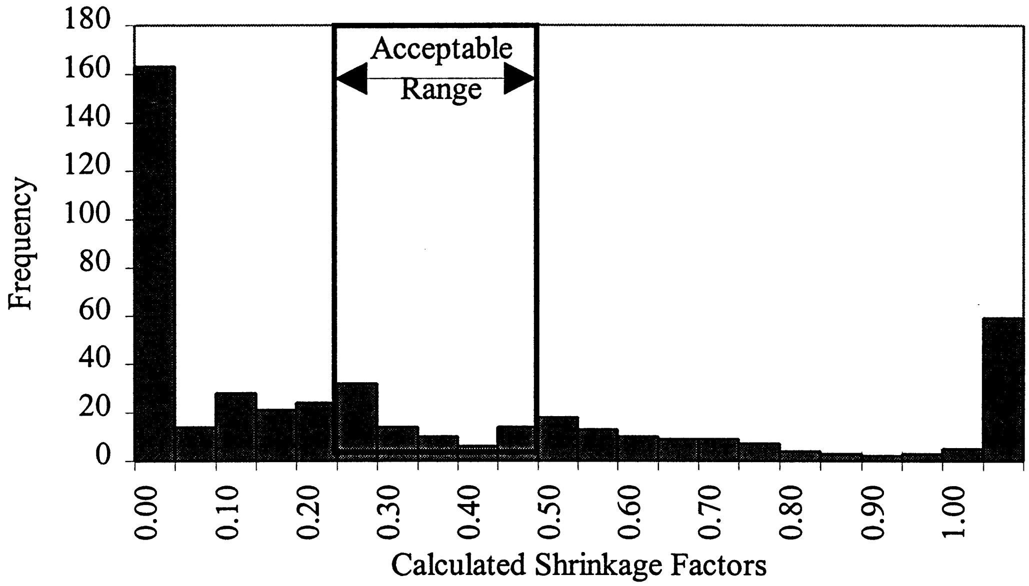

Figure 3.2. Calculated Shrinkage Factors based on current FDOT Definitions

From both cases, there seems to be a considerable amount of deviation from the FDOT recommended shrinkage, even more so when the FDOT definitions are used. It is the opinion of the author that the deviations are due to substantial amounts of soil excavated during the course of the FDOT projects not being used for the contacted work. Rather, the excess soil, in most cases, was used at other project sites not dealing with the FDOT. It is believed that this practice is a quite common and is often used to supplement bid cost for contractors in order to make a more substantial profit.

The data used in the statewide analysis was broken into the corresponding districts of Florida according to the district map and the results are presented in the next section.

Data Summarized on District Basis

The values obtained from the statewide analysis showed 65 to 84% of the projects feel outside the acceptable range for recommended shrinkage factors. An investigation into each district will provided further insight into the distribution of acceptable range of shrinkage factors throughout the state. Results of the statistical review of each district are discussed below.

As previously mentioned, the state of Florida is broken into seven districts. The Turnpike District, the eighth district, is a statewide district responsible for the construction and rehabilitation of Florida's Turnpike roads, which extend throughout the state. Consequently, the fill materials used are usually obtained near the project sites. It is important to note that most of the state of Florida is comprised of sedimentary soil deposits, quite often sandy soils, which makes an excellent fill material. States immediately north of Florida have soils that are generally more clayey in nature.

Tables 3.1 and 3.2 summarize the results of the statistical analyses conducted on the districts of Florida based on the theoretical and FDOT definitions. The total number of project surveyed from each district and the percentage of projects falling within the specified ranges are shown. In five of the seven cases, from the calculated shrinkage factors based on the theoretical definitions, a higher percentage of the projects fell within the acceptable range when compared individually to each range of study. The exceptions were from the Turnpike District and District 1. However, the sum of the percentages outside the acceptable almost always exceeded the percentage of projects within the acceptable range. The exception being District 6, with 53% of the projects lying within the acceptable range. It is also interesting to note is that no shrinkage factors were calculated above 100%, while 13% of the total project in the statewide analysis lie, when calculated using the FDOT definitions.

Table 3.1. Summary of Statistical Analyses on Districts Based on Theoretical Definitions

		Percent (%) of Project Within Ranges				
District	No. of Project Reviewed	≥ 0%	0 - 25%	25 - 45% Acceptable	45 - 100%	≤ 100%
1	62	39	15	29	18	0
2	97	27	19	31	24	0
3	82	32	12	30	26	0
4	58	7	19	47	28	0
5	79	32	11	42	15	0
6	19	11	11	53	26	0
7	49	27	18	33	22	0
Turnpike	22	23	23	23	32	0

Results obtained using the FDOT definitions for shrinkage and bulkage factors showed a more consistent deviation from the acceptable than the theoretically based results. There were no cases where the number of projects within the acceptable range exceeded the sum of the other ranges of study. In five of the seven cases, the percentage of projects below zero exceeded the percentage of projects in all other ranges. However, when this was not the case, the range of percentages immediately above the acceptable range was dominating.

It seems, from both sets of district analyses, that percentage of projects falling within the specified ranges are extremely dependent on the method of calculation. In the case of the theoretical definitions for shrinkage and bulkage factors, there is a tendency for the values to convergence within a narrow range. On the other hand, the values based on the FDOT definitions are inclined to diverge to extreme values, either negative or very large.

Table 3.2. Summary of Statistical Analyses on Districts Based on FDOT Definitions

		Percent (%) of Project Within Ranges				
District	No. of Project Reviewed	≥ 0%	0 - 25%	25 - 45% Acceptable	45 - 100%	≤ 100%
1	62	44	23	8	19	6
2	97	42	20	12	14	11
3	82	37	13	12	20	18
4	58	16	19	21	29	16
5	79	39	16	24	13	8
6	19	11	21	26	32	11
7	49	33	22	20	10	14
Turnpike	22	32	18	14	14	23

3.3 Detailed Review of Select Past Projects

From the list of projects discussed in the previous section, six projects with notable deviations in planned and actual quantities were selected for further review. The detailed records for these projects were obtained from the records department of the FDOT in Tallahassee and studied closely for possible causes for the over or under runs in earthwork quantities. The projects reviewed were:

1. Project Number 86070-3414/3472/3494
2. Project Number 86095-3485
3. Project Number 26010-3523
4. Project Number 93110-3512

Table 3.3 presents a summary of the planned and actual quantities of earthwork items for each of these projects. Approximate cost values are also provided in this table based on an average bid price on earthwork of $3 per cubic yard for some pay items. In some cases, however, the actual bid price was available and is used for the corresponding computation.

Table 3.3: Review of Planned and Actual Quantities for Select Projects

Project Number	Pay Item	Planned Quantity (CY)	Actual Quantity (CY)	Bid Price ($)	Cost ($)
86070-3414	120-6	233,237	174,197	8.00	472,320
86070-3472	120-6	41,804	16,593	8.00	201,688
86070-3494	120-6	37,006	14,003	8.00	184,024
86095-3485	120-1	27,294	18,691	3.00	25,809
26010-3523	120-2-2	72,257	2,786	3.00	69,471
93110-3512	120-2-2	16,302	34,533	3.00	54,693

This exercise helps in identifying other factors, besides shrinkage and bulkage factor values, which may influence the deviations in estimates.

<u>Project Number 86070-3414/3472/3494</u>

Location: *Sunrise Boulevard and I-95, Broward County*

State Road Number: I-95

Earthwork Pay Item: 120-6 (Embankment)

Overrun/Under-runs: 59,040 CY / 25,211 CY / 23,003 CY (under-runs)

Project Engineers Reasons for Overruns/Under-runs:

(i) *Shrinkage factor of 30% was very high leading to over-estimation*

(ii) *Template error, Supplemental Agreement between FDOT and the contractor to correct template errors*

(iii) *Ramp extension over-estimated*

(iv) *Logic error - wrong scale on cross-section plans*

(v) *Incident site investigation over-estimation*

(vi) *Computational errors*

<u>Project Number 86095-3485</u>

Location: State Road 7 from State Road 84 to SW 20th Street

State Road Number: State Road 7

Earthwork Pay Item: 120-1 (Regular Excavation)

Overruns/Under-runs: 8,603 CY (under-runs)

Project Engineers Reasons for Overruns/Under-runs:

(i) *Supplemental Agreements reduced the earthwork item by 1152 CY.*

(ii) *No muck was found at the site*

(iii) *Shrinkage factor (30%) was over-estimated*

<u>Project Number 26010-3523</u>

Location: State Road 25, Alachua County

State Road Number: State Road 25

Overruns/Under-runs: 69,471 CY (under-runs)

Earthwork Pay Item: 120-2-2 (Borrow Excavation, truck measure)

Project Engineers Reasons for Overruns/Under-runs:

(i) *Local regular excavation of 18,013 CY was sufficient and only 2,786 CY additional borrow material was needed.*

(ii) *Miscalculation at the estimation time*

<u>Project Number 93110-3512</u>

Location: State Road 89, Palm Beach County

State Road Number: State Road 80

Earthwork Pay Item: 120-2-2 (Borrow Excavation, truck measure)

Overruns/Under-runs: 18,231 CY (overrun)

Project Engineers Reasons for Overruns/Under-runs:

(i) *Incorrect estimate of borrow materials based on design fill*

(ii) *Truck capacities are a source of error.*

It is evident from the discussion of the project files reviewed above that, in addition to incorrect estimation due to the values adopted for shrinkage and bulkage factors, there are several other factors that may influence the earthwork volumes. Specifically, factors such as *template or computational errors*, *design alterations due to supplemental agreements* and *incorrect interpretation of plans* may contribute to these errors but are very hard to predict. In this spirit, the next section is devoted to obtaining feedback from FDOT engineering personnel on possible causes for deviations in planned and actual final earthwork quantities. This feedback is gathered in the form of a detailed questionnaire.

3.4 Responses to Questionnaire

In order to gather more information, a questionnaire was sent to the District Construction, Geotechnical, Materials and Final Estimates Engineers for each district. The questionnaire is provided in Appendix B and consists of four main questions. The four issues addressed by this questionnaire were:

- To provide a list of projects with major differences or variations of planned and final earthwork quantities over the past five years.
- The input on the possible causes for the inaccuracies in these estimates.
- Any projects with exceptionally good estimates of earthwork quantities.
- Projects with significant problems due to earthwork disputes or claims.

Unfortunately, only three districts, Districts 1, 4 and 6, provided responses to this questionnaire. A summary of the responses from the FDOT personnel from these three districts to the first question in the survey is provided in Table 3.4.

Table 3.4: Responses to Question 1 on Survey

District	Project Number	Location	Earthwork Pay Item
1	16180-3514	US 27 (Haines City to I-4)	120-2-2 Regular Excavation (Truck)
1	16030-3557	US 17 (Ave. G N.W. to Ave. T N.W., Winter Haven)	120-2-2 Borrow Excavation
1	03075-3406	I-75 Rest Area (M.P. 63)	120-6 / 120-4
1	07520-3607	Keri Road	120-2-2 (overrun - 22%)
1	12040-3519	Whiskey Creek	120-2-2 (overrun - 100%)
1	07030-3517	Clewiston	120-2-2 (overrun - 100%)
1	12060-3524	N. Ft. Myers	120-2-2 (overrun - 55%)
1	03010-3531	E. US 41	120-2-2 (overrun - 100%)
4	93160-3505	US 27 Palm Beach County	120-4 Subsoil Excavation
4	93160-3517	US 27 Palm Beach County	120-4 Subsoil Excavation
4	86190-3516	SR 823 Broward County	120-4 Subsoil Excavation
6	87003-3521	Airport Ramp Connector	120-2-2 Borrow Excavation
6	97871-3321	Florida Turnpike	120-2-2 Borrow Excavation
6	87001-3531	SR 94 North Kendall Drive	120-1 Regular Excavation 120-6 Embankment
6	90020-3558	Boco Chica Air Station Bridge Replacement Key West	120-4 Excavation Subsoil 120-6 Embankment
6	87110-3506	SR 90 / US 41 Tamiami Trail	120-6 Embankment

District 1 experienced a large number of overruns varying from 22% to 100%, possibly due to inaccurate shrinkage and bulkage factors. Subsoil excavation does not seem to be emphasized in District 4. District 6 has problems in their excavation and embankment pay items, also a possible result of inaccurate shrinkage and bulkage factors.

The response to question 2 was intended for exploring possible explanations for the variations in the original estimates and final quantities. The overwhelming response from the engineers was to emphasize improper cross-sections and lack of emphasis on earthwork at the level of designers. In particular, the response from District 1 was interesting and is listed below:

- No emphasis on cross-sections. Saved money on engineering up front.
- No emphasis on soil exploration. Muck areas not identified up front causing large overruns.
- Design consultant scope did not have emphasis on earthwork.
- No original cross-sections taken. Contractor did not establish vertical control.
- Most discrepancies come from lack of Engineering by design-construction-and contractor. Original and final cross-sections necessary for accurate earthwork determination.

The comments from District 4 stressed the need for more geotechnical subsoil investigation. It was noted that muck is pre-dominant in many areas of District 4, resulting in more excavations and an increased need for borrow fill. The project-specific responses from District 4 are summarized below:

- Project No. 93160-3505: Added subsoil right of the baseline, where the 2:1 slope and the top of muck intersect vertically, also actual depth of the muck was greater than the plan. (overrun 35,335 CY, original plan quantity 344,394 CY)

- Project No. 93160-3517: Overrun due to significant differences in the original ground surface and a deeper muck stratum. (overrun 32,348 CY, original plan quantity 150,452 CY)
- Project No. 86190-3516: Overrun due to significant differences in the original ground surface and a deeper muck stratum. (overrun 70,756 CY, original plan quantity 151,640 CY)

District 6 personnel noted they had encountered poor and unsuitable fill material at a number of locations and stressed the need for a more in-depth subsoil exploration. The following are some remarks reported by District 6:

- Project No. 87003-3521: Existing material on the project was unsuitable for use as select fill in construction of the Reinforced Earth wall.
- Project No. 87001-3531: On the north side of Kendall Drive, large limestone boulders were discovered lying over a 3' x 6' open trench. Boulders had to be removed from trench location and new backfill was required.

The responses to the third question prove earthwork can be estimated within reason, resulting in significant savings in material and administrative costs. However, the responses to question 4 on the projects with claims or disputes shows the degree to which inaccurate estimating of earthwork can result in costly losses.

A summary of projects provided by Districts 1, 4, and 6 with large claims and disputes are shown in Table 3.5.

Table 3.5. Examples of Projects with Claims as a Result of Earthwork

Project Number	Location	Dispute/Claim Amount
16180-3514	US 27 (Haines City to I-4)	$16,170
06075-3406	I-75 Rest Area (M.P. 63)	$400,000
03050-3517	SR 951 Surcharge Job	$2,500,000
12000-3609	Six Mile Cypress (Bike Path)	$12,280
87170-3529	Sunny Isle Blvd.	$277,000

3.5 Conclusion

This chapter discussed the effect of different factors including the shrinkage and bulkage factors, based upon the historical data obtained from FDOT database. It also presented a summary of the feedback obtained from the district engineers on possible causes for over- and under-runs in earthwork calculations. A cost analysis of the financial repercussions of the differences in earthwork quantities was also included.

CHAPTER 4

FIELD AND LABORATORY TESTING

4.1 Introductory Remarks

This chapter deals with the detailed field and laboratory investigations of the selected field projects. Initial project selection was based on a number of factors, such as:

- time of construction within the scheduled research frame,
- presence of planned retention ponds as potential sources of embankment fill for the project, and
- variation of soil classifications available within the planned excavations to broaden the scope of this study as much as possible.

The details of the seven field projects selected for detailed study are summarized below:

(i) State Road 5A (Nova Road) in Brevard County, (79190-35101-4),
(ii) Interstate 4 (State Road 434 to Lake Mary Blvd.) in Seminole County (77160-3601),
(iii) State Road 44 (Wildwood) in Marion County, (18070-3517),
(iv) State Road 312 (St. Augustine) in St. Johns County (78002-3510),
(v) State Road 5 (West Palm Beach) in St. Lucie County (94010-3533),
(vi) State Road 70 (Bradenton) in Manatee County, (13160-3512),
(vii) State Road 50 (Brooksville) in Hernando County, (08070-3502)

Investigations of the seven projects were completed in mid-November of 1998. The detailed results of the field investigations and laboratory testing of samples collected are discussed on a project-by-project basis in this report. The following sections describe the various steps in monitoring the densities of the soil during different stages of earthwork and the field tests performed. In addition to direct determination of density using Nuclear Density tests, CPT and Dilatometer tests were also performed at the borrow pits and a discussion of the correlation between the readings from these tests and the in situ density is also presented. A new unit box test is also introduced to model a scaled truck as an alternative to actual loose density measurement in the trucks.

4.2 Soil Tracking Program

The soil tracking program established to study the volumetric changes of the soil, as it is moved from the borrow pit to the job site, is discussed below. Figure 4.1 depicts the three stages of this program wherein a volume of soil is tracked from its in-place pit location to its final compacted state. Assuming no significant volumetric losses of soil during transport, dry densities of the soil at each stage may be determined and used in calculating the shrinkage and bulkage factors. These densities are used to represent the overall volumetric change of the soil.

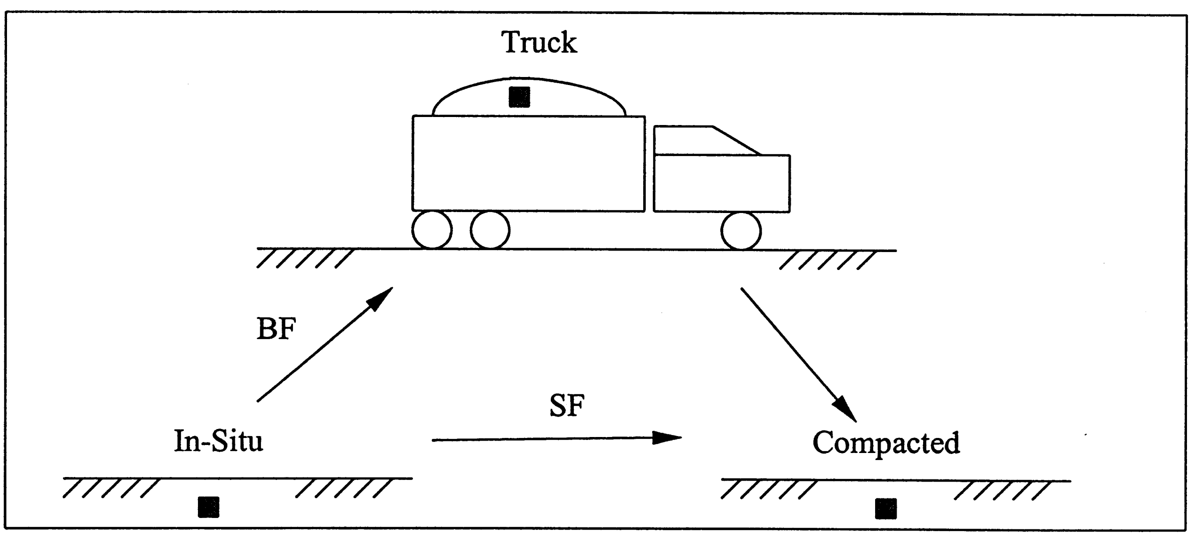

Figure 4.1 Soil Tracking Program

4.3 Field and Laboratory Tests Performed

This section discusses some of the field and laboratory tests performed on the soil in order to determine the unit weight and moisture content. These properties are directly available from some of the tests, such as nuclear gauge, and have to be indirectly computed from other tests such as the Cone Penetrometer and the Dilatometer. Sieve analysis and maximum/minimum density tests were performed to determine other parameters used in the indirect computations.

4.3.1 Nuclear Density and Speedy Moisture Content Tests

The nuclear density gauge device, shown in Figure 4.2, was used to obtain the density of in-situ soils in the excavation ponds, in haul trucks loaded with the same soil at the point of loading, and at the site where the soil was compacted. It should be noted that the drive sleeve test and the nuclear gauge test were conducted at the same location allowing for a direct comparison of the two methods.

The dry unit weight was then calculated using the moisture content values determined using a Speedy Moisture Tester.

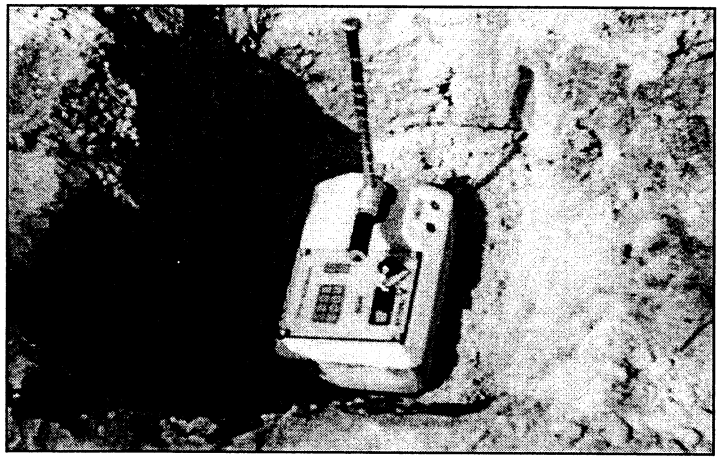

Figure 4.2 Nuclear Density Test

4.3.2 Cone Penetration Tests

Cone Penetration tests were performed at several locations of the borrow pits where the suitable borrow material was found to be at greater depths than the range of the nuclear density equipment. District Five's cone rig was used to perform several cone soundings at both projects and the results are summarized in the next chapter. The task of correlating the cone tip resistance readings to the in-situ densities through the relative density and the vertical effective stresses at a certain depth, was based upon certain correlation from literature and is described in this section. An iterative procedure was developed and implemented within a computer program.

An indirect relationship was obtained between the cone tip resistance and in-situ densities from work by Baldi *et al.* (1986). Figure 4.3 shows this correlation for normally consolidated, uncemented, and non-aged quartz sands where K_o = 0.45. Robertson and Campanella (1983) suggest that the horizontal effective stress (σ'_{ho}) should be used instead of the vertical effective stress (σ'_{vo}) for overconsolidated or aged sands. According to the authors, this relationship should be used merely as a guide to in-situ relative density, but it can be expected to yield good results for clean, normally consolidated, moderately compressible, quartz sands. Visual classifications of the grain characteristics would significantly improve the choice of relative density correlation.

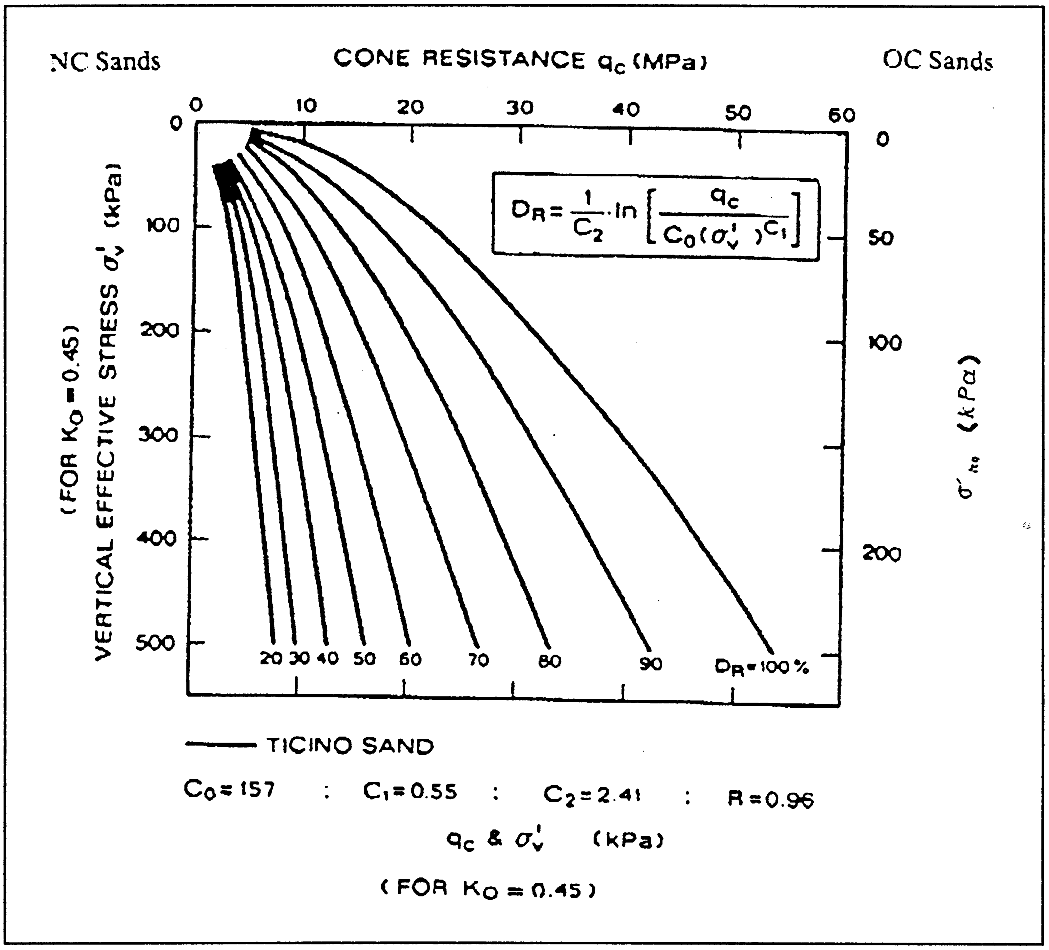

Figure 4.3. Correlation between D_r and Q_c (Baldi *et al.*, 1986)

The mathematical relationship proposed by Baldi *et al.* (1986) can be expressed as

$$D_r = \frac{1}{C_2} \ln \left[\frac{Q_c}{C_0 (\sigma'_{vo})^{C_1}} \right] \tag{4.1}$$

where, for Ticino Sands, $C_0 = 157$, $C_1 = 0.55$, $C_2 = 2.41$, and Q_c and σ'_{vo} are expressed in kPa. The regression correlation (R) for the equation is 0.96. The obtained relative density is once again corrected for field measurement and Q_c using the factor K_q, given by the following expression:

$$K_q = 1 + \frac{0.2(D_r - 30)}{60} \tag{4.2}$$

The correlation obtained using Baldi *et al.* (1986) allows for the estimation of the in-situ relative density and is used within an iterative method to obtain the in-situ dry density.

Iterative Procedure

The first step in the iterative procedure is to assume an arbitrary initial in-situ dry density. It is set equal to the minimum dry density to start the iterative process. Based on this in-situ dry density, the relative density is calculated from the following relationship:

$$D_r = \left[\frac{\gamma_d - \gamma_{d(\min)}}{\gamma_{d(\max)} - \gamma_{d(\min)}}\right]\left[\frac{\gamma_{d(\max)}}{\gamma_d}\right] \tag{4.3}$$

where $\gamma_{d(max)}$ and $\gamma_{d(min)}$ represent the dry density of the soil in the densest and loosest condition.. The maximum and minimum dry densities are obtained using either maximum/minimum density tests in the laboratory or from correlation with the coefficient of uniformity obtained from sieve analysis. These relations only apply to sandy soils.

The theoretical maximum and minimum densities of a soil were obtained in accordance with test procedures from ASTM D 2049-69 and were used in this research as a reference for the range of maximum possible shrinkage or bulkage of the soil. Both the maximum and minimum tests involved the use of a steel Proctor mold, 6 in. diameter and 6 in. high, with a vibrating table used to find the maximum density. It is important to note that the validity of these tests has been under continual scrutiny. Other researchers have cited several disadvantages with the procedure including high acceleration of the table and segregation of particles due to coarse sand and gravel. In most cases, it was found that the compacting procedures are sensitive to the gradation and percentage of fines present in the material. Therefore, the gradation of the soil will be an important soil characteristic for this research.

Johnston (1973) found that an empirical relationship can be established between the coefficient of uniformity of a soil and its corresponding maximum and minimum dry densities. The coefficient of uniformity may be defined as

$$C_u = \frac{D_{60}}{D_{10}} \tag{4.4}$$

The correlation is based on (1) the assumption that cohesionless soil are a function of their grain-size distribution and specific gravity and (2) test results on subangular to rounded granular soils having all material retained on the U.S. 200 sieve and specific gravity from 2.65 to 2.89. Figure 4.4 displays the maximum and minimum density relationships proposed by Johnston (1973) and may be expressed mathematically as follows:

$$\tilde{\gamma}_{d(\max)} = 31.5\log(C_u) + 92.5 \tag{4.5}$$

$$\tilde{\gamma}_{d(\min)} = 31.5\log(C_u) + 70.5 \tag{4.6}$$

where $\tilde{\gamma}_{d(\max)}$ and $\tilde{\gamma}_{d(\min)}$ are normalized at a specific gravity of 2.65.

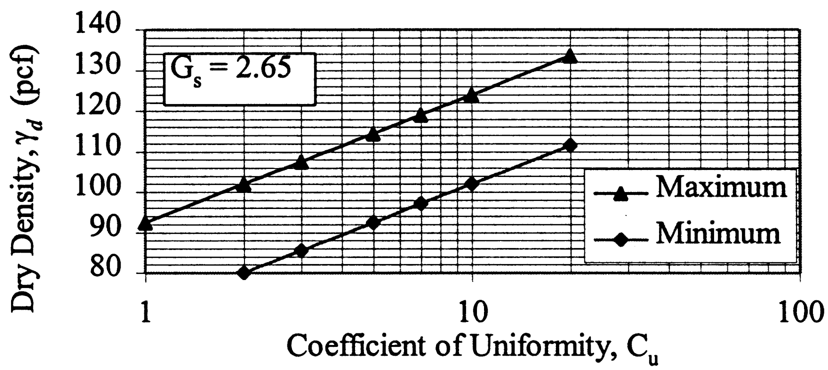

Figure 4.4 Plot of Maximum and Minimum Densities versus Coefficient of Uniformity at Specific Gravity, $G_s = 2.65$ (Johnston , 1973)

The second step of this procedure is to calculate the vertical effective stress based on the present depth of penetration and its relation to the groundwater table. For this process, the soil is considered to be either completely saturated below the groundwater table or partially saturated above the groundwater table. For the completely saturated condition, the vertical effective stress can be expressed as,

$$\sigma'_{vo} = \frac{\gamma_d z (G_s - 1)}{G_s} \tag{4.7}$$

where G_s is the specific gravity of the soil determined from the laboratory test and z is the depth or current cone penetration depth. For the partially saturated condition, the vertical effective stress is,

$$\sigma'_{vo} = \gamma_d (1 + \omega) z \tag{4.8}$$

Equation (4.7) or (4.8) are used to calculate the vertical effective stress of the soil, with the moisture content, ω, depending on the moisture content obtained from the samples used in the maximum and minimum density tests in the laboratory.

The third step in the iterative procedure uses the equation developed by Baldi *et al.* (1986) to estimate the in-situ relative density. The relative density from the first step of the procedure is used to calculate the cone tip correction from Equation (4.2). Equation (4.1) is then used to calculate the relative density.

In the final step of the iterative procedure, the relative density computed from the above step is compared with the value computed in the first step until the two values are within a small tolerance. The converged value is the best estimate for the in-situ density under the constraints of known cone tip resistance, depth, minimum and maximum density. Sensitivity tests on the two governing equations have indicated that the choice of moisture content does not significantly affect the results obtain from the iterative process. An increase of moisture content from 3% to 20 % only caused less than a 1% change in the dry density. A computer program has been written, in Microsoft Excel and Visual Basic, for this iterative procedure and is included in Appendix A.

4.3.3 Dilatometer Soundings

The second field testing method for determining the in-situ density is the flat-blade Dilatometer. District Five personnel were once again utilized for conducting dilatometer soundings at same locations as the CPTs on all field projects. This section details the relationship between the dilatometer readings and the dry unit weight. The results of this process are summarized in the next chapter.

The relationship between dilatometer soundings and in-situ density is the direct solution used by the 1988 Dilatometer Manual which is also used by the FDOT for reporting the results of this field test. This relationship comes from Marchetti and Crapps (1981) based on an investigation of laboratory data from 10 well-documented sites in Italy. Figure 4 shows the relationship between the dilatometer modulus, E_D in BARS, the material index, I_D , the relative density, and the approximate in-situ density in tonne/m^2 for clays, silts, and sands. The dilatometer modulus and material index for a flat dilatometer are approximated as

$$E_D = 34.7(P_1 - P_0)$$
$$I_D = \frac{P_1 - P_0}{P_0 - u_0} \tag{4.9}$$

where P_0 and P_1 are the A and B dilatometer readings corrected for membrane stiffness and u_0 is the equilibrium pore pressure, often assumed to be hydrostatic.

The equations of the lines from Figure 4.5 may be expressed in a general form as follows:

$$E_D = 10^{(n + m \log I_D)} \tag{4.10}$$

where *m* and *n* are summarized in Table 4.1.

Table 4.1: *m* and *n* Values for Dilatometer Equation

LINE	*m*	*n*
A	0.585	1.737
B	0.621	2.013
C	0.657	2.289
D	0.694	2.564

The dilatometer data from the field projects is provided in Appendix E. These results were used to determine the in-situ density in the pit. The shrinkage and bulkage factors were then computed using this density as the density of the excavated volume and the measured density in the truck and the compacted fill. The resulting values of the factors are summarized in the next chapter for each project.

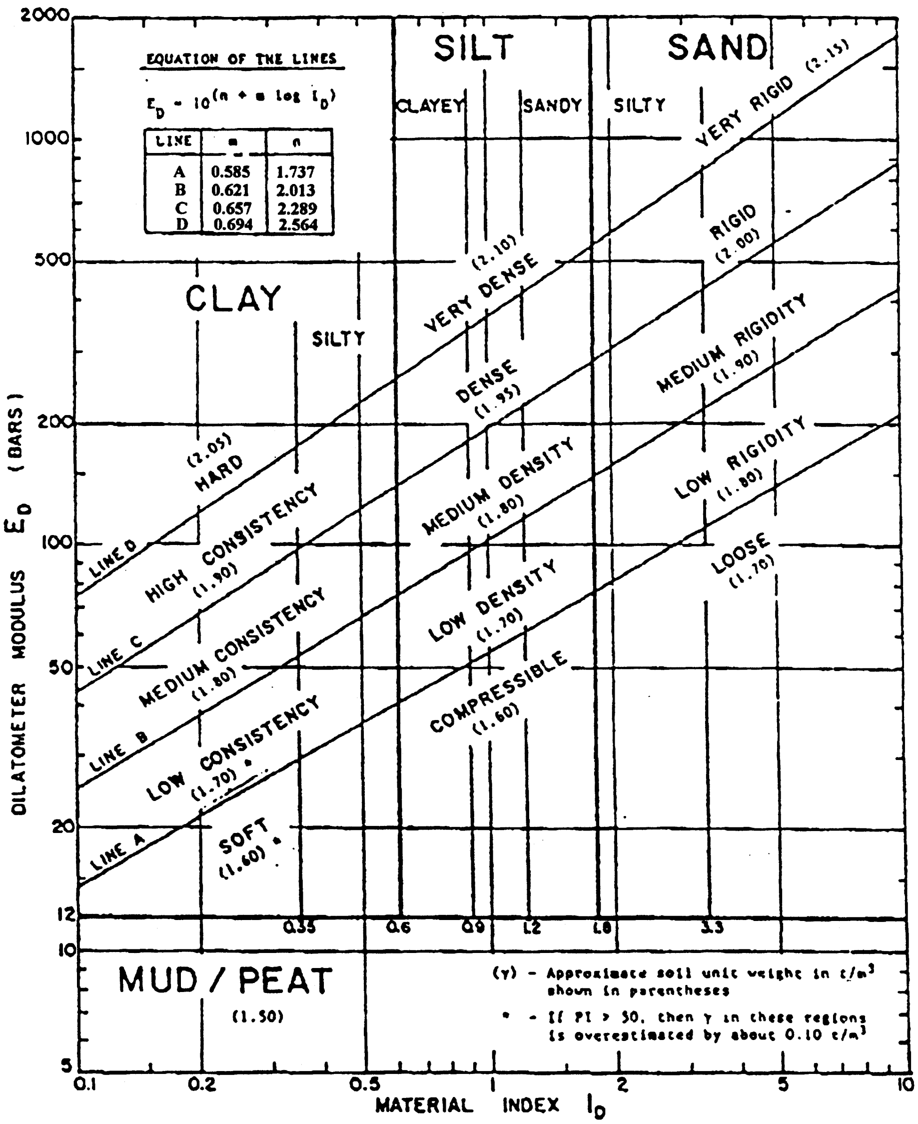

Figure 4.5 Chart for Relating Unit Weights and Dilatometer Modulus (Marchetti and Crapps, 1981)

4.3.4 Unit Box Test

A field testing method used for determining dry densities during the truck stage of the soil tracking program is the Unit Box Test. Boxes with a volume of exactly one cubic foot each were constructed at the University of Central Florida. The unit volume (1 ft^3) box test, shown in Figure 4.6, was used to determine weight densities of soil under loose conditions in any moisture condition (dry or wet). Due to local densification of soils by other tests, this test was used to model the looseness of the soil as it was transported in a truck from the in-situ state to the compacted state. During the fieldwork, the assumption was made that the actual moisture content obtained using the Speedy Moisture Test was a sufficient indicator of the moisture in the soil. These boxes were taken to the various sites to be filled with the soil, and then weighed. Samples were also taken to obtain moisture contents for the soils tested. This method is used to simulate the truck dry densities while the soil is in its loosest state.

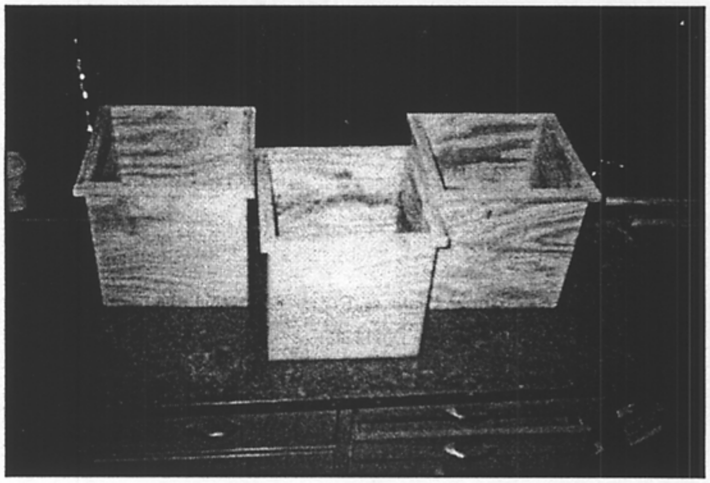

Figure 4.6. Unit Volume Boxes for Loose Density Measurement

4.3.5 Drive Sleeve Test

The drive sleeve test consisted of a 1.5 lb steel spoon attached to a three foot steel rod. The spoon and rod were driven into the ground, a sample was extracted, and then weighed to determine weight densities of the in-situ soil. These tests were conducted at or near the same locations as the Nuclear Density Tests, Cone Penetration Test, and Dilatometer Soundings.

4.4 Conclusion

This chapter discusses the various field and laboratory tests used to determine the field weight densities for calculating the shrinkage and bulkage factors. A number of direct and indirect methods were used and three field projects were monitored using the soil tracking program. The next chapter will discuss the results from the various tests for each of the field project and the computed factors.

