Reliability Associated with the Estimation of Soil Resilient Modulus at Different Hierarchical Levels of Pavement Design

by

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ABSTRACT

Deterministic solutions are available to estimate the resilient modulus of unbound materials, which are difficult to interpret because they do not incorporate the variability associated with the inherent soil heterogeneity and that associated with environmental conditions.

This thesis presents the stochastic evaluation of the Enhanced Integrated Climatic Model (EICM), which is a model used in the Mechanistic-Empirical Pavement Design Guide to estimate the soil long-term equilibrium resilient modulus. The stochastic evaluation is accomplished by taking the deterministic equations in the EICM and applying stochastic procedures to obtain a mean and variance associated with the final design parameter, the resilient modulus at equilibrium condition.

In addition to the stochastic evaluation, different statistical analyses were applied to determine that the uses of hierarchical levels are valid in the unbound pavement material design and the climatic region has an impact on the final design resilient moduli at equilibrium. After determining that the climatic regions and the hierarchical levels are valid, reliability was applied to the resilient moduli at equilibrium. Finally, the American Association of State Highway and Transportation Officials (AASHTO) design concept based on the Structural Number (SN) was applied in order to illustrate the true implications the hierarchical levels of design and the variability associated with environmental effects and soil properties have in the design of pavement structures.

The stochastic solutions developed as part of this thesis work together with the SN design concept were applied to five soils with different resilient moduli at optimum compaction condition in order to evaluate the variability associated with the resilient moduli at equilibrium condition. These soils were evaluated in five different climatic regions ranging from arid to extremely wet conditions. The analysis showed that by using the most accurate input parameters obtained from laboratory testing (hierarchical Level 1) instead of Level 3 analysis could potentially save the State Department of Transportation up to 10.12 inches of asphalt in arid and semi-arid regions.

DEDICATION

To my loving wife Kelly, who gave the me the encouragement while writing my thesis.

To my parents Billy and Cathy, for their endless love, support, and teaching me that determination is required to succeed in life.

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NOMENCLATURE

%S	Degree of Saturation
$E[X^3]$	Skewness
$E[X^4]$	Kurtosis
2-Point	Rosenblueth 2-Point Estimation
3-Point	Rosenblueth 3-Point Estimation
a	Minimum Value
AASHTO	American Association of State Highway and Transportation Officials
AZ	Arizona
b	Maximum Value
$B(\alpha,\beta)$	Beta Function
CBR	California Bearing Ratio
cdf	Cumulative Distribution Function
CFGM	Clayey Fine Grained Material
CI	Confidence Interval
CV	Coefficient of Variation
D_{60}	Diameter of Particle corresponding to 60 Percent Passing
df	Degree of Freedom
E	Resilient Modulus
EICM	Enhanced Integrated Climatic Model
ESAL	Equivalent Single Axle Loads
F&X	Fredlund and Xing Soil Water Characteristic Curve

Fenv	Unfrozen Environmental Factor
FGM	Fine Grained Material
GB	Granular Base Material
Gs	Specific Gravity of Soil Solids
GSB	Granular Subbase and Subgrade Material
h	Layer Thickness
H_0	Null Hypothesis
H_1	Alternative Hypothesis
Hy	Yearly Heat Index
ksi	Kilo-pounds Per Square Inch
LA	Louisiana
LL	Liquid Limit
Max	Maximum Value
MEPDG	Mechanistic-Empirical Pavement Design
Min	Minimum Value
Monte	Monte Carlo Simulation
M_R	Unbound Resilient Modulus
M_{Req}	Unbound Resilient Modulus at Equilibrium
M_{Ropt}	Unbound Resilient Modulus at Optimum
MSE	Mean Square Error
MT	Montana
NM	New Mexico

NV	Nevada
$P_{\#200}$	Percent Passing a Number 200 U.S. Sieve
$P_{\#40}$	Percent Passing a Number 40 U.S. Sieve
$P_{\#60}$	Percent Passing a Number 60 U.S. Sieve
$P_{0.5''}$	Percent Passing a 0.5 inch U.S. Sieve
$P_{1.0''}$	Percent Passing a 1.0 inch U.S. Sieve
$P_{1.5''}$	Percent Passing a 1.5 inch U.S. Sieve
$P_{2.0''}$	Percent Passing a 2.0 inch U.S. Sieve
pdf	Probability Density Function
PE	Potential Evapotranspiration
PI	Plasticity Index
PI_{adj}	Adjusted Plasticity Index
PL	Plastic Limit
psi	Pounds Per Square Inch
P_y	Yearly Precipitation
SFGM	"Silty" Fine Grained Material
SHRP	Strategic Highway Research Program
SN	Structural Number
S_{opt}	Optimum Saturation
SPS-1	Specific Pavement Studies
SSE	Standard Square Error
SWCC	Soil Water Characteristic Curve

Taylor	First Order Taylor Series expansion
TMI	Thornthwaite Moisture Index
TMI-ASU	Thornthwaite Moisture Index - Arizona State University Model
TX	Texas
W_{18}	Number of 18,000 Pound Single Axle Loads
*w*PI	Weighted Plasticity Index
α	Alpha Shape Factor
β	Beta Shape Factor
$\Gamma(x)$	Gamma Function
γ_{dry}	Dry Unit Weight of Soil
γ_w	Unit Weight of Water
Θ	Bulk Stress
Θ_{sat}	Saturated Volumetric Water Content
Θ_w	Volumetric Water Content
μ	Mean
σ	Standard Deviation
σ^2	Variance
σ_d	Deviator Stress
ψ	Matric Suction

Chapter 1

INTRODUCTION

1.1 Background Information

In the recent years, significant studies have been made to change the pavement design process. This shift in pavement design has focused on using engineering mechanics to describe the pavement structure and properties instead of empirical correlations. With this shift from the empirical correlations to using engineering mechanics, the Mechanistic-Empirical Pavement Design Guide program or the MEDPG was introduced to the pavement community. The MEPDG calculates the pavement performance for either flexible or ridged pavements by using hierarchical levels of design (NCHRP 2004). Before the MEPDG the concept of hierarchical levels have always been used by engineers; however, it was primarily based on how much time and money the engineer was given to design the pavement cross-section. The MEPDG, on the other hand, gives the engineer capability to analyze the difference in designing the pavement cross-section using the different hierarchical levels.

Within the MEPDG, it is sub-divided into different analysis tools. The MEPDG gives the engineer two design options either a new construction of a pavement structure or a rehabilitation pavement of structure. For both options the engineer has the capability to design using either an asphalt composite pavement cross-section (asphalt concrete roadways) or a concrete composite pavement cross-section (Portland cement concrete). Regardless, of the analysis/material option chosen, the strength of the unbound material of the base, and/or subbase, and subgrade is required. The unbound material strength is determined by the Enhanced Integrated Climatic Model or the EICM. The EICM calculates the resilient modulus at equilibrium for the unbound material for a given hierarchical level, using various models. The hierarchical levels that the EICM offers include the following: Level 1 - extensive laboratory testing for all soil properties, Level 2 – laboratory testing on basic soil properties and using engineering assumptions/correlations, and Level 3 – engineering assumptions/default values (NCHRP 2004).

However, the EICM only use deterministic solutions sets to solve the unbound resilient modulus at equilibrium. The deterministic solution does not incorporate the inherent climatic variability for the design region or the inherent variability of the unbound material. By not incorporating the inherent climatic variability or the inherent unbound material variability associated with a given hierarchical level of design, it can potentially lead to premature failures of the pavement structure or the thickness of the pavement structure is over predicted. In either case, it costs a state's department of transportation or DOT substantial amounts of money that could have been saved, used to start new paving projects, or used to maintain the current pavement infrastructure.

To address the problem of the state's DOT losing money, a stochastic evaluation of the EICM is required, which the stochastic evaluation will lead to using the concept of reliability with the unbound material. The stochastic evaluation of the EICM utilizes the deterministic models and employs stochastic methodologies so that the end result of the unbound resilient modulus at equilibrium will have a mean and variance associated with it. Nevertheless, to obtain a mean and variance associated with the resilient modulus at equilibrium, it will require the stochastic treatment of the following models in the EICM: the Thornthwaite Moisture Index, matric (or matrix) suction, the soil water characteristic curve, degree of saturation, optimum saturation, the environmental factor, and the unbound resilient modulus at optimum.

After a stochastic evaluation of the EICM is completed, the concept of reliability can be applied to the pavement design by using mean and variance associated with the unbound resilient modulus at optimum. When the deterministic solution is used, from a reliability aspect, the probability of success is fifty percent and the probability of failure is fifty percent, which means fifty percent of the time the unbound material in the pavement cross-section will have the calculated resilient modulus at equilibrium from the deterministic evaluation and fifty percent of the times the unbound resilient modulus at equilibrium will be different. This change can either be an increase or decrease in the unbound resilient modulus at equilibrium. By using reliability with the EICM it will change the probability of success and probability of failure for strength of the unbound material.

In addition to the concept of reliability, the differences in hierarchical levels are evaluated and coupled with the concept of reliability. The variances of the hierarchical levels will increase as the hierarchical level increases from Level 1 to Level 2 to Level 3. When the levels are increased, the amount of actual testing completed goes from testing all the soil properties to testing some of the soil properties to assuming values for the soil properties, the changing in soil testing is reflected by the level chosen. Figure 1.1 represents the fundamental concept of the differences in the hierarchical level, with respect to the variance that each level creates. Figure 1.1 assumes that the mean values are the same, while the variance is different. When one looks at the reliability associated with these three levels, Figure 1.2 is developed.

Therefore, the work presented in this thesis will show how to stochastically evaluate, incorporate variance, and reliability for any given hierarchical level into the enhanced integrated climatic model which is used in the MEPDG.

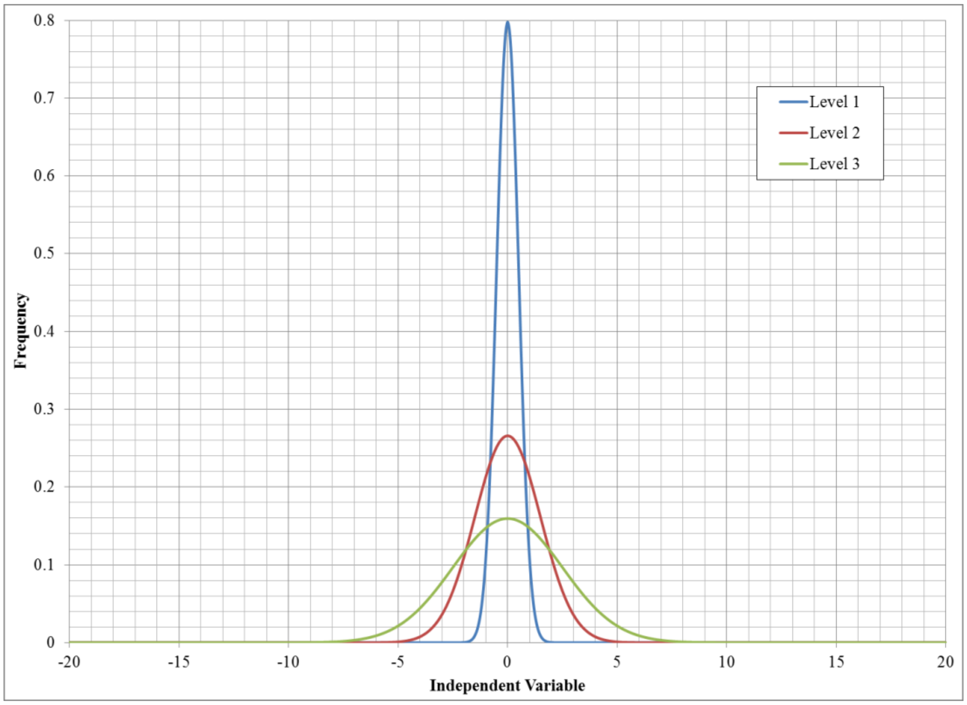

Figure 1.1: Fundamental differences in variances between the hierarchical levels.

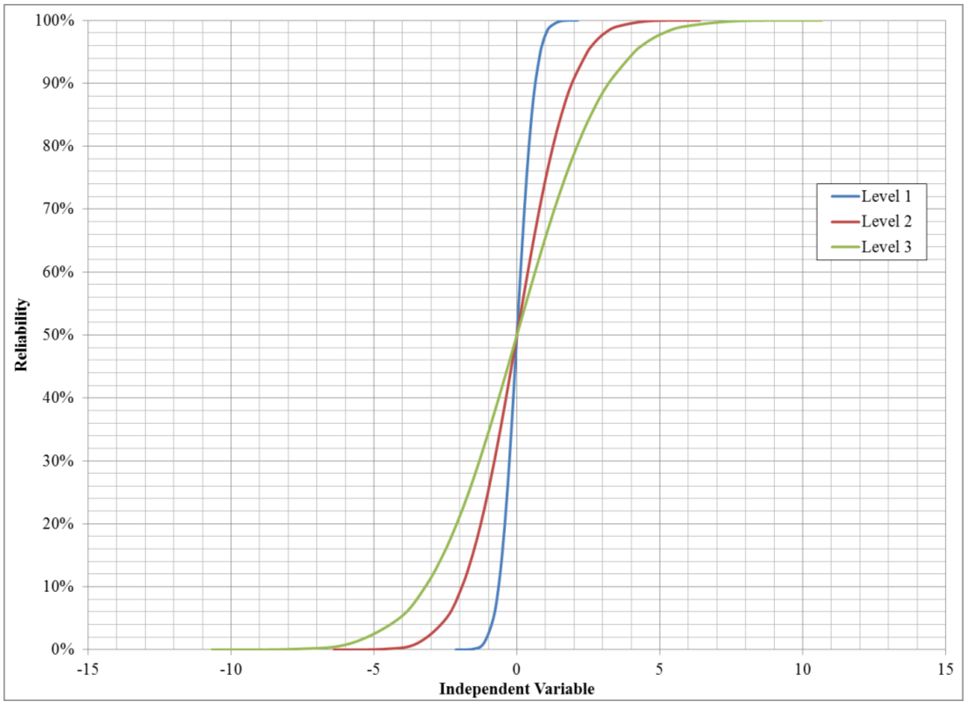

Figure 1.2: Fundamental differences in reliability between the hierarchical levels.

1.2 Objectives

- Postulate the methodologies of a stochastic evaluation of site equilibrium conditions of the resilient moduli using the MEPDG hierarchical concept approach.
- Complete a quantitative comparison of the MEPDG equilibrium resilient moduli of unbound materials based upon a reliability analysis of hierarchical inputs.
- Find the implications of different levels of reliability on the potential estimated cost of pavement design utilizing the structural number concept from the empirical AASHTO design model.

By completing the three objects of this thesis it will show the difference between testing every soil parameter versus guessing at the characteristics of the unbound material by means of using a stochastic evaluation of the hierarchical levels. In addition to differences, this thesis will show the importance of laboratory testing on projects, by incorporating reliability into the unbound resilient modulus at equilibrium.

1.3 Methodologies to Accomplish the Objectives

In order to accomplish the objectives, of this thesis, it requires several methodologies. The methodologies required to accomplish this thesis are as followed:

1. Compile a literature review that will encompass the various statistical moments and the beta distribution. Along with the statistical components,

the literature review will include different methods of the first and second moment analysis. This methods will include the first order Taylor Series expansion, Rosenblueth 2-Point, Rosenblueth 3-Point, and the Monte Carlo Simulation.

2. Compile a literature review that will include the current environmental model that is implement in to the MEPDG as well as newer refined environmental models that aids in the prediction of the resilient modulus at equilibrium.
3. Define a hierarchical level of analysis similar to the MEPDG and state the difference between the MEPDG levels versus the new hierarchical levels.
4. Develop statistical parameters of soils for the hierarchical levels of analysis.
5. Create an analysis program that will create four statistical moments of all the dependent variable utilizing stochastic input parameters. The analysis program will be created in C++ for runtime efficiency.
6. Using the analysis program, the variability of the hierarchical levels will be determined for several cities located in the United States. By selecting various cities, it will encompass several different environmental conditions, i.e. high temperatures and low precipitation, low temperatures and high precipitation, and finally high temperatures and high precipitation.

1.4 Chapter Organization

In the coming chapters, important concepts will be discussed. Chapters 2 and 3 are considered the needed background information and literature review that is needed to complete this thesis. In Chapter 2, the background information and literature review will be presented. In this chapter key methodologies are discussed, which includes statistics, introduction to the hierarchical levels, background information of the environmental model, and reliability concepts. Chapter 3 discusses the development of the soil variability for the hierarchical levels that are employed by this thesis. In addition, presented in this chapter, is the introduction of two new hierarchical levels of design, which splits Level 3 into two different classification systems.

With the literature review, background information, and the soil variability determined for the hierarchical levels the backbone of this thesis can be presented. Chapter 4 is the postulation of the methodologies for a stochastic evaluation. Without this chapter, this research would not be complete. This chapter discusses how to change a deterministic solution set to a stochastic solution set using four different methodologies. By completing a stochastic evaluation of the environmental model implemented into the MEPDG, it will give the user the opportunity to design with either the mean value or with a level of reliability using the distribution associated with the resilient modulus at equilibrium.

Chapter 5 will discuss a quantitative comparison of the stochastic methodologies. This chapter validates which of the four methodologies produce statically the same mean and variance for a given variable. By knowing which methodology produces statistically the same mean and variance, it will allow the user to select a particular methodology with confidence that it will produce the same mean and variance as any other stochastic methodology.

In Chapter 6, a quantitative comparison of the unbound resilient modulus at equilibrium at different hierarchical levels will be discussed. The quantitative comparison arbitrarily sets the means of the hierarchical levels equal to one another and the variance is compared. By comparing the variance between the hierarchical levels, it will show if the hierarchical levels are statistically the same or different, which will validate if hierarchical levels are need in pavement design. In addition, In Chapter 6 the implications of hierarchical levels in pavement reliability design using the structural number concept is discussed. Using the same mean value between the three hierarchical levels and the different variance, it will show how much of a difference in pavement design occurs. To accomplish this task the AASTHO structural number concept coupled with the reliability factor is used. The reliability for the traffic in the AASHTO structural number equation will be used for the resilient modulus at equilibrium. Once the structural number between the three levels is determined, for the different levels of traffic, the difference will be quantified by thickness of asphalt.

Chapter 7, the summary, conclusion and of this thesis will be presented. Finally in Chapter 8 the recommendations for future work will be discussed.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

In this chapter the statistical moments, hypothesis testing, statistical distributions, stochastic procedures, hierarchical levels, the environmental model, AASHTO structural number concept, reliability application in geotechnical engineering, and reliability applications in pavement design are discussed. The statistical moments, hypothesis testing, and the statistical distributions are referenced to refresh the reader's understanding of statistics. The introduction of hierarchical levels and the environmental model implemented in the MEPDG are discussed so that the basis of this thesis can be discussed. In addition, current application of reliability in geotechnical engineering as well as pavement engineering is discussed so that presented work in the following chapters can be fully comprehended. Finally, the AASHTO structural number concept of design is shown so that when it is reference in the later chapters of this thesis the reader has a basis of understanding of this concept.

2.2 Statistical moments

There are four statistical moments that are used to describe any distribution. Each statistical moment informs the reader of different things, which includes the mean, variance, skewness, and kurtosis. Each one of these moments are described in the subsections below.

2.2.1 First Statistical Moment (Mean)

The mean value or the first statistical moment, of the dependent, variable is defined equation 2.1 (Montgomery et al. 2007).

$$E[X] = \bar{x} = \left(\frac{1}{n}\right)\sum_{i=1}^{n} x_i \quad \text{...}(2.1)$$

Where:

$\bar{x}$ = Arithmetic mean of the random variable

x_i = The ith observation of the random variable from the simulation

n = Number of simulations/Number of point estimations

2.2.2 Second Statistical Moment (Variance/Standard Deviation)

The variance or the second statistical moment, of the dependent variable, requires mean of the dependent variable and the ith observation from the Monte Carlo simulation/Rosenblueth 2/3point estimation, which is shown in equation 2.2 (Montgomery et al. 2007).

$$E\left[X^2\right] = \sigma^2 = \left(\frac{1}{n}\right)\sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2 \quad \text{...}(2.2)$$

However, the standard deviation of the dependent variable is also known as the second statistical moment. The standard deviation, dependent variable, is just the square root of the variance, which is shown in equation 2.3 (Montgomery, 2007).

$$\sigma = \sqrt{\sigma^2} = \sqrt{\left(\frac{1}{n}\right)\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2} \quad \text{...} (2.3)$$

2.2.3 Third Statistical Moment (Skewness)

Once the first and second statistical moments, of the dependent variable is described, the skewness or the third statistical moment can be describe in equation 2.4 ("Nist," May).

$$E\left[X^3\right] = \left(\frac{1}{n}\right)\sum_{i=1}^{n}\left(\frac{x_i - \bar{x}}{\sigma}\right)^3 \quad \text{...} (2.4)$$

The skewness of the random variable is required since it describes if the data is normal or skewed left or skewed right. If the skewness is negative the data is skewed left and if the data is positive the data is skewed right and if the skewness is zero the data is normally distributed about the mean of the random variable. By knowing if the data is skewed right or left, it allows the user to make the appropriate choice when deciding which method to choose. If the data is highly skewed right or left, the Rosenblueth 2-Point estimation or the Rosenblueth 3-Point estimation might not be the best statistical approach. Shown in Figure 2.1 is the difference in skewed left or skewed right data. Finally the skewness informs the user if log transformation is possible for the data. If the data is highly skewed left, it could allow for log transformation of the data; however log transformation of the data will not work for data that is skewed right. The log transformation for skewed right data will cause the data to be skewed more to the right.

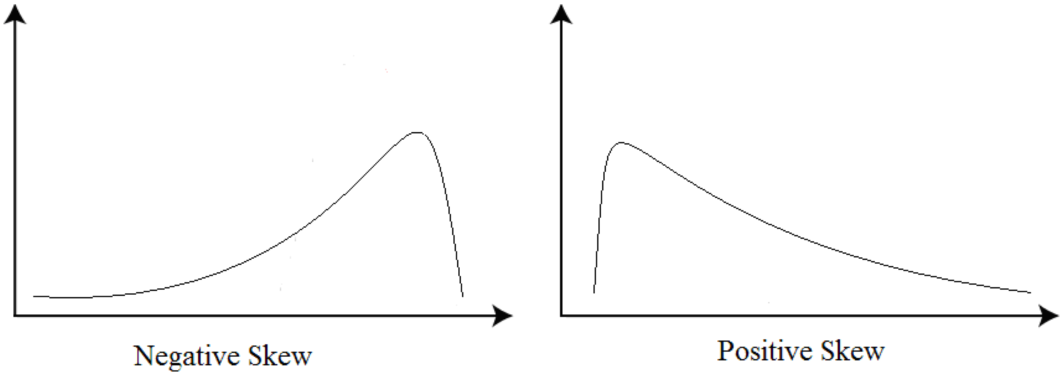

Figure 2.1: Difference in skewness.

2.2.4 Fourth Statistical Moment (Kurtosis)

The kurtosis is the fourth statistical moment, which describes if the data is leptokurtic or platykurtic. If the data is leptokurtic, the shape of the distribution is peaked and the data is grouped about the mean. If the data is platykurtic, the shape of the distribution is flat and the data is dispersed about the mean. By knowing if the data has kurtosis, it allows for the appropriate statistical method to be chosen. The kurtosis of the random variable is defined by equation 2.5 ("Nist," May). Figure 2.2 shows the differences in kurtosis. If the kurtosis is positive then it is known as leptokurtic. If the kurtosis is negative then the distribution is known as platykurtic. The kurtosis of the data is highly important when the point estimation of Rosenblueth is used. When the data is platykurtic, the Rosenblueth point estimation will be less accurate since the point estimation does not cover the normal distribution.

$$E\left[X^4\right]=\left(\left(\frac{1}{n}\right)\sum_{i=1}^{n}\left(\frac{x_i-\bar{x}}{\sigma}\right)^4\right)-3.0 \text{ ....} (2.5)$$

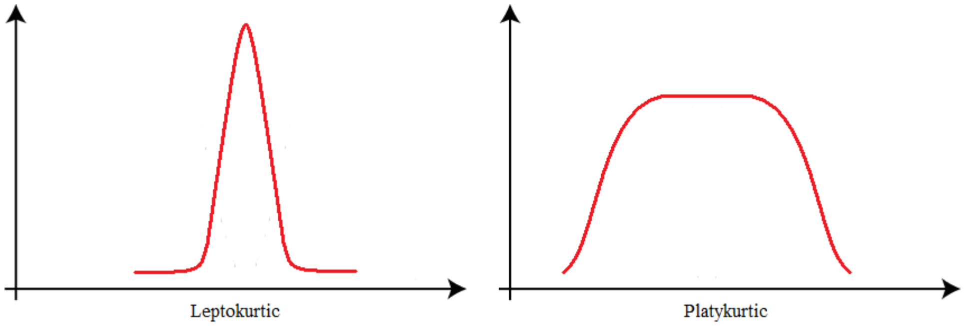

Figure 2.2: Differences in kurtosis.

2.3 Hypothesis Testing

Hypothesis testing establishes if the null hypothesis of the user is true. Normally, the null hypothesis is testing can be one of four things: (one) testing if the ith independent value is less than the mean value, (two) testing if the ith independent value is greater than the mean value, or (three) testing if the ith independent value is equal to the mean value, or testing if the variance of one population is equal to the variance of another population. Hypothesis testing using one of the following test statistics to prove or disprove the null hypothesis: Z-test, t-test, F-test, and the Chi-test (Montgomery et. al, 2007). Of the four test statistics, the Z-test, t-test, and the F-test are used in the following chapters for hypothesis testing. The Z-test statistic, which is used to compare mean of two different populations that have unequal variances, is shown in equation 2.6 (Montgomery et al. 2007).

$$Z = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.6)$$

Where:

$\bar{x}_1$ is the mean of population 1

$\bar{x}_2$ is the mean of population 2

s_1^2 is the variance of population 1

s_2^2 is the variance of population 2

n_1 is the number of combination of population 1

n_2 is the number of combination of population 2

The student's t-test statistic when comparing the two means assuming the variances are equal will utilize equation 2.7, while the degree of freedom is determined by using equation 2.8. The degree of freedom coupled with the level of significance will determine the acceptance region of the null hypothesis (Montgomery et al. 2007).

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \text{ ....} (2.7)$$

Where:

$$s_p = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}$$

$$n_1 + n_2 - 2 \quad \text{..........} \quad (2.8)$$

The F-test, which is used to compare the variance, is calculated using equation 2.9 (Montgomery et al. 2007).

$$F = \frac{s_1^2}{s_2^2} \quad \text{..........} \quad (2.9)$$

With the Z-statistic, student’s t-statistic and the F-statistic equations determined, the hypothesis testing of the mean and variance is determined by the following:

$$\begin{array}{ll} H_0 : \mu_1 = \mu_2 & H_0 : s_1^2 = s_2^2 \\ H_1 : \mu_1 \neq \mu_2 & H_1 : s_1^2 \neq s_2^2 \end{array}$$

Where:

H_0 is the null hypothesis that is being tested.

$H_1$is the alternative hypothesis.

By checking if the means and variances are equal, the hypothesis testing will use a two-tailed testing, which the level of significance will be equal to alpha divided by two. Therefore, the level of significance, unless stated otherwise, will be 5 percent, which will give an acceptance region of 95 percent.

2.4 Statistical Distributions

Two statistical distributions are needed to describe the dependent variables. The two statistical distributions include the normal distribution and the beta distribution. The normal distribution is used for the First order Taylor Series expansion, Rosenblueth 2-Point estimation, and the Rosenblueth 3-Point estimation. The Monte Carlo Simulation, on the other hand, utilizes the beta distribution. The normal distribution had to be used since the authors of the methodology used the normal distribution to describe the variable. Nevertheless, the beta distribution was selected since the beta distribution can be bounded between zero and one or one hundred percent, depending on the variable.

2.4.1 Normal Distribution

The normal distribution or the "Gaussian" distribution follows a bell curve (Montgomery et al. 2007). The normal distribution is centered about the mean while the variance of the variable describes how dispersed (platykurtic) or tight (leptokurtic) the tails of the distribution will be from the mean. Nevertheless, the normal distribution is not bounded between any values the left tail of the distribution will approach negative infinity while the right tail of the distribution will approach positive infinity. The distribution is determined by Equation 2.10. Equation 2.10 will determine the probability density function or the (pdf). This function is used to describe the shape of the independent/dependent variable.

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.10)$$

Where:

σ^2 = Variance of the independent variable

x = random variable

μ = Mean value of the independent variable

On the other hand, if the cumulative density function (cdf) is needed it requires a different equation. The cdf is required when the reliability of a variable is need the cdf gives a cumulative percentage as the variable is increased or decreased from the mean. The cdf is bounded from zero percent to one hundred percent, as the cdf increases the independent/dependent variable will increase. The cdf is described by Equation 2.11 (Montgomery et al. 2007).

$$F(x) = P(X \le x) = \int_{-\infty}^{x} f(u)du \quad \text{...} (2.11)$$

Where:

$F(x) = P(X \le x)$ = cumulative probability of the independent/dependent variable

2.4.2 Beta Distribution

The beta distribution is similar to the normal distribution in some aspects. The beta distribution uses the mean and variance of the independent variable, similarly to the normal distribution; however, the beta distribution is bounded between a minimum and a maximum value, and uses a two shape factor parameters, alpha and beta (Johnson et al. 1994). By bounding the independent variable between a minimum and maximum, and using the alpha and beta shape parameters, it can describe the true distribution shape of the independent variable. The beta distribution pdf is described by Equation 2.12.

$$f(x;\alpha,\beta)=\frac{1}{B(\alpha,\beta)}\left(\frac{x-a}{b-a}\right)^{\alpha-1}\left(\frac{b-x}{b-a}\right)^{\beta-1} \quad \text{..(2.12)}$$

Where,

a = minimum value

b = maximum value

$$B(\alpha,\beta)=\frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)}$$

$\Gamma(n)=(n-1)!$ = Gamma function

$$\alpha=\left(\frac{\mu-a}{b-a}\right)\left(\frac{\left(\frac{\mu-a}{b-a}\right)\left(1-\left(\frac{\mu-a}{b-a}\right)\right)}{\frac{\sigma^2}{(b-a)^2}}-1\right) \text{ = alpha shape parameter}$$

$$\beta=\left(1-\left(\frac{\mu-a}{b-a}\right)\right)\left(\frac{\left(\frac{\mu-a}{b-a}\right)\left(1-\left(\frac{\mu-a}{b-a}\right)\right)}{\frac{\sigma^2}{(b-a)^2}}-1\right) \text{= beta shape parameter}$$

The cdf of the beta distribution, which is important for reliability of any variable, can be found in Equation 2.13. To obtain the cdf of the variable, it uses the alpha and beta shape factor, and the x value in the Equation 2.13 is solved by using Equation 2.14, which the x value corresponds to the cumulative percentage.

$$I_x(\alpha,\beta)=\frac{\int_0^x t^{\alpha-1}(1-t)^{\beta-1}dt}{\int_0^1 t^{\alpha-1}(1-t)^{\beta-1}dt} \quad \text{...(2.13)}$$

Where:

$I_x(\alpha,\beta)$ is the cumulative percentage or probability

$$x=\frac{(x_i-a)}{(b-a)} \quad \text{..(2.14)}$$

Where:

x_i = random variable that is bounded between a and b.

2.5 Stochastic Procedures

Presented in this thesis are four different stochastic methodologies that will create a mean and variance for each dependent variable. The four methodologies require different statistical moments, which will be outlined in the coming sub-sections. The methodologies that are used include the First order Taylor Series expansion, Rosenblueth 2-Point estimation, Rosenblueth 3-Point estimation, and the Monte Carlo Simulation (Montgomery et al. 2007, Rosenblueth 1975, Metropolis and Ulam 1949).

2.5.1 First Order Taylor Series Expansion

The First order Taylor Series expansion uses the mean and variance of the independent variable to develop the mean and variance of the dependent variable (Montgomery et al. 2007). The mean of the dependent variable will use the same deterministic equation, while the variance of the dependent variable will be calculated using Equation 2.15. After the mean and variance of the dependent variable is determined, the reliability of the variable can be determined. The reliability of a First order Taylor Series expansion is determined by using a normal distribution with the mean and variance of the dependent variable.

$$\sigma_Y^2 = \sum_{i=1}^{n} \left(\frac{d}{dX_i} \right)^2 \sigma_{X_i}^2 \quad \text{..} (2.15)$$

Where:

σ_Y^2 = The variance of the dependent variable.

$\frac{\partial X_i}{\partial y}$ = The derivative of the function with respect to the i^{th} independent variable.

$\sigma_{X_i}^2$ = The variance of the i^{th} independent variable.

2.5.2 Rosenblueth Estimation

The Rosenblueth point estimation requires the mean and standard deviation of the independent variable. The mean and standard deviation, of the independent variable, is obtained from various databases or just knowing the mean value of the independent variable and applying a coefficient of variation to obtain the standard deviation. The mean value of the Rosenblueth point estimation should be the same value obtained from the deterministic solution if the independent variable has no skewness (non-symmetrical distribution). However, if the independent variable has some slight skewness, the mean value of the Rosenblueth point estimation will vary slightly from the deterministic solution and if the independent variable is highly skewed, the mean value of the Rosenblueth point estimation will be significantly different from the deterministic solution.

The Rosenblueth 2-Point or 3-Point estimation determines the number of simulations that are needed to compute a stochastic evaluation of the dependent variable. The number of simulations that are need, it is governed by Equation 2.16 for the 2-Point or Equation 2.17 for the 3-Point (Rosenblueth 1975).

$$N_S = 2^X \quad \text{..........} (2.16)$$

$$N_S = 3^X \quad \text{..........} (2.17)$$

Where:

N_s = Number of simulations

X = Number of independent variables

The Rosenblueth 2-Point uses the following combinations: $\bar{x}+\sigma$ and $\bar{x}-\sigma$, where $\bar{x}$ is the mean of the independent variable and σ is the standard deviation of the independent variable, while the Rosenblueth uses the following combinations: $\bar{x}+\sigma$, $\bar{x}$, and $\bar{x}-\sigma$. The grouping of the combinations $\bar{x}+\sigma$, $\bar{x}-\sigma$, and/or $\bar{x}$, for each independent variable, is based on a factorial design. Let's assume that there are two independent variables used to calculate the dependent variable, the combinations for both methods are shown in Table 2.1.

Table 2.1: Combinations for Rosenblueth Analysis.

Rosenblueth 2-Point Method			
Simulation Number	Variable 1	Variable 2	Dependent Variable
1	$\bar{x}_1+\sigma_1$	$\bar{x}_2+\sigma_2$	f($\bar{x}_1+\sigma_1, \bar{x}_2+\sigma_2$)
2	$\bar{x}_1+\sigma_1$	$\bar{x}_2-\sigma_2$	f($\bar{x}_1+\sigma_1, \bar{x}_2-\sigma_2$)
3	$\bar{x}_1-\sigma_1$	$\bar{x}_2+\sigma_2$	f($\bar{x}_1-\sigma_1, \bar{x}_2+\sigma_2$)
4	$\bar{x}_1-\sigma_1$	$\bar{x}_2-\sigma_2$	f($\bar{x}_1-\sigma_1, \bar{x}_2-\sigma_2$)
Rosenblueth 3-Point Method			
Simulation Number	Variable 1	Variable 2	Dependent Variable
1	$\bar{x}_1+\sigma_1$	$\bar{x}_2+\sigma_2$	f($\bar{x}_1+\sigma_1, \bar{x}_2+\sigma_2$)
2	$\bar{x}_1+\sigma_1$	$\bar{x}_2$	f($\bar{x}_1+\sigma_1, \bar{x}_2$)
3	$\bar{x}_1+\sigma_1$	$\bar{x}_2-\sigma_2$	f($\bar{x}_1+\sigma_1, \bar{x}_2-\sigma_2$)
4	$\bar{x}_1$	$\bar{x}_2+\sigma_2$	f($\bar{x}_1, \bar{x}_2+\sigma_2$)
5	$\bar{x}_1$	$\bar{x}_2$	f($\bar{x}_1, \bar{x}_2$)
6	$\bar{x}_1$	$\bar{x}_2-\sigma_2$	f($\bar{x}_1, \bar{x}_2-\sigma_2$)
7	$\bar{x}_1-\sigma_1$	$\bar{x}_2+\sigma_2$	f($\bar{x}_1-\sigma_1, \bar{x}_2+\sigma_2$)
8	$\bar{x}_1-\sigma_1$	$\bar{x}_2$	f($\bar{x}_1-\sigma_1, \bar{x}_2$)
9	$\bar{x}_1-\sigma_1$	$\bar{x}_2-\sigma_2$	f($\bar{x}_1-\sigma_1, \bar{x}_2-\sigma_2$)

2.5.3 Monte Carlo Simulation

The Monte Carlo simulation is the most powerful tool to use for statistical analysis. The Monte Carlo simulation is able to generate through various runs every possible combination of each independent variable that is used to calculate the dependent variable. The Monte Carlo simulation takes all the independent variables and chooses a value, at random, of the within the limit of the independent variable and uses it to determine the dependent variable (Metropolis and Ulam 1949).

2.6 Hierarchical Levels

The MEPDG currently use three hierarchical levels of design within the EICM and other design modules. These three levels govern which of the equation listed in section 2.6 as well as the methodologies in Chapter 4. Table 2.2 is the parameters that are required for each given hierarchical level.

Table 2.2: Parameters Associated with the Hierarchical Levels.

Soil Properties		Level 1	Level 2	Level 3
Gran Size Parameters	$P_{2.0"}$	Not Needed	Not Needed	Needed
	$P_{1.5"}$	Not Needed	Not Needed	Needed
	$P_{1.0"}$	Not Needed	Not Needed	Needed
	$P_{0.5"}$	Not Needed	Not Needed	Needed
	$P_{\#40}$	Not Needed	Not Needed	Needed
	$P_{\#60}$	Not Needed	Not Needed	Needed
	D_{60}	Not Needed	Not Needed	Needed
	$P_{\#200}$	Needed	Needed	Needed
Atterberg Limits	LL	Needed	Needed	Needed or Estimated
	PL	Needed	Needed	Needed or Estimated
	PI	Needed	Needed	Needed or Estimated
Compaction Properties	G_s	Needed	Needed	Needed or Estimated
	w_{opt}	Needed	Needed	Estimated
	γ_{dmax}	Needed	Needed	Estimated
SWCC	a_f	Needed	Estimated	Estimated
	b_f	Needed	Estimated	Estimated
	c_f	Needed	Estimated	Estimated
	h_{rf}	Needed	Estimated	Estimated
Modulus	M_{ropt}	Needed	Estimated	Estimated

2.6.1 Level 1

“Level 1 is the most current implementable procedure available, normally involving comprehensive laboratory or field tests” (NCHRP 2004).The comprehensive laboratory testing includes the following (NCHRP 2004):

1. Sieve Analysis from AASHTO T27 “Sieve Analysis of Fine and Coarse Aggregates”
2. Specific Gravity from user input normally obtained from ASTM D854 “Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer”
3. Atterberg Limits from AASHTO T90 “Determining the Plastic Limit and Plasticity of Soils” and AASHTO T89 “Determining the Liquid Limit of Soils.”
4. Compaction from AASHTO T99 “Moisture-Density Relations of Soils Using a 5.5-lb Rammer and a 12-in Drop”
5. Soil Water Characteristic Curve Testing using ASTM D6836 “Standard Test Methods for Determination of the Soil Water Characteristic Curve for Desorption Using Hanging Column, Pressure Extractor, Chilled Mirror Hygrometer, or Centrifuge” and/or ASTM D5298 “Stand Test Method for Measurement of Soil Potential (Suction) Using Filter Paper”
6. Resilient Modulus at Optimum Testing using either NCHRP 1-28A “Harmonized Test Methods for Laboratory Determination of Resilient Modulus for Flexible Pavement Design” or AASHTO T307 “Determining the Resilient Modulus of Soil and Aggregate Materials”

After completing AASHTO T27, T89, T90, the soil needs to be classified. The soil is classified using AASHTO M145 "The Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes." With the soil classification determined for the soil, the user then selects Level 1 analysis in the EICM along with the soil classification. Then the user inputs the soil properties and the EICM calculates the resilient modulus at equilibrium per month until the design life that the user inputted has been reached.

2.6.2 Level 2

"Level 2 are estimated through correlations with other material properties that are measure in the laboratory or field" (NCHRP 2004). The following properties that are measured in the laboratory:

1. Sieve Analysis from AASHTO T27 "Sieve Analysis of Fine and Coarse Aggregates"
2. Specific Gravity from user input normally obtained from ASTM D854 "Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer"
3. Atterberg Limits using AASHTO T90 "Determining the Plastic Limit and Plasticity of Soils" and AASHTO T89 "Determining the Liquid Limit of Soils."

Using the information from the three tests above, correlations between percent passing and the Atterberg limits are then used correlate the compaction information, the soil water characteristic curve, and the resilient modulus at optimum. The correlation equations are shown in section 2.6.

2.6.3 Level 3

"Level 3 requires the designer to estimate the most appropriate design input value of the material property based on experience with little or no testing" (NCRHP 2004). In The EICM, the user has two options; 1) use the EICM soil defaults for the sieve analysis and Atterberg Limits, which are then used to make correlation between compaction, the soil water characteristic curve, and the resilient modulus at optimum and 2) complete some of the soil testing and still use the default values of the database for information that was not tested or the user does not know.

2.7 Environmental Models Implemented into the EICM

The environment models implemented into the EICM is described in Figure 2.3. Figure 2.3 shows a general flow diagram that the EICM uses to compute the resilient modulus at equilibrium for Level 1 analysis. In the general flow diagram only the main variables that are used are shown, later in this chapter, the correlation between the main variables with subsequent variables are shown, which are dependent of the hierarchical level chosen.

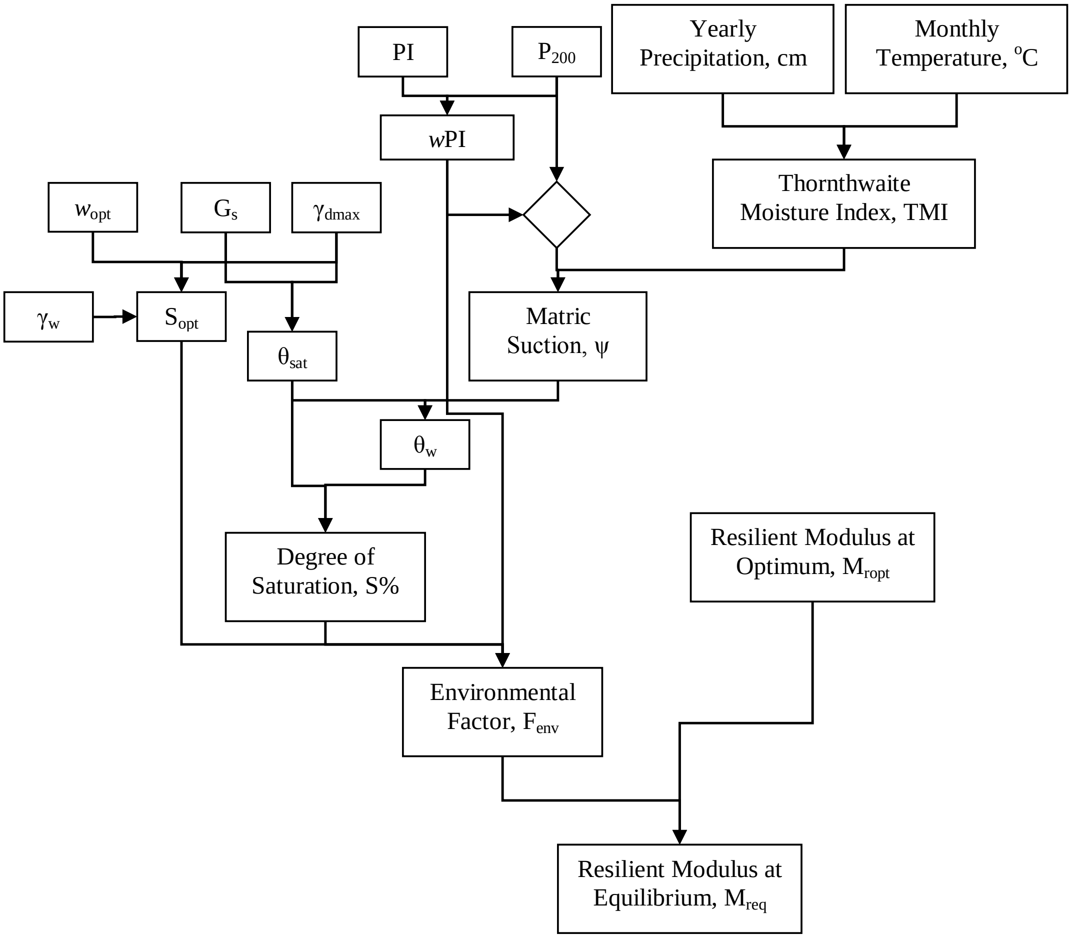

Figure 2.3: General flow of the EICM.

2.7.1 Thornthwaite Moisture Index

In 1948, Thornthwaite created a unit-less parameter that determines the climatic region. The original Thornthwaite Moisture Index utilizes the aridity or the humidity of a climatic region with the effect of the annual evaporation, precipitation, deficit, storage, and runoff (Perera 2003, Houston et al. 2006). The TMI is calculated by combining the aridity index and the humidity index for the region, which are shown in Equation 2.18 and 2.19 respectively. When Equation

2.18 and 2.19 are combined, it creates the year TMI for the given site, which is shown in Equation 2.10.

$$I_a = 100\left(\frac{DF}{PE}\right) \qquad (2.18)$$

$$I_h = 100\left(\frac{R}{PE}\right) \qquad (2.19)$$

Where:

DF is the moisture deficit

R is the moisture surplus or the runoff

PE is the potential evapotranspiration

$$TMI_y = \frac{100(R_y) - 60(DF_y)}{PE_y} \qquad (2.20)$$

Where:

R_y is the runoff in centimeters for year y

DF_y is the moisture deficit in centimeters for year y

PE is the potential evapotranspiration in centimeters for year y

However, when Thornthwaite develop this equation DF_y's multiplication factor was reduced to 60 from 100. Thornthwaite determined that the water infiltrating the soil more easily than evaporating from the soil. The potential evapotranspiration can be calculated using the Thornthwaite evapotranspiration equation (Chow 1964). To calculate the evapotranspiration equation, it requires the temperature, the annual heat index, and latitude. In Equations 2.21 through 2.26 are the steps that are required to calculate the potential evapotranspiration.

$$h_i = (0.2t_i)^{1.514} \quad \text{.......} \quad (2.21)$$

Where:

h_i is the heat index for the i^{th} month

t_i is the temperature for the i^{th} month

After the i^{th} month heat index is determined the annual heat index can be determined by using Equation 2.22. However, with the monthly heat index, it requires one constraint when the ambient air temperature is below freezing or below 0^0C, it will cause an error with the equation; therefore when the ambient air temperature is below 0^0C, set the ambient air temperature to 0^0C.

$$H_y = \sum_{i=1}^{12} h_i \quad \text{.......} \quad (2.22)$$

Where:

H_y is the yearly heat index

With the annual heat index determined, the unadjusted potential evapotranspiration can be determined by using Equation 2.23.

$$PE_i = 1.6\left(\frac{10_{t_i}}{Hy}\right)^a \text{ .... } (2.23)$$

Where:

$$a = 6.75x10^{-7}Hy^3 - 7.71x10^{-5}Hy^2 + 0.017921Hy + 0.49239$$

The value of PE$_i$ in Equation 2.23 represents the potential evapotranspiration in centimeters of water per month for a 30 day month and only for a 12 hour day. The PE$_i$ represents a 30 day month that gets 12 hours of sunlight; however, this is only appropriate for months of: April, June, September, and November for the length of the month and not the 12 hour of sunlight. Therefore, a month and daylight correction factor is needed to include all 12 months of the year and the period of sunlight the given month experiences. In Equation 2.24 is the adjusted potential evapotranspiration for each given month.

$$PE = \sum_{i=1}^{12} PE_i\left(\frac{D_i N_i}{30}\right) \text{ .... } (2.24)$$

Where:

D$_i$ is the daylight correction factor obtained from Table 2.3

N$_i$ is the number of days in the i^{th} month

Expanding the Equation 2.24 by using Equation 2.23 and assuming the number of days in the month is 30.34 Equation 2.25 is developed, which is further reduced to Equation 2.26.

$$PE=\sum_{i=1}^{12}1.6\left(\frac{10_{t_i}}{Hy}\right)^{a}\left(\frac{30.4375}{30}\right)(D_i)\ldots\ldots\ldots(2.25)$$

$$PE=\sum_{i=1}^{12}1.6213(D_i)\left(\frac{10_{t_i}}{Hy}\right)^{a}\ldots\ldots\ldots(2.26)$$

Table 2.3: Northern Hemisphere Daylight Correction Factors (Perera 2003).

Lat	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
0	1.04	0.94	1.04	1.01	1.04	1.01	1.04	1.04	1.01	1.04	1.01	1.04
5	1.02	0.93	1.03	1.02	1.06	1.03	1.06	1.05	1.01	1.03	0.99	1.02
10	1.00	0.91	1.03	1.03	1.08	1.06	1.08	1.07	1.02	1.02	0.98	0.99
15	0.97	0.91	1.03	1.04	1.11	1.08	1.12	1.08	1.02	1.01	0.95	0.97
20	0.95	0.90	1.03	1.05	1.13	1.11	1.14	1.11	1.02	1.00	0.93	0.94
25	0.93	0.89	1.03	1.06	1.15	1.14	1.17	1.12	1.02	0.99	0.91	0.91
26	0.92	0.88	1.03	1.06	1.15	1.15	1.17	1.12	1.02	0.99	0.91	0.91
27	0.92	0.88	1.03	1.07	1.16	1.15	1.18	1.13	1.02	0.99	0.90	0.90
28	0.91	0.88	1.03	1.07	1.16	1.16	1.18	1.13	1.02	0.98	0.90	0.90
29	0.91	0.87	1.03	1.07	1.17	1.16	1.19	1.13	1.03	0.98	0.90	0.89
30	0.90	0.87	1.03	1.08	1.18	1.17	1.20	1.14	1.03	0.98	0.89	0.88
31	0.90	0.87	1.03	1.08	1.18	1.18	1.20	1.14	1.03	0.98	0.89	0.88
32	0.89	0.86	1.03	1.08	1.19	1.19	1.21	1.15	1.03	0.98	0.88	0.87
33	0.88	0.86	1.03	1.09	1.19	1.20	1.22	1.15	1.03	0.97	0.88	0.86
34	0.88	0.85	1.03	1.09	1.20	1.20	1.22	1.16	1.03	0.97	0.87	0.86
35	0.87	0.85	1.03	1.09	1.21	1.21	1.23	1.16	1.03	0.97	0.86	0.85
36	0.87	0.85	1.03	1.10	1.21	1.22	1.24	1.16	1.03	0.97	0.86	0.84
37	0.86	0.84	1.03	1.10	1.22	1.23	1.25	1.17	1.04	0.97	0.85	0.83
38	0.85	0.84	1.03	1.10	1.23	1.24	1.25	1.17	1.04	0.96	0.84	0.83
39	0.85	0.84	1.03	1.11	1.23	1.24	1.26	1.18	1.04	0.96	0.84	0.82
40	0.84	0.83	1.03	1.11	1.24	1.25	1.27	1.18	1.04	0.96	0.83	0.81
41	0.83	0.83	1.03	1.11	1.25	1.26	1.27	1.19	1.04	0.96	0.82	0.80
42	0.82	0.83	1.03	1.12	1.26	1.27	1.28	1.19	1.04	0.95	0.82	0.79
43	0.81	0.82	1.02	1.12	1.26	1.28	1.29	1.20	1.04	0.95	0.81	0.77
44	0.81	0.82	1.02	1.13	1.27	1.29	1.30	1.20	1.04	0.95	0.80	0.76
45	0.80	0.81	1.02	1.13	1.28	1.29	1.31	1.21	1.04	0.94	0.79	0.75
46	0.79	0.81	1.02	1.13	1.29	1.31	1.32	1.22	1.04	0.94	0.79	0.74
47	0.77	0.80	1.02	1.14	1.30	1.32	1.33	1.22	1.04	0.93	0.78	0.73
48	0.76	0.80	1.02	1.14	1.31	1.33	1.34	1.23	1.05	0.93	0.77	0.72
49	0.75	0.79	1.02	1.14	1.32	1.34	1.35	1.24	1.05	0.93	0.76	0.71
50	0.74	0.78	1.02	1.15	1.33	1.36	1.37	1.25	1.06	0.92	0.73	0.70

Although, the TMI equation presented above, was used in the integrated climatic model (ICM) version 2.6, which was updated to the current version of the

EICM version 0.7. In the EICM version 0.7, TMI was updated when the digitalization of Figure 2.4 occurred; however, with the digitalization of Figure 2.4, it added additional run time that was deemed not necessary. The NCHRP 1-40D team wanted to make an universal model that would work within the United States as well as foreign countries, which lead to the development of the TMI-ASU model that is currently implemented into the EICM.

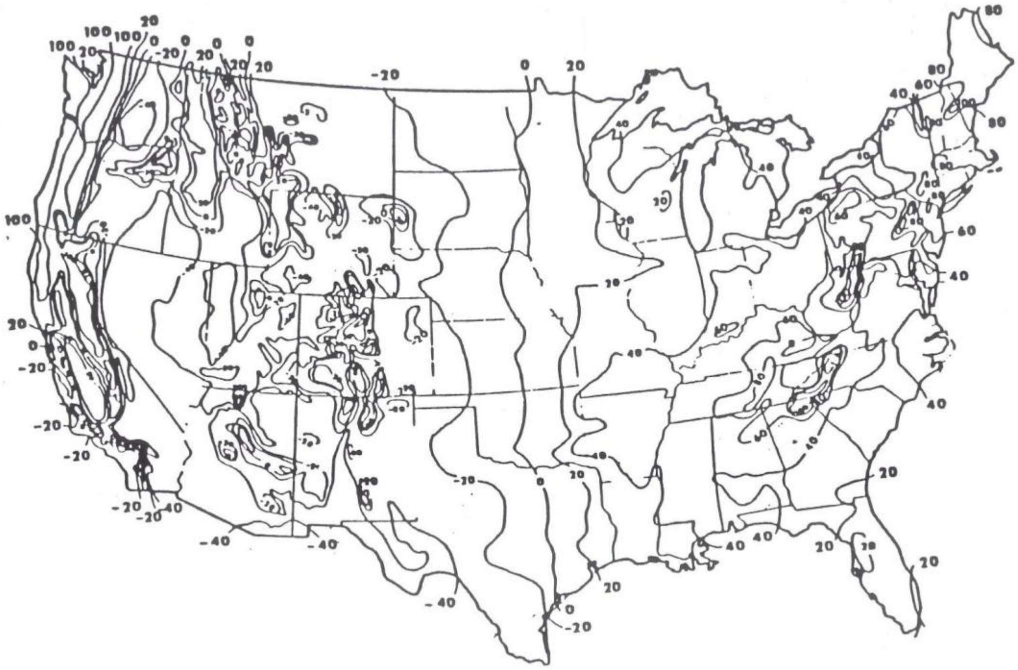

Figure 2.4: TMI contour map (FHWA 1993).

The TMI-ASU model was validated with the contour map; it only requires the temperature and precipitation inputs that are obtained from a climatic file. The TMI-ASU model is presented in Equation 2.27. The PE in the equation is still calculated using Equation 2.21 through Equation 2.26.

$$\mathrm{TMI} = 10 + 75\left(\frac{P_y}{PE} - 1\right) \quad (2.27)$$

Where:

P_y is the yearly precipitation

With the development of Equation 2.27, the EICM then calculates the TMI monthly instead of yearly. The TMI monthly value is calculated using the same principles as it would calculate the yearly TMI. The EICM uses a rolling twelve month average, which give a rough estimate of the TMI-ASU for a given month (Witczak et al. 2006). Figure 2.5 shows conceptually how the EICM calculates TMI-ASU for each month. Once the EICM calculates the twelve TMI-ASU, the EICM back calculates TMI-ASU from month$_i$ to month$_{i-11}$. By back calculating TMI-ASU it keeps a progression of monthly TMI-ASU's until the end of the .hcd file is reached.

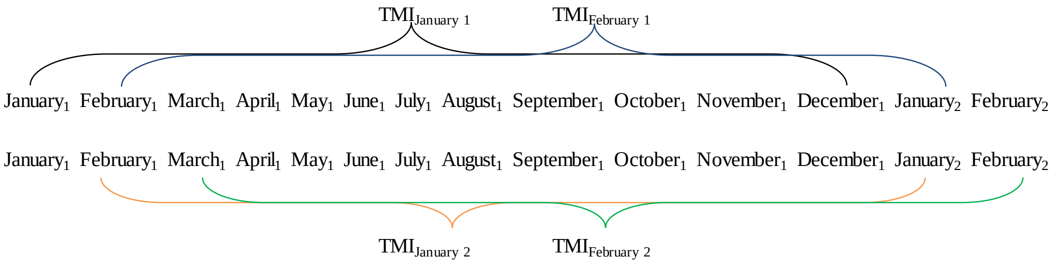

Figure 2.5: Calculation of TMI-ASU using a rolling twelve month interval.

However, this rolling twelve month average follows the old climatic data and will repeat once TMI-ASU is calculated for the last month in the climatic history. The inherent problems of calculating TMI-ASU this way are (one) a rain event that happen in given month will be forecasted for every TMI-ASU that month is used and (two) a drought season might be predicted with the EICM, while true precipitation is for that year is above average or an average rainfall for that year.

2.7.2 TMI-Matric Suction Model

The TMI-Matric suction model was originally presented in 1961 by Russam and Coleman, which was a correlated the aridity or humidity index (TMI) to the pF matric suction of the soil (Perera 2003). Then further research has been compiled by various authors. In 2003, Yugantha Perera completed a study that measured in-situ moisture content and related it to the matric suction of soil by utilizing the using the soil water characteristic curve. Then Yugantha calculated the Thornthwaite Moisture Index for the soil, which allowed him to create a correlation between certain soil properties, TMI, and, matric suction of the soil. The correlations were split into two groups, (1) the granular base model or the TMI-P_{200} model, and (2) and subbase and subgrade model or the TMI-*w*PI model.

2.7.2.1 Base Model (TMI-P_{200} model)

The TMI-P_{200} model correlates the percent passing the number 200 sieve and the climatic location, which the climatic location is the TMI. In this model P_{200} is bounded between the zero and sixteen percent. The TMI-P_{200} model is represented by Equation 2.28.

$$\psi = \alpha + e^{[\beta + \gamma(TMI + 101)]} \quad \text{...} (2.28)$$

Where:

ψ is the matric suction of the soil

α, β, γ are regression constants

The α, β, and γ regression constants can be found in Table 2.4. The four percent to sixteen percent regression constant were developed by Yugantha, which were updated by the NCHRP 9-23 report to include zero to four percent regression constants. With the update, a constraint was added. If the soil in the base course has a P_{200} greater than sixteen percent used, the sixteen percent regression constant will be used. When the EICM version 0.7 was released, it uses the regression constants, constraints, and equation to calculate the matric suction of the soil. For programming purposes, using linear interpolation as the author states to use will require multiple equations to be programmed; therefore, using a single equation for each regression constant will aid in programming. In Equation 2.29 through 2.31 is the single equation for each regression constant. Table 2.5 is a comparison of the regression constants with the regression constants obtained from the equations. In addition, Table 2.5 also shows the R^2 of the equations.

Table 2.4: TMI-P_{200} Regression Constants (Perera 2003, Houston et al. 2006).

P_{200}	α	β	γ
0	3.649	3.338	-0.05046
2	4.196	2.741	-0.03824
4	5.285	3.473	-0.04004
6	6.877	4.402	-0.03726
8	8.621	5.379	-0.03836
10	12.18	6.646	-0.04688
12	15.59	7.599	-0.04904
14	20.202	8.154	-0.05164
16	23.564	8.283	-0.05218

$$\alpha = -0.00157(P_{200})^3 + 0.110566(P_{200})^2 - 0.11352(P_{200}) + 3.8218 \quad ..(2.29)$$

$$\beta = -0.0044713(P_{200})^3 + 0.112094(P_{200})^2 - 0.33636(P_{200}) + 3.2358 \quad (2.30)$$

$$\gamma = 2.87563E-05(P_{200})^3 - 0.00085(P_{200})^2 + 0.006108(P_{200}) - 0.04977 \quad (2.31)$$

Table 2.5: Prediction Constants versus Actual Constants.

P_{200}	**Actual α**	**Predicted α**	**Actual β**	**Predicted β**	**Actual γ**	**Predicted γ**
0.0	3.6490	3.8218	3.3380	3.2358	-0.0505	-0.0498
2.0	4.1960	4.0245	2.7410	2.9757	-0.0382	-0.0407
4.0	5.2850	5.0363	3.4730	3.3977	-0.0400	-0.0371
6.0	6.8770	6.7819	4.4020	4.2872	-0.0373	-0.0375
8.0	8.6210	9.1859	5.3790	5.4297	-0.0384	-0.0406
10.0	12.1800	12.1729	6.6460	6.6104	-0.0469	-0.0450
12.0	15.5900	15.6676	7.5990	7.6147	-0.0490	-0.0493
14.0	20.2020	19.5946	8.1540	8.2281	-0.0516	-0.0521
16.0	23.5640	23.8785	8.2830	8.2359	-0.0522	-0.0520
	R^2	**99.780%**	**R^2**	**99.748%**	**R^2**	**92.404%**

2.7.2.2 Subbase and Subgrade Model (TMI-P_{200}/*w*PI model)

Subbases and subgrades use the TMI-P_{200}/*w*PI model, which correlates the $P_{200,}$ PI, and the climatic region to the matric suction of the given soil. The TMI-P_{200}/*w*PI model is presented in Equation 2.32.

$$\psi = \alpha\left[e^{\left[\frac{\beta}{TMI+\gamma}\right]}+\delta\right] \quad\text{...}(2.32)$$

Where:

ψ is the matric suction of the soil

α, β, γ, and δ are regression constants

The regression constants α, β, γ, and δ can be found Table 2.6. Table 2.6, it is subdivided into two sections, if the *w*PI of the soil is less than 0.5 it will use the P_{200}; however, if the P_{200} of the soil is less than ten, the predictive model used will revert back to the granular base model or the TMI-P_{200} model. On the other hand, if the *w*PI of the soil is greater than 50, the *w*PI curve will be used in the calculation of the matric suction. The regression constants shown in Table 2.6 are a result of the NCHRP 9-23 report, which updated the original parameters that Perera produced in 2003. In addition, the EICM version 0.7 still uses the same regression constants and equations.

Table 2.6: TMI-P_{200}/*w*PI Regression Coefficients (Houston et al. 2006).

P_{200}	*w*PI	α	β	γ	δ
10		0.3	419.07	133.45	15.0
50	0.5	0.3	521.50	137.3	16.0
	5.0	0.3	663.50	142.5	17.5
	10	0.3	801.00	147.6	25.0
	20	0.3	975.00	152.5	32.0
	50	0.3	1171.2	157.5	27.8

The TMI-P_{200}/*w*PI regression constants just like the TMI-P_{200} regression constants, universal equations are needed to be fit to the regression constants so that interpolation between the values are possible. In Equations 2.33 through 2.38 is the single equation for each regression constant. Equations 2.33 through 2.35 are when the *w*PI is less than 0.5 and Equation 2.36 through Equation 2.38 are used when the *w*PI of the soil is greater than or equal to 0.5. Table 2.7 is the comparison between the regression coefficients and the regression constants obtained using the equation as well as the R^2 for the equations.

$$\beta = 2.56075(P_{200}) + 393.4625 \qquad (2.33)$$

$$\gamma = 0.09625(P_{200}) + 132.4875 \qquad (2.34)$$

$$\delta = 0.025(P_{200}) + 14.75 \qquad (2.35)$$

$$\beta = 0.006236(wPI)^3 - 0.7798334(wPI)^2 + 36.786486(wPI) + 501.9512 \qquad (2.36)$$

$$\gamma = 0.00395(wPI)^3 - 0.04042(wPI)^2 + 1.454066(wPI) + 136.4775 \qquad (2.37)$$

$$\delta = -0.01988(wPI)^2 + 1.27358(wPI) + 13.91244 \quad \ldots\ldots\ldots\ldots\ldots\ldots (2.38)$$

Table 2.7: Predicted Regression Coefficients versus Actual Regression Coefficients.

***P*$_{200}$**	**Actual β**	**Predicted β**	**Actual γ**	**Predicted γ**	**Actual δ**	**Predicted δ**
10	419.07	419.07	133.45	133.45	15	15
50	521.5	521.5	137.3	137.3	16	16
	R^2	**100.000%**	**R^2**	**100.000%**	**R^2**	**100.000%**
***w*PI**	**Actual β**	**Predicted β**	**Actual γ**	**Predicted γ**	**Actual δ**	**Predicted δ**
0.5	521.50	520.15	137.30	137.19	16.00	14.54
5	663.50	667.17	142.50	142.79	17.50	19.78
10	801.00	798.07	147.60	147.37	25.00	24.66
20	975.00	975.63	152.50	152.55	32.00	31.43
50	1171.20	1171.18	157.50	157.50	27.80	27.88
	R^2	**99.991%**	**R^2**	**99.942%**	**R^2**	**95.798%**

2.7.3 Volumetric Water Prediction

The volumetric water content prediction, is determined either the soil water characteristic curve or from a TMI-P$_{200}$ model. The soil water characteristic curve is used for all of Level 1 soils and Levels 2 and 3 that have soils with a *w*PI greater than 2.0. Perera in 2003 created predictive equations from granular material that had *w*PI less than 2.0, which when it was incorporated into the EICM, it was deactivated and the TMI-P$_{200}$ model is used (Witczak et al 2006). Perera's predictive equations, for soil with *w*PI less than 2.0 would crash the program since it is possible to create an undefined value with the predictive equation.

2.7.3.1 Soil Water Characteristic Curve Prediction

The soil water characteristic curve is obtained from either Level 1 tested data or Levels 2 and 3 correlations. In either case, all three levels need the saturated volumetric water content or the porosity of the soil. In Equation 2.39 is the saturated volumetric water content.

$$\theta_{sat} = \left(1 - \frac{\gamma_{dry}}{G_s * \gamma_{water}}\right) \qquad (2.39)$$

Where:

γ_{dry} is the dry unit weight of the soil

G_s is the specific gravity of the soil solids

γ_{water} is the unit weight of water, which is 62.4 lb/ft^3 (9.81 kN/m^3)

2.7.3.1.1 Level 1

The soil water characteristic curve is determined from obtaining data points from testing. The SWCC testing can be accomplished by using either ASTM D6836 “Standard Test Methods for Determination of the Soil Water Characteristic Curve for Desorption Using Hanging Column, Pressure Extractor, Chilled Mirror Hygrometer, or Centrifuge” or ASTM D5298 “Stand Test Method for Measurement of Soil Potential (Suction) Using Filter Paper”. ASTM D6386 will obtain points less than 1500 kPa, which a Fredlund and Xing SWCC (F&X) is capped at 1,000,000 kPa, which leaves a large void in the SWCC and when the

SWCC equation is fitted to the data points it might not capture then behavior of the SWCC in the higher suction ranges. Therefore, for appropriate SWCC ASTM D6386 testing needs to be supplemented with ASTM D5298, which will obtain points in the higher suction values. Nevertheless, after the data points are obtained from either or both testing methods, the data is then fitted to Equation 2.40 (Fredlund and Xing 1994). Using Microsoft Excel© solver, $a_{f,}$ b_f, $c_{f,}$ and h_{rf} will be determined by minimizing the residual sum squared error. Normally a_f will be set to 100 kPa, b_f 1, c_f 2, and h_{rf} is dependent on soil type and it ranges from 100 to 3,000 kPa.

$$\theta_w = C(h)x\left[\frac{\theta_{sat}}{\left[\ln\left[\exp(1)+\left(\frac{\psi}{a_f}\right)^{b_f}\right]\right]^{c_f}}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.40)$$

Where:

$$C(h)=\left[1-\frac{\ln\left(1+\frac{\psi}{h_r}\right)}{\ln\left(1+\frac{1x10^6}{h_r}\right)}\right]$$

$a_{f,}$ b_f, $c_{f,}$ and h_{rf} are regression constants

2.7.3.1.2 Levels 2 and 3

Levels 2 and 3 will use correlations between the SWCC fitting parameters $a_{f,}$ b_f, and $c_{f,}$ with the *w*PI of the soil. The Fredlund and Xing Equation shown in

Equation 2.40 will still be used to determine the volumetric water content of the soil with the saturated volumetric water content, which was shown in Equation 2.39. The correlations for the fitting parameters are shown in Equation 2.41 through 2.43 (Houston et al. 2006, Witczak et al. 2006). In addition to these equations, the proposed h_{rf} will equal 500 kPa.

$$a_f = 32.835(\ln(wPI)) + 32.438 \qquad (2.41)$$

$$b_f = 1.421 wPI^{-0.3185} \qquad (2.42)$$

$$c_f = -0.2154(\ln(wPI)) + 0.07145 \qquad (2.43)$$

2.7.3.2 TMI-P_{200} Model

When the soil has a *w*PI less than 2.0, it will use the TMI-P_{200} model to obtain the volumetric water content of the soil. This is due to the error with the granular equation not able to converge correctly (Witczak et al. 2006). The TMI-P_{200} model uses the sites TMI value and the P_{200} of the soil. In Equation 2.44 is the TMI-P_{200} model proposed by Houston et al. in 2006. There are three constraints associated with this equation: 1) if the P_{200} is less than two percent use two percent and 2) if the θ_w from Equation 2.44 is greater than 40 percent, use Equation 2.45 and 3) if the θ_w is greater than θ_{sat} then the θ_w will equal θ_{sat}.

$$\theta_w = 4 + 1.5 P_{200}^{0.6994} + 0.03(TMI) \qquad (2.44)$$

$$\theta_w = 40 + 0.11(P_{200} - 53) \qquad (2.45)$$

2.7.4 Degree of Saturation

Regardless of the hierarchical level, the degree of saturation is calculated the same. It requires the saturated volumetric water content and the volumetric water content, which the volumetric water content is obtained from either the SWCC or the TMI-P_{200} model. In Equation 2.41 is the degree of saturation (Houston et al. 2006, Witczak et al. 2006).

$$\%S = \left(\frac{\theta_w}{\theta_{sat}}\right)*100\% \qquad (2.46)$$

Where:

%S is the degree of saturation

2.7.5 Soil Compaction and Optimum Saturation

2.7.5.1 Level 1

The soil compaction and the optimum saturation is obtained by completing the following tests: AASHTO T99 "Moisture-Density Relations of Soils Using a 5.5-lb Rammer and a 12-in Drop", which will give the maximum dry density and the optimum moisture content and Specific Gravity from user input normally obtained from ASTM D854 "Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer", which will give the specific gravity of the soil solids. By having these three parameters the optimum saturation can be computed by using Equation 2.42.

$$S_{opt} = \frac{w_{opt}}{\frac{\gamma_w}{\gamma_{d\max}} - \frac{1}{G_s}} \quad \text{...}(2.47)$$

Where:

w_{opt} is the optimum moisture content obtained from compaction recorded a percentage

$\gamma_{d\max}$ is the maximum dry density

2.7.5.2 Non-plastic soils

Non-plastic soils or soils with *w*PI or PI equal to zero will use two correlations between the percentage passing certain sieve sizes and the diameter of the soil particles for Levels 2 and 3 (Witczak et al. 2006). The Witczak et al. equations are the current equations that are used in the EICM version 0.7. Equation 2.48 is the optimum saturation, Equation 2.49 is the optimum moisture content, and Equation 2.50 is the dry maximum dry unit weight for the soil. The specific gravity of the soil solids can be obtained from either laboratory testing, using the default specific gravity in the guide, or the user will assume a specific gravity of soil solids.

$$S_{opt} = -100.17 + (1.4991)P_{2''} + (0.56155)P_{1''} - (0.36755)P_{0.5''} \quad \text{.................}(2.48)$$

$$\begin{aligned} w_{opt} &= -120.14 - (0.06766)P_{1.5''} + (3.7269)D_{60} \\ &- (0.167)P_{\#40} + (0.117)P_{\#60} + 142.53e^{(-(0.0389)D_{60})} \end{aligned} \quad \text{.......................}(2.49)$$

$$\gamma_{d\,\max} = \frac{(\gamma_{water})}{1 + \dfrac{w_{opt}(G_s)}{S_{opt}}} \quad \text{..}(2.50)$$

Where:

$P_{2.0"}$ is the Percent Passing the 2.0” U.S. standard sieve

$P_{1.5"}$ is the Percent Passing the 1.5” U.S. standard sieve

$P_{1.0"}$ is the Percent Passing the 1.0” U.S. standard sieve

$P_{0.5"}$ is the Percent Passing the 0.5” U.S. standard sieve

$P_{\#40}$ is the Percent Passing the #40 U.S. standard sieve

$P_{\#60}$ is the Percent Passing the #60 U.S. standard sieve

P_{60} is the Particle diameter associated with the 60% cumulative percent passing

2.7.5.3 Plastic soils

Plastic soils are soils that have *w*PI or PI greater than zero and it uses multiple correlations of the soil properties. First before the optimum saturation or the compaction information can be determined, it requires a check to see if the PI that either the user inputs or the default value given by the guide is with reason, Equation 2.51 is used. In this equation it uses a correlation of the P_{200} to the PI of the soil. If the user or default value is outside the range of the adjust PI in Equation 2.51 the adjusted PI is used in the calculations. If the PI is less than the PI adjusted, the PI adjusted will be set equal to the PI that was inputted.

$$PI_{adj} = e^{\frac{P_{200}+42.13}{33.94}} \quad \text{.......................................}(2.51)$$

Once the PI$_{adj}$ is obtained the *w*PI$_{adj}$ of the soil is determined, if the *w*PI$_{adj}$ is less than one then *w*PI$_{adj}$ will equal a value of one (Witczak et al 2006). The *w*PI$_{adj}$ is calculated the same as *w*PI, only the PI will equal the PI$_{adj.}$ With the *w*PI$_{adj}$ obtained, the optimum moisture content of the soil can be obtained by using Equation 2.52. Using Equation 2.53 the dry unit weight of the soil can be determined.

$$w_{opt} = 8.3932wPI_{adj}^{0.3075} \quad \text{.......................................}(2.52)$$

$$\gamma_{dry} = \gamma_{dry\max\_comp\_std} = 142.115 - (1.959)w_{opt} \quad \text{...........................}(2.53)$$

Now that the optimum moisture content and the maximum dry density of the soil have been determined, the optimum saturation can be determined by using Equation 2.47. When Equation 2.47 is used, the specific gravity of the soil solids is needed, just like with the non-plastic soil the specific gravity of the soil solids can be obtained from testing, the default value, or the user assumes a value for the specific gravity of the soil solids.

2.7.6 Unbound Resilient Moduli at Optimum

The unbound resilient modulus at optimum is subdivided into three categories, (1) the data is obtained through Level 1 testing, (2) it is obtained by using correlations to non-plastic soil properties, and (3) it is obtained by using correlations to plastic soil properties.

2.7.6.1 Level 1

As stated previously, the unbound resilient moduli at optimum for granular and fine grained material will be collected using one of the following test methods: NCHRP 1-28A "Harmonized Test Methods for Laboratory Determination of Resilient Modulus for Flexible Pavement Design" or AASHTO T307 "Determining the Resilient Modulus of Soil and Aggregate Materials".

2.7.6.2 Non-Plastic Soils

The resilient modulus at optimum relies on three correlations, one of which is a soil property and the other two relate the soil property to an in-situ resilient modulus then to the resilient modulus at optimum (Witczak et al. 2001). The D_{60} of the soil is correlated to the CBR of the soil by using Equation 2.54.

$$CBR = 28.09(D_{60})^{0.358} \qquad (2.54)$$

The CBR of the soil is correlated to the in-situ modulus by using Equation 2.55, which was developed by Lister and Powel 1987. Then the correlation between the in-situ resilient modulus and the resilient modulus at optimum can be made using Equation 2.56.

$$M_{insitu} = 2555(CBR)^{0.64} \qquad (2.55)$$

$$M_{Ropt} = M_{insitu}\left[2.11 - 2.78x10^{-5} M_{insitu}\right] \qquad (2.56)$$

2.7.6.3 Plastic soils

Plastic soils use the same correlations as the non-plastic soils; however, the CBR correlation is now correlated to the *w*PI of the soil instead of the D_{60}. The CBR *w*PI correlation can be found in Equation 2.57. To obtain the resilient modulus at optimum, it will require Equation 2.57, 2.54, and 2.55.

$$CBR = \frac{75}{1 + 0.728wPI} \quad \text{(2.57)}$$

2.7.7 Unfrozen Environmental Factor

The unfrozen environmental factor has been developed over the past few years, with the most current that was developed by Cary and Zapata in 2007, which at this time is not implemented into the EICM version 0.7; however, in this thesis, it is the unfrozen environmental factor that is used. The EICM currently is using the model that was developed by Witczak et al in 2000. The 2000 Witczak et al. model is presented in Equation 2.58. This model only accounts for either coarse-grained or fine-grained classification and it is capped with an upper and lower bound.

$$\log F_u = a + \frac{b - a}{1 + e^{\left(\ln\frac{-b}{a} + k_m\left(S - S_{opt}\right)\right)}} \quad \text{(2.58)}$$

Where:

$F_u = \frac{M_{req}}{M_{ropt}}$, is the ratio of modulus at equilibrium to modulus at optimum a is the min of Log F_u (-0.3123 and -0.5934 for coarse- and fine-grained, respectively)

b is the max of Log F_u (0.3010 and 0.3979 for coarse- and fine-grained, respectively)

k_m = regression parameter (6.8157 and 6.1324 for coarse-and fine-grained, respectively)

$(S-S_{opt})$ is variation in degree of saturation expressed in decimal form

The Cary and Zapata model is a universal model that is not bounded by soil type or bounded by a maximum or minimum value as well. The Cary and Zapata model built upon the environment factor the Witczak et al. developed by adding the *w*PI parameter, which allows for a better representation of the resilient modulus at equilibrium for a site. Equation 2.59 is the unfrozen environmental factor.

$$F_{env} = 10^{1.002x\left[\alpha^{-1} + \frac{\beta-\alpha^{-1}}{1+e^{\ln\left(\frac{-\beta}{\alpha^{-1}}\right)+\gamma\left(\frac{S-S_{opt}}{100}\right)}}\right]} \quad \text{...(2.59)}$$

Where:

$$\alpha = (-0.6) + (-1.87194)e^{-wPI}$$

$$\beta = 0.8 + 0.08(wPI)^{0.5}$$

$$\gamma = \left(11.96518 + (-10.19111)e^{-wPI}\right)^{0.5}$$

2.7.8 Unbound Resilient Moduli at Equilibrium

The unbound resilient modulus at equilibrium is the most important design factor when it is considered in the pavement design. The unbound modulus determines the thickness of the manufactured lifts of the asphalt, base, or subbase material to be placed on top of the unbound material. The thickness of the manufacture lifts will depend heavily on the strength of the material, which is determined by the environmental factor and the strength at optimum conditions. The unbound resilient modulus at equilibrium is determined by Equation 2.60. When the stochastic process is applied to the resilient modulus at equilibrium, for Levels 2 and 3, it creates a highly skewed left distribution and resilient modulus at equilibrium needs a log transformation to make the distribution to follow a log-normal distribution. In Equation 2.61 is the log transformation of the resilient modulus at equilibrium.

$$M_{\mathrm{Re}q} = (F_{env})(M_{Ropt}) \qquad (2.60)$$

$$\log(M_{\mathrm{Re}q}) = \log((F_{env})(M_{Ropt})) \qquad (2.61)$$

2.8 AASHTO Structural Number Design Concept

In 1962, multiple road tests were performed. Out of these road tests, three empirical design equations were formulated. When the three empirical design equations were combined and normalized for an 18-kip single axle load, Equation 2.62 was formed. In the original road tests, only one subgrade soil was used, which had a resilient modulus of 3,000 psi. After accounting for different subgrade strengths and environmental conditions, Equation 2.63 was formulated and released with the 1986 AASHTO design guide (AASHTO 1986).

$$\log W_{18} = 9.36\log(SN-1) - 0.20 + \frac{\log\left((4.2-p_t)/(4.2-1.5)\right)}{0.4+1094/(SN-1)^{5.19}} \text{ ....}(2.62)$$

Where:

W_{18} is number of 18-kip single axle loads

p_t is the final serviceability index

SN is the structural number

$$\log W_{18} = Z_R S_o + 9.36\log(SN-1) - 0.20 + \frac{\log\left((4.2-p_t)/(4.2-1.5)\right)}{0.4+1094/(SN-1)^{5.19}} + 2.32\log M_R - 8.07 \quad (2.63)$$

Where:

Z_R is the normal deviate for a given reliability, R

S_o is the standard deviation

M_R is the resilient modulus at equilibrium

In the design process, the Z_R, S_o, M_R, and the p_t are known variables that are used to solve for either the W_{18} or the SN. When the SN is needed to be determined, the W_{18} of the roadway life is known along with the other variables. Presented in this thesis, the Z_R, S_o, M_R, p_t, and the W_{18} will be known and the SN will be found by iterating the SN in Equation 2.63 until the left-hand and right-hand side of the equation is equal. The SN of the pavement structure is calculated by using Equation 2.64 (AASHTO 1986).

$$SN = a_1 D_1 + a_2 D_2 m_2 + \cdots + a_i D_i m_i \quad \text{......} (2.64)$$

Where:

D_i is the i^{th} thickness in inches

m_i is the i^{th} drainage coefficient

a_i is the i^{th} layer coefficient

2.9 Current Geotechnical Reliability Applications

Currently the geotechnical community is working on reliability design with respect to the limit equilibrium utilizing the load resistance factor design.

2.10 Current Reliability Applications in Pavement Design

Presented in Chapter 13 in the Yoder and Witczak book (1975) is soil variability and of historical pavement layer variability is also shown. The soil variability discussed in Chapter 13 is based on soil pedological series, which relates to a hierarchical level 3 design. This information was the starting point in finding soil variability for any given hierarchical level. The historical pavement layer variability, on the other hand, was developed for various properties of concrete.

Presented in the Huang Pavement Analysis and Design (2004), are several concepts of pavement reliability. Huang presents the concepts of using the Rosenblueth 2-Point estimation and First Order Taylor Series expansion. He presents how to use the Rosenblueth 2-Point estimation and the First Order Taylor Series expansion on the closed-form thickness equation for airfield design using the US Corps of Engineers design equation. In addition airfield design equation, Huang presents a reliability analysis on the traffic prediction based on different axle configurations.

In appendix BB of the “Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures” or the NCHRP 1-37A Final Report (NCHRP 2004), pavement reliability is discussed. Appendix BB shows how the MEPDG incorporates the reliability into the form of pavement distress for both Portland Concrete Cement and Asphalt Concrete pavements. In the appendix, the LTPP database was used for prediction and validation of the pavement reliability. However, the reliability presented in this report does not include reliability in the EICM.

2.11 Summary and Conclusions

Presented in this chapter was a review of statistical parameters that are needed for the four different methodologies. Along with the statistical parameters, statistical distributions as well as hypothesis testing was presented. These two concepts are used in the coming chapters to validate the results obtained from the stochastic procedures. Along with the review of statistics, the introduction of the hierarchical levels and the environmental model equations are discussed. The importance of the environmental models along with the hierarchical levels will be shown in the coming chapters. The impact of the hierarchical level of design in the environmental parameters will be apparent in the later in this thesis.

Finally the reliability applications and the AASHTO structural number design concept were presented. The AASHTO structural number design along with the reliability applications will be apparent in Chapter 6 of this thesis. In Chapter 6, reliability application along with the structural number application in design will be present to show how reliability changes the design using the stochastic procedures as well as the hierarchical level of design in the environmental models.

Chapter 3

DEVELOPMENT OF SOIL VARIABILITY FOR THE HIERARCHICAL LEVELS

3.1 Introduction

There are multiple engineering soils databases that have been used to develop default inputs into the MEPDG; however, the default input for the soils in the EICM only use the mean value from combing multiple engineering databases and does not include the variability associated with the variable each in question. In addition, the default inputs, of the MEPDG, are based on a few soils that generalize the population, which can cause problems in either under predicting or over predicting the resilient modulus at equilibrium. To acknowledge the soil variability, it requires additional engineering databases and additional descriptive statistics. Discussed in this chapter is the formulation of hierarchical levels and the descriptive statistics that are required for them as well. To develop the soil variability, for a given level it requires larger engineering databases.

The engineering databases that will be used to develop the addition descriptive statistics include the LTPP DataPave database, and NCRHP 9-23A soils database (FHWA 2010, Zapata 2010). At the time of the default value creation, the MEPDG relied on the LTPP DataPave database, which at the time of the default value creation, roughly 200 soils were used. With the update in the LTPP DataPave database and the addition of the NCHRP 9-23A, the development of the soil variability will use over 20,000 soil data points.

3.2 Objectives

The objectives of this chapter are to discuss the following:

- First, show the differences in the hierarchical levels that are in implemented into MEPDG and the level definitions that are made by the author.
- Second, obtain project related coefficients of variation for Level 1.
- Third, obtain the four statistical moments, the minimum value, the maximum value, and the alpha and beta shape factors for Level 2.
- Fourth, obtain the four statistical moments, the minimum value, the maximum value, and the alpha and beta shape factors for Level 3.

3.3 Hierarchical Level 1

3.3.1 Description and Differences of Level 1

As stated in Chapter 2, Level 1 is a project soil that has been tested extensively in the laboratory or field testing (NCHRP 2004). Level 1 by the author's definition will be the same, the soil will require extensive geotechnical laboratory testing that includes:

1. Sieve Analysis from AASHTO T27 "Sieve Analysis of Fine and Coarse Aggregates"
2. Specific Gravity from user input normally obtained from ASTM D854 "Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer"

3. Atterberg Limits from AASHTO T90 “Determining the Plastic Limit and Plasticity of Soils” and AASHTO T89 “Determining the Liquid Limit of Soils.”
4. Compaction from AASHTO T99 “Moisture-Density Relations of Soils Using a 5.5-lb Rammer and a 12-in Drop”
5. Soil Water Characteristic Curve Testing using ASTM D6836 “Standard Test Methods for Determination of the Soil Water Characteristic Curve for Desorption Using Hanging Column, Pressure Extractor, Chilled Mirror Hygrometer, or Centrifuge” and/or ASTM D5298 “Stand Test Method for Measurement of Soil Potential (Suction) Using Filter Paper”
6. Resilient Modulus at Optimum Testing using either NCHRP 1-28A “Harmonized Test Methods for Laboratory Determination of Resilient Modulus for Flexible Pavement Design” or AASHTO T307 “Determining the Resilient Modulus of Soil and Aggregate Materials”

From these testing procedures, an average values is obtained, which when inputting these values into a deterministic solution only a men value is produced; however, to obtain a stochastic answer, it requires replicates of the test results that requires either more time and money for testing or using a historical project variance or a coefficient of variation to obtain the statistical parameters required. With a historical project variance or a coefficient of variations for a project, there is little need to spend time on addition testing. Therefore, only the coefficient of variation or project variance is required; however, the author was unable to find historical project variance of coefficient of variance for projects and subsection

4.3 outlines the statistical analyses used to obtain project variance and/or coefficient of variance for each parameter.

3.3.2 Data Collection

The acquisition of project variance and coefficients of variation were obtained from two sources the LTPP DataPave library and Claudia Zapata's dissertation (FHWA 2010, Zapata 1999). Within the LTPP DataPave library only SPS-1 section were utilized since the SPS-1 top layer, of the cross section, was an asphalt concrete, which allowed the use multilayer elastic theory for developing the resilient modulus at optimum mean, variance, and coefficient of variation. The SPS-1 sections had multiple soils within the given location, which were used to develop the coefficients of variation of the as long as there were two or more soils. From the SPS-1 sections, 58 soils were used for $P_{200,}$ PI, maximum dry unit weight, and the optimum moisture content. In addition, the SPS-1 sections had resilient modulus at optimum test data. The resilient modulus at optimum data, for each state varied, and only the soils that had more than 30 data points for the resilient modulus at optimum data used to develop the constitutive relationship between the resilient modulus and the first stress invariant since each soil test had 15 data points. By having 30 or more data points, it allows for a universe set of regression constants for the entire SPS-1 section since 30 or more data points represent two or more of the same soil in the SPS-1 section.

3.3.3 Statistical Analysis

3.3.3.1 P_{200}, PI, Dry Unit Weight, and Optimum Moisture Content

The LTPP SPS-1 sections were used to develop the project variance or the coefficient of variation for the P_{200}, PI, dry unit weight, and the optimum moisture content. The LTPP SPS-1 sections used in the study included seven states, which included: Texas, Arizona, New Mexico, Oklahoma, Nevada, Montana, and Louisiana. Each state had multiple subsections with in the SPS-1 sections that allowed for the creation of the project variance and coefficient of variation. However, within the subsections, there were some soils with only one occurrence, which cannot be used in the statistical analysis. A total of 28 granular soils and 28 fine grained soils were analyzed from the seven states. In Table 3.1 through Table 3.7 the mean, variance, standard deviation, and coefficient of variation, for the P_{200}, PI, maximum dry unit weight, and the optimum moisture content for the seven states are shown. In addition, any zero in the PI column in Tables 3.1 through 3.7 are non-plastic soils, the zero were used in the statistical analysis of the PI parameter if the NP was present in the column it would have been disregarded when using the equation in Microsoft Excel 2010$^{©}$.

Table 3.1: Oklahoma SPS Section Four Parameter Analyses.

SHRP ID	AASHTO	P_{200}	PI	Gamma	w_{opt}
0114	A-1-a	8	0	138	7
0117	A-1-a	9.6	0	139	6
0120	A-1-a	11.7	0	137	7
	μ	**9.77**	**0.00**	**138.00**	**6.67**
	σ^2	**2.30**	**0.00**	**0.67**	**0.22**
	σ	**1.52**	**0.00**	**0.82**	**0.47**
	CV	**15.51%**	**0.00%**	**0.59%**	**7.07%**
SHRP ID	AASHTO	P_{200}	PI	Gamma	w_{opt}
0122	A-6	38.8	15	117	11
0123	A-6	45.9	20	117.5	12
	μ	**42.35**	**17.50**	**117.25**	**11.50**
	σ^2	**25.21**	**12.50**	**0.13**	**0.50**
	σ	**5.02**	**3.54**	**0.35**	**0.71**
	CV	**11.85%**	**20.20%**	**0.30%**	**6.15%**
SHRP ID	AASHTO	P_{200}	PI	Gamma	w_{opt}
0116	A-7-6	45.2	25	110	15
0120	A-7-6	43.5	24	112	14
	μ	**44.35**	**24.50**	**111.00**	**14.50**
	σ^2	**1.45**	**0.50**	**2.00**	**0.50**
	σ	**1.20**	**0.71**	**1.41**	**0.71**
	CV	**2.71%**	**2.89%**	**1.27%**	**4.88%**

Table 3.2: Nevada SPS Section Four Parameter Analyses.

SHRP ID	AASHTO	P_{200}	PI	Gamma	w_{opt}
0102	A-2-6	11.2	11	139	6
0104	A-2-6	24.6	12	140.1	6
0109	A-2-6	15.6	12	136.8	6
	μ	**17.13**	**11.67**	**138.63**	**6.00**
	σ^2	**31.10**	**0.22**	**1.88**	**0.00**
	σ	**5.58**	**0.47**	**1.37**	**0.00**
	CV	**32.55%**	**4.04%**	**0.99%**	**0.00%**

Table 3.3: Texas SPS Section Four Parameter Analyses.

SHRP ID	AASHTO	P_{200}	PI	Gamma	w_{opt}
0114	A-1-a	7.1	0	137.3	5
0119	A-1-a	6.4	0	143.5	4
	μ	**6.75**	**0.00**	**140.40**	**4.50**
	σ^2	**0.24**	**0.00**	**19.22**	**0.50**
	σ	**0.49**	**0.00**	**4.38**	**0.71**
	CV	**7.33%**	**0.00%**	**3.12%**	**15.71%**
SHRP ID	AASHTO	P_{200}	PI	Gamma	w_{opt}
0167	A-2-4	10.4	8	111.1	15
0123	A-2-4	8.2	0	109.4	11
	μ	**9.30**	**4.00**	**110.25**	**13.00**
	σ^2	**2.42**	**32.00**	**1.44**	**8.00**
	σ	**1.56**	**5.66**	**1.20**	**2.83**
	CV	**16.73%**	**141.42%**	**1.09%**	**21.76%**
SHRP ID	AASHTO	P_{200}	PI	Gamma	w_{opt}
0113	A-3	6.4	0	106	13
0119	A-3	7.3	0	107.1	13
0121	A-3	8.5	0	107.2	13
0164	A-3	8.6	0	105.8	12
0167	A-3	8.1	0	106.7	13
	μ	**7.78**	**0.00**	**106.56**	**12.80**
	σ^2	**0.86**	**0.00**	**0.40**	**0.20**
	σ	**0.93**	**0.00**	**0.63**	**0.45**
	CV	**11.90%**	**0.00%**	**0.60%**	**3.49%**

Table 3.4: New Mexico SPS Section Four Parameter Analyses.

SHRP ID	AASHTO	P_{200}	PI	Gamma	w_{opt}
0103	A-7-6	89.6	42	97.5	22
0105	A-7-6	86.4	31	98.3	22
0107	A-7-6	78.6	39	98.4	20
0109	A-7-6	66.7	37	105.3	19
	μ	**80.33**	**37.25**	**99.88**	**20.75**
	σ^2	**103.85**	**21.58**	**13.24**	**2.25**
	σ	**10.19**	**4.65**	**3.64**	**1.50**
	CV	**12.69%**	**12.47%**	**3.64%**	**7.23%**

Table 3.5: Montana SPS Section Four Parameter Analyses.

SHRP ID	AASHTO	P_{200}	PI	Gamma	w_{opt}
0113	A-1-a	10.2	0	135	7
0113	A-1-a	8.2	0	141	6
0117	A-1-a	10.4	0	142	6
0121	A-1-a	7.3	0	143	6
	μ	**9.03**	**0.00**	**140.25**	**6.25**
	σ^2	**2.31**	**0.00**	**12.92**	**0.25**
	σ	**1.52**	**0.00**	**3.59**	**0.50**
	CV	**16.84%**	**0.00%**	**2.56%**	**8.00%**
SHRP ID	AASHTO	P_{200}	PI	Gamma	w_{opt}
0113	A-2-4	27.8	0	101	14
0116	A-2-4	23.5	0	106	17
0116	A-2-4	32.1	0	111	14
0117	A-2-4	16.1	0	111	13
0117	A-2-4	23.1	0	109	14
0119	A-2-4	20.8	0	108	13
0119	A-2-4	28.8	0	110	14
	μ	**24.60**	**0.00**	**108.00**	**14.14**
	σ^2	**29.05**	**0.00**	**12.67**	**1.81**
	σ	**5.39**	**0.00**	**3.56**	**1.35**
	CV	**21.91%**	**0.00%**	**3.30%**	**9.51%**

Table 3.6: Louisiana SPS Section Four Parameter Analyses.

SHRP ID	AASHTO	P_{200}	PI	Gamma	w_{opt}
0118	A-4	91.3	4	116	11
0119	A-4	80.8	0	114	11
0119	A-4	80.8	6	119	11
0119	A-4	87.3	6	119	11
0121	A-4	80.6	0	111	13
0121	A-4	95.4	0	111	13
0124	A-4	90	0	115	12
	μ	**86.60**	**2.29**	**115.00**	**11.71**
	σ^2	**35.81**	**8.57**	**11.00**	**0.90**
	σ	**5.98**	**2.93**	**3.32**	**0.95**
	CV	**6.91%**	**128.09%**	**2.88%**	**8.12%**
SHRP ID	AASHTO	P_{200}	PI	Gamma	w_{opt}
0113	A-6	92.1	19	108	15
0117	A-6	95.7	13	113	13
	μ	**93.90**	**16.00**	**110.50**	**14.00**
	σ^2	**6.48**	**18.00**	**12.50**	**2.00**
	σ	**2.55**	**4.24**	**3.54**	**1.41**
	CV	**2.71%**	**26.52%**	**3.20%**	**10.10%**
SHRP ID	AASHTO	P_{200}	PI	Gamma	w_{opt}
0118	A-7-6	96.5	26	109	15
0124	A-7-6	93.3	22	112	14
	μ	**94.90**	**24.00**	**110.50**	**14.50**
	σ^2	**5.12**	**8.00**	**4.50**	**0.50**
	σ	**2.26**	**2.83**	**2.12**	**0.71**
	CV	**2.38%**	**11.79%**	**1.92%**	**4.88%**

Table 3.7: Arizona SPS Section Four Parameter Analyses.

SHRP ID	AASHTO	P_{200}	PI	Gamma	w_{opt}
0118	A-1-a	7.6	0	142	6
0120	A-1-a	7.1	0	141	4
0161	A-1-a	6.7	0	140	6
	μ	**7.13**	**0.00**	**141.00**	**5.33**
	σ^2	**0.14**	**0.00**	**0.67**	**0.89**
	σ	**0.37**	**0.00**	**0.82**	**0.94**
	CV	**5.16%**	**0.00%**	**0.58%**	**17.68%**
SHRP ID	AASHTO	P_{200}	PI	Gamma	w_{opt}
0113	A-1-b	8.8	0	126	10
0116	A-1-b	16.3	0	135	8
0119	A-1-b	13.2	0	138	8
0123	A-1-b	14	0	135	8
0162	A-1-b	9.4	0	135	8
	μ	**12.34**	**0.00**	**133.80**	**8.40**
	σ^2	**10.09**	**0.00**	**20.70**	**0.80**
	σ	**3.18**	**0.00**	**4.55**	**0.89**
	CV	**25.74%**	**0.00%**	**3.40%**	**10.65%**
SHRP ID	AASHTO	P_{200}	PI	Gamma	w_{opt}
0119	A-1-b	12.2	0	142	5
0115	A-1-b	24.7	2	132	9
0121	A-1-b	15.6	3	133	8
	μ	**17.50**	**1.67**	**135.67**	**7.33**
	σ^2	**41.77**	**2.33**	**30.33**	**4.33**
	σ	**6.46**	**1.53**	**5.51**	**2.08**
	CV	**36.93%**	**91.65%**	**4.06%**	**28.39%**
SHRP ID	AASHTO	P_{200}	PI	Gamma	w_{opt}
0114	A-2-4	18.3	7	133	8
0121	A-2-4	15.8	10	132	8
	μ	**17.05**	**8.50**	**132.50**	**8.00**
	σ^2	**3.13**	**4.50**	**0.50**	**0.00**
	σ	**1.77**	**2.12**	**0.71**	**0.00**
	CV	**10.37%**	**24.96%**	**0.53%**	**0.00%**

With the statistical parameters completed for the seven states, now a pooled project variance and average coefficient of variation is needed. In Table

3.8 is the pooled variance and Table 3.9 is the average coefficient of variation; however, these tables are broken into three categories, which includes: non-plastic soils, plastic soils, and all soils. The three categories show how the variance and coefficient of variation vary between the three categories.

Table 3.8: Project Pooled Variance for the Four Parameter Analyses.

Non-Plastic Soils

State	Count	AASHTO	P_{200}	PI	Gamma	w_{opt}
Oklahoma	3	A-1-a	2.30	0.00	0.67	0.22
Texas	2	A-1-a	0.24	0.00	19.22	0.50
Texas	5	A-3	0.86	0.00	0.40	0.20
Montana	4	A-1-a	2.31	0.00	12.92	0.25
Montana	7	A-2-4	29.05	0.00	12.67	1.81
Arizona	3	A-1-a	0.14	0.00	0.67	0.89
Arizona	5	A-1-b	10.09	0.00	20.70	0.80
Non-Plastic Soils σ^2_{pooled}			**10.46**	**0.00**	**10.05**	**0.83**

Plastic Soils

State	Count	AASHTO	P_{200}	PI	Gamma	w_{opt}
Nevada	3	A-2-6	31.10	0.22	1.88	0.00
Oklahoma	2	A-7-6	1.45	0.50	2.00	0.50
Arizona	3	A-1-b	41.77	2.33	30.33	4.33
Arizona	2	A-2-4	3.13	4.50	0.50	0.00
Louisiana	2	A-7-6	5.12	8.00	4.50	0.50
Louisiana	7	A-4	35.81	9.14	11.00	0.90
Oklahoma	2	A-6	25.21	12.50	0.13	0.50
Louisiana	2	A-6	6.48	18.00	12.50	2.00
New Mexico	4	A-7-6	103.85	21.58	13.24	2.25
Texas	2	A-2-4	2.42	32.00	1.44	8.00
Plastic Soils σ^2_{pooled}			**37.68**	**10.54**	**10.06**	**1.70**
All soils σ^2_{pooled}			**23.07**	**4.88**	**10.06**	**1.24**

Table 3.9: Project Coefficient of Variation for the Four Parameters.

Non-Plastic Soils						
State	Count	AASHTO	P_{200}	PI	Gamma	w_{opt}
Oklahoma	3	A-1-a	15.51%	0.00%	0.59%	7.07%
Texas	2	A-1-a	7.33%	0.00%	3.12%	15.71%
Texas	5	A-3	11.90%	0.00%	0.60%	3.49%
Montana	4	A-1-a	16.84%	0.00%	2.56%	8.00%
Montana	7	A-2-4	21.91%	0.00%	3.30%	9.51%
Arizona	3	A-1-a	5.16%	0.00%	0.58%	17.68%
Arizona	5	A-1-b	25.74%	0.00%	3.40%	10.65%
Non-Plastic $CV_{average}$			**14.91%**	**0.00%**	**2.02%**	**10.30%**

Plastic Soils						
State	Count	AASHTO	P_{200}	PI	Gamma	w_{opt}
Nevada	3	A-2-6	32.55%	4.04%	0.99%	0.00%
Oklahoma	2	A-7-6	2.71%	2.89%	1.27%	4.88%
Arizona	3	A-1-b	36.93%	91.65%	4.06%	28.39%
Arizona	2	A-2-4	10.37%	24.96%	0.53%	0.00%
Louisiana	2	A-7-6	2.38%	11.79%	1.92%	4.88%
Louisiana	7	A-4	6.91%	96.21%	2.88%	8.12%
Oklahoma	2	A-6	11.85%	20.20%	0.30%	6.15%
Louisiana	2	A-6	2.71%	26.52%	3.20%	10.10%
New Mexico	4	A-7-6	12.69%	12.47%	3.64%	7.23%
Texas	2	A-2-4	16.73%	141.42%	1.09%	21.76%
Plastic $CV_{average}$			**13.58%**	**43.21%**	**1.99%**	**9.15%**
All soils $CV_{average}$			**14.13%**	**25.42%**	**2.00%**	**9.62%**

Although, the coefficient of variation and project pooled variance has been determined for all soils, non-plastic soils, and plastic soils it needs to be determined if the coefficient of variation or the pooled project variance can be applied to the mean value of the testing or if an equation is needed. In Figure 3.1 through Figure 3.4 is the coefficient of variation of the parameter versus the mean value of the parameter. By comparing the mean to the coefficient of variation, it will show is there is any correlation.

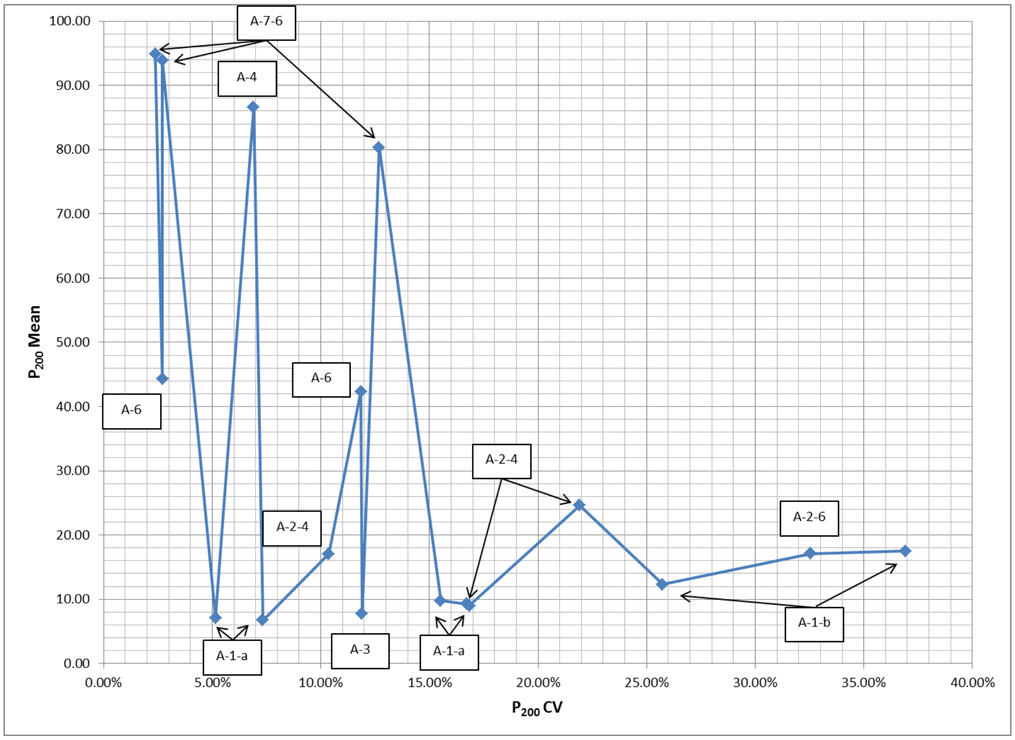

Figure 3.1: Percent passing 200 mean versus the coefficient of variation.

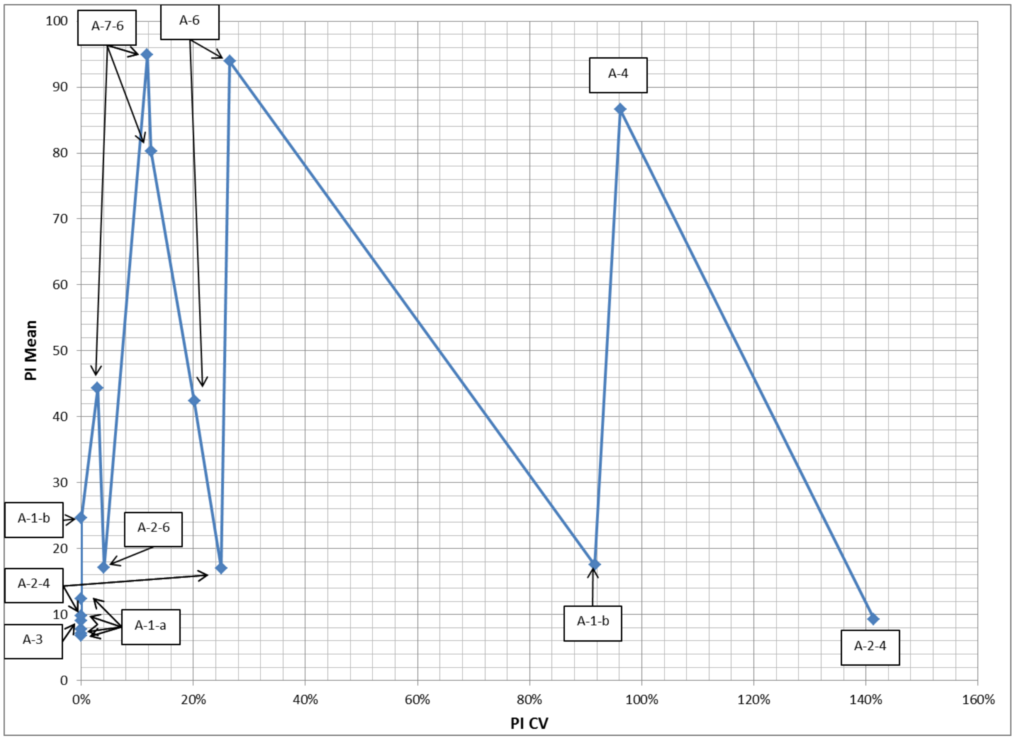

Figure 3.2: Plasticity index mean versus the coefficient of variation.

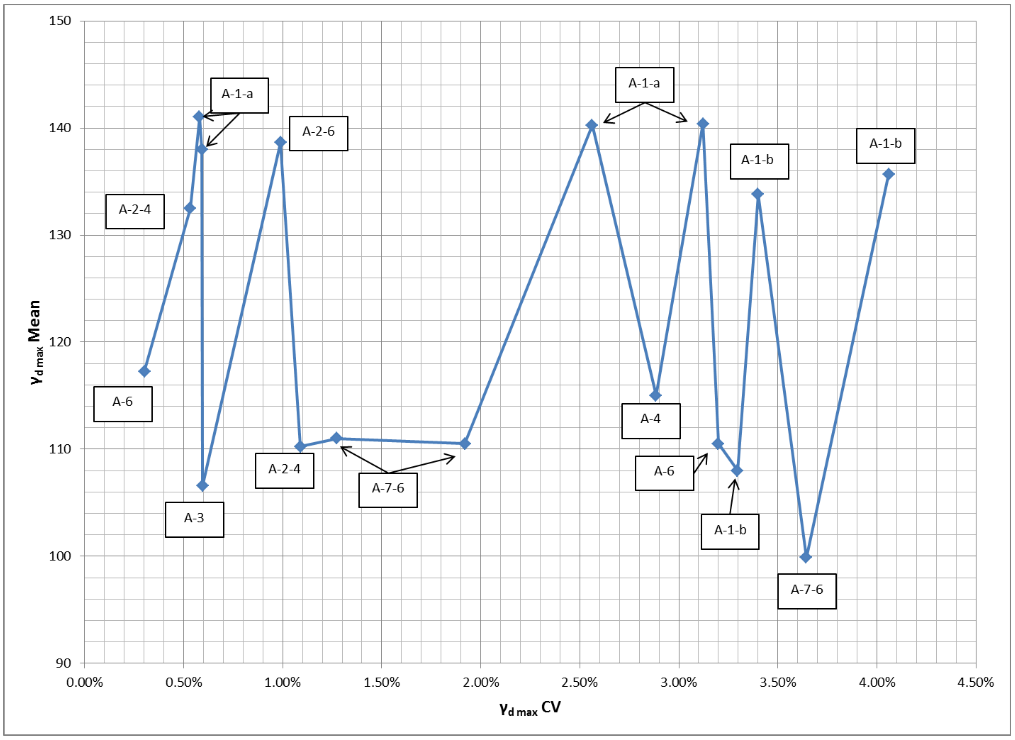

Figure 3.3: Maximum dry density mean versus coefficient of variation.

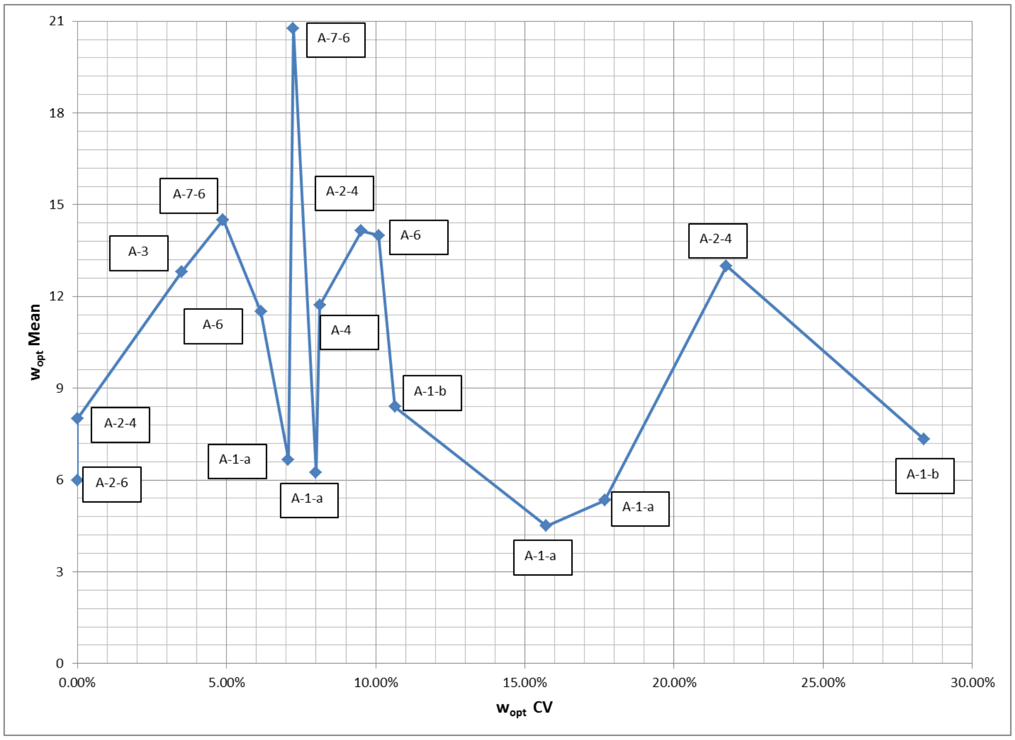

Figure 3.4: Optimum moisture content mean versus coefficient of variation.

As seen in Figures 3.1 through 3.4 there is no correlation between the mean and coefficient of variation; therefore, either the non-plastic soils, plastic soils, or all the soils coefficient of variation can be applied to the mean value or the value obtained from laboratory testing.

After showing there is no correlation between the mean value and the coefficient of variation, there needs to be a check if the there is a correlation between the mean value and the project variance. In Figures 3.5 through Figure 3.8, is the mean value of the parameter versus the project variance.

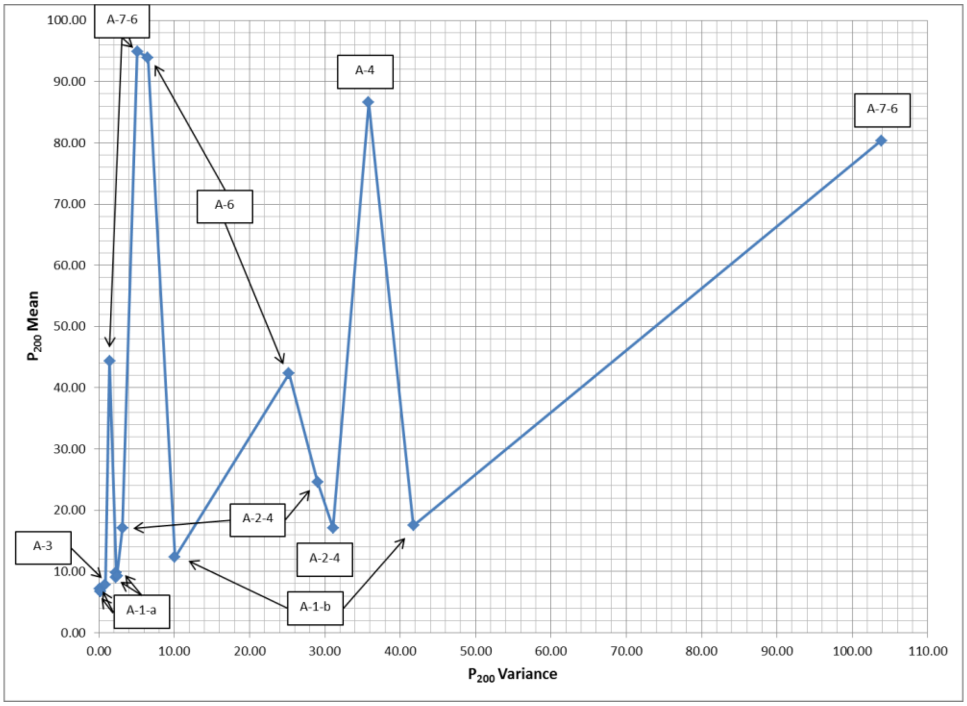

Figure 3.5: Percent passing 200 mean versus the project variance.

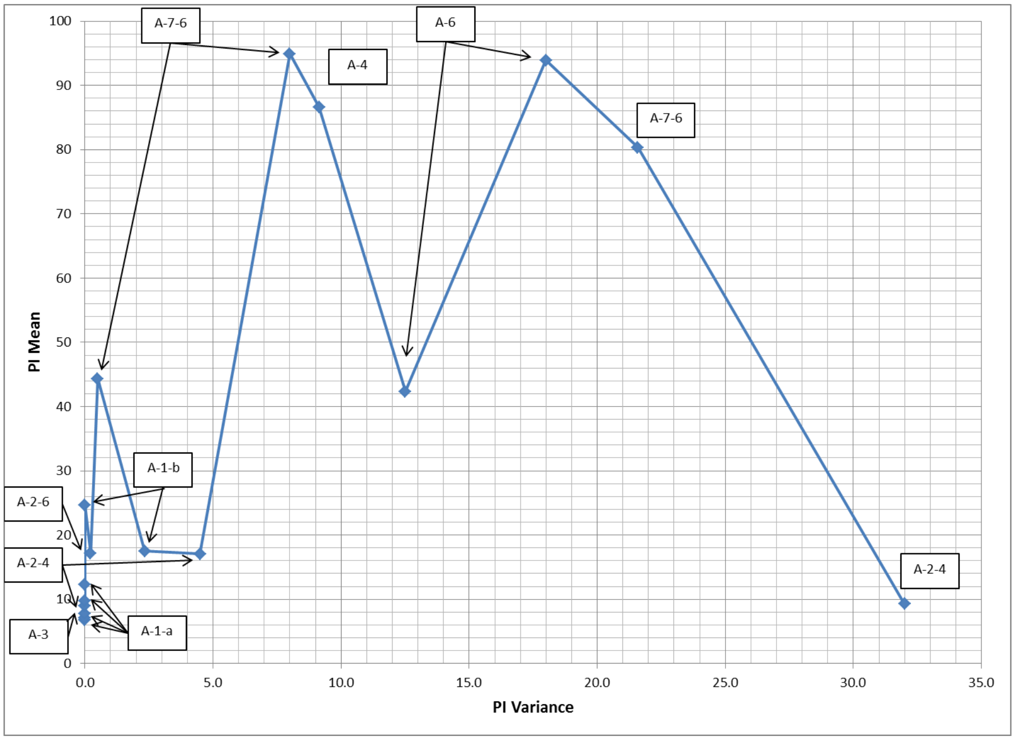

Figure 3.6: Plasticity Index mean versus the variance.

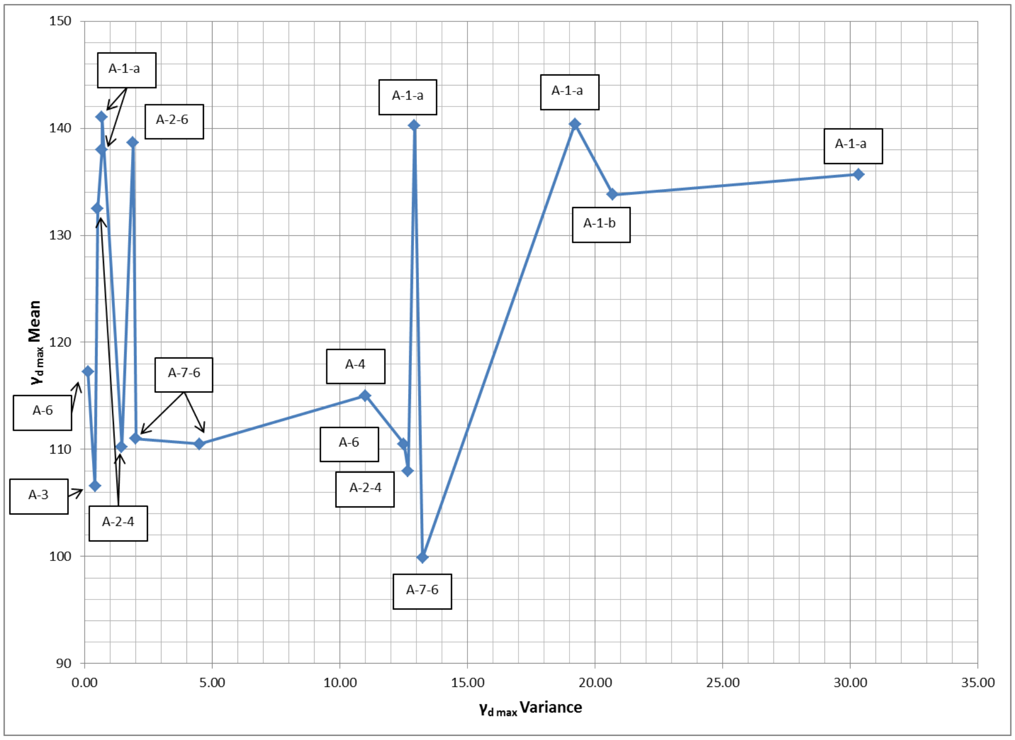

Figure 3.7: Maximum dry density mean versus the variance.

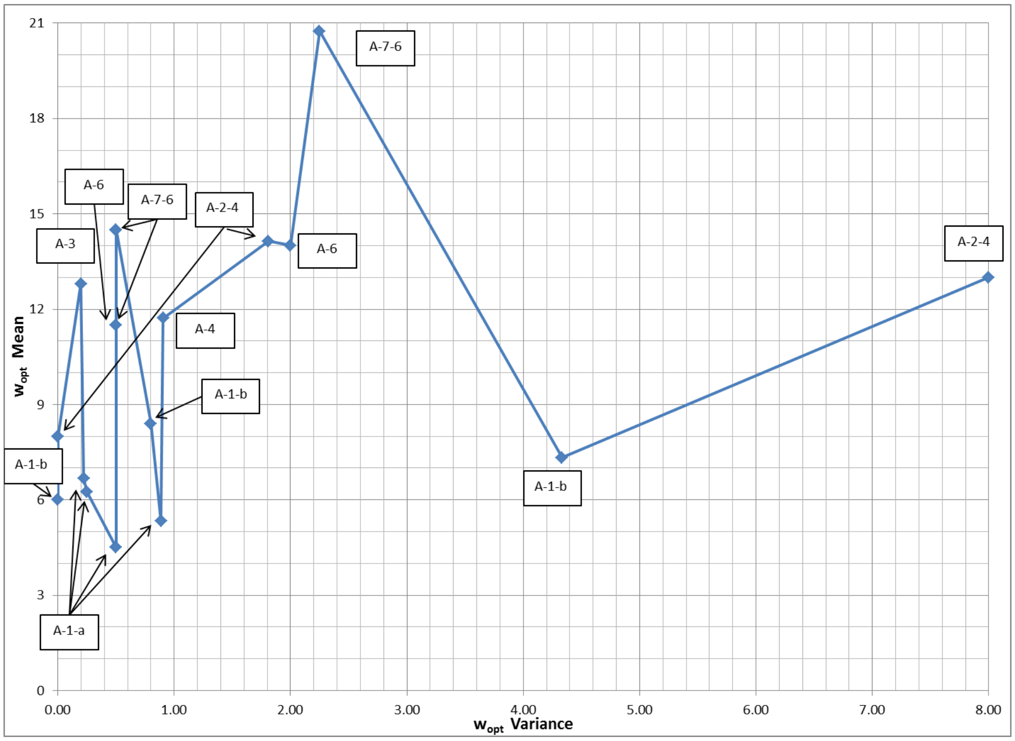

Figure 3.8: Optimum moisture mean versus the variance.