CHAPTER 5

ANALYSIS OF DATA FROM FIELD PROJECTS

5.1 Introductory Remarks

The results of the field tests from selected field projects are analyzed and reduced in this chapter. Several field tests are used for determining the in-place pit density. The loose truck density is found using the unit box and the final compacted density is found from the project records. The average dry densities obtained for the three stages of earthwork in the soil-tracking program from the different field tests are then used to determine the shrinkage and bulkage factors.

5.2 Field Project 1 – Volusia County (79190-3510)

This project was described in detail above and the investigation of this project is complete. During the period covered by this report, two additional tests were conducted, namely, the unit box test for the truck density and the Standard Proctor test for the final compacted density. Table 5.1 describes the various laboratory and field tests performed on the soil at different excavation classification stages.

Table 5.1 Summary of Laboratory and Field Tests for Field Project 1

Test Performed	Excavation Classification		
	In Situ	Truck	Compacted
Nuclear Density Test	✓	✓	✓
Standard Proctor			✓
Maximum/Minimum Test	✓		
Sieve Analysis	✓		
Unit Box		✓	
Cone Penetration	✓		
Dilatometer	✓		

Laboratory Investigations

The portion of the retention pond (pit) tested for this investigation consisted of gray/tan sand with shell classified as A-3 soil with 2 to 7% passing the 200 sieve. Two Standard Proctor Tests were performed at the District Five laboratory on the compacted soil yielding values of 16.97 kN/m^3 and 17.12 kN/m^3 with an average density of 17.04 kN/m^3 at 12.5 % optimum moisture content. Specific Gravity test on this soil provided an average value of 2.75. The results of the Min/Max tests performed at the Materials Testing Laboratory in Gainesville on this soil are described along with the CPT results in the next section.

Field Investigations

Cone Penetration Tests (CPT) and Dilatometer Soundings were conducted by District Five geotechnical personnel at four test holes in the retention pond. Nuclear density, speedy moisture and the unit box tests were performed on relatively, undisturbed soils at an average depth of twelve feet below grade. The results of all the tests are summarized below and used to compute average values of shrinkage and bulkage factors from this project. The dry unit weights and moisture contents from each location are shown and averaged in Table 5.2.

Table 5.2. Dry Densities From Using Nuclear/Speedy Tests

Test #	Depth From Grade - m (ft)	γ_d - kN/m^3 (pcf)	ω (%)
I - 1	3.66 (12)	14.88 (94.7)	20.4
I - 2	1.52 (5)	14.23 (90.6)	13.6
I - 3	3.66 (12)	14.34 (91.3)	11.4
I - 4	3.66 (12)	14.33 (91.2)	10.8
	Average =	14.44 (91.95)	14.1

Two nuclear density tests were conducted in the bed of a truck to obtain loose (Truck) densities. The resulting densities and moisture contents are shown and averaged in Table 5.3.

Table 5.3 Truck Densities Using Nuclear/Speedy Tests

Test #	γ_d - kN/m^3 (pcf)	ω (%)
T - 1	14.03 (89.3)	17.5
T - 2	14.31 (91.1)	17.2
Average =	14.17 (90.2)	17.4

These truck density values were considered to be on the higher side, which may be due to local densification caused by the placement of the nuclear device. An alternative test for determining the loose density simulating the state of soil in the truck was developed using a unit box.

Unit Box Tests were also performed on the soil excavated from this field site. The average dry density obtained from this test was 11.9 kN/m^3 (75.7 pcf) and the moisture content was found to be 10.3 %. These values are substantially lower than those obtained from the Nuclear Density tests and are better estimates of the actual soil condition.

Lastly, the field contractor provided the compacted densities and moisture contents to the researchers. Nuclear density and speedy moisture tests were performed at thirteen locations in the compacted fill and are summarized in Table 5.4. The average compacted density of 17.34 kN/m^3 (110.4 pcf) was within the allowable range (100-103%) around the maximum compacted density of 17.04 kN/m^3 (108.5 pcf) obtained from the Standard Proctor test performed in the laboratory.

Table 5.4 Compacted Dry Densities Using Nuclear/Speedy Tests

Test #	γ_d - kN/m^3 (pcf)	ω (%)	Test #	γ_d - kN/m^3 (pcf)	ω (%)
C - 1	17.47 (111.2)	12.8	C - 8	17.22 (109.6)	12.5
C - 2	17.42 (110.9)	12.6	C - 9	17.15 (109.2)	13.5
C - 3	17.44 (111.0)	13.6	C - 10	17.09 (108.8)	13.2
C - 4	17.50 (111.4)	12.5	C - 11	17.19 (109.4)	13.1
C - 5	17.44 (111.0)	12.4	C - 12	17.48 (111.3)	13.1
C - 6	17.47 (111.2)	12.1	C - 13	17.47 (111.2)	12.8
C - 7	17.15 (109.2)	12.4			

A summary of the in-situ dry densities based upon the CPT data is tabulated in Table 5.5. The average values of the results from CPT performed based on max\min density data is 16.64 kN/m^3 (106.0 pcf) and based on the correlation with C_u is 19.5 kN/m^3 (124.1 pcf).

Table 5.5 Weighted Average In-Situ Dry Densities Using Cone Penetration Tests

CPT #	γ_d - kN/m^3 (pcf) - Max/Min Based	γ_d - kN/m^3 (pcf) - C_u Based	ω (%)
1	16.94 (107.8)	19.64 (125.0)	14
2	17.25 (109.8)	19.83 (126.2)	14
3	16.77 (106.8)	19.62 (124.9)	14
4	15.62 (99.4)	18.89 (120.3)	14

In-situ dry densities were also obtained from dilatometer soundings. These values are shown in Table 5.6 with an average value of 17.47 kN/m^3 (111.2 pcf) for assumed moisture content of 14% for all soundings.

Table 5.6 In-Situ Dry Densities Using Dilatometer Soundings

Sounding #	γ_d - kN/m^3 (pcf)	ω (%)
1	16.61 (105.7)	14
2	16.96 (107.9)	14
3	17.31 (110.2)	14
4	19.00 (120.9)	14

The results obtained in each excavation classification were averaged in Table 5.7.

Table 5.7 Summary of Average Dry Densities for Field Project 1

Test Performed	Average Dry Density - kN/m^3 (pcf)		
	In Situ	Truck	Compacted
Nuclear Density Test	14.44 (91.95)	14.17 (90.2)*	17.34 (110.4)
Standard Proctor			17.04 (108.5)*
Unit Box		11.89 (75.7)	
CPT	16.64 (106.0)		
Dilatometer	17.47 (111.2)		
AVERAGE	**16.18 (103.0)**	**11.89 (75.7)**	**17.34 (110.4)**

* - Not Used in Averaging of Values

Based upon the average values from Table 5.7, the average shrinkage factor is found to be 6.7 % and average bulkage factor is 36 % for this project. The bulkage factor is higher the 25% value currently used while the shrinkage factor is well below the Department's 30 - 35% range. It is important to note that the construction debris found at the site may have caused large cone resistance or erroneous dilatometer readings leading to higher than normal in-situ dry densities.

5.3 Field Project 2 – Seminole County (77160-3601)

This project site consisted of nine retention ponds as potential borrow pits for the Interstate I-4 expansion project at Lake Mary Boulevard, in Seminole County. Three retention ponds were selected for further field investigation, and are referred to on the I-4 project plans as Retention Ponds "A", "J", and "F". Laboratory and field tests were conducted and the results are presented in this section. Table 5.8 describes the various tests performed on the soil at different excavation classification stages for each pond.

Table 5.8 Summary of Laboratory and Field Tests at I-4 Project

Test Performed	Excavation Classification								
	In Situ			Truck			Compacted		
Pond	A	F	J	A	F	J	A	F	J
Nuclear Density Test	✓	✓	✓			✓	✓		✓
Standard Proctor							✓	✓	✓
Minimum/Maximum Test	✓	✓	✓						
Sieve Analysis	✓	✓	✓						
Unit Box Test				✓	✓	✓			
Cone Penetration Tests	✓	✓	✓						
Dilatometer	✓	✓	✓						

Laboratory Investigations

The soil encountered at Pond "A" was a light tan to tan sand (A-3) with 6% passing the 200 sieve, the soil at Pond "J" was an light gray to tan fine sand classified as an A-3 material (2.5 % passing 200 sieve), and the soil at Pond "F" was a light tan sand classified as A-3 with 4% passing the 200 sieve. Results of the other laboratory data for this project are presented in Mehta (1997). The results of the maximum/minimum density, Standard Proctor tests and specific gravity tests are summarized in Table 5.9 below and were subsequently used in the iterative procedure to correlate CPT readings.

Table 5.9 Laboratory Results for I-4 Borrow Pits

	Minimum/Maximum Density Test			Standard Proctor Test		
Sample from CPT Locations	$\gamma_{d(max)}$ pcf	$\gamma_{d(min)}$ pcf	ω (%)	$\gamma_{d\,(max)}$ kN/m^3 (pcf)	OMC (%)	Specific Gravity, G_s
A - 1	98.26	66.57	12	16.65 (106.0)	13 %	2.67
A - 2	98.26	66.57	12	16.65 (106.0)	13 %	2.67
F - 1	101.14	66.77	12	15.87 (101.0)	14 %	2.63
J - 1	99.79	59.99	13.65	15.74 (100.2)	16.5 %	2.66
J - 2	100.75	62.80	13.75	15.81 (100.6)	14.3 %	2.62

Field Investigations

Cone Penetration Tests and Dilatometer Soundings were conducted by District 5 geotechnical personnel at the three retention ponds. The depths of penetration ranged from 5 to 6.25 m.

A soil tracking program using Nuclear density tests and Speedy moisture tests, similar to the one performed for the first project, was conducted at the Pond "J" as well as in haul trucks from this borrow pit. The results of the Nuclear density tests are tabulated below with the associated excavation classification. The average in-situ dry density is 14.84 kN/m^3 (94.5 pcf), the average truck dry density is 13.18 kN/m^3 (83.9 pcf) and the average compacted dry density is 16.13 kN/m^3 (102.7 pcf).

Table 5.10 Field Results Obtained at Pond "J" Using Nuclear Density Test

Sample Number	Excavation Classification	γ kN/m^3(pcf)	ω (%)	γ_d kN/m^3(pcf)
I-1	In-Situ	15.7 (100.3)	3.7	15.2 (96.7)
I-2	In-Situ	15.2 (96.9)	5.5	14.4 (91.8)
I-3	In-Situ	15.6 (99.5)	4.8	14.9 (94.9)
T-1	Truck	13.9 (88.9)	4.3	13.4 (85.2)
T-2	Truck	13.57 (86.4)	4.5	13.0 (82.7)
C-1	Compacted	17.0 (108.2)	5.2	16.2 (102.9)
C-2	Compacted	17.1 (108.8)	5.8	16.1 (102.8)
C-3	Compacted	17.2 (109.3)	6.0	16.2 (103.1)
C-4	Compacted	16.9 (108.1)	5.5	16.1 (102.5)
C-5	Compacted	16.8 (107.4)	5.8	15.9 (101.5)
C-6	Compacted	17.0 (108.3)	6.4	16.0 (101.8)
C-7	Compacted	17.7 (112.5)	6.9	16.5 (105.2)
C-8	Compacted	17.4 (111.1)	7.1	16.3 (103.7)
C-9	Compacted	17.3 (110.4)	8.7	15.9 (101.6)
C-10	Compacted	17.4 (110.9)	8.3	16.1 (102.4)
C-11	Compacted	17.1 (108.6)	6.5	16.0 (102.0)
C-12	Compacted	17.2 (109.5)	6.8	16.1 (102.5)

Unit Box Tests were also performed to obtain loose (truck measure) densities at each Pond. The results of these tests are provided in Table 5.11. To this point, the dry densities from this test for Ponds "A" and "F" are the only indication of the bulking effect of these soils.

Table 5.11 Unit Box Test Results for I - 4 Project

POND	γ kN/m^3((pcf)	ω (%)	γ_d kN/m^3((pcf)
A	12.8 (81.68)	3.69	12.4 (78.8)
F	12.5 (79.55)	3.53	12.1 (76.8)
J	13.1 (83.8)	0	13.2 (83.8)

Each of the retention ponds in Field Project 2 has associated maximum/minimum densities that were determined in the laboratory as shown in Table 5.9. The iterative program assumes a moisture content value in order to determine the in-situ densities based upon CPT cone resistance values obtained from the three ponds. The tabulated data for the method developed from the Baldi *et al.* (1986) equation using the CPT results from Field Project 2 are shown in Appendix D. A table of the weighted average in-situ dry densities calculated based on the two methods is presented below (Table 5.12):

Table 5.12 Weighted Average In-Situ Dry Densities Using CPT's

Pond - Sample	γ_d - kN/m^3 (pcf) - Max/Min Based	γ_d - kN/m^3 (pcf) - C_u Based	ω (%)
A - 1	14.26 (90.8)	15.61 (99.4)	12
A - 2	13.87 (88.3)	15.52 (98.8)	12
F - 1	13.05 (83.1)	14.47 (92.1)	12
J - 1	12.74 (81.1)	14.22 (90.5)	13.65
J - 2	12.48 (79.4)	13.62 (86.7)	13.75

The average dry density based on the C_u correlation, for Pond A is 15.57 kN/m^3 (99.1 pcf), Pond F is 14.47 kN/m^3 (92.1 pcf), and Pond J is 13.92 kN/m^3 (88.6 pcf). The dry densities shown above display a better match between the two methods and provide for favorable foundation for the further data analysis.

In-situ dry densities were also obtained from dilatometer soundings at each pond. These values are shown in Table 5.13 with an average value of 17.52 kN/m^3 (111.5 pcf) at Pond "A", 15.79 kN/m^3 (100.5 pcf) at Pond "F", and 17.08 kN/m^3 (108.7 pcf) at Pond "J".

Table 5.13 Average In-Situ Dry Densities Using Dilatometer Soundings

Pond Sounding #	γ_d kN/m^3(pcf)	ω (%)
A -1	17.5 (111.5)	12
A -2	17.5 (111.6)	12
F - 1	15.8 (100.5)	12
J - 1	17.4 (110.5)	13.65
J - 2	16.8 (106.8)	13.75

The results obtained in each excavation classification were averaged and are shown in Table 5.14 below.

Table 5.14 Summary of Average Dry Densities for Project 2

Test Performed	Average Dry Density - kN/m³ (pcf)								
	In Situ			Truck			Compacted		
Pond	A	F	J	A	F	J	A	F	J
Nuclear Density	15.66 (99.7)	16.13 (102.7)	14.84 (94.5)	NA	NA	13.18 (83.9)	16.35 (104.1)	NA	16.13 (102.7)
Standard Proctor							16.65 (106.0)*	15.87 (101.0)	15.77 (100.4)*
Drive Sleeve Test	15.57 (99.1)	16.05 (102.2)	16.40 (104.4)						
Unit Box				12.38 (78.8)	12.06 (76.8)	13.16 (83.8)			
CPT - Max\Min	14.11 (89.8)	13.06 (83.1)	12.76 (81.2)						
CPT - C_u	15.71 (100.0)	14.50 (92.3)	14.05 (89.4)						
Dilatometer	17.52 (111.5)	15.79 (100.5)	17.08 (108.7)						
AVERAGE	**15.71 (100.0)**	**15.11 (96.16)**	**15.02 (96.64)**	**12.38 (78.8)**	**12.06 (76.7)**	**13.17 (83.8)**	**16.35 (104.0)**	**15.87 (101.0)**	**16.13 (102.6)**

* - Not Used in Averaging of Values

It was found that compacted densities are within the Department's 100-103% compaction requirements and are used as the expected compacted density when no field test has been conducted. The shrinkage and bulkage factors were computed for each pond and are also shown below.

Table 5.15 Preliminary Shrinkage and Bulkage Factors

Pond	SF (%)	BF (%)
A	3.9	26.9
F	4.8	25.3
J	6.9	14.0

The average values of shrinkage and bulkage factors for this project are found to be 5.2% and 22.1% respectively. It is interesting to note that, based on the study of this field project, the calculated shrinkage factors are well below the Department's established 30 - 35 % range, while the calculated bulkage factors are close to the 25 % value currently being used.

5.4 Field Project 3 – Marion County (18070-3517)

The field project under investigation is State Project Number 18070-3517. This project involves the widening and resurfacing of State Road (S.R.) 44, from I-75 to S.R. 301. S.R. 44, also known as Wildwood Road, is located in Ocala, in Sumter County and runs east and west. The borrow pit is a retention pond, known as Pond 4 in the project plans and is located on the north side of Wildwood Road, and is selected for a detailed investigation. The pit is fairly clean of debris, but contains clayey material beginning at depths of 2.25 meters (or 7.4 feet). Since clay does not make good fill material, it is not used and was disregarded. No soil borings or subsurface explorations are performed since the entire pond was marked for excavation. All suitable fill material salvaged at this pond was used elsewhere within the project to save on borrow material. Table 5.16 describes the various laboratory and field tests performed on the soil at different excavation classification stages.

Table 5.16 Summary of Laboratory and Field Tests for Soil Density Determination

Test Performed	Excavation Classification		
	In Situ	Truck	Compacted
Nuclear /Speedy	✓	✓	✓
Standard Proctor			✓
Max/Min Density	✓		
Unit Box		✓	
Cone Penetration	✓		
Dilatometer	✓		

The portion of the pond tested for this investigation consisted of gray/tan sand with shell classified as A-3 soil with about 8 to 9% passing the 200 sieve.

Laboratory Investigations

Laboratory maximum/minimum density tests conducted with dry samples and at percent moisture, and are shown in Table 5.17. The differences of the maximum and minimum densities of dry samples from the borrow pits ranged from 80.2 kN/m^3(12.6 pcf) to 100.0 kN/m^3 (15.7 pcf), with an average value of 89.7 kN/m^3 (14.1 pcf). The results of the laboratory maximum/minimum density test at percent moisture and the uniformity coefficient from the sieve analysis were subsequently used in the iterative procedure to correlate CPT readings. The results of the Standard Proctor tests conducted at optimum moisture are also shown in Table 5.17.

Table 5.17. Maximum/Minimum Density and Standard Proctor Results from Laboratory

Samples from Borrow Pit	Laboratory Maximum/Minimum Density kN/m^3 (pcf)					Standard Proctor	
	Dry		At ω (%)				
	$\gamma_{d(max)}$	$\gamma_{d(min)}$	$\gamma_{d(max)}$	$\gamma_{d(min)}$	ω (%)	$\gamma_{d(max)}$	OMC (%)
Pond #4 - 1	16.76 (106.7)	14.34 (91.1)	16.01 (101.9)	9.32 (59.3)	13.6	18.07 (115.0)	11.0
Pond #4 - 2	16.15 (102.8)	14.0 (89.1)	16.02 (102.0)	10.45 (66.5)	12.6	18.07 (115.0)	11.0

From sieve analysis, the soil samples were found to have the grain size diameter at 60% passing, D_{60}, ranging from 0.18 to 0.22 mm, at 30% passing, D_{30}, ranging from 0.15 to 0.17 mm, and at 10% passing, D_{10}, ranging from 0.078 to 0.12 mm. The grain size diameters at 60% finer, 3% finer, and 10% finer, and the corresponding Uniformity

Coefficient, C_u, and Coefficient of Gradation, C_c, for each borrow pit have been calculated in the Appendix and are summarized in Table 5.18.

Table 5.18. Properties from Sieve Analysis of Borrow Pit Soils

Borrow Pit	D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c
Pond #4	0.18	0.15	0.078	2.31	1.60

Results of the specific gravity tests and sieve analyses were used to find the maximum and minimum density values from the C_u correlation as described in Chapter 4. The coefficient of uniformity, computed maximum and minimum density, and specific results for the soils at the borrow pit are shown in Table 5.19 and compared well to the laboratory results conducted at dry and percent moisture. The maximum and minimum densities correlated from the Uniformity Coefficient were also used in the iterative procedure to correlate CPT readings.

Table 5.19. Results of Maximum/Minimum from Coefficient of Uniformity Correlation

Samples from Pond	C_u	Maximum/Minimum Dry Density kN/m^3 (pcf)		Specific Gravity, G_s
		$\gamma_{d(max)}$	$\gamma_{d(min)}$	
#4 - 1	2.31	16.32 (103.9)	12.86 (81.9)	2.65
#4 - 2	2.31	16.14 (102.7)	12.68 (80.7)	2.62

Field Investigations

The in-situ densities are found with the same three methods as the other two field projects, i.e., CPT, dilatometer, and nuclear density gauge. Two runs of each test are performed at the same locations in Pond 4. The specific gravity and the moisture content are averaged from the values found in the laboratory analysis. The average maximum and minimum density values are obtained from the laboratory tests as well. The in-situ density at two locations is obtained using the nuclear density gauge, and the moisture contents are once again found with the speedy moisture tests. Both tests are taken at a depth of two feet. These results are summarized in Table 5.20.

Table 5.20 Nuclear Density Results for Project 3

Test #	Depth of Test (ft)	Density kN/m³(pcf)	Moisture Content (%)	Dry Density kN/m³(pcf)
I-1	2	18.4 (117.1)	7.0	17.18 (109.4)
I-2	2	18.76 (119.4)	16.1	16.15 (102.8)

CPT and dilatometer readings were taken at the two locations as well. The weighted average CPT reading calculations using the Baldi Method. A depth of 0.91 meters for the water table is assumed from the dilatometer readouts. Table 5.21 presents the dry densities based on the maximum and minimum densities and the Uniformity Coefficient, as discussed earlier.

Table 5.21. Weighted Average In-Situ Dry Densities Using Cone Penetration Tests

Borrow Pit - CPT Number	Average Q_c (tsf)	Max/Min Test Based		C_u - Based	
		γ_d kN/m³(pcf)	ω (%)	γ_d kN/m³(pcf)	ω (%)
Pond #4 - 1	49.9	14.5 (92.1)	13.6	15.7 (99.9)	0.0
Pond #4 - 2	45.1	14.1 (89.7)	12.6	14.8 (95.3)	0.0

The average in-situ dry weight densities for both the tests for Pond #4 were found to be 14.3 kN/m³ (90.9 pcf) and 15.3 kN/m³ (97.6 pcf) respectively.

The dilatometer densities are averaged from the dilatometer sounding data found in the Appendix. The moisture content is determined from the laboratory tests and used to find the average dry density as shown in Table 5.22 below. The corresponding values from nuclear density determination are also provided in the table for comparison.

Table 5.22 Dry Densities from Nuclear Density Test and Dilatometer Soundings

Borrow Pit - Sounding No.	Nuclear Density γ_d kN/m^3 (pcf)	Dilatometer γ_d kN/m^3 (pcf)	ω (%)
Pond #4 – 1	16.15 (102.8)	16.32 (103.9)	13.6
Pond #4 – 2	17.18 (109.4)	16.76 (106.7)	12.6

The final results for all three field determination methods are shown in Table 5.23 along with the average values. Only the Cu-based dry density values from Table 5.21 for CPT results are utilized for further calculations. As before, it appears an average value is the best judge for the in-situ density of Pond 4. The max/min-based results are not included in the averaging process this time. The final report for this phase of the project will reflect this change for the other projects as well and supercede the results provided in previous quarterly reports. These average values will represent the in-situ density in the final calculations for shrinkage and bulkage factors.

Table 5.23 Average In-Situ Dry Densities

Drill / Test #	γ_d (pcf) CPT	γ_d (pcf) Dilatometer	γ_d (pcf) Nuclear Density	Average Values
1	15.7 (99.9)	16.3 (103.9)	16.2 (102.8)	16.0 (102.2)
2	14.9 (95.3)	16.7 (106.7)	17.2 (109.4)	16.3 (103.8)
Average Values	15.3 (97.6)	16.5 (105.3)	16.7 (106.1)	16.2 (103.0)

Unit volume box tests are performed on samples obtained from Pond 4. These samples are obtained from the same location in the compacted soil mass. The average wet soil's unit weight is found to be 12.7 kN/m^3 (80.67 pcf), with moisture content of 1.43% and thus the average dry density for the Unit Box Test is 12.5 kN/m^3 (79.6 pcf). This value will be used subsequently in the shrinkage and bulkage calculations.

Nuclear densities are also taken in the bed of the truck. The individual and average values are provided in Table 5.24. Similar to Projects 1 and 2, these values are rather high due to local compaction caused by the weight of the density gauge itself and, therefore, will *not be used* for further computations. Only the results of the unit box tests for loose state dry density will be used subsequently.

Table 5.24 Truck Densities Using Nuclear Density Gauge

Test #	Location	Density (γ) kN/m^3 (lb/ft^3)	Moisture Content (%)	Dry Density (γ_d) kN/m^3 (lb/ft^3)
T-1	Top of Pile	17.2 (109.7)	15.0	14.9 (95.4)
T-2	Middle of Pile	16.8 (106.9)	15.3	14.6 (92.7)
Average Values		17.1 (108.3)	15.15	14.7 (94.05)

Twelve compacted densities are obtained using nuclear density tests at different points in the design fill. These values are summarized in Table 5.25. As before, these samples are found to be compacted to within 95 - 103% of their maximum densities. The maximum densities are found in the laboratory through standard Proctor tests. The average value of 17.9 kN/m^3 (114.28 pcf) for the dry density in Table 5.27 is used in final shrinkage and bulkage calculations.

Table 5.25 Compacted Dry Densities Using Nuclear/Speedy Tests

Test Number	Density (γ) KN/m^3 (lb/ft^3)	Moisture Content (%)	Dry Density (γ_d) kN/m^3 (lb/ft^3)
C-1	19.2 (122.52)	9.2	17.6 (112.2)
C-2	19.6 (124.49)	9.2	17.9 (114.0)
C-3	19.5 (124.20)	10.4	17.7 (112.5)
C-4	19.9 (126.67)	12.8	17.6 (112.3)
C-5	19.7 (125.30)	7.0	18.4 (117.1)
C-6	19.1 (121.79)	6.0	18.0 (114.9)
C-7	19.6 (124.83)	9.4	17.9 (114.1)
C-8	19.8 (126.13)	9.2	18.1 (115.5)
C-9	12.7 (125.80)	9.2	18.1 (115.2)
C-10	20.0 (127.46)	12.0	17.9 (113.8)
C-11	19.1 (121.80)	6.1	18.0 (114.8)
C-12	19.1 (121.91)	6.1	18.0 (114.9)
Average Values	19.5 (124.41)	8.88	17.9 (114.3)

Finally, a summary of the average values of dry density from different field tests is presented in Table 5.26 below. Based upon Table 5.26, the shrinkage and bulkage factors from field project 3 are found to be 12.2% and 25.3% respectively.

Table 5.26 Summary of Average Dry Densities for Project 3

Test Performed	Average Dry Density - kN/m^3 (pcf)		
	In Situ	Truck	Compacted
Nuclear Density	16.7 (106.1)	14.7 (94.05)*	17.9 (114.3)
Standard Proctor			16.65 (106.0)*
Drive Sleeve Test			
Unit Box		12.5 (79.8)	
CPT	15.3 (97.6)		
Dilatometer	16.5 (105.3)		
AVERAGE	**15.71 (100.0)**	**12.54 (79.8)**	**17.9 (114.3)**

* - Not Used in Averaging of Values

5.5 State-Wide Projects

In the second phase of this investigation, the field study was extended to state-wide projects. Initially, a list of ten potential projects was compiled from information provided by FDOT personnel. Ultimately, the following four projects were selected for detailed monitoring.

Table 5.27 Summary of Selected Projects

District Number	Field Project number	Project number	Location	Earthwork Pay Item
2	4	78002-3510	State Road 312 St. Johns County	Borrow Excavation 120-2
4	5	94010-3533	State Road 5 St. Lucie County	Borrow Excavation 120-1
1	6	13160-3512	State Road 70 Manatee County	Borrow Excavation 120-2
7	7	08070-3502	State Road 50 Hernando County	Borrow Excavation 120-2

5.6 Field Project 4 – St. Johns County (78002-3510)

This project is located in District Two in St. Johns County. It consists of five retention ponds to serve as borrow pits for the significant amount of earthwork involved. It mainly deals with the expansion and resurfacing State Road 312 in St. Augustine, which runs East and West of A1A. This project is classified by the FDOT as Borrow Excavation (Pay Item 120-2). At the time of the selection of this project, two ponds had already been excavated and sodded, namely ponds 1 and 3. Other such as ponds 2, 4 and 5 were just under construction and to be excavated, and are studied here.

CPT was conducted at different locations at each pond. CPT tests were conducted at two different locations at pond 2 and three different locations at pond 5 respectively. Subsequently, considerable amount of non-suitable materials was found at both ponds (2 and 5). These materials consist of poor quality soils and debris. Therefore, these ponds were not selected to serve as borrow materials for this project. Nevertheless, it was decided to go ahead with the necessary tests in the field for both ponds. In addition to field tests, the site personnel also collected four bags of soil samples for laboratory testing. Four bags of soil sample from pond 2, and four bags of soil samples from pond 5 were collected for testing in the laboratory. It should be noted that the Dilatometer Test was not conducted on any of the ponds at this project site due to equipment malfunction. Table 5.28 summarizes the laboratory and field tests that were conducted on these three ponds

Table 5.28. Summary of Laboratory and Field Tests for Field Project 4

Test Performed	In-Situ			Truck			Compacted		
Ponds	2	4	5	2	4	5	2	4	5
Nuclear Density	✓	✓	✓	✖	✖	✖	✖	✓	✖
Standard Proctor							✓	✓	✓
Sieve Analysis	✓	✓	✓						
Unit Box				✓	✓	✓			
Cone Penetration	✓	✓	✓						
Dilatometer	✖	✖	✖						

(✓) Indicates test was conducted, (✖) Indicates test was not conducted, Shaded area indicates not applicable

Laboratory Results

Of the three ponds that are presented in Table 5.28 for this project, only the soil from pond 4 was suitable for any further use in earthwork construction. Four bags of soil samples were collected from the field, of which two bags were delivered to the State Material Laboratory in Gainesville to perform the necessary tests on the soil samples. Meanwhile, the other two bags were retained in the laboratory at the University of Central Florida for supplemental laboratory testing. The State Laboratory performed various tests on the two samples including Standard Proctor test, specific gravity, and grain size distribution analysis.

Standard Proctor Test

The Standard Proctor test was conducted at the State Material office in Gainesville. The maximum dry density (γ_d), and the optimum moisture content (OMC) were obtained for the three ponds. The following tables present the maximum dry density and the optimum moisture content results for ponds 2, 4, and 5 respectively.

Table 5.29 Summary of Standard Proctor Test for Pond 2

Sample Number	Maximum Dry Density (γ_d)		Optimum Moisture Content
	kN/m^3	lb/ft^3	(%)
1	16.32	103.60	16.40
2	16.16	102.80	16.20
Average	16.24	103.30	16.30

Table 5.30 Summary of Standard Proctor Test for Pond 4

Sample Number	Maximum Dry Density (γ_d)		Optimum Moisture Content
	kN/m^3	lb/ft^3	(%)
1	15.97	101.60	15.80
2	16.00	101.80	15.50
Average	15.99	101.70	15.65

Table 5.31 Summary of Standard Proctor Test for Pond 5

Sample Number	Maximum Dry Density (γ_d)		Optimum Moisture Content
	kN/m^3	lb/ft^3	(%)
1	14.29	90.90	11.20
2	14.29	90.90	11.20
Average	14.29	90.90	11.20

Sieve Analysis and Specific Gravity

The samples from pond 2 consisted of gray silty sand/ shell and rocks and were classified as AASHTO type A-3 soil 2%-7% passing the 200 sieve. The soil from pond 4 the portion consisted of yellow / red sand which was classified A-3 soil with 2% - 4% passing the 200 sieve. Lastly, the samples from Pond 5 consisted of crushed shell that was classified as Type A-1-a soil. This soil was not acceptable as borrow material by FDOT standards and is not used for calculation of shrinkage and bulkage factors.

Sieve Analysis test was performed on the same samples for the three ponds (2, 4 and 5) at the State Material Laboratory in Gainesville. This test was used to determine the

Uniformity Coefficient (C_u) and Coefficient of Gradation (C_c) by plotting the Particle Diameter (mm) versus Percent Finer (%). D_{10}, D_{30} and D_{60} values were determined and were used to calculate the Uniformity Coefficient (C_u) and Coefficient of Gradation (C_c). The Uniformity Coefficient was then used to determine the maximum and minimum dry density values used in the iterative procedure to relate the CPT results to the in-situ dry density. Also, the State Material Laboratory personnel performed the specific gravity test for all samples from the borrow pits. Table 5.32 displays the results of the grain size distribution and the specific gravity for the three ponds that were under investigations for this research.

Table 5.32 Results of Sieve Analysis and Specific Gravity for Field Project 4

Pond Number	D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	Average C_u	Average C_c	Average Specific Gravity
2	0.12	0.090	0.078	1.54	0.87	2.65
4	0.13	0.094	0.080	1.63	0.85	2.65
5	N/A	N/A	N/A	N/A	N/A	N/A

(N/A) Indicates not applicable.

Unit Box Test

To obtain the density in the loose condition in the truck, a unit box test was conducted in the geotechnical laboratory at the University of Central Florida this test simulated a scaled truck and the loosely packed (loose density) soil in the truck. This test was performed three different times on the soil samples collected from the field project for each pond. For each pond, the average results for the three tests are presented in the table below.

Table 5.33 Average Summary for Loose Density for Field Project 4

Pond Number	Dry Density	
	kN/m^3	lb/ft^3
2	12.54	79.75
4	13.19	83.92
5	11.64	74.07

Field Results

A variety of field tests were performed in order to determine the in-situ density. These tests were conducted either by the contractor or by the state personnel, and include the following: Cone penetration test, Nuclear density test, and Speedy moisture test.

Cone Penetration Test

The Cone Penetration Test (CPT) was performed at two or three locations, at each pond. The procedure developed by Negron (1997), based on the works of Baldi at el. (1986) and Robertson and Campanella (1983) was used to interpret the Cone tip resistance (q_c). The detailed results for the Cone Penetration Tests are presented in Appendix D for each of the three ponds and summarized in this section.

For this field project, sieve analysis was used to determine the average Uniformity Coefficient (C_u) which was then used to determine the maximum and minimum dry density values. These values were used in the iterative procedure to relate the CPT results to the in-situ dry density. Table 5.34 summarizes the CPT data for Ponds 2 and 4. It should be noted that the average moisture content values shown in the table were obtained from the Speedy Moisture Test for each pond individually. These values of the average moisture contents were used to determine the in-situ dry density (γ_d) for ponds 2 and 4, using the C_u based procedure. The dry density (γ_d) for pond 5 was not computed from CPT data since the soil was found to be Type A-1-a and the uniformity coefficient C_u was unrealistic for CPT- based calculations.

Table 5.34 Average In-Situ Dry Density Using CPT for Field Project 4

Pond Number	Average Depth		Average Dry Density (γ_d)		ω (%)
	meter	feet	kN/m^3	lb/ft^3	
2	1.65	5.41	13.81	87.82	15.20
4	4.43	14.52	15.32	97.42	6.30

Nuclear Density and Speedy Moisture Tests

In addition to the CPT, Nuclear density and Speedy Moisture tests were also performed in the field for all three ponds (2, 4, and 5). These tests were conducted on relatively undisturbed soil at a minimum of three different locations. As discussed earlier, the effective depth of exploration is only about 12 inches due to the limitation of the Nuclear density test device. Thus, other tests such as CPT and Dilatometer were needed to obtain a better estimate for the overall density in the borrow pits. Table 5.35 presents the average values for the moist density, moisture content and the corresponding dry density for the three ponds at this project site.

Table 5.35 Average Dry Density by Using Nuclear and Speedy Moisture Tests

Pond Number	Depth		Moist Density (γ)		Moisture Content (ω)	Dry Density (γ_d)	
	meter	feet	KN/m³	lb/ft³	(%)	KN/m³	lb/ft³
2	0.31	1.0	14.48	92.13	15.20	12.57	79.97
4	0.31	1.0	14.19	90.27	6.30	13.35	84.79
5	0.15	0.5	14.65	93.20	3.70	14.12	89.85

Compacted Density Test

The compacted densities were obtained in the field by using the Nuclear density device at the final stage (compacted) soil at least at three different locations as a part of the normal earthwork inspection procedure. Typically, the compacted densities were found to be within 95% – 103% of their maximum dry densities obtained from the Standard Proctor Test, which are prescribed by FDOT as acceptance criteria. The average value for the compacted moist field density for the soil from pond 4 was determined to be 17.73 kN/m³ (112.77 lb/ft³) with an average of 8.8% of moisture content. Thus, the field compaction dry densities $(\gamma_d)_c$ was back calculated to be 16.29 kN/m³ (103.62 lb/ft³) as shown in Table 5.36.

However, since the soil from ponds 2 and 5 was not suitable for any earthwork at this project site, the compacted densities in the field were not available. The maximum dry densities from the Standard Proctor test were used instead to calculate the shrinkage and bulkage factors for these two ponds. For the soil from ponds 2 and 5, the compacted dry density $(\gamma_d)_c$ was assumed to be 100% of the maximum dry density, which is conservative based on observed field compacted densities for other comparable FDOT projects. The average compaction density from the Standard Proctor test for the soil samples from pond 2 was found to be 16.24 kN/m³ (103.30 lb/ft³). Therefore, the compacted dry density $(\gamma_d)_c$ for this pond was computed as 16.24 kN/m^3 (103.30 lb/ft^3), with the corresponding optimum moisture content of 16.30%. Table 5.36 presents a summary the compacted densities at this project site.

Table 5.36 Average Compacted Dry Density Using Nuclear Density Test for Field Project 4

Pond Number	Average Moist Density (γ)		Average Moisture Content (ω)	Average Dry Density $(\gamma_d)_c$	
	kN/m^3	lb/ft^3	(%)	kN/m^3	lb/ft^3
2	*18.89	*120.14	16.30	16.24	103.30
4	17.73	112.77	8.83	16.29	103.62
5	N/A	N/A	N/A	N/A	N/A

* Values were obtained from the Standard Proctor Test.
(N/A) Indicates not applicable

Lastly, Table 5.37 summarizes the results of the field and laboratory tests conducted at each pond for this field project along with the excavation classifications.

Table 5.37 Summary of Laboratory and Field Tests for Field Project 4

Test	In-Situ kN/m^3 (pcf)			Truck kN/m^3 (pcf)			Compacted kN/m^3 (pcf)		
Ponds	2	4	5	2	4	5	2	4	5
Nuclear Density	12.57 (80.0)	13.35 (84.9)	14.12 (89.8)	✖	✖	✖	✖	16.26 (103.4)	✖
Standard Proctor							16.24 (103.3)	15.99 (101.7)	14.29 (90.9)
Unit Box				12.54 (79.7)	13.19 (83.9)	11.64 (74.0)			
CPT C_u Based	14.20 (90.3)	14.55 (92.5)	✖						
Dilatometer	✖	✖	✖						
Average	**13.39 (85.2)**	**13.95 (88.7)**	**14.12 (89.8)**	**12.54 (79.7)**	**13.19 (83.9)**	**11.64 (74.0)**	**16.24 (103.3)**	**16.26 (103.4)**	**14.29 (90.9)**

(✖) Indicates test was not conducted, Shaded area indicates not applicable

The shrinkage and bulkage factors were computed for each pond and are also shown below.

Table 5.38 Preliminary Shrinkage and Bulkage Factors

Pond	SF (%)	BF (%)
2	17.5	6.8
4	14.2	5.8
5	1.2	21.3

The average values of shrinkage and bulkage factors for this project are found to be 10.9% and 11.3% respectively.

5.7 Field Project 5 – St. Lucie County (94010-3533)

Field project 5 dealt with widening and resurfacing of State Road 5, which is also known as US1. It starts from St. Lucie Boulevard to Rio Mar Drive in St. Lucie County. This project is about 7662.690 meter in length (4.79 miles) and runs North and South on State Road 5. Lateral ditches will serve as a borrow materials for this project. This earthwork project is designated by the FDOT as Roadway Excavation pay item, which often referred to as Regular Excavation (Pay Item 120-1) in FDOT literature and plans. Since it has significant amount of roadway excavation and lateral ditches a detailed summary for earthwork was presented in the original plans based on the roadway cross sections. The earthwork summary was based on the current practice by the FDOT and applies a value of 40% for shrinkage factor and 25% for the bulkage factor.

Field tests were conducted at this project site and soil samples were collected for further testing in the laboratory. Table 5.39 summaries the laboratory and field tests that were conducted at this project site.

Table 5.39 Summary of Laboratory and Field Tests for Field Project 5

Test Performed	In-Situ			Truck			Compacted		
Test Locations	1	2	3	1	2	3	1	2	3
Nuclear Density	✓	✓	✓	✖	✖	✖	✓	✓	✓
Standard Proctor							✓	✓	✓
Sieve Analysis	✓	✓	✓						
Unit Box				✓	✓	✓			
Cone Penetration	✓	✓	✓						
Dilatometer	✓	✓	✓						

(✓) Indicates test was conducted, (✖) Indicates test was not conducted,
Shaded area indicates not applicable

Laboratory Results

This project did not consist of any retention ponds and was of a cut and fill type. All tests were conducted at suitable locations where substantial excavation was envisaged, within three stations along State Road 5. In particular, these stations are (167+20, 167+60 and 168+10). In Table 5.39 these stations are referred to as test locations 1, 2 and 3 respectively. The results for this investigation at this project site will be presented based on these three locations. A total of five bags of soil samples were obtained from the project site for further testing in the laboratory. Of these five bags, three were delivered to the State Material Laboratory for various tests. The remaining samples were retained in the laboratory at the University of Central Florida to perform the unit box test.

Standard Proctor Test

Standard Proctor Test was performed on the three samples that were obtained from this field project. The results for these samples tested at the State Material Laboratory are presented in Table 5.40, indicating the results for the maximum dry density (γ_d) and the optimum moisture content (OMC). The results for sample number three are significantly different from the other two indicating the presence of different soil types within the confines of the tested area.

Table 5.40 Summary of Standard Proctor Test for Field Project 5

Sample Number	Maximum Dry Density (γ_d)		Optimum Moisture Content
	kN/m^3	lb/ft^3	(%)
1	16.05	102.10	14.90
2	16.16	102.80	14.10
3	16.82	107.00	13.30
Average	16.34	103.97	14.10

Sieve Analysis and Specific Gravity

Sieve Analysis was performed in the State Material laboratory on the same samples as described in the previous section for this project. The soil samples consisted of gray silty sand/ fine sand and was classified as AASHTO type A-3 soil with range between 2% - 7% passing the 200 sieve. This test was utilized to calculate the Uniformity Coefficient (C_u) and Coefficient of Gradation (C_c). The values for each sample are summarized in Table 5.41 along with the average of the three samples. In addition, the specific gravity test was also performed on these soil samples, and the values are shown in the table below.

Table 5.41 Properties for Sieve Analysis and Specific Gravity for Field Project 5

Sample Number	D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	Average C_u	Average C_c	Specific Gravity
1	0.185	0.125	0.085	2.18	0.99	2.65
2	0.190	0.125	0.085	2.24	0.97	2.62
3	0.200	0.125	0.085	2.35	0.92	2.62
			Average	2.25	0.96	2.63

The average value for the C_u along with the average specific gravity from the three samples was used as the required input for the computer program to determine the C_u based in-situ dry density.

Unit Box Test

The loose dry density was determined at the University of Central Florida, by utilizing the unit box test. This test was performed three different times on the soil samples that were collected from the project site. The values for the three tests along with average are presented in Table 5.42.

Table 5.42 Average Summary for Loose Density for Field Project 5

Test Number	Dry Density	
	kN/m^3	lb/ft^3
1	13.72	87.25
2	13.58	86.41
3	13.69	87.09
Average	13.66	86.92

Field Results

Once again, in-situ tests such as the Cone penetration test, Nuclear density and Speedy moisture tests were performed at this project site. In addition, for this project, Dilatometer tests were also performed close to the locations where CPT was conducted. These tests were described in detail in the previous chapter and all the results presented in this section.

Cone Penetration Test

Cone Penetration Test (CPT) was used in the field to determine the in-situ dry density (γ_d). The State Material Office personnel were able to conduct one test at each station using the FDOT Cone Rig. The tests were conducted at three different locations, namely tests 1, 2 and 3. Detailed results for the CPT are presented in Appendix D.

The average Uniformity Coefficient (C_u) and Coefficient of Gradation (C_c) were determined from sieve analysis. Based on the C_u-correlation method, the in-situ dry density (γ_d) was then computed. It should be noted that these in-situ dry densities were based on the average moisture content of 12.13%, which was obtained from the Speedy moisture tests and based on a specific gravity of 2.63. Table 5.43 summarizes the CPT data for tests 1,2 and 3.

Table 5.43 Average In-Situ Dry Density Using CPT for Field Project 5

Test Number	Average Depth Of Penetration		In-situ Dry Density (γ_d)		ω (%)
	meter	feet	kN/m^3	lb/ft^3	
1	1.60	4.76	14.87	94.59	12.0
2	1.85	6.07	14.78	94.02	14.4
3	2.10	6.89	15.01	95.49	10.0
Average	1.85	6.07	14.89	94.70	12.13

Dilatometer Sounding

The other test was conducted using the FDOT Cone Rig at this project site was the Dilatometer Test. One dilatometer sounding was conducted at each station next to the CPT location. The dilatometer sounding results are presented in Appendix E. In most cases, this test over-predicted the in-situ dry density when compared to the CPT and the Nuclear density test, for the same test locations. Table 5.44 displays the Dilatometer data and the average of the soundings. The average value for the dry density in Table 5.44 was used to compute the shrinkage and bulkage factors subsequently.

Table 5.44 In-Situ Dry Density Using Dilatometer Soundings for Field Project 5

Test Number	Maximum Depth of Penetration		Dry Density (γ_d)	
	meter	feet	kN/m^3	lb/ft^3
1	2.75	9.02	17.48	111.22
2	2.75	9.02	17.40	110.65
3	2.75	9.02	18.38	116.89
Average	2.75	9.02	17.75	112.92

Nuclear Density and Speedy Moisture Tests

As the third in-situ test, the Nuclear density and Speedy moisture tests were also utilized to determine the in-situ dry density at the project site in addition to the CPT and the Dilatometer soundings. Both tests were conducted at three locations within the same area where the CPT and the Dilatometer tests had been conducted. The in-situ moist density (γ) from this test is shown in Table 5.45. The average moisture content of 12.13% was then used to determine the C_u based in-situ dry density.

Table 5.45 Dry Density Using Nuclear and Speedy Moisture Tests for Field Project 5

Test Number	Depth		Moist Density (γ)		Moisture Content (ω)	Dry Density (γ_d)	
	meter	feet	KN/m^3	lb/ft^3	(%)	KN/m^3	lb/ft^3
1	0.31	1.0	18.09	115.10	12.0	16.16	102.77
2	0.31	1.0	16.81	106.92	14.4	14.69	93.46
3	0.31	1.0	17.44	110.94	10.0	15.73	100.04
	Average		17.40	110.69	12.13	15.53	98.76

Compacted Density Test

The Nuclear density test was also performed at the final compacted site in order to determine the in-place compacted densities. Based on the soil-tracking program, an effort was made to perform these tests close to the final locations of the same soil mass as that tested in the pits and in the laboratory. This test was performed at eight different locations.

The compacted densities were found to be typically within 95% –103% of their maximum dry densities based on the Standard Proctor Test. Table 5.46 provides the detailed test results and the average values of the compacted density. In this case, the compacted densities exceeded the maximum dry densities by as much as 17%.

Table 5.46 Compacted Dry Density Using Nuclear and Speedy Moisture Tests

Test Number	Depth		Moist Density (γ)		Moisture Content (ω)	Dry Density $(\gamma_d)_c$	
	meter	feet	KN/m³	lb/ft³	(%)	KN/m³	lb/ft³
1	0.15	0.50	20.42	129.89	5.8	19.34	123.00
2	0.15	0.50	20.36	129.52	5.3	19.35	123.12
3	0.15	0.50	20.15	128.14	5.8	19.08	121.35
4	0.15	0.50	20.75	132.01	5.6	19.67	125.13
5	0.15	0.50	20.61	131.08	6.5	19.39	123.31
6	0.15	0.50	21.04	133.82	6.3	19.83	126.13
7	0.15	0.50	20.42	129.89	4.8	19.50	124.06
8	0.15	0.50	20.79	132.26	5.8	19.69	125.25
	Average		20.31	129.18	5.74	19.48	123.92

Table 5.47 summarizes the field and laboratory tests results that were conducted at each station for field project 5. The average values that are presented in Table 5.47 are used later in this chapter to compute the shrinkage and bulkage factors for this field project.

Table 5.47 Average Summary of Dry Densities from Laboratory and Field Tests for Field Project 5

Test Performed	In-Situ $(\gamma_d)_E$	Truck $(\gamma_d)_L$	Compacted$(\gamma_d)_c$
	kN/m³ (pcf)	kN/m³ (pcf)	kN/m³ (pcf)
Nuclear Density	15.53 (98.8)	✖	19.48 (123.9)
Standard Proctor			16.34 (103.9)*
Unit Box		13.66 (86.8)	
Cone Penetration C_u Based	14.89 (94.7)		
Dilatometer	17.75 (112.9)		
Average	**16.06 (102.1)**	**13.66 (86.8)**	**19.48 (123.9)**

(✖) Indicates test was not conducted, * indicates value not used for calculation

From the data above, the average values of shrinkage and bulkage factors for this project are found to be 17.5% and 17.6% respectively.

5.8 Field Projects 6 – Manatee County (13160-3512)

This project is located in Manatee County in District One and deals with widening and resurfacing of State Road 70 in Bradenton, which runs east and west of Interstate 75. The FDOT designated this project as Borrow excavation (Pay Item 120-2). This project involves a large amount of earthwork in terms of roadway excavation and embankment. It is about 3021 meter in length (1.88 miles). It consists of three retention ponds, namely B-1, D-2 and E-1. All three ponds served as borrow pits for this project. The earthwork summary was provided on the plans based on the current practice of the FDOT. For this project, the designer used 35% for the shrinkage factor and 25% for the bulkage factor.

At the time of starting this investigation, the excavation of two of the three ponds was almost completed, these ponds are B-1 and E-1. However, the researcher and the State Material Personnel were able to conduct the cone penetration test (CPT) between State Road 70 and the berm of pond E-1, where the material appeared to be similar to the pit and was intact under similar overburden conditions. Since pond E-1 had already been excavated, soil samples were unattainable and for any testing in the laboratory. However, visual inspection and CPT data indicated that the soil at pond E-1 was very similar to the adjoining pond D-2. Therefore, an assumption was made that both ponds E-1 and D-2 have the same material with similar properties. Hence, the computed in-situ dry densities for pond E-1 are based on the soil properties for pond D-2. Pond D-2 was the only pond not under construction at the start of this study and was about to be excavated. This pond was studied completely and all in-situ and laboratory tests were performed. Three CPT tests were conducted at this pond. In addition, the FDOT site personnel and the contractor helped conduct Nuclear density and Speedy moisture tests at pond D-2. This section provides the results for both ponds E-1 and D-2. Field and laboratory results are based on pond D-2 data. The third borrow pit, pond B-1 was not accessible for any field testing or soil sampling. Table 5.48 summarizes the field and laboratory tests at each pond of the field project 6, and the excavation classifications.

Table 5.48 Summary of Field and Laboratory Tests for Soil Density Determination for Field Project 6

Test Performed	In-Situ		Truck		Compacted	
Ponds	E-1	D-2	E-1	D-2	E-1	D-2
Nuclear Density	✖	✓	✖	✖	✓	✖
Standard Proctor					✖	✓
Sieve Analysis	✖	✓				
Unit Box			✖	✓		
Cone Penetration	✓	✓				
Dilatometer	✖	✖				

(✓) Indicates test was conducted, (✖) Indicates test was not conducted, Shaded area indicates not applicable

Laboratory Results

From the three retention ponds that were originally found in this project, only ponds D-2 and E-1 were available in-situ investigations. The third pond B-1 had already been excavated. The researchers obtained six bags of soil samples from pond (D-2) for further laboratory testing. Unfortunately, E-1 was also excavated before any soil samples could be taken. However, based on CPT data and visual inspection, the soil at E-1 was very similar to pond D-2 and the laboratory results from D-2 were applied to E-1 as well.

Standard Proctor Test

The soil samples obtained from pond D-2 were tested in the State Material Laboratory. The maximum dry density (γ_d), and the optimum moisture content was determined for the three soil samples using the Standard Proctor test. The results for the three samples are presented in the Table 5.49.

Table 5.49 Summary of Standard Proctor Test for Field Project 6

Sample Number	Maximum Dry Density (γ_d)		Optimum Moisture Content
	kN/m^3	lb/ft^3	(%)
1	16.11	102.50	14.20
2	17.09	108.70	12.30
3	16.37	104.10	13.30
Average	16.52	105.10	13.27

Sieve Analysis and Specific Gravity

The samples from pond D-2 consisted of light gray sand organic soils, and were classified as AASHTO type A-3 soil type with 2% - 9% passing the 200 sieve. Sieve analysis results are considered representative for the entire project due to the unavailability of soil samples from any of the other ponds. Table 5.50 provides the D_{10}, D_{30}, and D_{60} values for the soil and the average C_u and C_c, along with the specific gravity value for the three samples.

Table 5.50 Properties from Sieve Analysis for Field Project 6

Sample Number	D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	Average C_u	Average C_c	Specific Gravity
1	0.210	0.120	0.088	2.39	0.78	2.70
2	0.190	0.120	0.077	2.47	0.98	2.64
3	0.198	0.120	0.085	2.33	0.93	2.60
			Average	2.39	0.90	2.65

Unit Box Test

Similar to the other projects, the unit box test was performed at the University of Central Florida on samples collected from this project. Table 5.51 displays the average loose density values from the three samples.

Table 5.51 Summary for Loose Density from Unit Box for Field Project 6

Test Number	Loose Dry Density	
	kN/m^3	lb/ft^3
1	14.44	91.84
2	14.45	91.84
3	14.52	92.38
Average	14.47	92.05

It is interesting to observe that the loose density for this project is significantly higher than the others values. This may be due to a well-graded soil sample.

Field Results

The following sections presented the results of the field tests performed at this project site to determine the soil densities.

Cone Penetration Test

CPT tests were performed at three different locations for pond D-2 and E-1. The same procedure used for the previous field projects was used again to interpret the Cone Tip Resistance (q_c). The CPT results are based on the average moisture content obtained from Speedy moisture test, as presented in Table 5.52. It is then used to determine the in-situ dry density (γ_d) for each test location at each pond individually. The detailed CPT results are presented in Appendix D and the results are summarized in Table 5.52. As it was discussed in the previous section, the results of the sieve analysis and specific gravity tests used for the CPT data from E-1 are based on the data obtained from pond D-2.

Table 5.52 Average In-Situ Dry Density Using CPT for Field Project 6

Pond Number	Depth of Penetration		In-situ Dry Density (γ_d)		ω (%)
	meter	feet	kN/m^3	lb/ft^3	
E-1	2.82	9.24	15.61	99.30	10.33
D-2	3.57	11.70	15.27	97.13	10.33
		Average	15.44	98.21	

Nuclear Density and Speedy Moisture Tests

The Nuclear density test was also were utilized to determine the in-situ dry density for both ponds E-1 and D-2. Ten tests were conducted at pond D-2. The moist in-situ density and the moisture content average for the ten tests were used to compute the in-situ dry density as shown in Table 5.53. The average of the moisture content, from the Speedy moisture test, was found to be 10.33%. Table 5.52 presents the average of the ten tests that were conducted at pond D-2.

Table 5.53 Average Dry Density by Using Nuclear and Speedy Moisture Tests

Test Number	Depth		Moist Density (γ)		Moisture Content (ω)	Dry Density (γ_d)	
	meter	feet	KN/m^3	lb/ft^3	(%)	KN/m^3	lb/ft^3
1	0.31	1.0	16.57	105.40	3.30	16.04	102.03
2	0.31	1.0	16.48	104.80	3.10	15.98	101.65
3	0.31	1.0	19.09	121.40	6.60	17.90	113.88
4	0.31	1.0	18.41	117.10	8.20	17.01	108.23
5	0.31	1.0	18.02	114.60	9.50	16.45	104.66
6	0.31	1.0	17.36	110.40	10.00	15.78	100.36
7	0.31	1.0	18.55	118.00	13.80	16.30	103.69
8	0.31	1.0	18.17	115.60	13.00	16.08	102.30
9	0.31	1.0	18.63	118.50	17.90	15.80	100.51
10	0.31	1.0	18.03	114.70	17.90	15.29	97.29
	Average		17.93	114.05	10.33	16.26	103.46

Compacted Density Test

The compacted densities $(\gamma_d)_c$ for pond E-1 were not available since the borrow material was never utilized for further earthwork. Therefore, the maximum dry density was used as the compacted value instead to determine the shrinkage and bulkage factors. The maximum dry density was obtained in the laboratory using Standard Proctor test. The compacted density was assumed 100% of the maximum dry density. From Table

5.47 the average compaction density for pond E-1 was 16.52 kN/m³ (105.10 lb/ft³) and the moisture content was 16.30%. This data is used to back calculate for moist density as shown in Table 5.54. The field density values are used for pond D-2.

Table 5.54 Average Compacted Dry Density Using Nuclear Density Test

Pond Number	Average Moist Density (γ)		Average Moisture Content (ω)	Average Dry Density $(\gamma_d)_c$	
	lb/ft³	kN/m³	(%)	kN/m³	lb/ft³
E-1	*119.05	*18.71	13.27	*16.52	*105.10
D-2	114.17	17.94	11.23	16.13	102.64

* Values were obtained from the Standard Proctor Test.

Table 5.55 summarizes the results of the field and the laboratory tests that were performed at each pond for field project 6.

Table 5.55 Average Summary of Dry Density from Laboratory and Field Tests For Project 6

Test Performed	In-Situ $(\gamma_d)_E$ kN/m³ (pcf)		Truck $(\gamma_d)_L$ kN/m³ (pcf)		Compacted $(\gamma_d)_c$ kN/m³ (pcf)	
Ponds	E-1	D-2	E-1	D-2	E-1	D-2
Nuclear Density	✖	16.26 (103.4)	✖	✖	✖	✖
Standard Proctor					16.52 (105.0)	16.13 (102.6)
Unit Box			14.47 (92.0)	14.47 (92.0)		
(CPT) C_u Based	15.61 (99.3)	15.27 (97.1)				
Dilatometer	✖	✖				
Average	**15.61 (99.3)**	**15.77 (100.3)**	**14.47 (92.0)**	**14.47 (92.0)**	**16.52 (105.0)**	**16.13 (102.6)**

(✓) Indicates test was conducted, (✖) Indicates test was not conducted, Shaded area indicates not applicable

The shrinkage and bulkage factors were computed for each pond and are also shown below.

Table 5.56 Preliminary Shrinkage and Bulkage Factors

Pond	SF (%)	BF (%)
E-1	5.5	7.9
D-2	2.2	8.9

The average values of shrinkage and bulkage factors for this project are found to be 3.9% and 8.4% respectively.

5.9 Field Project 7 – Hernando County (08070-3502)

The final field project site is located in Hernando County in District Seven in the city of Brooksville. It mainly deals with widening and resurfacing State Road 50 that runs east and west of State Road 700 in Brooksville. This project consists of seven retention ponds, namely A, B, C, D, E, F, and G, that serve as borrow pits for the project. It involves with a significant amount of earthwork, in terms of excavation and embankment. The Florida Department of Transportation (FDOT) designates this project as Borrow excavation (Pay Item 120-2). The net length for this project is about 3139.62 meter (1.96 mile). Unfortunately, only limited testing was possible at this particular job site due to the several delays in construction.

Cone penetration test was conducted on three of the retention ponds namely (B, C, and F). The State Material personnel were able to conduct limited field and the laboratory tests in these three ponds. Three (CPT) tests were conducted at each pond as listed in Appendix D. The remaining ponds were still at early stages of construction, where trees and rubbles still in place. In addition, to the CPT, the contractor assisted in conducting Nuclear and Speedy moisture tests. Pond B-1 was not accessible for any testing while three CPT tests were conducted at pond D-2. In addition, Nuclear and Speedy moisture tests were conducted by the contractor on pond D-2. The results are for pond E-1 are also based on the field and laboratory data pond D-2 since it was in very close proximity to D-1 and no testing was possible at E-1. Table 5.57 summarizes the laboratory and field tests that were conducted at this project site.

Table 5.57 Summary of Laboratory and Field Tests for Field Project 7

Test Performed	In-Situ			Truck			Compacted		
Tests	B	C	F	B	C	F	B	C	F
Nuclear Density	✓	✓	✓	✖	✖	✖	✖	✓	✖
Standard Proctor							✓	✓	✓
Sieve Analysis	✓	✓	✓						
Unit Box				✓	✓	✓			
Cone Penetration	✓	✓	✓						
Dilatometer	✖	✖	✖						

(✓) Indicates test was conducted, (✖) Indicates test was not conducted, Shaded area indicates not applicable

This section presents the results for all ponds that were tested at by the time of this research. Since the soil from these pits was not selected for use in the construction of the embankment, there were no data available for the compaction density. The compacted density values were assumed to be 105% of the Standard proctor test.

Laboratory Results

The results for this investigation at this project site will be presented based on these three retention ponds. A total of six bags of soil samples were obtained from the project site for further testing in the laboratory. Of these five bags, three were delivered to the State Material Laboratory for various tests. The remaining samples were retained in the laboratory at the University of Central Florida to perform the unit box test.

Standard Proctor Test

Standard Proctor Test was performed on the three samples that were obtained from this field project. The results for these samples tested at the State Material Laboratory are presented in Table 5.58, indicating the results for the maximum dry density (γ_d) and the optimum moisture content (OMC). The results for sample number three are significantly different from the other two indicating the presence of different soil types within the confines of the tested area.

Table 5.58 Summary of Standard Proctor Test for Field Project 7

Sample Number	Maximum Dry Density (γ_d)		Optimum Moisture Content
	kN/m^3	lb/ft^3	(%)
B	16.94	107.75	13.2
C	16.61	105.63	12.87
F	17.98	114.40	12.10
Average	17.18	109.27	12.72

Sieve Analysis and Specific Gravity

Sieve Analysis was performed in the State Material laboratory on the same samples as described in the previous section for this project. In addition, the specific gravity test was also performed on these soil samples, and the values are shown in the table below.

Table 5.59 Properties for Sieve Analysis and Specific Gravity for Field Project 7

Sample Number	D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	Average C_u	Average C_c	Specific Gravity
B	0.17	0.11	0.075	2.27	0.95	2.64
C	0.17	0.11	0.080	2.22	0.95	2.66
F	0.17	0.09	0.075	2.20	0.73	2.63
			Average	2.23	0.87	2.64

The average value for the C_u along with the average specific gravity from the three samples was used as the required input for the computer program to determine the C_u based in-situ dry density from CPT.

Unit Box Test

The loose dry density was determined at the University of Central Florida, by utilizing the unit box test. This test was performed three different times on the soil samples that were collected from each pond. The average values for the three tests are presented in Table 5.60.

Table 5.60 Average Summary for Loose Density for Field Project 7

Pond	Dry Density	
	kN/m^3	lb/ft^3
B	13.78	87.69
C	12.54	79.75
F	13.74	87.42
Average	13.35	84.95

Field Results

In-situ tests such as the Cone penetration test, Nuclear density and Speedy moisture tests were performed at all possible and accessible ponds as discussed earlier. For this project, Dilatometer tests were not performed due to the malfunction of FDOT Dilatometer equipment.

Cone Penetration Test

Cone Penetration Test (CPT) was used in the field to determine the in-situ dry density (γ_d). The State Material Office personnel were able to conduct at few locations using the FDOT Cone Rig. Table 5.61 summarizes the CPT data for tests 1,2 and 3.

Table 5.61 In-Situ Dry Density Using CPT for Field Project 7

Pond	Average Depth Of Penetration		In-situ Dry Density (γ_d)		ω (%)
	meter	feet	kN/m^3	lb/ft^3	
B	3.68	12.08	15.16	96.43	13.2
C	2.47	8.10	15.36	97.72	12.8
F	1.87	6.12	15.41	98.04	12.1

Nuclear Density and Speedy Moisture Tests

As the second in-situ test, the Nuclear density and Speedy moisture tests were also utilized to determine the in-situ dry density to supplement the CPT results. Unfortunately, the contractor did not cooperate with the research project to obtain Nuclear and Speedy moisture data for ponds B and F. The research team had the original goal of not interfering with the on-going projects and did not pursue any further testing when asked to leave the site. The density (γ) from the test at Pond C is shown in Table 5.63.

Table 5.63 Dry Density Using Nuclear and Speedy Moisture Tests for Field Project 7

Pond	Depth		Moist Density (γ)		Moisture Content (ω)	Dry Density (γ_d)	
	meter	feet	kN/m³	lb/ft³	(%)	kN/m³	lb/ft³
C	0.15	0.5	16.27	103.48	3.3	15.75	100.75

Compacted Density Test

The compacted densities were not available since the borrow material was never utilized for further embankment earthwork. Therefore, the maximum dry density from Standard Proctor tests was used as the compacted value by assuming 105% of the maximum dry density as shown below.

Table 5.64 Compacted Dry Density for Field Project 7

Pond Number	Average Dry Density (γ)		Average Moisture Content (ω)
	kN/m³	lb/ft³	(%)
B	17.78	113.1	13.2
C	17.44	110.9	12.9
F	18.88	120.1	12.1

* Values were obtained from the Standard Proctor Test.

Table 5.65 summarizes the results of the field and the laboratory tests that were performed at each pond for field project 7.

Table 5.65 Summary of Dry Density from Laboratory and Field Tests for Field Project 7

Test Performed	In-Situ $(\gamma_d)_E$ kN/m³ (pcf)			Truck $(\gamma_d)_L$ kN/m³ (pcf)			Compacted $(\gamma_d)_c$ kN/m³ (pcf)		
Ponds	B	C	F	B	C	F	B	C	F
Nuclear Density	✖	15.75 (100.2)	✖				✖	✖	✖
Standard Proctor							17.8 (113.2)	17.4 (110.6)	18.9 (120.2)
Unit Box				13.8 (87.7)	12.5 (79.5)	13.7 (87.1)			
(CPT) C_u Based	15.16 (96.4)	15.36 (97.7)	15.41 (98.0)						
Dilatometer	✖	✖	✖						
Average	**15.16 (96.4)**	**15.55 (98.9)**	**15.41 (98.0)**	**13.8 (87.7)**	**12.5 (79.5)**	**13.7 (87.1)**	**17.8 (113.2)**	**17.4 (110.7)**	**18.9 (120.2)**

(✓) Indicates test was conducted, (✖) Indicates test was not conducted, Shaded area indicates not applicable or available.

The shrinkage and bulkage factors were computed for each pond and are also shown below.

Table 5.66 Preliminary Shrinkage and Bulkage Factors

Pond	SF (%)	BF (%)
B	14.8	9.8
C	10.6	24.4
F	18.4	11.9

The average values of shrinkage and bulkage factors for this project are found to be 14.6% and 15.4% respectively.

5.10 Shrinkage and Bulkage Factor Calculations

The shrinkage and bulkage factors are computed for all of the field projects using the universal (Equation 2.8) and currently used FDOT (Equation 2.2) equations relating dry densities at the different soil tracking stages to the appropriate factors. The equations for both methods are shown again in Table 5.68 for convenience.

It is important to note that the bulkage factor equation of the FDOT definition is correct in the example problem found in the FDOT design manual but not in the pay item definition. The values of shrinkage factors obtained from each definition are shown in Tables 5.69 and 5.70 for District Five and statewide projects respectively. Finally, the bulkage factors from the universal and current FDOT definitions, for District Five and statewide projects are shown in Tables 5.71 and 5.72 respectively.

Table 5.68 Equations Used in Computing Shrinkage and Bulkage Factors

	Universal Definitions	Current FDOT Definitions
Shrinkage Factor	$SF = 1 - \frac{(\gamma_d)_E}{(\gamma_d)_C}$	$SF_{(FDOT)} = \frac{(\gamma_d)_C}{(\gamma_d)_E} - 1$
Bulkage Factor	$BF = \frac{(\gamma_d)_E}{(\gamma_d)_T} - 1$	$BF = \frac{(\gamma_d)_E}{(\gamma_d)_T} - 1$

Table 5.69 Shrinkage Factor Calculations for Phase I (District 5 projects)

Earthwork Stage	Universal Definitions			Current FDOT Definitions		
	Proj 1	Proj 2	Proj 3	Proj 1	Proj 2	Proj 3
In-Situ Density kN/m^3 (pcf)	16.18 (103.0)	15.33 (97.6)	15.71 (100.0)	16.18 (103.0)	15.33 (97.6)	15.71 (100.0)
Compacted Density kN/m^3 (pcf)	17.34 (110.4)	16.11 (102.5)	17.9 (114.3)	17.34 (110.4)	16.11 (102.5)	17.9 (114.3)
Shrinkage Factor (%)	**6.7**	**4.8**	**12.2**	**7.2**	**5.1**	**13.9**

Table 5.70 Shrinkage Factor Calculations for Phase II (Statewide projects)

Earthwork Stage	Universal Definitions				Current FDOT Definitions			
	Proj 4	Proj 5	Proj 6	Proj 7	Proj 4	Proj 5	Proj 6	Proj 7
In-Situ Density kN/m^3 (pcf)	13.82 (87.9)	16.06 (102.2)	15.69 (99.9)	15.37 (97.8)	13.82 (87.9)	16.06 (102.2)	15.69 (99.9)	15.37 (97.8)
Comp. Density kN/m^3 (pcf)	15.60 (99.3)	19.48 (124.0)	16.33 (103.9)	18.04 (114.8)	15.60 (99.3)	19.48 (124.0)	16.33 (103.9)	18.04 (114.8)
Shrinkage Factor (%)	**11.4**	**17.6**	**3.9**	**14.8**	**12.9**	**21.3**	**4.1**	**17.4**

Table 5.71 Bulkage Factor Calculations for Phase I (District 5 projects)

Earthwork Stage	Universal Definitions			Current FDOT Definitions		
	Proj 1	Proj 2	Proj 3	Proj 1	Proj 2	Proj 3
In-Situ Density kN/m^3 (pcf)	16.18 (103.0)	15.33 (97.6)	15.71 (100.0)	16.18 (103.0)	15.33 (97.6)	15.71 (100.0)
Truck Density kN/m^3 (pcf)	11.89 (75.7)	12.53 (79.7)	12.54 (79.8)	11.89 (75.7)	12.53 (79.7)	12.54 (79.8)
Bulkage Factor (%)	**36.0**	**22.3**	**25.3**	**36.0**	**22.3**	**25.3**

Table 5.72 Bulkage Factor Calculations for Phase II (Statewide projects)

Earthwork Stage	Universal Definitions				Current FDOT Definitions			
	Proj 4	Proj 5	Proj 6	Proj 7	Proj 4	Proj 5	Proj 6	Proj 7
In-Situ Density kN/m³ (pcf)	13.82 (87.9)	16.06 (102.2)	15.69 (99.9)	15.37 (97.8)	13.82 (87.9)	16.06 (102.2)	15.69 (99.9)	15.37 (97.8)
Truck Density kN/m³ (pcf)	12.46 (79.3)	13.66 (86.9)	14.47 (92.1)	13.34 (84.9)	12.46 (79.3)	13.66 (86.9)	14.47 (92.1)	13.34 (84.9)
Bulkage Factor (%)	**10.9**	**17.6**	**8.4**	**15.2**	**10.9**	**17.6**	**8.4**	**15.2**

Based upon the previous study by Mehta [14] and Negron [15] for the initial phase of this research, which covered District Five in Central Florida, and the current study, the recommended ranges for shrinkage and bulkage factors for primarily sandy soils (AASHTO Type A-3) is presented in Table 5.73. *These recommended values take into account <u>other factors</u> that contribute to the differences in earthwork quantities as discussed in Chapter Three.*

Table 5.73. Recommended Shrinkage and Bulkage Factors from the Current Study

Factors	Value (%)
Shrinkage	**15-20**
Bulkage	**25**

Using either the new definition or the FDOT pay-item definitions, there is a substantial difference in the shrinkage factors obtained from the field investigation and the currently FDOT recommended shrinkage factors of 30 - 35%. However, the bulkage factor for both cases is in the vicinity of the currently recommended value of 25 %. *From the field investigations, a shrinkage factor of 15-20% is recommended for general use with A-3* *soils in the Central Florida area. A bulkage factor of 25%, which is currently being used by the FDOT, is also recommended.*

5.11 Conclusion

This chapter presented the results of the field and laboratory investigations at the seven field projects. The results of these investigations are used to determine the dry unit weights of the soil at different stages of earthwork. In some cases, such as nuclear density gauge, the determination is done directly while indirect methods are used to correlate the results of other tests such as CPT and dilatometer and the dry unit weights.

CHAPTER 6
CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This research was aimed at developing a procedure for estimating improved shrinkage and bulkage factors based on volumetric changes of soils. The volumetric changes of the soil was tracked from the in-situ state, to a bulked state during transport, and in a compacted state using the direct and indirect methods for estimating dry densities. A combined approach, including three phases, namely, statistical, theoretical, and detailed site investigation, has been used for this task. The universal definitions of shrinkage and bulkage factors are introduced in order to correct some inaccuracies in the definitions used in present FDOT practice.

Chapter 5 presented the dry density values obtained from the borrow pits, used in the implementation of this study, and shrinkage factors of 15 to 20% for A-3 soils and a bulkage factor of 25% were recommended. These recommendations are based on the theoretical definitions and there is significant disagreement with the 30 - 35% shrinkage factor currently being used by the FDOT. A comparison of the actual shrinkage factor with the FDOT definitions indicates that the factors are significantly smaller than the 30 - 35% range. Hence, for both definitions, the shrinkage factor appears to be in the 10 - 15% range.

One of the most important contributions of this research was a procedure for estimating in-situ dry densities of soils from CPT values. This procedure was based on an iterative method and has been used extensively during the course of this research. However, more testing is needed to establish the applicability to all cohesionless soils.

The statistical and cost analyses conducted in Chapter 3, on the calculated shrinkage factors for the state of Florida, revealed a consistent trend within the state. In most cases, the frequency of occurrence of the calculated shrinkage factors lied outside an acceptable range, which was ±10% of the FDOT recommended shrinkage factors. However, the shrinkage factors recommended by the FDOT were found to over-predict those found in the field study, and were believed to be governed by other factors besides just these two earthwork calculation factors.

It is important to note that this detailed procedure for estimating shrinkage and bulkage factors is not entirely practical for every project use, but gives a realistic overview of soils used in earthwork. However, this procedure should be considered a viable alternative when there is very little knowledge of local soils. For every day use, adopting proper factors based on knowledge of soils in the local areas and engineering experience with these soils is the best alternative.

6.2 Suggestions for Future Work

1. More field studies in the state of Florida should be conducted to get a wider range of shrinkage and bulkage factors for different soil classifications. Care should be exercised in monitoring the soil during the three stages of excavation, and planned visits to the project sites should be within a short period of time in order to preserve the integrity of the study.
2. Based on the algorithm and methodology developed in this thesis, other state and federal agencies should continue this investigation to obtain more accurate shrinkage and bulkage factors for local soil conditions.

3. More accurate methods for correlating field test data to the dry density of a soil mass should be researched. In particular, the CPT tip resistance and sleeve friction readings should be related to the density without the use of additional laboratory tests for maximum and minimum density.
4. A better method for finding the loose truck density should be developed. A possible option may be to use weigh stations to measure the weight of an actual truck when it is empty and then filled with borrow fill. Knowing the volume of the truck, a more realistic estimate of the truck soil density may be obtained.
5. This research can also further extend into clay materials. The effects of cohesion and pore pressure in clay can result in different shrinkage and bulkage factors and should be taken into account. Dewatering is also a common tool used in construction. The sudden change of pore pressure can have adverse effects on shrinkage and bulkage factors in clayey soils.