As seen in Figure 3.1 through Figure 3.4 and Figures 3.5 through Figure 3.8 show no correlation between the mean and variance of parameters; therefore, either the non-plastic soils, plastic soils, or all the soils variance can be applied to the mean value or the value obtained from laboratory testing.

3.3.3.2 SWCC Parameters

The SWCC parameter analysis requires laboratory data; however, the LTPP DataPave database does not include the SWCC parameters for project related data as this time. In addition, the NCHRP 9-23A database includes the SWCC parameters for soil pedological and not project related data; therefore, therefore, the SWCC database provided by Claudia Zapata's dissertation research will be used as project related data. In the dissertation database, three soils were analyzed, which included a sand, silt, and clay soil. The soils were tested at multiple laboratories to develop laboratory and operator variance; however, only Laboratory 6 (ASU laboratory) information will be used to develop the project coefficients of variations and project variance. In her dissertation, the discussion of the confidence interval is disused, which was used to develop an upper and lower bound of the SWCC. Equation 3.1 is the confidence interval that is used.

$$CI = \frac{t_{inv}(p,\upsilon)(\sigma)}{n+1} \quad \text{..........}(3.1)$$

Where:

t_{inv} is the inverse of the student’s t distribution or the in terms of the CDF

p is the probability

υ is the degrees of freedom (Data Points – Number of Variables)

σ is the standard deviation is determined from the mean square error (MSE)

n is the number of data points

The standard deviation of that is applied in the CI is determined by obtaining the sum of square errors and the then determining the mean square error, which is determined by Equation 3.2.

$$\sigma = \sqrt{\sigma^2} = \sqrt{MSE} = \sqrt{\frac{SSE}{df}} \quad \text{..........}(3.2)$$

The SSE is determined by the following steps:

1. The Fredlund and Xing equation (Equation 2.40) is fitted to the actual SWCC data points using a regression analysis.
2. Compute the squared error between the F&X value and the actual SWCC data points.
3. Sum the squared error of all the data points.

After the SSE, MSE, and CI is computed, the CI is then applied to the fitted Fredlund and Xing data points by adding or subtracting the CI from the fitted Fredlund and Xing equation, which gives an upper and lower bound, respectively. With the new data points at the given suction values, the regression analysis is then completed for the upper and lower bounds thus giving new SWCC parameters for the upper and lower bound. Then the upper bound, the actual Fredlund and Xing, and the lower bound parameters are averaged together, which is then used to find the variance between the three values. In Tables 3.10 through 3.12 are the SWCC data points, fitting parameters, Fredlund and Xing curve values, SSE, MSE, and CI analysis for the sand, silt, and clay respectively. The sand analysis had a total of 13 measured values that ranged from 15 kPa to 1360 kPa. The silt analysis had a total of 7 measured values that ranged from 40 kPa to 1360 kPa. The clay analysis had a total of 6 measured values that ranged from 40 kPa to 1360 kPa. The silt and clay analysis had less data points than the sand due to the time that the soil will come to equilibrium within the SWCC testing device. The time it takes the soil to come to equilibrium in the SWCC devices depend on the unsaturated hydraulic conductivity of the soil, sands have a higher unsaturated hydraulic conductivity than silts, and silts have a higher unsaturated hydraulic conductivity. The differences in sands, silts, and clays, are orders of magnitude on a log-scale; therefore the time to equilibrium is dependent on water movement through the specimen, at the given suction value.

Table 3.10: Sand SWCC Analysis

El Paso Sand			
F&X Parameters		Soil Properties	
a	9.1977	G_s	2.650
b	0.1278	γ_d	1.380
c	4.6325	Θ_{sat}	0.479
h_r	100.00	υ	9.0
Suction	Actual	F&X	Squared Error
15	0.1415540	0.1255340	0.0002566
30	0.1091870	0.1137077	0.0000204
40	0.1071832	0.1083777	0.0000014
40	0.1019029	0.1083688	0.0000418
60	0.0955587	0.1010637	0.0000303
80	0.0930328	0.0958361	0.0000079
100	0.0839905	0.0917739	0.0000606
100	0.0912118	0.0917648	0.0000003
300	0.0823363	0.0719337	0.0001082
500	0.0589929	0.0631624	0.0000174
795	0.0539730	0.0556434	0.0000028
800	0.0565679	0.0555450	0.0000010
1360	0.0579302	0.0475733	0.0001073
		SSE	**0.0006561**
		MSE	**0.0000729**
		σ	**0.0085379**
		CI (95%)	**0.0013796**

Table 3.11: Silt SWCC Analysis.

Price Club Silt			
F&X Parameters		Soil Properties	
a	9.4577	G_s	2.730
b	0.2464	γ_d	1.280
c	3.4420	Θ_{sat}	0.531
h_r	500.00	υ	3.0
Suction	Actual	F&X	Squared Error
40	0.1666966	0.1565402	0.0001032
100	0.1128346	0.1267977	0.0001950
300	0.0890135	0.0943380	0.0000283
500	0.0784545	0.0806029	0.0000046
778	0.0716939	0.0695436	0.0000046
800	0.0722459	0.0688743	0.0000114
1360	0.0653209	0.0568345	0.0000720
		SSE	**0.0004191**
		MSE	**0.0001397**
		σ	**0.0118194**
		CI (95%)	**0.0132988**

Table 3.12: Clay SWCC Analysis.

Fountain Hills Clay			
F&X Parameters		Soil Properties	
a	25.9769	G_s	2.770
b	2.7907	γ_d	1.180
c	0.1500	Θ_{sat}	0.574
h_r	500.00	υ	2.0
Suction	Actual	F&X	Squared Error
40	0.5171718	0.5202132	0.0000092
100	0.4722191	0.4581553	0.0001978
300	0.3792877	0.4036717	0.0005946
500	0.3681485	0.3800936	0.0001427
800	0.3723158	0.3576601	0.0002148
1360	0.3424054	0.3311544	0.0001266
		SSE	**0.0012857**
		MSE	**0.0006428**
		σ	**0.0253543**
		CI (95%)	**0.0304975**

A 95% confidence interval was selected for use in the upper and lower analysis. By using a 95% confidence interval, it will cover two standard deviations from the mean value of the Fredlund and Xing SWCC curve. In Tables 3.13 through 3.15 is the sand, silt, and clay analysis for both the upper and lower bounds. In addition, the fitted Fredlund and Xing parameters are shown, which will be used in the analysis to produce the project variance and project coefficients of variation.

Table 3.13: Sand Upper and Lower Bound Analysis.

	El Paso Sand					
	F&X Parameters Upper Limit			F&X Parameters Lower Limit		
	a	3.6097		a	8.5883	
	b	0.1303		b	0.1283	
	c	4.1967		c	4.6522	
	h_r	100.00		h_r	100.00	
Suction	Upper	F&X	SE	Lower	F&X	SE
15	0.1429336	0.1521438	0.0000848	0.1401744	0.1481837	0.0000641
30	0.1105665	0.1380541	0.0007556	0.1078074	0.1340799	0.0006902
40	0.1085628	0.1316993	0.0005353	0.1058036	0.1277324	0.0004809
40	0.1032825	0.1316886	0.0008069	0.1005233	0.1277218	0.0007398
60	0.0969383	0.1229716	0.0006777	0.0941792	0.1190317	0.0006177
80	0.0944124	0.1167275	0.0004980	0.0916532	0.1128199	0.0004480
100	0.0853701	0.1118712	0.0007023	0.0826110	0.1079968	0.0006444
100	0.0925914	0.1118603	0.0003713	0.0898322	0.1079860	0.0003296
300	0.0837159	0.0880937	0.0000192	0.0809567	0.0844872	0.0000125
500	0.0603725	0.0775469	0.0002950	0.0576133	0.0741175	0.0002724
795	0.0553526	0.0684862	0.0001725	0.0525934	0.0652396	0.0001599
800	0.0579474	0.0683676	0.0001086	0.0551883	0.0651236	0.0000987
1360	0.0593097	0.0587383	0.0000003	0.0565506	0.0557232	0.0000007
		SSE	**0.0050274**		**SSE**	**0.0045589**

Table 3.14: Silt Upper and Lower Bound Analysis.

	Price Club Silt					
	F&X Parameters Upper Limit			F&X Parameters Lower Limit		
	a	8.9995		a	7.2230	
	b	0.2487		b	0.2477	
	c	3.0074		c	3.6115	
	h_r	500.00		h_r	500.00	
Suction	Upper	F&X	SE	Lower	F&X	SE
40	0.179995	0.194905	0.000222	0.153398	0.149967	0.000012
100	0.126133	0.161412	0.001245	0.099536	0.119536	0.000400
300	0.102312	0.123630	0.000454	0.075715	0.087218	0.000132
500	0.091753	0.107153	0.000237	0.065156	0.073853	0.000076
778	0.084993	0.093639	0.000075	0.058395	0.063233	0.000023
800	0.085545	0.092813	0.000053	0.058947	0.062594	0.000013
1360	0.078620	0.077804	0.000001	0.052022	0.051188	0.000001
		SSE	**0.0022867**		**SSE**	**0.0006572**

Table 3.15: Clay Upper and Lower Bound Analysis.

	Fountain Hills Clays					
	F&X Parameters			F&X Parameters		
	a	30.0292		a	26.7267	
	b	1.6785		b	1.3865	
	c	0.1357		c	0.2762	
	h_r	500.00		h_r	500.00	
Suction	Upper	F&X	SE	Lower	F&X	SE
40	0.547669	0.539401	0.000068	0.486674	0.508304	0.000468
100	0.502717	0.499562	0.000010	0.441722	0.451095	0.000088
300	0.409785	0.447411	0.001416	0.348790	0.382729	0.001152
500	0.398646	0.422309	0.000560	0.337651	0.353151	0.000240
800	0.402813	0.398005	0.000023	0.341818	0.326608	0.000231
1360	0.372903	0.369037	0.000015	0.311908	0.297113	0.000219
		SSE	**0.0020920**		**SSE**	**0.0023980**

With the upper and lower limits determined for the three soils, the coefficient of variation and the project variance can be determined by computing the mean, variance, and standard deviation. The mean, variance, and standard deviation are determined by using the mean, upper bound, and lower bound

SWCC parameters. In Table 3.16 is statistical analysis of the sand, silt, clay. In addition, in Table 3.16 is the project variance and coefficient of variation are shown, which both values are determined by the predominate percentage of material sand, silt, or clays. Gravels will utilizes the same project variance and coefficient of the as the sands.

Table 3.16: Project Variance and Coefficient of Variation Analysis.

El Paso Sand			
	SWCC Parameters		
F&X Curve	a	b	c
Mean	9.1977	0.1278	4.6325
Upper Bound	3.6097	0.1303	4.1967
Lower Bound	8.5883	0.1283	4.6522
Average	**7.1319**	**0.1288**	**4.4938**
Project Variance	**9.3972E+00**	**1.7549E-06**	**6.6306E-02**
Standard Deviation	**3.0655E+00**	**1.3247E-03**	**2.5750E-01**
CV	**42.983%**	**1.029%**	**5.730%**
Price Club Silt			
	SWCC Parameters		
F&X Curve	a	b	c
Mean	9.4577	0.2464	3.4420
Upper Bound	8.9995	0.2487	3.0074
Lower Bound	7.2230	0.2477	3.6115
Average	**8.5601**	**0.2476**	**3.3536**
Project Variance	**1.3933E+00**	**1.2917E-06**	**9.7096E-02**
Standard Deviation	**1.1804E+00**	**1.1365E-03**	**3.1160E-01**
CV	**13.789%**	**0.459%**	**9.291%**
Fountain Hills Clay			
	SWCC Parameters		
F&X Curve	a	b	c
Mean	25.9769	2.7907	0.1500
Upper Bound	30.0292	1.6785	0.1357
Lower Bound	26.7267	1.3865	0.2762
Average	**27.5776**	**1.9519**	**0.1873**
Project Variance	**4.6484E+00**	**5.4901E-01**	**5.9765E-03**
Standard Deviation	**2.1560E+00**	**7.4095E-01**	**7.7308E-02**
CV	**7.818%**	**37.961%**	**41.277%**

3.3.3.3 Resilient Modulus at Optimum

The resilient modulus at optimum was determined by using resilient modulus testing of the unbound material collected from the LTPP DataPave database. The soils that were in the SPS-1 section were classified by matching the State Code, SHRP ID, Layer number, and location number to the AASHTO classification that was determined in section 3.3.3.1. After the soils were classified, the soils with a given SPS-1 state section were then grouped together and the Lister and Powel (1987) model was then fitted through the data points. After the Lister and Powel regression constants were determined, JULEA was then used to determine the backcalculated resilient modulus of the unbound material by multiple steps (Uzan). The steps that are used to obtain the backcalculated resilient modulus at optimum are outlined below, which are similar to the steps outline by Lytton in 1989:

1. Input the pavement and load properties into a computer program that calculates stresses, strains, and deflections in the pavement structure by layer elastic theory, in this thesis JULEA was used. The applied load to the pavement structure chosen was a 9000-lb single wheel load with an air pressure of 80-psi.
2. For the pavement structure, input a seed modulus for the layer that the resilient modulus at optimum is needed to be backcalculated.
3. Calculate the overburden stress of the pavement cross-section for the layer that the resilient modulus at optimum is needed.

4. Add the overburden stress and stress from the applied load together, making sure both the overburden and the applied stress from the load is adjusted for the type of unbound material. It is wise to calculate applied stress in multiple locations within the layer so that the layer can be represented by the average of the locations.
5. Apply the regression constants to either the bulk stress or the deviatoric stress that was found in step 4 to obtain the resilient modulus at optimum.
6. Compare the results of the seed modulus with the modulus obtained in step 5, if the seed modulus and the regression modulus have an algebraic error greater than five percent, return to step 2 and use the regression modulus as the new seed modulus. Repeat these steps until the algebraic error is less than five percent.

The Lister and Powel model can be found in Equation 3.3 for granular material and Equation 3.4 for fine grained material.

$$M_{Ropt} = k_1 \theta^{k_2} \quad \text{..........}(3.3)$$

Where:

k_1 and k_2 are regression constants

Ɵ is the bulk stress or the first stress invariant for coarse grain soil

$$M_{Ropt} = k_1 \sigma_d^{-k_2} \quad \text{..........}(3.4)$$

Where:

σ_d is the deviatoric stress $(\sigma_d = \sigma_1 - \sigma_3)$ for fine grained soils

The overburden stress from the pavement structure can be calculated by using either Equation 3.5 or Equation 3.6 depending on the regression model that is used. If Equation 3.3 is then Equation 3.5 will be used to calculate the overburden stress for the unbound material. On the other hand, if Equation 3.4 is used then Equation 3.6 will be used to calculate the overburden stress. Both Equation 3.4 and 4.5 are versions of the equation that are shown in Huang's book (Huang 2004). The deviation between the Huang's equation can are shown in Equation 3.6. Huang subtracts the twice the confining pressure or σ_3 and in Equation 3.6 the vertical stress or σ_1 is reduced by half. Regardless of the equation chosen, the unit weight of the material is required. The unit weight of the soil was obtained from the SPS-1 compaction data and the unit weight of asphalt was assumed to equal 150-lb/ft^3.

$$\theta_{overburden} = \gamma z(1 + 2K_o) \quad \text{.......}(3.5)$$

Where:

γ is the unit weight of the material (lb/in^3)

z is the depth of interest in inches

K_o is the coefficient of lateral earth pressure, assumed to be 0.5

$$\theta_{d_{overburden}} = \gamma z(1 - K_o) \quad \text{.......}(3.6)$$

After determining the equations to use to find the unbound resilient modulus at optimum within the pavement structure, Equation 3.3 and 3.4 can be fitted to the soil data in the SPS-1 sections. Of the SPS-1 sections, six SPS-1 section were selected from six various states. The six states selected include: Texas, New Mexico, Arizona, Nevada, Montana, and Louisiana. These six states were also used in determining the coefficient of variation and project variance associated with the P_{200}, PI, dry maximum unit weight, and the optimum moisture content. In Figures 3.9 through 3.18 are the resilient modulus at optimum correlations to either the bulk stress or the deviatoric stress for the soils that were identified within the six SPS-1 sections. In Table 3.17 is the summary of the regression constants from the figures that will be used in determining the resilient modulus at optimum for the SPS-1 sections. The regression k_1 constant in Table 3.17 was changed from ksi to psi units, which is then used to determine the backcalculated resilient modulus at optimum.

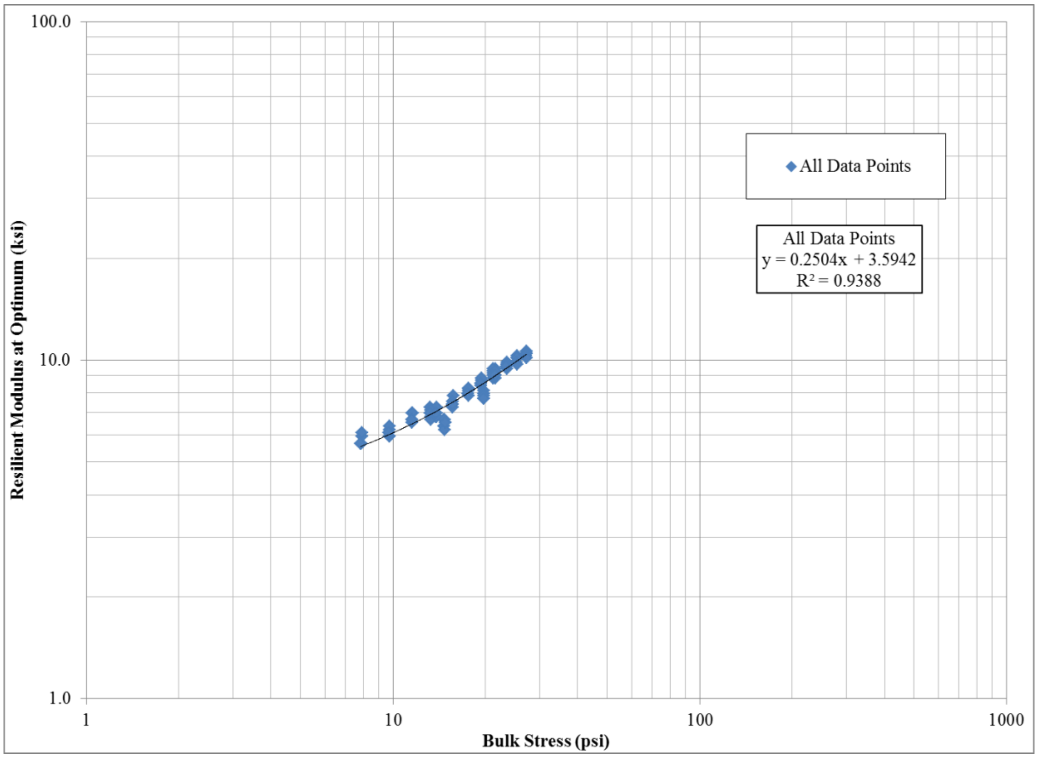

Figure 3.9: Texas A-3 resilient modulus soil correlation.

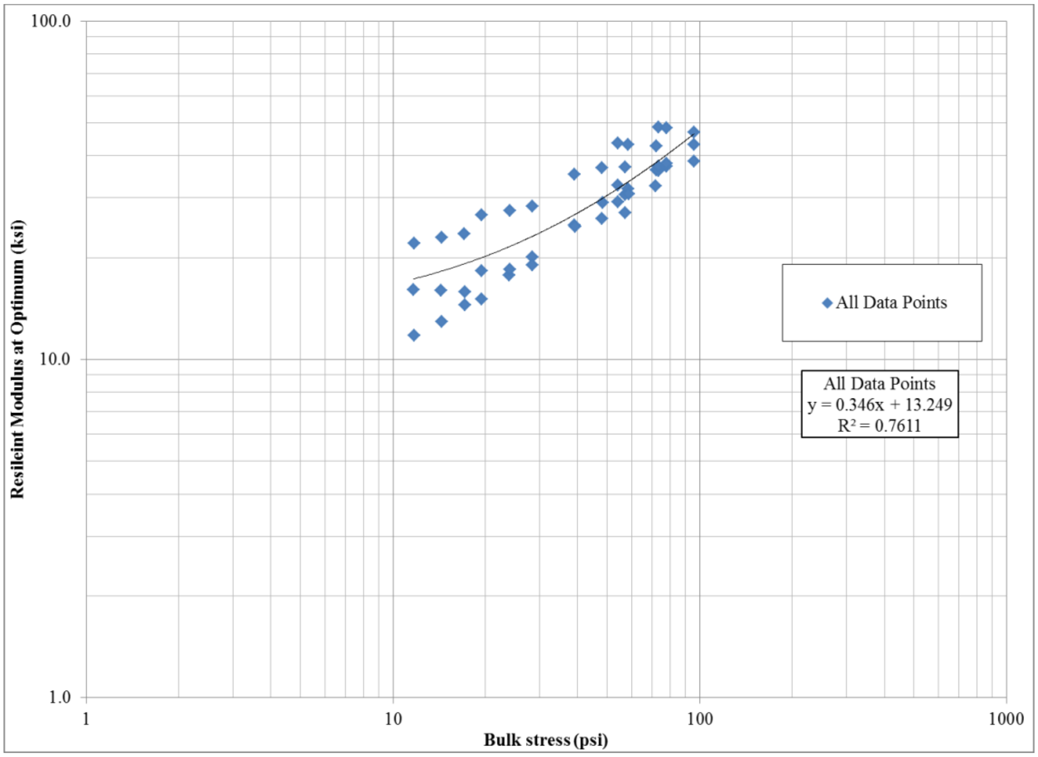

Figure 3.10: Nevada A-2-6 resilient modulus correlation.

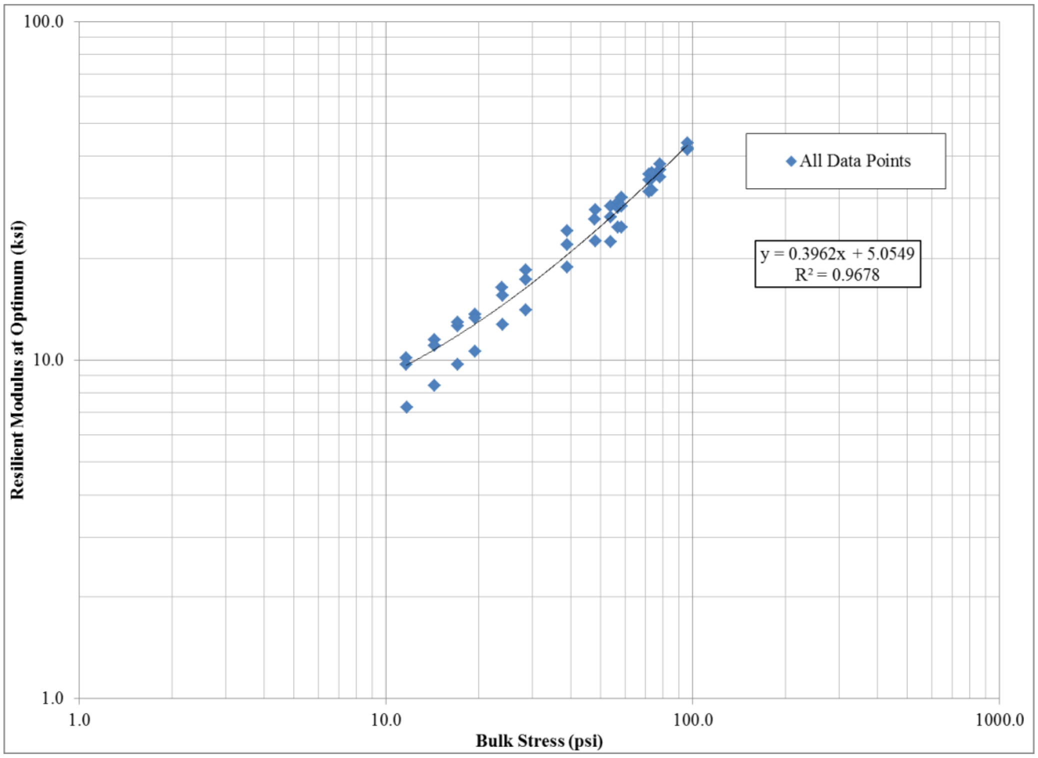

Figure 3.11: Montana A-1-a resilient modulus soil correlation.

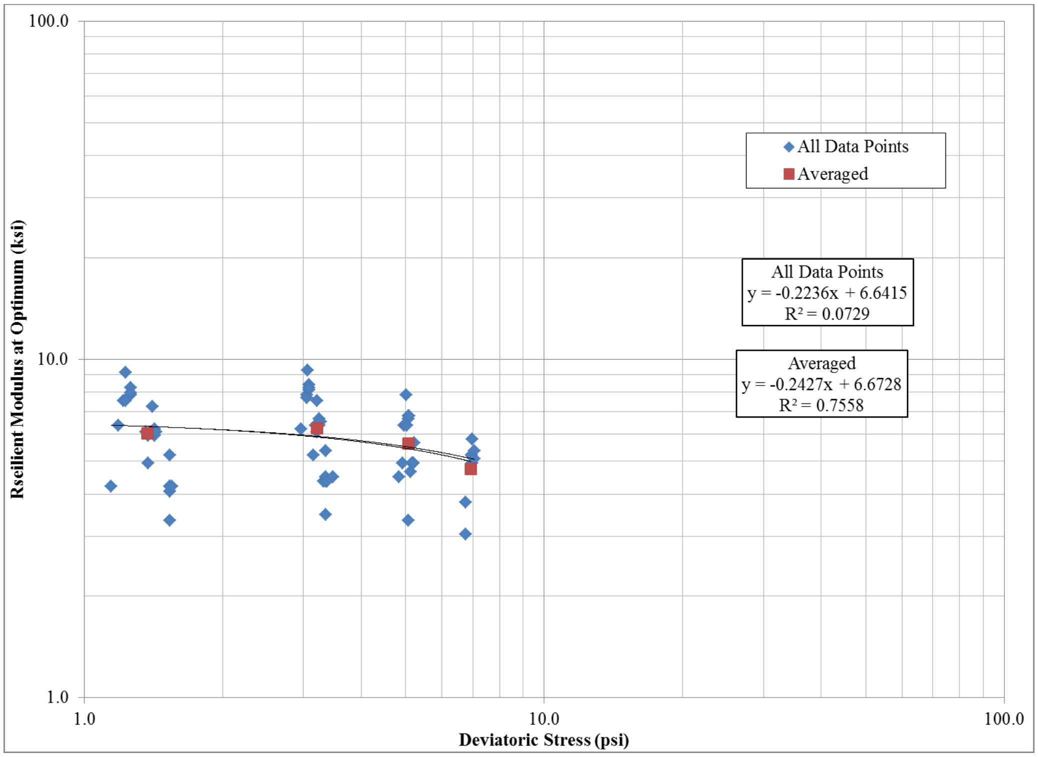

Figure 3.12: Montana A-2-4 resilient modulus soil correlation.

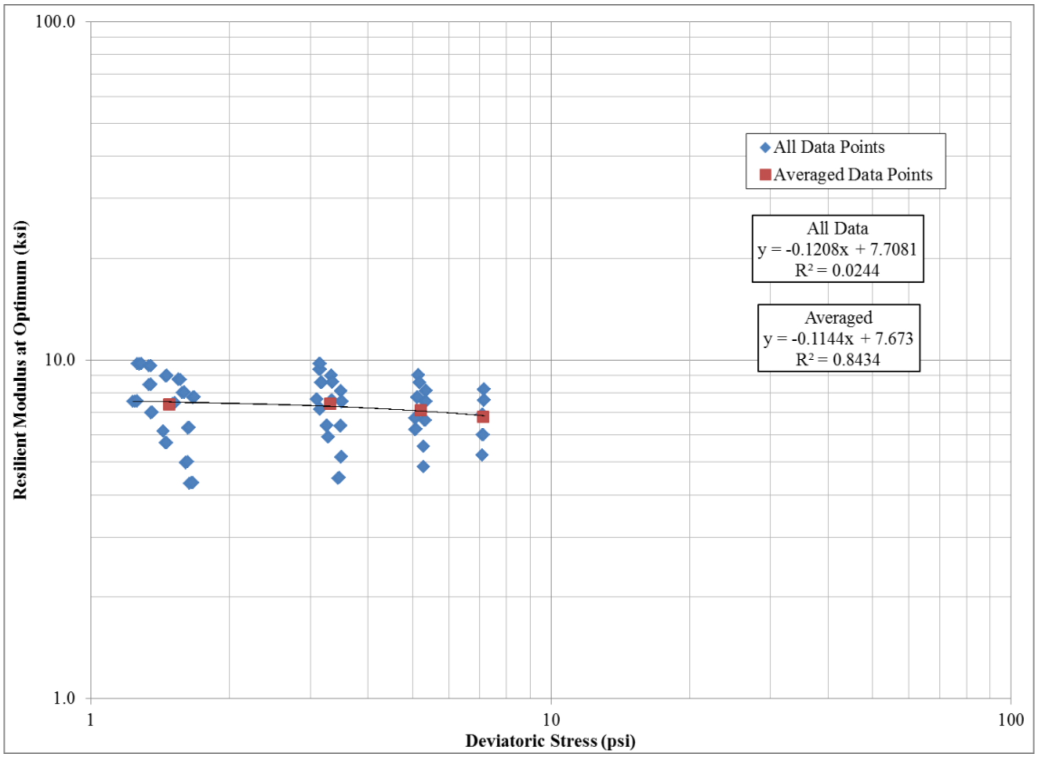

Figure 3.13: Louisiana A-4 resilient modulus soil correlation.

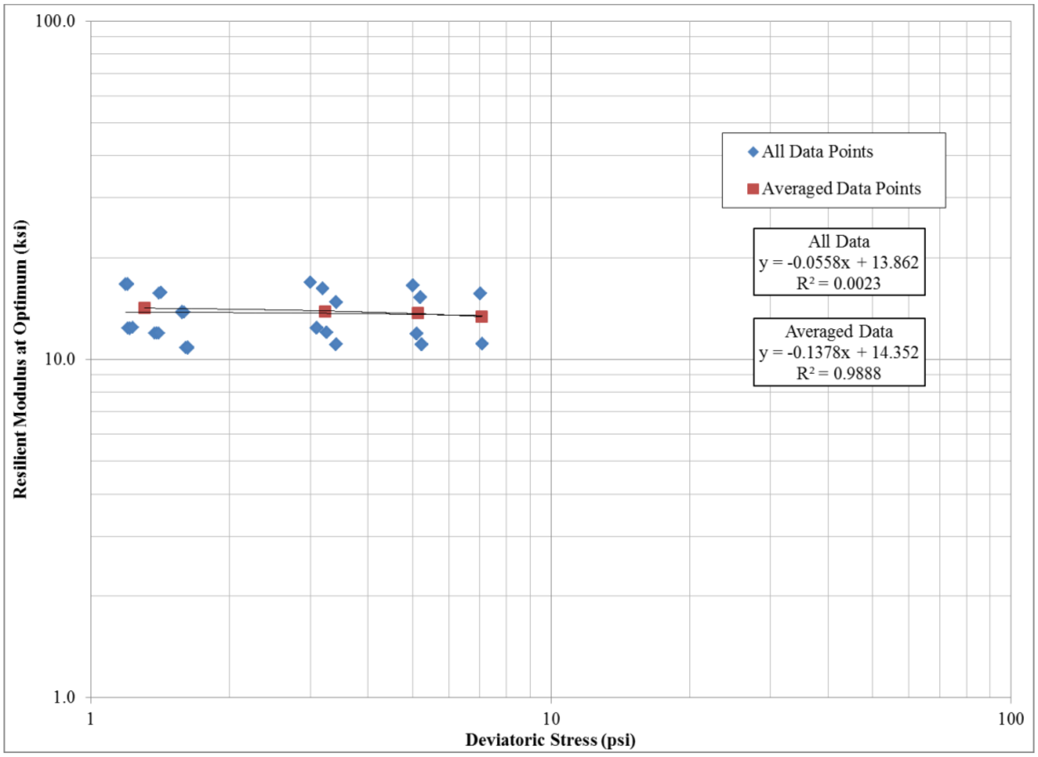

Figure 3.14: Louisiana A-6 resilient modulus soil correlation.

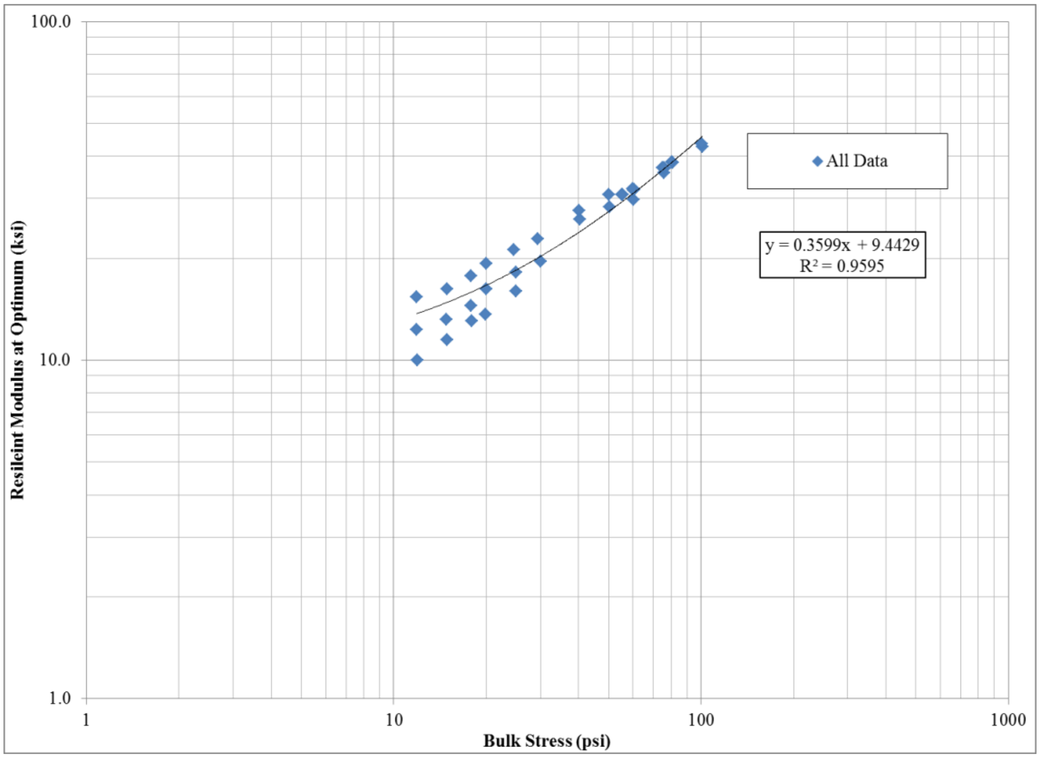

Figure 3.15: Arizona A-1-a resilient modulus soil correlation.

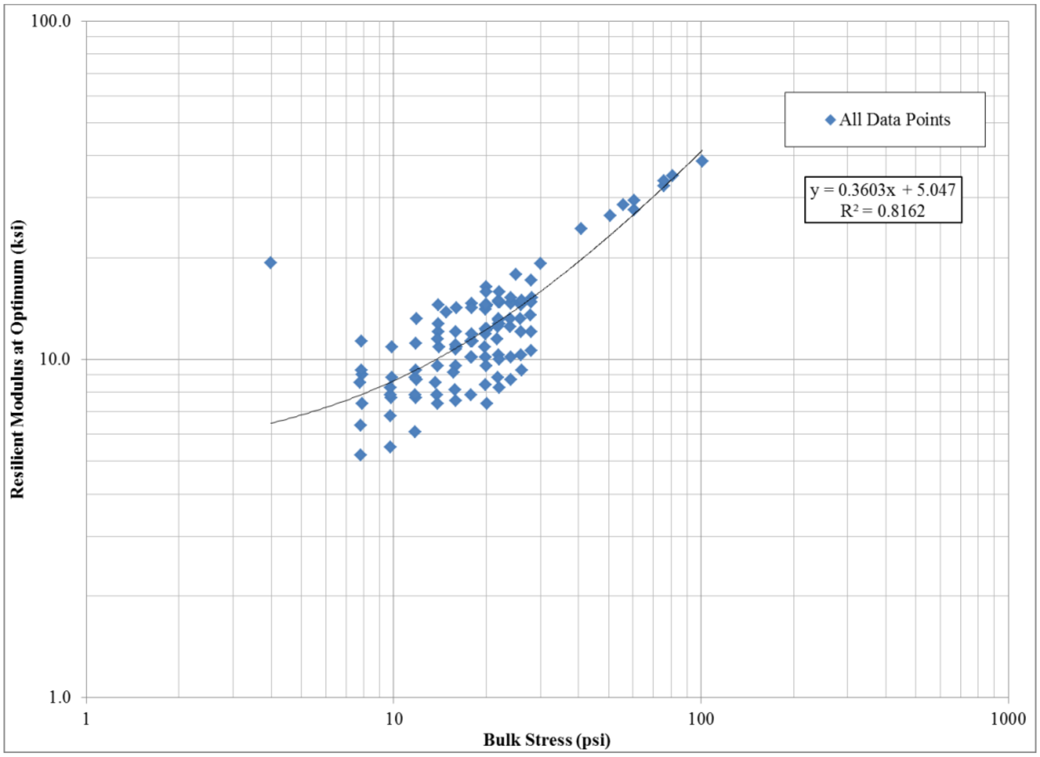

Figure 3.16: Arizona A-1-b resilient modulus soil correlations.

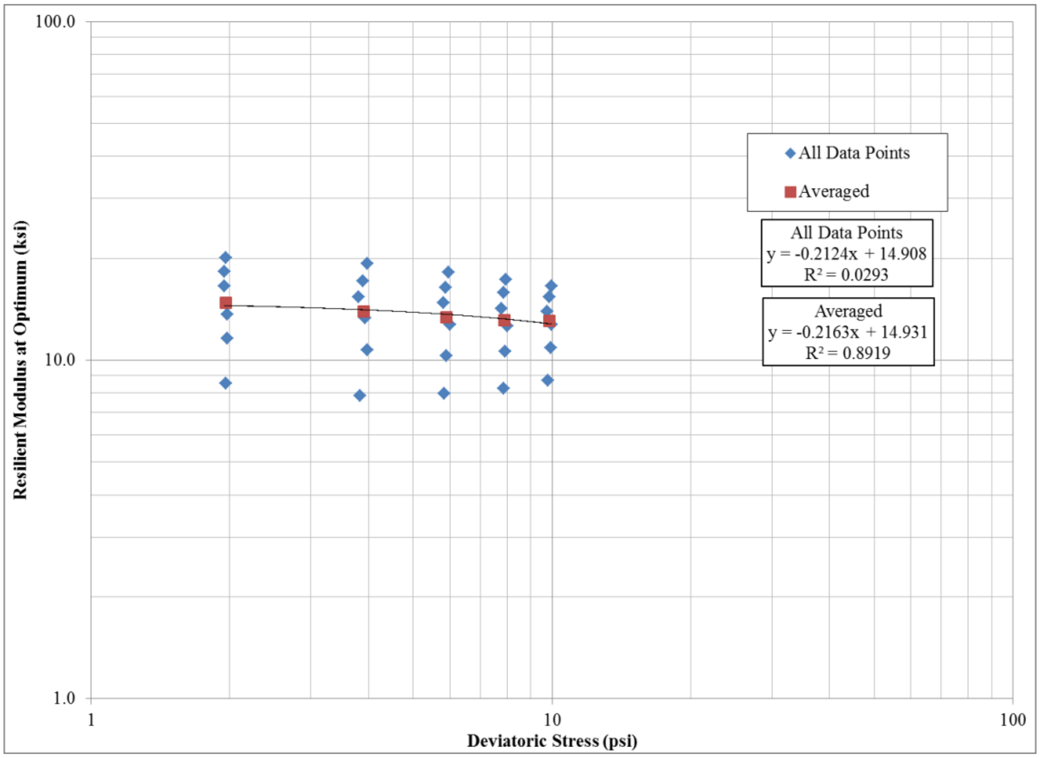

Figure 3.17: Arizona A-2-4 resilient modulus soil correlation.

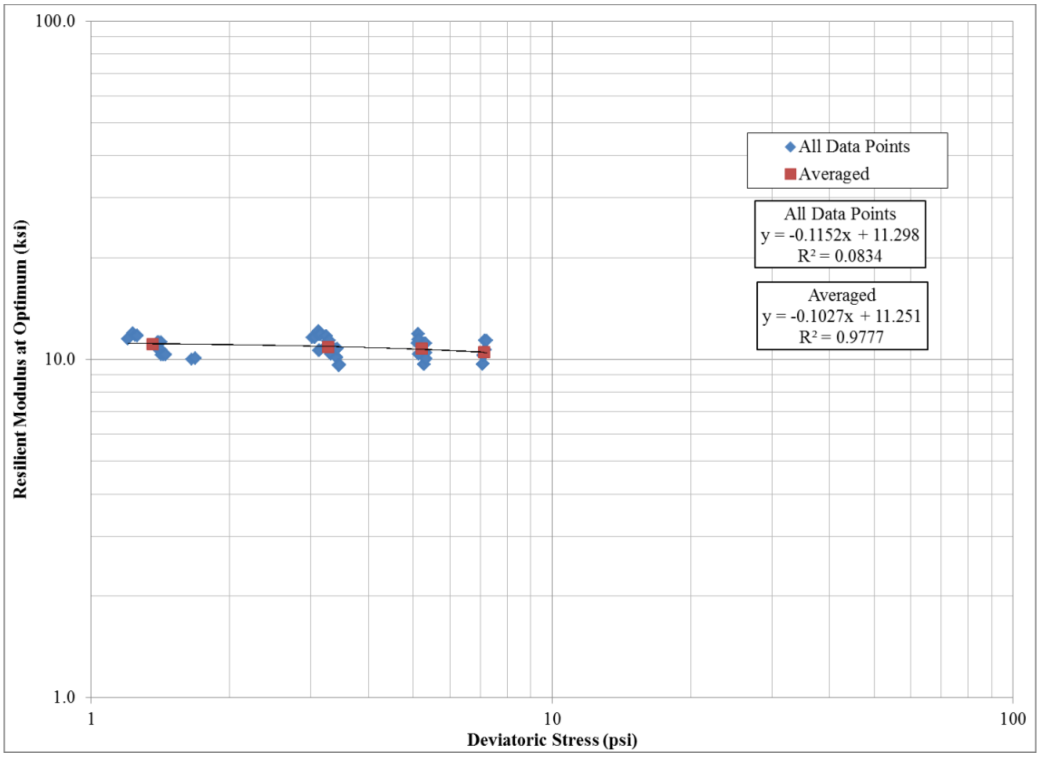

Figure 3.18: New Mexico A-7-6 resilient modulus soil correlation.

Table 3.17: Regression Constants for the Resilient Modulus at Optimum by SPS-1 Sections.

State	Soil	k_1	k_2
Texas	A-3	3594.2	0.250
Nevada	A-2-6	13249.4	0.346
Montana	A-1-a	6198.1	0.396
Montana	A-2-4	7804.0	-0.409
Louisiana	A-4	7673.0	-0.114
Louisiana	A-6	14351.7	-0.138
Arizona	A-1-a	9818.6	0.335
Arizona	A-1-b	4726.7	0.369
Arizona	A-2-4	14930.9	-0.216
New Mexico	A-7-6	11251.0	-0.103

Using the regression constants in Table 3.17, the iteration steps, listed above, with the pavement cross-sections in Figure 3.19 through Figure 3.27 the resilient modulus at optimum for the given layers can be determined. The modulus of the material in the pavement cross-section was either assumed or computed using the regression model. The assumptions include the asphalt layer, any treated layer, and layers that did not have regression constants to determine the soil resilient moduli. The asphalt layer in the pavement structure will have a modulus of 100,000-psi and any treated material will use a modulus of 50,000-psi. When the pavement cross-section has an unbound material that does not have the regression constants defined, it will use a set modulus that will not change during the iteration steps that corresponds to the layer type. The pavement cross-section thickness can be found in Table 3.18 and Table 3.19.

AC Layer	E = 100,000 psi h = thickness from LTPP
Subgrade Layer	E = Regression Model

Figure 3.19: Typical cross-section for AZ 0162.

AC Layer	E = 100,000 psi h = thickness from LTPP
Granular Base Layer	E = Regression Model h = thickness from LTPP
Subgrade Layer	E = Regression Model

Figure 3.20: Typical cross-section for AZ 0113, 0114, 0161, 01243 and MT 0113.

AC Layer	E = 100,000 psi h = thickness from LTPP
Treated Base	E = 50,000 psi h = thickness from LTPP
Subgrade Layer	E = Regression Model

Figure 3.21: Typical cross-section for AZ 0114, 0115, and MT 0113.

AC Layer	E = 100,000 psi h = thickness from LTPP
Granular Base Layer	E = Regression Model h = thickness from LTPP
Treated Subbase	E = 50,000 psi h = thickness from LTPP
Subgrade Layer	E = Regression Model

Figure 3.22: Typical cross-section for TX 0113, 0116.

AC Layer	E = 100,000 psi h = thickness from LTPP
Treated Base	E = 50,000 psi h = thickness from LTPP
Treated Subbase	E = 50,000 psi h = thickness from LTPP
Subgrade Layer	E = Regression Model

Figure 3.23: Typical cross-section for NM 0103.

AC Layer	E = 100,000 psi h = thickness from LTPP
Treated Base	E = 50,000 psi h = thickness from LTPP
Granular Base Layer	E = Regression Model h = thickness from LTPP
Subgrade Layer	E = Regression Model

Figure 3.24:Typical cross-section for AZ 0118, 0119, 0120, 0121 and MT 0119, 0120.

AC Layer	E = 100,000 psi h = thickness from LTPP
Treated Base	E = 50,000 psi h = thickness from LTPP
Granular Base Layer	E = Regression Model h = thickness from LTPP
Treated Subbase	E = 50,000 psi h = thickness from LTPP
Subbase Layer	E = Regression Model h = thickness from LTPP
Subgrade Layer	E = Regression Model

Figure 3.25: Typical cross-section for LA 0113, 0117, 0119, 0121 and NV 0104.

AC Layer	E = 100,000 psi h = thickness from LTPP
Treated Base	E = 50,000 psi h = thickness from LTPP
Granular Base Layer	E = Regression Model h = thickness from LTPP
Treated Subbase	E = 50,000 psi h = thickness from LTPP
Subgrade Layer	E = Regression Model

Figure 3.26: Typical cross-section for NM 0105, 0107.

AC Layer	E = 100,000 psi h = thickness from LTPP
Treated Base	E = 50,000 psi h = thickness from LTPP
Granular Base Layer	E = Regression Model h = thickness from LTPP
Subbase Layer	E = Regression Model h = thickness from LTPP
Treated Subbase	E = 50,000 psi h = thickness from LTPP
Subgrade Layer	E = Regression Model

Figure 3.27: Typical cross-section for NV 0102, 0109.

Table 3.18: SPS-1 Pavement Cross-Section Thickness.

State	SHRP ID	Layer	Type	Thick	State	SHRP ID	Layer	Type	Thick
Montana	0113	1	SS		New Mexico	0103	1	SS	
	0113	2	GB	8.4		0103	2	TS	6.0
	0113	3	AC	5.6		0103	3	TB	7.2
	0116	1	SS			0103	4	AC	5.3
	0116	2	TB	12.8		0105	1	SS	
	0116	3	AC	4.8		0105	2	TS	6.0
	0117	1	SS			0105	3	GB	3.7
	0117	2	GB	4.7		0105	4	TB	4.0
	0117	3	TB	4.6		0105	5	AC	5.9
	0117	4	AC	7.4		0107	1	SS	
	0119	1	SS			0107	2	TS	6.0
	0119	2	GB	4.3		0107	3	GB	4.0
	0119	3	TB	4.7		0107	4	TB	3.7
	0119	4	AC	7.8		0107	5	AC	5.9
Texas	0113	1	SS		Nevada	0102	1	SS	
	0113	2	TS	24.0		0102	2	TS	12.0
	0113	3	GB	7.8		0102	3	GS	21.4
	0113	4	AC	6.1		0102	4	GB	11.7
	0164	1	SS			0102	5	AC	4.3
	0164	2	TS	24.0		0104	1	SS	
	0164	3	GB	9.4		0104	2	TS	12.0
	0164	3	AC	5.3		0104	3	GS	18.4
						0104	4	TB	12.4
						0104	5	AC	7.3
						0109	1	SS	
						0109	2	TS	12.0
						0109	3	GS	14.4
						0109	4	GB	12.1
						0109	5	TB	4.0
						0109	6	AC	7.0

Table 3.19: SPS-1 Pavement Cross-Section Thickness.

State	SHRP ID	Layer	Type	Thick	State	SHRP ID	Layer	Type	Thick
Louisiana	0113	1	SS		Arizona	0113	1	SS	
	0113	2	GS	12.0		0113	2	GB	7.5
	0113	3	TS	6.0		0113	3	AC	4.9
	0113	4	GB	8.1		0114	1	SS	
	0113	5	AC	4.9		0114	2	GB	12.0
	0117	1	SS			0114	3	AC	7.3
	0117	2	GS	12.0		0115	1	SS	
	0117	3	TS	6.0		0115	2	TB	8.5
	0117	4	GB	5.3		0115	3	AC	6.6
	0117	5	TB	3.9		0116	1	SS	
	0117	6	AC	7.0		0116	2	TB	12.1
	0118	1	SS			0116	3	AC	4.5
	0118	2	GS	18.0		0118	1	SS	
	0118	3	TS	6.0		0118	2	GB	4.1
	0118	4	GB	4.1		0118	3	TB	7.7
	0118	5	TB	7.0		0118	4	AC	4.4
	0118	6	AC	4.4		0119	1	SS	
	0119	1	SS			0119	2	GB	4.2
	0119	2	GS	12.6		0119	3	TB	4.5
	0119	3	TS	6.0		0119	4	AC	6.3
	0119	4	GB	4.4		0120	1	SS	
	0119	5	TB	3.7		0120	2	GB	7.6
	0119	6	AC	7.1		0120	3	TB	4.3
	0121	1	SS			0120	4	AC	4.5
	0121	2	GS	12.6		0121	1	SS	
	0121	3	TS	6.0		0121	2	GB	11.8
	0121	4	GB	13.2		0121	3	TB	4.2
	0121	5	TB	3.9		0121	4	AC	4.6
	0121	6	AC	4.3		0123	1	SS	
	0124	1	SS			0123	2	TB	11.7
	0124	2	GS	30.0		0123	3	AC	6.8
	0124	3	TS	6.0		0161	1	SS	
	0124	4	TB	3.6		0161	2	GB	3.8
	0124	5	TB	10.6		0161	3	AC	6.2
	0124	6	AC	7.2		0162	1	SS	
						0162	2	AC	9.0

The results of the resilient modulus for the pavement cross-sections are located in Table 3.20. In the table, the state, SHRP ID, the layer location, and the

AASTHO classification as well as the resilient modulus at optimum determined by using the iterations steps outline above.

Table 3.20: Results of the Resilient Modulus Backcalculation.

State	SHRP ID	Layer	Location	AASHTO	M_{ropt}
Montana	0113	2	B13	A-1-a	25682.52
Montana	0113	2	B13	A-1-a	25126.75
Montana	0117	2	B14	A-1-a	24645.07
Montana	0113	1	B7	A-2-4	12744.06
Montana	0116	1	B2	A-2-4	12972.64
Montana	0116	1	B8	A-2-4	12972.64
Montana	0117	1	B9	A-2-4	13018.94
Montana	0117	1	B3	A-2-4	13018.94
Montana	0119	1	B5	A-2-4	12975.14
Montana	0119	1	B11	A-2-4	12975.14
Arizona	0118	2	B312	A-1-a	29169.94
Arizona	0120	2	B316	A-1-a	29198.94
Arizona	0161	2	B319	A-1-a	34397.02
Arizona	0113	1	B317	A-1-b	13616.37
Arizona	0115	1	B303	A-1-b	12332.31
Arizona	0116	1	B310	A-1-b	12007.4
Arizona	0119	1	B307	A-1-b	12156.15
Arizona	0119	2	B308	A-1-b	14925.52
Arizona	0121	1	B314	A-1-b	11751.49
Arizona	0123	1	B306	A-1-b	11559.08
Arizona	0162	1	B320	A-1-b	14049.19
Arizona	0114	1	B309	A-2-4	19818.26
Arizona	0121	1	BA263	A-2-4	19245.23
Nevada	0102	1	B9	A-2-6	30928.3
Nevada	0104	1	BA261	A-2-6	30847.4
Nevada	0109	1	BA265	A-2-6	30907.2
Texas	0113	1	B7	A-3	5812.37
Texas	0164	1	B6	A-3	5791.12
Louisiana	0113	1	B6	A-6	16327
Louisiana	0117	1	B5	A-6	16492
Louisiana	0118	2	B10	A-4	9479
Louisiana	0119	2	B7	A-4	9367
Louisiana	0121	2	B8	A-4	9490
Louisiana	0124	2	B9	A-4	9794
New Mexico	0103	1	B2	A-7-6	12587.75
New Mexico	0105	1	B3	A-7-6	12479.4
New Mexico	0107	1	B4	A-7-6	12479.4

With the backcalculated resilient modulus at optimum determined, the mean, variance, pooled variance, and the coefficient of variation can be determined for the SPS-1 section. In Table 3.21 are the results of the statistical analysis for the backcalculated resilient modulus at optimum. However, it needs to be determined if a pooled variance or an average coefficient of variation can be used for any mean resilient modulus at optimum. In Figures 3.28 and 3.29 is the comparison of the coefficient of variation or the pooled project variance with mean resilient modulus at optimum respectively. As one can see in both figures, there is no correlation between the mean resilient modulus at optimum and the coefficient of variation or the pooled project variance; therefore the pooled project variance and coefficient of variation shown in Table 3.21 is valid to use with any mean resilient modulus at optimum value.

Table 3.21: Statistical Analysis of the Backcalculated Resilient Modulus at Optimum.

State	AASHTO	Average	Variance	CV
Montana	A-1-a	25151	269533	2.06%
Montana	A-2-4	12954	9016	0.73%
Arizona	A-1-a	30922	9057207	9.73%
Arizona	A-1-b	12800	1520788	9.63%
Arizona	A-2-4	19532	164182	2.07%
Nevada	A-2-6	30894	1761	0.14%
Texas	A-3	5802	226	0.26%
Louisiana	A-6	16410	13613	0.71%
Louisiana	A-4	9533	33480	1.92%
New Mexico	A-7-6	12516	3913	0.50%
	σ^2_{pooled}		**1,097,885**	
	σ_{pooled}		**1,047.80**	
	$CV_{average}$		**2.777%**	

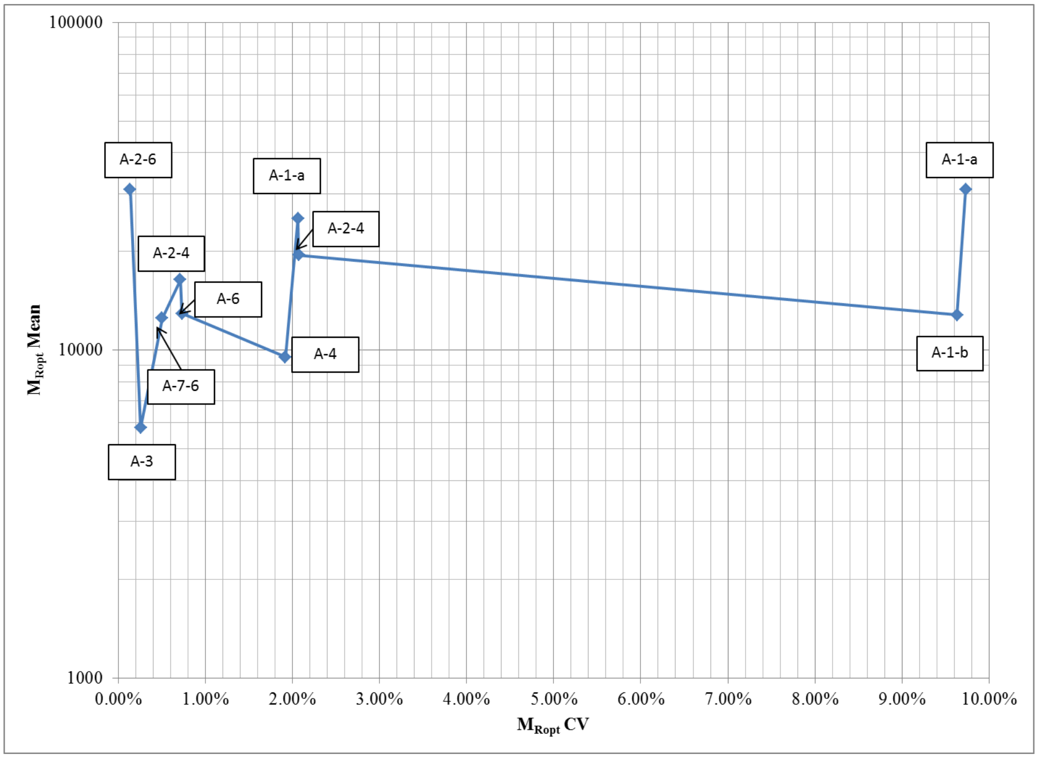

Figure 3.28: Comparison of the CV and the modulus at optimum.

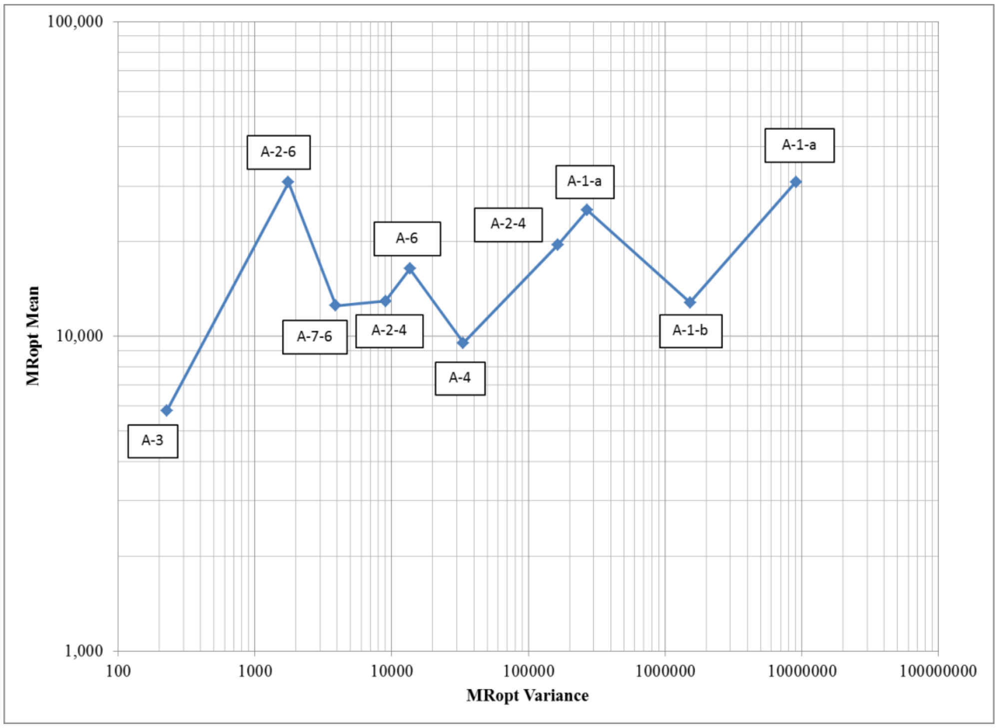

Figure 3.29: Comparison of the variance and the modulus at optimum.

3.3.4 Obtaining Level 1 Parameters

As stated earlier in 4.3.1, Level 1 data requires the following test to be performed to insure the proper calculations to be performed by the analytical program:

1. Sieve Analysis from AASHTO T27 "Sieve Analysis of Fine and Coarse Aggregates"
2. Specific Gravity from user input normally obtained from ASTM D854 "Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer"
3. Atterberg Limits from AASHTO T90 "Determining the Plastic Limit and Plasticity of Soils" and AASHTO T89 "Determining the Liquid Limit of Soils."
4. Compaction from AASHTO T99 "Moisture-Density Relations of Soils Using a 5.5-lb Rammer and a 12-in Drop"
5. Soil Water Characteristic Curve Testing using ASTM D6836 "Standard Test Methods for Determination of the Soil Water Characteristic Curve for Desorption Using Hanging Column, Pressure Extractor, Chilled Mirror Hygrometer, or Centrifuge" and/or ASTM D5298 "Stand Test Method for Measurement of Soil Potential (Suction) Using Filter Paper"
6. Resilient Modulus at Optimum Testing using either NCHRP 1-28A "Harmonized Test Methods for Laboratory Determination of Resilient Modulus for Flexible Pavement Design" or AASHTO T307 "Determining the Resilient Modulus of Soil and Aggregate Materials"

3.4 Hierarchical Level 3A

3.4.1 Description and Differences of Level 3 and Level 3A

In The EICM, the user has two options; 1) use the EICM soil defaults for the sieve analysis and Atterberg Limits, which are then used to make correlation between compaction, the soil water characteristic curve, and the resilient modulus at optimum and 2) complete some of the soil testing and still use the default values of the database for information that was not tested or the user does not know. For Level 3A, the user will be able to choose form the AASHTO classification system. If the user knows AASHTO classification and does not know the properties of the soil, the user is able to select the appropriate AASHTO classification. By allowing the user to choose the AASHTO classification, it gives the user an opportunity to decrease the amount of variance when compared with Level 3B.