CHAPTER 7

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APPENDIX A

COMPUTER PROGRAM
FOR
CORRELATING CPT AND In-SITU DRY DENSITY

CPT - *IN-SITU* DRY DENSITY CORRELATION PROGRAM CODE

```
Sub drydensity()

Dim gammadry0, gammadry, gammadrymax, gammadrymin, Dr1, Dr2, dDr, Dg

Dim Dr, Kq, C0, C1, C2, a, b, GWE, Gs, depth, layer1, layer2, sigvo, gammasum,
gamma

Dim qc, qckpa, OMC, z, zft, Num

Worksheets("Sheet1").Activate

depth = InputBox("Enter the total depth of penetration (m):")

gammadrymax = InputBox("Enter the maximum dry density (pcf):")

gammadrymin = InputBox("Enter the minimum dry density (pcf):")

OMC = InputBox("Enter the optimum moisture of soil:")

Gs = InputBox("Enter the specific gravity of the soil:")

GSE = InputBox("Enter the elevation of the ground surface in meters:")

GWE = InputBox("Enter the ground water table elevation in meters:")

l = InputBox("Please select from the following: 1. Field Correction Included 2. Not
Included")

insheet = InputBox("Enter Input Sheet Name")

Cells(1, 1).Value = "DEPTH (M)"

Cells(1, 2).Value = "DEPTH (FT)"

Cells(1, 3).Value = "Qc (TSF)"
```

```
Cells(1, 4).Value = "SOIL TYPE CLASSIFICATION"

Cells(1, 5).Value = "LAYER #"

Cells(1, 6).Value = "gd (pcf) - Baldi"

Cells(1, 7).Value = "table #s"

C0 = 157

C1 = 0.55

C2 = 2.41

j = 0

gammasum = 0

numdata = depth * 20

For i = 1 To numdata

z = Sheets(insheet).Cells(i + 4, 1).Value

qc = Sheets(insheet).Cells(i + 4, 2).Value

Num = Sheets(insheet).Cells(i + 4, 8).Value

STYPE = Sheets(insheet).Cells(i + 4, 9).Value

gammadry0 = gammadrymin

dz = 0.05

k = 0

Dg = 0.1

'Baldi Method

Do
```

```
Dr1 = (gammadry0 - gammadrymin) * (gammadrymax / (gammadry0 * (gammadrymax - gammadrymin)))

If l = 1 Then

Kq = 1 + 0.2 * (Dr1 * 100 - 30) / 60

Else

Kq = 1

End If

qckpa = qc * 2 * 4.44822161526 / 0.3048 ^ 2

gammadry = gammadry0 * 4.44822131526 / (0.3048 ^ 3 * 1000)

If z < GWE Then

sigvo = (gammasum + gammadry) * dz * (1 + OMC)

Dr2 = 1 / C2 * Log(qckpa / (Kq * C0 * (sigvo) ^ C1))

Else

sigvo = (gammasum + gammadry) * dz * Gs / (Gs - 1)

Dr2 = 1 / C2 * Log(qckpa / (Kq * C0 * (sigvo) ^ C1))

End If

dDr = (Dr1 - Dr2) / Dr2

gammadry0 = gammadry0 + Dg

k = k + 1

If k > ((gammadrymax - gammadrymin) + 20) / Dg Then

gammadry0 = gammadrymin
```

```
dDr = 0.001

End If

Loop While Abs(dDr) > 0.005

gammasum = gammadry + gammasum

zft = z / 0.3048

Cells(i + 1, 1).Value = z

Cells(i + 1, 2).Value = zft

Cells(i + 1, 3).Value = qc

Cells(i + 1, 4).Value = STYPE

Cells(i + 1, 6).Value = gammadry0

Cells(i + 1, 7).Value = Num

Cells(i + 1, 8).Value = Dr1

layer1 = Cells(i, 7)

layer2 = Cells(i + 1, 7)

If layer1 = layer2 Then Cells(i + 1, 5).Value = " " Else Cells(i + 1, 5).Value = j

Next i

End Sub
```

APPENDIX B

QUESTIONNAIRE FOR FDOT PERSONNEL

FDOT WPI # 0510796

Title: Investigation of Shrink and Swell Factors for Soils used in FDOT Construction

(1) Can you help us identify projects within the last 5 years where you have had major variations / overruns in the earthwork quantities / estimates. Please include project numbers, location, and earthwork pay items.

Project Number	Location	Earthwork Pay Item

(2) Can you remark on or attribute any reasons for the variations in quantities.

____

____

____

____

____

(3) Can you also list projects for which the estimated quantities were very close.

Project Number	Location

(4) Please help us in identifying projects that had major earthwork disputes or claims. If possible, please provide approximate amounts of the dispute or claim.

Project Number	Location	Dispute/Claim Amount

Note: Attach additional sheets if necessary.

APPENDIX C

SUMMARY OF STATE WIDE PROJECTS SHOWING PLANNED AND ACTUAL BORROW QUANTITIES

Table C.1. Summary of Regular and Borrow Quantities for District 1

Project Number	Plan Qty. Borrow (CY)	Actual Qty. Borrow (CY)	Plan Qty. Regular (CY)	Actual Qty. Regular (CY)	Approximate Fill Qty. (CY)	Calculated Shrinkage Factor
010103509	46	57	0	0	23.92	0.48
010303505	149182	132602	0	0	77574.64	0.27
030003622	1461	137	0	0	759.72	-5.93
030103524	4919	3938	0	0	2557.88	0.19
030103560	256	159	0	0	133.12	-0.05
030603601	5149	3566	0	0	2677.48	0.06
030803518	35809	30275	6803	6431	23042.63	0.25
030803521	0	0	3187	3429	2071.55	0.40
045703606	13721	7327	0	0	7134.92	-0.22
050103523/4	24907	14060	0	0	12951.64	-0.15
055303603	37736	31534	12476	10380	27732.12	0.22
065903905	1380	1073	0	0	717.60	0.16
075203607	111291	119723	0	0	57871.32	0.40
090603520	5000	4713	0	0	2600.00	0.31
095003902	352	285	0	0	183.04	0.20
095013603	23591	33904	0	0	12267.32	0.55
120013509	0	0	23818	19667	15481.70	0.21
120043506	1676	1898	1063	1163	1562.47	0.42
120053515	525	130	0	0	273.00	-1.63
120103563	3208	335	0	0	1668.16	-5.22
120203538	5587	6040	0	0	2905.24	0.40
120403516	1221	2422	337	442	853.97	0.64
120603524	3393	5266	0	0	1764.36	0.58
120703519	6042	4381	0	0	3141.84	0.10
125603606	14836	5601	0	0	7714.72	-0.72
130003401	125	23	0	0	65.00	-2.53
130203524	264	143	0	0	137.28	-0.20
130403525	11218	8330	0	0	5833.36	0.12
130753428	0	0	26288	11326	17087.20	-0.51
130753431	4504	2275	0	0	2342.08	-0.29
131203521	0	0	562	448	365.30	0.18
131303436/7	4193	1134	0	0	2180.36	-1.40

Project Number	Plan Qty. Borrow (CY)	Actual Qty. Borrow (CY)	Plan Qty. Regular (CY)	Actual Qty. Regular (CY)	Approximate Fill Qty. (CY)	Calculated Shrinkage Factor
131603519	6687	4229	0	0	3477.24	-0.03
131753412	2531	540	0	0	1316.12	-2.05
135603611	178	439	0	0	92.56	0.74
160003645	9000	2888	0	0	4680.00	-1.03
160033511/2	0	0	159149	90859	103446.85	-0.14
160203536	448	1576	1984	2195	1522.56	0.56
160203543	0	0	2856	2412	1856.40	0.23
160303531	47694	50867	0	0	24800.88	0.39
160303543	59706	50624	0	0	31047.12	0.23
160303557	1260	1131	0	0	655.20	0.28
160303559	0	0	4141	3785	2691.65	0.29
160603515	25	37	0	0	13.00	0.56
160603534	0	0	81	186	52.65	0.72
160703523	0	0	5815	5026	3779.75	0.25
161003513	2000	413	0	0	1040.00	-2.15
161003902	0	0	198	70	128.70	-0.84
161303519	0	0	5067	3938	3293.55	0.16
161703514	15798	166	7108	9487	12835.16	-0.33
161803903/4	2551	1071	831	724	1866.67	-0.18
162103503	23444	16738	79274	72344	63718.98	0.26
162503502	0	0	1299	570	844.35	-0.48
165013941	398	570	0	0	206.96	0.55
165603607	0	0	33005	18311	21453.25	-0.17
166303601	3103	2143	0	0	1613.56	0.06
170203560	810	1013	231	268	571.35	0.47
170753428	0	0	149	161	96.85	0.40
170753435	16209	8226	0	0	8428.68	-0.28
170753438	0	0	17127	16105	11132.55	0.31
170803513	336	125	0	0	174.72	-0.75
910203532	1048	1248	0	0	544.96	0.45

Table C.2. Summary of Regular and Borrow Quantities for District 2

Project Number	Plan Qty. Borrow (CY)	Actual Qty. Borrow (CY)	Plan Qty. Regular (CY)	Actual Qty. Regular (CY)	Approximate Fill Qty. (CY)	Calculated Shrinkage Factor
260003532	629	692	0	0	327.08	0.41
260103523	72257	2786	0	0	37573.64	-15.86
260203508	5770	5339	0	0	3000.40	0.30
260203557	2032	1757	0	0	1056.64	0.25
260203558	14089	12934	0	0	7326.28	0.29
260903501	0	0	1772	887	1151.80	-0.30
260903518	0	0	61209	82020	39785.85	0.51
260903524	0	0	1557	388	1012.05	-1.61
261003508	1349	1166	0	0	701.48	0.25
261103512	9993	12804	0	0	5196.36	0.49
261103513/4	0	0	86939	87489	56510.35	0.35
261303510	10670	1725	0	0	5548.40	-3.02
262503527	5280	6545	0	0	2745.60	0.48
266003607	79096	41328	0	0	41129.92	-0.24
267003605	600	421	0	0	312.00	0.07
270003601	2035	2770	0	0	1058.20	0.52
270103523	0	0	8200	6697	5330.00	0.20
275103606	11635	7640	0	0	6050.20	0.01
280003601	488	1332	0	0	253.76	0.76
280503501	3184	2264	0	0	1655.68	0.09
290203516/7	1265	685	0	0	657.80	-0.20
290303514	6400	1196	0	0	3328.00	-2.48
290303517	0	0	722	791	469.30	0.41
290303518	4473	4731	0	0	2325.96	0.39
290703512/3	5510	4238	160	170	2969.20	0.17
291803430	60499	56659	21329	22282	45323.33	0.33
291803448	7014	1563	0	0	3647.28	-1.92
305303602	56836	71042	35067	37887	52348.27	0.45
305303606	22031	16616	9553	8518	17665.57	0.19
320103504	4890	3550	0	0	2542.80	0.10
320303506	864	619	0	0	449.28	0.09
321003448	12489	5873	10493	9841	13314.73	0.08

Project Number	Plan Qty. Borrow (CY)	Actual Qty. Borrow (CY)	Plan Qty. Regular (CY)	Actual Qty. Regular (CY)	Approximate Fill Qty. (CY)	Calculated Shrinkage Factor
321003463	0	0	4450	3863	2892.50	0.25
325073601	10619	19431	0	0	5521.88	0.64
330103518	45729	44160	0	0	23779.08	0.33
340703514	279	614	0	0	145.08	0.70
340803503	537	565	0	0	279.24	0.38
340903601	23200	4118	0	0	12064.00	-2.66
350103527	230	217	0	0	119.60	0.31
350603512	1018	420.1	0	0	529.36	-0.58
370103518	400	161	487.54	367	524.90	-0.06
370103520	4301	5845	0	0	2236.52	0.52
370703504	793	133	0	0	412.36	-2.88
371203421	100	248	0	0	52.00	0.74
380103522	200	952	6819	7512	4536.35	0.45
380903501	11019	13816	0	0	5729.88	0.48
385803603	4090	1834	0	0	2126.80	-0.45
390903502	2528	1829	0	0	1314.56	0.10
710403505	0	0	2417	2543	1571.05	0.38
710503520	2604	2881	0	0	1354.08	0.41
710703540	0	0	800	402	520.00	-0.29
711103515	10422	3223	0	0	5419.44	-1.10
715503602	14374	12144	0	0	7474.48	0.23
720003505	4000	713	11414	3492	9499.10	-1.34
720003646	1542	1628	0	0	801.84	0.38
720003647	2464	2685	0	0	1281.28	0.40
720013456	0	0	2248	1248	1461.20	-0.17
720123506	18334	16891	0	0	9533.68	0.29
720203474	0	0	9128	8388	5933.20	0.29
720403555	1500	1165	0	0	780.00	0.16
720703501	756	643	506	427	722.02	0.23
720903546	16436	5099	2808	1601	10371.92	-0.83
721003527	316	507	0	0	164.32	0.59
721003565	25246	6871	3374	3276	15321.02	-0.75

Project Number	Plan Qty. Borrow (CY)	Actual Qty. Borrow (CY)	Plan Qty. Regular (CY)	Actual Qty. Regular (CY)	Approximate Fill Qty. (CY)	Calculated Shrinkage Factor
721603553	1521	1442	0	0	790.92	0.31
721903539	3019	6530	0	0	1569.88	0.70
721903542	44144	31078	0	0	22954.88	0.08
722403511	0	0	147	118	95.55	0.19
722503501	21380	7628	35812	30022	34395.40	0.05
722503537	1442	447	455	229	1045.59	-0.78
722503553	7126	1446	0	0	3705.52	-2.20
722903411	72406	57585	13232	11020	46251.92	0.19
722903418	2756	3504	1338	1769	2302.82	0.50
726903606	688	902	5169	3050	3717.61	0.01
740203508	3180	813	989	604	2296.45	-0.83
740303513	18283	11726	3727	3434	11929.71	0.07
740303514	2400	3251	1644	1490	2316.60	0.43
740303515	0	0	340	319	221.00	0.31
740403516	15739	21490	0	0	8184.28	0.52
740403520	0	0	11413	30000	7418.45	0.75
741103502	0	0	2201	1782	1430.65	0.20
741603416	49540	70844	8033	8636	30982.25	0.53
760103504	634	528	0	0	329.68	0.22
760103523	0	0	586	178	380.90	-1.14
760203519	653	19	0	0	339.56	-21.34
760303517/8	28399	35166	131422	119481	100191.78	0.32
780103504	0	0	2600	3653	1690.00	0.54
780103528	30700	9129	0	0	15964.00	-1.19
780303525	230	434	0	0	119.60	0.66
780403529	0	0	4565	4254	2967.25	0.30
780403542	0	0	2278.9	7214	1481.29	0.79
780503502	12856	1486	0	0	6685.12	-4.62
780503514	140	262	0	0	72.80	0.65
780503518	6574	4461	826	974	3955.38	0.13
780803420	19325	17587	0	0	10049.00	0.29
780803422	10322	24595	0	0	5367.44	0.73
780803423	14896	20298	0	0	7745.92	0.52

Table C.3. Summary of Regular and Borrow Quantities for District 3

Project Number	Plan Qty. Borrow (CY)	Actual Qty. Borrow (CY)	Plan Qty. Regular (CY)	Actual Qty. Regular (CY)	Approximate Fill Qty. (CY)	Calculated Shrinkage Factor
460103539	0	0	7500	5305	4875.00	0.08
460803512	1654	2097	0	0	860.08	0.49
461403523	1438	6288	0	0	747.76	0.85
461403530	1485	442	0	0	772.20	-1.18
461603511	9966	10666	0	0	5182.32	0.39
461603514	23883	11314	0	0	12419.16	-0.37
465003605	3724	3532	0	0	1936.48	0.31
480103550	3534	3145	0	0	1837.68	0.27
480133509	25	221	0	0	13.00	0.93
480203556	5126	5985	0	0	2665.52	0.44
480303511	0	0	688	744	447.20	0.40
480403565	500	22642	0	0	260.00	0.99
480603520	600	545	0	0	312.00	0.28
480603523	12030	1512	0	0	6255.60	-4.17
480993811	763	33	2599	2823	2086.11	0.27
481903507	1316	221	0	0	684.32	-2.87
482603458	21094	14956	0	0	10968.88	0.08
487313605	3774	2010	0	0	1962.48	-0.22
490103533	33754	36923	0	0	17552.08	0.41
490603509	1409	1814	0	0	732.68	0.50
500013437	30000	24370	0	0	15600.00	0.20
500013444	0	0	791	97	514.15	-4.30
500103537	4415	6747	0	0	2295.80	0.57
500503509	484	540	0	0	251.68	0.42
520103523	1695	1229	0	0	881.40	0.10
520303516	30587	36089	0	0	15905.24	0.45
520503520	4919	2942	0	0	2557.88	-0.09
521103601	879	435	0	0	457.08	-0.31
521203502	5279	4481	0	0	2745.08	0.23
530023430	456	1804	399	1319	496.47	0.82
530103522	2040	1298	0	0	1060.80	-0.02
530303525	0	0	4500	3922	2925.00	0.25

Project Number	Plan Qty. Borrow (CY)	Actual Qty. Borrow (CY)	Plan Qty. Regular (CY)	Actual Qty. Regular (CY)	Approximate Fill Qty. (CY)	Calculated Shrinkage Factor
530603515	3564	2793	0	0	1853.28	0.17
530703518/9	33683	35025	0	0	17515.16	0.37
540013421	17630	6733	4700	599	12222.60	-1.04
540013429	10776	3501	0	0	5603.52	-1.00
540013431	158	83	70	221	127.66	0.56
540203509	2117	1045	0	0	1100.84	-0.32
540303509	28020	17128	0	0	14570.40	-0.06
540603507	0	0	37886	37672	24625.90	0.35
550003643	5103	3886	56	156	2689.96	0.18
550023524	8251	4310	0	0	4290.52	-0.24
550023530	861	596	0	0	447.72	0.06
550103523	1424	279	0	0	740.48	-2.32
550203521	5980	1213	0	0	3109.60	-2.20
550403530	351	247	1230	1156	982.02	0.27
550503532	31358	13231	0	0	16306.16	-0.54
550603537	12709	10114	0	0	6608.68	0.18
550803537	200	455	0	0	104.00	0.71
550803539	1696	694	0	0	881.92	-0.59
550903529	481	560	0	0	250.12	0.44
551203505	146	84	0	0	75.92	-0.13
553003503	2039	6460	0	0	1060.28	0.79
555803614	52483	120556	0	0	27291.16	0.72
560103521	689	907	0	0	358.28	0.51
570103523	176	301	498	802	415.22	0.60
570303593	625	115	0	0	325.00	-2.53
570303599	75	112	0	0	39.00	0.56
570403561	2494	1136	0	0	1296.88	-0.43
570403571	201	169	0	0	104.52	0.23
570603512	6220	2242	0	0	3234.40	-0.80
570703505	15106	15933	0	0	7855.12	0.38
570703506	0	0	1178	1983	765.70	0.61
571303505	0	0	10000	4210	6500.00	-0.54

Project Number	Plan Qty. Borrow (CY)	Actual Qty. Borrow (CY)	Plan Qty. Regular (CY)	Actual Qty. Regular (CY)	Approximate Fill Qty. (CY)	Calculated Shrinkage Factor
580023444	13670	6922	2885	1939	8983.65	-0.20
580303526	3058	3501	1628	1787	2648.36	0.42
580503518	14020	6459	0	0	7290.40	-0.41
580603505	920	730	0	0	478.40	0.18
580803521/2	59951	54983	0	0	31174.52	0.29
595123602	5378	4453	0	0	2796.56	0.21
600023418	2214	4925	0	0	1151.28	0.71
600023424	8890	6979	0	0	4622.80	0.17
600103516	1550	693	0	0	806.00	-0.45
600203515	424	955	37605	49479	24663.73	0.51
600403527	7631	12457	1032	956	4638.92	0.58
600703508	7767	8435	0	0	4038.84	0.40
601003505	19464.75	24206	0	0	10121.67	0.48
610013418	7068	16039	25	259	3691.61	0.72
610013425	186	400	224	86	242.32	0.40
610403518	9920	10913	998	707	5807.10	0.38
610803529	748	2038	0	0	388.96	0.76
615203604	2079	2362	0	0	1081.08	0.43

Table C.4. Summary of Regular and Borrow Quantities for District 4

Project Number	Plan Qty. Borrow (CY)	Actual Qty. Borrow (CY)	Plan Qty. Regular (CY)	Actual Qty. Regular (CY)	Approximate Fill Qty. (CY)	Calculated Shrinkage Factor
860003628	0	0	1423	1188	924.95	0.22
860103547	0	0	1377	1512	895.05	0.41
860143513	0	0	1607	1463	1044.55	0.29
860283503	85	184	0	0	44.20	0.70
860283902	0	0	105	418	68.25	0.84
860403504	12648	15321	0	0	6576.96	0.46
860603500	11988	13668	0	0	6233.76	0.43
860653503	0	0	549	614	356.85	0.42
860703410	0	0	456	338	296.40	0.12
860753448	4645	5285	0	0	2415.40	0.43
860753450	100	2128	0	0	52.00	0.97
860903511	0	0	260	172	169.00	0.02
860953401	0	0	5087	5010	3306.55	0.34
860953449	97140	118311	0	0	50512.80	0.47
860953457	2000	2446	11655	16374	8615.75	0.53
860953464	0	0	468	439	304.20	0.31
860953468	0	0	70699	78226	45954.35	0.41
860953485	0	0	26142	18672	16992.30	0.09
860953491	53105	49099	0	0	27614.60	0.30
861003507	0	0	225	553	146.25	0.74
861003512	0	0	14844	13141	9648.60	0.27
861003548	5238	1041	28984	25945	21563.36	0.19
861003574	0	0	1541	1333	1001.65	0.25
861103512	100	107.9	24	13	67.60	0.32
861303524	0	0	880	807	572.00	0.29
861703507	0	0	14787	17332	9611.55	0.45
861703509	0	0	18406	19423	11963.90	0.38
861703521	0	0	28465	30438	18502.25	0.39
862203530	0	0	9359	9942	6083.35	0.39
880103523	0	0	5420	5961	3523.00	0.41
880103901	0	0	3360	1721	2184.00	-0.27
880603525	2006	1466	506	1752	1372.02	0.53

Project Number	Plan Qty. Borrow (CY)	Actual Qty. Borrow (CY)	Plan Qty. Regular (CY)	Actual Qty. Regular (CY)	Approximate Fill Qty. (CY)	Calculated Shrinkage Factor
880813413	100	41	0	0	52.00	-0.59
890203503	23000	19552	5340	5865	15431.00	0.28
890303528	1750	3307	2492	2080	2529.80	0.46
890503512	4134	4351	1377	2058	3044.73	0.45
890603520	116520	81526	0	0	60590.40	0.07
890703501	0	0	219	183	142.35	0.22
930003635	1565	1079	0	0	813.80	0.06
930023500	625	530	0	0	325.00	0.23
930103532	0	0	3766	4294	2447.90	0.43
930263501	0	0	436	664	283.40	0.57
930403501	1679	811	0	0	873.08	-0.35
931003512	0	0	12609	6769	8195.85	-0.21
931103512	16302	34544	0	0	8477.04	0.69
931103542	20	80	0	0	10.40	0.84
931103544	1123	2828	0	0	583.96	0.74
931203523	0	0	66712	59312	43362.80	0.27
931803519	0	0	1369	974	889.85	0.09
931903510	0	0	71017	56096	46161.05	0.18
932203411	1364	1673	0	0	709.28	0.47
932903508	14006	15645	0	0	7283.12	0.42
933103502	0	0	2025	2190	1316.25	0.40
940013433	100	866	0	0	52.00	0.92
940053506	3704	2905	1054	719	2611.18	0.14
940303528	5416	4964	14586	13083	12297.22	0.28
940703903	8296	6644	0	0	4313.92	0.19
941203501	0	0	72566	57765	47167.90	0.18

Table C.5. Summary of Regular and Borrow Quantities for District 5

Project Number	Plan Qty. Borrow (CY)	Actual Qty. Borrow (CY)	Plan Qty. Regular (CY)	Actual Qty. Regular (CY)	Approximate Fill Qty. (CY)	Calculated Shrinkage Factor
110103557	4035	3659	9010	6765	7954.70	0.18
110403528	1546	5360	0	0	803.92	0.81
110403531	0	0	211	190	137.15	0.28
110603506	0	0	19	28	12.35	0.56
111003518	0	0	2325	1926	1511.25	0.22
111003519	10890	9930	0	0	5662.80	0.29
111003520	1157	1029	0	0	601.64	0.27
111103519	0	0	1364	1292	886.60	0.31
111303513	0	0	30519	19841	19837.35	0.00
112003527/8	3224	199	12098	16095	9540.18	0.41
180103505	4583	542	0	0	2383.16	-4.50
180103528	898	211	0	0	466.96	-1.77
180303512	0	0	5040	5888	3276.00	0.44
180703515	0	0	483	433	313.95	0.27
181203502	0	0	749	592	486.85	0.18
181303427	0	0	47450	45795	30842.50	0.33
360013512	0	0	6525	5860	4241.25	0.28
360043501/2	675	173	11151	9787	7599.15	0.23
260103531	0	0	482	220	313.30	-0.42
360503504	743	1243	0	0	386.36	0.61
360803529	3636	2068	0	0	1890.72	-0.14
360903501	0	0	1181	1017	767.65	0.25
700013505	0	0	70	101	45.50	0.55
700023511	49	17	0	0	25.48	-0.87
700043513	2738	2379	0	0	1423.76	0.25
700073504	10170	6413	8333	6468	10704.85	0.08
700103517	0	0	1703	2480	1106.95	0.55
700103522	0	0	1821.86	1976	1184.21	0.40
700103523	2557	2556	3776	3579	3784.04	0.33
700503541	0	0	3145	2730	2044.25	0.25
700603533	0	0	2764	1976	1796.60	0.09
700603535	0	0	7154	6422	4650.10	0.28

Project Number	Plan Qty. Borrow (CY)	Actual Qty. Borrow (CY)	Plan Qty. Regular (CY)	Actual Qty. Regular (CY)	Approximate Fill Qty. (CY)	Calculated Shrinkage Factor
700703529	2999	3431	3673	3464	3946.93	0.36
701103511	2709	2182	0	0	1408.68	0.19
701403520	1108	209	0	0	576.16	-2.45
702203435	16205	11829	182	137	8544.90	0.11
702203437	765	1217	92	85	457.60	0.57
702253415	26746	18669	0	0	13907.92	0.07
702253418	4178	1880	1999	2209	3471.91	0.06
730013419	107609	16431	1534	976	56953.78	-3.03
730103521	1830	5888	1614	1428	2000.70	0.67
730103522	0	0	1299	1372	844.35	0.38
730203519	659	823	651	504	765.83	0.34
750023524	0	0	74205	66158	48233.25	0.27
750023535	0	0	4652	3012	3023.80	0.00
750023539	0	0	542.4	667	352.56	0.47
750103527	650	169	0	0	338.00	-1.50
750503540	2255	793	0	0	1172.60	-0.85
750373501	1894	2029	0	0	984.88	0.39
750503501	120	69	0	0	62.40	-0.13
750503546	0	0	4964	3070	3226.60	-0.05
750503548	0	0	1227	1022	797.55	0.22
750603556	627	1354	1315	1148	1180.79	0.47
751903529	1740	245	1105	1042	1623.05	-0.31
751903531	0	0	1818	2150	1181.70	0.45
752203503	5042	605	316	423	2827.24	-2.12
752503520/1	234	178	871	956	687.83	0.37
752803457	0	0	13052	10796	8483.80	0.21
752803462	0	0	88045	94045	57229.25	0.39
770403504	5631	1648	0	0	2928.12	-1.22
770403517/8	83846.51	8461	14936.3	15734	53308.78	-1.37
770403520	1881	1203	0	0	978.12	-0.02
770703522	0	0	1371	1247	891.15	0.29
770803550	15165	5786	224	811	8031.40	-0.48

Project Number	Plan Qty. Borrow (CY)	Actual Qty. Borrow (CY)	Plan Qty. Regular (CY)	Actual Qty. Regular (CY)	Approximate Fill Qty. (CY)	Calculated Shrinkage Factor
771703504	0	0	3754	4105	2440.10	0.41
790013511	361	265	1489	1314	1155.57	0.24
790103543	88	178	0	0	45.76	0.68
790103903	795	720	0	0	413.40	0.28
790403501	1309	274	0	0	680.68	-2.11
790503515/6	0	0	14053	11567	9134.45	0.21
790703549	131.9	60	0	0	68.59	-0.43
791003530	4263	3679	0	0	2216.76	0.25
791203506	10004	18715	2571	2410	6873.23	0.60
791703514	1965	1392	202	16	1153.10	-0.02
791803520	1496	830	173	158	890.37	-0.08
791813518	0	0	19056	2516	12386.40	-3.92
920103524	940	853	0	0	488.80	0.28
920303541	3607	738	2023	1753	3190.59	-0.36
920603504	1143	449	0	0	594.36	-0.65

Table C.6. Summary of Regular and Borrow Quantities for District 6

Project Number	Plan Qty. Borrow (CY)	Actual Qty. Borrow (CY)	Plan Qty. Regular (CY)	Actual Qty. Regular (CY)	Approximate Fill Qty. (CY)	Calculated Shrinkage Factor
870003656	100	162	0	0	52.00	0.60
870003687	3238	4242	0	0	1683.76	0.50
870033521	80000	75039	0	0	41600.00	0.31
870043415	0	0	29417	27608	19121.05	0.31
870083508	14508	8284	0	0	7544.16	-0.14
870203536	0	0	350	420	227.50	0.46
870263505	0	0	1895	1723	1231.75	0.29
870373507	21717	17265	0	0	11292.84	0.18
870443503	0	0	7155	7740	4650.75	0.40
870443910	0	0	1100	1472	715.00	0.51
870533502	0	0	6406	6000	4163.90	0.31
870603554	0	0	318	369	206.70	0.44
871003543	15	25	0	0	7.80	0.61
873003507	0	0	22958.5	21284	14923.03	0.30
900203568	3999	3460	0	0	2079.48	0.25
900403508	0	0	3000	437	1950.00	-3.46
900403518	0	0	97521	83096	63388.65	0.24
900603576	1550	1047	600	529	1196.00	0.12
900603584	500	564	0	0	260.00	0.42

Table C.7. Summary of Regular and Borrow Quantities for District 7

Project Number	Plan Qty. Borrow (CY)	Actual Qty. Borrow (CY)	Plan Qty. Regular (CY)	Actual Qty. Regular (CY)	Approximate Fill Qty. (CY)	Calculated Shrinkage Factor
020103905	2358	456	0	0	1226.16	-2.36
020103516	0	0	196706	175527	127858.90	0.27
020303537	19	35	0	0	9.88	0.65
020503523	0	0	410232	309304	266650.80	0.14
020503528	0	0	93	203	60.45	0.70
080103531	0	0	8151	5028	5298.15	-0.05
080403505	28094	34925	0	0	14608.88	0.48
080603501	12998	1127	2091	2614	8118.11	-1.31
080803902	4121	3302	66872	40851	45609.72	-0.05
100103528	12974.9	9246.24	0	0	6746.93	0.09
100103544	0	0	2545	1844	1654.25	0.10
100303509	1411	2968	0	0	733.72	0.69
100403531	0	0	1862	1761	1210.30	0.31
100603580	700	1616	8418	7117	5835.70	0.31
100603581	0	0	7426	5612	4826.90	0.14
100753466	1688	244	0	0	877.76	-3.50
100903532	0	0	5734	4772	3727.10	0.22
101103548	140	105	0	0	72.80	0.13
101103565/6	1582	2158	2544	2747	2476.24	0.45
101203511	0	0	16175	17284	10513.75	0.39
101203514	2500	7296	0	0	1300.00	0.78
101203519	7455	10697	28257	25015	22243.65	0.34
101203522	5474	3984	1159	1286	3599.83	0.20
101403502	733	1164	2848	2582	2232.36	0.36
101403527	225636	193098	0	0	117330.72	0.24
101503532	0	0	56788	45488	36912.20	0.19
101503541	245	100	0	0	127.40	-0.59
101603525	104535	96673	0	0	54358.20	0.30
101903420	23840	11410	0	0	12396.80	-0.36
101903470	0	0	30200	27714	19630.00	0.29
102103513	17729	7222	0	0	9219.08	-0.60
102503522	3260	7751	0	0	1695.20	0.73

Project Number	Plan Qty. Borrow (CY)	Actual Qty. Borrow (CY)	Plan Qty. Regular (CY)	Actual Qty. Regular (CY)	Approximate Fill Qty. (CY)	Calculated Shrinkage Factor
102503524	0	0	1639	2192	1065.35	0.51
102603515	9341	5488	0	0	4857.32	-0.11
102903513	0	0	42994	37550	27946.10	0.26
103103515	0	0	1113	610	723.45	-0.19
103103516	0	0	325	418	211.25	0.49
103303506	1200	955	0	0	624.00	0.18
105303605	12681	5600	0	0	6594.12	-0.47
140303554	0	0	110041	92648	71526.65	0.23
140503541	1386	404	0	0	720.72	-1.23
140803506	6669	3632	0	0	3467.88	-0.19
141203506	15977	11047	0	0	8308.04	0.06
150203527	0	0	862	816	560.30	0.31
150403517	2000	1795	0	0	1040.00	0.28
150503529	0	0	715	602	464.75	0.23
150903518	750	1146	0	0	390.00	0.57
151903483	30000	51954	0	0	15600.00	0.62
155603603	139	324	529	599	416.13	0.52

Table C.8. Summary of Regular and Borrow Quantities for Turnpike District

Project Number	Plan Qty. Borrow (CY)	Actual Qty. Borrow (CY)	Plan Qty. Regular (CY)	Actual Qty. Regular (CY)	Approximate Fill Qty. (CY)	Calculated Shrinkage Factor
977503354	0	0	909	819	590.85	0.28
977703311	0	0	261	1006	169.65	0.83
978643306	19378	15275	0	0	10076.56	0.18
978693357	1000	6386	5890	5493	4348.50	0.59
978713321	44255	60406	42334	34401	50529.70	0.39
978713340	0	0	3154	3773	2050.10	0.46
978713398	0	0	469	141	304.85	-1.16
978803313/4	2039	2958	738.1	522	1540.05	0.47
978803316/7	1800	1059	3469	3122	3190.85	0.20
978903327/8	0	0	78310	88213	50901.50	0.42
979103331	1057	1329	2523	512	2189.59	-0.39
979203326	1128	4904	893	713	1167.01	0.75
979203329	0	0	361	329	234.65	0.29
979203340	7200	2420	9572	10113	9965.80	0.17
979203341	0	0	8351	7341	5428.15	0.26
979303301	2000	4413	0	0	1040.00	0.71
979303325	0	0	2162	1552	1405.30	0.09
979303375	100	310	0	0	52.00	0.79
979313348	0	0	62883	44739	40873.95	0.09
979403361	316	101	0	0	164.32	-1.03
979403384	44834	23751	0	0	23313.68	-0.23
990013417	594	24	0	0	308.88	-15.09

Table C.9 Detailed Year-by-Year Cost Analysis based on Difference in Planned and Actual Quantities

Year	Project #	ITEM	Planned Quantity	Final Quantity	Bid	DifQ	DifQ(%)	Cost ($) Overrun/ Underrun
1991	102903513	120-1	42994.00	37550.00	1.350	5444.00	12.66	$7,349.40
1991	150203527	120-1	862.00	816.00	14.000	46.00	5.34	$644.00
1991	160603534	120-1	81.00	186.00	60.000	-105.00	-129.63	$6,300.00
1991	162103503	120-1	34398.00	30236.00	2.400	4162.00	12.10	$9,988.80
1991	162103503	120-1	44876.00	42108.00	2.400	2768.00	6.17	$6,643.20
1991	180703515	120-1	483.00	433.00	6.000	50.00	10.35	$300.00
1991	290303517	120-1	722.00	791.00	8.000	-69.00	-9.56	$552.00
1991	370103518	120-1	487.54	367.00	8.000	120.54	24.72	$964.32
1991	540013421	120-1	4700.00	599.00	3.150	4101.00	87.26	$12,918.15
1991	700013505	120-1	70.00	101.00	26.900	-31.00	-44.29	$833.90
1991	700103517	120-1	1703.00	2480.00	6.500	-777.00	-45.63	$5,050.50
1991	700103522	120-1	1821.86	1976.00	11.040	-154.14	-8.46	$1,701.71
1991	710703540	120-1	800.00	402.00	4.600	398.00	49.75	$1,830.80
1991	722403511	120-1	147.00	118.00	6.000	29.00	19.73	$174.00
1991	730103521	120-1	1614.00	1428.00	10.000	186.00	11.52	$1,860.00
1991	740203508	120-1	989.00	604.00	17.390	385.00	38.93	$6,695.15
1991	740203514	120-1	1644.00	1490.00	4.500	154.00	9.37	$693.00
1991	750023535	120-1	4652.00	3012.00	5.500	1640.00	35.25	$9,020.00
1991	752503520	120-1	871.00	956.00	5.200	-85.00	-9.76	$442.00
1991	752803457	120-1	13052.00	10796.00	1.500	2256.00	17.28	$3,384.00
1991	791803520	120-1	173.00	158.00	10.000	15.00	8.67	$150.00
1991	860283902	120-1	105.00	418.00	10.000	-313.00	-298.10	$3,130.00
1991	860953464	120-1	468.00	439.00	3.300	29.00	6.20	$95.70
1991	861303524	120-1	880.00	807.00	6.000	73.00	8.30	$438.00
1991	870443910	120-1	1100.00	1472.00	15.680	-372.00	-33.82	$5,832.96
1991	880103523	120-1	5420.00	5961.00	3.700	-541.00	-9.98	$2,001.70
1991	880103901	120-1	3360.00	1721.00	2.870	1639.00	48.78	$4,703.93
1991	890203503	120-1	5340.00	5865.00	2.950	-525.00	-9.83	$1,548.75
1991	900403508	120-1	3000.00	437.00	6.750	2563.00	85.43	$17,300.25
1991	931803519	120-1	1369.00	974.00	3.000	395.00	28.85	$1,185.00
1991	978803316	120-1	3469.00	3122.00	3.720	347.00	10.00	$1,290.84
1991	979203340	120-1	9572.00	10113.00	2.000	-541.00	-5.65	$1,082.00
1991	020503528	120-1	93.00	203.00	3.000	-110.00	-118.28	$330.00
1991	NA	120-1	637.00	686.00	10.000	-49.00	-7.69	$490.00
1991	NA	120-1	20001.00	25702.00	1.650	-5701.00	-28.50	$9,406.65
1991	NA	120-1	5396.00	16822.00	1.500	-11426.00	-211.75	$17,139.00
1992	110103557	120-1	4530.00	2850.00	1.000	1680.00	37.09	$1,680.00
1992	110103557	120-1	4480.00	3915.00	1.000	565.00	12.61	$565.00
1992	120403516	120-1	337.00	442.00	10.000	-105.00	-31.16	$1,050.00

Year	Project #	ITEM	Planned Quantity	Final Quantity	Bid	DifQ	DifQ(%)	Cost ($) Overrun/ Underrun
1992	131203521	120-1	562.00	448.00	15.250	114.00	20.28	$1,738.50
1992	150503529	120-1	715.00	602.00	8.000	113.00	15.80	$904.00
1992	160033511	120-1	104743.	47070.00	1.700	57673.00	55.06	$98,044.10
1992	160303559	120-1	4141.00	3785.00	3.000	356.00	8.60	$1,068.00
1992	161803904	120-1	831.00	724.00	5.400	107.00	12.88	$577.80
1992	170753428	120-1	149.00	161.00	9.500	-12.00	-8.05	$114.00
1992	360103531	120-1	482.00	220.00	22.000	262.00	54.36	$5,764.00
1992	460103539	120-1	7500.00	5305.00	5.000	2195.00	29.27	$10,975.00
1992	550403530	120-1	1230.00	1156.00	7.500	74.00	6.02	$555.00
1992	610403518	120-1	998.00	707.00	2.250	291.00	29.16	$654.75
1992	700103523	120-1	3776.00	3579.00	1.430	197.00	5.22	$281.71
1992	700603533	120-1	2764.00	1976.00	4.360	788.00	28.51	$3,435.68
1992	720013456	120-1	2248.00	1248.00	4.500	1000.00	44.48	$4,500.00
1992	750023539	120-1	542.40	667.00	13.140	-124.60	-22.97	$1,637.24
1992	760103523	120-1	586.00	178.00	4.320	408.00	69.62	$1,762.56
1992	780403529	120-1	4565.00	4254.00	8.950	311.00	6.81	$2,783.45
1992	790013511	120-1	1489.00	1314.00	9.000	175.00	11.75	$1,575.00
1992	791203506	120-1	2571.00	2410.00	5.000	161.00	6.26	$805.00
1992	860953401	120-1	2930.00	2610.00	5.000	320.00	10.92	$1,600.00
1992	860953401	120-1	2157.00	2400.00	3.000	-243.00	-11.27	$729.00
1992	861003548	120-1	28984.00	25945.00	1.720	3039.00	10.49	$5,227.08
1992	870533502	120-1	6406.00	6000.00	13.070	406.00	6.34	$5,306.42
1992	890303528	120-1	2492.00	2080.00	6.500	412.00	16.53	$2,678.00
1992	890503512	120-1	1377.00	2058.00	14.050	-681.00	-49.46	$9,568.05
1992	977503354	120-1	909.00	819.00	5.000	90.00	9.90	$450.00
1992	978693357	120-1	5890.00	5493.00	3.800	397.00	6.74	$1,508.60
1992	978803313	120-1	738.10	522.00	10.000	216.10	29.28	$2,161.00
1992	978903327	120-1	40631.00	44476.00	1.710	-3845.00	-9.46	$6,574.95
1992	978903328	120-1	37679.00	43737.00	2.190	-6058.00	-16.08	$13,267.02
1992	979103331	120-1	2523.00	512.00	7.000	2011.00	79.71	$14,077.00
1992	979203329	120-1	361.00	329.00	20.000	32.00	8.86	$640.00
1992	979303325	120-1	2162.00	1552.00	5.000	610.00	28.21	$3,050.00
1992	979313348	120-1	62883.00	44739.00	1.150	18144.00	28.85	$20,865.60
1992	030803518	120-1	6803.00	6431.00	3.270	372.00	5.47	$1,216.44
1993	103103515	120-1	1113.00	610.00	7.500	503.00	45.19	$3,772.50
1993	103103516	120-1	325.00	418.00	15.000	-93.00	-28.62	$1,395.00
1993	111003518	120-1	1742.00	1464.00	6.700	278.00	15.96	$1,862.60
1993	111003518	120-1	583.00	462.00	6.700	121.00	20.75	$810.70
1993	111103519	120-1	1364.00	1292.00	4.000	72.00	5.28	$288.00
1993	120043506	120-1	1063.00	1163.00	5.000	-100.00	-9.41	$500.00
1993	120203538	120-1	5587.00	6040.00	3.180	-453.00	-8.11	$1,440.54
1993	160033512	120-1	54406.00	43789.00	3.250	10617.00	19.51	$34,505.25