3.4.2 Data Collection

The data used to create the parameters associated with the AASHTO soil classification was obtained from the general data in the LTPP DataPave database as well as the NCHRP 9-23A database. The NCHRP 9-23A database was obtained from Gustavo Torres Hernandez, which was sorted by AASHTO classification (Torres Hernandez, 2011, FHWA 2010, Zapata 2011). After collecting the data from both databases, the data was sorted and grouped by AASHTO classification.

3.4.3 Statistical Analysis

In Table 3.22 through 3.33 are the AASHTO soil properties. In the tables, each variable will show how many soils were used from the databases, the mean value, variance, standard deviation, skewness, kurtosis, the minimum value, the maximum value, and the two shape factors, alpha and beta. The skewness and kurtosis is reported to show if the data obtained from the two databases follow a normal distribution. Recall from Chapter 2, if the skewness is negative then the distribution is skewed left and if the skewness is positive then the distribution is skewed right. The kurtosis of the data will show if the distribution platykurtic or leptokurtic. If the distribution is platykurtic the distribution shape is broader than a normal distribution or if the distribution is leptokurtic the distribution shape is narrower than a normal distribution. By knowing the skewness and kurtosis of the variables, it informs the user of the most appropriate stochastic procedure to use.

Table 3.22: A-1-a Soil Properties.

	$P_{2.0"}$	$P_{1.5"}$	$P_{1.0"}$	$P_{0.5"}$	$P_{\#40}$	$P_{\#60}$	$P_{\#200}$	PI	G_s	D_{60}	wPI
#	1213	1213	1213	1213	2175	2175	2175	2175	489	1271	2175
μ	97.9	96.0	90.91	71.34	19.6	15.5	8.72	0.75	2.702	9.15	0.08
σ^2	43.8	80.5	144.40	188.82	38.72	26.05	14.14	2.19	0.01	42.34	0.03
σ	6.62	8.97	12.02	13.74	6.22	5.10	3.76	1.48	0.11	6.51	0.17
CV (%)	6.8	9.3	13.2	19.3	31.7	32.9	43.1	195	4.0	71.1	206.4
a	30.0	28.0	25.0	8.0	0.0	0.0	0.0	0.0	2.243	2.4	0.000
b	100	100	100	99.0	30.0	25.9	15.0	6.0	3.152	72.2	0.894
$E[X^3]$	-5.3	-3.7	-2.2	-0.9	-0.5	-0.4	-0.1	1.9	0.3	4.4	2.2
$E[X^4]$	35.2	17.5	6.3	2.0	-0.1	-0.2	-0.7	2.5	2.6	29.7	4.4
α	2.19	2.22	2.767	5.762	2.786	3.104	1.671	0.103	8.55	0.882	0.120
β	0.07	0.13	0.381	2.517	1.478	2.085	1.204	0.713	8.40	8.205	1.168

Table 3.23: A-1-b Soil Properties.

	$P_{2.0"}$	$P_{1.5"}$	$P_{1.0"}$	$P_{0.5"}$	$P_{\#40}$	$P_{\#60}$	$P_{\#200}$	**PI**	G_s	D_{60}	**wPI**
#	1033	1033	1033	1033	2610	2610	2610	2610	472	1939	2610
μ	99.1	98.1	95.1	83.99	35.50	28.51	16.52	1.492	2.661	2.824	0.308
σ^2	7.17	13.39	32.90	80.26	59.61	46.47	39.35	3.59	0.01	4.70	0.17
σ	2.68	3.66	5.74	8.96	7.72	6.82	6.27	1.89	0.10	2.17	0.41
CV	2.7	3.7	6.0	10.7	21.8	23.9	38.0	127	3.7	76.8	132
a	74.0	73.0	69.0	57.0	7.5	5.6	0.2	0.0	2.243	0.6	0.000
b	100.0	100.0	100.0	100.0	50.0	44.2	25.0	6.0	3.025	13.9	1.500
$E[X^3]$	-4.3	-2.7	-1.4	-0.2	0.1	-0.2	-0.4	0.9	-0.3	1.6	1.1
$E[X^4]$	22.8	8.8	1.4	-0.5	-0.5	-0.3	-0.8	-0.6	2.2	3.0	-0.1
α	2.114	2.330	2.425	2.752	3.828	3.996	1.656	0.218	7.882	0.725	0.247
β	0.077	0.173	0.454	1.632	1.983	2.738	0.861	0.658	6.848	3.553	0.955

Table 3.24: A-2-4 Soil Properties.

	$P_{2.0"}$	$P_{1.5"}$	$P_{1.0"}$	$P_{0.5"}$	$P_{\#40}$	$P_{\#60}$	$P_{\#200}$	**PI**	G_s	D_{60}	**wPI**
#	1683	1683	1683	1683	4218	4218	4218	4218	691	3282	4218
μ	99.5	99.1	98.0	93.9	56.08	46.03	26.7	4.24	2.677	1.34	1.16
σ^2	8.81	13.2	24.9	94.5	401	195.40	46.64	10.48	0.00	6.53	0.84
Σ	2.97	3.64	4.99	9.72	20.03	13.98	6.83	3.24	0.07	2.56	0.92
CV	3.0	3.7	5.1	10.4	35.7	30.4	25.6	76.4	2.6	191	78.9
a	54.0	44.0	36.0	31.0	8.0	6.6	2.8	0.0	2.445	0.1	0.000
B	100.0	100.0	100.0	100.0	99.0	98.3	35.4	10.0	2.975	54.9	3.500
$E[X^3]$	-9.3	-7.7	-4.9	-2.2	0.3	0.3	-0.8	0.3	0.4	6.9	0.5
$E[X^4]$	102.9	74.4	33.2	5.3	-0.7	-0.1	-0.2	-1.1	2.0	89.6	-0.7
α	1.540	2.514	3.884	2.794	2.190	4.105	2.537	0.563	5.816	0.204	0.742
β	0.017	0.039	0.126	0.271	1.955	5.443	0.925	0.767	7.469	8.900	1.495

Table 3.25: A-2-5 Soil Properties.

	P$_{2.0"}$	**P$_{1.5"}$**	**P$_{1.0"}$**	**P$_{0.5"}$**	**P$_{\#40}$**	**P$_{\#60}$**	**P$_{\#200}$**	**PI**	**G$_s$**	**D$_{60}$**	**wPI**
#	561	561	561	561	1219	1219	1219	1219	5	1186	1219
μ	100	100	99.9	99.8	69.0	55.0	22.06	0.075	2.835	0.431	0.021
σ^2	0.00	0.00	0.50	3.07	189.9	85.85	39.76	0.39	0.00	0.34	0.03
σ	0.00	0.00	0.71	1.75	13.78	9.27	6.31	0.62	0.05	0.58	0.18
CV	0.0	0.0	0.7	1.8	20.0	16.8	28.6	828	1.8	135	848
a	100	100	92.0	81.0	30.0	27.8	10.5	0.0	2.781	0.2	0.000
b	100	100	100.0	100.0	97.5	74.8	35.0	10.0	2.877	4.8	3.250
$E[X^3]$	0.0	0.0	-10.8	-10.5	-0.1	-0.1	0.2	10.4	-0.6	6.3	10.7
$E[X^4]$	0.0	0.0	116.9	109.0	-0.3	-0.5	-0.8	128.7	-3.3	42.4	138.3
α	1.00	1.00	0.052	0.018	2.805	3.063	1.303	0.007	-0.049	0.141	0.007
β	1.00	1.00	4E-4	2E-4	2.045	2.229	1.459	0.911	-0.037	2.285	1.134

Table 3.26: A-2-6 Soil Properties.

	P$_{2.0"}$	**P$_{1.5"}$**	**P$_{1.0"}$**	**P$_{0.5"}$**	**P$_{\#40}$**	**P$_{\#60}$**	**P$_{\#200}$**	**PI**	**G$_s$**	**D$_{60}$**	**wPI**
#	209	209	209	209	729	729	729	729	77	330	729
μ	99.6	98.4	95.6	85.2	41.1	36.16	26.99	14.15	2.653	3.003	3.839
σ^2	2.76	11.29	36.79	173.7	256.9	139.46	44.63	6.42	0.00	12.41	1.60
σ	1.66	3.36	6.07	13.18	16.03	11.81	6.68	2.53	0.05	3.52	1.26
CV	1.7	3.4	6.3	15.5	39.0	32.7	24.8	17.9	2.0	117	32.9
a	90.0	78.0	67.0	45.0	10.0	9.3	2.8	10.5	2.507	0.1	0.448
b	100	100	100.0	100.0	99.0	78.8	35.4	25.0	2.780	19.4	8.073
$E[X^3]$	-4.4	-3.2	-1.7	-0.8	1.5	1.0	-0.9	1.1	-0.3	1.9	0.4
$E[X^4]$	20.2	11.9	2.8	-0.2	2.5	1.8	0.4	0.7	0.7	3.8	0.6
α	0.532	1.784	2.101	1.774	2.098	2.798	2.641	1.301	2.998	0.411	3.552
β	0.025	0.142	0.324	0.655	3.910	4.434	0.919	3.867	2.592	2.355	4.435

Table 3.27: A-2-7 Soil Properties.

	$P_{2.0''}$	$P_{1.5''}$	$P_{1.0''}$	$P_{0.5''}$	$P_{\#40}$	$P_{\#60}$	$P_{\#200}$	PI	G_s	D_{60}	wPI
#	28	28	28	28	174	174	174	174	1	46	174
μ	96.8	94.9	89.25	76.89	35.7	33.4	28.4	24.66	2.767	5.758	7.026
σ^2	22.54	43.83	124	254	52.08	40.91	31.21	47.11	N/A	23.36	6.28
σ	4.75	6.62	11.12	15.95	7.22	6.40	5.59	6.86	N/A	4.83	2.51
CV	4.9	7.0	12.5	20.7	20.2	19.2	19.6	27.8	N/A	83.9	35.7
a	86.0	82.0	70.0	50.0	15.0	13.2	8.6	12.5	2.767	0.4	1.892
b	100	100.0	100.0	100.0	60.0	51.0	35.3	50.0	2.767	18.4	16.95
$E[X^3]$	-1.1	-0.9	-0.8	-0.4	-0.4	-0.9	-1.4	1.2	N/A	1.7	1.0
$E[X^4]$	-0.4	-1.1	-1.0	-0.8	1.5	1.6	1.9	2.2	N/A	2.2	2.1
α	0.414	0.363	0.433	0.776	3.976	4.111	2.499	1.796	1.0	0.559	2.427
β	0.123	0.145	0.242	0.666	4.680	3.599	0.865	3.744	1.0	1.320	4.693

Table 3.28: A-3 Soil Properties.

	$P_{2.0''}$	$P_{1.5''}$	$P_{1.0''}$	$P_{0.5''}$	$P_{\#40}$	$P_{\#60}$	$P_{\#200}$	PI	G_s	D_{60}	wPI
#	508	508	508	508	689	689	689	689	92	689	689
μ	99.96	99.90	99.68	98.94	75.40	50.67	6.75	0.0	2.665	0.351	0.0
σ^2	0.31	0.61	1.70	8.66	237.25	200.87	5.41	0.0	0.00	0.03	0.0
σ	0.56	0.78	1.30	2.94	15.40	14.17	2.33	0.0	0.06	0.17	0.0
CV	0.6	0.8	1.3	3.0	20.4	28.0	34.5	0.0	0.02	49.2	0.0
a	88.0	85.0	84.0	75.0	51.0	22.0	0.3	0.0	2.445	0.1	0.0
b	100.0	100.0	100.0	100.0	100.0	96.2	10.4	0.0	2.884	2.0	0.0
$E[X^3]$	-19.7	-14.7	-6.9	-4.7	-0.1	0.1	-0.5	0.0	0.05	3.5	0.0
$E[X^4]$	413.1	263.0	61.0	27.0	-1.5	-0.8	-0.4	0.0	1.51	25.3	0.0
α	0.498	1.478	1.888	1.860	0.762	2.122	2.141	1.0	5.28	1.393	0.0
β	0.002	0.010	0.038	0.083	0.768	3.372	1.214	1.0	5.25	10.130	0.0

Table 3.29: A-4 Soil Properties.

	$P_{2.0"}$	$P_{1.5"}$	$P_{1.0"}$	$P_{0.5"}$	$P_{\#40}$	$P_{\#60}$	$P_{\#200}$	PI	G_s	D_{60}	wPI
#	1211				11002				465	11002	
μ	99.6	99.4	98.6	95.96	78.46	73.00	60.17	5.99	2.677	0.30	3.704
σ^2	2.81	3.98	8.30	32.4	215	215	295	7.96	0.00	0.51	4.85
σ	1.68	1.99	2.88	5.69	14.65	14.67	17.18	2.82	0.07	0.71	2.20
CV	1.7	2.0	2.9	5.9	18.7	20.1	28.6	47.1	0.03	239	59.5
a	86.0	83.0	79.0	64.0	36.0	36.0	35.5	0.0	2.494	0.0	0.00
b	100	100	100	100	100	99.3	99.0	10.0	2.935	10.8	9.76
$E[X^3]$	-5.9	-5.1	-3.4	-2.2	-0.4	-0.1	0.5	-0.2	0.11	5.5	0.5
$E[X^4]$	39.2	30.0	14.1	5.9	-0.9	-1.0	-0.9	-0.9	1.48	40.9	-0.4
α	0.851	1.406	2.131	2.648	2.170	2.054	0.872	1.208	3.58	0.141	1.375
β	0.024	0.051	0.151	0.335		1.458	1.373	0.809	5.05	4.967	2.248

Table 3.30: A-5 Soil Properties.

	$P_{2.0"}$	$P_{1.5"}$	$P_{1.0"}$	$P_{0.5"}$	$P_{\#40}$	$P_{\#60}$	$P_{\#200}$	PI	G_s	D_{60}	wPI
#	31	31	31	31	332	332	332	332	14	330	332
μ	99.5	99.1	98.1	94.8	78.3	71.5	55.23	2.054	2.749	0.260	1.302
σ^2	2.92	8.69	17.66	48.47	184	179	278	8.42	0.00	0.26	3.68
σ	1.71	2.95	4.20	6.96	13.6	13.38	16.68	2.90	0.07	0.51	1.92
CV	1.7	3.0	4.3	7.3	17.3	18.7	30.2	141	0.03	195	147
a	92.0	87.0	81.0	69.0	40.0	39.3	36.3	0.0	2.620	0.0	0.000
b	100	100	100	100	100	99.3	97.5	10.0	2.869	4.8	9.250
$E[X^3]$	-3.6	-3.4	-3.1	-2.2	-0.4	0.1	0.8	1.3	0.16	5.5	1.7
$E[X^4]$	13.0	10.9	9.9	5.7	-0.5	-0.7	-0.6	0.6	0.17	39.6	2.6
α	0.300	0.239	0.781	1.460	2.251	2.145	0.580	0.193	1.13	0.181	0.255
β	0.021	0.018	0.089	0.292	1.273	1.852	1.295	0.746	1.05	3.223	1.555

Table 3.31: A-6 Soil Properties.

	$P_{2.0"}$	$P_{1.5"}$	$P_{1.0"}$	$P_{0.5"}$	$P_{\#40}$	$P_{\#60}$	$P_{\#200}$	PI	G_s	D_{60}	wPI
#	926	926	926	926	6860	6860	6860	6860	251	6740	6860
μ	99.83	99.59	99.06	97.26	84.69	79.94	69.06	14.81	2.686	0.171	10.29
σ^2	0.89	1.94	4.81	19.0	167	178	269	8.83	0.00	0.32	11.50
σ	0.94	1.39	2.19	4.36	12.92	13.35	16.39	2.97	0.06	0.57	3.39
CV	0.9	1.4	2.2	4.5	15.3	16.7	23.7	20.1	0.02	331	33.0
a	91.0	89.0	85.0	71.0	37.5	37.5	35.6	10.5	2.507	0.0	3.885
b	100	100	100	100	100	99.4	98.2	29.0	3.089	8.8	24.36
$E[X^3]$	-6.7	-4.5	-3.4	-2.4	-1.2	-0.8	-0.1	1.0	0.57	6.4	0.6
$E[X^4]$	46.5	22.7	13.2	5.9	0.9	0.0	-1.0	0.8	7.12	47.4	0.1
α	0.636	1.181	1.627	2.519	2.512	2.490	1.406	1.383	5.54	0.067	2.137
β	0.012	0.045	0.108	0.262	0.815	1.141	1.225	4.550	12.47	3.445	4.703

Table 3.32: A-7-5 Soil Properties.

	$P_{2.0"}$	$P_{1.5"}$	$P_{1.0"}$	$P_{0.5"}$	$P_{\#40}$	$P_{\#60}$	$P_{\#200}$	PI	G_s	D_{60}	wPI
#	58	58	58	58	683	683	683	683	17	487	683
μ	99.2	98.8	98.2	96.4	91.2	88.83	83.37	28.92	2.666	0.08	24.60
σ^2	15.41	25.29	37.47	53.15	109	122	176	83.33	0.00	0.17	95.71
σ	3.93	5.03	6.12	7.29	10.44	11.05	13.26	9.13	0.07	0.41	9.78
CV	4.0	5.1	6.2	7.6	11.5	12.4	15.9	31.6	0.03	517	39.8
a	79.0	73.0	67.0	63.0	40.0	39.3	37.0	10.5	2.605	0.0	5.52
b	100	100	100	100	100	100	100	55.0	2.875	4.8	52.25
$E[X^3]$	-5.0	-4.9	-4.8	-3.5	-2.3	-1.9	-1.2	0.1	1.95	9.5	0.2
$E[X^4]$	24.1	24.1	23.0	14.2	5.8	4.0	1.0	-0.8	4.13	101.5	-1.0
α	0.080	0.173	0.504	1.128	2.688	2.887	2.490	1.973	0.36	0.018	1.842
β	0.003	0.008	0.030	0.121	0.465	0.650	0.893	2.792	1.23	1.109	2.670

Table 3.33: A-7-6 Soil Properties.

	$P_{2.0"}$	$P_{1.5"}$	$P_{1.0"}$	$P_{0.5"}$	$P_{\#40}$	$P_{\#60}$	$P_{\#200}$	PI	G_s	D_{60}	wPI
#	618	618	618	618	4935	4935	4935	4935	141	4617	4935
μ	99.6	99.2	98.7	97.3	88.75	86.18	80.09	28.496	2.676	0.086	23.06
σ^2	3.81	7.91	14.75	31.46	138	146	193	63.06	0.00	0.20	69.70
σ	1.95	2.81	3.84	5.61	11.75	12.09	13.88	7.94	0.06	0.44	8.35
CV	2.0	2.8	3.9	5.8	13.2	14.0	17.3	27.9	0.02	516	36.2
a	83.0	75.0	70.0	66.0	40.0	39.3	36.4	14.0	2.550	0.0	6.630
b	100	100	100	100	100	99.4	99.0	75.0	2.884	8.7	66.24
$E[X^3]$	-5.7	-4.9	-4.1	-3.2	-1.8	-1.5	-1.0	1.1	0.26	9.6	0.9
$E[X^4]$	35.0	27.0	19.0	10.9	3.0	2.2	0.5	1.7	-0.15	112.3	1.1
α	0.776	1.322	1.459	1.525	2.415	2.533	2.295	2.303	2.25	0.026	2.529
β	0.019	0.042	0.066	0.130	0.557	0.714	0.993	7.387	3.69	2.686	6.649

3.4.4 Obtaining Level 3A Parameters

Level 3A parameters are determined by the user. The user will know or select the AASHTO classification of the soil located in the project site.

3.5 Hierarchical Level 3B

3.5.1 Description and Differences of Level 3 and Level 3B

In The EICM, the user has two options; 1) use the EICM soil defaults for the sieve analysis and Atterberg Limits, which are then used to make correlation between compaction, the soil water characteristic curve, and the resilient modulus at optimum and 2) complete some of the soil testing and still use the default values of the database for information that was not tested or the user does not know. For Level 3B, the user will be able to choose from general classifications. For the general classification, the user only knows if the soil that is used in design is either a unbound granular material or a unbound fine grained material. This level will produce the highest level of variability for a given pavement structure.

3.5.2 Data Collection

After the AASHTO soil classification was determined for Level 3A, the soils were then grouped together to form a general classification. Level 3B uses the same soil databases, which includes the general LTPP DataPave database and the NCHRP 9-23A soils database.

3.5.3 Statistical Analysis

The user is able to choose from the following soil classifications: granular base material, granular subbase and subgrade material, fine grained soils. Within the fine grained soils category, the user can choose from three classifications, which includes the fine grained soils, “clayey” fine grained soils and “silty” fine grained soils.

The granular base material is a grouping of the A-l-a and the A-l-b soils from Level 3A. The granular subbase and subgrade material is a grouping of all of A-1’s, A-2’s, and A-3 soil classification. The A-1’s were added to this grouping since the A-1 soils can be found naturally occurring the field as subgrade soils and A-1 soils are also used for subbases in some instances.

The fine grained soils include all the A-4, A-5, A-6, and A-7’s soils. By AASHTO classification any soil with a P_{200} greater than 35 percent falls within this range; therefore, this grouping is valid. The “clayey” fine grained soils use the A-6 and the A-7 groups since these two groups are primarily clayey soils. On the other hand, the “silty” fine grained soils use the A-4 and A-5 grouping since these two soil groups are primarily composed of more silt than clays. However, with the “silty” fine grained soils group, the A-4 soils govern the shape of the distributions of the gradation as well as the Atterberg Limits due to the number of A-4 soils compared to the A-5 soils. In Table 3.34 through 3.38 are the soil properties for the granular base material, granular subbase and subgrade material, fine grained material, “clayey” fine grained material, and “silty” fine grained material respectively. In these tables, one can find the number of soils used in the statistical analysis, the mean value, the variance, standard deviation, the coefficient of variation, skewness, kurtosis, the minimum value, the maximum value, and the two shape factors alpha and beta for the parameters that are needed in the calculation of the resilient modulus at equilibrium.

Table 3.34: Granular Base Material Soil Properties.

	$P_{2.0"}$	$P_{1.5"}$	$P_{1.0"}$	$P_{0.5"}$	$P_{\#40}$	$P_{\#60}$	$P_{\#200}$	PI	G_s	D_{60}	wPI
#	2272				4785				961	3210	4785
μ	98.5	97.0	92.9	77.4	28.3	22.59	12.97	1.159	2.682	5.330	0.206
σ^2	27.0	50.24	96.9	182	1123	79.2	42.98	3.08	0.01	29.18	0.12
σ	5.20	7.09	9.85	13.51	10.62	8.90	6.56	1.76	0.10	5.40	0.34
CV	5.3	7.3	10.6	17.4	37.6	39.4	50.5	152	0.04	101	166
a	30.0	28.0	25.0	8.0	0.0	0.0	0.0	0.0	2.243	0.6	0.00
b	100	100	100	100	50.0	44.2	25.0	6.0	3.152	72.2	1.50
$E[X^3]$	-6.4	-4.5	-2.6	-0.9	0.1	0.1	0.3	1.2	0.07	4.3	1.7
$E[X^4]$	53.8	27.7	10.1	2.0	-0.5	-0.6	-1.0	0.2	2.53	34.7	1.9
α	2.827	2.943	3.584	5.728	2.515	2.640	1.365	0.158	8.57	0.657	0.176
β	0.063	0.126	0.373	1.863	1.933	2.525	1.265	0.661	9.19	9.241	1.103

Table 3.35: Granular Subbase and Subgrade Material Soil Properties.

	$P_{2.0"}$	$P_{1.5"}$	$P_{1.0"}$	$P_{0.5"}$	$P_{\#40}$	$P_{\#60}$	$P_{\#200}$	PI	G_s	D_{60}	wPI
#	3062	3062	3062	3062	7029	7029	7029	7029	866	5533	7029
μ	99.7	99.4	98.4	95.2	58.16	46.70	24.00	4.632	2.675	1.158	1.272
σ^2	5.41	8.96	19.82	85.62	420	197	76.38	33.30	0.00	5.47	2.77
σ	2.33	2.99	4.45	9.25	20.49	14.03	8.74	5.77	0.07	2.34	1.66
CV	2.3	3.0	4.5	9.7	35.2	30.0	36.4	125	0.03	202	131
a	54.0	44.0	36.0	31.0	8.0	6.6	0.3	0.0	2.445	0.1	0.00
b	100	100	100	100	100	98.3	35.4	50.0	2.975	54.9	16.95
$E[X^3]$	-11.2	-8.5	-5.0	-2.6	0.1	0.2	-0.7	1.9	0.41	6.6	2.3
$E[X^4]$	155.8	96.1	35.4	7.1	-0.9	-0.4	-0.5	5.5	1.93	83.3	8.2
α	1.846	2.949	3.852	2.410	2.181	4.158	1.713	0.492	5.83	0.178	0.466
β	0.014	0.034	0.097	0.180	1.819	5.350	0.824	4.819	7.62	9.136	5.739

Table 3.36: Fine Grained Material Soil Properties.

	$P_{2.0"}$	$P_{1.5"}$	$P_{1.0"}$	$P_{0.5"}$	$P_{\#40}$	$P_{\#60}$	$P_{\#200}$	PI	G_s	D_{60}	wPI
#	11206				23814				888	23814	
μ	99.9	99.9	99.7	99.2	82.75	78.16	67.45	13.80	2.680	0.214	10.18
σ^2	0.78	1.38	2.84	9.64	201	218	330	104	0.00	0.39	83.61
σ	0.88	1.17	1.68	3.11	14.17	14.75	18.17	10.18	0.07	0.63	9.14
CV	0.9	1.2	1.7	3.1	17.1	18.9	26.9	73.7	0.02	292	89.8
a	79.0	73.0	67.0	63.0	10.0	36.0	35.5	0.0	2.494	0.0	0.000
b	100	100	100	100	100	100	100	75.0	3.089	10.8	66.24
$E[X^3]$	-14.1	-12.4	-9.2	-5.6	-0.9	-0.5	0.0	1.2	0.26	6.3	1.5
$E[X^4]$	237	198	115	39.4	-0.2	-0.7	-1.2	1.3	2.42	50.2	2.3
α	1.36	1.99	2.66	2.13	4.242	2.130	1.064	1.316	5.00	0.094	0.895
β	0.01	0.01	0.03	0.05	1.006	1.103	1.084	5.837	10.97	4.657	4.929

Table 3.37: “Clayey” Fine Grained Material Soil Properties.

	$\mathbf{P}_{2.0"}$	$\mathbf{P}_{1.5"}$	$\mathbf{P}_{1.0"}$	$\mathbf{P}_{0.5"}$	$\mathbf{P}_{\#40}$	$\mathbf{P}_{\#60}$	$\mathbf{P}_{\#200}$	**PI**	$\mathbf{G}_s$	$\mathbf{D}_{60}$	**wPI**
#	1604				12480				409	12480	
μ	99.7	99.4	98.9	97.3	86.65	82.89	74.21	21.0	2.682	0.134	16.12
σ^2	2.55	5.11	9.84	25.0	157	173	266	81.07	0.00	0.27	80.84
σ	1.60	2.26	3.14	5.00	12.54	13.17	16.32	9.00	0.06	0.52	8.99
CV	1.6	2.3	3.2	5.1	14.5	15.9	22.0	42.9	0.02	386	55.8
a	79.0	73.0	67.0	63.0	37.5	37.5	35.6	10.5	2.507	0.0	3.885
b	100	100	100	100	100	100	100	75.0	3.089	8.8	66.24
$E[X^3]$	-7.6	-6.3	-5.0	-3.0	-1.4	-1.0	-0.5	1.2	0.52	7.4	1.2
$E[X^4]$	69.3	51.3	32.2	11.0	1.6	0.6	-0.8	1.3	4.28	64.4	1.3
α	1.293	1.930	2.501	2.546	2.494	2.525	1.642	0.976	5.26	0.050	1.293
β	0.018	0.042	0.087	0.203	0.677	0.951	1.097	5.018	12.24	3.226	5.295

Table 3.38: “Silty” Fine Grained Material Soil Properties.

	$\mathbf{P}_{2.0"}$	$\mathbf{P}_{1.5"}$	$\mathbf{P}_{1.0"}$	$\mathbf{P}_{0.5"}$	$\mathbf{P}_{\#40}$	$\mathbf{P}_{\#60}$	$\mathbf{P}_{\#200}$	**PI**	$\mathbf{G}_s$	$\mathbf{D}_{60}$	**wPI**
#	4606				11334				479	11334	
μ	99.9	99.8	99.6	98.9	78.46	72.95	60.02	5.873	2.679	0.298	3.63
σ^2	0.79	1.17	2.68	12.11	214	214	295	8.41	0.01	0.50	4.98
σ	0.89	1.08	1.64	3.48	14.62	14.64	17.19	2.90	0.07	0.71	2.23
CV	0.9	1.1	1.6	3.5	18.6	20.1	28.6	49.4	0.03	238	61.4
a	86.0	83.0	79.0	64.0	10.0	36.0	35.5	0.0	2.494	0.0	0.00
b	100	100	100	100	100	99.3	99.0	10.0	2.935	10.8	9.76
$E[X^3]$	-11.5	-10.0	-6.9	-4.7	-0.4	-0.1	0.5	-0.2	0.12	5.6	0.5
$E[X^4]$	153	116	58	27.2	-0.8	-1.0	-0.9	-0.9	1.37	41.2	-0.4
α	0.851	1.321	1.870	2.098	4.491	2.066	0.863	1.105	3.52	0.142	1.292
β	0.006	0.013	0.034	0.066	1.413	1.470	1.372	0.776	4.88	5.032	2.178

3.5.4 Obtaining Level 3B Parameters

The Level 3B soil classification will be determined by using either visual classification or knowing the pedological series in the geographic region the site is located. The pedological series normally is known to the user from previous jobs that the user has completed or the information the user obtains from various websites.

3.6 Summary and Conclusions

In this chapter, the development of soil variability is discussed. Two engineering database were utilized to create the desired descriptive statistics for the three different hierarchical levels of soil selection used in the EICM. In addition to the two soil databases, work from Claudia Zapata's dissertation was discussed. From the soils databases and information from the dissertation work, the coefficients of variation and project pooled variance were developed for Level 1, which will be applied to the mean values obtained from testing. By applying either the coefficient of variation or project pooled variance to the mean value, it allows for the creation of the standard deviation, variance, the minimum value, the maximum value, and the alpha and beta shape factors that are needed either for the Monte Carlo simulation, Rosenblueth 2 or 3-Point estimation, or the First order Taylor Series expansion.

In addition to the development of Level 1 project pooled variance and coefficient of variation for the various testing procedures, the development of two new hierarchical levels, Level 3A and 3B were discussed. Level 3A uses

AASHTO classification to determine the mean and variance associated with the resilient modulus at equilibrium similarly to the defaults that the EICM has for the AASHTO classification. The difference between Level 3 and Level 3A, Level 3A includes a larger database that encompasses the entirety of the AASHTO classification instead using a mean value associated with the Atterberg Limits and the grain size distribution. On the other hand, if the user does not know the AASTHO classification, Level 3B is utilized. Level 3B allows the user to select from soil classification that would follow visual classification. The visual classification includes the granular and fine grained material.

Chapter 4

POSTULATION OF THE METHODOLOGIES FOR A STOCHASTIC EVALUATION

4.1 Introduction

The EICM uses multiple deterministic models to determine the modulus at equilibrium. By using the deterministic models, it only evaluates the mean value of the independent variable. The deterministic models used in the EICM give the foundation to build upon and add uncertainty to the models by using stochastic variables. The stochastic variables give the ability to incorporate reliability into the resilient modulus at equilibrium. To incorporate stochastic variables into the models and ultimately give the design resilient modulus at equilibrium reliability, it requires a stochastic treatment of the deterministic models. This is accomplished by using one of the four methodologies: First order Taylor Series expansion, Rosenblueth 2-Point estimation, Rosenblueth 3-Point estimation, and a Monte Carlo simulation. Each of these methodologies relies upon different descriptive statistics, which include: the mean, variance, standard deviation, minimum value, maximum value, and shape factor parameters of the independent variable.

4.2 Objectives

- Graphically depict and explain the flow of the EICM.
- Develop an analysis program that is capable of analyzing the different methodologies and provide a solution in a reasonable amount of time.

- Mathematically explain the stochastic evaluation of the four different methodologies.
- Complete a quantitative analysis of the four methodologies and compare the results of the four methodologies using only one climatic region, one soil type and, all three hierarchical levels.

4.3 Flow of the EICM

4.3.1 General Flow of the EICM

The general flow of the EICM is the most important aspect when trying to postulate the stochastic evaluation of the unbound resilient moduli at equilibrium. The general flow of the EICM starts with input from the user, which includes the hierarchical level, the climatic location, and basic and advanced geotechnical properties, which the geotechnical properties will be derived from actual project testing or subsets to the different models of the EICM. After the user chooses the location and either inputs the geotechnical properties or derived from the subsets of the different models, the EICM will follow the general flow diagram shown in Figure 4.1.

Although the flow diagram, in Figure 4.1, shows the conceptual steps that are required to calculate the unbound resilient moduli at equilibrium, regardless of the climatic location, it does not reflect the impact of the hierarchical levels. The differentiation of the general flow diagram that reflects the impact of the hierarchal level will be shown in the following subsection. Regardless, of the hierarchal level, the flow diagram will always require historical climatic conditions of the project site.

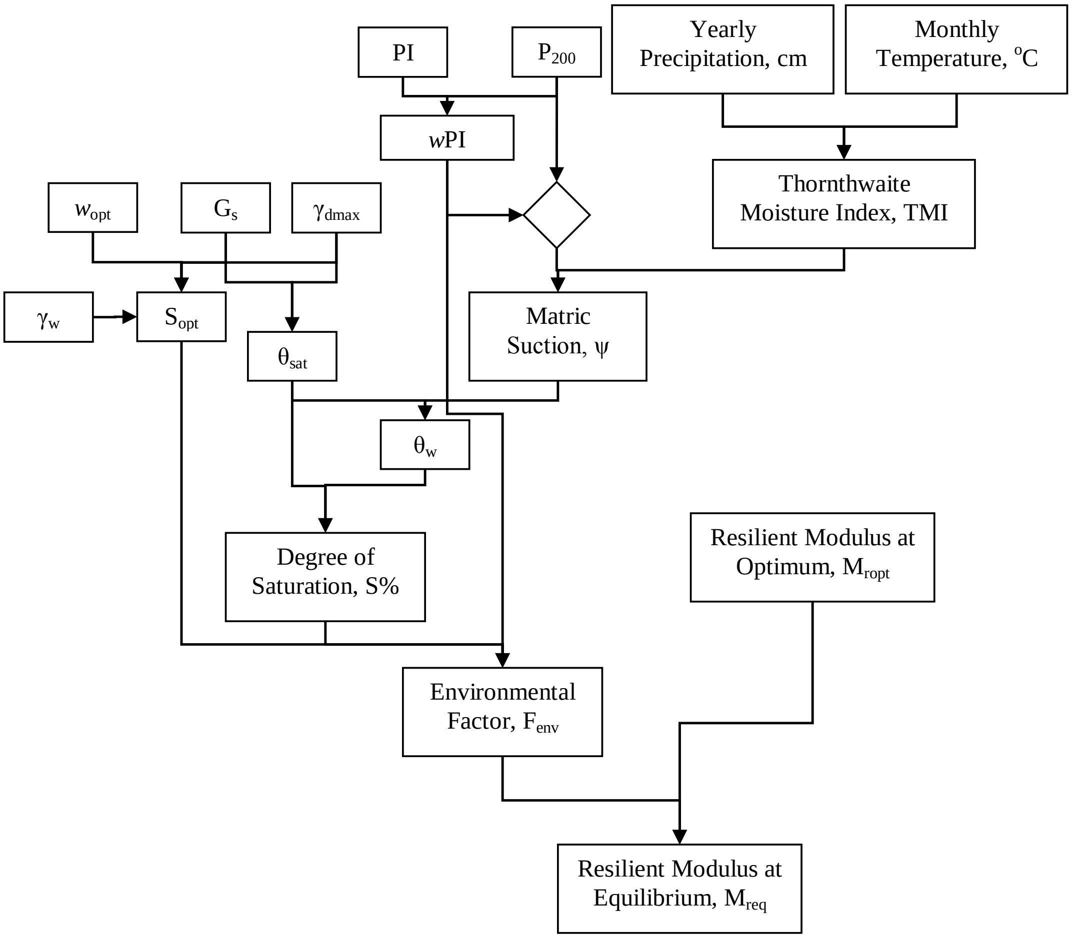

Figure 4.1: General Flow of the EICM.

4.3.2 Hierarchical Level Flow

The hierarchical levels require various geotechnical inputs, which ranges from advanced geotechnical laboratory testing, to basic geotechnical laboratory testing, to engineering assumptions and/or data from engineering databases. Out of the three levels, Level 1 will have the lowest variability; the variability in Level 1 is due to the project site and the precision of the laboratory testing of the laboratory technician. Level 2 will have a higher variability than Level 1 due to the variability in the soil located in the project site, the precision of the laboratory testing, and the variability due to predictive model. Finally, Level 3 will have the highest variability out of the three levels since Level 3 is uses values from large engineering databases, which has high variability associated with it and variability due to the predictive models, which the variability of the predictive models is due to the R^2 of the prediction versus the actual value.

4.3.2.1 Level 1Flow diagram

Level 1 will have a similar flow as the general flow diagram. The general flow diagram, in Figure 4.1, is the true flow for Level 1 of the hierarchical level.

4.3.2.2 Level 2 and Level 3 Flow Diagram

Both Level 2 and Level 3 use the same flow diagram even though they are two different hierarchical levels. The only difference between Level 2 and Level 3 is the variability with the of the soil properties. Therefore, the flow diagrams for Level 2 and Level 3 will be sub-divided into two soil classifications plastic soils and non-plastic soils. Plastic soil in for are soils that have a PI greater than zero or a *w*PI greater than zero; Non-Plastic soils are soils that have a PI equal to zero or a *w*PI equal to zero, which is shown in Figure 4.2. However; with in the plastic sub-division, the EICM sub-divides the degree of saturation estimation into two sub-sets, which is dependent on the *w*PI of the soil. If the *w*PI of the soil is greater than zero but less than two, it will use a different model than the SWCC; if the *w*PI of the soil is greater than two it will use the SWCC regression correlations.

The SWCC is used to obtain the volumetric water content θ_w. The difference in models will be shown as an asterisk in Figure 4.3 and it will be covered in detailed later in the chapter.

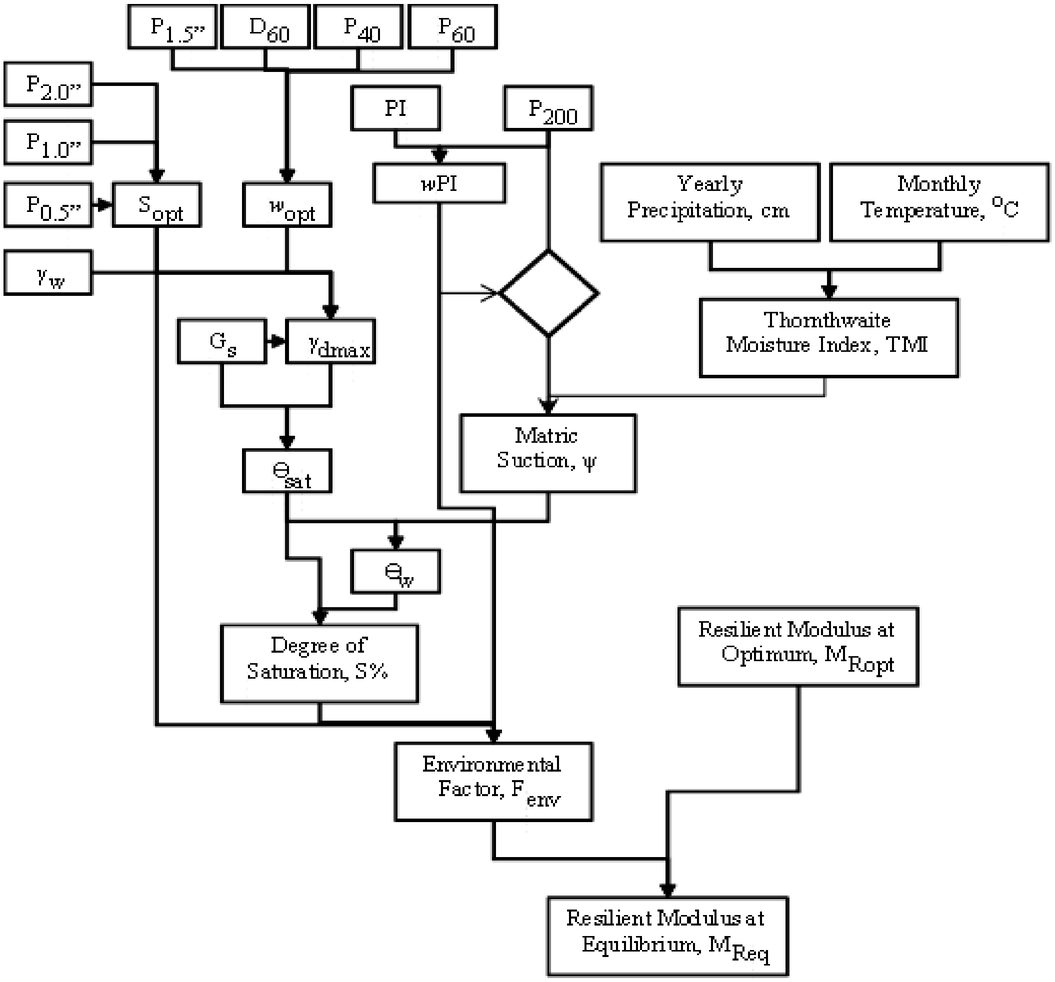

Figure 4.2: Level 2 and Level 3 non-plastic soil flow diagram.

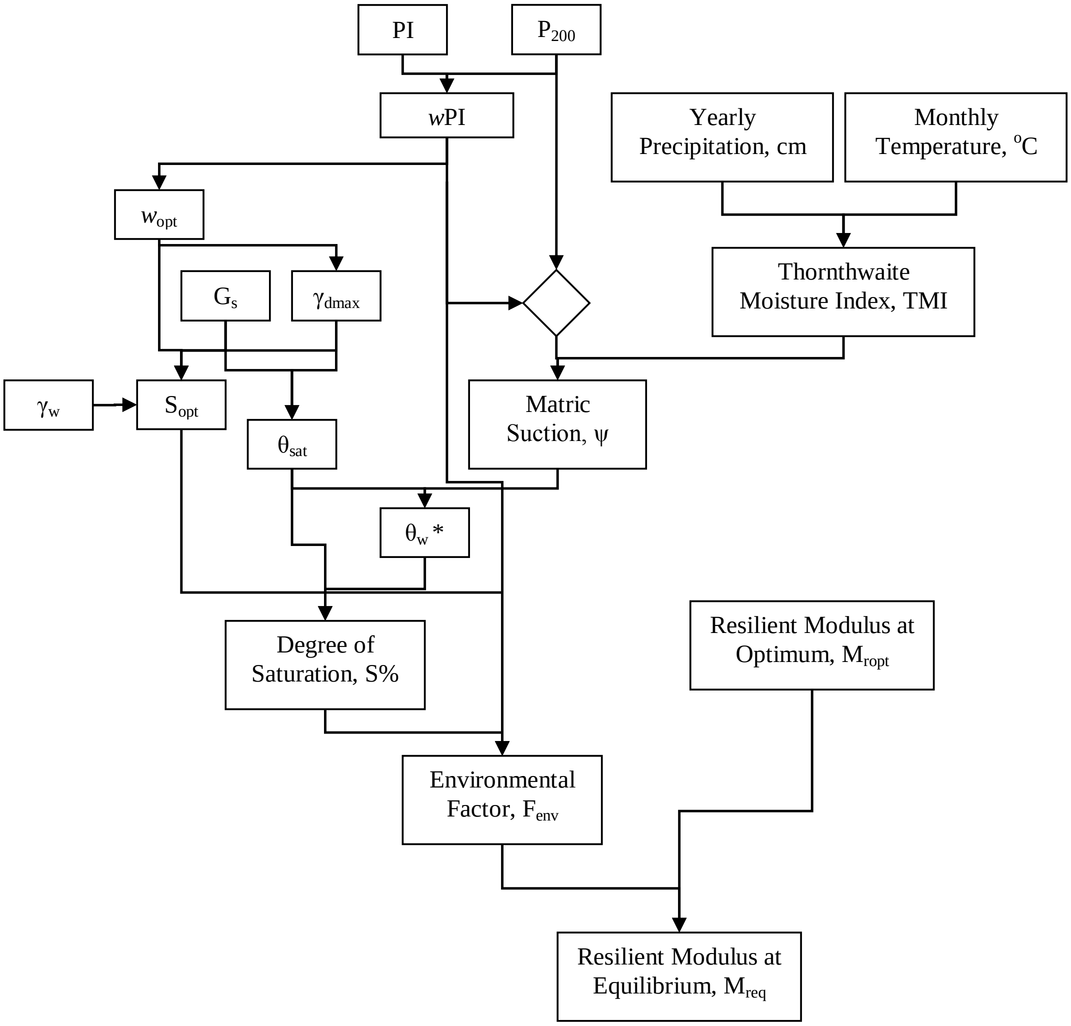

Figure 4.3: Level 2 and Level 3 plastic soil's flow diagram.

4.4 Development of the Analysis Program

There was a need to develop a statistical analysis program that was able to evaluate the stochastic solution of the resilient modulus at equilibrium. This program was first developed in Microsoft Excel © 2007; however, this program was lethargic and would crash when certain function were used. After finding out problems with the Microsoft Excel © 2007 workbook, the program was then coded in C++. Microsoft Visual C++ 2008 Express Edition was then used.

Nevertheless, there were some limitations encountered when coding the stochastic evaluation in C++. The default libraries of C++ do not include any statistical packages, which posed a problem when coding the Monte Carlo simulation in C++. This problem was adverted when a precompiled statistical library was found. The C++ computer code is located in Appendix A.

4.4.1 Acquisition of the Statistical Library for C++

The statistical library for the C++ program was obtained from GNU software, which is a free open source library. The software version that was used for the statistical analysis was gsl version 1.13. The outputs of the statistical analysis were validated with the original Microsoft Excel © workbook.

4.4.2 Computer Program Inputs

The C++ program requires inputs of the soil properties, climatic properties (monthly temperature and precipitation), and the daylight correction factor. The input for the program is obtained from text file with the name "Excel_Output_Data.txt". Table 4.1 shows the climatic properties that are needed to compute the TMI for the program. The soil properties required for the execution of the program are listed in Table 4.2. The properties in Table 4.2 were condensed to have all the soil properties on one page.

When looking at Table 4.1, the first row is the "Taylor_Series" this is where one of the four methodologies is selected. In this instance, the First Order Talyor Series expansion was chosen. To select the Rosenblueth 2 or 3 point estimation it will be either Rosenblueth_2 or Rosenblueth_3 respectively and it will replace the Taylor_Series in the first row. Finally, if one is selecting the Monte Carlo Simulation, Monte_Carlo and the number of simulations are needed in the first row. The next row is the 1-40D restraints, if yes is selected the restraints on TMI will be used which corresponds to capping the TMI value to 100. The third row, output_simulations, if yes is select, the program will output the simulations for each given run within its own given text file. The fourth row is the location, this shows the user when multiple simulations are completed which location was used to obtain the equilibrium moduli.

After the first four rows, the next twelve rows correspond to the historical monthly precipitation for the given site. Within the historical monthly precipitation row, the following descriptive statistics are required: the mean, variance, standard deviation, the minimum value, the maximum value, and the alpha and beta shape factors are required. Regardless of the methodology chosen the alpha and beta are required inputs into the program. Once the monthly precipitation for the site is inputted into the text file the next twelve rows, require the daylight correction factor, which is obtained from the Table 2.3. Then the next twelve rows correspond to the historical monthly temperature. Within the historical monthly temperature the descriptive statistics are required, which includes the mean, variance, standard deviation, the minimum value, the maximum value, and the alpha and beta shape factors.

The actual input file starts with the information presented in Table 4.1 and then continues with Table 4.2; however, the data is continuous. After the

P40_Beta row, the D60_Mean row follows, then after the wPI_beta row it is then followed by the Gs_mean row, and finally the SWCC_AAlpha row is then followed by the SWCC_ABeta row. As one can see, there is row for the level input. The level input will either be Level_1, Level_2, Level_3A, or Level_3B.

Now regardless, of the level, the program can handle up to 72 different soil inputs or soil layers. The program requires the input of the layer description, which includes the base or non-base. This input changes the suction model that is used for the given soil layer. After the soil description, it is follow by the row layer compaction; this is used to correct the maximum dry density that is either inputted or calculated values per the NCHRP 1-40D constraints. Before the soil inputs, the last row, layer name, this is the name of the soil layer that is used in the calculation. It requires an underscore instead of a space if it longer than two words; if the underscore is not used and the space is used, it will cause the program to crash.

Table 4.1: Required Climatic Properties.

Taylor_Series							
1-40D_Constraints	Yes						
Output_Simulations	No						
Location	City Name						
January_P	μ	σ^2	σ	Min	Max	α	β
February_P	μ	σ^2	σ	Min	Max	α	β
March_P	μ	σ^2	σ	Min	Max	α	β
April_P	μ	σ^2	σ	Min	Max	α	β
May_P	μ	σ^2	σ	Min	Max	α	β
June_P	μ	σ^2	σ	Min	Max	α	β
July_P	μ	σ^2	σ	Min	Max	α	β
August_P	μ	σ^2	σ	Min	Max	α	β
September_P	μ	σ^2	σ	Min	Max	α	β
October_P	μ	σ^2	σ	Min	Max	α	β
November_P	μ	σ^2	σ	Min	Max	α	β
December_P	μ	σ^2	σ	Min	Max	α	β
January_L	Latitude Correction Factor						
February_L	Latitude Correction Factor						
March_L	Latitude Correction Factor						
April_L	Latitude Correction Factor						
May_L	Latitude Correction Factor						
June_L	Latitude Correction Factor						
July_L	Latitude Correction Factor						
August_L	Latitude Correction Factor						
September_L	Latitude Correction Factor						
October_L	Latitude Correction Factor						
November_L	Latitude Correction Factor						
December_L	Latitude Correction Factor						
January_T	μ	σ^2	σ	Min	Max	α	β
February_T	μ	σ^2	σ	Min	Max	α	β
March_T	μ	σ^2	σ	Min	Max	α	β
April_T	μ	σ^2	σ	Min	Max	α	β
May_T	μ	σ^2	σ	Min	Max	α	β
June_T	μ	σ^2	σ	Min	Max	α	β
July_T	μ	σ^2	σ	Min	Max	α	β
August_T	μ	σ^2	σ	Min	Max	α	β
September_T	μ	σ^2	σ	Min	Max	α	β
October_T	μ	σ^2	σ	Min	Max	α	β
November_T	μ	σ^2	σ	Min	Max	α	β
December_T	μ	σ^2	σ	Min	Max	α	β

Table 4.2: Required Soil Properties.

Num_layers	#		
Layer_Description	Base Or Non_Base		
Layer_Compacted	Yes or No		
Layer_Name			
P20_Mean	P60_Mean	Gs_Mean	SWCC_ABeta
P20_Variance	P60_Variance	Gs_Variance	SWCC_BMean
P20_Stdev	P60_Stdev	Gs_Stdev	SWCC_BVariance
P20_Min	P60_Min	Gs_Min	SWCC_BStdev
P20_Max	P60_Max	Gs_Max	SWCC_BMin
P20_Alpha	P60_Alpha	Gs_Alpha	SWCC_BMax
P20_Beta	P60_Beta	Gs_Beta	SWCC_BAlpha
P15_Mean	D60_Mean	Level	SWCC_BBeta
P15_Variance	D60_Variance	wopt_Mean	SWCC_CMean
P15_Stdev	D60_Stdev	wopt_Variance	SWCC_CVariance
P15_Min	D60_Min	wopt_Stdev	SWCC_CStdev
P15_Max	D60_Max	wopt_Min	SWCC_CMin
P15_Alpha	D60_Alpha	wopt_Max	SWCC_CMax
P15_Beta	D60_Beta	wopt_Alpha	SWCC_CAlpha
P10_Mean	P200_Mean	wopt_Beta	SWCC_CBeta
P10_Variance	P200_Variance	CBR_Mean	SWCC_H
P10_Stdev	P200_Stdev	CBR_Variance	Mropt_Mean
P10_Min	P200_Min	CBR_Stdev	Mropt_Variance
P10_Max	P200_Max	CBR_Min	Mropt_Stdev
P10_Alpha	P200_Alpha	CBR_Max	Mropt_Min
P10_Beta	P200_Beta	CBR_Alpha	Mropt_Max
P05_Mean	PI_Mean	CBR_Beta	Mropt_Alpha
P05_Variance	PI_Variance	gamma_dry_Mean	Mropt_Beta
P05_Stdev	PI_Stdev	gamma_dry_Variance	
P05_Min	PI_Min	gamma_dry_Stdev	
P05_Max	PI_Max	gamma_dry_Min	
P05_Alpha	PI_Alpha	gamma_dry_Max	
P05_Beta	PI_Beta	gamma_dry_Alpha	
P40_Mean	wPI_Mean	gamma_dry_Beta	
P40_Variance	wPI_Variance	SWCC_AMean	
P40_Stdev	wPI_Stdev	SWCC_AVariance	
P40_Min	wPI_Min	SWCC_AStdev	
P40_Max	wPI_Max	SWCC_AMin	
P40_Alpha	wPI_Alpha	SWCC_AMax	
P40_Beta	wPI_Beta	SWCC_AAlpha	

4.4.3 Computer Program Outputs

In Appendix B, the computer program outputs can be found. The program will output the same data; however, the symbols for the descriptive statistics will not in the row heading. The row heading will have the following notation, mean, variance, std_dev, skewness, kurtosis, min, max, alpha, and beta. The Greek symbols were used in Appendix B so that the row heading would fit within the margins of this thesis. Nevertheless, the output of this program is in a .csv format. The csv format was selected so that a user could open up the data in any version Microsoft Excel© to manipulate the data as needed.

4.5 Mathematical Explanation of the Variance

In this subsection, the following mathematical solution sets, first order Taylor Series expansion, Rosenblueth's 2-Point estimation, Rosenblueth's 3-Point estimation, and a Monte Carlo simulation that utilizes the beta distribution will be discussed. Each method utilizes different mathematical approaches. Regardless, of the mathematical solution set chosen, excluding the first order Taylor Series expansion, the following statistical properties: mean, variance, skewness, and kurtosis are needed to describe the stochastic solution set. The Taylor Series expansion, on the other hand, only develops the mean and variance of the stochastic solution.

4.5.1 First Order Taylor Series Expansion

The first order Taylor Series expansion uses the mean and variance of the independent variable to develop the mean and variance of the dependent variable. The mean value of the dependent variable will have the same solution as the deterministic solution since the dependent variable is a function of only the mean variable. However, the variance of the dependent variable is a function of the mean and variance of each of the independent variable, shown in equation 2.15.

4.5.1.1 Thornthwaite Moisture Index

Regardless of the level, the Thornthwaite Moisture Index as well as the matric suction of the soil will utilize the same equations. The variance associated with TMI-ASU requires two inputs; both inputs are historical climatic data. The MEPDG has on average five to ten years of climatic data stored in various .hcd files. With the amount of data that is stored in the .hcd files, the four statistical moments can be developed for a given month's precipitation (in centimeters) and temperature (in ^{0}C) with confidence. By calculating TMI-ASU using the mean and variance of the temperature and precipitation, it will create a site specific average TMI-ASU similar to the monthly TMI-ASU that the EICM calculates. Equation 4.1 shows how mean TMI-ASU is calculated for a given site.

$$\mathrm{TMI} = 10 + 75\left(\frac{\mathrm{P_y}}{\mathrm{PE}} - 1\right) \quad \text{...} (4.1)$$

To accomplish the stochastic evaluation of TMI-ASU, the following equations will be utilized. The first and second statistical moments for the annual precipitation are as followed.

$$P_y = \mu_P = \sum_{i=1}^{12} \mu_{P_i} \quad \text{...} (4.2)$$

$$\sigma_P^2 = \sum_{i=1}^{12} \sigma_{P_i}^2 \quad \text{...} (4.3)$$

Where:

μ_{P_i} = Mean monthly rainfall [cm]

$\sigma^2_{P_i}$ = Monthly rainfall variance [cm^2]

Once the first and second statistical moments are created for the annual precipitation, the first and second statistical moments of the annual heat index can be calculated.

$$\mu_{H_i} = \sum_{i=1}^{12} \left(0.2\mu_{t_i}\right)^{1.514} \tag{4.4}$$

$$\sigma^2_{Hy} = \sum_{i=1}^{12} \left(0.3028\left(\mu_{t_i}\right)^{0.514}\right)^2 \sigma^2_{t_i} \tag{4.5}$$

Where:

μ_{t_i} = Mean monthly temperature [^{0}C]

$\sigma^2_{t_i}$ = Monthly temperature variance [^{0}C^2]

With the mean and variance of the annual heat index computed, the mean and variance of the PE is calculated using Equation 4.6. In addition to the temperature and annual heat index, there is another constants required D$_i$, which D$_i$ is a function of the latitude.

$$\mu_{PE} = \sum_{i=1}^{12} \left(1.6213\left(D_i\right)\left(a\right)\left(\frac{10\mu_{t_i}}{Hy}\right)^a \right) \tag{4.6}$$

$$\sigma_{PE}^{2} = \sum_{i=1}^{12}\left(1.6213(D_i)\left(\frac{10t_i}{Hy}\right)^{a}\left(\ln\left(\frac{10\mu_{t_i}}{Hy}\right)(a') - \frac{a}{Hy}\right)\right)\sigma_{Hy}^{2} + \qquad \text{.............}(4.7)$$
$$\sum_{i=1}^{12}\left(1.6213(D_i)(a)\left(\frac{10}{Hy}\right)^{a}\left(\mu_{t_i}\right)^{a-1}\right)\sigma_{t_i}^{2}$$

Where:

$a = 6.75x10^{-7}Hy^{3} - 7.71x10^{-5}Hy^{2} + 0.017921Hy + 0.49239$

$a' = 2.025x10^{-6}Hy^{2} - 1.542x10^{-4}Hy + 0.017921$

D_i = Day-length correction factor based on Latitude.

With the stochastic evaluation of PE and the P_y completed, the stochastic evaluation of TMI-ASU can occur. The mean of TMI-ASU was shown in Equation 4.1 and the variance of TMI-ASU will be as followed:

$$\sigma_{TMI}^{2} = \left(\frac{75}{\mu_{PE}}\right)^{2}\left(\sum_{i=1}^{12}\sigma_{P_i}^{2}\right) +$$
$$\left(\frac{-75\mu_{P}}{\mu_{PE}^{2}}\right)^{2} * \left(\begin{array}{l}\sum_{i=1}^{12}\left(1.6213(D_i)\left(\frac{10t_i}{Hy}\right)^{a}\left(\ln\left(\frac{10\mu_{t_i}}{Hy}\right)(a') - \frac{a}{Hy}\right)\right)\sigma_{Hy}^{2} + \\ \sum_{i=1}^{12}\left(1.6213(D_i)(a)\left(\frac{10}{Hy}\right)^{a}\left(\mu_{t_i}\right)^{a-1}\right)\sigma_{t_i}^{2}\end{array}\right) \qquad \text{.......}(4.8)$$

4.5.1.2 TMI-Matric Suction

The first and second statistical moments of TMI-ASU have been explained now the matric suction model for a given unbound layer will be discussed. The matric suction model requires three inputs, soil properties, unbound layer location, and the site TMI-ASU. Out of those three inputs, only the soil properties and the site TMI-ASU are stochastic; however, the layer location will change the matric suction model. The matric suction model is sub-divided into two groups, if the layer is a base coarse material or if the layer is a non-base coarse material. Now within the non-base coarse material matric suction model, it is sub-divided by amount P_{200} and/or the *w*PI of the soil.