Year	Project #	ITEM	Planned Quantity	Final Quantity	Bid	DifQ	DifQ(%)	Cost ($) Overrun/ Underrun
1993	160703523	120-1	5815.00	5026.00	3.150	789.00	13.57	$2,485.35
1993	161303519	120-1	5067.00	3938.00	1.850	1129.00	22.28	$2,088.65
1993	161303519	120-1	5067.00	3938.00	2.000	1129.00	22.28	$2,258.00
1993	170203560	120-1	231.00	268.00	30.110	-37.00	-16.02	$1,114.07
1993	170753438	120-1	17127.00	16105.00	5.200	1022.00	5.97	$5,314.40
1993	305303606	120-1	9553.00	8518.00	5.000	1035.00	10.83	$5,175.00
1993	571303505	120-1	10000.00	4210.00	3.750	5790.00	57.90	$21,712.50
1993	600403527	120-1	1032.00	956.00	5.000	76.00	7.36	$380.00
1993	610013418	120-1	25.00	259.00	20.000	-234.00	-936.00	$4,680.00
1993	700073504	120-1	8333.00	6468.00	3.850	1865.00	22.38	$7,180.25
1993	700603535	120-1	7154.00	6422.00	8.800	732.00	10.23	$6,441.60
1993	700703529	120-1	3673.00	3464.00	4.000	209.00	5.69	$836.00
1993	720203474	120-1	9128.00	8388.00	3.600	740.00	8.11	$2,664.00
1993	726903606	120-1	5169.00	3050.00	2.000	2119.00	40.99	$4,238.00
1993	740203513	120-1	3727.00	3434.00	5.020	293.00	7.86	$1,470.86
1993	740203515	120-1	340.00	319.00	7.000	21.00	6.18	$147.00
1993	751903529	120-1	1105.00	1042.00	8.190	63.00	5.70	$515.97
1993	752203503	120-1	316.00	423.00	5.000	-107.00	-33.86	$535.00
1993	752803462	120-1	88045.00	94045.00	4.000	-6000.00	-6.81	$24,000.00
1993	770403517	120-1	14936.30	15734.00	4.250	-797.70	-5.34	$3,390.23
1993	770703522	120-1	1371.00	1247.00	11.250	124.00	9.04	$1,395.00
1993	770803550	120-1	224.00	811.00	12.600	-587.00	-262.05	$7,396.20
1993	771703504	120-1	3754.00	4105.00	4.000	-351.00	-9.35	$1,404.00
1993	780703518	120-1	17725.00	5225.00	3.000	12500.00	70.52	$37,500.00
1993	790503515	120-1	4053.00	3554.00	7.000	499.00	12.31	$3,493.00
1993	791813518	120-1	19056.00	2516.00	0.010	16540.00	86.80	$165.40
1993	860143513	120-1	1607.00	1463.00	10.010	144.00	8.96	$1,441.44
1993	860653503	120-1	549.00	614.00	5.770	-65.00	-11.84	$375.05
1993	860953457	120-1	6833.00	11167.00	0.400	-4334.00	-63.43	$1,733.60
1993	860953457	120-1	4822.00	5207.00	6.400	-385.00	-7.98	$2,464.00
1993	861003512	120-1	14844.00	13141.00	3.150	1703.00	11.47	$5,364.45
1993	861703509	120-1	18406.00	19423.00	1.500	-1017.00	-5.53	$1,525.50
1993	861703521	120-1	28465.00	30438.00	6.550	-1973.00	-6.93	$12,923.15
1993	870043415	120-1	29417.00	27608.00	5.000	1809.00	6.15	$9,045.00
1993	870203536	120-1	350.00	420.00	10.000	-70.00	-20.00	$700.00
1993	870603554	120-1	318.00	369.00	20.000	-51.00	-16.04	$1,020.00
1993	890703501	120-1	219.00	183.00	31.720	36.00	16.44	$1,141.92
1993	900403518	120-1	54005.00	45005.00	7.000	9000.00	16.67	$63,000.00
1993	900403518	120-1	11616.00	12240.00	2.800	-624.00	-5.37	$1,747.20
1993	900403518	120-1	26500.00	21859.00	2.000	4641.00	17.51	$9,282.00
1993	900403518	120-1	5400.00	3992.00	4.000	1408.00	26.07	$5,632.00
1993	900603576	120-1	600.00	529.00	23.000	71.00	11.83	$1,633.00

Year	Project #	ITEM	Planned Quantity	Final Quantity	Bid	DifQ	DifQ(%)	Cost ($) Overrun/ Underrun
1993	931203523	120-1	66712.00	59312.00	3.680	7400.00	11.09	$27,232.00
1993	930263501	120-1	436.00	664.00	10.000	-228.00	-52.29	$2,280.00
1993	931903510	120-1	71017.00	56096.00	0.420	14921.00	21.01	$6,266.82
1993	020503523	120-1	410232.0	309304.0	0.900	100928.00	24.60	$90,835.20
1993	080803902	120-1	66872.00	40851.00	4.000	26021.00	38.91	$104,084.00
1994	100403531	120-1	1862.00	1761.00	12.950	101.00	5.42	$1,307.95
1994	100603580	120-1	3219.00	2709.00	3.400	510.00	15.84	$1,734.00
1994	100603580	120-1	5199.00	4408.00	3.400	791.00	15.21	$2,689.40
1994	100603581	120-1	5080.00	4443.00	4.600	637.00	12.54	$2,930.20
1994	100603581	120-1	566.00	437.00	4.600	129.00	22.79	$593.40
1994	100603581	120-1	1780.00	732.00	4.600	1048.00	58.88	$4,820.80
1994	100903532	120-1	5734.00	4772.00	3.500	962.00	16.78	$3,367.00
1994	101203511	120-1	16175.00	17284.00	2.000	-1109.00	-6.86	$2,218.00
1994	101203519	120-1	28257.00	25015.00	3.680	3242.00	11.47	$11,930.56
1994	101203522	120-1	1159.00	1286.00	8.000	-127.00	-10.96	$1,016.00
1994	101503532	120-1	29814.00	22744.00	1.600	7070.00	23.71	$11,312.00
1994	101503532	120-1	26974.00	22744.00	1.600	4230.00	15.68	$6,768.00
1994	101903470	120-1	30200.00	27714.00	0.750	2486.00	8.23	$1,864.50
1994	140303554	120-1	110041.0	92648.00	2.450	17393.00	15.81	$42,612.85
1994	160203536	120-1	1984.00	2195.00	2.600	-211.00	-10.64	$548.60
1994	161703514	120-1	7108.00	9487.00	2.740	-2379.00	-33.47	$6,518.46
1994	180303512	120-1	5040.00	5888.00	1.800	-848.00	-16.83	$1,526.40
1994	260903501	120-1	1772.00	887.00	3.500	885.00	49.94	$3,097.50
1994	261103513	120-1	58888.00	55050.00	2.850	3838.00	6.52	$10,938.30
1994	261103514	120-1	27881.00	31836.00	3.000	-3955.00	-14.19	$11,865.00
1994	261103514	120-1	170.00	603.00	3.000	-433.00	-254.71	$1,299.00
1994	270103523	120-1	8200.00	6697.00	4.000	1503.00	18.33	$6,012.00
1994	360013512	120-1	6525.00	5860.00	3.000	665.00	10.19	$1,995.00
1994	360043501	120-1	10672.00	9411.00	6.000	1261.00	11.82	$7,566.00
1994	360093502	120-1	479.00	376.00	7.500	103.00	21.50	$772.50
1994	380103522	120-1	6819.00	7512.00	8.000	-693.00	-10.16	$5,544.00
1994	480303511	120-1	688.00	744.00	7.800	-56.00	-8.14	$436.80
1994	530023430	120-1	399.00	1319.00	7.810	-920.00	-230.58	$7,185.20
1994	550003643	120-1	56.00	156.00	20.000	-100.00	-178.57	$2,000.00
1994	710403505	120-1	2417.00	2543.00	3.500	-126.00	-5.21	$441.00
1994	720703501	120-1	482.00	397.00	18.900	85.00	17.63	$1,606.50
1994	720703501	120-1	24.00	30.00	18.900	-6.00	-25.00	$113.40
1994	720903546	120-1	2808.00	1601.00	2.290	1207.00	42.98	$2,764.03
1994	721003565	120-1	2738.00	2165.00	3.000	573.00	20.93	$1,719.00
1994	721003565	120-1	596.00	1067.00	11.700	-471.00	-79.03	$5,510.70
1994	721003565	120-1	40.00	44.00	11.700	-4.00	-10.00	$46.80
1994	722903418	120-1	1338.00	1769.00	6.000	-431.00	-32.21	$2,586.00

Year	Project #	ITEM	Planned Quantity	Final Quantity	Bid	DifQ	DifQ(%)	Cost ($) Overrun/ Underrun
1994	741603416	120-1	8033.00	8636.00	4.000	-603.00	-7.51	$2,412.00
1994	750023524	120-1	74205.00	66158.00	2.530	8047.00	10.84	$20,358.91
1994	780503518	120-1	826.00	974.00	4.500	-148.00	-17.92	$666.00
1994	860953468	120-1	70699.00	78226.00	2.100	-7527.00	-10.65	$15,806.70
1994	861003512	120-1	24.00	13.00	17.800	11.00	45.83	$195.80
1994	870443503	120-1	7155.00	7740.00	6.500	-585.00	-8.18	$3,802.50
1994	880603525	120-1	506.00	1752.00	9.080	-1246.00	-246.25	$11,313.68
1994	933103502	120-1	2025.00	2190.00	6.000	-165.00	-8.15	$990.00
1994	940303528	120-1	14586.00	13083.00	3.890	1503.00	10.30	$5,846.67
1994	978713340	120-1	3154.00	3773.00	2.600	-619.00	-19.63	$1,609.40
1994	055303603	120-1	12476.00	10380.00	2.630	2096.00	16.80	$5,512.48
1995	100103544	120-1	2545.00	1844.00	7.110	701.00	27.54	$4,984.11
1995	101103566	120-1	2544.00	2747.00	6.000	-203.00	-7.98	$1,218.00
1995	101403502	120-1	2848.00	2582.00	2.220	266.00	9.34	$590.52
1995	102503524	120-1	1639.00	2192.00	4.100	-553.00	-33.74	$2,267.30
1995	110403531	120-1	211.00	190.00	10.000	21.00	9.95	$210.00
1995	110603506	120-1	19.00	28.00	11.400	-9.00	-47.37	$102.60
1995	111303513	120-1	30519.00	19841.00	2.700	10678.00	34.99	$28,830.60
1995	112003527	120-1	12098.00	16095.00	0.580	-3997.00	-33.04	$2,318.26
1995	120013509	120-1	23818.00	19667.00	5.150	4151.00	17.43	$21,377.65
1995	130753428	120-1	26288.00	11326.00	2.050	14962.00	56.92	$30,672.10
1995	155603603	120-1	529.00	599.00	15.750	-70.00	-13.23	$1,102.50
1995	161003902	120-1	198.00	70.00	6.500	128.00	64.65	$832.00
1995	165603607	120-1	33005.00	18311.00	2.000	14694.00	44.52	$29,388.00
1995	181303427	120-1	45983.00	42893.00	1.500	3090.00	6.72	$4,635.00
1995	181303427	120-1	1467.00	2902.00	2.000	-1435.00	-97.82	$2,870.00
1995	290703513	120-1	160.00	170.00	25.000	-10.00	-6.25	$250.00
1995	291803430	120-1	19084.00	17621.00	3.000	1463.00	7.67	$4,389.00
1995	291803430	120-1	2245.00	4661.00	3.000	-2416.00	-107.62	$7,248.00
1995	530303525	120-1	4500.00	3922.00	2.670	578.00	12.84	$1,543.26
1995	540013431	120-1	70.00	221.00	7.000	-151.00	-215.71	$1,057.00
1995	570103523	120-1	498.00	802.00	8.720	-304.00	-61.04	$2,650.88
1995	580023444	120-1	2885.00	1939.00	6.410	946.00	32.79	$6,063.86
1995	580303526	120-1	1628.00	1787.00	14.750	-159.00	-9.77	$2,345.25
1995	610013425	120-1	224.00	86.00	10.000	138.00	61.61	$1,380.00
1995	702203437	120-1	92.00	85.00	9.100	7.00	7.61	$63.70
1995	702253418	120-1	1999.00	2209.00	13.000	-210.00	-10.51	$2,730.00
1995	720003505	120-1	6419.97	1498.00	7.000	4921.97	76.67	$34,453.79
1995	720003505	120-1	4994.00	1994.00	7.000	3000.00	60.07	$21,000.00
1995	722503501	120-1	35812.00	30022.00	1.870	5790.00	16.17	$10,827.30
1995	722503537	120-1	455.00	229.00	13.620	226.00	49.67	$3,078.12
1995	730013419	120-1	1534.00	976.00	5.250	558.00	36.38	$2,929.50

Year	Project #	ITEM	Planned Quantity	Final Quantity	Bid	DifQ	DifQ(%)	Cost ($) Overrun/ Underrun
1995	730203519	120-1	651.00	504.00	15.000	147.00	22.58	$2,205.00
1995	741103502	120-1	2201.00	1782.00	9.280	419.00	19.04	$3,888.32
1995	750503548	120-1	800.00	655.00	6.820	145.00	18.13	$988.90
1995	750503548	120-1	427.00	367.00	6.820	60.00	14.05	$409.20
1995	750603556	120-1	1315.00	1148.00	3.500	167.00	12.70	$584.50
1995	751903531	120-1	1818.00	2150.00	15.000	-332.00	-18.26	$4,980.00
1995	760303518	120-1	131422.	119481.0	1.750	11941.00	9.09	$20,896.75
1995	780403542	120-1	2278.90	7214.00	5.000	-4935.10	-216.56	$24,675.50
1995	791703514	120-1	202.00	16.00	15.000	186.00	92.08	$2,790.00
1995	860003628	120-1	1423.00	1188.00	4.430	235.00	16.51	$1,041.05
1995	860103547	120-1	1377.00	1512.00	10.000	-135.00	-9.80	$1,350.00
1995	860703410	120-1	456.00	338.00	20.000	118.00	25.88	$2,360.00
1995	860903511	120-1	260.00	172.00	20.000	88.00	33.85	$1,760.00
1995	860953485	120-1	26142.00	18672.00	4.500	7470.00	28.57	$33,615.00
1995	861003507	120-1	225.00	553.00	16.000	-328.00	-145.78	$5,248.00
1995	861003574	120-1	1541.00	1333.00	8.000	208.00	13.50	$1,664.00
1995	862203530	120-1	9359.00	9942.00	5.000	-583.00	-6.23	$2,915.00
1995	870263505	120-1	1895.00	1723.00	6.100	172.00	9.08	$1,049.20
1995	920303541	120-1	2023.00	1753.00	16.200	270.00	13.35	$4,374.00
1995	931003512	120-1	12609.00	6769.00	4.000	5840.00	46.32	$23,360.00
1995	940053506	120-1	1054.00	719.00	15.000	335.00	31.78	$5,025.00
1995	941203501	120-1	72566.00	57765.00	2.450	14801.00	20.40	$36,262.45
1995	978713321	120-1	23891.00	19571.00	3.430	4320.00	18.08	$14,817.60
1995	978713321	120-1	18443.00	14830.00	3.430	3613.00	19.59	$12,392.59
1995	978713398	120-1	469.00	141.00	8.400	328.00	69.94	$2,755.20
1995	979203326	120-1	893.00	713.00	5.000	180.00	20.16	$900.00
1995	020103516	120-1	102459.0	86738.00	2.000	15721.00	15.34	$31,442.00
1995	020103516	120-1	94247.00	88789.00	2.000	5458.00	5.79	$10,916.00
1995	030803521	120-1	3187.00	3429.00	5.000	-242.00	-7.59	$1,210.00
1995	080103531	120-1	8151.00	5028.00	3.490	3123.00	38.31	$10,899.27
1995	080603501	120-1	2091.00	2614.00	8.000	-523.00	-25.01	$4,184.00
1996	160203543	120-1	2856.00	2412.00	2.150	444.00	15.55	$954.60
1996	162503502	120-1	1299.00	570.00	7.500	729.00	56.12	$5,467.50
1996	181203502	120-1	749.00	592.00	5.500	157.00	20.96	$863.50
1996	305303602	120-1	35067.00	37887.00	2.250	-2820.00	-8.04	$6,345.00
1996	321003448	120-1	10493.00	9841.00	5.000	652.00	6.21	$3,260.00
1996	321003463	120-1	4450.00	3863.00	8.000	587.00	13.19	$4,696.00
1996	360903501	120-1	1181.00	1017.00	4.750	164.00	13.89	$779.00
1996	480993811	120-1	2599.00	2823.00	2.500	-224.00	-8.62	$560.00
1996	500013444	120-1	791.00	97.00	4.000	694.00	87.74	$2,776.00
1996	540603507	120-1	18943.00	21176.00	4.400	-2233.00	-11.79	$9,825.20
1996	540603507	120-1	18943.00	16496.00	4.400	2447.00	12.92	$10,766.80

Year	Project #	ITEM	Planned Quantity	Final Quantity	Bid	DifQ	DifQ(%)	Cost ($) Overrun/ Underrun
1996	570703506	120-1	1178.00	1983.00	5.000	-805.00	-68.34	$4,025.00
1996	600203515	120-1	37605.00	49479.00	3.200	-11874.00	-31.58	$37,996.80
1996	700503541	120-1	3145.00	2730.00	2.350	415.00	13.20	$975.25
1996	702203435	120-1	182.00	137.00	9.900	45.00	24.73	$445.50
1996	722903411	120-1	13232.00	11020.00	4.500	2212.00	16.72	$9,954.00
1996	730103522	120-1	1299.00	1372.00	6.500	-73.00	-5.62	$474.50
1996	740403520	120-1	11413.00	30000.00	7.500	-18587.00	-162.86	$139,402.50
1996	750503546	120-1	4964.00	3070.00	5.000	1894.00	38.15	$9,470.00
1996	780103504	120-1	2600.00	3653.00	9.330	-1053.00	-40.50	$9,824.49
1996	790503516	120-1	10000.00	8013.00	3.500	1987.00	19.87	$6,954.50
1996	861703507	120-1	14787.00	17332.00	4.000	-2545.00	-17.21	$10,180.00
1996	873003507	120-1	22958.50	21284.00	5.560	1674.50	7.29	$9,310.22
1996	930103532	120-1	3766.00	4294.00	11.000	-528.00	-14.02	$5,808.00
1996	977703311	120-1	261.00	1006.00	2.000	-745.00	-285.44	$1,490.00
1996	979203341	120-1	8351.00	7341.00	3.000	1010.00	12.09	$3,030.00

Note: This data is summarized in Chapter Three (Table 3.1) on a year-by-year basis.

APPENDIX D

CONE PENETRATION TEST DATA

Table D.1. Cone Penetration Test Results for Pond A #1 (project 2)

DEPTH (meters)	(feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE
0.25	0.82	28.67	0.17	0.59	0.01	silty sand to sandy silt
0.5	1.64	67.23	0.34	0.5	0.03	sand to silty sand
0.75	2.46	52.5	0.31	0.59	0.05	sand to silty sand
1	3.28	27.71	0.13	0.46	0.08	silty sand to sandy silt
1.25	4.1	23.24	0.09	0.39	0.1	silty sand to sandy silt
1.5	4.92	25.92	0.07	0.27	0.12	silty sand to sandy silt
1.75	5.74	39.92	0.17	0.42	0.14	sand to silty sand
2	6.56	52.9	0.31	0.6	0.16	sand to silty sand
2.25	7.38	67.33	0.64	0.96	0.18	sand to silty sand
2.5	8.2	87.53	0.72	0.83	0.2	sand to silty sand
2.75	9.02	149.76	1.18	0.79	0.23	sand
3	9.84	241.87	2.4	0.99	0.25	sand
3.25	10.66	263.14	2.77	1.05	0.27	sand
3.5	11.48	251.56	2.76	1.1	0.29	sand
3.75	12.3	184.1	2.2	1.19	0.31	sand
4	13.12	157.79	2.23	1.41	0.33	sand to silty sand
4.25	13.94	239.03	1.79	0.75	0.36	sand
4.5	14.76	250.17	2.17	0.87	0.38	sand
4.75	15.58	218.5	1.81	0.83	0.4	sand
5	16.4	205.07	1.46	0.71	0.42	sand

Table D.2. Cone Penetration Test Results for Pond A #2 (project 2)

DEPTH (meters)	(feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE
0.25	0.82	18.9	0.09	0.49	0.01	silty sand to sandy silt
0.5	1.64	56.95	0.35	0.62	0.03	sand to silty sand
0.75	2.46	46.64	0.36	0.78	0.05	silty sand to sandy silt
1	3.28	24.61	0.16	0.64	0.08	silty sand to sandy silt
1.25	4.1	17.42	0.08	0.44	0.1	sandy silt to clayey silt
1.5	4.92	18.32	0.08	0.42	0.12	silty sand to sandy silt
1.75	5.74	26	0.14	0.52	0.14	silty sand to sandy silt
2	6.56	44.8	0.26	0.59	0.16	sand to silty sand
2.25	7.38	73.15	0.46	0.63	0.18	sand to silty sand
2.5	8.2	87.27	0.72	0.82	0.2	sand to silty sand
2.75	9.02	96.85	0.91	0.94	0.23	sand to silty sand
3	9.84	77.83	2.21	2.84	0.25	sandy silt to clayey silt
3.25	10.66	82.67	2.44	2.96	0.27	sandy silt to clayey silt
3.5	11.48	87.09	2.49	2.86	0.29	sandy silt to clayey silt
3.75	12.3	111.26	2.41	2.17	0.31	silty sand to sandy silt
4	13.12	121.24	2.49	2.05	0.33	silty sand to sandy silt
4.25	13.94	122.46	2.86	2.34	0.36	silty sand to sandy silt
4.5	14.76	145.35	2.95	2.03	0.38	silty sand to sandy silt
4.75	15.58	147.33	2.81	1.91	0.4	silty sand to sandy silt
5	16.4	157.44	1.47	0.93	0.42	sand
5.25	17.22	164.4	1.66	1.01	0.44	sand
5.5	18.04	188.8	1.69	0.89	0.46	sand
5.75	18.86	215.76	2.82	1.31	0.48	sand
6	19.69	218.07	3.16	1.45	0.51	sand to silty sand
6.25	20.51	253.18	---	---	0.53	undefined

Table D.3. Cone Penetration Test Results for Pond F #1 (project 2)

DEPTH (meters)	(feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE
0.25	0.82	21.27	0.19	0.92	0.01	sandy silt to clayey silt
0.5	1.64	24.95	0.25	1.02	0.03	silty sand to sandy silt
0.75	2.46	26.39	0.25	0.95	0.05	silty sand to sandy silt
1	3.28	28.25	0.24	0.86	0.08	silty sand to sandy silt
1.25	4.1	37.76	0.26	0.7	0.1	silty sand to sandy silt
1.5	4.92	45.59	0.29	0.63	0.12	sand to silty sand
1.75	5.74	54.31	0.3	0.55	0.14	sand to silty sand
2	6.56	58.26	0.28	0.48	0.16	sand to silty sand
2.25	7.38	54.38	0.24	0.44	0.18	sand to silty sand
2.5	8.2	47.9	0.26	0.54	0.2	sand to silty sand
2.75	9.02	43.97	0.27	0.62	0.23	silty sand to sandy silt
3	9.84	42.51	0.28	0.66	0.25	silty sand to sandy silt
3.25	10.66	44.84	0.3	0.67	0.27	silty sand to sandy silt
3.5	11.48	48.51	0.33	0.69	0.29	sand to silty sand
3.75	12.3	55.02	0.39	0.72	0.31	sand to silty sand
4	13.12	61.27	0.43	0.71	0.33	sand to silty sand
4.25	13.94	75.08	0.47	0.63	0.36	sand to silty sand
4.5	14.76	77.01	0.52	0.68	0.38	sand to silty sand
4.75	15.58	72.38	0.57	0.79	0.4	sand to silty sand
5	16.4	71.1	0.7	0.98	0.42	sand to silty sand
5.25	17.22	49.28	---	---	0.44	undefined

Table D.4. Cone Penetration Test Results for Pond J #1 (project 2)

DEPTH (meters)	(feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE
0.25	0.82	16.49	0.11	0.67	0.01	sandy silt to clayey silt
0.5	1.64	40.99	0.23	0.57	0.03	silty sand to sandy silt
0.75	2.46	38.72	0.25	0.64	0.05	silty sand to sandy silt
1	3.28	23.83	0.16	0.67	0.08	silty sand to sandy silt
1.25	4.1	13.33	0.05	0.34	0.1	sandy silt to clayey silt
1.5	4.92	5.54	-0.01	-0.12	0.12	undefined
1.75	5.74	8.57	0.02	0.28	0.14	sensitive fine grained
2	6.56	15.85	0.06	0.39	0.16	sandy silt to clayey silt
2.25	7.38	27.09	0.15	0.54	0.18	silty sand to sandy silt
2.5	8.2	69	0.44	0.63	0.2	sand to silty sand
2.75	9.02	139.21	0.89	0.64	0.23	sand
3	9.84	137.01	1.42	1.04	0.25	sand to silty sand
3.25	10.66	58.43	1.63	2.79	0.27	sandy silt to clayey silt
3.5	11.48	47.38	1.6	3.37	0.29	clayey silt to silty clay
3.75	12.3	79.15	0.58	0.74	0.31	sand to silty sand
4	13.12	70.96	0.55	0.77	0.33	sand to silty sand
4.25	13.94	104.06	0.69	0.66	0.36	sand to silty sand
4.5	14.76	108.51	0.71	0.65	0.38	sand
4.75	15.58	96.56	0.59	0.62	0.4	sand to silty sand
5	16.4	113.91	0.65	0.57	0.42	sand
5.25	17.22	126.19	0.66	0.52	0.44	sand
5.5	18.04	142.87	0.7	0.49	0.46	sand
5.75	18.86	150.37	0.69	0.46	0.48	sand
6	19.69	135.92	0.67	0.49	0.51	sand
6.25	20.51	69.39	0.75	1.09	0.53	sand to silty sand
6.5	21.33	76.23	0.56	0.74	0.55	sand to silty sand
6.75	22.15	98.95	0.62	0.62	0.57	sand to silty sand
7	22.97	93.04	0.59	0.63	0.59	sand to silty sand

Table D.5. Cone Penetration Test Results for Pond J #2 (project 2)

DEPTH (meters)	DEPTH (feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE
0.25	0.82	15.6	0.1	0.62	0.01	sandy silt to clayey silt
0.5	1.64	25.06	0.19	0.74	0.03	silty sand to sandy silt
0.75	2.46	21.54	0.16	0.74	0.05	silty sand to sandy silt
1	3.28	16.75	0.12	0.71	0.08	sandy silt to clayey silt
1.25	4.1	18.09	0.11	0.61	0.1	sandy silt to clayey silt
1.5	4.92	19.71	0.11	0.55	0.12	silty sand to sandy silt
1.75	5.74	18.44	0.1	0.57	0.14	sandy silt to clayey silt
2	6.56	19.62	0.12	0.61	0.16	silty sand to sandy silt
2.25	7.38	26.41	0.17	0.66	0.18	silty sand to sandy silt
2.5	8.2	35.41	0.24	0.69	0.2	silty sand to sandy silt
2.75	9.02	49.64	0.33	0.66	0.23	sand to silty sand
3	9.84	61.93	0.39	0.63	0.25	sand to silty sand
3.25	10.66	63.86	0.39	0.61	0.27	sand to silty sand
3.5	11.48	59.74	0.36	0.6	0.29	sand to silty sand
3.75	12.3	64.86	0.38	0.59	0.31	sand to silty sand
4	13.12	67.74	0.4	0.59	0.33	sand to silty sand
4.25	13.94	73.19	0.42	0.58	0.36	sand to silty sand
4.5	14.76	70.51	0.44	0.62	0.38	sand to silty sand
4.75	15.58	72.72	0.44	0.6	0.4	sand to silty sand
5	16.4	71.05	0.42	0.59	0.42	sand to silty sand
5.25	17.22	76.68	0.44	0.57	0.44	sand to silty sand
5.5	18.04	83.83	0.47	0.56	0.46	sand to silty sand
5.75	18.86	95.01	0.53	0.55	0.48	sand to silty sand
6	19.69	106.13	0.61	0.57	0.51	sand
6.25	20.51	134.94	---	---	0.53	undefined

Table D.6. Cone Penetration Test Results for Pond #4-1 (project 3)

DEPTH (meters)	(feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE
0.25	0.82	24.93	0.2	0.79	0.02	silty sand to sandy silt
0.5	1.64	30.3	0.23	0.74	0.07	silty sand to sandy silt
0.75	2.46	47.19	0.35	0.75	0.11	silty sand to sandy silt
1	3.28	80.86	0.56	0.7	0.13	sand to silty sand
1.25	4.1	64.08	0.32	0.5	0.15	sand to silty sand
1.5	4.92	29.89	0.45	1.52	0.17	sandy silt to clayey silt
1.75	5.74	90.82	0.69	0.76	0.19	sand to silty sand
2	6.56	188.85	1.24	0.65	0.21	sand
2.25	7.38	130.81	1.42	1.08	0.23	sand to silty sand
2.5	8.2	25.9	0.61	2.37	0.25	sandy silt to clayey silt
2.75	9.02	15.87	0.58	3.63	0.27	silty clay to clay
3	9.84	27.95	1.23	4.41	0.29	silty clay to clay
3.25	10.66	22.35	0.88	3.96	0.31	silty clay to clay
3.5	11.48	17.98	0.83	4.59	0.33	clay
3.75	12.3	25.39	0.83	3.28	0.35	clayey silt to silty clay
4	13.12	55.52	0.76	1.37	0.36	silty sand to sandy silt
4.25	13.94	16.48	0.62	3.75	0.38	silty clay to clay
4.5	14.76	16.95	0.27	1.62	0.4	sandy silt to clayey silt

Table D.7. Cone Penetration Test Results for Pond #4-2 (project 3)

DEPTH (meters)	(feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE
0.25	0.82	21.12	0	0.01	0.02	silty sand to sandy silt
0.5	1.64	58.11	0.14	0.24	0.07	sand to silty sand
0.75	2.46	71.52	0.29	0.4	0.11	sand to silty sand
1	3.28	74.1	0.31	0.42	0.16	sand to silty sand
1.25	4.1	86.15	0.57	0.66	0.18	sand to silty sand
1.5	4.92	51.41	0.59	1.14	0.2	silty sand to sandy silt
1.75	5.74	63.36	0.22	0.34	0.22	sand to silty sand
2	6.56	80.86	0.09	0.12	0.24	sand
2.25	7.38	45.35	0.15	0.34	0.26	sand to silty sand
2.5	8.2	47.05	0.2	0.44	0.28	sand to silty sand
2.75	9.02	25.34	0.74	2.91	0.3	clayey silt to silty clay
3	9.84	31.01	1.31	4.22	0.32	silty clay to clay
3.25	10.66	27.06	0.99	3.65	0.34	clayey silt to silty clay
3.5	11.48	30.95	1.27	4.1	0.36	silty clay to clay
3.75	12.3	20.73	0.91	4.39	0.38	clay
4	13.12	15.64	0.67	4.28	0.4	clay
4.25	13.94	17.53	---	---	0.41	undefined

Table D.8. Cone Penetration Test Results for SR5 project (run #1)

DEPTH (meters)	(feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE
0.25	0.82	75.57	0.41	0.54	0.01	sand to silty sand
0.5	1.64	239.36	2.36	0.99	0.03	sand
0.75	2.46	142.6	1.9	1.33	0.05	sand to silty sand
1	3.28	31.61	0.22	0.7	0.08	silty sand to sandy silt
1.25	4.1	54.44	0.39	0.71	0.1	sand to silty sand
1.5	4.92	289.03	2.61	0.9	0.12	sand
1.75	5.74	241.48	1.47	0.61	0.14	sand
2	6.56	282.55	1.47	0.52	0.16	gravelly sand to sand
2.25	7.38	270.43	1.26	0.47	0.18	gravelly sand to sand
2.5	8.2	295.39	1.65	0.56	0.2	gravelly sand to sand
2.75	9.02	270.35	0.35	0.13	0.23	gravelly sand to sand
3	9.84	280.92	0.38	0.13	0.25	gravelly sand to sand
3.25	10.7	229.39	---	---	0.27	undefined

Table D.9. Cone Penetration Test Results for SR5 project (run #2)

DEPTH (meters)	(feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE
0.25	0.82	40.29	0.54	1.33	0.01	silty sand to sandy silt
0.5	1.64	84.97	1.23	1.45	0.03	silty sand to sandy silt
0.75	2.46	21.74	0.83	3.8	0.05	silty clay to clay
1	3.28	9.84	0.51	5.22	0.08	clay
1.25	4.1	63.72	0.58	0.9	0.1	sand to silty sand
1.5	4.92	209.04	1.46	0.7	0.12	sand
1.75	5.74	273.7	1.74	0.64	0.14	sand
2	6.56	360.44	2.2	0.61	0.16	gravelly sand to sand
2.25	7.38	381.64	3.14	0.82	0.18	gravelly sand to sand
2.5	8.2	426.69	2.01	0.47	0.2	gravelly sand to sand
2.75	9.02	382.49	0.88	0.23	0.23	gravelly sand to sand
3	9.84	273.39	0.46	0.17	0.25	gravelly sand to sand

Table D.10. Cone Penetration Test Results for SR5 project (run #3)

DEPTH (meters)	(feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE
0.25	0.82	67.59	0.1	0.15	0.01	sand to silty sand
0.5	1.64	109.22	1	0.91	0.03	sand to silty sand
0.75	2.46	123.53	1.55	1.26	0.05	sand to silty sand
1	3.28	155.55	1.42	0.92	0.08	sand
1.25	4.1	59.13	0.47	0.8	0.1	sand to silty sand
1.5	4.92	148.52	0.77	0.52	0.12	sand
1.75	5.74	242.03	1.75	0.72	0.14	sand
2	6.56	246.03	1.38	0.56	0.16	sand
2.25	7.38	334.44	2.2	0.66	0.18	gravelly sand to sand
2.5	8.2	323.15	2.02	0.63	0.2	gravelly sand to sand
2.75	9.02	304.14	1.95	0.64	0.23	gravelly sand to sand
3	9.84	380.72	1.33	0.35	0.25	gravelly sand to sand
3.25	10.7	263.85	---	---	0.27	undefined

Table D.11. Cone Penetration Test Results for SR5 project (run #4)

DEPTH (meters)	(feet)	Qc (avg) (tsf)	Fs (avg) (tsf)	Rf (avg) (%)	SIGV' (tsf)	SOIL BEHAVIOUR TYPE
0.25	0.82	91.32	0.47	0.52	0.01	sand to silty sand
0.5	1.64	123.04	1.51	1.23	0.03	sand to silty sand
0.75	2.46	105.08	1.78	1.69	0.05	silty sand to sandy silt
1	3.28	42.74	1.3	3.04	0.08	sandy silt to clayey silt
1.25	4.1	120.71	0.32	0.27	0.1	sand
1.5	4.92	124.87	0.33	0.27	0.12	sand
1.75	5.74	153.3	0.37	0.24	0.14	sand
2	6.56	164.51	0.29	0.18	0.16	sand
2.25	7.38	145.36	0.38	0.26	0.18	sand
2.5	8.2	295.39	3.43	1.16	0.2	sand
2.75	9.02	356.58	2.05	0.57	0.23	gravelly sand to sand
3	9.84	226.11	0.37	0.16	0.25	gravelly sand to sand
3.25	10.66	251.75	0.24	0.09	0.27	gravelly sand to sand

Table D12. Weighted Average In-Situ Dry Density for Pond A CPT #1

Based on Max\Min Tests

Layer	Avg Dry Density/Layer	Depth of Layer (m)	%Depth	Weighted Dry Density (pcf)
1	N/A	0.00	0.00	0.00
2	N/A	0.10	1.79	0.00
3	96.15	0.50	8.93	8.58
4	96.14	0.50	8.93	8.58
5	78.94	0.90	16.07	12.69
6	85.37	0.90	16.07	13.72
7	100.74	1.15	20.54	20.69
8	92.72	0.30	5.36	4.97
9	96.52	1.25	22.32	21.55
	Σ =	5.60	Σ =	90.78

Table D-13. Weighted Average In-Situ Dry Density for Pond A CPT #1

Based on C_u Correlation

Layer	Avg Dry Density/Layer	Depth of Layer (m)	%Depth	Weighted Dry Density (pcf)
1	N/A	0.00	0.00	0.00
2	N/A	0.10	1.79	0.00
3	104.85	0.50	8.93	9.36
4	104.90	0.50	8.93	9.37
5	92.47	0.90	16.07	14.86
6	97.71	0.90	16.07	15.70
7	107.41	1.15	20.54	22.06
8	102.68	0.30	5.36	5.50
9	105.05	1.25	22.32	23.45
	Σ =	5.60	Σ =	100.30

Table D.14. Weighted Average In-Situ Dry Density for Pond A CPT #2

Based on Max\Min Tests

Layer	Avg Dry Density/Layer	Depth of Layer (m)	%Depth	Weighted Dry Density (pcf)
1	N/A	0.00	0.00	0.00
2	N/A	0.00	0.00	0.00
3	94.85	0.10	1.92	1.82
4	95.67	0.35	6.73	6.44
5	82.14	0.40	7.69	6.32
6	N/A	0.00	0.00	0.00
7	73.60	0.05	0.96	0.71
8	N/A	0.00	0.00	0.00
9	76.97	0.55	10.58	8.14
10	87.63	0.85	16.35	14.32
11	85.90	0.05	0.96	0.83
12	N/A	0.00	0.00	0.00
13	87.25	0.10	1.92	1.68
14	N/A	0.00	0.00	0.00
15	86.35	0.10	1.92	1.66
16	N/A	0.00	0.00	0.00
17	88.10	0.05	0.96	0.85
18	89.80	0.05	0.96	0.86
19	89.73	1.05	20.19	18.12
20	90.80	0.05	0.96	0.87
21	91.46	0.40	7.69	7.04
22	90.90	0.05	0.96	0.87
23	92.99	0.35	6.73	6.26
24	94.50	0.10	1.92	1.82
25	95.55	0.10	1.92	1.84
26	93.77	0.15	2.88	2.70
27	96.12	0.30	5.77	5.55
28	N/A	0.00	0.00	0.00
	Σ =	5.20	Σ =	88.69

Table D.15. Weighted Average In-Situ Dry Density for Pond A CPT #2

Based on C_u Correlation

Layer	Avg Dry Density/Layer	Depth of Layer (m)	%Depth	Weighted Dry Density (pcf)
1	N/A	0.00	0.00	0.00
2	N/A	0.00	0.00	0.00
3	103.10	0.10	1.92	1.98
4	104.13	0.35	6.73	7.01
5	95.46	0.40	7.69	7.34
6	N/A	0.00	0.00	0.00
7	89.50	0.05	0.96	0.86
8	N/A	0.00	0.00	0.00
9	89.80	0.55	10.58	9.50
10	99.16	0.85	16.35	16.21
11	98.10	0.05	0.96	0.94
12	N/A	0.00	0.00	0.00
13	98.95	0.10	1.92	1.90
14	N/A	0.00	0.00	0.00
15	98.40	0.10	1.92	1.89
16	N/A	0.00	0.00	0.00
17	99.50	0.05	0.96	0.96
18	100.60	0.05	0.96	0.97
19	100.62	1.05	20.19	20.32
20	101.35	0.05	0.96	0.97
21	101.77	0.40	7.69	7.83
22	101.40	0.05	0.96	0.97
23	102.73	0.35	6.73	6.91
24	103.70	0.10	1.92	1.99
25	104.30	0.10	1.92	2.01
26	103.27	0.15	2.88	2.98
27	104.68	0.30	5.77	6.04
28	N/A	0.00	0.00	0.00
	Σ =	5.20	Σ =	99.59

Table D.16. Weighted Average In-Situ Dry Density for Pond F CPT #1

Based on Max\Min Tests

Layer	Avg Dry Density/Layer	Depth of Layer (m)	%Depth	Weighted Dry Density (pcf)
1	N/A	0.00	0.00	0.00
2	91.10	0.15	2.97	2.71
3	N/A	0.00	0.00	0.00
4	83.97	1.05	20.79	17.46
5	84.85	1.20	23.76	20.16
6	79.79	0.75	14.85	11.85
7	82.55	1.65	32.67	26.97
8	79.40	0.20	3.96	3.14
9	78.10	0.05	0.99	0.77
	Σ =	5.05	Σ =	83.07

Table D.17. Weighted Average In-Situ Dry Density for Pond F CPT #1

Based on C_u Correlation

Layer	Avg Dry Density/Layer	Depth of Layer (m)	%Depth	Weighted Dry Density (pcf)
1	N/A	0.00	0.00	0.00
2	97.57	0.15	2.97	2.90
3	N/A	0.00	0.00	0.00
4	93.03	1.05	20.79	19.34
5	93.55	1.20	23.76	22.23
6	89.63	0.75	14.85	13.31
7	92.03	1.65	32.67	30.07
8	89.95	0.20	3.96	3.56
9	89.10	0.05	0.99	0.88
	Σ =	5.05	Σ =	92.30

Table D.18. Weighted Average In-Situ Dry Density for Pond J CPT #1

Based on C_u Correlation

Layer	Avg Dry Density/Layer	Depth of Layer (m)	%Depth	Weighted Dry Density (pcf)
1	N/A	0.00	0.00	0.00
2	N/A	0.00	0.00	0.00
3	95.57	0.20	3.57	3.41
4	96.90	0.05	0.89	0.87
5	90.88	0.55	9.82	8.93
6	N/A	0.00	0.00	0.00
7	N/A	0.00	0.00	0.00
8	N/A	0.00	0.00	0.00
9	83.84	0.35	6.25	5.24
10	92.10	0.20	3.57	3.29
11	97.85	0.40	7.14	6.99
12	96.00	0.05	0.89	0.86
13	93.10	0.05	0.89	0.83
14	N/A	0.00	0.00	0.00
15	89.20	0.05	0.89	0.80
16	N/A	0.00	0.00	0.00
17	N/A	0.00	0.00	0.00
18	N/A	0.00	0.00	0.00
19	89.20	0.05	0.89	0.80
20	90.50	0.60	10.71	9.70
21	93.30	0.30	5.36	5.00
22	91.63	0.35	6.25	5.73
23	93.56	1.30	23.21	21.72
24	88.15	0.10	1.79	1.57
25	86.10	0.05	0.89	0.77
26	N/A	0.00	0.00	0.00
27	77.90	0.05	0.89	0.70
28	88.76	0.80	14.29	12.68
29	88.00	0.05	0.89	0.79
30	87.20	0.05	0.89	0.78
	$\Sigma =$	5.60	$\Sigma =$	91.43

Table D.19. Weighted Average In-Situ Dry Density for Pond #4 CPT #1

Based on C_u Correlation

Layer	Avg Dry Density/Layer	Depth of Layer (m)	%Depth	Weighted Dry Density (pcf)
1	N/A	0.00	0.00	0.00
2	N/A	0.00	0.00	0.00
3	98.36	0.55	26.19	25.76
4	100.85	0.55	26.19	26.41
5	91.30	0.05	2.38	2.17
6	N/A	0.00	0.00	0.00
7	95.27	0.15	7.14	6.80
8	98.50	0.05	2.38	2.35
9	105.72	0.45	21.43	22.65
10	101.00	0.10	4.76	4.81
11	N/A	0.00	0.00	0.00
12	N/A	0.00	0.00	0.00
13	N/A	0.00	0.00	0.00
14	N/A	0.00	0.00	0.00
15	N/A	0.00	0.00	0.00
16	N/A	0.00	0.00	0.00
17	N/A	0.00	0.00	0.00
18	N/A	0.00	0.00	0.00
19	N/A	0.00	0.00	0.00
20	N/A	0.00	0.00	0.00
21	N/A	0.00	0.00	0.00
22	N/A	0.00	0.00	0.00
23	93.40	0.05	2.38	2.22
24	95.05	0.10	4.76	4.53
25	91.80	0.05	2.38	2.19
26	N/A	0.00	0.00	0.00
	Σ =	2.10	Σ =	99.90

Table D.20. Weighted Average In-Situ Dry Density for Pond #4 CPT #2

Based on C_u Correlation

Layer	Avg Dry Density/Layer	Depth of Layer (m)	%Depth	Weighted Dry Density (pcf)
1	N/A	0.00	0.00	0.00
2	98.12	0.20	8.33	8.18
3	100.70	1.10	45.83	46.16
4	94.40	0.05	2.08	1.97
5	N/A	0.05	2.08	0.00
6	90.40	0.05	2.08	1.88
7	95.20	0.10	4.17	3.97
8	97.52	0.30	12.50	12.19
9	92.42	0.20	8.33	7.70
10	90.70	0.05	2.08	1.89
11	91.94	0.25	10.42	9.58
12	88.00	0.05	2.08	1.83
13	N/A	0.00	0.00	0.00
14	N/A	0.00	0.00	0.00
15	N/A	0.00	0.00	0.00
16	N/A	0.00	0.00	0.00
17	N/A	0.00	0.00	0.00
18	N/A	0.00	0.00	0.00
19	N/A	0.00	0.00	0.00
20	N/A	0.00	0.00	0.00
21	N/A	0.00	0.00	0.00
22	N/A	0.00	0.00	0.00
	Σ =	2.40	Σ =	95.34

Table D.21. CPT In-Situ Dry Density (C_u) Based for Pond #2 Run #1 Project 4

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
0.05	0.16	0.99	20.70	14.93	94.99	1	6	SANDY SILT TO CLAYEY SILT
0.10	0.33	2.09	43.60	15.44	98.19	2	7	SILTY SAND TO SANDY SILT
0.15	0.49	3.00	62.72	15.64	99.49		7	SILTY SAND TO SANDY SILT
0.20	0.66	3.98	83.10	15.81	100.59		7	SILTY SAND TO SANDY SILT
0.25	0.82	5.53	115.48	16.13	102.59	3	8	SAND TO SILTY SAND
0.30	0.98	5.59	116.72	15.99	101.69		8	SAND TO SILTY SAND
0.35	1.15	5.90	123.22	15.94	101.39		8	SAND TO SILTY SAND
0.40	1.31	6.19	129.34	15.89	101.09		8	SAND TO SILTY SAND
0.45	1.48	5.98	124.84	15.75	100.19		8	SAND TO SILTY SAND
0.50	1.64	4.75	99.12	15.33	97.49		8	SAND TO SILTY SAND
0.55	1.80	4.88	101.94	15.28	97.19		8	SAND TO SILTY SAND
0.60	1.97	5.28	110.34	15.33	97.49		8	SAND TO SILTY SAND
0.65	2.13	5.13	107.04	15.23	96.89		8	SAND TO SILTY SAND
0.70	2.30	4.75	99.30	15.06	95.79		8	SAND TO SILTY SAND
0.75	2.46	3.00	62.62	14.41	91.69	4	7	SILTY SAND TO SANDY SILT
0.80	2.62	1.74	36.42	13.72	87.29	5	6	SANDY SILT TO CLAYEY SILT
0.85	2.79	1.39	29.02	12.78	81.29		6	SANDY SILT TO CLAYEY SILT
0.90	2.95	0.92	19.24	12.78	81.29	6	5	CLAYEY SILT TO SILTY CLAY
0.95	3.12	0.51	10.58	12.78	81.29	7	4	SILTY CLAY TO CLAY
1.00	3.28	0.23	4.84	12.78	81.29	8	3	CLAY
1.05	3.45	0.20	4.16	12.78	81.29	9	1	SENSITIVE FINE GRAINED
1.10	3.61	0.21	4.34	12.78	81.29		1	SENSITIVE FINE GRAINED
1.15	3.77	0.20	4.16	12.78	81.29		1	SENSITIVE FINE GRAINED
1.20	3.94	0.19	3.90	12.78	81.29		1	SENSITIVE FINE GRAINED
1.25	4.10	0.18	3.82	12.78	81.29		1	SENSITIVE FINE GRAINED
1.30	4.27	0.17	3.52	12.78	81.29		1	SENSITIVE FINE GRAINED
1.35	4.43	0.16	3.44	12.78	81.29		1	SENSITIVE FINE GRAINED
1.40	4.59	0.14	3.02	12.78	81.29		1	SENSITIVE FINE GRAINED
1.45	4.76	0.23	4.72	12.78	81.29		1	SENSITIVE FINE GRAINED
1.50	4.92	0.26	5.40	12.78	81.29		1	SENSITIVE FINE GRAINED
1.55	5.09	0.18	3.74	12.78	81.29		1	SENSITIVE FINE GRAINED
1.60	5.25	0.18	3.78	12.78	81.29		1	SENSITIVE FINE GRAINED
1.65	5.41	1.75	36.62	12.78	81.29	10	7	SILTY SAND TO SANDY SILT
1.70	5.58	2.36	49.28	12.78	81.29		7	SILTY SAND TO SANDY SILT
1.75	5.74	2.50	52.22	13.33	84.79		7	SILTY SAND TO SANDY SILT
1.80	5.91	2.09	43.56	12.78	81.29		7	SILTY SAND TO SANDY SILT
1.85	6.07	1.57	32.84	12.78	81.29	11	6	SANDY SILT TO CLAYEY SILT
1.90	6.23	1.25	26.18	12.78	81.29		6	SANDY SILT TO CLAYEY SILT
1.95	6.40	1.22	25.40	12.78	81.29		6	SANDY SILT TO CLAYEY SILT
2.00	6.56	1.24	25.92	12.78	81.29		6	SANDY SILT TO CLAYEY SILT
2.05	6.73	1.36	28.42	12.78	81.29		6	SANDY SILT TO CLAYEY SILT

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
2.10	6.89	1.51	31.52	12.78	81.29		6	SANDY SILT TO CLAYEY SILT
2.15	7.05	1.68	35.14	12.78	81.29		6	SANDY SILT TO CLAYEY SILT
2.20	7.22	2.06	43.04	12.78	81.29	12	7	SILTY SAND TO SANDY SILT
2.25	7.38	2.26	47.30	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.30	7.55	2.40	50.10	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.35	7.71	2.49	52.04	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.40	7.87	2.57	53.70	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.45	8.04	2.63	54.86	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.50	8.20	2.70	56.42	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.55	8.37	2.76	57.70	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.60	8.53	2.82	58.80	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.65	8.69	2.87	59.92	13.16	83.69		7	SILTY SAND TO SANDY SILT
2.70	8.86	2.95	61.60	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.75	9.02	3.08	64.24	13.22	84.09	13	8	SAND TO SILTY SAND

Table D.22. Weighted Average In-Situ Dry Density (C_u) Based for Pond #2 Run #1 Project 4

Layer	Average Dry Density/Layer		Depth of Layer		Depth	Dry Density	
	KN/m³	lb/ft³	Meter	Feet	(%)	KN/m³	lb/ft³
1	14.93	94.99	N/a	N/a	0.00	0.00	0.00
2	15.63	99.42	0.15	0.49	0.10	1.56	9.94
3	15.59	99.18	0.50	1.64	0.33	5.20	33.06
4	14.41	91.69	0.05	0.16	0.03	0.48	3.06
5	13.25	84.29	N/a	N/a	0.00	0.00	0.00
6	12.78	81.29	N/a	N/a	0.00	0.00	0.00
7	12.78	81.29	N/a	N/a	0.00	0.00	0.00
8	12.78	81.29	N/a	N/a	0.00	0.00	0.00
9	12.78	81.29	N/a	N/a	0.00	0.00	0.00
10	12.92	82.17	0.20	0.66	0.13	1.72	10.96
11	12.78	81.29	N/a	N/a	0.00	0.00	0.00
12	12.81	81.51	0.55	1.80	0.37	4.70	29.89
13	13.22	84.09	0.05	0.16	0.03	0.44	2.80
			Σ= 1.50	4.92	Σ=	14.10	89.70

Table D.23. CPT In-Situ Dry Density (C_u) Based for Pond #2 Run #2 Project 4

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
0.05	0.16	1.33	27.88	15.33	97.49	1	6	SANDY SILT TO CLAYEY SILT
0.10	0.33	2.34	48.78	15.59	99.19	2	7	SILTY SAND TO SANDY SILT
0.15	0.49	2.93	61.18	15.59	99.19		7	SILTY SAND TO SANDY SILT
0.20	0.66	2.94	61.44	15.37	97.79		7	SILTY SAND TO SANDY SILT
0.25	0.82	3.19	66.54	15.31	97.39		7	SILTY SAND TO SANDY SILT
0.30	0.98	6.56	137.02	16.25	103.39	3	8	SAND TO SILTY SAND
0.35	1.15	8.08	168.72	16.44	104.59		8	SAND TO SILTY SAND
0.40	1.31	9.75	203.62	16.63	105.79	4	9	SAND
0.45	1.48	10.18	212.62	16.60	105.59		9	SAND
0.50	1.64	8.09	169.06	16.11	102.49	5	8	SAND TO SILTY SAND
0.55	1.80	8.66	180.96	16.14	102.69		8	SAND TO SILTY SAND
0.60	1.97	8.20	171.36	15.97	101.59		8	SAND TO SILTY SAND
0.65	2.13	6.21	129.68	15.48	98.49		8	SAND TO SILTY SAND
0.70	2.30	4.41	92.04	14.95	95.09	6	7	SILTY SAND TO SANDY SILT
0.75	2.46	5.01	104.66	15.07	95.89	7	8	SAND TO SILTY SAND
0.80	2.62	6.04	126.24	15.29	97.29		8	SAND TO SILTY SAND
0.85	2.79	4.45	92.96	14.82	94.29		8	SAND TO SILTY SAND
0.90	2.95	3.87	80.90	14.60	92.89	8	7	SILTY SAND TO SANDY SILT
0.95	3.12	4.38	91.48	14.73	93.69		7	SILTY SAND TO SANDY SILT
1.00	3.28	3.65	76.26	14.46	91.99		7	SILTY SAND TO SANDY SILT
1.05	3.45	1.65	34.46	12.78	81.29	9	6	SANDY SILT TO CLAYEY SILT
1.10	3.61	0.59	12.36	12.78	81.29	10	4	SILTY CLAY TO CLAY
1.15	3.77	0.34	7.10	12.78	81.29	11	3	CLAY
1.20	3.94	0.32	6.58	12.78	81.29	12	1	SENSITIVE FINE GRAINED
1.25	4.10	0.34	7.10	12.78	81.29		1	SENSITIVE FINE GRAINED
1.30	4.27	0.35	7.30	12.78	81.29		1	SENSITIVE FINE GRAINED
1.35	4.43	0.31	6.46	12.78	81.29		1	SENSITIVE FINE GRAINED
1.40	4.59	0.29	6.16	12.78	81.29		1	SENSITIVE FINE GRAINED
1.45	4.76	0.26	5.48	12.78	81.29		1	SENSITIVE FINE GRAINED
1.50	4.92	0.26	5.40	12.78	81.29		1	SENSITIVE FINE GRAINED
1.55	5.09	0.24	5.02	12.78	81.29		1	SENSITIVE FINE GRAINED
1.60	5.25	0.26	5.44	12.78	81.29		1	SENSITIVE FINE GRAINED
1.65	5.41	0.33	6.96	12.78	81.29		1	SENSITIVE FINE GRAINED
1.70	5.58	0.47	9.74	12.78	81.29		1	SENSITIVE FINE GRAINED
1.75	5.74	0.80	16.62	12.78	81.29		1	SENSITIVE FINE GRAINED
1.80	5.91	0.84	17.60	12.78	81.29		1	SENSITIVE FINE GRAINED
1.85	6.07	1.24	26.00	12.78	81.29	13	6	SANDY SILT TO CLAYEY SILT
1.90	6.23	1.53	31.96	12.78	81.29		6	SANDY SILT TO CLAYEY SILT
1.95	6.40	1.83	38.28	12.78	81.29	14	7	SILTY SAND TO SANDY SILT
2.00	6.56	2.19	45.64	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.05	6.73	2.48	51.80	12.78	81.29		7	SILTY SAND TO SANDY SILT

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
2.10	6.89	2.68	55.96	13.30	84.59		7	SILTY SAND TO SANDY SILT
2.15	7.05	2.82	58.84	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.20	7.22	2.93	61.14	13.38	85.09		7	SILTY SAND TO SANDY SILT
2.25	7.38	3.01	62.96	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.30	7.55	3.06	63.94	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.35	7.71	3.15	65.82	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.40	7.87	3.19	66.70	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.45	8.04	3.20	66.88	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.50	8.20	3.19	66.70	13.38	85.09		7	SILTY SAND TO SANDY SILT
2.55	8.37	3.18	66.32	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.60	8.53	3.20	66.88	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.65	8.69	3.24	67.64	12.78	81.29		7	SILTY SAND TO SANDY SILT
2.70	8.86	3.27	68.24	12.78	81.29	15	8	SAND TO SILTY SAND
2.75	9.02	3.29	68.74	12.78	81.29		8	SAND TO SILTY SAND

Table D.24. Weighted Average In-Situ Dry Density (C_u) Based for Pond #2 Run #2 Project 4

Layer	Average Dry Density/Layer		Depth of Layer		Depth	Dry Density	
	KN/m³	lb/ft³	Meter	Feet	(%)	KN/m³	lb/ft³
1	15.33	97.49	N/a	N/a	0.00	0.00	0.00
2	15.47	98.39	0.20	0.66	0.11	1.72	10.93
3	16.35	103.99	0.10	0.33	0.06	0.91	5.78
4	16.62	105.69	0.10	0.33	0.06	0.92	5.87
5	15.93	101.31	0.20	0.66	0.11	1.77	11.26
6	14.95	95.09	0.05	0.16	0.03	0.42	2.64
7	15.06	95.82	0.15	0.49	0.08	1.26	7.99
8	14.60	92.86	0.15	0.49	0.08	1.22	7.74
9	12.78	81.29	N/a	N/a	0.00	0.00	0.00
10	12.78	81.29	N/a	N/a	0.00	0.00	0.00
11	12.78	81.29	N/a	N/a	0.00	0.00	0.00
12	12.78	81.29	N/a	N/a	0.00	0.00	0.00
13	12.78	81.29	N/a	N/a	0.00	0.00	0.00
14	12.89	82.02	0.75	2.46	0.42	5.37	34.17
15	12.78	81.29	0.10	0.33	0.06	0.71	4.52
			Σ= 1.80	3.12	Σ=	14.29	90.89

Table D.25. CPT In-Situ Dry Density (C_u) Based for Pond #4 Test #1 Project 4

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
0.05	0.16	1.19	24.94	15.16	96.46	1	6	SANDY SILT TO CLAYEY SILT
0.10	0.33	3.14	65.60	16.01	101.86	2	7	SILTY SAND TO SANDY SILT
0.15	0.49	4.88	101.98	16.36	104.06	3	8	SAND TO SILTY SAND
0.20	0.66	6.07	126.74	16.45	104.66		8	SAND TO SILTY SAND
0.25	0.82	7.23	150.96	16.53	105.16		8	SAND TO SILTY SAND
0.30	0.98	8.18	170.86	16.56	105.36		8	SAND TO SILTY SAND
0.35	1.15	8.66	180.92	16.52	105.06		8	SAND TO SILTY SAND
0.40	1.31	8.88	185.38	16.44	104.56		8	SAND TO SILTY SAND
0.45	1.48	8.72	182.12	16.30	103.66		8	SAND TO SILTY SAND
0.50	1.64	8.81	184.02	16.22	103.16		8	SAND TO SILTY SAND
0.55	1.80	8.54	178.38	16.08	102.26		8	SAND TO SILTY SAND
0.60	1.97	8.20	171.36	15.95	101.46		8	SAND TO SILTY SAND
0.65	2.13	7.82	163.28	15.81	100.56		8	SAND TO SILTY SAND
0.70	2.30	7.33	153.00	15.64	99.46		8	SAND TO SILTY SAND
0.75	2.46	6.87	143.48	15.49	98.56		8	SAND TO SILTY SAND
0.80	2.62	6.17	128.78	15.29	97.26		8	SAND TO SILTY SAND
0.85	2.79	5.93	123.90	15.18	96.56		8	SAND TO SILTY SAND
0.90	2.95	5.62	117.32	15.07	95.86		8	SAND TO SILTY SAND
0.95	3.12	5.41	112.98	14.98	95.26		8	SAND TO SILTY SAND
1.00	3.28	5.40	112.68	14.94	95.06		8	SAND TO SILTY SAND
1.05	3.45	5.37	112.22	14.90	94.76		8	SAND TO SILTY SAND
1.10	3.61	5.43	113.40	14.88	94.66		8	SAND TO SILTY SAND
1.15	3.77	5.55	116.00	14.88	94.66		8	SAND TO SILTY SAND
1.20	3.94	5.73	119.74	14.90	94.76		8	SAND TO SILTY SAND
1.25	4.10	5.92	123.56	14.90	94.76		8	SAND TO SILTY SAND
1.30	4.27	6.10	127.46	14.91	94.86		8	SAND TO SILTY SAND
1.35	4.43	6.31	131.84	14.94	95.06		8	SAND TO SILTY SAND
1.40	4.59	6.51	135.88	14.96	95.16		8	SAND TO SILTY SAND
1.45	4.76	6.63	138.52	14.96	95.16		8	SAND TO SILTY SAND
1.50	4.92	6.72	140.30	14.94	95.06		8	SAND TO SILTY SAND
1.55	5.09	6.78	141.66	14.93	94.96		8	SAND TO SILTY SAND
1.60	5.25	6.78	141.54	14.91	94.86		8	SAND TO SILTY SAND
1.65	5.41	6.77	141.36	14.88	94.66		8	SAND TO SILTY SAND
1.70	5.58	6.71	140.22	14.85	94.46		8	SAND TO SILTY SAND
1.75	5.74	6.42	134.18	14.77	93.96		8	SAND TO SILTY SAND
1.80	5.91	6.51	136.06	14.77	93.96		8	SAND TO SILTY SAND
1.85	6.07	6.53	136.44	14.76	93.86		8	SAND TO SILTY SAND
1.90	6.23	6.53	136.44	14.74	93.76		8	SAND TO SILTY SAND
1.95	6.40	6.52	136.26	14.72	93.66		8	SAND TO SILTY SAND
2.00	6.56	6.49	135.54	14.69	93.46		8	SAND TO SILTY SAND
2.05	6.73	6.47	135.08	14.68	93.36		8	SAND TO SILTY SAND

2.10	6.89	6.41	133.84	14.65	93.16		8	SAND TO SILTY SAND
2.15	7.05	6.33	132.18	14.61	92.96		8	SAND TO SILTY SAND
2.20	7.22	6.24	130.32	14.58	92.76		8	SAND TO SILTY SAND
2.25	7.38	6.20	129.46	14.55	92.56		8	SAND TO SILTY SAND
2.30	7.55	6.14	128.32	14.54	92.46		8	SAND TO SILTY SAND
2.35	7.71	6.04	126.06	14.49	92.16		8	SAND TO SILTY SAND
2.40	7.87	5.94	124.16	14.46	91.96		8	SAND TO SILTY SAND
2.45	8.04	5.79	120.92	14.41	91.66		8	SAND TO SILTY SAND
2.50	8.20	5.67	118.38	14.38	91.46		8	SAND TO SILTY SAND
2.55	8.37	5.54	115.74	14.33	91.16		8	SAND TO SILTY SAND
2.60	8.53	5.51	114.98	14.32	91.06		8	SAND TO SILTY SAND
2.65	8.69	5.48	114.50	14.28	90.86		8	SAND TO SILTY SAND
2.70	8.86	5.47	114.34	14.28	90.86		8	SAND TO SILTY SAND
2.75	9.02	5.38	112.30	14.24	90.56		8	SAND TO SILTY SAND
2.80	9.19	5.53	115.48	14.27	90.76		8	SAND TO SILTY SAND
2.85	9.35	5.62	117.32	14.27	90.76		8	SAND TO SILTY SAND
2.90	9.51	5.69	118.76	14.28	90.86		8	SAND TO SILTY SAND
2.95	9.68	5.88	122.72	14.32	91.06		8	SAND TO SILTY SAND
3.00	9.84	6.09	127.12	14.35	91.26		8	SAND TO SILTY SAND
3.05	10.01	6.33	132.22	14.38	91.46		8	SAND TO SILTY SAND
3.10	10.17	6.51	135.96	14.41	91.66		8	SAND TO SILTY SAND
3.15	10.34	6.83	142.56	14.46	91.96		8	SAND TO SILTY SAND
3.20	10.50	7.15	149.36	14.50	92.26		8	SAND TO SILTY SAND
3.25	10.66	7.57	158.02	14.57	92.66		8	SAND TO SILTY SAND
3.30	10.83	7.81	163.08	14.60	92.86		8	SAND TO SILTY SAND
3.35	10.99	8.01	167.32	14.61	92.96		8	SAND TO SILTY SAND
3.40	11.16	8.27	172.64	14.65	93.16		8	SAND TO SILTY SAND
3.45	11.32	8.60	179.52	14.69	93.46		8	SAND TO SILTY SAND
3.50	11.48	8.71	181.98	14.69	93.46		8	SAND TO SILTY SAND
3.55	11.65	8.79	183.68	14.69	93.46		8	SAND TO SILTY SAND
3.60	11.81	8.94	186.70	14.71	93.56		8	SAND TO SILTY SAND
3.65	11.98	9.31	194.44	14.76	93.86		8	SAND TO SILTY SAND
3.70	12.14	9.29	194.10	14.74	93.76		8	SAND TO SILTY SAND
3.75	12.30	8.63	180.28	14.63	93.06		8	SAND TO SILTY SAND
3.80	12.47	8.88	185.46	14.66	93.26		8	SAND TO SILTY SAND
3.85	12.63	9.33	194.78	14.72	93.66		8	SAND TO SILTY SAND
3.90	12.80	9.54	199.20	14.74	93.76		8	SAND TO SILTY SAND
3.95	12.96	9.88	206.28	14.77	93.96		8	SAND TO SILTY SAND
4.00	13.12	10.33	215.84	14.83	94.36	4	9	SAND
4.05	13.29	10.86	226.86	14.88	94.66		9	SAND
4.10	13.45	11.01	230.00	14.90	94.76	5	8	SAND TO SILTY SAND

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
4.15	13.62	10.89	227.36	14.87	94.56		8	SAND TO SILTY SAND
4.20	13.78	10.67	222.82	14.83	94.36		8	SAND TO SILTY SAND
4.25	13.94	10.55	220.36	14.82	94.26		8	SAND TO SILTY SAND
4.30	14.11	10.69	223.32	14.82	94.26		8	SAND TO SILTY SAND
4.35	14.27	11.11	231.96	14.87	94.56		8	SAND TO SILTY SAND
4.40	14.44	11.44	238.96	14.90	94.76	6	9	SAND
4.45	14.60	11.52	240.50	14.90	94.76	7	8	SAND TO SILTY SAND
4.50	14.76	11.43	238.62	14.88	94.66	8	9	SAND
4.55	14.93	11.36	237.30	14.87	94.56		9	SAND

Table D.26. Weighted Average In-Situ Dry Density (C_u) Based for Pond #4 Run #1
Project 4

Layer	Average Dry Density/Layer		Depth of Layer		Depth	Dry Density	
	KN/m³	lb/ft³	Meter	Feet	(%)	KN/m³	lb/ft³
1	15.16	96.46	N/a	N/a	0.00	0.00	0.00
2	16.01	101.86	0.05	0.16	0.01	0.18	1.13
3	14.93	94.94	3.85	12.63	0.86	12.77	81.23
4	14.86	94.51	0.10	0.33	0.02	0.33	2.10
5	14.85	94.46	0.30	0.98	0.07	0.99	6.30
6	14.90	94.76	0.05	0.16	0.01	0.17	1.05
7	14.90	94.76	0.05	0.16	0.01	0.17	1.05
8	14.87	94.61	0.10	0.33	0.02	0.33	2.10
		Σ=	4.50	14.76	Σ=	14.93	94.96

Table D.27. CPT In-Situ Dry Density (C_u) Based for Pond #4 Run #2 Project 4

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
0.05	0.16	0.52	10.84	14.13	89.86	1	1	SENSITIVE FINE GRAINED
0.10	0.33	0.96	19.98	14.41	91.66		1	SENSITIVE FINE GRAINED
0.15	0.49	1.17	24.48	14.38	91.46	2	6	SANDY SILT TO CLAYEY SILT
0.20	0.66	2.40	50.22	15.12	96.16	3	7	SILTY SAND TO SANDY SILT
0.25	0.82	3.31	69.14	15.38	97.86	4	8	SAND TO SILTY SAND
0.30	0.98	3.91	81.62	15.48	98.46		8	SAND TO SILTY SAND
0.35	1.15	4.42	92.28	15.53	98.76		8	SAND TO SILTY SAND
0.40	1.31	4.96	103.50	15.57	99.06		8	SAND TO SILTY SAND
0.45	1.48	5.54	115.66	15.65	99.56		8	SAND TO SILTY SAND
0.50	1.64	5.78	120.62	15.62	99.36		8	SAND TO SILTY SAND
0.55	1.80	5.85	122.28	15.56	98.96		8	SAND TO SILTY SAND
0.60	1.97	5.87	122.62	15.49	98.56		8	SAND TO SILTY SAND
0.65	2.13	5.90	123.22	15.43	98.16		8	SAND TO SILTY SAND
0.70	2.30	5.81	121.44	15.35	97.66		8	SAND TO SILTY SAND
0.75	2.46	5.72	119.48	15.27	97.16		8	SAND TO SILTY SAND
0.80	2.62	5.25	109.66	15.10	96.06		8	SAND TO SILTY SAND
0.85	2.79	4.98	103.98	14.98	95.26		8	SAND TO SILTY SAND
0.90	2.95	4.94	103.16	14.93	94.96		8	SAND TO SILTY SAND
0.95	3.12	4.86	101.56	14.87	94.56		8	SAND TO SILTY SAND
1.00	3.28	4.84	101.12	14.82	94.26		8	SAND TO SILTY SAND
1.05	3.45	4.89	102.18	14.80	94.16		8	SAND TO SILTY SAND
1.10	3.61	4.95	103.46	14.79	94.06		8	SAND TO SILTY SAND
1.15	3.77	5.01	104.66	14.77	93.96		8	SAND TO SILTY SAND
1.20	3.94	5.06	105.76	14.76	93.86		8	SAND TO SILTY SAND
1.25	4.10	5.12	106.86	14.74	93.76		8	SAND TO SILTY SAND
1.30	4.27	5.18	108.18	14.72	93.66		8	SAND TO SILTY SAND
1.35	4.43	5.38	112.34	14.76	93.86		8	SAND TO SILTY SAND
1.40	4.59	5.44	113.70	14.74	93.76		8	SAND TO SILTY SAND
1.45	4.76	5.46	114.12	14.72	93.66		8	SAND TO SILTY SAND
1.50	4.92	5.48	114.50	14.69	93.46		8	SAND TO SILTY SAND
1.55	5.09	5.51	115.14	14.68	93.36		8	SAND TO SILTY SAND
1.60	5.25	5.57	116.42	14.68	93.36		8	SAND TO SILTY SAND
1.65	5.41	5.66	118.12	14.68	93.36		8	SAND TO SILTY SAND
1.70	5.58	5.71	119.18	14.66	93.26		8	SAND TO SILTY SAND
1.75	5.74	5.70	119.14	14.65	93.16		8	SAND TO SILTY SAND
1.80	5.91	5.46	114.08	14.57	92.66		8	SAND TO SILTY SAND
1.85	6.07	5.63	117.56	14.58	92.76		8	SAND TO SILTY SAND
1.90	6.23	5.66	118.16	14.57	92.66		8	SAND TO SILTY SAND
1.95	6.40	5.71	119.22	14.57	92.66		8	SAND TO SILTY SAND
2.00	6.56	5.74	119.94	14.55	92.56		8	SAND TO SILTY SAND
2.05	6.73	5.90	123.30	14.58	92.76		8	SAND TO SILTY SAND

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
2.10	6.89	6.15	128.36	14.61	92.96		8	SAND TO SILTY SAND
2.15	7.05	6.19	129.38	14.60	92.86		8	SAND TO SILTY SAND
2.20	7.22	6.15	128.48	14.58	92.76		8	SAND TO SILTY SAND
2.25	7.38	6.04	126.20	14.54	92.46		8	SAND TO SILTY SAND
2.30	7.55	5.85	122.08	14.49	92.16		8	SAND TO SILTY SAND
2.35	7.71	5.54	115.78	14.39	91.56		8	SAND TO SILTY SAND
2.40	7.87	5.41	112.94	14.36	91.36		8	SAND TO SILTY SAND
2.45	8.04	5.44	113.70	14.35	91.26		8	SAND TO SILTY SAND
2.50	8.20	5.40	112.80	14.33	91.16		8	SAND TO SILTY SAND
2.55	8.37	5.23	109.16	14.27	90.76		8	SAND TO SILTY SAND
2.60	8.53	5.00	104.48	14.21	90.36		8	SAND TO SILTY SAND
2.65	8.69	4.78	99.86	14.14	89.96		8	SAND TO SILTY SAND
2.70	8.86	4.64	96.92	14.10	89.66	5	7	SILTY SAND TO SANDY SILT
2.75	9.02	4.55	95.10	12.76	81.16	6	8	SAND TO SILTY SAND
2.80	9.19	4.50	93.98	14.02	89.16	7	7	SILTY SAND TO SANDY SILT
2.85	9.35	4.16	86.80	13.91	88.46		7	SILTY SAND TO SANDY SILT
2.90	9.51	4.43	92.58	12.76	81.16	8	8	SAND TO SILTY SAND
2.95	9.68	4.43	92.46	13.95	88.76		8	SAND TO SILTY SAND
3.00	9.84	4.45	92.92	12.76	81.16	9	7	SILTY SAND TO SANDY SILT
3.05	10.01	4.47	93.34	12.76	81.16		7	SILTY SAND TO SANDY SILT
3.10	10.17	4.49	93.78	12.76	81.16	10	8	SAND TO SILTY SAND
3.15	10.34	4.51	94.24	12.76	81.16		8	SAND TO SILTY SAND
3.20	10.50	4.49	93.86	13.88	88.26		8	SAND TO SILTY SAND
3.25	10.66	4.49	93.86	12.76	81.16	11	7	SILTY SAND TO SANDY SILT
3.30	10.83	4.48	93.64	13.84	88.06		7	SILTY SAND TO SANDY SILT
3.35	10.99	4.44	92.66	12.76	81.16		7	SILTY SAND TO SANDY SILT
3.40	11.16	4.43	92.46	12.76	81.16		7	SILTY SAND TO SANDY SILT
3.45	11.32	4.39	91.66	12.76	81.16		7	SILTY SAND TO SANDY SILT
3.50	11.48	4.33	90.38	12.76	81.16		7	SILTY SAND TO SANDY SILT
3.55	11.65	4.38	91.40	13.73	87.36		7	SILTY SAND TO SANDY SILT
3.60	11.81	4.38	91.48	13.73	87.36	12	8	SAND TO SILTY SAND
3.65	11.98	4.33	90.46	12.76	81.16		8	SAND TO SILTY SAND
3.70	12.14	4.30	89.78	13.69	87.06	13	7	SILTY SAND TO SANDY SILT
3.75	12.30	4.27	89.10	13.67	86.96	14	8	SAND TO SILTY SAND
3.80	12.47	4.34	90.58	13.69	87.06		8	SAND TO SILTY SAND
3.85	12.63	4.27	89.10	13.66	86.86		8	SAND TO SILTY SAND