There is only one constraint with the base coarse matric suction model, which the P_{200} of the granular material cannot be greater than 16 percent, if the soil has a P_{200} greater than 16 percent P_{200} is set equal to 16 percent. This constraint is due to the amount of soils that were originally tested to develop the correlation of matric suction. The base coarse matric suction model is as followed:

$$\mu_{\psi} = \alpha + e^{\left[\beta+\gamma\left(\mu_{TMI}+101\right)\right]} \quad \text{..(4.9)}$$

$$\begin{aligned}\sigma_{\psi}^{2} &= \left(\alpha' + e^{\left(\beta+\gamma\left(\mu_{TMI}+101\right)\right)}\left(\beta' + \gamma'\left(TMI+101\right)\right)\right)^{2}\sigma_{P_{200}}^{2} \\ &+ \left(\gamma e^{\left(\beta+\gamma\left(\mu_{TMI}+101\right)\right)}\right)^{2}\sigma_{TMI}^{2}\end{aligned} \quad \text{....................(4.10)}$$

Where:

$$\alpha' = -0.0048\left(P_{200}\right)^{2} + 0.232\left(P_{200}\right) - 0.1135$$

$$\beta' = -0.0135\left(P_{200}\right)^{2} + 0.2242\left(P_{200}\right) - 0.3364$$

$$\gamma' = 9E-05\left(P_{200}\right)^{2} - 0.0018\left(P_{200}\right) - 0.0061$$

If the matric suction for a non-base coarse layer has a *w*PI equal 0.0 it will use Equations 4.11 and 4.12 to find the first and second moments. This model has two constraints that are associated with it, which includes the amount of P_{200} the soil is able to have. If the non-base coarse layer has a P_{200} greater than 50 percent then P_{200} equals 50 percent. Also, if the soil has a P_{200} less than 10 percent, the soil use the base coarse matric suction model.

If the matric suction for a non-base coarse layer has a *w*PI greater than 0 it will use Equation 4.13 and 4.14 to find the first and second moments. However, this equation has two constraints. The first constraint, if the *w*PI is greater than 0 and less than 0.5, then use *w*PI equal to 0.5 in the computations. The second constraint, if the *w*PI is greater than 50 then *w*PI will equal 50.

$$\mu_{\psi} = \alpha\left[e^{\left[\frac{\beta}{\mu_{TMI}+\gamma}\right]} + \delta \right] \text{...} (4.11)$$

$$\begin{aligned}\sigma_{\psi}^{2} = &\left(\alpha\left(0.025 + e^{\frac{\beta}{(\mu_{TMI}+\gamma)}}\right)\left(\frac{\beta'(\mu_{TMI}+\gamma)-\gamma'\beta}{(\mu_{TMI}+\gamma)^{2}}\right)\right)^{2}\sigma_{P_{200}}^{2} \\ &+\left(-\frac{\alpha\beta e^{\frac{\beta}{(\mu_{TMI}+\gamma)}}}{(\mu_{TMI}+\gamma)^{2}}\right)^{2}\sigma_{TMI}^{2} \qquad \text{...............} (4.12)\end{aligned}$$

Where:

$\alpha = 0.3$

$\beta' = 2.56075$

$\gamma' = 0.09625$

$\delta' = 0.025$

$$\mu_{\psi} = \alpha\left[e^{\left[\frac{\beta}{\mu_{TMI} + \gamma}\right]} + \delta \right] \tag{4.13}$$

$$\sigma_{\psi}^{2} = \left(\alpha\left[e^{\frac{\beta}{(\mu_{TMI} + \gamma)}} + \delta' \right]\left(\frac{\beta'(\mu_{TMI} + \gamma) - \gamma'\beta}{(\mu_{TMI} + \gamma)} \right) \right)^{2} \sigma_{wPI}^{2} + \left(- \frac{\left(\alpha\left(\beta e^{\frac{\beta}{(\mu_{TMI} + \gamma)}} \right) \right)}{(\mu_{TMI} + \gamma)^{2}} \right)^{2} \sigma_{TMI}^{2} \tag{4.14}$$

Where:

$\alpha = 0.3$

$\beta' = 0.018708(wPI)^{2} - 1.5597(wPI) + 36.786486$

$\gamma' = 0.01185(wPI)^{2} - 0.08084(wPI) + 1.454066$

$\delta' = -0.03977(wPI) + 1.273$

$$wPI = \frac{P_{200}PI}{100}$$

The first and second statistical moments for TMI-ASU and matric suction are now mathematical described, using the Taylor Series expansion, the advent of the hierarchical levels are now needed to describe the first and second moments.

4.5.1.3 Volumetric Water Content

The volumetric water content of the soil, for Level 1 and Levels 2 and 3 with soils that have *w*PI > 2.0 will be calculated using Fredlund and Xing's soil water characteristic curve (SWCC). Fredlund and Xing's uses the saturated volumetric water content or the porosity of the soil, the matric suction of the soil, and four fitting parameters. In Level 1, the porosity and the four fitting parameters are measured and Levels 2 and 3 use correlations to calculate the porosity and the fitting parameters, while the matric suction is obtained using Equations 4.9 through 4.14, depending on the location of the soil in the pavement cross-section and soil properties. Regardless of the Level chosen, Equation 4.15 is used to determine the mean value of the volumetric water content.

$$\mu_{\theta_w} = C(h)x\left[\frac{\mu_{\theta_s}}{\left[\ln\left[\exp(1)+\left(\frac{\mu_\psi}{a_f}\right)^{b_f}\right]\right]^{c_f}}\right] \quad \text{...(4.15)}$$

Where:

$$C(h) = \left[1 - \frac{\ln\left(1 + \frac{\mu_h}{h_r}\right)}{\ln\left(1 + \frac{1x10^6}{h_r}\right)} \right]$$

$a_{f,}$ b_f, c_f, and h_r = Fredlund and Xing fitting parameters

However, for Levels 2 and 3 with soils that have a *w*PI < 2.0 the volumetric water content is calculated using the P_{200}-TMI model, which uses correlations of TMI and P_{200}.

3.5.1.3.1 Level 1

The volumetric water content for Level 1 utilizes the soil water characteristic curve to obtain the volumetric water content of the soil. The mean value of the SWCC is calculated using Equation 4.15, shown above, and the variance is calculated using Equation 4.16.

$$\mu_{\theta_w} = \left(\frac{\partial \mu_{\theta_s}}{\partial \mu_{\theta_w}} \right)^2 \sigma^2_{\mu_{\theta_s}} + \left(\frac{\partial a_f}{\partial \mu_{\theta_w}} \right)^2 \sigma^2_{a_f} + \left(\frac{\partial b_f}{\partial \mu_{\theta_w}} \right)^2 \sigma^2_{b_f} + \left(\frac{\partial c_f}{\partial \mu_{\theta_w}} \right)^2 \sigma^2_{c_f} + \left(\frac{\partial \mu_\psi}{\partial \mu_{\theta_w}} \right)^2 \sigma^2_{\mu_\psi} \quad \text{..(4.16)}$$

Where:

$$\left(\frac{\partial \mu_{\theta_s}}{\partial \mu_{\theta_w}} \right) = C(h) x \left[\frac{1}{\left[\ln\left[\exp(1) + \left(\frac{\mu_\psi}{a_f} \right)^{b_f} \right] \right]^{c_f}} \right]$$

$$\left(\frac{\partial a_f}{\partial \mu_{\theta_w}}\right) = C(h)x\left[\frac{\mu_{\theta_s}\left(b_f\right)\left(c_f\right)\left(\frac{\mu_\psi}{a_f}\right)^{b_f}}{\left(\left[\ln\left[\exp(1)+\left(\frac{\mu_\psi}{a_f}\right)^{b_f}\right]\right]^{c_f+1}\right)\left(\left(a_f\right)\left(\frac{\mu_\psi}{a_f}\right)^{b_f}+\left(a_f\right)\exp(1)\right)}\right]$$

$$\left(\frac{\partial b_f}{\partial \mu_{\theta_w}}\right) = C(h)x\left[\frac{\mu_{\theta_s}\left(c_f\right)\left(\frac{\mu_\psi}{a_f}\right)^{b_f}\ln\left(\frac{\mu_\psi}{a_f}\right)}{\left(\left[\ln\left[\exp(1)+\left(\frac{\mu_\psi}{a_f}\right)^{b_f}\right]\right]^{c_f+1}\right)\left(\left(\frac{\mu_\psi}{a_f}\right)^{b_f}+\exp(1)\right)}\right]$$

$$\left(\frac{\partial c_f}{\partial \mu_{\theta_w}}\right) = -C(h)x\left[\frac{\mu_{\theta_s}\ln\left[\ln\left[\exp(1)+\left(\frac{\mu_\psi}{a_f}\right)^{b_f}\right]\right]}{\left(\left[\ln\left[\exp(1)+\left(\frac{\mu_\psi}{a_f}\right)^{b_f}\right]\right]^{c_f}\right)}\right]$$

$$\left(\frac{\partial \mu_{\psi}}{\partial \mu_{\theta_w}}\right) = C(h)x\left(\frac{\dfrac{\mu_{\theta_s}\left(b_f\right)\left(c_f\right)\left(\dfrac{\mu_{\psi}}{a_f}\right)^{b_f}}{\left(\left[\ln\left[\exp(1)+\left(\dfrac{\mu_{\psi}}{a_f}\right)^{b_f}\right]\right]^{c_f}\right)\left(\left(\dfrac{\mu_{\psi}}{a_f}\right)^{b_f}+\exp(1)\right)} - \dfrac{1}{\ln\left(\dfrac{10^6}{h_r}\right)}}{\left(\left[\ln\left[\exp(1)+\left(\dfrac{\mu_{\psi}}{a_f}\right)^{b_f}\right]\right]^{c_f}\right)\mu_{\psi}}\right)$$

4.5.1.3.2 Levels 2 and 3 *w*PI > 2.0

As stated earlier, Levels 2 and 3 with soils that have a *w*PI > 2.0 will utilize Equation 4.16; however, the fitting parameters are now a function of the soils *w*PI, which are shown in Equations 4.17 through 4.19. The variance of the volumetric water content is calculated using Equation 4.20 and using Equation 4.17 through 3.19, for the fitting parameters.

$$\mu_{\mathrm{a_f}} = 32.835\left(\ln\left(\mu_{\mathrm{wPI}}\right)\right) + 32.438 \text{ ....(4.17)}$$

$$\mu_{\mathrm{b_f}} = 1.421\left(\mu_{\mathrm{wPI}}\right)^{-0.3185} \text{ ....(4.18)}$$

$$\mu_{\mathrm{c_f}} = -0.2154\left(\ln\left(\mu_{\mathrm{wPI}}\right)\right) + 0.07145 \text{ ....(4.19)}$$

$$\mu_{\theta_w} = \left(\frac{\partial \mu_{\theta_s}}{\partial \mu_{\theta_w}}\right)^2 \sigma^2_{\mu_{\theta_s}} + \left(\frac{\partial wPI}{\partial \mu_{\theta_w}}\right)^2 \sigma^2_{wPI} + \left(\frac{\partial \mu_{\psi}}{\partial \mu_{\theta_w}}\right)^2 \sigma^2_{\mu_{\psi}} \text{ ....(4.20)}$$

Where:

$$\left(\frac{\partial wPI}{\partial \mu_{\theta_w}}\right)=\left(\mu_{\theta_w}\left(\frac{\left(b_f^{'}\left(c_f\right)\right)\left(0.3185\left(a_f\right)\ln\left(\frac{\mu_\psi}{a_f}\right)+32.835\right)\left(\frac{\mu_\psi}{a_f}\right)^{b_f+1}}{\left(\mu_\psi\left(\left(\frac{\mu_\psi}{a_f}\right)^{b_f}+\exp(1)\right)\ln\left(\left(\frac{\mu_\psi}{a_f}\right)^{b_f}+\exp(1)\right)\right)+\frac{c_f^{'}}{wPI}}\right)\right)$$

$$b_f^{'}=1.421wPI^{-1.3185}$$

$$c_f^{'}=\ln\left(\ln\left(\left(\frac{\mu_\psi}{a_f}\right)^{b_f}+\exp(1)\right)\right)$$

4.5.1.3.2 Levels 2 and 3 *w*PI < 2.0

The volumetric water content for soils with *w*PI < 2.0 utilize a correlation between the TMI-ASU and percent passing the number 200 US standard sieve size. This correlation disregards the SWCC since the predictive models are unable to describe the behavior of the SWCC. The TMI-ASU-P_{200} is described by Equation 4.21; however, there are two constraints associated with this model. When the volumetric water content is greater than 40 percent, the volumetric water content of the soil is described by Equation 4.22. In regards to Equation 4.21 and 4.22, if the volumetric water content of the soil is greater than the saturated volumetric water content, the volumetric water content is set equal to the saturated water content. This constraint is used since the volumetric water content of the soil can never be greater than the saturated volumetric water content or the porosity of the soil. Once the constraints are applied, the variance of the volumetric water content can be calculated. The variance of the volumetric water content is calculated using Equation 4.23 if Equation 4.21 is used and Equation 4.24 if Equation 4.21 is used to determine the mean value of the volumetric water content.

$$\mu_{\theta_w} = 4 + 1.5\mu_{P_{200}}^{0.6994} + 0.03\mu_{TMI} \quad \text{...(4.21)}$$

$$\mu_{\theta_w} = 40 + 0.11\left(\mu_{P_{200}} - 53\right) \text{...(4.22)}$$

$$\sigma_{\theta_w}^2 = \sigma_{P_{200}}^2 \left(1.0491\left(P_{200}\right)^{-0.3006}\right)^2 + 0.009\sigma_{TMI}^2 \quad \text{.............................(4.23)}$$

$$\sigma_{\theta_w}^2 = 0.0121\sigma_{P_{200}}^2 \quad \text{...(4.24)}$$

4.5.1.4 Saturated Volumetric Water Content

The saturated volumetric water content, regardless of the hierarchical level chosen, the mean is calculated using Equation 4.25 and the variance is calculated using Equation 4.26. The hierarchical levels become important when the dry unit weight is selected. Level 1 uses actual compaction data, while Levels 2 and 3 use correlation of soil properties to determine the dry unit weight. The determination of the specific gravity of the soil solids does not use correlations; Level 1 uses measured laboratory data while Levels 2 and 3 rely upon engineering databases and assumptions.

$$\mu_{\theta_{sat}} = \left(1 - \frac{\mu_{\gamma_{dry}}}{\mu_{G_s} * \gamma_{water}}\right) \quad \text{...} (4.25)$$

$$\sigma^2_{\theta_{sat}} = \left(-\frac{1}{\gamma_w \mu_{G_s}}\right)^2 \sigma^2_{\gamma_{dry}} + \left(\frac{\mu_{\gamma_{dry}}}{\left(\gamma_w \mu_{G_s}\right)^2}\right) \sigma^2_{G_s} \quad \text{.................................} (4.26)$$

4.5.1.5 Degree of Saturation

Regardless of the hierarchical level chosen, the degree of saturation is calculated the same. Even though the degree of saturation equation is the same for all the levels, the level of uncertainty or the variance of the degree of saturation will increase due to the correlations that are made in Levels 2 and 3 when determining the volumetric water content, the dry unit weight, and the using engineering databases for the specific gravity of the solids. The degree of saturation is calculated using Equation 4.27 and the variance of the degree of saturation is calculated using Equation 4.28.

$$\mu_{\%S} = \left(\frac{\mu_{\theta_w}}{\mu_{\theta_{sat}}}\right) \quad \text{...} (4.27)$$

$$\sigma^2_{\%S} = \left(-\frac{\mu_{\theta_w}}{\mu^2_{\theta_{Sat}}}\right)^2 \sigma^2_{\theta_{Sat}} + \left(\frac{1}{\mu_{\theta_{Sat}}}\right)^2 \sigma^2_{\theta_w} \quad \text{..} (4.28)$$

4.5.1.6 Soil Compaction and Optimum Saturation

The soil compaction information is dependent on the hierarchical level. Level 1 relies on ASTM D-698 standard compaction efforts or AASHTO T99, while Levels 2 and 3 rely on correlations between soil properties and compaction. Therefore, Level 1 will not use any correlations of soil properties to the optimum moisture content and the maximum dry unit weight. However, Levels 2 and 3 are dependent of the *w*PI of the soil for correlations. When the soil is non-plastic or a *w*PI of 0, correlation to the grain size distribution are used; on the other hand, when the soil is plastic or has a *w*PI greater than 0, correlations of *w*PI are used.

The optimum saturation of the soil is a function of the optimum moisture content, the specific gravity of the soil solids, the maximum dry unit weight. When the hierarchical levels are used the optimum saturation calculated similarly for Level 1 and Level2 and 3 plastic soils (*w*PI>0) and the mean value of the optimum saturation will utilize Equation 4.29 and the variance of the optimum saturation will utilize Equation 4.30. However, when Levels 2 and 3 have a non-plastic soil, Equations 4.31 and 4.32 will be used to calculate the mean and variance respectively.

$$\mu_{S_{opt}} = \frac{\mu_{w_{opt}}}{\frac{\gamma_w}{\gamma_{d\max}} + \frac{1}{\mu_{G_s}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.29)$$

$$\sigma_{S_{opt}}^2 = \left(\frac{\partial w_{opt}}{\partial S_{opt}}\right)^2 \sigma_{w_{opt}}^2 + \left(\frac{\partial \gamma_{dry}}{\partial S_{opt}}\right)^2 \sigma_{\gamma_{dry}}^2 + \left(\frac{\partial G_s}{\partial S_{opt}}\right)^2 \sigma_{G_s}^2 \quad \ldots\ldots\ldots\ldots (4.30)$$

$$\mu_{S_{opt}} = -100.17 + 1.4991\mu_{P_{2''}} + 0.56155\mu_{P_{1''}} - 0.36755\mu_{P_{0.5''}} \ldots\ldots\ldots\ldots\ldots\ldots (4.31)$$

$$\sigma_{S_{opt}}^2 = (1.4991)^2 \sigma_{P_{2.0''}}^2 + (0.56155)^2 \sigma_{P_{1.0''}}^2 + (-0.36755)^2 \sigma_{P_{0.5''}}^2 \ldots\ldots (4.32)$$

Where

$$\left(\frac{\partial w_{opt}}{\partial S_{opt}}\right)=\frac{1}{\dfrac{\gamma_w}{\mu_{\gamma_{dry}}}+\dfrac{1}{\mu_{G_s}}}$$

$$\left(\frac{\partial \gamma_{dry}}{\partial S_{opt}}\right)=\frac{\mu_{w_{opt}}\gamma_w}{\left(\dfrac{1}{\mu_{G_s}}+\dfrac{\gamma_w}{\mu_{\gamma_{dry}}}\right)^2\left(\mu_{\gamma_{dry}}\right)^2}$$

$$\left(\frac{\partial G_s}{\partial S_{opt}}\right)=\frac{\mu_{w_{opt}}}{\left(\dfrac{1}{\mu_{G_s}}+\dfrac{\gamma_w}{\mu_{\gamma_{dry}}}\right)^2\left(\mu_{G_s}\right)^2}$$

4.5.1.6.1 Levels 2 and 3 soils with *w*PI = 0

When Levels 2 or 3 are chosen for analysis, the dry density is a function of the optimum moisture content, specific gravity of the soil solids, and the optimum saturation, which the optimum moisture content and the optimum saturation is a function of the soil's grain size distribution. The mean dry density is calculated by solving for the mean dry density in Equation 4.29, which is shown in Equation 4.33. The variance of the dry density is calculated using Equation 4.34. The optimum moisture content is calculated using Equation 4.35 and the variance is calculated by using Equation 4.36.

$$\mu_{\gamma_{d\max}}=\frac{\mu_{G_s}\left(\gamma_{water}\right)}{1+\dfrac{\mu_{w_{opt}}\mu_{G_s}}{\mu_{S_{opt}}}} \quad \text{...(4.33)}$$

$$\sigma_{\gamma_{dry}}^{2} = \left(\frac{\partial G_s}{\partial \gamma_{dry}}\right)^{2} \sigma_{G_s}^{2} + \left(\frac{\partial w_{opt}}{\partial \gamma_{dry}}\right)^{2} \sigma_{w_{opt}}^{2} + \left(\frac{\partial S_{opt}}{\partial \gamma_{dry}}\right)^{2} \sigma_{S_{opt}}^{2} \quad \text{............}(4.34)$$

Where:

$$\left(\frac{\partial G_s}{\partial \gamma_{dry}}\right) = \frac{\gamma_w\left(1+\frac{\mu_{w_{opt}}\mu_{G_s}}{\mu_{S_{opt}}}\right) - \gamma_w \mu_{G_s}\left(\frac{\mu_{w_{opt}}}{\mu_{S_{opt}}}\right)}{\left(1+\frac{\mu_{w_{opt}}\mu_{G_s}}{\mu_{S_{opt}}}\right)^{2}}$$

$$\left(\frac{\partial w_{opt}}{\partial \gamma_{dry}}\right) = \frac{-\frac{\mu_{G_s}^{2}}{\mu_{S_{opt}}}\gamma_w}{\left(1+\frac{\mu_{w_{opt}}\mu_{G_s}}{\mu_{S_{opt}}}\right)^{2}}$$

$$\left(\frac{\partial S_{opt}}{\partial \gamma_{dry}}\right) = \frac{-\frac{\mu_{G_s}^{2}}{\mu_{S_{opt}}^{2}}\gamma_w \mu_{w_{opt}}}{\left(1+\frac{\mu_{w_{opt}}\mu_{G_s}}{\mu_{S_{opt}}}\right)^{2}}$$

$$\begin{aligned}\mu_{w_{opt}} &= -120.14 - 0.06766\mu_{P_{1.5''}} + 3.7269\mu_{D_{60}} \\ &\quad - 0.167\mu_{P_{\#40}} + 0.117\mu_{P_{\#60}} + 142.53e^{\left(-0.0389*\mu_{D_{60}}\right)}\end{aligned} \quad \text{......................}(4.35)$$

$$\begin{aligned}\sigma_{w_{opt}}^{2} &= \left(-0.06766\right)^{2}\sigma_{P_{1.5}}^{2} + \left(-0.167\right)^{2}\sigma_{P_{\#40}}^{2} + \left(0.117\right)\sigma_{P_{\#60}}^{2} \\ &\quad + \left(3.7269 - 5.4403e^{-0.0339\mu_{D_{60}}}\right)^{2}\sigma_{D_{60}}^{2}\end{aligned} \quad \text{............}(4.36)$$

4.5.1.6.2 Levels 2 and 3 with *w*PI > 0.0

When the soil has some plasticity, the optimum moisture content is correlated to the *w*PI of the soil, while the maximum dry density of the soil is correlated to the optimum moisture content. However, for this correlation to be made, it requires a check of the soils PI. The mean PI adjust, which is shown in Equation 4.37, while variance of the PI adjust is shown in Equation 4.38; however, the constraints, for this equation, are listed in chapter 2. The mean of the *w*PI adjusted is similar to the mean of the *w*PI of the soil.

$$\mu_{PI_{adj}} = e^{\frac{\mu_{P200}+42.13}{33.94}} \quad \ldots\ldots(4.37)$$

$$\sigma^2_{PI_{adj}} = \left(\frac{e^{\frac{\mu_{P200}+42.13}{33.94}}}{(33.94)} \right)^2 \sigma^2_{P200} \quad \ldots\ldots(4.38)$$

The optimum moisture content mean and variance is a function of the *w*PI of the soil. The optimum moisture content mean and variance are outlined in Equation 4.39 and Equation 4.40 respectively. Nevertheless, the maximum dry unit weight mean and variance is a function of the optimum moisture content which is shown in Equation 4.41 and Equation 4.42 respectively.

$$\mu_{w_{opt}} = 8.3932\mu^{0.3075}_{wPI_{adj}} \quad \ldots\ldots(4.39)$$

Where:

$$\mu_{wPI_{adj}} = \frac{\left(e^{\frac{\mu_{P_{200}}+42.13}{33.94}}\right)\mu_{P_{200}}}{100} \text{ or } \mu_{wPI_{adj}} = \frac{\mu_{P_{200}}\left(\mu_{PI}\right)}{100}$$

$$\sigma^2_{w_{opt}} = \left(2.58091\left(\mu_{wPI_{adj}}\right)^{-0.6925}\right)^2 \sigma^2_{wPI_{adj}} \quad \text{.......................................(4.40)}$$

Where:

$$\sigma^2_{wPI_{adj}} = \left(\frac{\mu_{PI}}{100}\right)^2 \sigma^2_{P_{200}} + \left(\frac{\mu_{P_{200}}}{100}\right)^2 \sigma^2_{PI} \text{ or}$$

$$\sigma^2_{wPI_{adj}} = \left(\frac{e^{\frac{\mu_{P_{200}}+42.13}{33.94}}}{100} + \frac{\mu_{P_{200}}}{(100)(33.94)} e^{\frac{\mu_{P_{200}}+42.13}{33.94}}\right)^2 \sigma^2_{P_{200}}$$

$$\mu_{\gamma_{dry}} = \gamma_{dry\max\_comp\_std} = 142.115 - 1.959\mu_{w_{opt}} \quad \text{.......................................(4.41)}$$

$$\sigma^2_{\gamma_{dry}} = (-1.959)^2 \sigma^2_{w_{opt}} \quad \text{...(4.42)}$$

4.5.1.7 Environmental Factor

The environmental factor requires the mean and variance of the degree of saturation, the optimum saturation, and the *w*PI of the soil. Using these three parameters, the mean of the environmental factor is explained in Equation 4.43, while the variance of the environmental factor is calculated using Equation 4.44.

$$\mu_{F_{env}} = 10^{1.002x\left[\alpha^{-1} + \frac{\beta-\alpha^{-1}}{1+e^{\ln\left(\frac{-\beta}{\alpha^{-1}}\right)+\gamma\left(\frac{\mu_S-\mu_{S_{opt}}}{100}\right)}}\right]} \quad \text{.....................................} (4.43)$$

Where:

$$\alpha = (-0.6) + (-1.87194)e^{-wPI}$$

$$\beta = 0.8 + 0.08(wPI)^{0.5}$$

$$\gamma = \left(11.96518 + (-10.19111)e^{-wPI}\right)^{0.5}$$

$$\sigma^2_{F_{env}} = \left(\frac{\partial wPI}{\partial F_{env}}\right)^2 \sigma^2_{wPI} + \left(\frac{\partial \%S}{\partial F_{env}}\right)^2 \sigma^2_{\%S} + \left(\frac{\partial S_{opt}}{\partial F_{env}}\right)^2 \sigma^2_{S_{opt}} \quad \text{.............} (4.44)$$

Where:

$$\left(\frac{\partial wPI}{\partial F_{env}}\right) = 2.307\left(\mu_{F_{env}}\right)\frac{\alpha'}{\alpha^2} +$$
$$2.307\left(\mu_{F_{env}}\right)\left(\frac{\left(\beta' - \frac{\alpha'}{\alpha^2}\right)\omega - \left((\beta - \alpha)(-(\omega - 1)) + (\beta'(\alpha)(\eta)) + 1.87194(\beta)(\eta)\right)}{\omega^2}\right)$$

$$\left(\frac{\partial \%S}{\partial F_{env}}\right) = -(2.307)(\omega - 1)(\gamma)\left(\beta - \alpha^{-1}\right)\left(10^{-2+1.002\left(\alpha^{-1} + \frac{\left(\beta - \alpha^{-1}\right)}{\omega}\right)}\right)(\omega)^{-2}$$

$$\left(\frac{\partial S_{opt}}{\partial F_{env}}\right) = (2.307)(\omega - 1)(\gamma)\left(\beta - \alpha^{-1}\right)\left(10^{-2+1.002\left(\alpha^{-1}+\frac{\left(\beta-\alpha^{-1}\right)}{\omega}\right)}\right)(\omega)^{-2}$$

$$\alpha' = -1.87194e^{-wPI}$$

$$\beta' = 0.04(wPI)^{-0.5}$$

$$\gamma' = -5.09556e^{-wPI}$$

$$\omega = \left(1 + e^{\ln\left(\frac{\beta}{\alpha^{-1}}\right)+\gamma(\chi)}\right)$$

$$\chi = \left(\frac{\mu_{\%s} - \mu_{S_{opt}}}{100}\right)$$

$$\eta = \left(e^{(\chi)(\gamma)-wPI}\right)$$

4.5.1.8 Resilient Modulus at Optimum

The resilient modulus at optimum is dependent on the hierarchical level chosen. Level 1 requires the NCHRP 1-28A testing protocol to be performed on the soil, while Levels 2 and 3 rely on correlations of grain sizes and Atterberg Limits. Therefore Level 1 will not use any correlations to obtain the resilient modulus at optimum and will use project associated coefficients of variation to determine the variance. Levels 2 and 3 use correlation depending on the *w*PI of the soil, which is correlated to a CBR value of the soil, once the CBR correlation is made, the correlation between CBR and the in-situ modulus value is made. After the CBR in-situ modulus correlation is made, a correlation between the in-situ modulus and the resilient modulus at optimum is made.

4.5.1.9.1 Levels 2 and 3 soil with *w*PI = 0.0

Levels 2 and 3 soils that have a *w*PI equal to zero or soils with no plasticity will use a correlation between D_{60} to obtain the CBR and then the South African correlation is made to correlate the modulus value to a CBR. In Equation 4.45 is the mean value of the resilient modulus at optimum, which uses all three correlations listed above, while the variance of the resilient modulus at optimum is shown in Equation 4.46.

$$\mu_{M_{Ropt}} = \mu_{M_{in-situ}} \left\lfloor 2.11 - 2.78x10^{-5}\, \mu_{M_{in-situ}} \right\rfloor \text{.................................} (4.45)$$

Where:

$$\mu_{M_{insitu}} = 2555\left(28.09\left(\mu_{D_{60}}\right)^{0.358}\right)^{0.64}$$

$$\sigma^2_{M_{Ropt}} = \left(\frac{10442.6}{\left(D_{60}\right)^{0.77088}} - \frac{5943.82}{\left(D_{60}\right)^{0.51476}}\right)^2 \sigma^2_{D_{60}} \text{ ....} (4.46)$$

4.5.1.9.2 Levels 2 and 3 soils with *w*PI > 0.0

When the soils have a *w*PI > zero or a plasticity index greater than zero, the resilient modulus at optimum uses *w*PI-CBR correlation then uses the CBR-$M_{R\ in\text{-}situ}$ correlation, then the $M_{R\ in\text{-}situ}$ - $M_{R\ opt}$ correlation is made. In Equation

4.47 is the mean value of the resilient modulus at optimum and Equation 4.48 is the variance of the resilient modulus at optimum.

$$\mu_{M_{Ropt}} = \mu_{M_{in-situ}} \left[2.11 - 2.78x10^{-5} \mu_{M_{in-situ}}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.47)$$

Where:

$$\mu_{M_{in-situ}} = 2555\left(\frac{75}{1+0.728\mu_{wPI}}\right)^{0.64}$$

$$\mu_{CBR} = \frac{75}{1+0.728\mu_{wPI}}$$

$$\sigma^2_{M_{Ropt}} = \left(169.109(\mu_{CBR})^{2.28} - 2511.8(\mu_{CBR})^{1.64}\right)^2 \sigma^2_{wPI} \ldots\ldots\ldots\ldots\ldots (4.48)$$

4.5.1.9 Resilient Modulus at Equilibrium

Regardless, of the hierarchical level chosen, the mean and variance of the resilient modulus at equilibrium is calculated the same. The only difference between the levels is the amount variance associated with each level. The resilient modulus at equilibrium mean is calculated using Equation 4.49 and the variance of the resilient modulus at equilibrium is calculated using Equation 4.50.

$$\log\left(\mu_{M_{\mathrm{Re}q}}\right) = \log\left(\mu_{F_{env}}\left(\mu_{M_{Ropt}}\right)\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.49)$$

$$\log\left(\sigma^2_{M_{\mathrm{Re}q}}\right) = \left(\frac{1}{\mu_{F_{env}}}\right)^2 \sigma^2_{F_{env}} + \left(\frac{1}{\mu_{M_{Ropt}}}\right)^2 \sigma^2_{M_{Ropt}} \ldots\ldots\ldots\ldots\ldots\ldots (4.50)$$

4.5.2 Rosenblueth Point Estimations

The Rosenblueth point estimation requires the mean and standard deviation of the independent variable. The mean and standard deviation, of the independent variable, is obtained from various databases. The mean value of the Rosenblueth point estimation should be the same value obtained from the deterministic solution if the independent variable has no skewness or kurtosis. However, if the independent variable has some slight skewness or kurtosis, the mean value of the Rosenblueth point estimation will vary slightly from the deterministic solution and if the independent variable is highly skewed, the mean value of the Rosenblueth point estimation will be significantly different from the deterministic solution.

4.5.2.1 Thornthwaite Moisture Index

The Thornthwaite Moisture Index mean, for a given site, will be calculated using Equation 4.51, which needs the annual precipitation and potential evapotranspiration. Once the mean of TMI is determined, the variance of TMI can be determined using Equation 4.52. The mean annual precipitation calculation can be found in Equation 4.53 and the variance of the annual precipitation is calculated using Equation 4.54. While the mean potential evapotranspiration is calculated using Equation 4.55 and the variance of the potential evapotranspiration is calculated using Equation 4.56.

$$\mu_{TMI} = \frac{1}{n}\left(\sum_{i=1}^{n} 10 + 75\left(\frac{P_{y_i}}{PE_i} - 1\right)\right) \quad \text{..}(4.51)$$

$$\sigma_{TMI}^{2} = \frac{\left(\sum_{i=1}^{n} \left(10 + 75 \left(\frac{P_{y_i}}{PE_i} - 1 \right) \right)^2 - \frac{\left(\sum_{i=1}^{n} 10 + 75 \left(\frac{P_{y_i}}{PE_i} - 1 \right) \right)^2}{n} \right)}{n-1} \text{ ....(4.52)}$$

Where:

n = 4 for Rosenblueth 2-Point estimation or n = 9 for Rosenblueth 3-Point estimation

$PE_i = \mu_{PE_i} + \omega(\sigma_{PE_i})$

$P_{y_i} = \mu_{P_{y_i}} + \rho(\sigma_{P_{y_i}})$

ρ, ω are point estimation variables (i.e. 1,-1 for 2-Point and 1,0,-1 for 3-Point)

$$P_y = \mu_P = \frac{1}{n} \left(\sum_{i=1}^{n} \sum_{j=1}^{12} (P_{ji}) \right) \text{ ....(4.53)}$$

$$\sigma_{P_y}^{2} = \frac{1}{n-1} \left(\left(\sum_{i=1}^{n} \sum_{j=1}^{12} (P_{ji})^2 \right) - \frac{\left(\sum_{i=1}^{n} \sum_{j=1}^{12} (P_{ji}) \right)^2}{n} \right) \text{ ....(4.54)}$$

Where:

n = 4096 for Rosenblueth 2-Point or n = 531441 for Rosenblueth 3-Point estimation j is the monthly precipitation (i.e. P_1 – P_{12} corresponds to the monthly precipitation P_1 = January,…, P12 = December)

$$P_{1i} = \mu_{P_{1i}} + \rho\left(\sigma_{P_{1i}}\right) \quad P_{2i} = \mu_{P_{2i}} + \omega\left(\sigma_{P_{2i}}\right) \quad P_{3i} = \mu_{P_{3i}} + \xi\left(\sigma_{P_{3i}}\right)$$

$$P_{4i} = \mu_{P_{4i}} + \tau\left(\sigma_{P_{4i}}\right) \quad P_{5i} = \mu_{P_{5i}} + \upsilon\left(\sigma_{P_{5i}}\right) \quad P_{6i} = \mu_{P_{6i}} + \psi\left(\sigma_{P_{6i}}\right)$$

$$P_{7i} = \mu_{P_{7i}} + \vartheta\left(\sigma_{P_{7i}}\right) \quad P_{8i} = \mu_{P_{8i}} + \eta\left(\sigma_{P_{8i}}\right) \quad P_{9i} = \mu_{P_{9i}} + \pi\left(\sigma_{P_{9i}}\right)$$

$$P_{10i} = \mu_{P_{10i}} + \nu\left(\sigma_{P_{10i}}\right) \quad P_{11i} = \mu_{P_{11i}} + \theta\left(\sigma_{P_{11i}}\right) \quad P_{12i} = \mu_{P_{12i}} + \kappa\left(\sigma_{P_{12i}}\right)$$

$\rho, \omega, \xi, \tau, \upsilon, \psi, \vartheta, \eta, \pi, \nu, \theta, \kappa$ are point estimation variables

$$\mu_{PE} = \frac{1}{n}\left(\sum_{i=1}^{n}\sum_{j=1}^{12}\left(1.6213(a)\right)\left(D_j\right)\left(\frac{10t_{ji}}{Hy_i}\right)^{a}\right) \text{..} (4.55)$$

Where:

j is the corresponding month

n = 8192 for Rosenblueth 2-Point or 1594323 for Rosenblueth 3-Point

$Hy_i = \mu_{Hy} + \omega\sigma_{H_y}$

$$\sigma_{PE}^2 = \frac{1}{n-1}\left(\sum_{i=1}^{n}\sum_{j=1}^{12}\left(\left(1.6213(a)\right)\left(D_j\right)\left(\frac{10t_{ji}}{Hy_i}\right)^{a}\right)^2 - \frac{\sum_{i=1}^{n}\sum_{j=1}^{12}\left(1.6213(a)\right)\left(D_j\right)\left(\frac{10t_{ji}}{Hy_i}\right)^{a}}{n}\right) \text{...........................} (4.56)$$

However, to compute the potential evapotranspiration of the site, it requires the annual heat index, which is a function of the monthly temperature. The mean yearly heat index is calculated using Equation 4.57, while the variance of the annual heat index is calculated using Equation 4.58.

$$\mu_{H_y} = \frac{1}{n}\left(\sum_{i=1}^{n} \sum_{j=1}^{12} \left(0.2\mu_{t_{ji}}\right)^{1.514} \right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.57)$$

$$\sigma^2_{H_y} = \frac{1}{n-1}\left[\left(\sum_{i=1}^{n} \sum_{j=1}^{12} \left(\left(0.2\mu_{t_{ji}}\right)^{1.514}\right)^2 \right) - \frac{\left(\sum_{i=1}^{n} \sum_{j=1}^{12} \left(0.2\mu_{t_{ji}}\right)^{1.514} \right)^2}{n} \right] \quad \ldots\ldots(4.58)$$

Where:

n = 4096 for Rosenblueth 2-Point or n = 531441 for Rosenblueth 3-Point estimation

j is the corresponding monthly temperature

$t_{1i} = \mu_{t_{1i}} + \alpha\left(\sigma_{t_{1i}}\right) \quad t_{2i} = \mu_{t_{2i}} + \beta\left(\sigma_{t_{2i}}\right) \quad t_{3i} = \mu_{t_{3i}} + \chi\left(\sigma_{t_{3i}}\right) \quad t_{4i} = \mu_{t_{4i}} + \delta\left(\sigma_{t_{4i}}\right)$

$t_{5i} = \mu_{t_{5i}} + \varepsilon\left(\sigma_{t_{5i}}\right) \quad t_{6i} = \mu_{t_{6i}} + \phi\left(\sigma_{t_{6i}}\right) \quad t_{7i} = \mu_{t_{7i}} + \varphi\left(\sigma_{t_{7i}}\right) \quad t_{8i} = \mu_{t_{8i}} + \gamma\left(\sigma_{t_{8i}}\right)$

$t_{9i} = \mu_{t_{9i}} + \eta\left(\sigma_{t_{9i}}\right) \quad t_{10i} = \mu_{t_{10i}} + \kappa\left(\sigma_{t_{10i}}\right) \quad t_{11i} = \mu_{t_{11i}} + \lambda\left(\sigma_{t_{11i}}\right) \quad t_{12i} = \mu_{t_{12i}} + \nu\left(\sigma_{t_{12i}}\right)$

$\alpha, \beta, \chi, \delta, \varepsilon, \phi, \varphi, \gamma, \eta, \kappa, \lambda, \nu$ are point estimation variables

$t_1 - t_{12}$ is the average monthly temperature (i.e. t_1 = January,…, t_{12} = December)

4.5.2.2 TMI-Matric Suction

The matric suction of the soil is dependent on the layer location and the soil type. The matric suction when the soil is a base layer is a function of TMI and the P_{200}; however, when the soil is a non-base layer, the soil is a function of TMI and either a function of P_{200} or the *w*PI of the soil. The same constraints that were listed in section 3.5.1.2 still apply. If the soil is located in the base course layer it will use Equation 4.59 to obtain the mean value of the TMI-matric suction value. If the soil is a non-base course layer, it will use Equation 4.60; however, if the non-base course layer has a *w*PI equal to zero, the TMI-Matric Suction mean will use Equation 4.60 as well, the variables will change. The variance of the TMI-Matric Suction, for the base course layer, will be calculated using Equation 4.61 while the non-base course layer will utilize Equation 4.62.

$$\mu_{\psi} = \frac{1}{n}\left(\sum_{i=1}^{n} \alpha + e^{\left[\beta+\gamma\left(TMI_i+101\right)\right]}\right) \quad \text{...(4.59)}$$

Where:

n = 4 for Rosenblueth 2-Point or n=9 for Rosenblueth 3-Point

$$\alpha = -0.0016\left(P_{200_i}\right)^3 + 0.1106\left(P_{200_i}\right)^2 - 0.1135\left(P_{200_i}\right) + 3.8218$$

$$\beta = -0.0045\left(P_{200_i}\right)^3 + 0.1121\left(P_{200_i}\right)^2 - 0.3364\left(P_{200_i}\right) + 3.2358$$

$$\gamma = 3E-05\left(P_{200_i}\right)^3 - 0.0009\left(P_{200_i}\right)^2 + 0.0061\left(P_{200_i}\right) - 0.0498$$

$TMI_i = \mu_{TMI} + \eta(\sigma_{TMI})$

$P_{200_i} = \mu_{P_{200}} + \nu(\sigma_{P_{200}})$

η, ν are point estimation variables

$$\mu_{\psi} = \frac{1}{n}\left(\sum_{i=1}^{n}\alpha\left[e^{\left[\frac{\beta}{TMI_i+\gamma}\right]}+\delta\right]\right) \text{...}(4.60)$$

Where:

n = 4 for Rosenblueth 2-Point or n=9 for Rosenblueth 3-Point

$\alpha = 0.3$

$\beta = 0.006236(wPI_i)^3 - 0.7798334(wPI_i)^2 + 36.786486(wPI_i) + 501.9512$

$\gamma = 0.00395(wPI_i)^3 - 0.04042(wPI_i)^2 + 1.454066(wPI_i) + 136.4775$

$\delta = -0.022(wPI_i)^2 + 1.312(wPI_i) + 13.86$

$wPI_i = \mu_{wPI} + \vartheta(\sigma_{wPI})$

$\beta = 2.56075(P_{200_i}) + 393.4625$

$\gamma = 0.09625(P_{200_i}) + 132.4875$

$\delta = 0.025(P_{200_i}) + 14.75$

ϑ is a point estimation variable

$$\sigma_{\psi}^{2}=\frac{\left(\sum_{i=1}^{n}\left(\alpha+e^{\left[\beta+\gamma\left(TMI_i+101\right)\right]}\right)^{2}-\frac{\left(\sum_{i=1}^{n}\left(\alpha+e^{\left[\beta+\gamma\left(TMI_i+101\right)\right]}\right)\right)^{2}}{n}\right)}{n-1}\text{.....}(4.61)$$

$$\sigma_{\psi}^{2}=\frac{1}{n-1}\left(\left(\sum_{i=1}^{n}\left(\alpha\left[e^{\left[\frac{\beta}{TMI_i+\gamma}\right]}+\delta\right]\right)\right)-\frac{\left(\sum_{i=1}^{n}\left(\alpha\left[e^{\left[\frac{\beta}{TMI_i+\gamma}\right]}+\delta\right]\right)\right)^{2}}{n}\right)(4.62)$$

4.5.2.3 Volumetric Water Content

As stated previously, the volumetric water content of the soil relies on the hierarchical level chosen as well as the *w*PI of the soil. The generalized mean of the volumetric water content, which is described by Fredlund and Xing's fitting, is described by Equation 4.63. The variance of the volumetric water content is determined by Equation 4.64.

$$\mu_{\theta_w}=\frac{1}{n}\left[\sum_{i=1}^{n}C(h)_i\,x\left[\frac{\theta_{s_i}}{\left[\left[\ln\left[\exp(1)+\left(\frac{\psi_i}{a_{f_i}}\right)^{b_{f_i}}\right]\right]\right]^{c_{f_i}}}\right]\right]\text{..........................}(4.63)$$

Where:

$$C(h)_i = \left[1 - \frac{\ln\left(1 + \frac{\psi_i}{h_r}\right)}{\ln\left(1 + \frac{1x10^6}{h_r}\right)} \right]$$

$$\psi_i = \mu_\psi + \varepsilon(\sigma_\psi)$$

$$\theta_{si} = \mu_{\theta_s} + \delta(\sigma_{\theta_s})$$

$$a_{f_i} = \mu_{a_{f_i}} + \alpha(\sigma_{a_{f_i}})$$

$$b_{f_i} = \mu_{b_{f_i}} + \beta(\sigma_{b_{f_i}})$$

$$c_{f_i} = \mu_{c_{f_i}} + \chi(\sigma_{c_{f_i}})$$

$\alpha, \beta, \chi, \delta, \varepsilon$ are point estimation variables

$$\sigma_{\theta_w}^2 = \frac{1}{n-1}\left(\sum_{i=1}^{n}\left[\frac{Ch_i\theta_{s_i}}{\left[\ln\left[e+\left(\frac{\psi_i}{a_{f_i}}\right)^{b_{f_i}}\right]\right]^{c_{f_i}}} \right]^2 - \frac{1}{n}\left(\sum_{i=1}^{n} \frac{Ch_i\theta_{s_i}}{\left[\ln\left[e+\left(\frac{\psi_i}{a_{f_i}}\right)^{b_{f_i}}\right]\right]^{c_{f_i}}} \right)^2 \right) \qquad \text{..............................(4.64)}$$

4.5.2.3.1 Level 1

The volumetric water content, for the hierarchical level 1, will utilize Equation 4.63 and 4.64. The 2-Point estimation will need a total of 32 combinations, while the 3-Point estimation will need 243 combinations to obtain the mean and variance of the volumetric water content.

4.5.2.3.2 Levels 2 and 3 *w*PI > 2.0

Similar to Level 1, the volumetric water content mean and variance is described by Equation 4.63 and 4.64, respectively. However, the 2-Point estimation, of Level 2 and 3soils with *w*PI > 2.0, will require 8 combinations, while the 3-Point estimation will require 27 combinations. The changes between Level 1 and Levels 2 and 3 is that the fitting parameters a_{f_i}, b_{f_i}, and c_{f_i} are now a function of the *w*PI of the soil instead of the fitting that is associated with the SWCC. The fitting parameter equation are shown in Equations 4.65 – 3.67.

$$a_f = 32.835(\ln(wPI_i)) + 32.438 \qquad (4.65)$$

$$b_f = 1.421 wPI_i^{-0.3185} \qquad (4.66)$$

$$c_f = -0.2154(\ln(wPI_i)) + 0.07145 \qquad (4.67)$$

Where:

$wPI_i = \mu_{wPI} + \alpha(\sigma_{wPI})$

α is a point estimation variable

4.5.2.3.3 Levels 2 and 3 with *w*PI < 2.0

The volumetric water content for Levels 2 and 3 soils with *w*PI < 2.0 will use the same constraints that are listed in the Taylor Series sub-section. In either case, volumetric water content is a function of either the P_{200} or the TMI of the site and the P_{200}. If the volumetric water content is a function of the TMI and P_{200}, it will utilize Equation 4.68 for the mean and Equation 4.69 for the variance of the volumetric water content; however, if the volumetric water content is only a function of P_{200}, it will utilize Equation 4.70 for the mean and Equation 4.71 for variance of the volumetric water content.

$$\mu_{\theta_w} = \left(\frac{1}{n}\right)\sum_{i=1}^{n}\left(4 + 1.5P_{200i}^{0.6994} + 0.03TMI_i\right) \qquad (4.68)$$

Where:

n = 4 for 2-Point estimation or n = 9 for 3-Point estimation

$$\sigma_{\theta_w}^2 = \left(\frac{1}{n-1}\right)\left(\sum_{i=1}^{n}\left(4+1.5P_{200i}^{0.6994}+0.03TMI_i\right)^2 - \frac{\left(\sum_{i=1}^{n}\left(4+1.5P_{200i}^{0.6994}+0.03TMI_i\right)\right)^2}{n}\right) \quad \text{........................(4.69)}$$

$$\mu_{\theta_w} = \left(\frac{1}{n}\right)\sum_{i=1}^{n}\left(40+0.11\left(P_{200i}-53\right)\right) \quad \text{..(4.70)}$$

n = 2 for 2-Point estimation or n = 3 for 3 – Point estimation

$$\sigma_{\theta_w}^2 = \left(\frac{1}{n-1}\right)\left(\sum_{i=1}^{n}\left(40+0.11\left(P_{200i}-53\right)\right)^2 - \frac{\left(\sum_{i=1}^{n}\left(40+0.11\left(P_{200i}-53\right)\right)\right)^2}{n}\right) \quad \text{................................(4.71)}$$

4.5.2.4 Saturated Volumetric Water Content

As stated earlier, the saturated volumetric water content or the porosity of the soil is independent of the hierarchical level. The mean of the porosity is calculated by Equation 4.72 and the variance is calculated using Equation 4.73.

$$\mu_{\theta_{sat}} = \left(\frac{1}{n}\right)\sum_{i=1}^{n}\left(1-\frac{\gamma_{dry_i}}{\gamma_{G_{si}} * \gamma_{water}}\right) \quad \text{...(4.72)}$$

Where:

n = 4 for 2-Point estimation or n = 9 for 3-Point estimation

$\gamma_{dry_i} = \mu_{dry_i} + \alpha(\sigma_{dry_i})$

$G_{s_i} = \mu_{G_{s_i}} + \beta(\sigma_{G_{s_i}})$

α, β are point estimation variables

$$\sigma^2_{\theta_{sat}} = \frac{\left(\sum_{i=1}^{n} \left(1 - \frac{\gamma_{dry_i}}{\gamma_{G_{si}} * \gamma_{water}} \right)^2 - \frac{\left(\sum_{i=1}^{n} \left(1 - \frac{\gamma_{dry_i}}{\gamma_{G_{si}} * \gamma_{water}} \right) \right)^2}{n} \right)}{n-1} \quad \text{.........(4.73)}$$

4.5.2.5 Degree of Saturation

The degree of saturation, as well as the porosity is independent of the hierarchical level chosen. The mean degree of saturation is calculated utilizing Equation 4.74, while the variance of the degree of saturation is calculated using Equation 4.75.

$$\mu_{\%S} = \left(\frac{1}{n} \right) \sum_{i=1}^{n} \left(\frac{\theta_{w_i}}{\theta_{sat_i}} \right) \quad \text{...(4.74)}$$

Where:

n = 4 for 2-Point estimation or n = 9 for 3-Point estimation

$\theta_{w_i} = \mu_{\theta_w} + \alpha(\sigma_{\theta_w})$

$\theta_{sat_i} = \mu_{\theta_{sat}} + \beta(\sigma_{\theta_{sat}})$

α, β are point estimation variables

$$\sigma_{\%S}^2 = \frac{1}{n-1}\left(\sum_{i=1}^{n}\left(\frac{\theta_{w_i}}{\theta_{sat_i}}\right)^2 - \frac{\left(\sum_{i=1}^{n}\left(\frac{\theta_{w_i}}{\theta_{sat_i}}\right)\right)^2}{n}\right) \qquad (4.75)$$

4.5.2.6 Soil Compaction and Optimum Saturation

The soil compaction and the optimum saturation will follow the same constraints that are outlined in the Taylor Series sub-section. The mean optimum saturation for Level 1 and Levels 2 and 3 with soils have any plasticity are outlined in Equation 4.76, while Levels 2 and 3 with soils without plasticity mean optimum saturation is outlined in Equation 4.77 respectively. The variance of the optimum saturation for Level 1 and Levels 2 and 3 soils with plasticity is outlined in Equation 4.78, while Levels 2 and 3 soils without plasticity will be calculated using Equation 4.79.

$$\mu_{S_{opt}} = \left(\frac{1}{n}\right)\sum_{i=1}^{n}\left(\frac{w_{opt_i}}{\frac{\gamma_w}{\gamma_{d\max_i}} + \frac{1}{G_{s_i}}}\right) \qquad (4.76)$$

Where:

n = 8 for 2-Point estimation or n = 27 for 3-Point estimation

$w_{opt_i} = \mu_{w_{opt}} + \alpha(\sigma_{w_{opt}})$

$$\gamma_{d\max_i} = \mu_{\gamma_{d\max}} + \beta\left(\sigma_{\gamma_{d\max}}\right)$$

$$G_{s_i} = \mu_{G_s} + \chi\left(\sigma_{G_s}\right)$$

$$\mu_{S_{opt}} = \left(\frac{1}{n}\right)\sum_{i=1}^{n}\left(-100.17 + 1.4991P_{2''_i} + 0.56155P_{1''_i} - 0.36755P_{0.5''_i}\right) \quad (4.77)$$

Where:

n = 8 for 2-Point estimation or n = 27 for 3-Point estimation

$$P_{2''_i} = \mu_{P_{2''}} + \alpha\left(\sigma_{P_{2''}}\right)$$

$$P_{1''_i} = \mu_{P_{1''}} + \beta\left(\sigma_{P_{1''}}\right)$$

$$P_{0.5''_i} = \mu_{P_{0.5''}} + \chi\left(\sigma_{P_{0.5''}}\right)$$

α, β, χ are point estimation variables

$$\sigma^2_{S_{opt}} = \frac{1}{n-1}\left(\sum_{i=1}^{n}\left(\frac{w_{opt_i}}{\frac{\gamma_w}{\gamma_{d\max_i}} + \frac{1}{G_{s_i}}}\right)^2 - \frac{\left(\sum_{i=1}^{n}\left(\frac{w_{opt_i}}{\frac{\gamma_w}{\gamma_{d\max_i}} + \frac{1}{G_{s_i}}}\right)\right)^2}{n}\right) \quad ......(4.78)$$

$$\sigma^2_{S_{opt}} = \frac{1}{n-1}\left(\begin{array}{l} \sum_{i=1}^{n}\left(-100.17 + 1.4991P_{2"_i} + 0.56155P_{1"_i} - 0.36755P_{0.5"_i}\right)^2 \\ -\dfrac{\left(\sum_{i=1}^{n}\left(-100.17 + 1.4991P_{2"_i} + 0.56155P_{1"_i} - 0.36755P_{0.5"_i}\right)\right)^2}{n} \end{array} \right) \quad (4.79)$$

4.5.2.6.1 Levels 2 and 3 with *w*PI = 0.0

The mean optimum moisture content for soils without plasticity is a function of the particle size and percent passing certain sieve sizes, which is shown in Equation 4.80. The variance of the optimum moisture content is calculated using Equation 4.81. The maximum dry density is a function of the optimum saturation, the specific gravity of the soil solids and the optimum moisture. The mean maximum dry density is calculated using Equation 4.82 and the variance of the maximum dry density is calculated using Equation 4.83.

$$\mu_{w_{opt}} = \frac{1}{n}\sum_{i=1}^{n}\left(\begin{array}{l} -120.14 - 0.06766P_{1.5"_i} + 3.7269D_{60_i} \\ -0.167P_{\#40_i} + 0.117P_{\#60_i} + 142.53e^{\left(-0.0389*D_{60_i}\right)} \end{array} \right) \quad ..(4.80)$$

Where:

n = 16 for 2-Point estimation or n = 81 for 3-Point estimation

$P_{1.5"_i} = \mu_{P_{1.5"}} + \alpha\left(\sigma_{P_{1.5"}}\right)$

$D_{60_i} = \mu_{D_{60}} + \beta\left(\sigma_{D_{60}}\right)$

$P_{\#40_i} = \mu_{P_{\#40}} + \chi\left(\sigma_{P_{\#40}}\right)$

$$P_{\#60_i} = \mu_{P_{\#60}} + \delta\left(\sigma_{P_{\#60}}\right)$$

$$\sigma^2_{w_{opt}} = \frac{1}{n-1}\left(\left(\sum_{i=1}^{n}\begin{pmatrix}-120.14-0.06766P_{1.5''_i}+3.7269D_{60_i}\\ -0.167P_{\#40_i}+0.117P_{\#60_i}+142.53e^{\left(-0.0389*D_{60_i}\right)}\end{pmatrix}^2 - \left(\frac{\sum_{i=1}^{n}\begin{pmatrix}-120.14-0.06766P_{1.5''_i}+3.7269D_{60_i}\\ -0.167P_{\#40_i}+0.117P_{\#60_i}+142.53e^{\left(-0.0389*D_{60_i}\right)}\end{pmatrix}}{n}\right)^2\right)\right) \quad (4.81)$$

$$\mu_{\gamma_{d\max}} = \left(\frac{1}{n}\right)\sum_{i=1}^{n}\left(\frac{G_{s_i}\left(\gamma_{water}\right)}{1+\frac{w_{opt_i}G_{s_i}}{S_{opt_i}}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.82)$$

$$\sigma^2_{\gamma_{d\max}} = \left(\frac{1}{n-1}\right)\left(\sum_{i=1}^{n}\left(\frac{G_{s_i}\left(\gamma_{water}\right)}{1+\frac{w_{opt_i}G_{s_i}}{S_{opt_i}}}\right) - \frac{1}{n}\left(\sum_{i=1}^{n}\left(\frac{G_{s_i}\left(\gamma_{water}\right)}{1+\frac{w_{opt_i}G_{s_i}}{S_{opt_i}}}\right)\right)^2\right) \ldots\ldots (4.83)$$

Where:

n = 8 for 2-Point estimation and n = 27 for 3-Point estimation

$$S_{opt_i} = \mu_{S_{opt}} + \varepsilon\left(\sigma_{S_{opt}}\right)$$

ε is a point estimation variable

4.5.2.6.1 Levels 2 and 3 with *w*PI > 0.0

The mean optimum saturation will use Equation 4.78; however, to calculate the optimum saturation it will require the adjusted PI to be calculated, which is then used in the calculation of the optimum moisture content. After, the mean optimum moisture content is calculated; the maximum dry density is then calculated using correlations between the optimum moisture content and the maximum dry density. The mean and variance of the adjusted PI is shown in Equations 4.84 and 4.85 respectively. The mean optimum moisture content utilizes the adjusted *w*PI, which the constraints are outlined in chapter 2. To calculate the mean optimum moisture content, it utilizes Equation 4.86; while the variance of the optimum moisture content is calculated by Equation 4.87.

$$\mu_{PI_{adj}} = \frac{1}{n}\sum_{i=1}^{n}\left(e^{\frac{P_{200_i}+42.13}{33.94}}\right) \quad \text{...(4.84)}$$

Where:

n = 2 for 2-Point estimation or n = 3 for 3-Point estimation

$$\sigma^2_{PI_{adj}} = \frac{1}{n-1}\left(\sum_{i=1}^{n}\left(e^{\frac{P_{200_i}+42.13}{33.94}}\right)^2 - \frac{\left(\sum_{i=1}^{n}\left(e^{\frac{P_{200_i}+42.13}{33.94}}\right)\right)^2}{n}\right) \quad \text{............(4.85)}$$

$$\mu_{w_{opt}} = \frac{1}{n}\sum_{i=1}^{n}\left(8.3932wPI_{adj_i}^{0.3075}\right) \ldots\ldots (4.86)$$

Where:

n = 2 for 2-Point estimation or n = 3 for 3-Point estimation

$$wPI_{adj_i} = \mu_{wPI_{adj}} + \alpha\left(\sigma_{wPI_{adj}}\right)$$

$$\mu_{wPI_{adj}} = \frac{\left(e^{\frac{\mu_{P_{200}}+42.13}{33.94}}\right)\mu_{P_{200}}}{100} \text{ or } \mu_{wPI_{adj}} = \frac{\mu_{P_{200}}\left(\mu_{PI}\right)}{100}$$

$$\sigma^2_{w_{opt}} = \frac{1}{n-1}\left(\sum_{i=1}^{n}\left(8.3932wPI_{adj_i}^{0.3075}\right)^2 - \frac{\left(\sum_{i=1}^{n}\left(8.3932wPI_{adj_i}^{0.3075}\right)\right)^2}{n}\right) \ldots\ldots (4.87)$$

After calculating the mean and variance of the optimum moisture content, the maximum dry density mean and variance can be calculated. The mean maximum dry density is calculated using Equation 4.88, while the variance is calculated using Equation 4.89.

$$\mu_{\gamma_{dry}} = \gamma_{dry\max\_comp\_std} = \frac{1}{n}\sum_{i=1}^{n}\left(142.115 - 1.959w_{opt_i}\right) \ldots\ldots (4.88)$$

Where:

n = 2 for 2-Point estimation or n = 3 for 3-Point estimation

$$w_{opt_i} = \mu_{w_{opt}} + \alpha\left(\sigma_{w_{opt}}\right)$$

α is the point estimation variable

$$\sigma^2_{\gamma_{dry}} = \frac{1}{n-1}\left(\sum_{i=1}^{n}\left(142.115 - 1.959 w_{opt_i}\right)^2 - \frac{\left(\sum_{i=1}^{n}\left(142.115 - 1.959 w_{opt_i}\right)\right)^2}{n}\right) \quad (4.89)$$

4.5.2.7 Environmental Factor

The environmental factor is a function of the *w*PI, the degree of saturation, and the optimum saturation, of the soil. The mean environmental factor of the soil is calculated using Equation 4.90 and the variance of the environmental factor is calculated using Equation 4.91.

$$\mu_{F_{env}} = \frac{1}{n}\sum_{i=1}^{n}\left(10^{1.002x\left[\alpha^{-1} + \frac{\beta - \alpha^{-1}}{1 + e^{\ln\left(\frac{-\beta}{\alpha^{-1}}\right) + \gamma\left(\frac{\%S_i - S_{opt_i}}{100}\right)}}\right]}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.90)$$

Where:

n = 8 for 2-Point estimation or n = 27 for 3-Point estimation

$$\alpha = (-0.6) + (-1.87194)e^{-wPI_i}$$

$$\beta = 0.8 + 0.08\left(wPI_i\right)^{0.5}$$

$$\gamma = \left(11.96518 + (-10.19111)e^{-wPI_i}\right)^{0.5}$$

$$\%S_i = \mu_{\%S} + \chi\left(\sigma_{\%S}\right)$$

$$S_{opt} = \mu_{S_{opt}} + \delta\left(\sigma_{S_{opt}}\right)$$

χ, δ are point estimation variables

$$\sigma^2_{F_{env}} = \frac{1}{n-1}\sum_{i=1}^{n}\left(10^{1.002x\left(\alpha^{-1}+\frac{\beta-\alpha^{-1}}{1+e^{\ln\left(\frac{-\beta}{\alpha^{-1}}\right)+\gamma\left(\frac{\%S_i-S_{opt_i}}{100}\right)}}\right)}\right)^2 - \frac{1}{n(n-1)}\left(\sum_{i=1}^{n}10^{1.002x\left(\alpha^{-1}+\frac{\beta-\alpha^{-1}}{1+e^{\ln\left(\frac{-\beta}{\alpha^{-1}}\right)+\gamma\left(\frac{\%S_i-S_{opt_i}}{100}\right)}}\right)}\right)^2 \quad \text{.......................(4.91)}$$

4.5.2.8 Resilient Modulus at Optimum

As stated earlier, the mean resilient modulus at optimum will be calculated using NCHRP 1-28A testing protocol, for Level 1. Once the testing protocol is completed a project coefficient of variation will be applied to obtain the standard deviation, which is squared to obtain the variance of the resilient modulus at optimum.

4.5.2.8.1 Levels 2 and 3 *w*PI = 0.0

The resilient modulus for soils without any plasticity for Levels 2 and 3 are a function of the diameter size that corresponds to the 60 percent passing. The mean resilient modulus at optimum is calculated using Equation 4.92 and the variance of the resilient modulus at optimum is calculated using Equation 4.93.

$$\mu_{M_{Ropt}} = \frac{1}{n}\sum_{i=1}^{n}\left(M_{in-situ_i}\left[2.11 - 2.78x10^{-5} M_{in-situ_i}\right]\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.92)$$

Where:

n = 2 for 2-Point estimation or n = 3 for 3-Point estimation

$$\mu_{M_{in-situ}} = 2555\left(28.09\left(D_{60_i}\right)^{0.358}\right)^{0.64}$$

$$\sigma^2_{M_{Ropt}} = \frac{1}{n-1}\left(\begin{array}{c}\sum_{i=1}^{n}\left(M_{in-situ_i}\left[2.11 - 2.78x10^{-5} M_{in-situ_i}\right]\right)^2 \\ -\frac{\left(\sum_{i=1}^{n}\left(M_{in-situ_i}\left[2.11 - 2.78x10^{-5} M_{in-situ_i}\right]\right)\right)^2}{n}\end{array}\right) \ldots (4.93)$$

4.5.2.8.2 Levels 2 and 3 *w*PI > 0.0

The mean and variance of the Levels 2 and 3 soils with plasticity will be calculated using Equations 4.92 and 4.93; however, the $M_{in\text{-}situ}$ changes due to the increase in plasticity. The changes in $M_{in\text{-}situ}$ are reflected in Equation 4.94.

$$\mu_{M_{in-situ}} = 2555\left(\frac{75}{1 + 0.728wPI_i}\right)^{0.64} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.94)$$

4.5.2.9 Resilient Modulus at Equilibrium

The mean resilient modulus at equilibrium is a function of the resilient modulus at optimum as well as the environmental factor for the given layer. For a given hierarchical level, the mean and variance of the resilient modulus at equilibrium is independent of the level chosen; instead the mean and variance equations for the resilient modulus at equilibrium are the same for all three levels. The mean resilient modulus at equilibrium is calculated using Equation 4.95, and the variance is calculated using Equation 4.96.

$$\log\left(\mu_{M_{\mathrm{Re}q}}\right) = \frac{1}{n}\sum_{i=1}^{n}\log\left(F_{env_i}\left(M_{Ropt_i}\right)\right) \qquad (4.95)$$

Where:

n = 4 for 2-Point estimation or n = 9 for 3-Point estimation

$F_{env_i} = \mu_{F_{env}} + \alpha\left(\sigma_{F_{env}}\right)$

$M_{Ropt_i} = \mu_{M_{Ropt}} + \beta\left(\sigma_{M_{Ropt}}\right)$

α, β are point estimation variables

$$\log\left(\sigma^2_{M_{\mathrm{Re}q}}\right) = \frac{1}{n-1}\left(\sum_{i=1}^{n}\log\left(F_{env_i}\left(M_{Ropt_i}\right)\right)^2 - \frac{\left(\sum_{i=1}^{n}\log\left(F_{env_i}\left(M_{Ropt_i}\right)\right)\right)^2}{n}\right) \qquad (4.96)$$

4.5.3 Monte Carlo Simulation

The Monte Carlo Simulation requires a computer program to handle the multiple simulations that are required for convergence of the mean. The Monte Carlo Simulation utilizes the beta distribution since the beta distribution bounds the shape of the distribution between a minimum and a maximum value. Normally, the Monte Carlo Simulation is coupled with the normal distribution, which normally has no problem. In Figure 4.5 is an example of October’s precipitation for Phoenix, AZ showing both the normal distribution and the beta distribution, on the same frequency distribution plot. The mean precipitation is 1.503-cm while the precipitation standard deviation 2.335-cm, which when using a normal distribution the left tail of the distribution is negative. Precipitation and certain soil properties in reality are never negative; however, using normal probability, the precipitation and the soil properties can be possibly negative. The soil properties that cannot be negative include: percent passing all sieve sizes, degree of saturation, optimum saturation, and optimum moisture content.

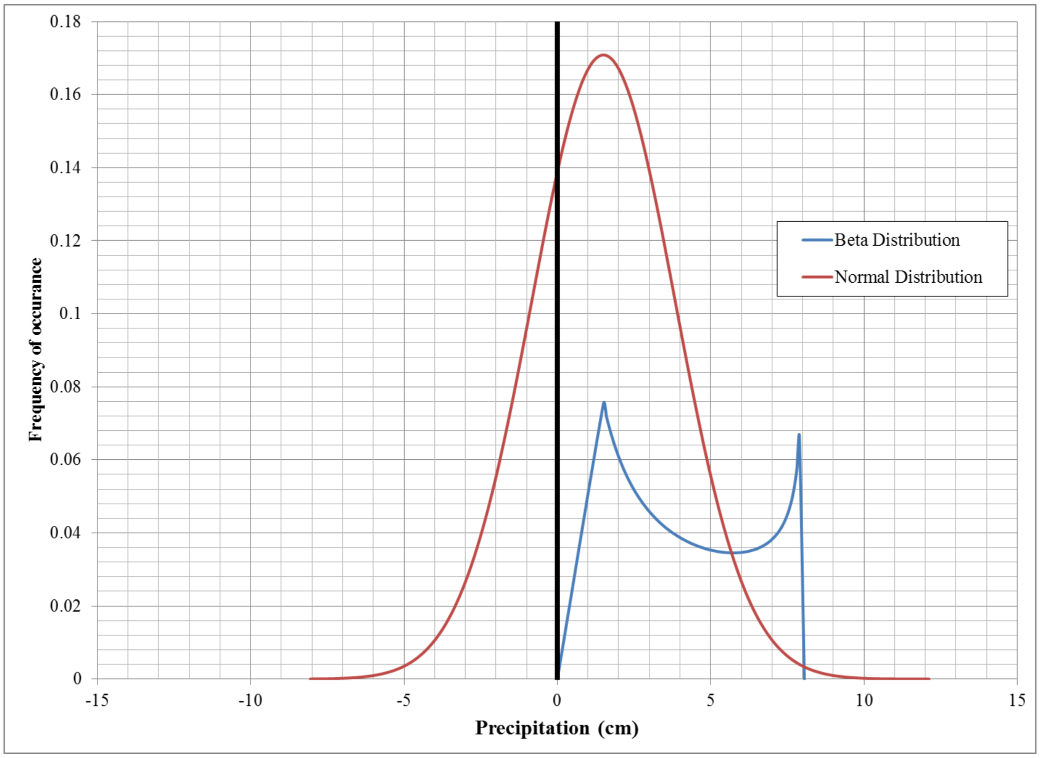

Figure 4.4: Differences between the normal and beta distribution.

As seen in Figure 4.5, there is a portion of the normal distribution that is negative, which is attributed to a having a mean of the independent variable that is with three standard deviations from zero or on the other extreme, for soils, near one hundred. Therefore, by only using the beta distribution with the Monte Carlo Simulation it will keep the soil properties and precipitation bounded between reasonable upper and lower bounds.

Regardless, of the hierarchical level or model, the number of simulations is dependent on a user input. To have convergence of the mean, it requires a minimum of 25,000 simulations, which was discussed in Chapter 2.4.4.

4.5.3.1 Thornthwaite Moisture Index

The mean of the TMI will use the same mean equation that was used to calculate the mean in the Rosenblueth, which is Equation 4.51. However, the variance associated with TMI will utilize Equation 4.97 instead of Equation 4.52.

$$\sigma_{TMI}^{2} = \frac{1}{n-1}\sum_{i=1}^{n}\left(TMI_i - \mu_{TMI}\right) \quad (4.97)$$

Where:

n is the number of simulations

TMI_i is the ith TMI simulation from the Monte Carlo Simulation

μ_{TMI} is the mean of TMI

Although, the mean of the precipitation and potential evapotranspiration, and the annual heat index remain the same, the variance of these three variables will be outlined in the following equations. Equation 4.98 corresponds to the variance of the precipitation Equation 4.99 corresponds to the variance of the potential evapotranspiration, and Equation 4.100 corresponds to the variance of the annual heat index.

$$\sigma_{P_y}^{2} = \frac{1}{n-1}\sum_{i=1}^{n}\left(P_{y_i} - \mu_{P_y}\right)^{2} \quad (4.98)$$

Where:

n is the number of simulations

$P_{y_i} = P_{y_{\min}} + \alpha\left(P_{y_{\max}} - P_{y_{\min}}\right)$ and is the ith Precipitation simulation

α is the Monte Carlo point estimation

μ_{P_y} is the mean precipitation for the site

$$\sigma_{PE}^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(PE_i - \mu_{PE}\right)^2 \quad \text{...(4.99)}$$

Where

n is the number of simulations

$PE_i = PE_{\min} + \alpha\left(PE_{\max} - PE_{\min}\right)$an is the ith PE simulation

α is the Monte Carlo point estimation

μ_{PE} is the mean PE for the site

$$\sigma_{H_y}^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(H_{y_i} - \mu_{H_y}\right)^2 \quad \text{...(4.100)}$$

Where:

n is the number of simulations

$H_{y_i} = H_{y_{\min}} + \alpha\left(H_{y_{\max}} - H_{y_{\min}}\right)$ and is the ith annual heat index simulation

α is the Monte Carlo point estimation

μ_{H_y} is the mean annual heat index for the site

4.5.3.2 TMI-Matric Suction

The matric suction of the soil is dependent on the layer location, when the layer is a base layer, it will use Equation 4.59. On the other hand, if the layer is a non-base layer with plasticity the mean will be calculated using Equation 4.60 and if the non-base layer had no plasticity, it will use Equation 4.60 as well for the calculation of the mean. Regardless of the mean equation, the variance of the matric suction will be calculated using Equation 4.101. In addition to the variance equation changing the P_{200i}, the *w*PI_i and TMI changes as well. These changes are reflected in Equations 4.102, 3.103, and 4.104 respectively.

$$\sigma_{\psi}^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(\psi_i - \mu_{\psi}\right)^2 \quad \text{..(4.101)}$$

Where:

n is the number of simulations

ψ_i is the ith ψ simulation from the Monte Carlo Simulation

μ_{ψ} is mean of the Matric Suction of the given layer

$$P_{200_i} = P_{200_{\min}} + \alpha\left(P_{200_{\max}} - P_{200_{\min}}\right) \text{...(4.102)}$$

$$wPI_i = wPI_{\min} + \alpha\left(wPI_{\max} - wPI_{\min}\right) \text{ ....(4.103)}$$

$$TMI_i = TMI_{\min} + \alpha\left(TMI_{\max} - TMI_{\min}\right) \text{...(4.104)}$$

Where:

α is the Monte Carlo point estimation

4.5.3.3 Volumetric Water Content

The mean of the volumetric water content will use Equation 4.63 to determine the mean, while the variance will use Equation 4.105.

$$\sigma_{\theta_w}^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(\theta_{wi} - \mu_{\theta_w}\right)^2 \text{...(4.105)}$$

Where:

n is the number of simulations

θ_{wi} is the ith volumetric water content simulation

μ_{θ_w} is the mean volumetric water content simulation

4.5.3.3.1 Level 1

With the changes of the variance so does the equation that describe the porosity, the four Fredlund and Xing fitting parameters as well as the changes in the equation that describes the matric suction. Equation 4.106 through Equation 4.110 describes the changes from the Rosenblueth point estimation to the Monte Carlo simulation.

$$\theta_{si} = \theta_{s\min} + \alpha\left(\theta_{s\max} - \theta_{s\min}\right) \text{...(4.106)}$$

Where:

α is the Monte Carlo point estimation

$$a_{f_i} = a_{f\min} + \beta\left(a_{f\max} - a_{f\min}\right) \text{...} (4.107)$$

Where:

β is the Monte Carlo point estimation

$$b_{f_i} = b_{f\min} + \chi\left(b_{f\max} - b_{f\min}\right) \text{...} (4.108)$$

Where:

χ is the Monte Carlo point estimation

$$c_{f_i} = c_{f\min} + \delta\left(c_{f\max} - c_{f\min}\right) \text{...} (4.109)$$

Where:

δ is the Monte Carlo point estimation

$$\psi_i = \psi_{\min} + \varepsilon\left(\psi_{\max} - \psi_{\min}\right) \text{...} (4.110)$$

Where:

ε is the Monte Carlo point estimation

4.5.3.3.2 Levels 2 and 3 *w*PI > 2.0

The changes in the variance equation change the following independent random variables: the porosity of the soil, the matric suction of the soil, and the *w*PI of soil. These changes are reflected in Equations 4.104, 3.106, and 4.110 respectively. The mean of the volumetric water content will still utilize Equation 4.63.

4.5.3.3.3 Levels 2 and 3 with *w*PI < 2.0

Unlike the Level 1 and Levels 2 and 3 with *w*PI > 2.0, it relies on the correlations of TMI and P_{200}. The mean of the volumetric water content of utilizes Equation 4.68 or 3.70, depending on the constraints. Nevertheless, the variance of the volumetric water content will be calculated using Equations 4.102 and 4.104 in the calculation of the mean.

4.5.3.4 Saturated Volumetric Water Content

The saturated volumetric water content is independent of the hierarchical level that is chosen. The saturated volumetric water content mean is calculated using Equation 4.72. The variance of the saturated volumetric water content is calculated utilizing Equation 4.111. The changes in the calculations are reflected in the calculation of the mean value. These changes are reflected in Equations 4.112 and 4.113.

$$\sigma^2_{\theta_{sat}} = \frac{1}{n-1}\sum_{i=1}^{n}\left(\theta_{sat_i} - \mu_{\theta_{sat}}\right)^2 \quad \text{...(4.111)}$$

Where:

n is the number of simulations

θ_{sat_i} is the ith saturated volumetric water content simulation

$\mu_{\theta_{sat}}$ is the mean saturated volumetric water content simulation

$$\gamma_{dry_i} = \gamma_{dry_{\min}} + \alpha\left(\gamma_{dry_{\max}} - \gamma_{dry_{\min}}\right) \ldots\ldots (4.112)$$

Where:

α is the Monte Carlo point estimation

$$G_{S_i} = G_{S_{\min}} + \beta\left(G_{S_{\max}} - G_{S_{\min}}\right) \ldots\ldots (4.113)$$

Where:

β is the Monte Carlo point estimation

4.5.3.5 Degree of Saturation

The degree of saturation is independent of the hierarchical level. The mean of the degree of saturation is calculated using 3.74. The variance of the degree of saturation is calculated using Equation 4.114. With the changes, the independent variables both the volumetric water content and the saturated water content are randomized by using Equations 4.115 and 4.116 respectively.

$$\sigma^2_{\%S} = \frac{1}{n-1}\sum_{i=1}^{n}\left(\%S_i - \mu_{\%S}\right)^2 \ldots\ldots (4.114)$$

Where:

n is the number of simulations

$\%S_i$ is the ith degree of saturation simulation

$\mu_{\%S}$ is the mean degree saturation

$$\theta_{wi} = \theta_{w\min} + \alpha\left(\theta_{w\max} - \theta_{w\min}\right) \quad (4.115)$$

Where:

α is the Monte Carlo point estimation

$$\theta_{sat\,i} = \theta_{sat\min} + \beta\left(\theta_{sat\max} - \theta_{sat\min}\right) \quad (4.116)$$

Where:

β is the Monte Carlo point estimation

4.5.3.6 Soil Compaction and Optimum Saturation

The soil compaction and the optimum saturation will follow the same constraints that are outlined in the Taylor Series sub-section. The mean optimum saturation for Level 1 and Levels 2 and 3 with soils have any plasticity are outlined in Equation 4.76, while Levels 2 and 3 with soils without plasticity mean optimum saturation is outlined in Equation 4.77 respectively. The variance of the optimum saturation, regardless, of the hierarchical level chosen, will utilize Equation 4.117.

$$\sigma^2_{S_{opt}} = \frac{1}{n-1}\sum_{i=1}^{n}\left(S_{opt_i} - \mu_{S_{opt}}\right)^2 \quad (4.117)$$

Where:

n is the number of simulations

S_{opt_i} is the ith optimum saturation simulation from either Equation 4.76 or 3.77

$\mu_{S_{opt}}$ is the optimum saturation mean

However, when Equation 4.77 is modified the Equations 4.118 through Equation 4.120 are modified as well, these are the soil properties that estimate the optimum saturation. It was coded in the program that the percent passing two inch will always be greater than the one inch and the one inch will always be greater than the half inch sieve. This was done to insure the grain size distribution does not have any inflection points. Nevertheless, the simulations were randomized and when the smaller sieve percent passing were larger that the larger sieves percent passing, the simulation of that particular sieve was re-randomized until the smaller sieves percent passing were smaller that the large sieve percent passing.

$$P_{2''_i} = P_{2''_{\min}} + \alpha\left(P_{2''_{\max}} - P_{2''_{\min}}\right) \quad \text{(4.118)}$$

Where:

α is the Monte Carlo point estimation

$$P_{1''_i} = P_{1''_{\min}} + \beta\left(P_{1''_{\max}} - P_{1''_{\min}}\right) \quad \text{(4.119)}$$

Where:

β is the Monte Carlo point estimation

$$P_{0.5''_i} = P_{0.5''_{\min}} + \chi\left(P_{0.5''_{\max}} - P_{0.5''_{\min}}\right) \quad \text{(4.120)}$$

Where:

χ is the Monte Carlo point estimation

4.5.3.6.1 Levels 2 and 3 with *w*PI = 0.0

The optimum moisture content mean is calculated using Equation 4.80; however the soil property estimation change. These changes are reflected in Equations 4.121 through Equation 4.124. Once the changes are complete, the variance of the optimum moisture content is calculated using Equation 4.125 instead of Equation 4.80.

$$P_{1.5''_i} = P_{1.5''_{\min}} + \alpha\left(P_{1.5''_{\max}} - P_{1.5''_{\min}}\right) \text{......................................} (4.121)$$

Where:

α is the Monte Carlo point estimation

$$D_{60_i} = D_{60_{\min}} + \beta\left(D_{60_{\max}} - D_{60_{\min}}\right) \text{......................................} (4.122)$$

Where:

β is the Monte Carlo point estimation

$$P_{\#40_i} = P_{\#40_{\min}} + \chi\left(P_{\#40_{\max}} - P_{\#40_{\min}}\right) \text{......................................} (4.123)$$

Where:

χ is the Monte Carlo point estimation

$$P_{\#60_i} = P_{\#60_{\min}} + \delta\left(P_{\#60_{\max}} - P_{\#60_{\min}}\right) \quad (4.124)$$

Where:

δ is the Monte Carlo point estimation

$$\sigma^2_{w_{opt}} = \frac{1}{n-1}\sum_{i=1}^{n}\left(w_{opt_i} - \mu_{w_{opt}}\right)^2 \quad (4.125)$$

Where:

n is the number of simulations

w_{opt_i} is the i^th^ optimum moisture content simulation

$\mu_{w_{opt}}$ is the mean optimum moisture content

Once the optimum moisture content is calculated, the maximum dry density mean is calculated using Equation 4.82, while the variance of the maximum dry density is calculated utilizing Equation 4.126.

$$\sigma^2_{\gamma_{d\max}} = \frac{1}{n-1}\sum_{i=1}^{n}\left(\gamma_{d\max_i} - \mu_{\gamma_{d\max}}\right)^2 \quad (4.126)$$

Where:

n is the number of simulations

$\gamma_{d\max_i}$ is the ith maximum dry density simulation

$\mu_{\gamma_{d\max}}$ is the mean maximum dry density

4.5.3.6.2 Levels 2 and 3 with *w*PI > 0.0

When the soils have plasticity or a *w*PI greater than zero, the optimum moisture content and maximum dry density has a few constraints. One of the constraints includes, the adjusted PI of the soil. It is possible that a user can input a P_{200} and a PI that are at opposite ends of the spectrum, which both are correlated. The adjusted PI checks and if the PI is within reason, which is the mean PI adjust is calculated by Equation 4.84. The variance of the PI adjust is explained by Equation 4.127.

$$\sigma^2_{PI_{adj}} = \frac{1}{n-1}\sum_{i=1}^{n}\left(PI_{adj_i} - \mu_{PI_{adj}} \right)^2 \text{ ....(4.127)}$$

Where:

n is the number of simulations

PI_{adj_i} is the ith PI adjust simulation

$\mu_{PI_{adj}}$ is the PI adjust mean

The optimum moisture content is still calculated using Equation 4.86, while the variance is calculated using Equation 4.125. Once the optimum moisture content is determined, the maximum dry density is then determined by using Equation 4.88, while the variance is calculated using Equation 4.126.

4.5.3.7 Environmental Factor

The environmental factor is independent of the hierarchical level, it a function of the degree of saturation, the optimum saturation, and the *w*PI of the soil. The degree of saturation and the optimum saturation, on the other hand, are dependent of the hierarchical level chosen. Regardless, of the hierarchical level chosen, the mean environmental factor is calculated using Equation 4.90. The variance on the other hand, requires another equation, Equation 4.128 for the calculation. This calculation relies on the changes in the mean environmental factor which are reflected in Equations 4.129 and 4.130. These changes are in how the degree of saturation, the optimum saturation, and the *w*PI of the soil, Equation 4.129 and 4.130 reflect the changes in the degree of saturation and the optimum saturation, while Equation 4.103 reflect the changes in how the *w*PI is calculated.

$$\sigma_{F_{env}}^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(F_{env_i} - \mu_{F_{env}}\right)^2 \quad \text{......}(4.128)$$

Where:

n is the number of simulations

F_{env_i} is the ith environmental factor simulation

$\mu_{F_{env}}$ is the mean environmental factor

$$\%S_i = \%S_{\min} + \alpha\left(\%S_{\max} - \%S_{\min}\right) \quad \text{......}(4.129)$$

Where:

α is the Monte Carlo point estimation

$$S_{opt_i} = S_{opt_{\min}} + \beta\left(S_{opt_{\max}} - S_{opt_{\min}}\right) \quad (4.130)$$

Where:

β is the Monte Carlo point estimation

4.5.3.8 Resilient Modulus at Optimum

The resilient modulus at optimum, when it is not calculated is correlated to soil properties, which will be shown below. When the resilient modulus at optimum is determined in the laboratory, a project coefficient of variation will be applied to the mean value obtained to create a standard deviation and a variance.

4.5.3.8.1 Levels 2 and 3 *w*PI = 0.0

The mean resilient modulus at optimum will be calculated using Equation 4.92, while the variance equation used will be calculated using Equation 4.131.

$$\sigma^2_{M_{Ropt}} = \frac{1}{n-1}\sum_{i=1}^{n}\left(M_{Ropt_i} - \mu_{M_{Ropt}}\right)^2 \quad (4.131)$$

Where

n is the number of simulations

M_{Ropt_i} is the ith resilient modulus at optimum simulation

$\mu_{M_{Ropt}}$ is the mean resilient modulus at optimum

4.5.3.8.2 Levels 2 and 3 *w*PI > 0.0

Levels 2 and 3 with soils that have plasticity will use the same mean equation, Equation 4.92 to calculate the resilient modulus at optimum, while the variance of the resilient modulus at optimum utilizes Equation 4.131. All changes in the mean equations are reflected in Equation 4.103, which changes how the *w*PI of the soil is calculated in Equation 4.94.

4.5.3.9 Resilient Modulus at Equilibrium

The mean of the resilient modulus at equilibrium will still be calculated using Equation 4.95 for any given layer or hierarchical level. The variance of the resilient modulus will be calculated using Equation 4.132 and with the changes of the resilient modulus at equilibrium variance, the point estimation for the mean changes, which these changes are shown in Equation 4.133 and 4.134 for both the environmental factor and the resilient modulus at optimum respectively.

$$\log\left(\sigma^2_{M_{\mathrm{Re}q}}\right) = \frac{1}{n-1}\sum_{i=1}^{n}\left(\log\left(M_{\mathrm{Re}q_i}\right) - \log\left(\mu_{M_{\mathrm{Re}q}}\right)\right)^2 \text{ .... } (4.132)$$

Where:

n is the number of simulations

$\mu_{M_{\mathrm{Re}q}}$ is the mean resilient modulus at equilibrium

$M_{\mathrm{Re}q_i}$ is the i$^{\text{th}}$ simulation

$$F_{env_i} = F_{env_{\min}} + \alpha\left(F_{env_{\max}} - F_{env_{\min}}\right) \qquad (4.133)$$

Where:

α is the Monte Carlo point estimation

$$M_{Ropt_i} = M_{Ropt_{\min}} + \beta\left(M_{Ropt_{\max}} - M_{Ropt_{\min}}\right) \qquad (4.134)$$

Where:

β is the Monte Carlo point estimation

4.6 Summary and Conclusions

Presented in this chapter was the development of the analysis program as well as the flow diagrams of how the EICM was coded into the analysis program. The flow diagrams are similar in nature to the EICM; the EICM follows the flow diagram on multiple iterations while the analysis program, at each module, creates a stochastic solution set that encompasses the deterministic solution sets that are created during the multiple iterations.

In addition the flow of the EICM, the four different methodologies that can be used to develop a stochastic solution of the resilient modulus at equilibrium as well as any other variable that is used in the EICM were discussed in detail. Even though each stochastic procedure is different, in theory the means and variances of the four methodologies should be statistically the same by using hypothesis testing of the means and hypothesis testing of the variance, between the four methodologies.

With the soil variability determined in Chapter 3, and using the work presented in this chapter, it will be combined for analysis in Chapter 5. In Chapter 5 a quantitative comparison of the four different methodologies will be discussed. In Chapter 5, hypothesis testing of the means and variance will be evaluated for a given hierarchical level.

Chapter 5

QUANTITATIVE COMPARISON OF THE METHODOLOGIES

5.1 Introduction

Now with all four methodologies outlined, in Chapter 3, and the soil variability determined, in Chapter 4, the quantitative comparison of the four methodologies can occur. The comparison of the methodologies will rely on using only one site location or TMI value and each of the hierarchical levels. For the complete quantitative comparison between the hierarchical levels, site conditions, and various soils conditions, will be shown in Chapter 6. By focusing the quantitative comparison only on a given hierarchical level, the comparison will show if there is a statistical difference between the mean and variance of each methodology, for a given hierarchical level.

The comparison between the methodologies, for a given hierarchical level, will rely on the student's t-test as well as the Z-test and the F-test, for hypothesis testing of the mean and variance respectively. The student's t-test will be utilized to show if there is a statistical difference between the mean values of each methodology when the number of combinations is greater than two. By using the student's t-test it will give emphasis to the degrees of freedom, which changes the acceptance region of the t-statistic. On the other hand, when the number of combinations is less than two, the Z-test will be used to show if there is a statistical difference between the mean values of each methodology, for a given hierarchical level. The Z-statistic acceptance region will always be fixed since the

Z-statistic is not based on a degree of freedom. The F-test will show if there is a statistical difference between the variances of each methodology, for a given hierarchical level. For the comparison between the methodologies only the contributing variables will be analyzed.

The contributing variables in the resilient modulus at equilibrium include the following: TMI, matric suction, degree of saturation, optimum saturation, the environmental factor, and the resilient modulus at optimum. These six variables are important to the overall design of the unbound resilient modulus at equilibrium. By focusing on these six variables, it highlights the chronological steps that are needed in calculating the unbound resilient modulus at equilibrium.

5.2 Objectives

The objectives of this chapter are to discuss the following:

- First, determine if there is a statistical difference between the mean values of the four methodologies, at a given hierarchical level.
- Second, determine if there is a statistical difference between the variance of the four methodologies, at a given hierarchical level.
- Finally, show the output of the analysis program, for a given methodology, and discuss the terminology that is used in the output.

5.3 Data Collection

Shown in Table 5.1 are the variables that will be analyzed along with the number of combinations that were used to derive the mean and variance of each variable. For Level 1 comparison, between the methodologies, the resilient modulus at optimum will not be analyzed since it is an input variable. Once the number of combinations for the variable determination was determined, the site location and soil properties for each hierarchical level can be determined.

Table 5.1: Number of Combination for Variable Determination.

Variable	Taylor Series	Rosenblueth 2-Point	Rosenblueth 3-Point	Monte Carlo Simulation
TMI	1	4	9	25000
Matric Suction	1	4	9	25000
%S	1	4	9	25000
S_{opt}	1	8	27	25000
F_{env}	1	8	27	25000
M_{Ropt}	1	2	3	25000
M_{Req}	1	4	9	25000

Table 5.2 shows the soil properties for Level 1. The soil properties for the Level 3A and Level 3B are located in Table 3.31 and Table 3.37. When comparing one variable, P_{200}, Level 1 ranges from 62.14% to 97.86% with a mean of 80.0%, Level 3A ranges from 36.40% to 99.00% with a mean of 80.09%, and Level 3B ranges from 35.60% to 100.00% with a mean of 74.21%. As one can see, the lower and upper bound grow wider, even though the mean values are similar. As the upper and lower bounds increase, the variance associated with the soil property increases as well. The variance increased from 117.8 to 192.69 to 266.32 as the change in hierarchical level respectively.

Table 5.2: Soil Property Information for Hierarchical Level 1.

	P_{200}	PI	*w*PI	Gs	w_{opt}	γ_{dry}	a_f	b_f	c_f	M_{ropt}
μ	80	50	40	2.82	24	98	81.414	0.9142	0.2914	13000
σ^2	117.8	186.3	148.7	8.00E-04	5.852	4	27.008	0.0802	0.0096	950625
σ	10.86	13.65	12.19	0.028	2.419	2	5.1969	0.2833	0.0982	975
a	62.14	27.55	19.94	2.774	20.02	94.711	72.865	0.4481	0.1298	11396
b	97.86	72.45	60.06	2.866	27.97	101.28	89.962	1.3802	0.4529	14604
α	0.852	0.852	0.852	0.852	0.852	0.8527	0.8527	0.8527	0.8527	0.8527
β	0.852	0.852	0.852	0.852	0.852	0.8527	0.8527	0.8527	0.8527	0.8527

Finally the site selection for the comparison can be determined. The site selection for this comparison is Phoenix, Arizona, which Phoenix the hottest climatic location out of the 851 climatic sites that were obtained from the MEPDG. By using Phoenix Arizona, it will show the greatest differences in the six primary variables. In Table 5.3 is the historical climatic statistics for Phoenix, AZ. The climatic data in the Phoenix, AZ climatic file started on July 1, 1996 and it ends on February 28, 2006, which gives each month a monthly average based on a minimum of nine months. One can see that the minimum precipitation for most of the months is 0.000 centimeters, which when coupled with the extreme temperature, it can creates a very negative TMI value for the site.

Table 5.3: Monthly Climatic Statistics for Phoenix, AZ.

Precipitation in cm										
Month	μ	σ^2	σ	CV	$E[X^3]$	$E[X^4]$	a	b	α	β
Jan	1.62	2.92	1.71	1.06	0.7	-0.8	0.0	4.71	0.245	0.471
Feb	3.08	8.96	2.99	0.97	0.6	-1.2	0.0	8.00	0.267	0.426
Mar	2.06	5.05	2.25	1.09	1.4	1.2	0.0	7.57	0.332	0.894
Apr	1.16	1.16	1.08	0.93	0.6	-1.4	0.0	2.87	0.287	0.421
May	0.02	.0012	0.03	1.82	1.6	1.2	0.0	0.10	0.062	0.277
Jun	0.10	0.07	0.27	2.67	2.5	4.1	0.0	0.86	0.007	0.052
Jul	2.38	4.31	2.08	0.87	1.4	1.1	0.4	7.53	0.372	0.974
Aug	1.74	1.13	1.06	0.61	0.2	-1.1	0.0	3.53	0.863	0.894
Sep	0.97	0.85	0.92	0.94	1.3	1.5	0.0	3.33	0.499	1.205
Oct	1.50	5.45	2.34	1.55	2.1	3.2	0.0	8.05	0.151	0.656
Nov	0.71	0.32	0.56	0.79	0.3	-1.3	0.0	1.68	0.498	0.677
Dec	1.09	1.65	1.28	1.17	1.0	-0.2	0.0	3.96	0.252	0.656
Temperature in Celsius										
Month	μ	σ^2	σ	CV	$E[X^3]$	$E[X^4]$	A	b	α	β
Jan	13.7	1.19	1.09	0.08	1.0	1.2	11.94	16.39	1.214	1.795
Feb	14.5	1.76	1.33	0.09	-0.3	-0.9	12.11	16.41	0.894	0.682
Mar	18.7	2.98	1.73	0.09	1.0	0.1	16.63	22.52	0.607	1.071
Apr	22.1	3.42	1.85	0.08	-0.2	-0.8	19.04	25.02	0.838	0.768
May	28.7	2.79	1.67	0.06	-0.6	-0.3	25.25	30.93	1.062	0.662
Jun	32.8	1.56	1.25	0.04	-0.6	-0.3	30.28	34.69	1.174	0.855
Jul	35.1	1.01	1.01	0.03	-0.8	0.8	32.79	36.68	1.553	0.982
Aug	34.2	0.4	0.64	0.02	0.0	-1.6	33.24	35.12	0.611	0.572
Sep	31.6	1.38	1.18	0.04	-0.8	0.3	28.97	33.40	1.443	0.938
Oct	24.6	2.58	1.61	0.07	0.7	-0.5	22.45	28.03	0.743	1.138
Nov	17.5	3.56	1.89	0.11	-0.7	-0.2	13.50	19.98	1.100	0.650
Dec	12.7	0.56	0.75	0.06	-0.4	-1.0	11.36	13.64	0.724	0.467

5.4 Statistical Analysis of the Methodologies

With the climatic descriptive statistics described for the site as well as the soil for the three different hierarchical levels, the four different methodologies can be applied to the mean and variance of the resilient modulus at equilibrium. To see if the four methodologies produce the same mean and variance for the seven variables listed in Table 5.1 the mean and variance of all four methodologies are needed. Table 5.4 shows the mean and variance of the seven variables for each given hierarchical level. The TMI value that is listed under Level 1 is the site TMI, which is the same TMI that is used in Levels 3A and 3B Matric Suction.

When completing the comparison between the hierarchical levels, the mean values of the four methodologies can be compared; while only three of the methodologies variances can be compared, which includes the Rosenblueth 2-Point estimation, Rosenblueth 3-Point estimation, and the Monte Carlo Simulation. The variance of the Taylor Series expansion cannot be compared to the other three methodologies since the Taylor Series only has one combination. When applying the degree of freedom in the F-test to the Taylor Series, the degree of freedom become zero, which cannot be used in the F-test, it gives an error. The student's t-test will be used for Rosenblueth's 2 and 3-Point estimation as well as the Monte Carlo Simulation. The Taylor Series will have to utilize the Z-test to determine if the mean value is different due to the same reason the F-test could not be used, the degree of freedom becomes zero, which is not possible for hypothesis testing using the F-test or the student's t-test.

The acceptance region of the student's t-statistic as well as the Z-statistic can found in Table 5.5 for all three levels, using Equations 2.8 and 2.7 respectively. In Tables 5.5, each methodology when compared to the Taylor Series used the Z-statistic, while the other methodologies when compared to each other used the student's t-statistic. Therefore, the acceptance regions for the methodologies correspond to if the Z-statistic or the student's t-statistic was used and is denoted by Z_{stat} or t_{stat} respectively. In Tables 5.6 is the acceptance region of the F-statistic, which was determined by using Equation 2.8, for the Rosenblueth 2 and 3-Point estimation as well as the Monte Carlo Simulation.

Table 5.4: Comparison of Site Hierarchical Levels for Phoenix, Arizona.

Level 1								
Var	Taylor Series		Rosenblueth 2 - Point		Rosenblueth 3 - Point		Monte Carlo Simulation	
	μ	σ^2	μ	σ^2	μ	σ^2	μ	σ^2
TMI	-58.2	5.45	-57.8	7.01	-57.89	2.64	-58.06	5.75
ψ	32614	2.32E8	29158	2.77E8	29427	1.13E08	29982	1.94E8
%S	46.02	79.45	50.49	187.89	48.62	50.99	50.43	52.20
S_{opt}	85.07	90.01	85.19	103.38	85.15	62.53	84.79	13.10
F_{env}	6.396	9.07	5.876	12.28	5.954	3.44	5.514	2.71
(M_{Req})	4.923	0.2249	4.742	0.1193	4.8753	0.015	4.8364	0.142
Level 2								
Var	Taylor Series		Rosenblueth 2 - Point		Rosenblueth 3 - Point		Monte Carlo Simulation	
	μ	σ^2	μ	σ^2	μ	σ^2	M	σ^2
ψ	12549	9.68E7	13826	1.37E8	13026	6.18E7	13853	9.85E7
%S	55.48	89.83	60.55	725.75	54.86	65.40	55.57	157.17
S_{opt}	85.74	203.74	81.92	8719.63	85.43	116.00	85.86	20.01
F_{env}	4.133	7.10	2.995	19.07	4.297	2.76	4.314	3.61
M_{Ropt}	12396	6E6	13087	1.4E7	12857	7.2E6	13078	7.1E6
(M_{Req})	4.713	0.4496	4.1998	0.876552	4.71501	0.0299	4.699	0.0525
Level 3								
Var	Taylor Series		Rosenblueth 2 - Point		Rosenblueth 3 - Point		Monte Carlo Simulation	
	M	σ^2	μ	σ^2	μ	σ^2	μ	σ^2
ψ	5960	49775600	8121	74169000	7202	35865700	7876	75019200
%S	64.52	243.78	65.13	1153.67	59.95	202.85	61.19	342.52
S_{opt}	85.69	432.89	78.23	16925.60	83.68	208.78	85.30	2.62
F_{env}	2.759	9.05	2.569	16.67	3.328	3.74	3.436	4.69
M_{Ropt}	15011	19003100	17004	53630100	16340	28139500	16655	21542900
(M_{Req})	4.62	1.266	4.262	0.85496	4.662	0.0801	4.645	0.11574

Table 5.5: Acceptance Region of the t-Statistic and Z-Statistic.

TMI, ψ, %S, and M_{Req}	Monte Carlo Simulation	Rosenblueth 3 - Point	Rosenblueth 2 - Point	Taylor Series
Monte Carlo	$-1.96 \leq t_{stat} \leq 1.96$	$-1.96 \leq t_{stat} \leq 1.96$	$-1.96 \leq t_{stat} \leq 1.96$	$-1.96 \leq Z_{st} \leq 1.96$
3 - Point	$-1.96 \leq t_{stat} \leq 1.96$	$-2.12 \leq t_{stat} \leq 2.12$	$-2.20 \leq t_{stat} \leq 2.20$	-1.96 ≤ Zst ≤ 1.96
2 - Point	$-1.96 \leq t_{stat} \leq 1.96$	$-2.20 \leq t_{stat} \leq 2.20$	$-2.45 \leq t_{stat} \leq 2.45$	-1.96 ≤ Zst ≤ 1.96
Taylor Series	-1.96 ≤ Zst ≤ 1.96	-1.96 ≤ Zst ≤ 1.96	-1.96 ≤ Zst ≤ 1.96	-1.96 ≤ Zst ≤ 1.96
S_{opt} and F_{env}	Monte Carlo Simulation	Rosenblueth 3 - Point	Rosenblueth 2 - Point	Taylor Series
Monte Carlo	$-1.96 \leq t_{stat} \leq 1.96$	$-1.96 \leq t_{stat} \leq 1.96$	$-1.96 \leq t_{stat} \leq 1.96$	-1.96 ≤ Zst ≤ 1.96
3 - Point	$-1.96 \leq t_{stat} \leq 1.96$	$-2.01 \leq t_{stat} \leq 2.01$	$-2.03 \leq t_{stat} \leq 2.03$	-1.96 ≤ Zst ≤ 1.96
2 - Point	$-1.96 \leq t_{stat} \leq 1.96$	$-2.03 \leq t_{stat} \leq 2.20$	$-2.14 \leq t_{stat} \leq 2.14$	-1.96 ≤ Zst ≤ 1.96
Taylor Series	-1.96 ≤ Zst ≤ 1.96	-1.96 ≤ Zst ≤ 1.96	-1.96 ≤ Zst ≤ 1.96	-1.96 ≤ Zst ≤ 1.96
M_{Ropt}	Monte Carlo Simulation	Rosenblueth 3 - Point	Rosenblueth 2 - Point	Taylor Series
Monte Carlo	$-1.96 \leq t_{stat} \leq 1.96$	$-1.96 \leq t_{stat} \leq 1.96$	$-1.96 \leq t_{stat} \leq 1.96$	-1.96 ≤ Zst ≤ 1.96
3 - Point	$-1.96 \leq t_{stat} \leq 1.96$	$-2.78 \leq t_{stat} \leq 2.78$	$-3.18 \leq t_{stat} \leq 3.18$	-1.96 ≤ Zst ≤ 1.96
2 - Point	$-1.96 \leq t_{stat} \leq 1.96$	$-3.18 \leq t_{stat} \leq 3.18$	$-4.30 \leq t_{stat} \leq 4.30$	-1.96 ≤ Zst ≤ 1.96
Taylor Series	-1.96 ≤ Zst ≤ 1.96	-1.96 ≤ Zst ≤ 1.96	-1.96 ≤ Zst ≤ 1.96	-1.96 ≤ Zst ≤ 1.96

Table 5.6: Acceptance Region for the F-Statistic.

TMI, ψ, %S, and M_{Req}	Monte Carlo Simulation	Rosenblueth 3 - Point	Rosenblueth 2 - Point
Monte Carlo	$0.976 \leq F_{stat} \leq 1.03$	$0.456 \leq F_{stat} \leq 3.67$	$0.321 \leq F_{stat} \leq 13.9$
3 - Point	$0.272 \leq F_{stat} \leq 2.19$	$0.226 \leq F_{stat} \leq 4.43$	$0.185 \leq F_{stat} \leq 14.54$
2 - Point	$0.072 \leq F_{stat} \leq 3.12$	$0.069 \leq F_{stat} \leq 5.42$	$0.065 \leq F_{stat} \leq 15.44$
S_{opt} and F_{env}	Monte Carlo Simulation	Rosenblueth 3 - Point	Rosenblueth 2 - Point
Monte Carlo	$0.976 \leq F_{stat} \leq 1.03$	$0.620 \leq F_{stat} \leq 1.88$	$0.437 \leq F_{stat} \leq 4.14$
3 - Point	$0.532 \leq F_{stat} \leq 1.61$	$0.456 \leq F_{stat} \leq 2.19$	$0.354 \leq F_{stat} \leq 4.39$
2 - Point	$0.241 \leq F_{stat} \leq 2.29$	$0.228 \leq F_{stat} \leq 2.82$	$0.200 \leq F_{stat} \leq 4.99$
M_{Ropt}	Monte Carlo Simulation	Rosenblueth 3 - Point	Rosenblueth 2 - Point
Monte Carlo	$0.976 \leq F_{stat} \leq 1.03$	$0.271 \leq F_{stat} \leq 39.50$	$0.199 \leq F_{stat} \leq 1018.24$
3 - Point	$0.025 \leq F_{stat} \leq 3.69$	$0.026 \leq F_{stat} \leq 39.00$	$0.026 \leq F_{stat} \leq 799.50$
2 - Point	$0.001 \leq F_{stat} \leq 5.02$	$0.001 \leq F_{stat} \leq 38.51$	$0.002 \leq F_{stat} \leq 647.79$

With the acceptance regions defined for all three test statistics, the hypothesis testing on the mean and variance can occur for each given hierarchical level. In Table 5.7, 5.8, and 5.9 are the results shown for the t-statistic and the Z-Statistic for Levels 1, 3A, and 3B respectively. In Tables 5.10, 5.11, and 5.12 are the results of the F-statistic for Levels 1, 3A, and 3B respectively.

Table 5.7: Level 1 t-Statistic and Z-Statistic Results.

TMI					Optimum Saturation				
	Monte	3-Point	2-Point	Taylor		Monte	3-Point	2-Point	Taylor
Monte	0.000	0.214	0.220	-0.079	Monte	0.000	0.518	0.315	0.029
3-Point	-0.214	0.000	0.078	-0.149	3-Point	-0.518	0.000	0.012	-0.008
2-Point	-0.220	-0.078	0.000	-0.167	2-Point	-0.315	-0.012	0.000	-0.012
Taylor	0.079	0.149	0.167	0.000	Taylor	-0.029	0.008	0.012	0.000
Matric Suction					Environmental Factor				
	Monte	3-Point	2-Point	Taylor		Monte	3-Point	2-Point	Taylor
Monte	0.000	-0.119	-0.118	0.172	Monte	0.000	1.388	0.621	0.292
3-Point	0.119	0.000	-0.035	0.203	3-Point	-1.388	0.000	-0.084	0.145
2-Point	0.118	0.035	0.000	0.199	2-Point	-0.621	0.084	0.000	0.159
Taylor	-0.172	-0.203	-0.199	0.000	Taylor	-0.292	-0.145	-0.159	0.000
Degree Saturation					Resilient Modulus at Equilibrium				
	Monte	3-Point	2-Point	Taylor		Monte	3-Point	2-Point	Taylor
Monte	0.000	-0.750	0.018	-0.494	Monte	0.000	0.793	0.437	0.292
3-Point	0.750	0.000	0.332	-0.281	3-Point	-0.793	0.000	-0.050	0.142
2-Point	-0.018	-0.332	0.000	-0.397	2-Point	-0.437	0.050	0.000	0.141
Taylor	0.494	0.281	0.397	0.000	Taylor	-0.292	-0.142	-0.141	0.000

Table 5.8: Level 3A t-Statistic and Z-Statistic Results.

Matric Suction					Environmental Factor				
	Monte	3-Point	2-Point	Taylor		Monte	3-Point	2-Point	Taylor
Monte	0.000	-0.249	-0.005	-0.132	Monte	0.000	-0.046	-1.962	-0.068
3-Point	0.249	0.000	0.146	-0.046	3-Point	0.046	0.000	-1.297	-0.061
2-Point	0.005	-0.146	0.000	-0.111	2-Point	1.962	1.297	0.000	0.369
Taylor	0.132	0.046	0.111	0.000	Taylor	0.068	0.061	-0.369	0.000
Degree of Saturation					Resilient Modulus at Optimum				
	Monte	3-Point	2-Point	Taylor		Monte	3-Point	2-Point	Taylor
Monte	0.000	-0.171	0.794	-0.010	Monte	0.000	-0.143	0.005	-3.671
3-Point	0.171	0.000	0.604	0.062	3-Point	0.143	0.000	0.081	-0.295
2-Point	-0.794	-0.604	0.000	-0.308	2-Point	-0.004	-0.081	0.000	-0.259
Taylor	0.010	-0.062	0.308	0.000	Taylor	3.671	0.295	0.259	0.000
Optimum Saturation					Resilient Modulus at Equilibrium				
	Monte	3-Point	2-Point	Taylor		Monte	3-Point	2-Point	Taylor
Monte	0.000	-0.505	-2.352	-0.008	Monte	0.000	-0.116	-4.351	-0.154
3-Point	0.505	0.000	-0.197	0.021	3-Point	0.116	0.000	-0.269	-0.118
2-Point	2.352	0.197	0.000	0.106	2-Point	4.351	0.269	0.000	0.039
Taylor	0.008	-0.021	-0.106	0.000	Taylor	0.154	0.118	-0.039	0.000

Table 5.9: Level 3B t-Statistic and Z-Statistic Results.

Matric Suction					Environmental Factor				
	Monte	3-Point	2-Point	Taylor		Monte	3-Point	2-Point	Taylor
Monte	0.000	-0.233	0.056	-0.271	Monte	0.000	-0.259	-1.132	-0.225
3-Point	0.233	0.000	0.224	-0.169	3-Point	0.259	0.000	-0.740	-0.187
2-Point	-0.056	-0.224	0.000	-0.261	2-Point	1.132	0.740	0.000	0.056
Taylor	0.271	0.169	0.261	0.000	Taylor	0.225	0.187	-0.056	0.000
Degree of Saturation					Resilient Modulus at Optimum				
	Monte	3-Point	2-Point	Taylor		Monte	3-Point	2-Point	Taylor
Monte	0.000	-0.201	0.425	0.213	Monte	0.000	-0.117	0.106	-4.770
3-Point	0.201	0.000	0.400	0.280	3-Point	0.117	0.000	0.120	-0.431
2-Point	-0.425	-0.400	0.000	-0.026	2-Point	-0.106	-0.120	0.000	-0.384
Taylor	-0.213	-0.280	0.026	0.000	Taylor	4.770	0.431	0.384	0.000
Optimum Saturation					Resilient Modulus at Equilibrium				
	Monte	3-Point	2-Point	Taylor		Monte	3-Point	2-Point	Taylor
Monte	0.000	-4.983	-7.364	0.019	Monte	0.000	0.212	-4.351	0.020
3-Point	4.983	0.000	-0.220	0.096	3-Point	-0.212	0.000	-1.678	-0.003
2-Point	7.364	0.220	0.000	0.147	2-Point	4.351	1.678	0.000	0.627
Taylor	-0.019	-0.096	-0.147	0.000	Taylor	-0.020	0.003	-0.627	0.000

Table 5.10: Level 1 F-Statistic Results.

TMI				Optimum Saturation			
F-Statistic	Monte	3-Point	2-Point	F-Statistic	Monte	3-Point	2-Point
Monte	1.0000	2.1808	0.8197	Monte	1.0000	0.2095	0.1267
3-Point	0.4585	1.0000	0.3759	3-Point	4.7734	1.0000	0.6048
2-Point	1.2200	2.6606	1.0000	2-Point	7.8920	1.6533	1.0000
Matric Suction				Environmental Factor			
F-Statistic	Monte	3-Point	2-Point	F-Statistic	Monte	3-Point	2-Point
Monte	1.0000	1.7232	0.7029	Monte	1.0000	0.7881	0.2206
3-Point	0.5803	1.0000	0.4079	3-Point	1.2688	1.0000	0.2799
2-Point	1.4227	2.4517	1.0000	2-Point	4.5324	3.5722	1.0000
Degree of Saturation				Resilient Modulus at Equilibrium			
F-Statistic	Monte	3-Point	2-Point	F-Statistic	Monte	3-Point	2-Point
Monte	1.0000	1.0236	0.2778	Monte	1.0000	1.0539	0.1725
3-Point	0.9769	1.0000	0.2714	3-Point	0.9489	1.0000	0.1637
2-Point	3.5997	3.6848	1.0000	2-Point	5.7973	6.1094	1.0000

Table 5.11: Level 3A F-statistic Results.

Matric Suction				Environmental Factor			
	Monte	3-Point	2-Point		Monte	3-Point	2-Point
Monte	1.0000	1.5949	0.7185	Monte	1.0000	1.3086	0.1892
3-Point	0.6270	1.0000	0.4505	3-Point	0.7642	1.0000	0.1446
2-Point	1.3918	2.2197	1.0000	2-Point	5.2843	6.9153	1.0000
Degree of Saturation				Resilient Modulus at Optimum			
	Monte	3-Point	2-Point		Monte	3-Point	2-Point
Monte	1.0000	2.4033	0.2166	Monte	1.0000	0.9878	0.5050
3-Point	0.4161	1.0000	0.0901	3-Point	1.0124	1.0000	0.5113
2-Point	4.6175	11.0972	1.0000	2-Point	1.9801	1.9558	1.0000
Optimum Saturation				Resilient Modulus at Equilibrium			
	Monte	3-Point	2-Point		Monte	3-Point	2-Point
Monte	1.0000	0.1725	0.0023	Monte	1.0000	1.7028	0.2236
3-Point	5.7956	1.0000	0.0133	3-Point	0.5873	1.0000	0.1313
2-Point	435.6569	75.1699	1.0000	2-Point	4.4714	7.6138	1.0000

Table 5.12: Level 3B F-Statistic Results.

Matric Suction				Environmental Factor			
	Monte	3-Point	2-Point		Monte	3-Point	2-Point
Monte	1.0000	1.5949	0.7185	Monte	1.0000	1.3086	0.1892
3-Point	0.6270	1.0000	0.4505	3-Point	0.7642	1.0000	0.1446
2-Point	1.3918	2.2197	1.0000	2-Point	5.2843	6.9153	1.0000
Degree of Saturation				Resilient Modulus at Optimum			
	Monte	3-Point	2-Point		Monte	3-Point	2-Point
Monte	1.0000	2.4033	0.2166	Monte	1.0000	0.9878	0.5050
3-Point	0.4161	1.0000	0.0901	3-Point	1.0124	1.0000	0.5113
2-Point	4.6175	11.0972	1.0000	2-Point	1.9801	1.9558	1.0000
Optimum Saturation				Resilient Modulus at Equilibrium			
	Monte	3-Point	2-Point		Monte	3-Point	2-Point
Monte	1.0000	0.1725	0.0131	Monte	1.0000	1.7028	0.0599
3-Point	29.7820	1.0000	0.3895	3-Point	0.5873	1.0000	0.0342
2-Point	76.4670	2.5676	1.0000	2-Point	16.7007	29.2316	1.0000

5.5 Results of the Statistical Analysis

The results of the mean and variance hypothesis testing can be found in Table 5.13 through Table 5.18. Table 5.13, 5.14, and 5.15 links the acceptance region in Table 5.5 to the t-statistic and Z-statistics for each hierarchical level, which are located in Tables 5.7, 5.8, and 5.9 respectively. Tables 5.16, 5.17, and 5.18 links the acceptance region located in Table 5.6 to the F-statistic for each hierarchical level, which are located in Tables 5.10, 5.11, and 5.12 respectively.

Table 5.13: Level 1 Mean Hypothesis Testing Results.

TMI					Optimum Saturation				
	Monte	3-Point	2-Point	Taylor		Monte	3-Point	2-Point	Taylor
Monte	Accept	Accept	Accept	Accept	Monte	Accept	Accept	Accept	Accept
3-Point	Accept	Accept	Accept	Accept	3-Point	Accept	Accept	Accept	Accept
2-Point	Accept	Accept	Accept	Accept	2-Point	Accept	Accept	Accept	Accept
Taylor	Accept	Accept	Accept	Accept	Taylor	Accept	Accept	Accept	Accept
Matric Suction					Environmental Factor				
	Monte	3-Point	2-Point	Taylor		Monte	3-Point	2-Point	Taylor
Monte	Accept	Accept	Accept	Accept	Monte	Accept	Accept	Accept	Accept
3-Point	Accept	Accept	Accept	Accept	3-Point	Accept	Accept	Accept	Accept
2-Point	Accept	Accept	Accept	Accept	2-Point	Accept	Accept	Accept	Accept
Taylor	Accept	Accept	Accept	Accept	Taylor	Accept	Accept	Accept	Accept
Degree of Saturation					Resilient Modulus at Equilibrium				
	Monte	3-Point	2-Point	Taylor		Monte	3-Point	2-Point	Taylor
Monte	Accept	Accept	Accept	Accept	Monte	Accept	Accept	Accept	Accept
3-Point	Accept	Accept	Accept	Accept	3-Point	Accept	Accept	Accept	Accept
2-Point	Accept	Accept	Accept	Accept	2-Point	Accept	Accept	Accept	Accept
Taylor	Accept	Accept	Accept	Accept	Taylor	Accept	Accept	Accept	Accept

Table 5.14: Level 3A Mean Hypothesis Testing Results.

Matric Suction					Environmental Factor				
	Monte	3-Point	2-Point	Taylor		Monte	3-Point	2-Point	Taylor
Monte	Accept	Accept	Accept	Accept	Monte	Accept	Accept	Reject	Accept
3-Point	Accept	Accept	Accept	Accept	3-Point	Accept	Accept	Accept	Accept
2-Point	Accept	Accept	Accept	Accept	2-Point	Reject	Accept	Accept	Accept
Taylor	Accept	Accept	Accept	Accept	Taylor	Accept	Accept	Accept	Accept
Degree of Saturation					Resilient Modulus at Optimum				
	Monte	3-Point	2-Point	Taylor		Monte	3-Point	2-Point	Taylor
Monte	Accept	Accept	Accept	Accept	Monte	Accept	Accept	Accept	Accept
3-Point	Accept	Accept	Accept	Accept	3-Point	Accept	Accept	Accept	Accept
2-Point	Accept	Accept	Accept	Accept	2-Point	Accept	Accept	Accept	Accept
Taylor	Accept	Accept	Accept	Accept	Taylor	Accept	Accept	Accept	Accept
Optimum Saturation					Resilient Modulus at Equilibrium				
	Monte	3-Point	2-Point	Taylor		Monte	3-Point	2-Point	Taylor
Monte	Accept	Accept	Reject	Accept	Monte	Accept	Accept	Reject	Accept
3-Point	Accept	Accept	Accept	Accept	3-Point	Accept	Accept	Accept	Accept
2-Point	Reject	Accept	Accept	Accept	2-Point	Reject	Accept	Accept	Accept
Taylor	Accept	Accept	Accept	Accept	Taylor	Accept	Accept	Accept	Accept

Table 5.15: Level 3B Mean Hypothesis Testing Results.

Matric Suction					Environmental Factor				
	Monte	3-Point	2-Point	Taylor		Monte	3-Point	2-Point	Taylor
Monte	Accept	Accept	Accept	Accept	Monte	Accept	Accept	Accept	Accept
3-Point	Accept	Accept	Accept	Accept	3-Point	Accept	Accept	Accept	Accept
2-Point	Accept	Accept	Accept	Accept	2-Point	Accept	Accept	Accept	Accept
Taylor	Accept	Accept	Accept	Accept	Taylor	Accept	Accept	Accept	Accept
Degree of Saturation					Resilient Modulus at Optimum				
	Monte	3-Point	2-Point	Taylor		Monte	3-Point	2-Point	Taylor
Monte	Accept	Accept	Accept	Accept	Monte	Accept	Accept	Accept	Accept
3-Point	Accept	Accept	Accept	Accept	3-Point	Accept	Accept	Accept	Accept
2-Point	Accept	Accept	Accept	Accept	2-Point	Accept	Accept	Accept	Accept
Taylor	Accept	Accept	Accept	Accept	Taylor	Accept	Accept	Accept	Accept
Optimum Saturation					Resilient Modulus at Equilibrium				
	Monte	3-Point	2-Point	Taylor		Monte	3-Point	2-Point	Taylor
Monte	Accept	Reject	Reject	Accept	Monte	Accept	Accept	Reject	Accept
3-Point	Reject	Accept	Accept	Accept	3-Point	Accept	Accept	Accept	Accept
2-Point	Reject	Accept	Accept	Accept	2-Point	Reject	Accept	Accept	Accept
Taylor	Accept	Accept	Accept	Accept	Taylor	Accept	Accept	Accept	Accept

Table 5.16: Level 1 Variance Hypothesis Results.

TMI				Optimum Saturation			
	Monte	3-Point	2-Point		Monte	3-Point	2-Point
Monte	Accept	Accept	Accept	Monte	Accept	Reject	Reject
3-Point	Accept	Accept	Accept	3-Point	Reject	Accept	Accept
2-Point	Accept	Accept	Accept	2-Point	Reject	Accept	Accept
Matric Suction				Environmental Factor			
	Monte	3-Point	2-Point		Monte	3-Point	2-Point
Monte	Accept	Accept	Accept	Monte	Accept	Accept	Reject
3-Point	Accept	Accept	Accept	3-Point	Accept	Accept	Reject
2-Point	Accept	Accept	Accept	2-Point	Reject	Reject	Accept
Degree of Saturation				Resilient Modulus at Equilibrium			
	Monte	3-Point	2-Point		Monte	3-Point	2-Point
Monte	Accept	Accept	Reject	Monte	Accept	Accept	Reject
3-Point	Accept	Accept	Accept	3-Point	Accept	Accept	Reject
2-Point	Reject	Accept	Accept	2-Point	Reject	Reject	Accept

Table 5.17: Level 3A Variance Hypothesis Results.