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
3.90	12.80	4.50	93.94	12.76	81.16		8	SAND TO SILTY SAND
3.95	12.96	4.73	98.84	12.76	81.16		8	SAND TO SILTY SAND
4.00	13.12	5.05	105.50	12.76	81.16		8	SAND TO SILTY SAND
4.05	13.29	5.29	110.56	13.86	88.16		8	SAND TO SILTY SAND
4.10	13.45	5.27	110.14	13.84	88.06		8	SAND TO SILTY SAND
4.15	13.62	5.18	108.22	12.76	81.16		8	SAND TO SILTY SAND
4.20	13.78	4.87	101.80	13.73	87.36		8	SAND TO SILTY SAND
4.25	13.94	4.58	95.64	12.76	81.16		8	SAND TO SILTY SAND
4.30	14.11	4.32	90.20	12.76	81.16		8	SAND TO SILTY SAND
4.35	14.27	4.44	92.80	13.59	86.46		8	SAND TO SILTY SAND
4.40	14.44	5.43	113.40	13.83	87.96		8	SAND TO SILTY SAND
4.45	14.60	6.36	132.78	14.00	89.06		8	SAND TO SILTY SAND
4.50	14.76	6.91	144.26	14.10	89.66		8	SAND TO SILTY SAND

Table D.28. Weighted Average In-Situ Dry Density (C_u) Based for Pond #4 Run #2 Project 4

Layer	Average Dry Density/Layer		Depth of Layer		Depth	Dry Density	
	KN/m³	lb/ft³	Meter	Feet	%	KN/m³	lb/ft³
1	14.27	90.76	N/a	N/a	0.00	0.00	0.00
2	14.38	91.46	N/a	N/a	0.00	0.00	0.00
3	15.12	96.16	0.05	0.164	0.01	0.17	1.11
4	14.82	94.27	2.45	8.038	0.56	8.35	53.09
5	14.10	89.66	0.05	0.164	0.01	0.16	1.03
6	12.76	81.16	0.05	0.164	0.01	0.15	0.93
7	13.96	88.81	0.10	0.328	0.02	0.32	2.04
8	13.36	84.96	0.10	0.328	0.02	0.31	1.95
9	12.76	81.16	0.10	0.328	0.02	0.29	1.87
10	13.13	83.53	0.15	0.492	0.03	0.45	2.88
11	13.05	83.03	0.35	1.148	0.08	1.05	6.68
12	13.25	84.26	0.10	0.328	0.02	0.30	1.94
13	13.69	87.06	0.05	0.164	0.01	0.16	1.00
14	13.41	85.28	0.80	2.625	0.18	2.47	15.68
		Σ=	4.35	14.27	Σ=	14.18	90.20

Table D.29. CPT. In-Situ Dry Density (C_u) Based for Test #1 Project 5

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
0.05	0.16	1.09	22.78	15.11	96.09	1	6	SANDY SILT TO CLAYEY SILT
0.10	0.33	1.04	21.76	14.56	92.59		6	SANDY SILT TO CLAYEY SILT
0.15	0.49	1.95	40.74	15.07	95.89	2	7	SILTY SAND TO SANDY SILT
0.20	0.66	2.63	54.90	15.28	97.19		7	SILTY SAND TO SANDY SILT
0.25	0.82	2.99	62.46	15.28	97.19		7	SILTY SAND TO SANDY SILT
0.30	0.98	3.88	81.02	15.50	98.59	3	8	SAND TO SILTY SAND
0.35	1.15	4.94	103.16	15.73	100.09		8	SAND TO SILTY SAND
0.40	1.31	5.90	123.30	15.89	101.09		8	SAND TO SILTY SAND
0.45	1.48	6.80	142.04	16.00	101.79		8	SAND TO SILTY SAND
0.50	1.64	7.72	161.16	16.11	102.49		8	SAND TO SILTY SAND
0.55	1.80	8.79	183.60	16.24	103.29		8	SAND TO SILTY SAND
0.60	1.97	8.94	186.66	16.18	102.89		8	SAND TO SILTY SAND
0.65	2.13	7.98	166.64	15.92	101.29		8	SAND TO SILTY SAND
0.70	2.30	6.21	129.64	15.48	98.49		8	SAND TO SILTY SAND
0.75	2.46	4.36	91.14	14.93	94.99	4	7	SILTY SAND TO SANDY SILT
0.80	2.62	3.46	72.28	14.59	92.79		7	SILTY SAND TO SANDY SILT
0.85	2.79	3.01	62.96	14.38	91.49		7	SILTY SAND TO SANDY SILT
0.90	2.95	2.77	57.92	14.24	90.59		7	SILTY SAND TO SANDY SILT
0.95	3.12	2.74	57.14	12.83	81.59		7	SILTY SAND TO SANDY SILT
1.00	3.28	2.94	61.36	12.83	81.59		7	SILTY SAND TO SANDY SILT
1.05	3.45	3.74	78.06	14.43	91.79		7	SILTY SAND TO SANDY SILT
1.10	3.61	4.46	93.22	14.63	93.09		7	SILTY SAND TO SANDY SILT
1.15	3.77	4.48	93.60	14.62	92.99	5	8	SAND TO SILTY SAND
1.20	3.94	5.52	115.32	14.85	94.49		8	SAND TO SILTY SAND
1.25	4.10	4.75	99.18	14.63	93.09	6	7	SILTY SAND TO SANDY SILT
1.30	4.27	4.60	96.02	14.57	92.69		7	SILTY SAND TO SANDY SILT
1.35	4.43	3.85	80.48	14.32	91.09		7	SILTY SAND TO SANDY SILT
1.40	4.59	3.26	68.12	14.10	89.69	7	6	SANDY SILT TO CLAYEY SILT
1.45	4.76	2.49	52.00	12.83	81.59		6	SANDY SILT TO CLAYEY SILT
1.50	4.92	2.19	45.68	12.83	81.59		6	SANDY SILT TO CLAYEY SILT
1.55	5.09	1.97	41.18	12.83	81.59		6	SANDY SILT TO CLAYEY SILT
1.60	5.25	1.70	35.60	13.17	83.79		6	SANDY SILT TO CLAYEY SILT
1.65	5.41	1.81	37.86	12.83	81.59		6	SANDY SILT TO CLAYEY SILT
1.70	5.58	1.70	35.48	12.83	81.59		6	SANDY SILT TO CLAYEY SILT
1.75	5.74	1.85	38.66	12.83	81.59		6	SANDY SILT TO CLAYEY SILT
1.80	5.91	1.98	41.26	12.83	81.59		6	SANDY SILT TO CLAYEY SILT
1.85	6.07	3.26	68.12	13.82	87.89		6	SANDY SILT TO CLAYEY SILT
1.90	6.23	3.71	77.46	12.83	81.59		6	SANDY SILT TO CLAYEY SILT
1.95	6.40	4.10	85.62	14.04	89.29	8	7	SILTY SAND TO SANDY SILT

2.00	6.56	5.15	107.62	14.30	90.99		7	SILTY SAND TO SANDY SILT
2.05	6.73	5.87	122.50	14.46	91.99		7	SILTY SAND TO SANDY SILT
2.10	6.89	6.50	135.76	14.57	92.69	9	8	SAND TO SILTY SAND
2.15	7.05	6.56	137.02	14.57	92.69		8	SAND TO SILTY SAND
2.20	7.22	7.01	146.42	14.65	93.19		8	SAND TO SILTY SAND
2.25	7.38	7.36	153.72	14.70	93.49	10	9	SAND

Table D.30 Weighted Average In-Situ Dry Density (C_u) Based for Test #1 Project 5

Layer	Average Dry Density/Layer		Depth of Layer		Depth	Dry Density	
	KN/m³	lb/ft³	Meter	Feet	%	KN/m³	lb/ft³
1	14.83	94.34	N/a	N/a	0.00	0.00	0.00
2	15.21	96.76	0.15	N/a	0.09	1.43	9.07
3	15.90	101.11	0.45	1.476	0.28	4.47	28.44
4	14.11	89.74	0.40	1.312	0.25	3.53	22.43
5	14.74	93.74	0.10	0.328	0.06	0.92	5.86
6	14.51	92.29	0.15	0.492	0.09	1.36	8.65
7	13.09	83.25	N/a	N/a	0.00	0.00	0.00
8	14.27	90.76	0.15	0.492	0.09	1.34	8.51
9	14.60	92.86	0.15	0.492	0.09	1.37	8.71
10	14.70	93.49	0.05	0.164	0.03	0.46	2.92
		Σ=	1.60	4.76	Σ=	14.87	94.59

Table D.31. CPT In-Situ Dry Density (C_u) Based for Test #2 Project 5

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
0.05	0.16	0.79	16.40	14.68	93.39	1	1	SENSITIVE FINE GRAINED
0.10	0.33	1.77	37.06	15.26	97.09	2	7	SILTY SAND TO SANDY SILT
0.15	0.49	2.46	51.36	15.40	97.99		7	SILTY SAND TO SANDY SILT
0.20	0.66	2.99	62.54	15.45	98.29		7	SILTY SAND TO SANDY SILT
0.25	0.82	3.65	76.26	15.56	98.99		7	SILTY SAND TO SANDY SILT
0.30	0.98	4.58	95.64	15.73	100.09	3	8	SAND TO SILTY SAND
0.35	1.15	5.41	112.94	15.86	100.89		8	SAND TO SILTY SAND
0.40	1.31	5.77	120.50	15.84	100.79		8	SAND TO SILTY SAND
0.45	1.48	5.48	114.42	15.67	99.69		8	SAND TO SILTY SAND
0.50	1.64	4.38	91.40	15.26	97.09	4	7	SILTY SAND TO SANDY SILT
0.55	1.80	3.32	69.34	14.81	94.19		7	SILTY SAND TO SANDY SILT
0.60	1.97	2.82	58.98	14.54	92.49	5	6	SANDY SILT TO CLAYEY SILT
0.65	2.13	2.46	51.42	14.32	91.09		6	SANDY SILT TO CLAYEY SILT
0.70	2.30	2.65	55.40	14.37	91.39	6	7	SILTY SAND TO SANDY SILT
0.75	2.46	3.25	67.98	14.57	92.69		7	SILTY SAND TO SANDY SILT
0.80	2.62	3.29	68.80	14.54	92.49		7	SILTY SAND TO SANDY SILT
0.85	2.79	2.83	59.14	14.32	91.09		7	SILTY SAND TO SANDY SILT
0.90	2.95	2.85	59.48	14.29	90.89		7	SILTY SAND TO SANDY SILT
0.95	3.12	3.00	62.68	14.32	91.09		7	SILTY SAND TO SANDY SILT
1.00	3.28	3.61	75.46	14.51	92.29		7	SILTY SAND TO SANDY SILT
1.05	3.45	6.14	128.20	15.18	96.59	7	8	SAND TO SILTY SAND
1.10	3.61	5.32	111.02	14.95	95.09	8	7	SILTY SAND TO SANDY SILT
1.15	3.77	4.07	85.02	14.57	92.69		7	SILTY SAND TO SANDY SILT
1.20	3.94	2.94	61.44	14.13	89.89	9	6	SANDY SILT TO CLAYEY SILT
1.25	4.10	2.06	42.96	13.69	87.09	10	5	CLAYEY SILT TO SILTY CLAY
1.30	4.27	1.94	40.46	12.83	81.59	11	6	SANDY SILT TO CLAYEY SILT
1.35	4.43	1.81	37.74	12.83	81.59		6	SANDY SILT TO CLAYEY SILT
1.40	4.59	1.68	35.06	12.83	81.59		6	SANDY SILT TO CLAYEY SILT
1.45	4.76	1.84	38.36	12.83	81.59		6	SANDY SILT TO CLAYEY SILT
1.50	4.92	2.12	44.28	13.50	85.89		6	SANDY SILT TO CLAYEY SILT
1.55	5.09	2.31	48.32	13.60	86.49	12	7	SILTY SAND TO SANDY SILT
1.60	5.25	2.45	51.12	12.83	81.59		7	SILTY SAND TO SANDY SILT
1.65	5.41	2.58	53.80	13.68	86.99		7	SILTY SAND TO SANDY SILT
1.70	5.58	2.84	59.28	13.77	87.59		7	SILTY SAND TO SANDY SILT
1.75	5.74	3.38	70.50	13.96	88.79		7	SILTY SAND TO SANDY SILT
1.80	5.91	4.00	83.44	14.15	89.99		7	SILTY SAND TO SANDY SILT
1.85	6.07	4.73	98.88	14.34	91.19	13	8	SAND TO SILTY SAND
1.90	6.23	5.70	119.06	14.56	92.59		8	SAND TO SILTY SAND
1.95	6.40	6.88	143.70	14.79	94.09		8	SAND TO SILTY SAND
2.00	6.56	8.41	175.70	15.04	95.69	14	9	SAND
2.05	6.73	8.90	185.94	15.11	96.09		9	SAND

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
2.10	6.89	8.93	186.48	15.09	95.99		9	SAND
2.15	7.05	9.14	190.90	15.11	96.09		9	SAND
2.20	7.22	9.41	196.60	15.14	96.29		9	SAND
2.25	7.38	9.74	203.48	15.17	96.49		9	SAND

Table D.32 Weighted Average In-Situ Dry Density (C_u) Based for Test #2 Project 5

Layer	Average Dry Density/Layer		Depth of Layer		Depth	Dry Density	
	KN/m³	lb/ft³	Meter	Feet	%	KN/m³	lb/ft³
1	14.68	93.39	N/a	N/a	0.00	0.00	0.00
2	15.42	98.09	0.20	0.66	0.11	1.67	10.60
3	15.78	100.36	0.20	0.66	0.11	1.71	10.85
4	15.04	95.64	0.20	0.66	0.11	1.63	10.34
5	14.43	91.79	N/a	N/a	0.00	0.00	0.00
6	14.42	91.70	0.35	1.15	0.19	2.73	17.35
7	15.18	96.59	0.05	0.16	0.03	0.41	2.61
8	14.76	93.89	0.10	0.33	0.05	0.80	5.08
9	14.13	89.89	N/a	N/a	0.00	0.00	0.00
10	13.69	87.09	N/a	N/a	0.00	0.00	0.00
11	12.96	82.45	N/a	N/a	0.00	0.00	0.00
12	13.66	86.91	0.30	0.98	0.16	2.22	14.09
13	14.56	92.62	0.15	0.49	0.08	1.18	7.51
14	15.11	96.11	0.30	0.98	0.16	2.45	15.58
		Σ=	1.85	6.07	Σ=	14.78	94.02

Table D.33. CPT In-Situ Dry Density (C_u) Based for Test #3 Project 5

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
0.05	0.16	0.97	20.22	14.95	95.09	1	6	SANDY SILT TO CLAYEY SILT
0.10	0.33	2.22	46.40	15.56	98.99	2	7	SILTY SAND TO SANDY SILT
0.15	0.49	2.81	58.60	15.58	99.09		7	SILTY SAND TO SANDY SILT
0.20	0.66	3.40	70.96	15.62	99.39		7	SILTY SAND TO SANDY SILT
0.25	0.82	4.08	85.14	15.70	99.89	3	8	SAND TO SILTY SAND
0.30	0.98	5.22	108.98	15.92	101.29		8	SAND TO SILTY SAND
0.35	1.15	6.64	138.60	16.18	102.89		8	SAND TO SILTY SAND
0.40	1.31	8.04	167.92	16.36	104.09		8	SAND TO SILTY SAND
0.45	1.48	7.56	157.94	16.14	102.69		8	SAND TO SILTY SAND
0.50	1.64	5.71	119.26	15.62	99.39		8	SAND TO SILTY SAND
0.55	1.80	5.18	108.10	15.40	97.99		8	SAND TO SILTY SAND
0.60	1.97	4.88	101.94	15.26	97.09	4	7	SILTY SAND TO SANDY SILT
0.65	2.13	4.90	102.32	15.20	96.69	5	8	SAND TO SILTY SAND
0.70	2.30	5.14	107.42	15.22	96.79		8	SAND TO SILTY SAND
0.75	2.46	5.27	110.04	15.20	96.69		8	SAND TO SILTY SAND
0.80	2.62	5.30	110.68	15.15	96.39		8	SAND TO SILTY SAND
0.85	2.79	5.37	112.18	15.14	96.29		8	SAND TO SILTY SAND
0.90	2.95	5.50	114.90	15.12	96.19		8	SAND TO SILTY SAND
0.95	3.12	5.73	119.66	15.14	96.29		8	SAND TO SILTY SAND
1.00	3.28	5.76	120.34	15.11	96.09		8	SAND TO SILTY SAND
1.05	3.45	5.72	119.40	15.06	95.79		8	SAND TO SILTY SAND
1.10	3.61	5.51	115.06	14.98	95.29		8	SAND TO SILTY SAND
1.15	3.77	4.92	102.74	14.79	94.09		8	SAND TO SILTY SAND
1.20	3.94	4.37	91.26	14.60	92.89		8	SAND TO SILTY SAND
1.25	4.10	4.46	93.22	14.60	92.89		8	SAND TO SILTY SAND
1.30	4.27	4.46	93.10	14.59	92.79		8	SAND TO SILTY SAND
1.35	4.43	4.61	96.24	14.60	92.89		8	SAND TO SILTY SAND
1.40	4.59	5.03	105.04	14.68	93.39		8	SAND TO SILTY SAND
1.45	4.76	4.95	103.42	14.63	93.09		8	SAND TO SILTY SAND
1.50	4.92	5.35	111.74	14.71	93.59		8	SAND TO SILTY SAND
1.55	5.09	4.65	97.04	14.51	92.29	6	7	SILTY SAND TO SANDY SILT
1.60	5.25	3.61	75.50	14.18	90.19	7	6	SANDY SILT TO CLAYEY SILT
1.65	5.41	3.93	82.00	14.26	90.69		6	SANDY SILT TO CLAYEY SILT
1.70	5.58	4.61	96.20	14.45	91.89	8	7	SILTY SAND TO SANDY SILT
1.75	5.74	5.01	104.66	14.52	92.39		7	SILTY SAND TO SANDY SILT
1.80	5.91	5.30	110.72	14.59	92.79	9	8	SAND TO SILTY SAND
1.85	6.07	5.00	104.52	14.49	92.19		8	SAND TO SILTY SAND
1.90	6.23	4.97	103.88	14.46	91.99	10	7	SILTY SAND TO SANDY SILT
1.95	6.40	5.01	104.56	14.46	91.99		7	SILTY SAND TO SANDY SILT
2.00	6.56	5.23	109.24	14.49	92.19	11	8	SAND TO SILTY SAND
2.05	6.73	5.37	112.18	14.51	92.29		8	SAND TO SILTY SAND

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
2.10	6.89	5.53	115.48	14.54	92.49		8	SAND TO SILTY SAND
2.15	7.05	5.51	115.18	14.51	92.29		8	SAND TO SILTY SAND
2.20	7.22	5.59	116.76	14.51	92.29		8	SAND TO SILTY SAND
2.25	7.38	5.83	121.74	14.56	92.59		8	SAND TO SILTY SAND

Table D.34. Weighted Average In-Situ Dry Density (C_u) Based for Test #3 Project 5

Layer	Average Dry Density/Layer		Depth of Layer		Depth	Dry Density	
	KN/m³	lb/ft³	Meter	Feet	%	KN/m³	lb/ft³
1	14.95	95.09	N/a	N/a	0.00	0.00	0.00
2	15.59	99.16	0.15	0.49	0.07	1.11	7.08
3	15.91	101.18	0.35	1.15	0.17	2.65	16.86
4	15.26	97.09	0.05	0.16	0.02	0.36	2.31
5	14.92	94.90	0.90	2.95	0.43	6.39	40.67
6	14.51	92.29	0.05	0.16	0.02	0.35	2.20
7	14.18	90.19	N/a	N/a	0.00	0.00	0.00
8	14.49	92.14	0.10	0.33	0.05	0.69	4.39
9	14.54	92.49	0.10	0.33	0.05	0.69	4.40
10	14.46	91.99	0.10	0.33	0.05	0.69	4.38
11	14.52	92.36	0.30	0.98	0.14	2.07	13.19
		Σ=	2.10	6.89	Σ=	15.01	95.49

Table D35. CPT In-Situ Dry Density (C_u) Based for Pond (E-1) Test #1 Project 6

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
0.05	0.16	1.73	36.12	16.82	106.96	1	6	SANDY SILT TO CLAYEY SILT
0.10	0.33	4.92	102.74	17.66	112.36	2	8	SAND TO SILTY SAND
0.15	0.49	7.87	164.30	17.99	114.46		8	SAND TO SILTY SAND
0.20	0.66	10.94	228.46	18.23	115.96	3	9	SAND
0.25	0.82	13.11	273.72	18.31	116.46		9	SAND
0.30	0.98	13.81	288.42	18.25	116.06		9	SAND
0.35	1.15	13.84	288.98	18.12	115.26		9	SAND
0.40	1.31	14.35	299.68	18.06	114.86		9	SAND
0.45	1.48	15.48	323.30	18.07	114.96		9	SAND
0.50	1.64	13.44	280.60	17.79	113.16		9	SAND
0.55	1.80	12.76	266.54	17.65	112.26		9	SAND
0.60	1.97	11.89	248.26	17.49	111.26		9	SAND
0.65	2.13	11.92	248.94	17.44	110.96		9	SAND
0.70	2.30	12.40	258.94	17.44	110.96		9	SAND
0.75	2.46	11.70	244.36	17.32	110.16	4	8	SAND TO SILTY SAND
0.80	2.62	11.22	234.42	17.22	109.56	5	9	SAND
0.85	2.79	13.76	287.44	17.44	110.96		9	SAND
0.90	2.95	11.48	239.76	17.16	109.16	6	8	SAND TO SILTY SAND
0.95	3.12	11.06	231.06	17.08	108.66	7	7	SILTY SAND TO SANDY SILT
1.00	3.28	13.98	291.98	17.35	110.36	8	8	SAND TO SILTY SAND
1.05	3.45	24.22	505.88	18.06	114.86	9	9	SAND
1.10	3.61	24.42	510.08	18.04	114.76		9	SAND
1.15	3.77	25.00	522.12	18.04	114.76		9	SAND
1.20	3.94	25.20	526.36	18.01	114.56		9	SAND
1.25	4.10	25.67	536.14	18.01	114.56		9	SAND
1.30	4.27	22.07	461.02	17.76	112.96		9	SAND
1.35	4.43	22.68	473.76	17.77	113.06		9	SAND
1.40	4.59	21.06	439.86	17.65	112.26		9	SAND
1.45	4.76	25.00	522.20	17.85	113.56		9	SAND
1.50	4.92	23.76	496.16	17.76	112.96		9	SAND
1.55	5.09	24.39	509.32	17.77	113.06		9	SAND
1.60	5.25	27.71	578.80	17.93	114.06	10	0	GRAVELY SAND TO SAND
1.65	5.41	28.44	593.88	17.93	114.06		0	GRAVELY SAND TO SAND
1.70	5.58	29.11	608.06	17.95	114.16	11	9	SAND
1.75	5.74	28.60	597.24	17.90	113.86		9	SAND
1.80	5.91	29.49	615.88	17.92	113.96		9	SAND
1.85	6.07	27.52	574.80	17.81	113.26		9	SAND
1.90	6.23	32.13	671.04	17.99	114.46	12	0	GRAVELY SAND TO SAND
1.95	6.40	29.10	607.82	17.84	113.46	13	9	SAND
2.00	6.56	27.10	566.00	17.73	112.76		9	SAND
2.05	6.73	25.45	531.58	17.62	112.06		9	SAND

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
2.10	6.89	25.56	533.76	17.60	111.96		9	SAND
2.15	7.05	24.57	513.10	17.54	111.56		9	SAND
2.20	7.22	22.31	465.86	17.38	110.56		9	SAND
2.25	7.38	20.75	433.36	17.27	109.86		9	SAND
2.30	7.55	19.71	411.64	17.19	109.36		9	SAND
2.35	7.71	18.02	376.38	17.07	108.56		9	SAND
2.40	7.87	19.00	396.72	17.11	108.86		9	SAND
2.45	8.04	20.07	419.24	17.18	109.26	14	1	SENSITIVE FINE GRAINED
2.50	8.20	18.29	381.90	17.05	108.46		1	SENSITIVE FINE GRAINED

Table D36. Weighted Average In-Situ Dry Density (C_u) Based for Pond (E-1) Test #1 Project 6

Layer	Average Dry Density/Layer		Depth of Layer		Depth	Dry Density	
	KN/m³	lb/ft³	Meter	Feet	%	KN/m³	lb/ft³
1	16.82	106.96	N/a	N/a	0.00	0.00	0.00
2	17.83	113.41	0.10	0.33	0.04	0.76	4.83
3	17.90	113.83	0.55	1.80	0.23	4.19	26.64
4	17.32	110.16	0.05	0.16	0.02	0.37	2.34
5	17.33	110.26	0.10	0.33	0.04	0.74	4.69
6	17.16	109.16	0.05	0.16	0.02	0.37	2.32
7	17.08	108.66	0.05	0.16	0.02	0.36	2.31
8	17.35	110.36	0.05	0.16	0.02	0.37	2.35
9	17.88	113.76	0.55	1.80	0.23	4.19	26.62
10	17.93	114.06	0.10	0.33	0.04	0.76	4.85
11	17.89	113.81	0.20	0.66	0.09	1.52	9.69
12	17.99	114.46	0.05	0.16	0.02	0.38	2.44
13	17.43	110.90	0.50	1.64	0.21	3.71	23.60
14	17.11	108.86	N/a	N/a	0.00	0.00	0.00
		Σ=	2.35	7.71	Σ=	17.71	112.68

Table D37. CPT. In-Situ Dry Density (C_u) Based for Pond (E-1) Test #2 Project 6

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
0.05	0.16	1.06	22.14	15.39	97.87	1	6	SANDY SILT TO CLAYEY SILT
0.10	0.33	2.89	60.30	16.69	106.16	2	7	SILTY SAND TO SANDY SILT
0.15	0.49	4.56	95.22	17.07	108.56	3	8	SAND TO SILTY SAND
0.20	0.66	6.88	143.62	17.44	110.96		8	SAND TO SILTY SAND
0.25	0.82	9.33	194.86	17.71	112.66	4	9	SAND
0.30	0.98	11.57	241.68	17.88	113.76		9	SAND
0.35	1.15	13.94	291.14	18.04	114.76		9	SAND
0.40	1.31	16.13	336.90	18.15	115.46		9	SAND
0.45	1.48	17.69	369.48	18.20	115.76		9	SAND
0.50	1.64	17.67	369.06	18.12	115.26		9	SAND
0.55	1.80	13.52	282.30	17.68	112.46		9	SAND
0.60	1.97	11.57	241.72	17.41	110.76		9	SAND
0.65	2.13	11.03	230.42	17.30	110.06		9	SAND
0.70	2.30	11.63	242.92	17.32	110.16		9	SAND
0.75	2.46	12.53	261.78	17.37	110.46		9	SAND
0.80	2.62	12.54	261.90	17.33	110.26		9	SAND
0.85	2.79	11.63	243.00	17.19	109.36		9	SAND
0.90	2.95	11.22	234.28	17.10	108.76		9	SAND
0.95	3.12	10.35	216.06	16.97	107.96		9	SAND
1.00	3.28	9.71	202.84	16.86	107.26		9	SAND
1.05	3.45	9.38	196.00	16.78	106.76		9	SAND
1.10	3.61	9.02	188.44	16.71	106.26		9	SAND
1.15	3.77	8.35	174.46	15.39	97.87	5	8	SAND TO SILTY SAND
1.20	3.94	7.46	155.76	15.39	97.87		8	SAND TO SILTY SAND
1.25	4.10	6.64	138.60	16.22	103.17		8	SAND TO SILTY SAND
1.30	4.27	5.99	125.04	15.39	97.87		8	SAND TO SILTY SAND
1.35	4.43	5.37	112.22	15.39	97.87		8	SAND TO SILTY SAND
1.40	4.59	4.68	97.72	15.39	97.87		8	SAND TO SILTY SAND
1.45	4.76	4.46	93.22	15.65	99.57		8	SAND TO SILTY SAND
1.50	4.92	5.18	108.14	15.79	100.47		8	SAND TO SILTY SAND
1.55	5.09	6.87	143.44	16.09	102.37		8	SAND TO SILTY SAND
1.60	5.25	8.14	170.08	16.27	103.47		8	SAND TO SILTY SAND
1.65	5.41	8.55	178.62	15.39	97.87	6	9	SAND
1.70	5.58	8.35	174.30	16.25	103.37	7	8	SAND TO SILTY SAND
1.75	5.74	7.71	161.12	15.39	97.87		8	SAND TO SILTY SAND
1.80	5.91	6.59	137.66	15.39	97.87		8	SAND TO SILTY SAND
1.85	6.07	6.38	133.34	15.39	97.87		8	SAND TO SILTY SAND
1.90	6.23	5.61	117.14	15.72	99.97		8	SAND TO SILTY SAND
1.95	6.40	4.37	91.32	15.39	97.87		8	SAND TO SILTY SAND
2.00	6.56	3.59	74.90	15.39	97.87	8	7	SILTY SAND TO SANDY SILT
2.05	6.73	3.25	67.94	15.39	97.87		7	SILTY SAND TO SANDY SILT

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m^3	lb/ft^3			
2.10	6.89	3.22	67.22	15.39	97.87		7	SILTY SAND TO SANDY SILT
2.15	7.05	3.07	64.20	15.39	97.87		7	SILTY SAND TO SANDY SILT
2.20	7.22	1.96	41.00	15.39	97.87		7	SILTY SAND TO SANDY SILT
2.25	7.38	1.27	26.60	15.39	97.87	9	6	SANDY SILT TO CLAYEY SILT
2.30	7.55	0.88	18.40	15.39	97.87	10	5	CLAYEY SILT TO SILTY CLAY
2.35	7.71	1.00	20.94	15.39	97.87		5	CLAYEY SILT TO SILTY CLAY
2.40	7.87	0.83	17.30	15.39	97.87		5	CLAYEY SILT TO SILTY CLAY
2.45	8.04	0.89	18.62	15.39	97.87		5	CLAYEY SILT TO SILTY CLAY
2.50	8.20	1.04	21.66	15.39	97.87		5	CLAYEY SILT TO SILTY CLAY
2.55	8.37	1.90	39.68	15.39	97.87	11	6	SANDY SILT TO CLAYEY SILT
2.60	8.53	1.68	35.10	15.39	97.87		6	SANDY SILT TO CLAYEY SILT
2.65	8.69	2.23	46.52	15.39	97.87	12	7	SILTY SAND TO SANDY SILT
2.70	8.86	2.28	47.68	15.39	97.87		7	SILTY SAND TO SANDY SILT
2.75	9.02	2.70	56.34	15.39	97.87		7	SILTY SAND TO SANDY SILT
2.80	9.19	2.09	43.60	15.39	97.87	13	6	SANDY SILT TO CLAYEY SILT
2.85	9.35	2.42	50.44	15.39	97.87	14	7	SILTY SAND TO SANDY SILT
2.90	9.51	2.67	55.70	15.39	97.87		7	SILTY SAND TO SANDY SILT
2.95	9.68	2.93	61.28	15.39	97.87	15	6	SANDY SILT TO CLAYEY SILT
3.00	9.84	2.42	50.44	15.39	97.87		6	SANDY SILT TO CLAYEY SILT
3.05	10.01	3.06	63.98	15.39	97.87	16	7	SILTY SAND TO SANDY SILT
3.10	10.17	5.43	113.36	15.39	97.87	17	8	SAND TO SILTY SAND
3.15	10.34	5.48	114.46	15.39	97.87	18	7	SILTY SAND TO SANDY SILT
3.20	10.50	7.20	150.42	15.39	97.87	19	8	SAND TO SILTY SAND
3.25	10.66	7.89	164.78	15.39	97.87		8	SAND TO SILTY SAND
3.30	10.83	13.07	273.00	15.39	97.87	20	9	SAND
3.35	10.99	12.00	250.60	15.39	97.87		9	SAND
3.40	11.16	14.43	301.38	16.27	103.47		9	SAND
3.45	11.32	18.78	392.18	15.39	97.87		9	SAND
3.50	11.48	20.94	437.26	16.69	106.16	21	1	SENSITIVE FINE GRAINED
3.55	11.65	20.10	419.88	15.39	97.87		1	SENSITIVE FINE GRAINED

Table D38. Weighted Average In-Situ Dry Density (C_u) Based for Pond (E-1) Test #2
Project 6

Layer	Average Dry Density/Layer		Depth of Layer		Depth	Dry Density	
	KN/m³	lb/ft³	Meter	Feet	%	KN/m³	lb/ft³
1	15.39	97.87	N/a	N/a	0.00	0.00	0.00
2	16.69	106.16	0.05	0.16	0.02	0.29	1.86
3	17.26	109.76	0.10	0.33	0.04	0.61	3.85
4	17.45	111.01	0.90	2.95	0.32	5.51	35.06
5	15.70	99.84	0.50	1.64	0.18	2.75	17.52
6	15.39	97.87	0.05	0.16	0.02	0.27	1.72
7	15.59	99.14	0.30	0.98	0.11	1.64	10.44
8	15.39	97.87	0.25	0.82	0.09	1.35	8.59
9	15.39	97.87	N/a	N/a	0.00	0.00	0.00
10	15.39	97.87	N/a	N/a	0.00	0.00	0.00
11	15.39	97.87	N/a	N/a	0.00	0.00	0.00
12	15.39	97.87	0.15	0.49	0.05	0.81	5.15
13	15.39	97.87	N/a	N/a	0.00	0.00	0.00
14	15.39	97.87	0.10	0.33	0.04	0.54	3.43
15	15.39	97.87	N/a	N/a	0.00	0.00	0.00
16	15.39	97.87	0.05	0.16	0.02	0.27	1.72
17	15.39	97.87	0.05	0.16	0.02	0.27	1.72
18	15.39	97.87	0.05	0.16	0.02	0.27	1.72
19	15.39	97.87	0.10	0.33	0.04	0.54	3.43
20	15.61	99.27	0.20	0.66	0.07	1.10	6.97
21	16.04	102.02	N/a	N/a	0.00	0.00	0.00
		Σ=	2.85	9.35	Σ=	16.22	103.16

Table D39. CPT In-Situ Dry Density (C_u) Based for Pond (E-1) Test #3 Project 6

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
0.05	0.16	0.44	9.22	15.39	97.87	1	1	SENSITIVE FINE GRAINED
0.10	0.33	2.48	51.80	16.52	105.07	2	7	SILTY SAND TO SANDY SILT
0.15	0.49	4.26	89.06	16.99	108.06		7	SILTY SAND TO SANDY SILT
0.20	0.66	6.98	145.82	17.46	111.06	3	8	SAND TO SILTY SAND
0.25	0.82	7.27	151.86	17.38	110.56		8	SAND TO SILTY SAND
0.30	0.98	8.44	176.20	17.46	111.06		8	SAND TO SILTY SAND
0.35	1.15	9.67	202.04	17.54	111.56		8	SAND TO SILTY SAND
0.40	1.31	10.16	212.28	17.52	111.46	4	9	SAND
0.45	1.48	10.44	218.02	17.48	111.16		9	SAND
0.50	1.64	9.47	197.78	17.29	109.96	5	8	SAND TO SILTY SAND
0.55	1.80	7.48	156.24	16.93	107.66		8	SAND TO SILTY SAND
0.60	1.97	7.46	155.80	16.86	107.26		8	SAND TO SILTY SAND
0.65	2.13	10.86	226.86	17.29	109.96	6	9	SAND
0.70	2.30	6.63	138.52	16.63	105.76	7	8	SAND TO SILTY SAND
0.75	2.46	4.48	93.56	15.39	97.87		8	SAND TO SILTY SAND
0.80	2.62	3.72	77.76	15.39	97.87		8	SAND TO SILTY SAND
0.85	2.79	3.79	79.20	15.81	100.57		8	SAND TO SILTY SAND
0.90	2.95	3.85	80.40	15.39	97.87		8	SAND TO SILTY SAND
0.95	3.12	3.84	80.22	15.39	97.87		8	SAND TO SILTY SAND
1.00	3.28	3.92	81.84	15.72	99.97		8	SAND TO SILTY SAND
1.05	3.45	4.17	87.02	15.39	97.87		8	SAND TO SILTY SAND
1.10	3.61	4.31	90.12	15.39	97.87		8	SAND TO SILTY SAND
1.15	3.77	4.08	85.28	15.39	97.87		8	SAND TO SILTY SAND
1.20	3.94	3.60	75.20	15.39	97.87	8	7	SILTY SAND TO SANDY SILT
1.25	4.10	2.97	62.00	15.39	97.87		7	SILTY SAND TO SANDY SILT
1.30	4.27	2.24	46.78	15.39	97.87		7	SILTY SAND TO SANDY SILT
1.35	4.43	1.84	38.50	15.39	97.87		7	SILTY SAND TO SANDY SILT
1.40	4.59	2.09	43.60	15.39	97.87		7	SILTY SAND TO SANDY SILT
1.45	4.76	3.29	68.74	15.39	97.87	9	8	SAND TO SILTY SAND
1.50	4.92	4.78	99.80	15.39	97.87		8	SAND TO SILTY SAND
1.55	5.09	5.86	122.46	15.39	97.87		8	SAND TO SILTY SAND
1.60	5.25	6.40	133.58	15.86	100.87		8	SAND TO SILTY SAND
1.65	5.41	5.69	118.88	15.39	97.87		8	SAND TO SILTY SAND
1.70	5.58	4.59	95.94	15.39	97.87		8	SAND TO SILTY SAND
1.75	5.74	4.05	84.64	15.39	97.87		8	SAND TO SILTY SAND
1.80	5.91	4.27	89.14	15.39	97.87		8	SAND TO SILTY SAND
1.85	6.07	4.76	99.42	15.39	97.87		8	SAND TO SILTY SAND
1.90	6.23	6.36	132.74	15.39	97.87		8	SAND TO SILTY SAND
1.95	6.40	7.09	148.16	15.83	100.67		8	SAND TO SILTY SAND
2.00	6.56	6.88	143.74	15.39	97.87		8	SAND TO SILTY SAND
2.05	6.73	5.81	121.26	15.39	97.87		8	SAND TO SILTY SAND