Matric Suction				Environmental Factor			
	Monte	3-Point	2-Point		Monte	3-Point	2-Point
Monte	Accept	Accept	Accept	Monte	Accept	Accept	Reject
3-Point	Accept	Accept	Accept	3-Point	Accept	Accept	Reject
2-Point	Accept	Accept	Accept	2-Point	Reject	Reject	Accept
Degree of Saturation				Resilient Modulus at Optimum			
	Monte	3-Point	2-Point		Monte	3-Point	2-Point
Monte	Accept	Accept	Reject	Monte	Accept	Accept	Accept
3-Point	Accept	Accept	Reject	3-Point	Accept	Accept	Accept
2-Point	Reject	Reject	Accept	2-Point	Accept	Accept	Accept
Optimum Saturation				Resilient Modulus at Equilibrium			
	Monte	3-Point	2-Point		Monte	3-Point	2-Point
Monte	Accept	Reject	Reject	Monte	Accept	Accept	Reject
3-Point	Reject	Accept	Accept	3-Point	Accept	Accept	Reject
2-Point	Reject	Accept	Accept	2-Point	Reject	Reject	Accept

Table 5.18: Level 3B Variance Hypothesis Results.

Matric Suction				Environmental Factor			
	Monte	3-Point	2-Point		Monte	3-Point	2-Point
Monte	Accept	Accept	Accept	Monte	Accept	Accept	Reject
3-Point	Accept	Accept	Accept	3-Point	Accept	Accept	Reject
2-Point	Accept	Accept	Accept	2-Point	Reject	Reject	Accept
Degree of Saturation				Resilient Modulus at Optimum			
	Monte	3-Point	2-Point		Monte	3-Point	2-Point
Monte	Accept	Accept	Reject	Monte	Accept	Accept	Accept
3-Point	Accept	Accept	Reject	3-Point	Accept	Accept	Accept
2-Point	Reject	Reject	Accept	2-Point	Accept	Accept	Accept
Optimum Saturation				Resilient Modulus at Equilibrium			
	Monte	3-Point	2-Point		Monte	3-Point	2-Point
Monte	Accept	Reject	Reject	Monte	Accept	Accept	Reject
3-Point	Reject	Accept	Accept	3-Point	Accept	Accept	Reject
2-Point	Reject	Accept	Accept	2-Point	Reject	Reject	Accept

The mean hypothesis testing for Level 1, at a level of significance of five percent, accepts the null hypothesis, for any given methodology; however, when comparing the null hypothesis for the variance, the variance was a mixture of accepting and rejecting the null hypothesis. When comparing the hypothesis testing for Level 3A, only the Rosenblueth 2-Point estimation was rejected for three of the six variables that were compared. Nevertheless, the hypothesis testing of the variance, for Level 3A, shows that four of the six variables rejected the null hypothesis, in which the variances of the methodologies are not equal. Finally, when comparing the means for Level 3B, only two of the six methodologies rejected the null hypothesis. The variance of Level 3B, on the other hand, four of the six methodologies rejected the null hypothesis.

The rejection of the null hypothesis, for the means, is related to the original assumption that was made. It was assumed that the variances of the populations would be equal, which the hypothesis testing of the variance shows that the assumption is not valid; therefore, either the level of significance needs to decrease or the assumption of the hypothesis testing of equal variances are needs to be changed, for the mean hypothesis testing. First the level of significance will be changed to one percent for the variance hypothesis testing that reject the null hypothesis. Located in Table 5.19 are the acceptance regions changes made. When Table 5.19 is coupled with Table 5.10, 5.11, and 5.12, the variables that now accept the null hypothesis are shown in Table 5.20. As one can see, Levels 1 and 3 had changes with accepting the null hypothesis and Level 2 had no changes.

Table 5.19: Updated Acceptance Region for the F-Statistic.

%S and M_{Req}	Monte Carlo Simulation	Rosenblueth 3 - Point	Rosenblueth 2 - Point
Monte Carlo	$0.976 \leq F_{stat} \leq 1.03$	$0.364 \leq F_{stat} \leq 5.95$	$0.234 \leq F_{stat} \leq 41.83$
3 - Point	$0.168 \leq F_{stat} \leq 2.75$	$0.133 \leq F_{stat} \leq 7.50$	$0.104 \leq F_{stat} \leq 44.13$
2 - Point	$0.024 \leq F_{stat} \leq 4.28$	$0.023 \leq F_{stat} \leq 9.60$	$0.021 \leq F_{stat} \leq 47.47$
S_{opt} and F_{env}	Monte Carlo Simulation	Rosenblueth 3 - Point	Rosenblueth 2 - Point
Monte Carlo	$0.968 \leq F_{stat} \leq 1.03$	$0.538 \leq F_{stat} \leq 2.33$	$0.345 \leq F_{stat} \leq 7.08$
3 - Point	$0.429 \leq F_{stat} \leq 1.86$	$0.353 \leq F_{stat} \leq 2.84$	$0.257 \leq F_{stat} \leq 7.60$
2 - Point	$0.141 \leq F_{stat} \leq 2.90$	$0.132 \leq F_{stat} \leq 3.89$	$0.113 \leq F_{stat} \leq 8.89$

Table 5.20: Changes in the Hypothesis Variance Results.

Level 1							
Degree of Saturation				Environmental Factor			
	Monte	**3-Point**	**2-Point**		**Monte**	**3-Point**	**2-Point**
Monte	Accept	Accept	Accept	**Monte**	Accept	Accept	Reject
3-Point	Accept	Accept	Accept	**3-Point**	Accept	Accept	Accept
2-Point	Accept	Accept	Accept	**2-Point**	Reject	Accept	Accept

Resilient Modulus at Equilibrium			
	Monte	**3-Point**	**2-Point**
Monte	Accept	Accept	Reject
3-Point	Accept	Accept	Accept
2-Point	Reject	Accept	Accept

Level 3B							
Degree of Saturation				Environmental Factor			
	Monte	**3-Point**	**2-Point**		**Monte**	**3-Point**	**2-Point**
Monte	Accept	Accept	Accept	**Monte**	Accept	Accept	Reject
3-Point	Accept	Accept	Accept	**3-Point**	Accept	Accept	Accept
2-Point	Accept	Accept	Accept	**2-Point**	Reject	Accept	Accept

With the change in the level of significance to one percent, it allowed the degree of saturation variance, for Levels 1 and 3B, to fall with the acceptance region. In addition, the change also allowed for null hypothesis on the Rosenblueth 3-Point, Levels 1 and 3B Environmental Factor and Level 1 Resilient Modulus at Equilibrium.

After revisiting the variance acceptance regions, now the mean acceptance region can be revised. The means that rejected the null hypothesis can be retested using the level of significance of as well. As stated earlier, Level 1 had accepted all null hypotheses, and Levels 3A and 3B reject some of the null hypothesis. The retesting of the null hypothesis needs to occur for the Environmental Factor (Level 3A), Optimum Saturation (Levels 3A and 3B), and the Resilient Modulus at Equilibrium (Levels 3A and 3B). In Table 5.21 is the updated mean acceptance region, for the three variables. Using the updated acceptance regions in Table 5.21 with Tables 5.8 and 5.9 the updated results for the mean hypothesis testing are found in Table 5.22.

Table 5.21: Updated Mean Acceptance Regions.

M_{Req}	Monte Carlo Simulation	Rosenblueth 3 - Point	Rosenblueth 2 - Point
Monte Carlo	$-2.576 \leq t_{stat} \leq 2.576$	$-2.576 \leq t_{stat} \leq 2.576$	$-2.576 \leq t_{stat} \leq 2.576$
3 - Point	$-2.576 \leq t_{stat} \leq 2.576$	$-2.921 \leq t_{stat} \leq 2.921$	$-3.106 \leq t_{stat} \leq 3.106$
2 - Point	$-2.576 \leq t_{stat} \leq 2.576$	$-3.106 \leq t_{stat} \leq 3.106$	$-3.707 \leq t_{stat} \leq 3.707$
S_{opt} and F_{env}	Monte Carlo Simulation	Rosenblueth 3 - Point	Rosenblueth 2 - Point
Monte Carlo	$-2.576 \leq t_{stat} \leq 2.576$	$-2.576 \leq t_{stat} \leq 2.576$	$-2.576 \leq t_{stat} \leq 2.576$
3 - Point	$-2.576 \leq t_{stat} \leq 2.576$	$-2.674 \leq t_{stat} \leq 2.674$	$-2.773 \leq t_{stat} \leq 2.773$
2 - Point	$-2.576 \leq t_{stat} \leq 2.576$	$-2.773 \leq t_{stat} \leq 2.773$	$-2.977 \leq t_{stat} \leq 2.977$

In Table 5.21 the confidence interval for the Z-statistic was removed since the First order Taylor Series expansion accepted the null hypothesis for the mean comparison.

Table 5.22: Updated Mean Hypothesis Testing.

Level 3A							
Optimum Saturation				Environmental Factor			
	Monte	3-Point	2-Point		Monte	3-Point	2-Point
Monte	Accept	Accept	Reject	Monte	Accept	Accept	Accept
3-Point	Accept	Accept	Accept	3-Point	Accept	Accept	Accept
2-Point	Reject	Accept	Accept	2-Point	Accept	Accept	Accept

Resilient Modulus at Equilibrium			
	Monte	3-Point	2-Point
Monte	Accept	Accept	Reject
3-Point	Accept	Accept	Accept
2-Point	Reject	Accept	Accept

Level 3B							
Optimum Saturation				Resilient Modulus at Equilibrium			
	Monte	3-Point	2-Point		Monte	3-Point	2-Point
Monte	Accept	Reject	Reject	Monte	Accept	Accept	Accept
3-Point	Reject	Accept	Accept	3-Point	Accept	Accept	Accept
2-Point	Reject	Accept	Accept	2-Point	Accept	Accept	Accept

As one can see, Level 2 still rejects the null hypothesis for the optimum saturation and resilient modulus at equilibrium when comparing the Monte Carlo Simulation to the Rosenblueth 2-Point method. In addition, Level 3 rejects the same null hypothesis for the optimum saturation.

5.6 Summary and Conclusions

Even though each methodology produces different means and variances, it was possible use hypothesis testing on both mean and variance to show that the four different methodologies can be statistically the same or statistically different. When comparing the mean and variance only certain variables become important of the six variables that were shown in the mean and variance comparison the most important out of the seven is the resilient modulus at equilibrium. Therefore, the statistical analysis associated with the resilient modulus at equilibrium will be used as the deciding factor in which methodologies can be used. Even though one or two of the other variables (i.e. Environmental Factor, Resilient Modulus at Optimum) can be statistically different the Resilient Modulus at Equilibrium is statistically the same. This occurrence is due to the magnitude of the variance associated with the mean value. The magnitude of the variance changes the null hypothesis of both the mean and variance. If the magnitude of the variance is small when coupled with a large variance it will create a statistically different mean and variance. On the other hand, if the magnitude of the variances is relatively the same with relatively same means, it is possible to have statistically different means and variances, this is due to the degree of freedom associated with the variables being compared. When the degree of freedom is large (greater than 30) it creates a tight acceptance region for both the mean and variance; however, when the degree of freedom is relative low (less than 30) the acceptance region is much broader than degree of freedom that is much larger.

Nevertheless, the comparison of the methodologies produced statistically different means and variances at two different levels of significance. Using a level of significance of five percent, the following methodologies can be used with confidence for mean comparison of the resilient modulus at equilibrium, for all three levels: First order Taylor Series expansion, Rosenblueth 3-Point, and the Monte Carlo Simulation. As for the variance, all hierarchical levels can use the Rosenblueth 3-Point and the Monte Carlo Simulation methodologies with confidence. In addition, a level of significance of one percent was used to determine if the Rosenblueth 2-Point estimation could be statistically the same as the other three methodologies, for all three levels.

The mean resilient modulus at equilibrium was proven to be statistically the same as the other methodologies at a level of significance of five percent, for Level 1; however, the variance was statistically different. Once the level of significance was lowered, the Rosenblueth 2-Point and Rosenblueth 3-Point became statistically the same, for Level 1 but the Rosenblueth 2-Point and the Monte Carlo simulation was still statistically different. In addition the lowering of the level of significance proved that the mean resilient modulus at equilibrium of the Rosenblueth 2-Point is statistically the same as the other methods; however, the variance is still statistically different. This is due to the variance and degrees of freedom used in the comparison. The degree of freedom was quite large with variances that were an order of magnitude apart.

After completing the statistical analysis of the mean and variance, it was determined that the Rosenblueth 3-Point and the Monte Carlo Simulation can be used with confidence to compare the mean and variance of the resilient modulus at equilibrium. Out of the two methods, the Rosenblueth 3-Point estimation requires more time to complete the number of simulations; therefore, the Monte Carlo Simulation will be used in Chapter 6 to show which of the geotechnical properties or climatic conditions has the greatest impact on the mean resilient modulus.

Chapter 6

QUANTITATIVE COMPARISON OF THE MEPDG EQUILIBRIUM MODULI

6.1 Introduction

With the completion of soil variability for a given hierarchical level, stochastic evaluation of the EICM, and the quantitative comparison of the stochastic methodologies, the quantitative comparison of the unbound resilient moduli at equilibrium can occur. The quantitative comparison of the equilibrium moduli will use the Monte Carlo stochastic methodology since it is the most powerful statistical tool for simulations. However, complete the quantitative comparison of the equilibrium moduli, it requires the means of the unbound resilient modulus distributions, of each hierarchical level, to be set equal so that the variance between the hierarchical levels can be evaluated. By evaluating the variances of the levels, it will show if there is a need to complete laboratory testing to obtain Level 1 values or if using Level 3A or 3B will suffice for a given project.

In addition to the mean values of the hierarchical levels being set equal, different soils and different climatic regions will be analyzed. By analyzing different soils and climatic regions, it will show the implications of the both the correlation models for the different soils as well as the impact of climatic variation with respect to the unbound resilient modulus at equilibrium. A total of three soils are evaluated, which includes granular base material, granular subbase material, and a fine grained subgrade material. The granular base material will correspond to an A-l-b soil; the granular subbase material will correspond to an A-2-4 soil, and the subgrade materials will correspond to an A-4 and A-6 soil. These four soils represent the largest collection of in-situ soils in the soil database (Zapata 2010, FHWA 2010). When comparing the three soils in the climatic regions, a total of five climatic regions were selected based on the TMI parameter. The five climatic regions encompass arid, semi-arid, moisture balance, and wet regions. By showing how the three soils interact with the climatic regions, it will show if there is a difference in the hierarchical levels.

Furthermore, the unbound resilient modulus at equilibrium distributions for the different hierarchical levels will also be used in determining the differences in asphalt thickness by using the AASHTO structural number concept. The AASHTO structural number concept will be used employed in this thesis will only evaluate the reliability associated with the soil layers instead of reliability associated with the amount of traffic. After determining the difference in asphalt thickness using the same mean values for the unbound resilient modulus at equilibrium mean, different unbound resilient modulus at optimum values for Level 1 will be used to determine new unbound resilient modulus at equilibrium and compared with the resilient modulus at equilibrium of Level 3B. Level 3B will always have a fixed unbound resilient modulus at optimum as well as an unbound resilient modulus at equilibrium, while Level 1, on the other hand is able have a different mean value within the same distribution of Level 3B. Figure 6.1 shows the conceptual concept that mean value of Level 1 can be different from the mean value of Level 3B.

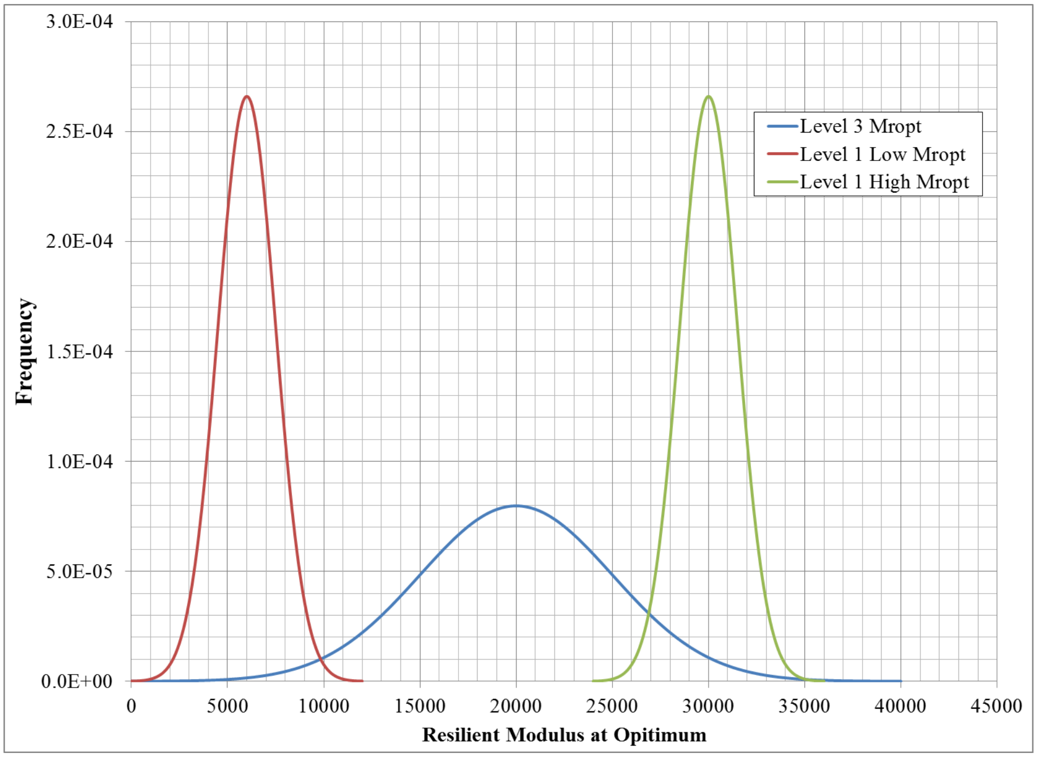

Figure 6.1: Conceptual differences in resilient modulus at optimum.

6.2 Objectives

The objects of this chapter are to show the following:

- First, show if there is a difference in hierarchical levels within the various climatic regions by setting the mean values of the unbound resilient modulus at equilibrium equal and using an F-test to compare the differences in the variance.
- Second, show if there is a difference in hierarchical levels using various climatic regions by setting the mean values of the unbound resilient modulus at equilibrium within the climatic region equal and using an F-test to compare the differences in the variance.

- Third, show if there is a difference in thickness of asphalt between the hierarchical levels using the AASHTO structural number concept for different levels of reliability assuming equal means and using the unequal variances of the resilient modulus at equilibrium for the different climatic regions.
- Finally, show if there is a difference in asphalt thickness between Level 1 and Level 3B using unequal means and variances associated with the unbound resilient modulus at equilibrium for Level 1.

6.3 Data Collection

The data collection of this chapter is composed into two sections; 6.3.1 is the soil collection and 6.3.2 is the climatic region selection for the statistical analysis.

6.3.1 Soil selection

A total of thirty-five soils are to be evaluated, five different soils each for Level 3A and 3B, and twenty-five soils for Level 1. The mean values of the soil properties of Level 3B are used for the analysis, which the mean values of Level 3A were changed to the mean values of Level 3A but Level 3A still retained the variance, standard deviation, and minimum and maximum values, the alpha and beta shape factors were adjusted to reflect the change in the mean value. In addition, the mean values of the Level 3B soil properties are used for Level 1; however, the coefficients of variation that were determined in Chapter 3 will be used determine the upper and lower bounds of the distributions. The upper and lower bounds or minimum and maximum value for each soil parameter, use a 95% confidence band, which each parameter will use the mean plus or mean minus 1.96 standard deviations to create the minimum and maximum values of the distribution. By using a 95% confidence band, it encompasses the normal variation ranges for a given parameter when in the layer is placed within the field.

The resilient modulus at optimum for Level 1 was obtained from running the Monte Carlo simulation to find the resilient modulus at optimum distribution for Level 3B and using five different values within the resilient modulus at optimum distribution. The five resilient moduli at optimum values range from the lowest value of the Level 3B to the highest value of the Level 3B resilient modulus at optimum distribution. The lowest value corresponds to the 5th percentile of strength of Level 3B optimum moduli. The low value corresponds to the 35th percentile of strength of Level 3B optimum moduli. The medium value corresponds to the mean value of the Level 3B optimum moduli. The high value corresponds to the 75th percentile of strength of Level 3B optimum moduli. The highest value corresponds to the 95th percentile of strength of the Level 3B optimum moduli.

In addition, for Level 3B soils with a *w*PI greater than two, the mean values of the SWCC parameters were used as the mean value of Level 1. For the soils with *w*PI less than two, the SWCC parameters were obtained from the NCHRP 9-23A database (Torres Hernandez 2011) by searching for soils that had the same soil properties that were being used for Level 1 analysis. By selecting a

SWCC from soils that had similar properties, the results from the Monte Carlo Simulation produced the same mean result for the degree of saturation. Table 6.1 through Table 6.5 shows the soil properties for five different Level 1 soils. These five tables correspond to the five soil classifications that associated are with Level 3B. The Level 1 soil properties fall within the following AASHTO soil classification: the granular base material is a A-1-b soil, the granular subbase material is a A-2-4 soil, the fine grain subgrade material is a A-6 soil, the "silty" fine grained subgrade material is a A-4 soil, and the "clayey" fine grained subgrade material is a A-6 soil as well. The two A-6 soils, for Level 1, show the differences on how broad one soil can be within the AASHTO soil classification. Table 6.6 shows the six unbound resilient modulus at optimum values that are used in the structural number design concept. In addition, the mean value in Table 6.6 is used in the variance comparison of the hierarchical levels. The six resilient moduli at optimum values were obtained from Level 3B resilient modulus at optimum distribution.

Level 3B soil selection includes the "granular" base material, "granular" subbase and subgrade material, fine grained material, "clayey" fine grained material, and "silty" fine grained material or Tables 3.34, 3.35, 3.36, 3.37, and 3.38 respectively. Recall from Chapter 3 that the "granular base material" is comprised of all A-1 soils, the "granular subbase and subgrade material" is comprised of all A-1, A-2 and A-3 soils, fine grained material is comprised of A-4, A-5, A-6, and A-7 soils, "silty" fine grained material is comprised of A-4 and

A-5 soils, and the “clayey” fine grained material” is comprised of all A-6 and A-7 soils.

Level 3A soils A-1-b, A-2-4, A-4, and A-6, were selected since these four soils had the highest number of soils in the database for the respective soils types. With the selection of Level 3A soils, the updated mean, alpha, and beta values can be found in Table 6.7. The variance, standard deviation, minimum and maximum values are not changed can still be referenced from Table 3.23, Table 3.24, Table 3.29, and Table 3.31 for A-1-b, A-2-4, A-4, and A-6 respectively. The comparison of Level 3A to Level 3B uses A-6 soil twice, it is compared the fine grained material and the “clayey” fine grained material. The A-4 is only compared to the “silty” fine grained material due to the minimum and maximum range of PI for an A-4 soil. The range of PI for an A-4 soil is bounded between 0 and 10.5; therefore, the A-4 cannot be compared to the fine grained material since the mean value of the fine grained material is greater than 10.5.

Table 6.1: Level 1 Descriptive Soil Properties for a Granular Base Material.

Level 1 (Granular Base Material)									
	$\mathbf{P_{\#200}}$	**PI**	***w*PI**	$\mathbf{G_s}$	$\mathbf{w_{opt}}$	$\boldsymbol{\gamma}_{\mathbf{dmax}}$	$\mathbf{a_f}$	$\mathbf{b_f}$	$\mathbf{c_f}$
μ	12.97	1.16	0.21	2.682	4.83	124.5	12.96	1.046	0.791
σ^2	3.360	0.087	0.002	0.001	0.018	143.515	31.01	0.000	0.002
σ	1.833	0.295	0.044	0.027	0.134	11.980	5.57	0.011	0.045
a	9.380	0.581	0.120	2.629	4.570	101.050	2.041	1.025	0.702
b	16.565	1.736	0.292	2.734	5.096	148.010	23.870	1.067	0.880
α	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421
β	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421

Table 6.2: Level 1 Descriptive Soil Properties for a Granular Subbase Material.

Level 1 (Granular Subbase Material)									
	$P_{\#200}$	**PI**	***w*PI**	G_s	w_{opt}	γ_{dmax}	a_f	b_f	c_f
μ	24.00	4.63	1.27	2.675	11.39	123.0	74.31	0.954	0.440
σ^2	11.504	1.387	0.105	0.001	0.100	140.004	1020.09	0.000	0.001
σ	3.392	1.178	0.323	0.027	0.316	11.832	31.94	0.010	0.025
a	17.356	2.324	0.639	2.622	10.767	99.806	11.707	0.935	0.390
b	30.652	6.940	1.906	2.727	12.007	146.188	136.905	0.973	0.489
α	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421
B	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421

Table 6.3: Level 1 Descriptive Soil Properties for a Fine Grained Material.

Level 1 (Fine Grained Material)									
	$P_{\#200}$	**PI**	***w*PI**	G_s	w_{opt}	γ_{dmax}	a_f	b_f	c_f
μ	67.45	13.80	10.18	2.680	5.67	111.4	105.75	0.719	0.239
σ^2	90.843	12.308	7.330	0.001	0.025	114.802	130.52	0.019	0.004
σ	9.531	3.508	2.707	0.027	0.157	10.715	11.42	0.138	0.060
a	48.773	6.925	4.872	2.628	5.359	90.378	83.358	0.448	0.121
b	86.134	20.677	15.485	2.733	5.976	132.378	128.142	0.989	0.358
α	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421
β	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421

Table 6.4: Level 1 Descriptive Soil Properties for a Silty Fine Grained Material.

Level 1 (Silty Fine Grained Material)									
	$P_{\#200}$	**PI**	***w*PI**	**G_s**	**w_{opt}**	**γ_{dmax}**	**a_f**	**b_f**	**c_f**
μ	60.02	5.87	3.63	2.679	12.04	118.5	80.27	0.901	0.401
σ^2	71.931	2.229	1.051	0.001	0.112	129.977	122.50	0.000	0.001
σ	8.481	1.493	1.025	0.027	0.334	11.401	11.07	0.004	0.037
a	43.400	2.947	1.624	2.627	11.386	96.166	58.575	0.893	0.328
b	76.646	8.799	5.643	2.731	12.697	140.856	101.961	0.909	0.474
α	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421
β	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421

Table 6.5: Level 1 Descriptive Soil Properties for a Clayey Fine Grained Material.

Level 1 (Clayey Fine Grained Material)									
	$P_{\#200}$	**PI**	***w*PI**	**G_s**	**w_{opt}**	**γ_{dmax}**	**a_f**	**b_f**	**c_f**
μ	74.21	21.00	16.12	2.684	16.75	111.9	118.48	0.627	0.159
σ^2	109.950	28.495	20.540	0.001	0.216	115.912	85.79	0.057	0.004
σ	10.486	5.338	4.532	0.027	0.465	10.766	9.26	0.238	0.066
a	53.657	10.537	7.241	2.631	15.838	90.814	100.323	0.161	0.030
b	94.760	31.462	25.007	2.736	17.662	133.016	136.631	1.094	0.288
α	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421
β	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421	1.421

Table 6.6: Level 1 Resilient Modulus at Optimum for Statistical Analysis.

Lowest	GB	GSM	FGM	SFGM	CFGM
M	31443	21095	9227	19408	9476
σ^2	762430	343171	65656	290478	69247
σ	873	586	256	539	263
Min	29732	19947	8725	18352	8960
Max	33154	22243	9729	20464	9992
α	1.421	1.421	1.421	1.421	1.421
β	1.421	1.421	1.421	1.421	1.421
Low	GB	GSM	FGM	SFGM	CFGM
μ	37260	32449	18357	27760	14357
σ^2	1070625	811997	259869	594279	158957
σ	1035	901	510	771	399
Min	35232	30683	17358	26249	13576
Max	39288	34215	19356	29271	15138
α	1.421	1.421	1.421	1.421	1.421
β	1.421	1.421	1.421	1.421	1.421
Medium	GB	GSM	FGM	SFGM	CFGM
μ	37262	33653.1	22926.9	29725.1	16656.3
σ^2	1070740	873377	405361	681394	213948
σ	1035	935	637	825	463
Min	35234	31821	21679	28107	15750
Max	39290	35485	24175	31343	17563
α	1.421	1.421	1.421	1.421	1.421
β	1.421	1.421	1.421	1.421	1.421
High	GB	GSM	FGM	SFGM	CFGM
μ	39880	38901	30347	34157	20166
σ^2	1226484	1167007	710204	899728	313611
σ	1107	1080	843	949	560
Min	37709	36784	28695	32298	19068
Max	42051	41018	31999	36016	21264
α	1.421	1.421	1.421	1.421	1.421
β	1.421	1.421	1.421	1.421	1.421
Highest	GB	GSM	FGM	SFGM	CFGM
μ	40036	39984	37431	37849	24558
σ^2	1236099	1232890	1080475	1104741	465091
σ	1112	1110	1039	1051	682
Min	37857	37808	35394	35789	23221
Max	42215	42160	39468	39909	25895
α	1.421	1.421	1.421	1.421	1.421
β	1.421	1.421	1.421	1.421	1.421

Table 6.7: Level 3A Mean, Alpha, and Beta Parameter Updates.

A-1-b(GB)										
	$\mathbf{P}_{2.0"}$	$\mathbf{P}_{1.5"}$	$\mathbf{P}_{1.0"}$	$\mathbf{P}_{0.5"}$	$\mathbf{P}_{\#40}$	$\mathbf{P}_{\#60}$	$\mathbf{D}_{60}$	$\mathbf{P}_{\#200}$	**PI**	**wPI**	$\mathbf{G}_{s}$
μ	98.5	97	92.9	77.4	28.27	22.59	5.33	12.97	1.1588	0.21	2.682
α	3.983	3.841	3.193	2.252	3.212	3.035	2.706	1.498	0.11	0.081	7.89
β	0.25	0.473	0.944	2.491	3.361	3.859	4.903	1.41	0.46	0.506	6.17
A-2-4(GSB)											
	$\mathbf{P}_{2.0"}$	$\mathbf{P}_{1.5"}$	$\mathbf{P}_{1.0"}$	$\mathbf{P}_{0.5"}$	$\mathbf{P}_{\#40}$	$\mathbf{P}_{\#60}$	$\mathbf{D}_{60}$	$\mathbf{P}_{\#200}$	**PI**	**wPI**	$\mathbf{G}_{s}$
μ	99.7	99.4	98.4	95.2	58.16	46.7	1.16	24	4.6322	1.27	2.675
α	0.748	1.674	2.866	2.097	2.263	4.193	0.148	2.719	0.634	0.854	5.668
β	0.006	0.019	0.072	0.156	1.843	5.395	7.528	1.461	0.735	1.495	7.41
A-4(SFGM)											
	$\mathbf{P}_{2.0"}$	$\mathbf{P}_{1.5"}$	$\mathbf{P}_{1.0"}$	$\mathbf{P}_{0.5"}$	$\mathbf{P}_{\#40}$	$\mathbf{P}_{\#60}$	$\mathbf{D}_{60}$	$\mathbf{P}_{\#200}$	**PI**	**wPI**	$\mathbf{G}_{s}$
μ	99.7	99.5	99.5	98.9	78.46	72.95	0.3	60.02	5.8733	3.63	2.679
α	0.477	0.898	0.202	0.176	2.165	2.057	0.142	0.864	1.201	1.336	3.634
β	0.011	0.025	0.005	0.006	1.098	1.466	4.996	1.373	0.844	2.252	5.029
A-6(CFGM)											
	$\mathbf{P}_{2.0"}$	$\mathbf{P}_{1.5"}$	$\mathbf{P}_{1.0"}$	$\mathbf{P}_{0.5"}$	$\mathbf{P}_{\#40}$	$\mathbf{P}_{\#60}$	$\mathbf{D}_{60}$	$\mathbf{P}_{\#200}$	**PI**	**wPI**	$\mathbf{G}_{s}$
μ	99.7	99.4	98.9	97.3	86.65	82.89	0.13	74.21	20.9994	16.12	2.682
α	1.753	1.989	2.044	2.518	2.304	2.35	0.039	1.51	4.837	4.651	5.642
β	0.057	0.11	0.163	0.262	0.626	0.854	2.54	0.938	3.686	3.136	13.135
A-6(FGM)											
	$\mathbf{P}_{2.0"}$	$\mathbf{P}_{1.5"}$	$\mathbf{P}_{1.0"}$	$\mathbf{P}_{0.5"}$	$\mathbf{P}_{\#40}$	$\mathbf{P}_{\#60}$	$\mathbf{D}_{60}$	$\mathbf{P}_{\#200}$	**PI**	**wPI**	$\mathbf{G}_{s}$
μ	99.7	99.4	98.9	99.2	82.75	78.16	0.21	67.45	13.801	10.18	2.68
α	1.753	1.989	2.044	0.25	2.661	2.526	0.114	1.346	0.836	2.081	5.562
β	0.057	0.11	0.163	0.008	1.015	1.32	4.554	1.3	3.851	4.694	13.114

6.3.2 Climatic Regions

A total of five climatic regions have been selected for the quantitative comparison of the unbound resilient modulus at equilibrium. The five climatic sites were selected based on the TMI parameter associated with each site. The average TMI value, of the five sites, range from -58 to 86, which covers most of the climatic conditions of the United States. The five climatic sites include:

Phoenix, AZ, Amarillo, TX, McAlester, OK, Salem, OR and Eureka, CA. These five sites were selected based on the TMI variation of the site, the mean TMI value, and the shape of the TMI distribution. The TMI distribution is an important factor when considering the site. The TMI sites that were selected have a TMI distribution that has a skewness and kurtosis value close to zero. By having sites that have a skewness and kurtosis close to zero, it shows the climatic conditions of the site follows a relatively normal distribution or the site experiences the same swings in climatic variability. In Tables 7.4 through Table 7.8 are the climatic parameters associated with each site. As one can see, each of the climatic locations selected have a minimum temperature greater than zero degrees Celsius. When selecting the sites, it required that the minimum temperature does not drop below zero degrees Celsius since the environmental factor that was purposed by Cary and Zapata in 2007, only focuses on the unfrozen unbound material. Table 7.9 is a summary of the mean annual air temperature, annual precipitation, and TMI for all five climatic sites.

Table 6.8: Phoenix, AZ Climatic Information.

Precipitation in cm										
Month	μ	σ^2	σ	CV	$E[X^3]$	$E[X^4]$	Min	Max	α	β
January	1.61	2.92	1.707	106%	0.782	-0.778	0.00	4.71	0.246	0.471
February	3.09	8.96	2.994	97.0%	0.601	-1.216	0.00	8.00	0.268	0.426
March	2.07	5.05	2.248	109%	1.439	1.195	0.03	7.57	0.332	0.894
April	1.16	1.16	1.079	92.8%	0.552	-1.409	0.00	2.87	0.287	0.421
May	0.02	0.00	0.034	182%	1.658	1.171	0.00	0.10	0.062	0.277
June	0.10	0.07	0.270	267%	2.470	4.112	0.00	0.86	0.007	0.052
July	2.38	4.31	2.077	87.2%	1.376	1.063	0.42	7.53	0.372	0.974
August	1.74	1.13	1.061	60.9%	0.213	-1.059	0.01	3.54	0.863	0.894
September	0.98	0.85	0.922	94.5%	1.398	1.533	0.00	3.33	0.499	1.204
October	1.50	5.45	2.335	155%	2.118	3.263	0.00	8.05	0.151	0.656
November	0.71	0.32	0.564	79.1%	0.250	-1.265	0.00	1.68	0.498	0.677
December	1.10	1.65	1.284	117%	0.972	-0.202	0.00	3.96	0.252	0.656
Temperature in Celsius										
Month	μ	σ^2	σ	CV	$E[X^3]$	$E[X^4]$	Min	Max	α	β
January	13.74	1.19	1.091	7.9%	0.955	1.284	11.94	16.39	1.214	1.795
February	14.56	1.77	1.329	9.1%	-0.342	-0.920	12.11	16.42	0.894	0.681
March	18.76	2.99	1.728	9.2%	1.037	0.055	16.63	22.52	0.607	1.071
April	22.16	3.42	1.850	8.4%	-0.197	-0.804	19.04	25.02	0.838	0.768
May	28.75	2.80	1.673	5.8%	-0.692	-0.263	25.25	30.93	1.062	0.662
June	32.84	1.56	1.250	3.8%	-0.629	-0.337	30.29	34.69	1.174	0.855
July	35.18	1.01	1.006	2.9%	-0.854	0.792	32.80	36.68	1.553	0.982
August	34.21	0.40	0.636	1.9%	0.027	-1.558	33.24	35.12	0.611	0.572
September	31.66	1.39	1.178	3.7%	-0.825	0.304	28.98	33.41	1.443	0.938
October	24.66	2.58	1.607	6.5%	0.697	-0.490	22.45	28.03	0.743	1.138
November	17.57	3.56	1.887	10.7%	-0.679	-0.289	13.50	19.98	1.100	0.650
December	12.75	0.56	0.751	5.9%	-0.486	-1.021	11.37	13.65	0.724	0.467

Table 6.9: Amarillo, TX Climatic Information.

Precipitation in cm										
Month	μ	σ2	σ	CV	E[X^3]	E[X^4]	Min	Max	α	β
January	2.29	4.04	2.011	87.7%	0.89	-0.02	0.00	6.80	0.523	1.028
February	1.65	2.60	1.612	97.5%	1.07	0.21	0.01	5.29	0.408	0.901
March	4.37	12.86	3.586	82.0%	0.67	-0.96	0.03	10.53	0.448	0.633
April	5.72	34.87	5.905	103%	1.02	-0.62	0.77	16.39	0.163	0.352
May	4.66	10.13	3.183	68.4%	0.54	-0.68	0.36	10.93	0.676	0.986
June	7.99	21.89	4.678	58.5%	0.00	-1.30	0.31	14.08	0.634	0.503
July	5.21	22.83	4.778	91.7%	0.65	-0.92	0.12	14.00	0.352	0.607
August	5.49	22.30	4.723	86.1%	1.13	0.14	0.74	16.34	0.399	0.912
September	4.14	7.18	2.679	64.8%	0.30	-0.43	0.08	9.25	0.838	1.057
October	5.21	26.07	5.105	97.9%	0.93	-0.30	0.13	16.46	0.371	0.821
November	2.43	5.93	2.434	100%	1.17	0.57	0.00	8.24	0.408	0.974
December	1.49	2.71	1.646	110%	1.38	0.61	0.02	5.37	0.305	0.804
Temperature in Celsius										
Month	μ	σ^2	σ	CV	E[X^3]	E[X^4]	Min	Max	α	β
January	3.34	1.46	1.209	36.2%	0.18	0.24	1.42	5.90	1.013	1.349
February	4.64	4.17	2.041	44.0%	0.63	-0.99	2.29	8.02	0.373	0.536
March	8.18	2.49	1.579	19.3%	0.51	-0.82	5.98	11.14	0.691	0.924
April	13.27	4.07	2.018	15.2%	-0.48	-0.30	9.12	16.27	1.195	0.867
May	19.07	2.46	1.569	8.2%	-0.04	-1.49	16.89	21.03	0.386	0.348
June	23.09	2.98	1.726	7.5%	0.15	-1.40	20.48	25.58	0.606	0.577
July	26.19	1.85	1.361	5.2%	0.72	-0.37	24.36	29.08	0.722	1.139
August	24.84	2.33	1.527	6.2%	0.33	-0.54	22.63	27.92	0.801	1.118
September	20.83	3.15	1.774	8.5%	0.09	-1.08	18.18	23.74	0.692	0.759
October	14.24	1.87	1.369	9.6%	-1.06	0.85	10.93	15.99	1.374	0.728
November	7.46	4.83	2.197	29.5%	-0.08	-0.91	3.53	11.02	0.998	0.905
December	2.67	2.17	1.473	55.1%	-0.29	-1.21	0.17	4.59	0.686	0.522

Table 6.10: McAlester, OK Climatic Information.

Precipitation in cm										
Month	μ	σ^2	σ	CV	$E[X^3]$	$E[X^4]$	Min	Max	α	β
January	5.49	17.60	4.195	76.5%	0.45	-0.85	0.17	13.60	0.574	0.876
February	5.56	22.67	4.761	85.7%	2.15	3.28	1.47	18.57	0.322	1.025
March	7.89	14.68	3.831	48.5%	0.69	-0.57	2.89	15.62	0.643	0.993
April	7.02	21.93	4.683	66.7%	0.56	-1.17	1.94	14.72	0.311	0.471
May	8.16	32.71	5.720	70.1%	1.08	-0.30	2.29	19.87	0.366	0.732
June	11.37	15.18	3.896	34.3%	0.47	-0.51	5.24	18.67	0.891	1.061
July	2.88	6.58	2.566	89.0%	0.56	-1.10	0.08	7.63	0.379	0.641
August	3.91	11.94	3.455	88.4%	1.31	0.49	0.10	11.92	0.501	1.054
September	6.68	27.24	5.219	78.2%	1.18	0.97	0.79	19.46	0.557	1.208
October	8.17	28.02	5.294	64.8%	0.53	-1.03	2.30	18.32	0.413	0.714
November	6.05	20.63	4.542	75.1%	0.47	-1.37	0.27	13.42	0.467	0.597
December	5.64	19.47	4.413	78.2%	0.66	-0.81	0.50	13.34	0.414	0.620

Temperature in Celsius										
Month	μ	σ^2	σ	CV	$E[X^3]$	$E[X^4]$	Min	Max	α	β
January	5.70	2.67	1.634	28.7%	0.93	0.78	3.47	9.60	0.818	1.432
February	7.84	4.97	2.229	28.4%	0.26	-1.04	4.82	11.54	0.561	0.688
March	11.25	2.21	1.486	13.2%	0.54	-1.15	9.42	13.86	0.476	0.681
April	16.54	1.88	1.370	8.3%	-0.17	-0.32	13.92	18.96	1.232	1.141
May	21.22	1.42	1.192	5.6%	0.45	-0.85	19.63	23.49	0.636	0.909
June	24.77	1.76	1.327	5.4%	1.05	-0.08	23.43	27.65	0.373	0.807
July	28.08	2.48	1.575	5.6%	1.08	0.73	25.93	31.74	0.800	1.368
August	27.56	2.87	1.695	6.2%	-0.20	-1.00	24.96	30.36	0.734	0.794
September	23.37	4.19	2.047	8.8%	0.12	-1.23	20.68	26.90	0.546	0.716
October	17.39	1.24	1.114	6.4%	-0.76	-0.34	15.02	18.79	1.054	0.622
November	11.23	5.55	2.355	21.0%	-0.23	-1.21	7.20	14.88	0.869	0.789
December	5.99	3.23	1.798	30.0%	-1.66	1.95	1.26	7.58	1.000	0.338

Table 6.11: Salem, OR Climatic Information.

Precipitation in cm

Month	μ	σ^2	σ	CV	$E[X^3]$	$E[X^4]$	Min	Max	α	β
January	18.96	74.69	8.642	45.6%	-0.44	-0.32	3.65	33.96	1.049	1.027
February	11.18	66.91	8.180	73.2%	0.85	-0.09	1.26	28.96	0.586	1.050
March	10.78	15.79	3.974	36.9%	0.12	-0.08	3.64	18.60	1.208	1.324
April	6.31	10.66	3.266	51.8%	1.47	1.25	3.31	14.33	0.341	0.913
May	6.53	13.09	3.618	55.4%	1.19	-0.18	3.49	14.14	0.220	0.549
June	3.51	1.51	1.227	34.9%	-0.37	-1.43	1.58	4.81	0.395	0.265
July	0.57	0.39	0.624	110%	1.97	2.87	0.01	2.29	0.365	1.116
August	1.06	1.15	1.073	102%	0.59	-1.35	0.06	2.87	0.203	0.370
September	3.64	7.41	2.723	74.7%	0.98	0.16	0.23	9.89	0.662	1.212
October	7.96	15.05	3.880	48.8%	0.66	0.45	1.23	16.54	1.245	1.588
November	15.80	61.15	7.820	49.5%	0.38	-1.11	5.47	29.73	0.576	0.777
December	20.38	92.29	9.607	47.1%	0.23	-1.06	7.71	38.13	0.599	0.838

Temperature in Celsius

Month	μ	σ^2	σ	CV	$E[X^3]$	$E[X^4]$	Min	Max	α	β
January	5.51	0.96	0.981	17.8%	0.40	-1.15	4.11	7.12	0.626	0.715
February	6.12	0.45	0.672	11.0%	-0.29	-0.12	4.82	7.33	1.289	1.189
March	8.16	1.13	1.062	13.0%	-0.23	-1.38	6.53	9.58	0.560	0.485
April	10.16	0.56	0.751	7.4%	0.21	-0.66	8.95	11.53	0.915	1.037
May	13.44	1.61	1.268	9.4%	0.63	-0.40	11.75	16.06	0.689	1.069
June	16.30	1.10	1.051	6.5%	0.28	-1.35	14.91	18.05	0.533	0.668
July	20.00	0.97	0.983	4.9%	-0.31	-1.47	18.56	21.22	0.444	0.374
August	19.90	0.42	0.648	3.3%	-0.40	-0.66	18.61	20.78	1.016	0.687
September	16.79	0.81	0.898	5.4%	-0.45	-1.17	15.28	17.99	0.690	0.550
October	11.77	0.64	0.799	6.8%	1.04	0.65	10.73	13.68	0.753	1.370
November	7.50	2.01	1.418	18.9%	-0.14	-1.31	5.26	9.57	0.683	0.629
December	5.20	0.49	0.700	13.5%	-0.20	-1.43	4.17	6.21	0.569	0.556

Table 6.12: Eureka, CA Climatic Information.

Precipitation in cm

Month	μ	σ^2	σ	CV	$E[X^3]$	$E[X^4]$	Min	Max	α	β
January	20.10	30.22	5.50	27.4%	0.99	-0.30	14.08	30.33	0.385	0.654
February	13.46	38.33	6.19	46.0%	0.32	-1.23	5.49	23.04	0.451	0.542
March	10.84	16.11	4.01	37.0%	-0.20	-1.70	5.69	15.58	0.268	0.246
April	14.07	102.80	10.14	72.1%	1.04	-0.49	5.26	32.82	0.194	0.413
May	4.68	15.08	3.88	83.1%	1.41	0.13	1.78	12.34	0.130	0.344
June	3.11	14.25	3.78	121%	1.27	-0.06	0.18	10.42	0.143	0.358
July	0.28	0.02	0.15	56.2%	0.91	-0.40	0.10	0.56	0.403	0.657
August	0.93	0.41	0.64	68.8%	0.04	-1.56	0.10	1.78	0.357	0.371
September	0.99	0.22	0.47	47.5%	-0.03	-1.66	0.43	1.60	0.256	0.279
October	5.49	21.47	4.63	84.4%	0.36	-1.34	0.15	12.65	0.332	0.446
November	14.77	71.50	8.46	57.2%	-0.07	-1.73	4.35	24.23	0.198	0.180
December	35.78	144.41	12.02	33.6%	1.05	-0.26	23.14	58.32	0.350	0.623

Temperature in Celsius

Month	μ	σ^2	σ	CV	$E[X^3]$	$E[X^4]$	Min	Max	α	β
January	9.03	2.06	1.44	15.9%	0.62	-0.75	7.33	11.51	0.424	0.621
February	8.49	0.47	0.69	8.1%	0.02	-1.51	7.60	9.44	0.378	0.404
March	9.33	0.97	0.99	10.6%	-0.88	-0.77	7.58	10.17	0.347	0.166
April	9.50	0.63	0.79	8.4%	-0.18	-0.70	8.23	10.68	0.717	0.657
May	11.57	1.38	1.17	10.2%	0.01	-1.51	9.92	12.95	0.357	0.299
June	12.73	0.51	0.72	5.6%	0.41	-1.12	11.82	13.88	0.455	0.574
July	13.46	0.42	0.65	4.8%	-0.38	-0.75	12.39	14.34	0.697	0.570
August	13.66	1.08	1.04	7.6%	0.04	-1.69	12.37	14.92	0.258	0.250
September	12.52	0.57	0.76	6.0%	0.23	-1.70	11.63	13.50	0.252	0.275
October	11.36	1.09	1.04	9.2%	-0.11	-0.93	9.74	12.87	0.648	0.604
November	9.66	0.44	0.66	6.9%	0.17	-1.60	8.80	10.52	0.338	0.337
December	9.02	0.18	0.42	4.7%	-0.27	-1.28	8.38	9.56	0.508	0.415

Table 6.13: Climatic Site Summary.

Mean Annual Air Temperature (^{0}C)								
City	μ	σ^2	σ	CV	Min	Max	α	β
Eureka, CA	10.86	0.07	0.26	2.40%	9.90	11.76	5.997	5.696
Salem, OR	11.73	0.08	0.28	2.37%	10.70	12.77	6.462	6.483
McAlester, OK	16.73	0.24	0.49	2.91%	14.91	18.49	6.404	6.149
Amarillo, TX	13.98	0.23	0.48	3.45%	12.15	15.82	6.682	6.754
Phoenix, AZ	23.90	0.16	0.40	1.68%	22.37	25.25	6.314	5.573
Annual Precipitation (cm)								
City	μ	σ^2	σ	CV	Min	Max	α	β
Eureka, CA	125.24	455.64	21.35	17.04%	63.64	211.53	4.443	6.223
Salem, OR	108.25	360.63	18.99	17.54%	44.94	176.70	5.293	5.723
McAlester, OK	83.95	226.77	15.06	17.94%	35.01	145.93	5.460	6.916
Amarillo, TX	58.04	150.31	12.26	21.12%	20.83	107.31	4.817	6.378
Phoenix, AZ	17.88	31.20	5.59	31.23%	4.47	39.57	3.182	5.142
TMI								
City	μ	σ^2	σ	CV	Min	Max	α	β
Eureka, CA	85.93	296.71	17.23	20.04%	15.68	100.00	1.942	0.389
Salem, OR	57.84	475.99	21.82	37.72%	-7.02	100.00	2.876	1.869
McAlester, OK	1.49	181.73	13.48	905.04%	-35.70	53.94	4.038	5.695
Amarillo, TX	-15.35	172.78	13.14	85.62%	-52.70	34.26	4.176	5.547
Phoenix, AZ	-58.24	5.67	2.38	4.09%	-64.10	-49.26	3.269	5.008

6.4 Program Results

After completing 25,000 Monte Carlo Simulations for each given twenty-five soils within the different climatic locations, the unbound resilient modulus at equilibrium values are shown in Tables 6.14 through Table 6.18. The entire statistics for the Monte Carlo Simulation can be found in Appendix B for all the soils within the five climatic locations.

Table 6.14: Phoenix, AZ Modulus at Equilibrium Descriptive Statistics.

Soil Name	μ (psi)	μ(log)	σ^2	$E[X^3]$	$E[X^4]$	Min	Max	α	β
GB	50234	4.701	0.029	-0.32	-0.18	4.048	5.176	5.684	4.124
GSB	37931	4.579	0.059	-0.36	-0.16	3.631	5.23	5.601	3.852
FGM	29444	4.469	0.231	-0.15	-0.71	3.206	5.678	2.87	2.747
SFGM	31696	4.501	0.126	-0.03	-0.95	3.523	5.354	3.012	2.63
CFGM	43551	4.639	0.119	-0.44	-0.24	3.406	5.478	4.594	3.126
A-1-b(GB)	49774	4.697	0.032	-0.32	-0.23	4.021	5.177	5.437	3.861
A-2-4(GSB)	43752	4.641	0.032	-0.26	-0.31	4.013	5.121	4.854	3.704
A-4(SFGM)	31405	4.497	0.124	-0.02	-0.94	3.35	5.331	3.874	2.816
A-6(CFGM)	49431	4.694	0.026	-0.5	0.18	3.992	5.12	6.678	4.048
A-6(FGM)	47753	4.679	0.049	-0.47	-0.08	3.818	5.24	5.31	3.459
GB Lowest	45814	4.661	0.002	-0.11	-0.37	4.523	4.785	4.693	4.206
GB Low	54325	4.735	0.002	-0.15	-0.37	4.584	4.857	5.286	4.273
GB Med	54325	4.735	0.002	-0.13	-0.38	4.586	4.86	5.433	4.597
GB High	58076	4.764	0.002	-0.16	-0.39	4.62	4.883	4.665	3.868
GB Highest	58345	4.766	0.002	-0.13	-0.39	4.626	4.886	4.678	3.992
GSB Lowest	20559	4.313	0.011	-0.25	-0.39	3.954	4.589	4.368	3.365
GSB Low	31623	4.5	0.011	-0.26	-0.37	4.131	4.782	4.617	3.524
GSB Med	32734	4.515	0.011	-0.25	-0.39	4.16	4.792	4.388	3.412
GSB High	38019	4.58	0.011	-0.24	-0.39	4.235	4.866	4.276	3.546
GSB Highest	38994	4.591	0.011	-0.21	-0.36	4.243	4.884	4.406	3.695
FGM Lowest	23227	4.366	0.020	-0.43	-0.23	3.861	4.703	4.441	2.959
FGM Low	46452	4.667	0.020	-0.5	-0.1	4.162	4.988	4.479	2.851
FGM Med	57943	4.763	0.02	-0.46	-0.18	4.235	5.084	4.649	2.833
FGM High	76560	4.884	0.020	-0.5	-0.19	4.379	5.197	4.195	2.596
FGM Highest	94189	4.974	0.020	-0.57	0.06	4.413	5.3	5.097	2.972
SFGM Lowest	32137	4.507	0.014	-0.4	-0.25	4.078	4.805	4.737	3.288
SFGM Low	46132	4.664	0.014	-0.36	-0.31	4.262	4.96	4.353	3.212
SFGM Med	49317	4.693	0.014	-0.37	-0.27	4.261	4.989	4.743	3.256
SFGM High	56234	4.75	0.014	-0.35	-0.28	4.327	5.038	4.485	3.061
SFGM Highest	62806	4.798	0.015	-0.39	-0.25	4.369	5.093	4.549	3.123
CFGM Lowest	31477	4.498	0.023	-0.59	0.12	3.831	4.831	5.833	2.92
CFGM Low	47863	4.68	0.023	-0.59	0	4.061	5.005	5.147	2.704
CFGM Med	55463	4.744	0.023	-0.56	0.04	4.154	5.087	5.061	2.939
CFGM High	67143	4.827	0.022	-0.57	0.01	4.246	5.163	4.87	2.812
CFGM Highest	80538	4.906	0.024	-0.6	0.08	4.301	5.261	4.972	2.92

Table 6.15: Amarillo, TX Modulus at Equilibrium Descriptive Statistics.

Soil Name	μ(psi)	μ(log)	σ^2	$E[X^3]$	$E[X^4]$	Min	Max	α	β
GB	47534	4.677	0.0271	-0.31	-0.15	4.062	5.146	5.473	4.174
GSB	31477	4.498	0.0697	-0.29	-0.33	3.55	5.209	4.955	3.713
FGM	15205	4.182	0.1586	0.29	-0.53	3.304	5.427	2.437	3.458
SFGM	17579	4.245	0.0711	0.37	-0.57	3.57	5.145	3.232	4.308
CFGM	13677	4.136	0.1288	0.22	-0.73	3.312	5.172	2.493	3.132
A-1-b(GB)	46666	4.669	0.0303	-0.28	-0.22	4.048	5.159	5.06	3.992
A-2-4(GSB)	32885	4.517	0.0519	-0.15	-0.56	3.826	5.132	3.804	3.387
A-4(SFGM)	17418	4.241	0.07	0.35	-0.51	3.259	5.047	5.668	4.651
A-6(CFGM)	12417	4.094	0.05	0.02	-0.7	3.568	4.76	2.654	3.356
A-6(FGM)	15101	4.179	0.0583	0.19	-0.73	3.612	4.91	2.669	3.442
GB Lowest	33343	4.523	0.0046	-0.06	-0.51	4.326	4.723	3.737	3.785
GB Low	39628	4.598	0.0047	-0.07	-0.55	4.399	4.788	3.572	3.419
GB Med	39537	4.597	0.0048	-0.01	-0.54	4.403	4.796	3.492	3.582
GB High	42560	4.629	0.0046	-0.04	-0.54	4.44	4.824	3.471	3.589
GB Highest	42560	4.629	0.0046	-0.12	-0.5	4.428	4.819	3.723	3.507
GSB Lowest	11429	4.058	0.0114	0.2	-0.64	3.824	4.388	2.41	3.385
GSB Low	17458	4.242	0.0116	0.29	-0.58	4.016	4.6	2.324	3.68
GSB Med	18197	4.26	0.0114	0.21	-0.63	4.029	4.58	2.287	3.174
GSB High	21038	4.323	0.0112	0.21	-0.65	4.094	4.664	2.407	3.569
GSB Highest	21627	4.335	0.0112	0.21	-0.64	4.102	4.648	2.351	3.154
FGM Lowest	6823	3.834	0.0309	0.16	-0.82	3.49	4.309	1.799	2.483
FGM Low	13583	4.133	0.0311	0.17	-0.82	3.789	4.612	1.794	2.503
FGM Med	17061	4.232	0.0306	0.18	-0.79	3.889	4.732	1.872	2.725
FGM High	22491	4.352	0.0303	0.17	-0.76	4.005	4.841	1.905	2.689
FGM Highest	27479	4.439	0.0307	0.2	-0.78	4.099	4.941	1.843	2.718
SFGM Lowest	11066	4.044	0.0219	0.2	-0.77	3.747	4.463	1.942	2.743
SFGM Low	15812	4.199	0.022	0.23	-0.77	3.91	4.635	1.884	2.844
SFGM Med	16866	4.227	0.0215	0.22	-0.78	3.942	4.669	1.898	2.953
SFGM High	19498	4.29	0.0218	0.27	-0.7	4.004	4.743	1.913	3.036
SFGM Highest	21677	4.336	0.0225	0.28	-0.73	4.051	4.771	1.791	2.733
CFGM Lowest	8147	3.911	0.0373	0.08	-0.74	3.495	4.451	2.187	2.839
CFGM Low	12331	4.091	0.0364	0.03	-0.76	3.676	4.597	2.147	2.619
CFGM Med	14289	4.155	0.0375	0.06	-0.79	3.746	4.676	2.058	2.621
CFGM High	17298	4.238	0.0357	0.03	-0.75	3.821	4.76	2.27	2.835
CFGM Highest	20893	4.32	0.036	0.06	-0.74	3.907	4.859	2.247	2.934

Table 6.16: McAlester, OK Modulus at Equilibrium Descriptive Statistics.

Soil Name	μ(psi)	μ(log)	σ2	E[X3]	E[X4]	Min	Max	α	β
GB	46132	4.664	0.0263	-0.33	-0.09	3.969	5.113	6.597	4.253
GSB	29717	4.473	0.0685	-0.27	-0.37	3.575	5.192	4.683	3.746
FGM	14622	4.165	0.1622	0.2	-0.6	3.233	5.361	2.575	3.303
SFGM	16368	4.214	0.0604	0.39	-0.48	3.542	5.045	3.687	4.561
CFGM	11912	4.076	0.1033	0.23	-0.66	3.318	5.039	2.673	3.392
A-1-b(GB)	45082	4.654	0.0289	-0.27	-0.25	4.032	5.134	5.273	4.06
A-2-4(GSB)	31477	4.498	0.0536	-0.11	-0.64	3.839	5.116	3.408	3.195
A-4(SFGM)	16634	4.221	0.0616	0.34	-0.45	3.288	5.013	5.945	5.05
A-6(CFGM)	10447	4.019	0.0374	0.11	-0.62	3.56	4.625	2.778	3.661
A-6(FGM)	13092	4.117	0.0478	0.27	-0.61	3.618	4.823	2.638	3.738
GB Lowest	31046	4.492	0.004	0	-0.55	4.314	4.678	3.608	3.786
GB Low	36813	4.566	0.004	0.01	-0.55	4.384	4.748	3.628	3.653
GB Med	36728	4.565	0.0039	0	-0.52	4.394	4.752	3.466	3.787
GB High	39355	4.595	0.0039	0.04	-0.49	4.421	4.793	3.65	4.137
GB Highest	39537	4.597	0.0039	0.02	-0.5	4.419	4.779	3.629	3.695
GSB Lowest	10789	4.033	0.0095	0.25	-0.61	3.823	4.347	2.386	3.577
GSB Low	16558	4.219	0.0092	0.26	-0.59	4.01	4.528	2.412	3.58
GSB Med	17219	4.236	0.0096	0.25	-0.6	4.022	4.56	2.497	3.762
GSB High	19907	4.299	0.0093	0.24	-0.59	4.086	4.606	2.455	3.543
GSB Highest	20464	4.311	0.0093	0.25	-0.61	4.101	4.626	2.45	3.681
FGM Lowest	5768	3.761	0.0213	0.3	-0.72	3.486	4.183	1.754	2.684
FGM Low	11482	4.06	0.0218	0.31	-0.68	3.789	4.53	1.772	3.066
FGM Med	14322	4.156	0.0211	0.31	-0.68	3.881	4.598	1.82	2.932
FGM High	18880	4.276	0.0216	0.27	-0.73	3.994	4.705	1.821	2.78
FGM Highest	23227	4.366	0.0214	0.32	-0.65	4.092	4.852	1.886	3.336
SFGM Lowest	9772	3.99	0.0163	0.31	-0.7	3.749	4.381	1.824	2.959
SFGM Low	13996	4.146	0.0168	0.35	-0.69	3.91	4.551	1.73	2.977
SFGM Med	14997	4.176	0.0167	0.32	-0.72	3.941	4.572	1.705	2.871
SFGM High	17219	4.236	0.017	0.39	-0.65	4.002	4.675	1.746	3.289
SFGM Highest	19187	4.283	0.0167	0.32	-0.71	4.041	4.669	1.765	2.821
CFGM Lowest	6653	3.823	0.0228	0.1	-0.7	3.488	4.267	2.379	3.148
CFGM Low	10209	4.009	0.0226	0.13	-0.67	3.677	4.478	2.431	3.434
CFGM Med	11668	4.067	0.0229	0.13	-0.73	3.745	4.497	2.156	2.88
CFGM High	14191	4.152	0.0221	0.15	-0.66	3.826	4.649	2.507	3.819
CFGM Highest	17418	4.241	0.0237	0.12	-0.75	3.914	4.675	2.157	2.856

Table 6.17: Salem, OR Modulus at Equilibrium Descriptive Statistics.