Depth		q_c		γ_d		Layer Number	Table Number	SOIL TYPE CLASSIFICATION
Meter	Feet	Mpa	PSF	KN/m³	lb/ft³			
2.10	6.89	4.12	86.12	15.39	97.87	10	7	SILTY SAND TO SANDY SILT
2.15	7.05	2.62	54.76	15.39	97.87		7	SILTY SAND TO SANDY SILT
2.20	7.22	1.85	38.54	15.39	97.87	11	6	SANDY SILT TO CLAYEY SILT
2.25	7.38	1.36	28.38	15.39	97.87		6	SANDY SILT TO CLAYEY SILT
2.30	7.55	1.34	28.04	15.39	97.87		6	SANDY SILT TO CLAYEY SILT
2.35	7.71	2.15	44.86	15.39	97.87	12	7	SILTY SAND TO SANDY SILT
2.40	7.87	3.02	63.06	15.39	97.87		7	SILTY SAND TO SANDY SILT
2.45	8.04	2.53	52.90	15.39	97.87		7	SILTY SAND TO SANDY SILT
2.50	8.20	2.90	60.54	15.39	97.87		7	SILTY SAND TO SANDY SILT
2.55	8.37	3.58	74.78	15.39	97.87	13	8	SAND TO SILTY SAND
2.60	8.53	4.10	85.70	15.39	97.87	14	7	SILTY SAND TO SANDY SILT
2.65	8.69	4.33	90.34	15.39	97.87		7	SILTY SAND TO SANDY SILT
2.70	8.86	3.31	69.22	15.39	97.87		7	SILTY SAND TO SANDY SILT
2.75	9.02	3.67	76.70	15.39	97.87		7	SILTY SAND TO SANDY SILT
2.80	9.19	3.94	82.30	15.39	97.87		7	SILTY SAND TO SANDY SILT
2.85	9.35	2.50	52.18	15.39	97.87	15	6	SANDY SILT TO CLAYEY SILT
2.90	9.51	3.74	78.02	15.39	97.87	16	7	SILTY SAND TO SANDY SILT
2.95	9.68	5.56	116.20	15.39	97.87	17	8	SAND TO SILTY SAND
3.00	9.84	5.18	108.14	15.39	97.87	18	7	SILTY SAND TO SANDY SILT
3.05	10.01	6.41	133.88	15.39	97.87	19	8	SAND TO SILTY SAND
3.10	10.17	6.34	132.32	15.39	97.87		8	SAND TO SILTY SAND
3.15	10.34	9.78	204.30	15.39	97.87		8	SAND TO SILTY SAND
3.20	10.50	9.40	196.22	15.39	97.87		8	SAND TO SILTY SAND
3.25	10.66	8.00	167.12	15.39	97.87		8	SAND TO SILTY SAND
3.30	10.83	9.52	198.76	15.39	97.87		8	SAND TO SILTY SAND
3.35	10.99	9.64	201.40	15.39	97.87		8	SAND TO SILTY SAND
3.40	11.16	8.47	176.92	15.39	97.87		8	SAND TO SILTY SAND
3.45	11.32	13.26	277.04	15.39	97.87	20	9	SAND
3.50	11.48	14.92	311.70	15.39	97.87		9	SAND

Table D40. Weighted Average In-Situ Dry Density (C_u) Based for Pond (E-1) Test #3
Project 6

Layer	Average Dry Density/Layer		Depth of Layer		Depth	Dry Density	
	KN/m^3	lb/ft^3	Meter	Feet	%	KN/m^3	lb/ft^3
1	15.39	97.87	N/a	N/a	0.00	0.00	0.00
2	16.75	106.56	0.1	0.33	0.03	0.52	3.28
3	17.46	111.06	0.2	0.66	0.06	1.07	6.83
4	17.50	111.31	0.1	0.33	0.03	0.54	3.42
5	17.02	108.30	0.15	0.49	0.05	0.79	5.00
6	17.29	109.96	0.05	0.16	0.02	0.27	1.69
7	15.59	99.14	0.5	1.64	0.15	2.40	15.25
8	15.39	97.87	0.25	0.82	0.08	1.18	7.53
9	15.46	98.32	0.65	2.13	0.20	3.09	19.66
10	15.39	97.87	0.1	0.33	0.03	0.47	3.01
11	15.39	97.87	N/a	N/a	0.00	0.00	0.00
12	15.39	97.87	0.2	0.66	0.06	0.95	6.02
13	15.39	97.87	0.05	0.16	0.02	0.24	1.51
14	15.39	97.87	0.25	0.82	0.08	1.18	7.53
15	15.39	97.87	N/a	N/a	0.00	0.00	0.00
16	15.39	97.87	0.05	0.16	0.02	0.24	1.51
17	15.39	97.87	0.05	0.16	0.02	0.24	1.51
18	15.39	97.87	0.05	0.16	0.02	0.24	1.51
19	15.39	97.87	0.4	1.31	0.12	1.89	12.05
20	15.39	97.87	0.1	0.33	0.03	0.47	3.01
		Σ=	3.25	10.66	Σ=	15.77	100.31

Table D41. CPT In-Situ Dry Density (C_u) Based for Pond B Test #4 Project 7

Depth		q_c		g_d		Layer	Table	SOIL TYPE CLASSIFICTION
Meter	Feet	Mpa	PSF	KN/m^3	lb/m^3	Number	Number	
0.05	0.16	0.57	11.90	15.13	96.23	1	1	SENSITIVE FINE GRAINED
0.10	0.33	1.33	27.69	15.13	96.23	2	6	SANDY SILT TO CLAYEY SILT
0.15	0.49	2.11	44.01	15.13	96.23	3	7	SILTY SAND TO SANDY SILT
0.20	0.66	2.76	57.61	15.13	96.23		7	SILTY SAND TO SANDY SILT
0.25	0.82	3.22	67.29	15.73	100.03	4	8	SAND TO SILTY SAND
0.30	0.98	3.45	71.97	15.13	96.23		8	SAND TO SILTY SAND
0.35	1.15	3.60	75.11	15.13	96.23		8	SAND TO SILTY SAND
0.40	1.31	3.63	75.75	15.13	96.23		8	SAND TO SILTY SAND
0.45	1.48	3.58	74.85	15.13	96.23		8	SAND TO SILTY SAND
0.50	1.64	3.56	74.39	15.13	96.23		8	SAND TO SILTY SAND
0.55	1.80	3.56	74.27	15.13	96.23		8	SAND TO SILTY SAND
0.60	1.97	3.64	76.09	15.13	96.23		8	SAND TO SILTY SAND
0.65	2.13	3.72	77.61	15.13	96.23		8	SAND TO SILTY SAND
0.70	2.30	3.77	78.77	15.13	96.23		8	SAND TO SILTY SAND
0.75	2.46	3.74	78.17	15.13	96.23		8	SAND TO SILTY SAND
0.80	2.62	3.83	79.95	15.13	96.23		8	SAND TO SILTY SAND
0.85	2.79	3.97	82.84	15.13	96.23		8	SAND TO SILTY SAND
0.90	2.95	4.13	86.24	15.13	96.23		8	SAND TO SILTY SAND
0.95	3.12	4.33	90.44	15.13	96.23		8	SAND TO SILTY SAND
1.00	3.28	4.54	94.78	15.13	96.23		8	SAND TO SILTY SAND
1.05	3.44	4.71	98.26	15.13	96.23		8	SAND TO SILTY SAND
1.10	3.61	4.88	101.92	15.13	96.23		8	SAND TO SILTY SAND
1.15	3.77	5.07	105.90	15.13	96.23		8	SAND TO SILTY SAND
1.20	3.94	5.26	109.78	15.29	97.23		8	SAND TO SILTY SAND
1.25	4.10	5.45	113.72	15.13	96.23		8	SAND TO SILTY SAND
1.30	4.27	5.71	119.30	15.13	96.23		8	SAND TO SILTY SAND
1.35	4.43	5.96	124.48	15.13	96.23		8	SAND TO SILTY SAND
1.40	4.59	6.21	129.58	15.13	96.23		8	SAND TO SILTY SAND
1.45	4.76	6.41	133.82	15.13	96.23		8	SAND TO SILTY SAND
1.50	4.92	6.61	138.07	15.13	96.23		8	SAND TO SILTY SAND
1.55	5.09	6.74	140.79	15.13	96.23		8	SAND TO SILTY SAND
1.60	5.25	6.84	142.83	15.13	96.23		8	SAND TO SILTY SAND
1.65	5.41	6.93	144.73	15.13	96.23		8	SAND TO SILTY SAND
1.70	5.58	7.00	146.21	15.13	96.23		8	SAND TO SILTY SAND

1.75	5.74	6.55	136.87	15.13	96.23		8	SAND TO SILTY SAND
1.80	5.91	6.99	145.87	15.13	96.23		8	SAND TO SILTY SAND
1.85	6.07	7.02	146.51	15.13	96.23		8	SAND TO SILTY SAND
1.90	6.23	6.79	141.75	15.13	96.23		8	SAND TO SILTY SAND
1.95	6.40	6.93	144.61	15.13	96.23		8	SAND TO SILTY SAND
2.00	6.56	6.87	143.49	15.27	97.13		8	SAND TO SILTY SAND
2.05	6.73	6.87	143.37	15.13	96.23		8	SAND TO SILTY SAND
2.10	6.89	6.89	143.93	15.13	96.23		8	SAND TO SILTY SAND
2.15	7.05	6.95	145.07	15.13	96.23		8	SAND TO SILTY SAND
2.20	7.22	7.01	146.47	15.13	96.23		8	SAND TO SILTY SAND
2.25	7.38	7.08	147.79	15.13	96.23		8	SAND TO SILTY SAND
2.30	7.55	7.11	148.51	15.13	96.23		8	SAND TO SILTY SAND
2.35	7.71	7.13	148.89	15.13	96.23		8	SAND TO SILTY SAND
2.40	7.87	7.07	147.57	15.13	96.23		8	SAND TO SILTY SAND
2.45	8.04	6.98	145.71	15.13	96.23		8	SAND TO SILTY SAND
2.50	8.20	6.89	143.93	15.13	96.23		8	SAND TO SILTY SAND
2.55	8.37	6.80	141.97	15.13	96.23		8	SAND TO SILTY SAND
2.60	8.53	6.67	139.37	15.13	96.23		8	SAND TO SILTY SAND
2.65	8.69	6.55	136.83	15.13	96.23		8	SAND TO SILTY SAND
2.70	8.86	6.51	135.93	15.13	96.23		8	SAND TO SILTY SAND
2.75	9.02	6.30	131.66	15.13	96.23		8	SAND TO SILTY SAND
2.80	9.19	6.53	136.31	15.13	96.23		8	SAND TO SILTY SAND
2.85	9.35	6.64	138.57	15.13	96.23		8	SAND TO SILTY SAND
2.90	9.51	6.71	140.15	15.13	96.23		8	SAND TO SILTY SAND
2.95	9.68	6.78	141.51	15.13	96.23		8	SAND TO SILTY SAND
3.00	9.84	6.79	141.81	15.13	96.23		8	SAND TO SILTY SAND
3.05	10.01	6.80	141.97	15.13	96.23		8	SAND TO SILTY SAND
3.10	10.17	6.91	144.39	15.13	96.23		8	SAND TO SILTY SAND
3.15	10.33	7.02	146.55	15.13	96.23		8	SAND TO SILTY SAND
3.20	10.50	7.06	147.49	15.13	96.23		8	SAND TO SILTY SAND
3.25	10.66	7.21	150.59	15.13	96.23		8	SAND TO SILTY SAND
3.30	10.83	7.42	154.89	15.13	96.23		8	SAND TO SILTY SAND
3.35	10.99	7.75	161.77	15.13	96.23		8	SAND TO SILTY SAND
3.40	11.15	8.20	171.17	15.13	96.23		8	SAND TO SILTY SAND
3.45	11.32	8.78	183.31	15.13	96.23		8	SAND TO SILTY SAND
3.50	11.48	9.29	193.92	15.13	96.23		8	SAND TO SILTY SAND
3.55	11.65	9.55	199.36	15.13	96.23		8	SAND TO SILTY SAND
3.60	11.81	8.54	178.43	15.13	96.23		8.00	SAND TO SILTY SAND
3.65	11.98	6.47	135.18	15.13	96.23	5	7.00	SILTY SAND TO SANDY SILT

3.70	12.14	4.44	92.74	15.13	96.23	6	6.00	SANDY SILT TO CLAYEY SILT
3.75	12.30	3.25	67.77	15.13	96.23		6.00	SANDY SILT TO CLAYEY SILT
3.80	12.47	3.61	75.41	15.13	96.23	7	7.00	SILTY SAND TO SANDY SILT
3.85	12.63	2.86	59.77	15.13	96.23	8	6.00	SANDY SILT TO CLAYEY SILT
3.90	12.80	2.87	59.91	15.13	96.23		6.00	SANDY SILT TO CLAYEY SILT
3.95	12.96	3.58	74.85	15.13	96.23		6.00	SANDY SILT TO CLAYEY SILT
4.00	13.12	3.41	71.21	15.13	96.23	9	7.00	SILTY SAND TO SANDY SILT
4.05	13.29	2.44	51.03	15.13	96.23	10	6.00	SANDY SILT TO CLAYEY SILT
4.10	13.45	2.48	51.87	15.13	96.23		6.00	SANDY SILT TO CLAYEY SILT
4.15	13.62	3.48	72.61	15.13	96.23		6.00	SANDY SILT TO CLAYEY SILT
4.20	13.78	4.09	85.42	15.13	96.23		6.00	SANDY SILT TO CLAYEY SILT
4.25	13.94	3.06	63.93	15.13	96.23	11	5.00	CLAYEY SILT TO SILTY CLAY
4.30	14.11	2.84	59.23	15.13	96.23	12	7.00	SILTY SAND TO SANDY SILT
4.35	14.27	2.75	57.47	15.13	96.23		7.00	SILTY SAND TO SANDY SILT

Table D42. Weighted Average In-Situ Dry Density (C_u) Based for Pond B Test #4 Project 7

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Layer	Avg Dry Density/Layer	Depth of Layer		%Depth	Dry Density	
		(Meter)	(Feet)		(kN/m^3)	(lb/ft^3)
1	15.13	N/A	N/a	0.00	0.00	0.00
2	15.13	N/A	N/a	0.00	0.00	0.00
3	15.13	0.10	0.33	0.03	0.41	2.60
4	15.14	3.35	10.99	0.91	13.71	87.22
5	15.13	0.05	0.16	0.01	0.20	1.30
6	15.13	N/A	N/A	0.00	0.00	0.00
7	15.13	0.05	0.16	0.01	0.20	1.30
8	15.13	N/A	N/A	0.00	0.00	0.00
9	15.13	0.05	0.16	0.01	0.20	1.30
10	15.13	N/a	N/A	0.00	0.00	0.00
11	15.13	N/a	N/A	0.00	0.00	0.00
12	15.13	0.10	0.33	0.03	0.41	2.60
					15.14	96.33

Table D43. CPT In-Situ Dry Density (C_u) Based for Pond C Test #9 Project 7

Depth		q_c		g_d		Layer	Table	SOIL TYPE CLASSIFICTION
Meter	Feet	Mpa	PSF	KN/m^3	lb/m^3	Number	Number	
0.05	0.16	1.45	30.29	15.02	95.53	1	7	SILTY SAND TO SANDY SILT
0.10	0.33	2.05	42.77	15.02	95.53		7	SILTY SAND TO SANDY SILT
0.15	0.49	2.90	60.59	15.02	95.53		7	SILTY SAND TO SANDY SILT
0.20	0.66	4.07	85.04	16.06	102.13	2	8	SAND TO SILTY SAND
0.25	0.82	5.15	107.56	16.25	103.33		8	SAND TO SILTY SAND
0.30	0.98	6.15	128.46	16.39	104.23		8	SAND TO SILTY SAND
0.35	1.15	7.09	148.01	16.50	104.92		8	SAND TO SILTY SAND
0.40	1.31	7.82	163.31	16.54	105.22	3	9	SAND
0.45	1.48	8.65	180.55	16.62	105.72		9	SAND
0.50	1.64	10.62	221.72	16.83	107.02		9	SAND
0.55	1.80	12.26	255.99	16.95	107.82		9	SAND
0.60	1.97	13.38	279.45	17.02	108.22		9	SAND
0.65	2.13	13.05	272.43	16.94	107.72		9	SAND
0.70	2.30	11.78	246.01	16.76	106.62		9	SAND
0.75	2.46	10.63	222.06	16.59	105.52		9	SAND
0.80	2.62	9.58	200.12	16.43	104.52		9	SAND
0.85	2.79	8.65	180.73	16.28	103.53		9	SAND
0.90	2.95	8.31	173.59	15.02	95.53	4	8	SAND TO SILTY SAND
0.95	3.12	7.93	165.59	16.07	102.23		8	SAND TO SILTY SAND
1.00	3.28	6.95	145.15	15.90	101.13	5	7	SILTY SAND TO SANDY SILT
1.05	3.44	5.88	122.86	15.02	95.53	6	5	CLAYEY SILT TO SILTY CLAY
1.10	3.61	6.29	131.36	15.71	99.93		5	CLAYEY SILT TO SILTY CLAY
1.15	3.77	5.79	120.94	15.60	99.23	7	1	VERY STIFF FINE GRAINED (*)
1.20	3.94	6.53	136.41	15.71	99.93		1	VERY STIFF FINE GRAINED (*)
1.25	4.10	8.94	186.79	15.02	95.53		1	VERY STIFF FINE GRAINED (*)
1.30	4.27	7.77	162.33	15.02	95.53		1	VERY STIFF FINE GRAINED (*)
1.35	4.43	9.19	191.98	15.02	95.53		1	VERY STIFF FINE GRAINED (*)
1.40	4.59	7.51	156.75	15.02	95.53		1	VERY STIFF FINE GRAINED (*)
1.45	4.76	6.64	138.65	15.02	95.53		1	VERY STIFF FINE GRAINED (*)
1.50	4.92	6.35	132.60	15.02	95.53		1	VERY STIFF FINE GRAINED (*)
1.55	5.09	6.21	129.74	15.02	95.53		1	VERY STIFF FINE GRAINED (*)
1.60	5.25	5.95	124.26	15.02	95.53		1	VERY STIFF FINE GRAINED (*)
1.65	5.41	6.10	127.32	15.02	95.53		1	VERY STIFF FINE GRAINED (*)
1.70	5.58	5.96	124.44	15.02	95.53		1	VERY STIFF FINE GRAINED (*)
1.75	5.74	7.65	159.77	15.02	95.53		1	VERY STIFF FINE GRAINED (*)

1.80	5.91	6.71	140.15	15.02	95.53		1	VERY STIFF FINE GRAINED (*)
1.85	6.07	6.02	125.62	15.02	95.53		1	VERY STIFF FINE GRAINED (*)
1.90	6.23	6.66	139.13	15.34	97.53		1	VERY STIFF FINE GRAINED (*)
1.95	6.40	9.26	193.38	15.68	99.73	8	6	SANDY SILT TO CLAYEY SILT
2.00	6.56	11.11	231.96	15.02	95.53	9	7	SILTY SAND TO SANDY SILT
2.05	6.73	15.67	327.28	16.26	103.43	10	8	SAND TO SILTY SAND
2.10	6.89	12.08	252.29	15.02	95.53	11	7	SILTY SAND TO SANDY SILT
2.15	7.05	9.76	203.82	15.68	99.73	12	6	SANDY SILT TO CLAYEY SILT
2.20	7.22	9.05	189.01	15.59	99.13	13	5	CLAYEY SILT TO SILTY CLAY
2.25	7.38	7.20	150.43	15.02	95.53		5	CLAYEY SILT TO SILTY CLAY
2.30	7.55	6.58	137.33	15.02	95.53	14	1	VERY STIFF FINE GRAINED (*)
2.35	7.71	6.41	133.86	15.02	95.53	15	5	CLAYEY SILT TO SILTY CLAY
2.40	7.87	5.48	114.44	15.02	95.53	16	4	SILTY CLAY TO CLAY
2.45	8.04	5.18	108.08	15.02	95.53		4	SILTY CLAY TO CLAY
2.50	8.20	4.42	92.22	15.02	95.53		4	SILTY CLAY TO CLAY
2.55	8.37	3.79	79.11	15.02	95.53	17	3	CLAY
2.60	8.53	4.65	97.02	15.02	95.53	18	5	CLAYEY SILT TO SILTY CLAY
2.65	8.69	3.65	76.21	15.02	95.53	19	3	CLAY
2.70	8.86	4.40	91.92	15.02	95.53	20	4	SILTY CLAY TO CLAY
2.75	9.02	3.81	79.53	15.02	95.53		4	SILTY CLAY TO CLAY
2.80	9.19	3.02	63.13	15.02	95.53		4	SILTY CLAY TO CLAY
2.85	9.35	2.93	61.21	15.02	95.53		4	SILTY CLAY TO CLAY
2.90	9.51	3.50	72.99	15.02	95.53	21	5	CLAYEY SILT TO SILTY CLAY
2.95	9.68	3.06	63.97	15.02	95.53	22	4	SILTY CLAY TO CLAY
3.00	9.84	2.98	62.27	15.02	95.53		4	SILTY CLAY TO CLAY
3.05	10.01	2.83	59.17	15.02	95.53	23	3	CLAY
3.10	10.17	3.23	67.37	15.02	95.53	24	4	SILTY CLAY TO CLAY
3.15	10.33	2.83	59.05	15.02	95.53	25	3	CLAY
3.20	10.50	3.00	62.75	15.02	95.53		3	CLAY
3.25	10.66	2.41	50.29	15.02	95.53		3	CLAY
3.30	10.83	2.20	45.93	15.02	95.53		3	CLAY
3.35	10.99	3.07	64.15	15.02	95.53		3	CLAY
3.40	11.15	3.04	63.39	15.02	95.53		3	CLAY
3.45	11.32	3.69	77.11	15.02	95.53	26	4	SILTY CLAY TO CLAY
3.50	11.48	5.21	108.84	15.02	95.53	27	5	CLAYEY SILT TO SILTY CLAY
3.55	11.65	6.43	134.34	15.02	95.53	28	6	SANDY SILT TO CLAYEY SILT
3.60	11.81	8.09	168.87	15.02	95.53	29	7	SILTY SAND TO SANDY SILT
3.65	11.98	8.99	187.69	15.02	95.53	30	9	SAND
3.70	12.14	8.33	174.01	15.02	95.53		9	SAND

Table D44. Weighted Average In-Situ Dry Density (C_u) Based for Pond C Test #9
Project 7

Layer	Avg Dry Density/Layer	Depth of Layer		%Depth	Dry Density	
		(Meter)	(Feet)		(kN/m^3)	(lb/ft^3)
1	15.02	0.15	0.49	0.12	1.73	11.02
2	16.30	0.2	0.66	0.15	2.51	15.95
3	16.70	0.5	1.64	0.38	6.42	40.85
4	15.55	0.1	0.33	0.08	1.20	7.61
5	15.90	0.05	0.16	0.04	0.61	3.89
6	15.37	N/a	N/a	0.00	0.00	0.00
7	15.12	N/a	N/a	0.00	0.00	0.00
8	15.68	N/a	N/a	0.00	0.00	0.00
9	15.02	0.05	0.16	0.04	0.58	3.67
10	16.26	0.05	0.16	0.04	0.63	3.98
11	15.02	0.05	0.16	0.04	0.58	3.67
12	15.68	N/a	N/a	0.00	0.00	0.00
13	15.30	N/a	N/a	0.00	0.00	0.00
14	15.02	N/a	N/a	0.00	0.00	0.00
15	15.02	N/a	N/a	0.00	0.00	0.00
16	15.02	N/a	N/a	0.00	0.00	0.00
17	15.02	N/a	N/a	0.00	0.00	0.00
18	15.02	N/a	N/a	0.00	0.00	0.00
19	15.02	N/a	N/a	0.00	0.00	0.00
20	15.02	N/a	N/a	0.00	0.00	0.00
21	15.02	N/a	N/a	0.00	0.00	0.00
22	15.02	N/a	N/a	0.00	0.00	0.00
23	15.02	N/a	N/a	0.00	0.00	0.00
24	15.02	N/a	N/a	0.00	0.00	0.00
25	15.02	N/a	N/a	0.00	0.00	0.00
26	15.02	N/a	N/a	0.00	0.00	0.00
27	15.02	N/a	N/a	0.00	0.00	0.00
28	15.02	N/a	N/a	0.00	0.00	0.00
29	15.02	0.05	0.16	0.04	0.58	3.67
30	15.02	0.1	0.33	0.08	1.16	7.35
					15.98	101.67

APPENDIX E

DILATOMETER TEST DATA

Table E.1. Dilatometer Test Results for Pond A #1

DEPTH (meters)	(feet)	THRUST (N*100)	ED (bars)	ID	SOIL TYPE	GAMMA (tonne/m^3)
0.20	0.66	88	253.95	4.94	sand	1.9
0.40	1.31	120	317.71	3.22	silty sand	1.9
0.60	1.97	100	255.77	2.80	silty sand	1.9
0.80	2.62	84	161.04	2.37	silty sand	1.9
1.00	3.28	64	139.18	2.89	silty sand	1.9
1.20	3.94	62	135.54	3.02	silty sand	1.9
1.40	4.59	78	157.40	2.90	silty sand	1.9
1.60	5.25	92	179.26	2.82	silty sand	1.8
1.80	5.91	110	208.41	2.74	silty sand	1.9
2.00	6.56	130	210.23	2.21	silty sand	1.9
2.20	7.22	140	213.87	2.17	silty sand	1.9
2.40	7.87	152	217.52	2.14	silty sand	1.9
2.60	8.53	154	212.05	2.04	silty sand	1.9
2.80	9.19	158	250.31	2.42	silty sand	1.9
3.00	9.84	185	332.29	2.57	silty sand	1.9
3.20	10.50	290	468.92	3.08	silty sand	2
3.40	11.16	380	625.59	2.32	silty sand	2
3.60	11.81	400	611.01	2.10	silty sand	2
3.80	12.47	430	607.37	1.86	silty sand	2.15
4.00	13.12	420	618.30	1.90	silty sand	2.15
4.20	13.78	460	581.87	1.61	sandy silt	2.1
4.40	14.44	440	600.08	1.75	sandy silt	2.1
4.60	15.09	460	600.08	1.75	sandy silt	2.1
4.80	15.75	460	600.08	1.75	sandy silt	2.1
5.00	16.41	470	589.15	1.66	sandy silt	2.1

Table E.2. Dilatometer Test Results for Pond A #2

DEPTH (meters)	(feet)	THRUST (N*100)	ED (bars)	ID	SOIL TYPE	GAMMA (tonne/m^3)
0.20	0.66	98	294.03	4.24	sand	1.9
0.40	1.31	134	297.67	2.46	silty sand	1.9
0.60	1.97	120	252.13	2.20	silty sand	1.9
0.80	2.62	88	193.83	2.45	silty sand	1.9
1.00	3.28	68	157.40	2.47	silty sand	1.9
1.20	3.94	62	150.11	2.35	silty sand	1.9
1.40	4.59	70	162.86	2.50	silty sand	1.9
1.60	5.25	88	213.87	2.67	silty sand	1.9
1.80	5.91	124	270.35	3.02	silty sand	1.9
2.00	6.56	170	363.26	2.68	silty sand	1.9
2.20	7.22	220	410.62	2.40	silty sand	2
2.40	7.87	240	461.63	1.76	sandy silt	1.95
2.60	8.53	230	359.61	1.14	silt	1.95
2.80	9.19	240	428.84	1.31	sandy silt	1.95
3.00	9.84	250	366.90	1.32	sandy silt	1.95
3.20	10.50	290	436.13	1.65	sandy silt	1.95
3.40	11.16	330	410.62	1.28	sandy silt	1.95
3.60	11.81	340	592.80	1.94	silty sand	2.15
3.80	12.47	340	512.64	1.97	silty sand	2
4.00	13.12	340	538.14	1.83	silty sand	2
4.20	13.78	380	567.29	1.81	silty sand	2.15
4.40	14.44	430	563.65	1.59	sandy silt	2.1
4.60	15.09	480	421.55	0.85	clayey silt	2.1
4.80	15.75	540	381.47	0.71	clayey silt	2.1

Table E.3. Dilatometer Test Results for Pond F #1

DEPTH (meters)	(feet)	THRUST (N*100)	ED (bars)	ID	SOIL TYPE	GAMMA (tonne/m^3)
0.40	1.31	44	209.50	3.97	sand	1.9
0.60	1.97	74	214.97	2.86	silty sand	1.9
0.80	2.62	80	220.43	2.88	silty sand	1.9
1.00	3.28	84	204.04	2.58	silty sand	1.9
1.20	3.94	80	169.42	2.47	silty sand	1.9
1.40	4.59	84	176.71	3.05	silty sand	1.9
1.60	5.25	110	220.43	2.53	silty sand	1.9
1.80	5.91	132	269.62	2.78	silty sand	1.9
2.00	6.56	138	278.73	2.41	silty sand	1.9
2.20	7.22	132	262.33	2.70	silty sand	1.9
2.40	7.87	114	224.08	2.58	silty sand	1.9
2.60	8.53	92	167.60	2.27	silty sand	1.8
2.80	9.19	70	129.34	2.60	silty sand	1.8
3.00	9.84	44	72.87	1.60	sandy silt	1.7
3.20	10.50	28	58.30	2.30	silty sand	1.7
3.40	11.16	22	41.90	1.50	sandy silt	1.6
3.60	11.81	18	40.08	1.64	sandy silt	1.6
3.80	12.47	17	38.26	1.68	sandy silt	1.6
4.00	13.12	17	41.90	2.19	silty sand	1.7
4.20	13.78	24	63.76	2.54	silty sand	1.7
4.40	14.44	25	60.12	1.77	sandy silt	1.6
4.60	15.09	21	49.19	1.68	sandy silt	1.6
4.80	15.75	16	32.79	1.16	silt	1.6
5.00	16.41	21	54.65	2.14	silty sand	1.7

Table E.4. Dilatometer Test Results for Pond J #1

DEPTH (meters)	(feet)	THRUST (N*100)	ED (bars)	ID	SOIL TYPE	GAMMA (tonne/m^3)
0.40	1.31	74	239.01	4.59	sand	1.9
0.60	1.97	84	195.29	2.87	silty sand	1.9
0.80	2.62	80	180.72	2.92	silty sand	1.9
1.00	3.28	72	142.46	2.30	silty sand	1.9
1.20	3.94	58	115.13	2.18	silty sand	1.9
1.40	4.59	92	166.14	2.66	silty sand	1.9
1.60	5.25	150	264.52	2.57	silty sand	1.9
1.80	5.91	200	399.33	2.46	silty sand	2
2.00	6.56	360	574.22	2.17	silty sand	2
2.20	7.22	480	566.93	1.59	sandy silt	2.1
2.40	7.87	550	508.63	1.23	sandy silt	2.1
2.60	8.53	520	333.74	0.57	silty clay	2.05
2.80	9.19	520	523.21	1.31	sandy silt	2.1
3.00	9.84	400	519.56	1.53	sandy silt	2.1
3.20	10.50	260	337.39	1.25	sandy silt	1.95
3.40	11.16	240	399.33	1.46	sandy silt	1.95
3.60	11.81	220	413.90	1.90	silty sand	2
3.80	12.47	200	330.10	1.71	sandy silt	1.95
4.00	13.12	230	344.68	1.73	sandy silt	1.95
4.20	13.78	245	362.89	1.82	silty sand	2
4.40	14.44	240	362.89	1.82	silty sand	2
4.60	15.09	220	319.17	1.77	sandy silt	1.95
4.80	15.75	245	392.04	1.98	silty sand	2
5.00	16.41	265	384.75	2.02	silty sand	2
5.20	17.06	300	457.62	2.13	silty sand	2
5.40	17.72	340	413.90	1.79	sandy silt	1.95
5.60	18.37	340	421.19	1.82	silty sand	2
5.80	19.03	315	399.33	1.89	silty sand	2
6.00	19.69	290	413.90	1.90	silty sand	2
6.20	20.34	260	370.18	1.74	sandy silt	1.95
6.40	21.00	260	311.88	1.04	silt	1.95

Table E.5. Dilatometer Test Results for Pond J #2

DEPTH (meters)	(feet)	THRUST (N*100)	ED (bars)	ID	SOIL TYPE	GAMMA (tonne/m^3)
0.40	1.31	74	159.22	2.53	silty sand	1.9
0.60	1.97	68	130.07	3.00	silty sand	1.9
0.80	2.62	56	130.07	3.00	silty sand	1.9
1.00	3.28	58	120.96	3.13	silty sand	1.9
1.20	3.94	56	110.03	2.81	silty sand	1.9
1.40	4.59	52	104.57	3.05	silty sand	1.9
1.60	5.25	60	80.89	2.18	silty sand	1.9
1.80	5.91	72	104.57	3.05	silty sand	1.7
2.00	6.56	91	131.89	2.72	silty sand	1.8
2.20	7.22	110	162.86	3.12	silty sand	1.8
2.40	7.87	130	195.66	3.20	silty sand	1.8
2.60	8.53	148	235.73	2.82	silty sand	1.9
2.80	9.19	150	253.95	2.73	silty sand	1.9
3.00	9.84	150	273.99	2.72	silty sand	1.9
3.20	10.50	155	286.74	2.81	silty sand	1.9
3.40	11.16	152	281.28	3.01	silty sand	1.9
3.60	11.81	154	252.13	2.48	silty sand	1.9
3.80	12.47	160	290.39	2.76	silty sand	1.9
4.00	13.12	170	355.97	3.07	silty sand	1.9
4.20	13.78	170	319.53	2.56	silty sand	1.9
4.40	14.44	180	363.26	2.53	silty sand	2
4.60	15.09	170	386.94	2.62	silty sand	2
4.80	15.75	160	330.47	2.74	silty sand	1.9
5.00	16.41	170	341.40	2.62	silty sand	1.9
5.20	17.06	180	385.12	3.00	silty sand	1.9
5.40	17.72	190	346.86	2.63	silty sand	1.9
5.60	18.37	230	383.30	2.66	silty sand	2
5.80	19.03	290	421.55	2.61	silty sand	2
6.00	19.69	370	501.71	2.43	silty sand	2
6.20	20.34	460	581.87	2.38	silty sand	2
6.40	21.00	450	501.71	1.30	sandy silt	2.1

Table E.6. Dilatometer Test Results for Pond #4-1 SR44

DEPTH (meters)	(feet)	Thrust (N*100)	ED (bars)	ID	SOIL TYPE	GAMMA (tonne/m^3)
0.4	1.31	101	227.72	4.91	sand	1.9
0.6	1.97	123	258.69	3.83	sand	1.9
0.8	2.62	170	309.70	3.76	sand	1.9
1	3.28	200	364.35	4.38	sand	1.9
1.2	3.94	125	296.95	3.99	sand	1.9
1.4	4.59	63	34.61	0.49	silty clay	1.9
1.6	5.25	59	54.65	0.66	clayey silt	1.9
1.8	5.91	80	171.24	1.66	sandy silt	1.8
2	6.56	97	178.53	1.33	sandy silt	1.8
2.2	7.22	109	173.07	1.27	sandy silt	1.8
2.4	7.87	107	165.78	1.22	sandy silt	1.8
2.6	8.53	96	138.45	1.17	silt	1.8
2.8	9.19	80	103.84	0.81	clayey silt	1.8
3	9.84	190	174.89	1.18	silt	1.8
3.2	10.50	500	415.36	2.76	silty sand	2

Table E.7. Dilatometer Test Results for Pond #4-2 SR44

DEPTH (meters)	(feet)	Thrust (N*100)	ED (bars)	ID	SOIL TYPE	GAMMA (tonne/m³)
0.4	1.31	120	284.19	3.88	sand	1.9
0.6	1.97	140	338.85	3.44	sand	1.9
0.8	2.62	180	449.97	5.12	sand	1.9
1	3.28	210	362.53	2.52	silty sand	1.9
1.2	3.94	146	309.70	2.81	silty sand	1.9
1.4	4.59	70	125.70	1.70	sandy silt	1.9
1.6	5.25	52	18.22	0.27	clay	1.9
1.8	5.91	147	247.76	3.47	sand	1.9
2	6.56	320	357.06	2.44	silty sand	2
2.2	7.22	360	346.13	2.54	silty sand	1.9
2.4	7.87	330	286.01	1.81	silty sand	1.9
2.6	8.53	280	269.62	2.85	silty sand	1.9
2.8	9.19	310	307.88	3.98	sand	1.9
3	9.84	425	357.06	2.70	silty sand	1.9
3.2	10.50	445	406.25	2.25	silty sand	2
3.4	11.16	430	391.68	2.09	silty sand	2
3.6	11.81	390	417.18	2.95	silty sand	2
3.8	12.47	360	404.43	2.62	silty sand	2

Table E.9. Dilatometer Test Results for Test #1 (Field Project #5)

Depth		Thrust	E_D (bars)	I_D	Soil Classification	(γ_d) Ton/m^3	(γ_d) lb/ft^3	(γ_d) KN/m^3
Meter	Feet							
0.25	0.82	1320	-76.51	-1.33	peat	1.5	93.63	14.72
0.50	1.64	1440	218.61	2.21	silty sand	1.9	118.59	18.64
0.75	2.46	1440	293.30	3.13	silty sand	1.9	118.59	18.64
1.00	3.28	1800	360.71	2.92	silty sand	1.9	118.59	18.64
1.25	4.10	1600	327.92	2.78	silty sand	1.9	118.59	18.64
1.50	4.92	980	194.93	1.27	sandy silt	1.8	112.35	17.66
1.75	5.74	550	78.34	0.98	silt	1.7	106.11	16.68
2.00	6.56	470	63.76	0.73	clayey silt	1.7	106.11	16.68
2.25	7.38	880	107.48	1.13	silt	1.7	106.11	16.68
2.50	8.20	1470	149.38	1.13	silt	1.8	112.35	17.66
2.75	9.02	1540	116.59	0.98	silt	1.8	112.35	17.66
					Average	1.78	111.22	17.48

Table E.10. Dilatometer Test Results for Test #2 (Field Project #5)

Depth		Thrust	E_D (bars)	I_D	Soil Classification	(γ_d) Ton/m^3	(γ_d) lb/ft^3	(γ_d) KN/m^3
Meter	Feet							
0.25	0.82	460	-32.79	-2.39	peat	1.5	93.63	14.72
0.50	1.64	2000	74.69	0.62	clayey silt	1.7	106.11	16.68
0.75	2.46	2600	326.09	2.65	silty sand	1.9	118.59	18.64
1.00	3.28	1950	235.01	2.73	silty sand	1.9	118.59	18.64
1.25	4.10	1320	96.55	0.85	clayey silt	1.8	112.35	17.66
1.50	4.92	980	-18.22	-0.16	peat	1.5	93.63	14.72
1.75	5.74	850	109.31	1.40	sandy silt	1.7	106.11	16.68
2.00	6.56	1580	238.65	2.73	silty sand	1.9	118.59	18.64
2.25	7.38	2150	315.16	3.40	sand	1.9	118.59	18.64
2.50	8.20	1950	222.25	2.25	silty sand	1.9	118.59	18.64
2.75	9.02	1700	154.85	1.95	silty sand	1.8	112.35	17.66
					Average	1.77	110.65	17.40

Table E.11. Dilatometer Test Results for Test #3 (Field Project #5)

Depth		Thrust	E_D (bars)	I_D	Soil Classification	(γ_d) Ton/m^3	(γ_d) lb/ft^3	(γ_d) KN/m^3
Meter	Feet							
0.25	0.82	720	107.48	3.25	silty sand	1.80	112.35	17.66
0.50	1.64	2075	238.65	3.03	silty sand	1.90	118.59	18.64
0.75	2.46	1950	249.58	2.43	silty sand	1.90	118.59	18.64
1.00	3.28	1340	216.79	3.04	silty sand	1.90	118.59	18.64
1.25	4.10	1380	162.14	1.75	sandy silt	1.80	112.35	17.66
1.50	4.92	1600	244.11	2.06	silty sand	1.90	118.59	18.64
1.75	5.74	1550	204.04	2.09	silty sand	1.90	118.59	18.64
2.00	6.56	1580	176.71	1.95	silty sand	1.90	118.59	18.64
2.25	7.38	1570	176.71	2.16	silty sand	1.90	118.59	18.64
2.50	8.20	1750	191.28	2.01	silty sand	1.90	118.59	18.64
2.75	9.02	1750	173.07	1.71	sandy silt	1.80	112.35	17.66
					Average	1.87	116.89	18.38