Soil Name	μ(psi)	μ(log)	σ2	E[X3]	E[X4]	Min	Max	α	β
GB	42364	4.627	0.0251	-0.26	-0.22	4.056	5.114	5.437	4.638
GSB	27102	4.433	0.0575	-0.27	-0.33	3.594	5.152	5.104	4.37
FGM	13274	4.123	0.1321	0.29	-0.47	3.299	5.246	2.54	3.462
SFGM	15241	4.183	0.0519	0.41	-0.39	3.512	4.906	4.023	4.33
CFGM	10046	4.002	0.0869	0.26	-0.54	3.297	4.931	2.823	3.715
A-1-b(GB)	41591	4.619	0.0262	-0.23	-0.26	4.048	5.119	5.273	4.618
A-2-4(GSB)	27797	4.444	0.0457	-0.12	-0.55	3.771	5.032	4.091	3.579
A-4(SFGM)	15171	4.181	0.0516	0.34	-0.3	3.085	4.937	8.91	6.14
A-6(CFGM)	8913	3.95	0.0281	0.19	-0.54	3.546	4.532	3.029	4.358
A-6(FGM)	11429	4.058	0.0369	0.28	-0.54	3.599	4.69	2.883	3.979
GB Lowest	28840	4.46	0.0035	0.06	-0.58	4.305	4.634	3.185	3.552
GB Low	34277	4.535	0.0035	0.08	-0.55	4.378	4.722	3.428	4.081
GB Med	34277	4.535	0.0035	0.07	-0.56	4.376	4.721	3.447	4.056
GB High	36559	4.563	0.0035	0.11	-0.55	4.412	4.757	3.216	4.157
GB Highest	36813	4.566	0.0036	0.07	-0.55	4.404	4.75	3.442	3.905
GSB Lowest	10257	4.011	0.008	0.27	-0.6	3.824	4.304	2.272	3.542
GSB Low	15740	4.197	0.0078	0.24	-0.64	4.008	4.466	2.31	3.277
GSB Med	16444	4.216	0.0081	0.25	-0.66	4.023	4.488	2.251	3.186
GSB High	18923	4.277	0.0078	0.23	-0.62	4.084	4.577	2.515	3.894
GSB Highest	19543	4.291	0.008	0.26	-0.63	4.099	4.579	2.363	3.546
FGM Lowest	4853	3.686	0.0143	0.49	-0.49	3.481	4.073	1.584	2.978
FGM Low	9727	3.988	0.0151	0.52	-0.49	3.782	4.4	1.547	3.088
FGM Med	12134	4.084	0.0148	0.46	-0.58	3.873	4.487	1.639	3.123
FGM High	16069	4.206	0.0149	0.48	-0.54	3.997	4.624	1.614	3.232
FGM Highest	19907	4.299	0.0151	0.5	-0.51	4.09	4.702	1.563	3.023
SFGM Lowest	8710	3.94	0.0124	0.49	-0.54	3.749	4.311	1.601	3.1
SFGM Low	12503	4.097	0.0127	0.48	-0.55	3.903	4.452	1.557	2.857
SFGM Med	13459	4.129	0.0128	0.48	-0.55	3.933	4.485	1.569	2.861
SFGM High	15382	4.187	0.0126	0.54	-0.43	3.994	4.598	1.682	3.584
SFGM Highest	16982	4.23	0.0123	0.5	-0.54	4.043	4.592	1.531	2.957
CFGM Lowest	5483	3.739	0.0148	0.27	-0.62	3.489	4.128	2.185	3.405
CFGM Low	8241	3.916	0.0147	0.27	-0.62	3.663	4.314	2.274	3.578
CFGM Med	9528	3.979	0.0142	0.25	-0.62	3.728	4.374	2.328	3.659
CFGM High	11641	4.066	0.0142	0.27	-0.58	3.81	4.47	2.426	3.837
CFGM Highest	14093	4.149	0.0147	0.28	-0.6	3.9	4.534	2.165	3.349

Table 6.18: Eureka, CA Modulus at Equilibrium Descriptive Statisticss.

Soil Name	μ(psi)	μ(log)	σ^2	$E[X^3]$	$E[X^4]$	Min	Max	α	β
GB	40738	4.61	0.0238	-0.25	-0.13	4.012	5.098	6.212	5.073
GSB	25586	4.408	0.0545	-0.22	-0.27	3.591	5.064	4.902	3.934
FGM	17338	4.239	0.1435	-0.12	-0.65	3.169	5.241	3.341	3.133
SFGM	14655	4.166	0.0554	0.32	-0.45	3.48	4.947	4.054	4.62
CFGM	9886	3.995	0.0774	0.3	-0.47	3.309	4.922	3.066	4.142
A-1-b(GB)	39628	4.598	0.0248	-0.29	-0.16	3.994	5.109	6.215	5.244
A-2-4(GSB)	25823	4.412	0.0413	-0.12	-0.53	3.798	4.98	3.866	3.583
A-4(SFGM)	14791	4.17	0.0517	0.36	-0.27	3.343	4.936	5.835	5.413
A-6(CFGM)	8710	3.94	0.0265	0.16	-0.58	3.549	4.484	2.935	4.092
A-6(FGM)	11220	4.05	0.034	0.3	-0.48	3.606	4.645	2.899	3.88
GB Lowest	28708	4.458	0.0035	0.13	-0.48	4.298	4.639	3.374	3.815
GB Low	33963	4.531	0.0034	0.08	-0.54	4.376	4.721	3.409	4.181
GB Med	33963	4.531	0.0035	0.08	-0.55	4.371	4.725	3.605	4.362
GB High	36475	4.562	0.0034	0.06	-0.54	4.402	4.741	3.434	3.847
GB Highest	36475	4.562	0.0034	0.1	-0.51	4.398	4.749	3.707	4.257
GSB Lowest	10162	4.007	0.0075	0.25	-0.63	3.818	4.275	2.353	3.354
GSB Low	15596	4.193	0.0074	0.27	-0.61	4.011	4.473	2.318	3.555
GSB Med	16255	4.211	0.0075	0.26	-0.61	4.022	4.486	2.41	3.517
GSB High	18750	4.273	0.0077	0.28	-0.62	4.084	4.543	2.325	3.317
GSB Highest	19364	4.287	0.0076	0.25	-0.62	4.097	4.557	2.375	3.384
FGM Lowest	4732	3.675	0.0133	0.49	-0.53	3.48	4.049	1.543	2.954
FGM Low	9462	3.976	0.0134	0.5	-0.52	3.776	4.364	1.626	3.16
FGM Med	11830	4.073	0.0136	0.51	-0.47	3.873	4.474	1.644	3.291
FGM High	15704	4.196	0.014	0.55	-0.45	3.998	4.599	1.547	3.148
FGM Highest	19275	4.285	0.0135	0.54	-0.43	4.088	4.687	1.6	3.259
SFGM Lowest	8590	3.934	0.0121	0.51	-0.49	3.746	4.305	1.612	3.174
SFGM Low	12331	4.091	0.0121	0.51	-0.5	3.905	4.458	1.56	3.074
SFGM Med	13092	4.117	0.0119	0.53	-0.47	3.93	4.466	1.565	2.933
SFGM High	15136	4.18	0.0118	0.5	-0.55	3.995	4.541	1.584	3.083
SFGM Highest	16788	4.225	0.0118	0.51	-0.48	4.037	4.595	1.651	3.248
CFGM Lowest	5297	3.724	0.0134	0.32	-0.53	3.486	4.119	2.249	3.733
CFGM Low	8017	3.904	0.0133	0.3	-0.56	3.668	4.298	2.251	3.758
CFGM Med	9333	3.97	0.0134	0.3	-0.54	3.732	4.373	2.279	3.857
CFGM High	11324	4.054	0.0136	0.28	-0.61	3.814	4.457	2.276	3.819
CFGM Highest	13740	4.138	0.0138	0.32	-0.56	3.897	4.52	2.193	3.478

6.5 Data Analysis

The Data analysis is sub-divided into three sections, the first section is the statistical analysis to prove or disprove the need for hierarchical levels with a given climatic location. The next section will be a continuation of the statistical analysis to prove or disprove the need to use different climatic locations or if one climatic value can be used. Finally, the data analysis will show if there is any benefit from completing laboratory testing by using the AASHTO structural number concept to determine the difference in asphalt thickness.

6.5.1 Within Climatic Location Data Analysis

A total of five soils are used to differentiate if there is a significant difference between the variances of the hierarchical levels, which shows that the hierarchical level designation is valid; on the other hand, if there is no significant differences between the variances associated with the hierarchical levels, it will show that there is no need for the hierarchical levels and using values from engineering database and assumption are valid for any level of design.

Out of the five climatic sites selected for the analysis, only one will be used to for the “within climatic location statistical analysis”. Even though all five sites have different means, minimum, and maximum values, and the variance of the distributions are the same. The distribution moves due to the matric suction the soil is subjected to, which is correlated to the TMI of the site. Using Phoenix, AZ information, Figures 6.2 through Figure 6.6 are developed for the five different soils.

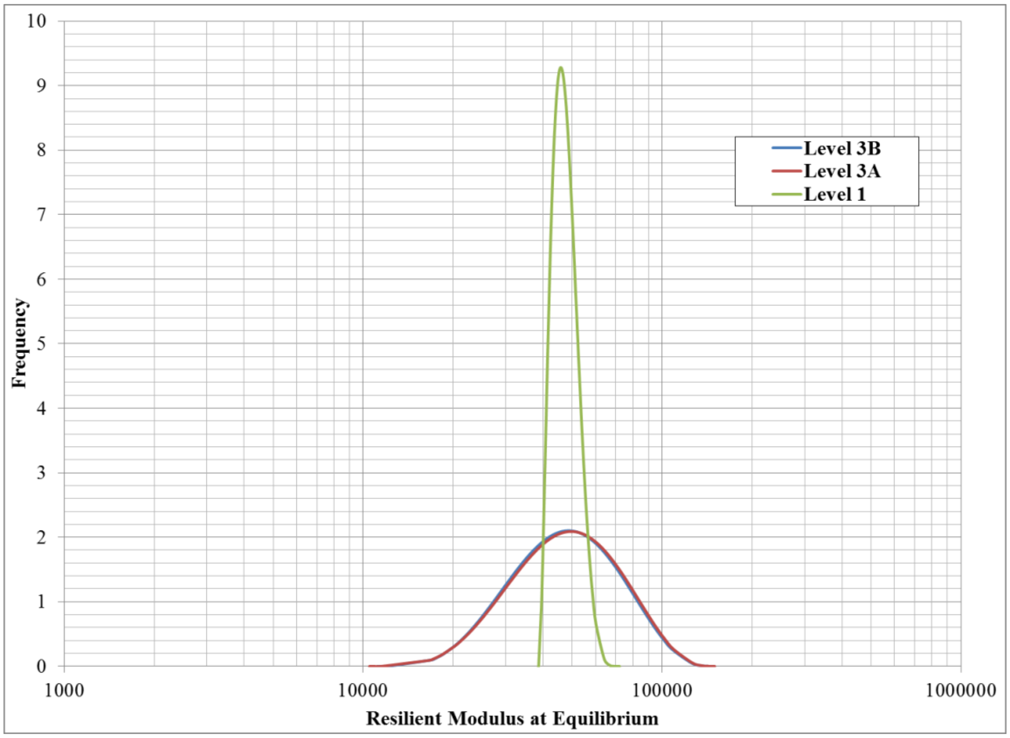

Figure 6.2: Granular base material distributions.

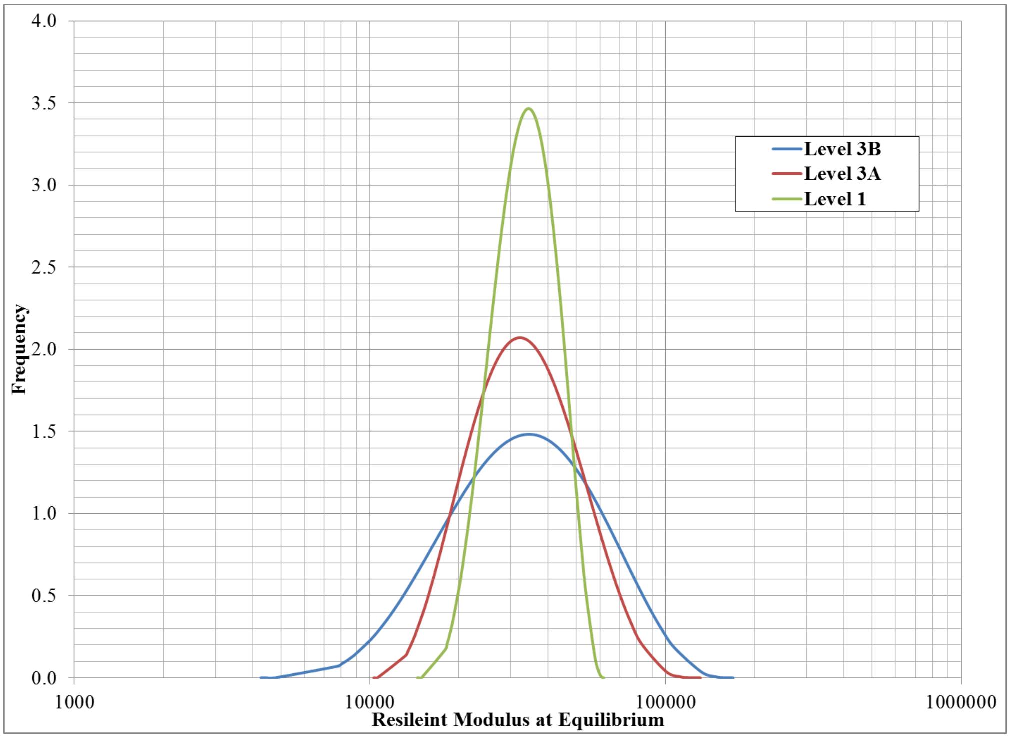

Figure 6.3: Granular subbase material distributions.

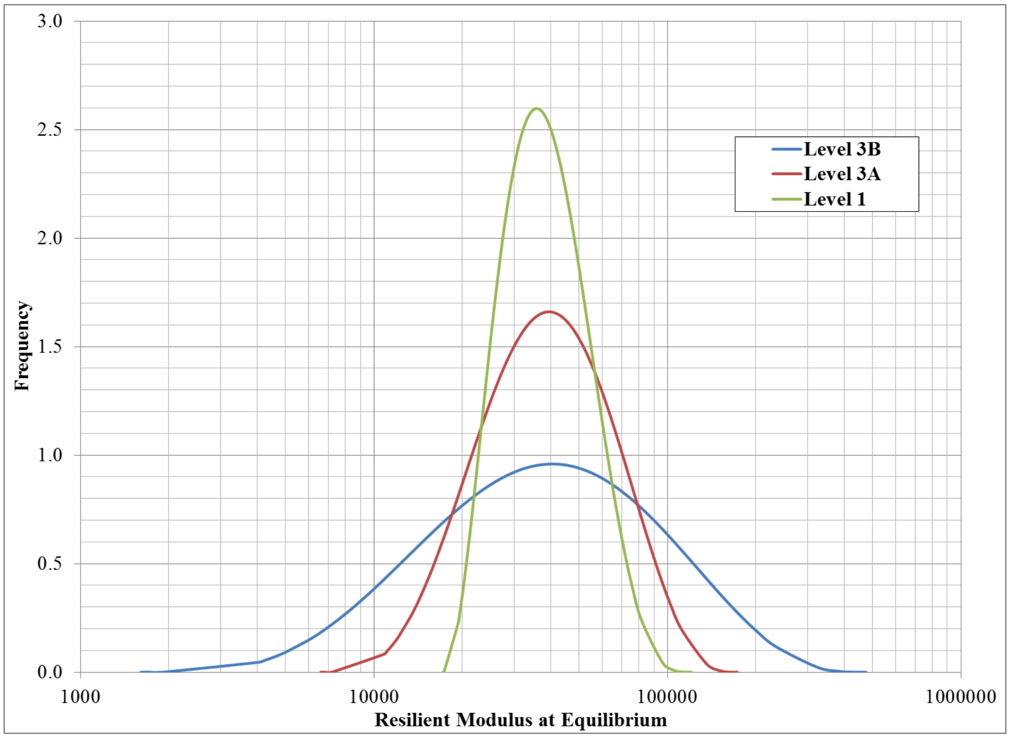

Figure 6.4: Fine grained material distributions.

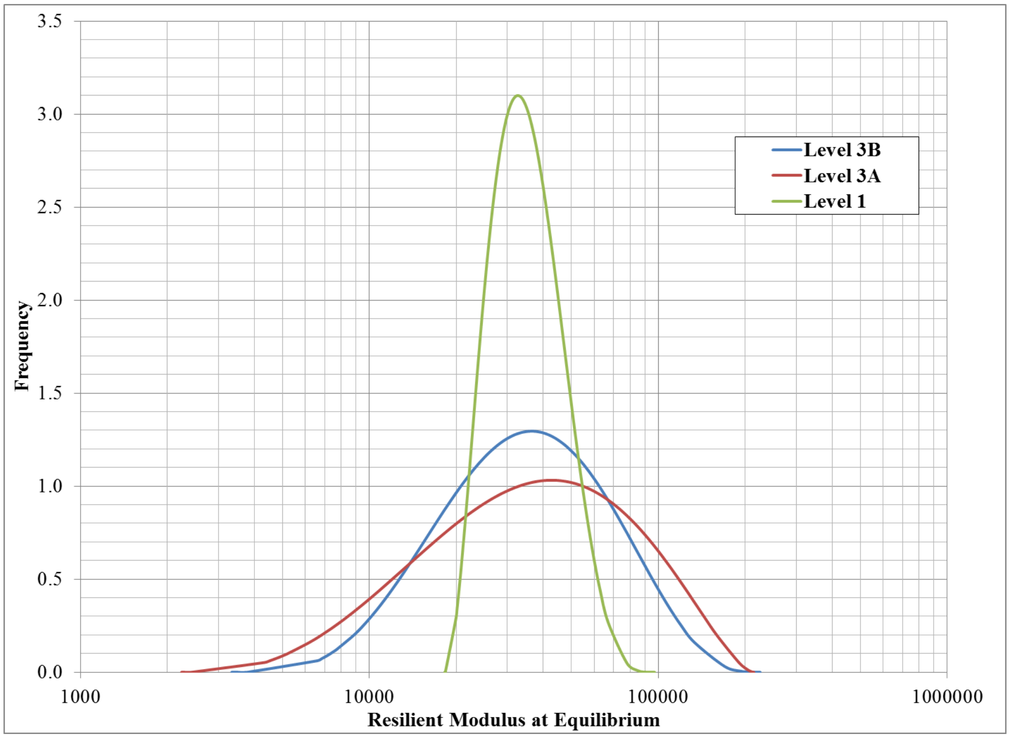

Figure 6.5: “Silty” fine grained material distributions.

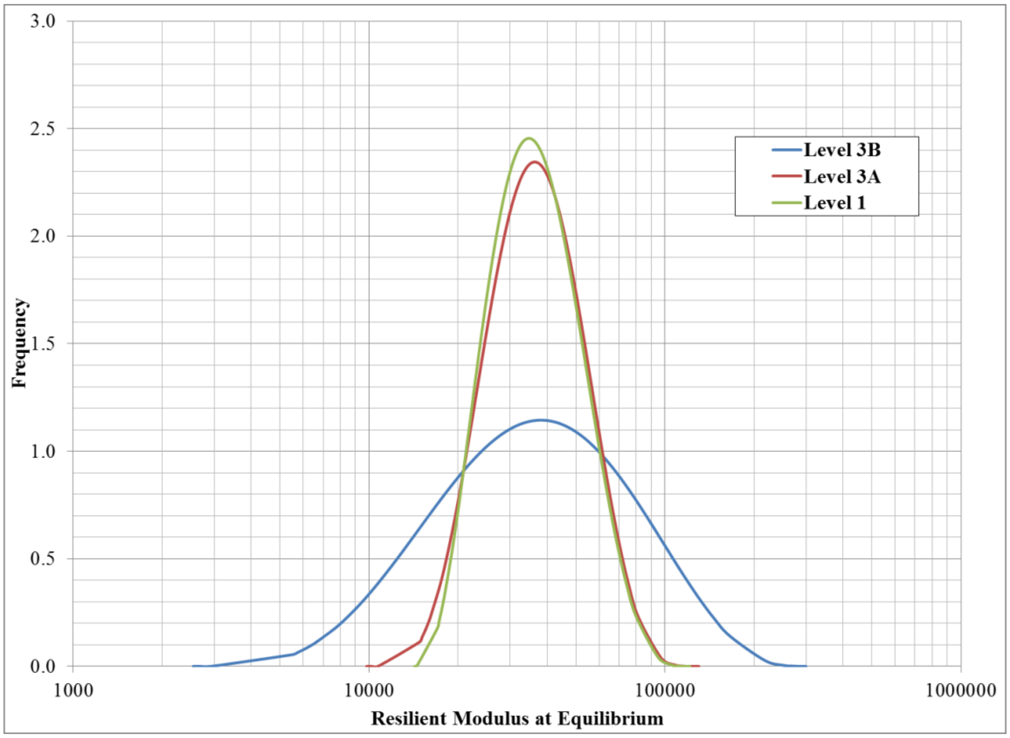

Figure 6.6: “Clayey” fine grained material distributions.

Recall from Chapter 2, that the F-statistic is used for variance comparison. The F-statistic can be found in Equation 2.9. Table 6.19 is the F-statistic for the five soil types, these values are compared against Level 1, Level 3A, and Level 3B. The null hypothesis for the comparison is that the variances of each level are equal to one another. The variance for the fifteen soils can be found in Table 6.14. The acceptance regions for the soils are located in Table 6.20. The acceptance region used for the F-statistic is a five percent level of significance or an acceptance region of 95 percent. The results of combining the acceptance region with the F-statistic are located in Table 6.21.

Table 6.19: F-Statistic of the Five Different Hierarchical Level Soils.

GB	Level 1	Level 3A	Level 3B
Level 1	1.0000	0.0535	0.0588
Level 3A	18.6753	1.0000	1.0978
Level 3B	17.0121	0.9109	1.0000
GSB	Level 1	Level 3A	Level 3B
Level 1	1.0000	0.3536	0.1886
Level 3A	2.8281	1.0000	0.5335
Level 3B	5.3012	1.8744	1.0000
FGM	Level 1	Level 3A	Level 3B
Level 1	1.0000	0.4047	0.0866
Level 3A	2.4707	1.0000	0.2140
Level 3B	11.5452	4.6729	1.0000
SFGM	Level 1	Level 3A	Level 3B
Level 1	1.0000	0.1145	0.1134
Level 3A	8.7307	1.0000	0.9905
Level 3B	8.8148	1.0096	1.0000
CFGM	Level 1	Level 3A	Level 3B
Level 1	1.0000	0.8828	0.1896
Level 3A	1.1328	1.0000	0.2148
Level 3B	5.2737	4.6556	1.0000

Table 6.20: Acceptance Region for the Hierarchical Level Variance.

	Level 1	Level 3A	Level 3B
Level 1	$0.976 \leq F_{stat} \leq 1.03$	$0.976 \leq F_{stat} \leq 1.03$	$0.976 \leq F_{stat} \leq 1.03$
Level 3A	$0.976 \leq F_{stat} \leq 1.03$	$0.976 \leq F_{stat} \leq 1.03$	$0.976 \leq F_{stat} \leq 1.03$
Level 3B	$0.976 \leq F_{stat} \leq 1.03$	$0.976 \leq F_{stat} \leq 1.03$	$0.976 \leq F_{stat} \leq 1.03$

Table 6.21: Results of the Hierarchical Level Variance Analysis.

GB	Level 1	Level 3A	Level 3B
Level 1	Accept	Reject	Reject
Level 3A	Reject	Accept	Reject
Level 3B	Reject	Reject	Accept
GSB	Level 1	Level 3A	Level 3B
Level 1	Accept	Reject	Reject
Level 3A	Reject	Accept	Reject
Level 3B	Reject	Reject	Accept
FGM	Level 1	Level 3A	Level 3B
Level 1	Accept	Reject	Reject
Level 3A	Reject	Accept	Reject
Level 3B	Reject	Reject	Accept
SFGM	Level 1	Level 3A	Level 3B
Level 1	Accept	Reject	Reject
Level 3A	Reject	Accept	Accept
Level 3B	Reject	Accept	Accept
CFGM	Level 1	Level 3A	Level 3B
Level 1	Accept	Reject	Reject
Level 3A	Reject	Accept	Reject
Level 3B	Reject	Reject	Accept

As one can see, the results presented in Table 6.21 every soil within the hierarchical levels are statistically different except the silty fine grained material. Recall that the silty fine grained soils are comprised of A-4 and A-5 soils. When looking at the number of soils within this soil classification, the A-4 dominates the A-5 soils, which is reflected in the variance results of the hierarchical levels. If there were more A-5 soils within the database, Level 3A and Level 3B would be statistically different; therefore, the results of the silty fine grained materials should be statistically different. When more A-5 soils are added to the database, it will change the mean values of the different parameters thus changing the variance associated with the parameters, which will change the variance of the unbound resilient modulus at equilibrium. The null hypothesis for the silty fine grained soils will not be accepted, which corresponds to a Type II error. Nevertheless, all the soils reject the null hypothesis when considering the Type II error of the SFGM, which shows the need for hierarchical levels are valid in the unbound pavement material design.

6.5.2 Climatic Location Data Analysis

Using the results presented in Tables 6.14 through 6.18, only the Level 3A, Level 3B, and Level 1 values corresponding to the mean value of the resilient modulus at optimum will be considered in the climatic location analysis. A total of 15 soils from each site will be used, which includes the results of the GB, GSB, FGM, SFGM, CFGM, A-1-b(GB), A-2-4(GSB), A-6(FGM), A-4(SFGM), A-6(CFGM), GB Medium, GSB Medium, FGM Medium, SFGM Medium, and CFGM Medium. These 15 soils correspond to a total of 75 soils used in the analysis.

Only the hierarchical levels across the climatic regions will be used in the analysis, since the within the hierarchical level was assessed in the previous subsection. To validate if using the climatic regions are valid, the means will be compared between the five climatic regions. This analysis will utilize the Z-statistic and a level of significance of five percent. The five percent significance acceptance region for the Z-statistic will be as followed: $-1.96 \leq Z_{stat} \leq 1.96$. The Z-statistic is being used since the number of simulations used in the Monte Carlo Simulation was 25,000, which the Z-statistic is valid after n approaches 30. The null hypothesis for the climatic region statistical analysis is that the means of the resilient modulus at equilibrium will be equal. The alternative hypothesis will be the resilient modulus at equilibrium will not be equal across the different climatic regions.

Tables 6.22 through Table 6.24 shows the Z-statistics for the five different climatic regions with respect to the five different soil types used in the analysis. In addition, Table 6.22 through Table 6.24 corresponds to Level 3B, Level 3A, and Level 1 respectively. Table 6.25 is the results of the statistical analysis for all of the soils within the climatic region. In Tables 6.22 Table, 6.23, Table 6.24, and Table 6.25 CA corresponds to the Eureka, CA location, OR corresponds to Salem, OR location, OK corresponds to the McAlester, OK location, TX corresponds to the Amarillo, TX location, and the AZ corresponds to the Phoenix, AZ location. All of the data used in this analysis was obtained from Tables 6.14 through 6.18.

Table 6.22: Level 3B Climatic Region Z-Statistics.

Granular Base Material

	CA	OR	OK	TX	AZ
CA	0.00	12.17	38.44	47.02	63.16
OR	-12.17	0.00	26.09	34.65	50.80
OK	-38.44	-26.09	0.00	8.66	25.02
TX	-47.02	-34.65	-8.66	0.00	16.36
AZ	-63.16	-50.80	-25.02	-16.36	0.00

Granular Subbase Material

	CA	OR	OK	TX	AZ
CA	0.00	11.93	29.43	40.50	79.97
OR	-11.93	0.00	17.82	28.82	67.22
OK	-29.43	-17.82	0.00	10.64	46.56
TX	-40.50	-28.82	-10.64	0.00	35.31
AZ	-79.97	-67.22	-46.56	-35.31	0.00

Fine Grained Subgrade Material

	CA	OR	OK	TX	AZ
CA	0.00	-34.89	-20.95	-16.40	59.55
OR	34.89	0.00	12.42	17.26	90.87
OK	20.95	-12.42	0.00	4.54	76.59
TX	16.40	-17.26	-4.54	0.00	72.83
AZ	-59.55	-90.87	-76.59	-72.83	0.00

"Silty" Fine Grained Subgrade Material

	CA	OR	OK	TX	AZ
CA	0.00	8.43	22.54	35.45	124.57
OR	-8.43	0.00	14.65	28.09	119.27
OK	-22.54	-14.65	0.00	13.63	105.13
TX	-35.45	-28.09	-13.63	0.00	91.06
AZ	-124.57	-119.27	-105.13	-91.06	0.00

"Clayey" Fine Grained Subgrade Material

	CA	OR	OK	TX	AZ
CA	0.00	2.85	30.30	49.10	229.97
OR	-2.85	0.00	26.89	45.52	222.05
OK	-30.30	-26.89	0.00	19.55	188.82
TX	-49.10	-45.52	-19.55	0.00	159.87
AZ	-229.97	-222.05	-188.82	-159.87	0.00

Table 6.23: Level 3A Climatic Region Z-statistics.

A-1-b GB					
	CA	OR	OK	TX	AZ
CA	0.00	11.59	40.21	46.48	55.94
OR	-11.59	0.00	28.54	34.87	44.35
OK	-40.21	-28.54	0.00	6.53	16.10
TX	-46.48	-34.87	-6.53	0.00	9.52
AZ	-55.94	-44.35	-16.10	-9.52	0.00

A-2-4 GSB					
	CA	OR	OK	TX	AZ
CA	0.00	12.50	34.06	48.42	132.75
OR	-12.50	0.00	21.59	35.50	115.60
OK	-34.06	-21.59	0.00	13.21	86.82
TX	-48.42	-35.50	-13.21	0.00	72.83
AZ	-132.75	-115.60	-86.82	-72.83	0.00

A-6 FGM					
	CA	OR	OK	TX	AZ
CA	0.00	-81.45	-51.31	-43.04	239.36
OR	81.45	0.00	24.10	27.88	309.07
OK	51.31	-24.10	0.00	4.89	268.76
TX	43.04	-27.88	-4.89	0.00	250.38
AZ	-239.36	-309.07	-268.76	-250.38	0.00

A-4 SFGM					
	CA	OR	OK	TX	AZ
CA	0.00	9.43	21.42	33.17	126.30
OR	-9.43	0.00	12.42	24.49	119.11
OK	-21.42	-12.42	0.00	12.02	106.17
TX	-33.17	-24.49	-12.02	0.00	93.97
AZ	-126.30	-119.11	-106.17	-93.97	0.00

A-6 CFGM					
	CA	OR	OK	TX	AZ
CA	0.00	4.74	50.87	79.69	492.97
OR	-4.74	0.00	45.92	74.91	480.81
OK	-50.87	-45.92	0.00	31.07	396.87
TX	-79.69	-74.91	-31.07	0.00	328.69
AZ	-492.97	-480.81	-396.87	-328.69	0.00

Table 6.24: Level 1 Climatic Region Z-Statistics.

<table>
<tr><td colspan="6">Level 1 GB Medium</td></tr>
<tr><td></td><td>CA</td><td>OR</td><td>OK</td><td>TX</td><td>AZ</td></tr>
<tr><td>CA</td><td>0.00</td><td>31.45</td><td>108.81</td><td>120.11</td><td>268.03</td></tr>
<tr><td>OR</td><td>-31.45</td><td>0.00</td><td>78.19</td><td>91.24</td><td>231.32</td></tr>
<tr><td>OK</td><td>-108.81</td><td>-78.19</td><td>0.00</td><td>17.08</td><td>132.89</td></tr>
<tr><td>TX</td><td>-120.11</td><td>-91.24</td><td>-17.08</td><td>0.00</td><td>103.41</td></tr>
<tr><td>AZ</td><td>-268.03</td><td>-231.32</td><td>-132.89</td><td>-103.41</td><td>0.00</td></tr>
<tr><td colspan="6">Level 1 GSB Medium</td></tr>
<tr><td></td><td>CA</td><td>OR</td><td>OK</td><td>TX</td><td>AZ</td></tr>
<tr><td>CA</td><td>0.00</td><td>29.51</td><td>80.29</td><td>107.50</td><td>116.98</td></tr>
<tr><td>OR</td><td>-29.51</td><td>0.00</td><td>51.10</td><td>79.32</td><td>88.43</td></tr>
<tr><td>OK</td><td>-80.29</td><td>-51.10</td><td>0.00</td><td>29.60</td><td>38.03</td></tr>
<tr><td>TX</td><td>-107.50</td><td>-79.32</td><td>-29.60</td><td>0.00</td><td>7.89</td></tr>
<tr><td>AZ</td><td>-116.98</td><td>-88.43</td><td>-38.03</td><td>-7.89</td><td>0.00</td></tr>
<tr><td colspan="6">Level 1 FGM Medium</td></tr>
<tr><td></td><td>CA</td><td>OR</td><td>OK</td><td>TX</td><td>AZ</td></tr>
<tr><td>CA</td><td>0.00</td><td>-128.75</td><td>-78.77</td><td>-62.22</td><td>449.17</td></tr>
<tr><td>OR</td><td>128.75</td><td>0.00</td><td>37.00</td><td>40.37</td><td>557.33</td></tr>
<tr><td>OK</td><td>78.77</td><td>-37.00</td><td>0.00</td><td>7.00</td><td>478.15</td></tr>
<tr><td>TX</td><td>62.22</td><td>-40.37</td><td>-7.00</td><td>0.00</td><td>423.86</td></tr>
<tr><td>AZ</td><td>-449.17</td><td>-557.33</td><td>-478.15</td><td>-423.86</td><td>0.00</td></tr>
<tr><td colspan="6">Level 1 SFGM Medium</td></tr>
<tr><td></td><td>CA</td><td>OR</td><td>OK</td><td>TX</td><td>AZ</td></tr>
<tr><td>CA</td><td>0.00</td><td>19.29</td><td>42.67</td><td>63.39</td><td>519.45</td></tr>
<tr><td>OR</td><td>-19.29</td><td>0.00</td><td>24.33</td><td>46.13</td><td>491.72</td></tr>
<tr><td>OK</td><td>-42.67</td><td>-24.33</td><td>0.00</td><td>22.32</td><td>436.17</td></tr>
<tr><td>TX</td><td>-63.39</td><td>-46.13</td><td>-22.32</td><td>0.00</td><td>382.93</td></tr>
<tr><td>AZ</td><td>-519.45</td><td>-491.72</td><td>-436.17</td><td>-382.93</td><td>0.00</td></tr>
<tr><td colspan="6">Level 1 CFGM Medium</td></tr>
<tr><td></td><td>CA</td><td>OR</td><td>OK</td><td>TX</td><td>AZ</td></tr>
<tr><td>CA</td><td>0.00</td><td>6.66</td><td>67.39</td><td>97.62</td><td>634.54</td></tr>
<tr><td>OR</td><td>-6.66</td><td>0.00</td><td>60.96</td><td>92.04</td><td>622.22</td></tr>
<tr><td>OK</td><td>-67.39</td><td>-60.96</td><td>0.00</td><td>37.36</td><td>504.07</td></tr>
<tr><td>TX</td><td>-97.62</td><td>-92.04</td><td>-37.36</td><td>0.00</td><td>401.04</td></tr>
<tr><td>AZ</td><td>-634.54</td><td>-622.22</td><td>-504.07</td><td>-401.04</td><td>0.00</td></tr>
</table>

Table 6.25: Climatic Region Statistical Analysis Results.

Granular Base Material, A-1-b GB, and Level 1 GB Medium

	CA	OR	OK	TX	AZ
CA	Accept	Reject	Reject	Reject	Reject
OR	Reject	Accept	Reject	Reject	Reject
OK	Reject	Reject	Accept	Reject	Reject
TX	Reject	Reject	Reject	Accept	Reject
AZ	Reject	Reject	Reject	Reject	Accept

Granular Subbase Material, A-2-4 GSB, and Level 1 GSB Medium

	CA	OR	OK	TX	AZ
CA	Accept	Reject	Reject	Reject	Reject
OR	Reject	Accept	Reject	Reject	Reject
OK	Reject	Reject	Accept	Reject	Reject
TX	Reject	Reject	Reject	Accept	Reject
AZ	Reject	Reject	Reject	Reject	Accept

Fine Grained Subgrade Material, A-6 FGM, and Level 1 FGM Medium

	CA	OR	OK	TX	AZ
CA	Accept	Reject	Reject	Reject	Reject
OR	Reject	Accept	Reject	Reject	Reject
OK	Reject	Reject	Accept	Reject	Reject
TX	Reject	Reject	Reject	Accept	Reject
AZ	Reject	Reject	Reject	Reject	Accept

"Silty" Fine Grained Subgrade Material, A-4 SFGM, and Level 1 SFGM Medium

	CA	OR	OK	TX	AZ
CA	Accept	Reject	Reject	Reject	Reject
OR	Reject	Accept	Reject	Reject	Reject
OK	Reject	Reject	Accept	Reject	Reject
TX	Reject	Reject	Reject	Accept	Reject
AZ	Reject	Reject	Reject	Reject	Accept

"Clayey" Fine Grained Subgrade Material, A-6 CFGM, and Level 1 CFGM Medium

	CA	OR	OK	TX	AZ
CA	Accept	Reject	Reject	Reject	Reject
OR	Reject	Accept	Reject	Reject	Reject
OK	Reject	Reject	Accept	Reject	Reject
TX	Reject	Reject	Reject	Accept	Reject
AZ	Reject	Reject	Reject	Reject	Accept

As one can see, the results in Table 6.25 show that regardless of the soil type and climatic region the null hypothesis is rejected; therefore, the climatic region is an important parameter in design.

6.5.3 AASHTO Structural Number Difference Data Analysis

Recall from Chapter 2, Equation 2.63 is the 1993 AASHTO Design equation and it a function of the 18-kip single axle load, the traffic reliability, the structural number, and the design moduli. To compare the difference in asphalt thickness between Level 1 and Level 3B it requires, SN_1, SN_3, M_{R1}, and M_{R3}. The structural numbers SN_1 and SN_3 are obtained by solving Equation 2.63 for a given level of traffic and a given level of reliability. Table 6.26 shows the levels of traffic, levels of reliability, the number of soils, and the number of climatic regions that will be used in the analysis.

Table 6.26: Factorial Design for AC Comparison.

Variable Name	Levels	Variable Levels				
Levels of Traffic	4	100,000	1,000,000	10,000,000	100,000,000	
Levels of Reliability	3	85%	95%	99%		
Climatic Regions	5	AZ	TX	OK	OK	CA
Soil Types	5	GB	GS	FG	SFG	CFG
Number of Level 3 Soils	5	GBM	GSM	FGM	SFMG	CFGM
Strength of Level 1 Soils	5	Lowest M_{Ropt}	Low M_{Ropt}	Medium M_{Ropt}	High M_{Ropt}	Highest M_{Ropt}
Combinations	1800					

The M_{R1} and M_{R3} values are determined by using distribution information in Table 6.14 through Table 6.18 and then obtaining the design values by reading the cdf of the distribution at one minus the given level of reliability. Table 6.27, shows both Phoenix, AZ and Amarillo, TX modulus values at the given reliability levels are shown for each soil. Table 6.28 shows McAlester, OK, Salem, OR, and Eureka, CA moduli values at the given reliability levels are show for each soil.

With the modulus values determined, the structure numbers for Level 1 and 3B can be obtained. To determine the structural number for Level 1, the structural number for Level 3B for a given level of reliability and a given level of traffic is needed, which is the structural number for Level 3B will use Equation 2.63. Since Level 1 and Level 3B use the same level of traffic and same level of reliability, the two equations can be set equal, which gives the following Equation or Equation 6.1. The final serviceability index or p_t used in determining the structural numbers was 2.5.

$$2.32\log\left(\frac{M_{R_3}}{M_{R_1}}\right)=9.36\log\frac{(SN_1+1)}{(SN_3+1)}+c_1\left(\frac{1}{0.4+\frac{1094}{(SN_1+1)^{5.19}}}-\frac{1}{0.4+\frac{1094}{(SN_3+1)^{5.19}}}\right)\qquad\text{..................................(6.1)}$$

Where:

$$c_1=\log\left(\frac{4.2-p_t}{2.7}\right)$$

Table 6.27: Phoenix, AZ and Amarillo, TX Design Values.

Resilient Modulus at Equilibrium						
Soil Name	Phoenix, AZ			Amarillo, TX		
	85%	95%	99%	85%	95%	99%
GB	32894	25787	20270	31463	24927	19846
GSB	20591	14443	10162	16200	11143	7768
FGM	8551	4717	2894	5549	3684	2711
SFGM	12709	8041	5470	9013	6675	5199
CFGM	18190	11013	6807	5478	3713	2761
GB Lowest	41246	39014	37027	28109	25803	23921
GB Low	48897	46136	43610	33274	30480	28221
GB Med	49002	46315	43851	40283	35690	31679
GB High	52138	49198	46572	35822	32940	30632
GB Highest	52561	49665	47080	35856	32844	30381
GSB Lowest	15685	13516	11755	8730	7822	7207
GSB Low	24161	20802	18045	13317	11992	11111
GSB Med	25081	21652	18862	25394	18155	13463
GSB High	29101	25204	22055	16131	14500	13396
GSB Highest	29868	25864	22614	16538	14816	13658
FGM Lowest	16196	13148	10776	4341	3683	3313
FGM Low	32562	26452	21668	8627	7324	6593
FGM Med	40426	32649	26531	9364	8374	7919
FGM High	53212	42971	35074	14393	12206	10939
FGM Highest	65677	52813	42547	17563	14956	13471
SFGM Lowest	23801	20035	16973	7570	6573	5978
SFGM Low	34188	28933	24726	10835	9458	8649
SFGM Med	36432	30628	25911	11833	10308	9389
SFGM High	41506	34888	29560	13413	11737	10745
SFGM Highest	46242	38800	32807	14785	12934	11876
CFGM Lowest	21518	16891	13171	4969	4073	3531
CFGM Low	32683	25735	20248	7534	6166	5343
CFGM Med	37959	30151	24000	8086	6768	6028
CFGM High	45936	36472	29060	10668	8735	7545
CFGM Highest	54284	42793	33842	12856	10561	9154

Table 6.28: McAlester, OK, Salem, OR, and Eureka, CA Design Values.

Soil Name	McAlester, OK			Salem, OR			Eureka, CA		
	85%	95%	99%	85%	95%	99%	85%	95%	99%
GB	30804	24199	18919	28513	22953	18603	27745	22376	18077
GSB	15376	10701	7589	14871	10722	7838	14229	10295	7554
FGM	5259	3399	2428	5285	3600	2685	6588	4065	2679
SFGM	8850	6622	5149	8605	6477	5022	8121	6084	4700
CFGM	5275	3706	2812	4775	3454	2669	4914	3609	2805
GB Lowest	26455	24472	22861	24855	23167	21839	24717	23018	21661
GB Low	31354	28957	27005	29549	27569	25984	29316	27376	25829
GB Med	40123	35396	31185	36686	32940	29553	35339	32054	29074
GB High	33638	31183	29190	31492	29447	27846	31450	29303	27578
GB Highest	33784	31240	29168	31684	29491	27731	31469	29324	27571
GSB Lowest	8434	7650	7118	8194	7511	7054	8153	7464	6993
GSB Low	12983	11783	10964	12598	11524	10797	12552	11531	10840
GSB Med	23972	18386	14191	23201	16508	12368	21086	16734	13419
GSB High	15578	14110	13099	15177	13884	12983	15024	13748	12882
GSB Highest	16047	14561	13541	15593	14260	13351	15512	14192	13288
FGM Lowest	3977	3496	3223	3600	3284	3113	3548	3254	3097
FGM Low	7923	6995	6468	7166	6544	6213	7088	6485	6152
FGM Med	9773	8635	7989	9371	8412	7836	12911	10867	9319
FGM High	12979	11374	10446	11866	10818	10245	11704	10733	10214
FGM Highest	16104	14197	13076	14634	13341	12648	14465	13262	12606
SFGM Lowest	7070	6322	5883	6602	6064	5769	6537	6013	5724
SFGM Low	10090	9056	8468	9422	8641	8220	9379	8640	8241
SFGM Med	11582	10201	9346	11335	10061	9232	10980	9829	9087
SFGM High	12427	11183	10473	11656	10706	10170	11543	10632	10134
SFGM Highest	13823	12355	11509	12882	11862	11317	12805	11775	11198
CFGM Lowest	4531	3868	3438	4035	3591	3306	3962	3550	3282
CFGM Low	6976	5975	5321	6074	5401	4962	6007	5388	4984
CFGM Med	7880	6768	6078	7241	6412	5852	7191	6403	5870
CFGM High	9777	8413	7511	8625	7667	7025	8454	7569	6990
CFGM Highest	11765	10061	9001	10376	9238	8510	10224	9140	8442

Recall from Table 6.26, there is 1,800 combinations, which 300 of the 1,800 are solutions for the Level 3B analysis. These 300 solutions were used to create the other 1,500 solutions for Level 1. In Figure 6.7 shows all 1,500 solutions by solving for the asphalt deficiency. The asphalt deficiency is determined by using Equation 6.2.

$$\Delta AC = \frac{SN_1 - SN_3}{a_1} \quad \text{..(6.2)}$$

Where:

a_1 is the asphalt layer coefficient or 0.44

When the delta AC is negative, it indicates that Level 3B requires more asphalt for the given level of traffic and given level of reliability, will be occur when the modulus at equilibrium ratio is below 1. However, on the other hand, if the delta AC is positive and the modulus at equilibrium ratio is greater than 1, it indicates that Level 1 requires more asphalt than Level 3B to satisfy the same level of traffic and reliability. This will be apparent when looking at Figure 6.7.

Figure 6.8 shows the fundamental differences in the level of reliability and level of traffic. In this Figure, only one soil is shown to within one climatic region to see the effects of traffic and reliability on a given soil. The soil that was select for Figure 6.8 was the granular base material with the lowest strength of the design moduli for the Phoenix, AZ. However, when the modulus ratio is greater than one, the trend is reversed, where the highest level of traffic requires more AC than the lowest level of traffic.

Now if the data set, in Figure 6.7, is subdivided into the five soil classifications, then Figures 6.9 through Figure 6.13 are created. These five figures represent the five soil classifications across the five climatic regions. Using the information presented in Figure 6.8, one can see the apparent differences, in Figures 6.9 through Figure 6.13, with respect to the strength of the material, the level of traffic and level of reliability applied to the pavement design.

As stated previously, as the strength of the material increases, the modulus ratio will decrease. When the modulus ratio is one, it shows that the design strength between the two hierarchical levels are the same. If the modulus ratio is less than one then the design strength of Level 1 is greater than Level 3B, which corresponds to a negative AC deficiency. On the other hand, when the modulus ratio is greater than one, it shows the strength of Level 3B is greater than Level 1, which corresponds to a positive AC deficiency. The structural numbers for Level 1 and Level 3B are located in Appendix C. In addition the asphalt deficiencies for the 1,500 data points are located in Appendix D.

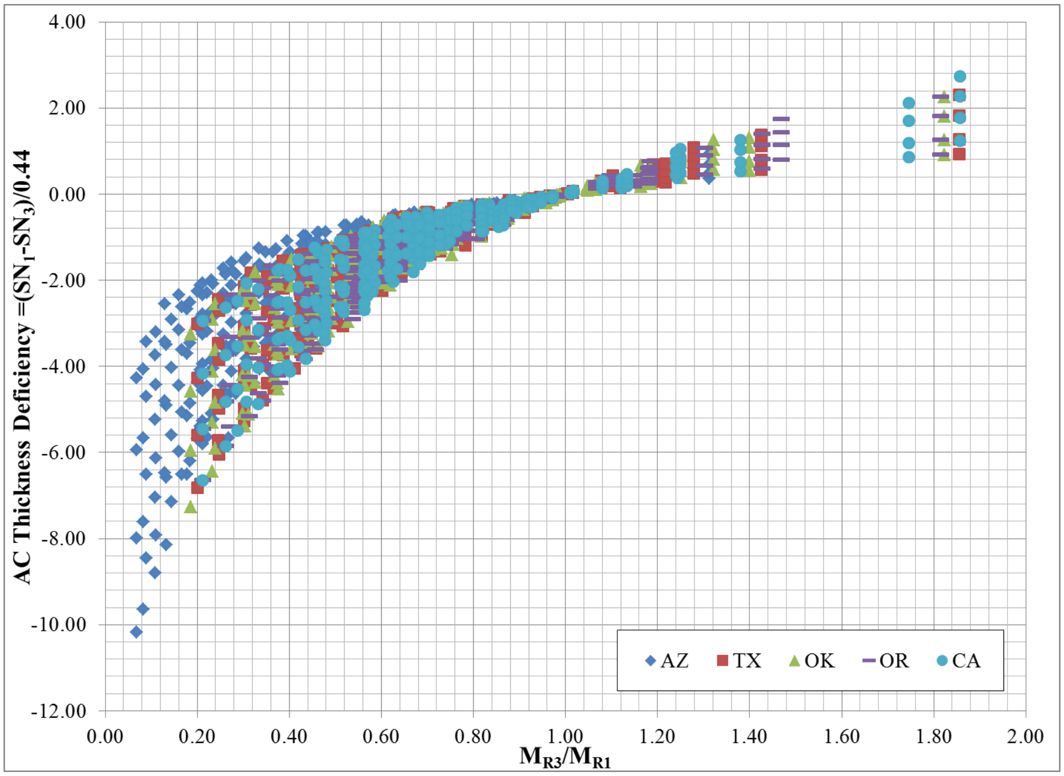

Figure 6.7: AC thickness deficiency for all 1,500 data points.

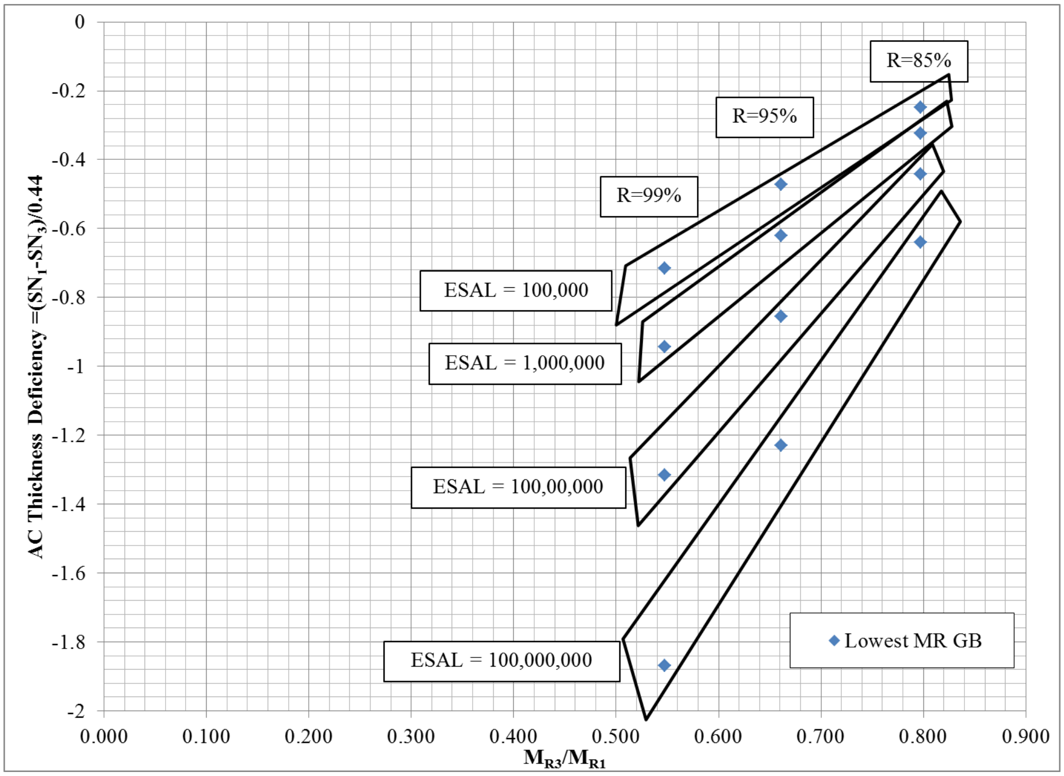

Figure 6.8: Fundamental differences in levels of traffic and reliability.

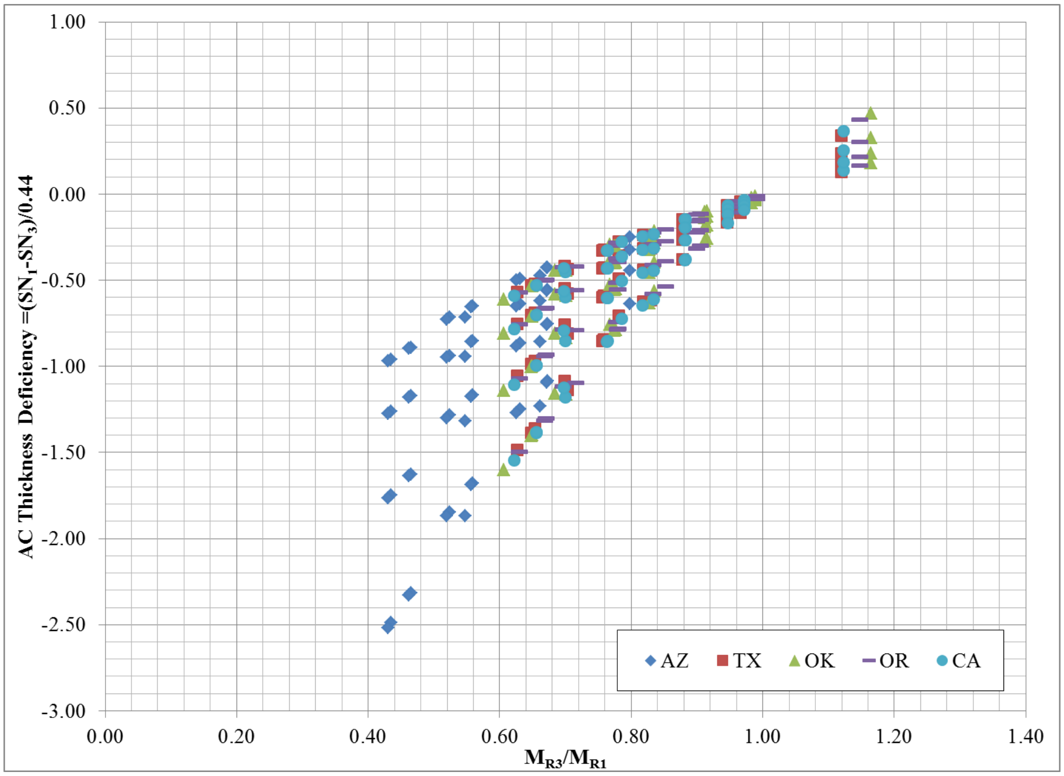

Figure 6.9: Granular base AC deficiencies.

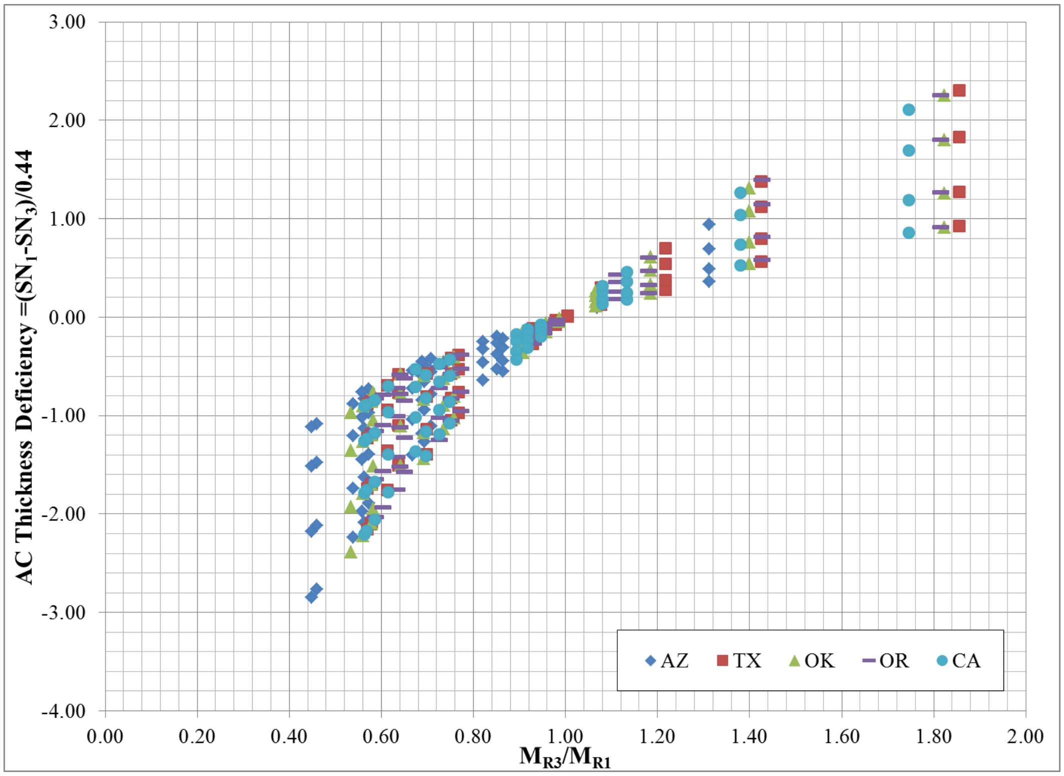

Figure 6.10: Granular subbase AC deficiencies.

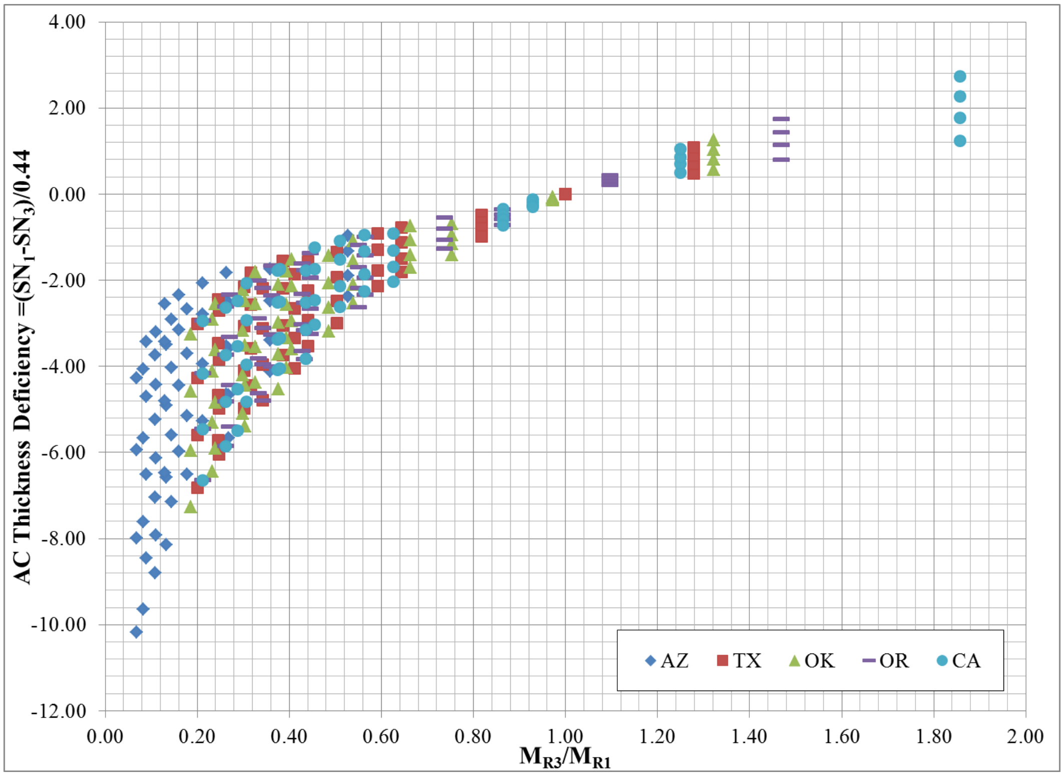

Figure 6.11: Fine grained subgrade AC deficiencies.

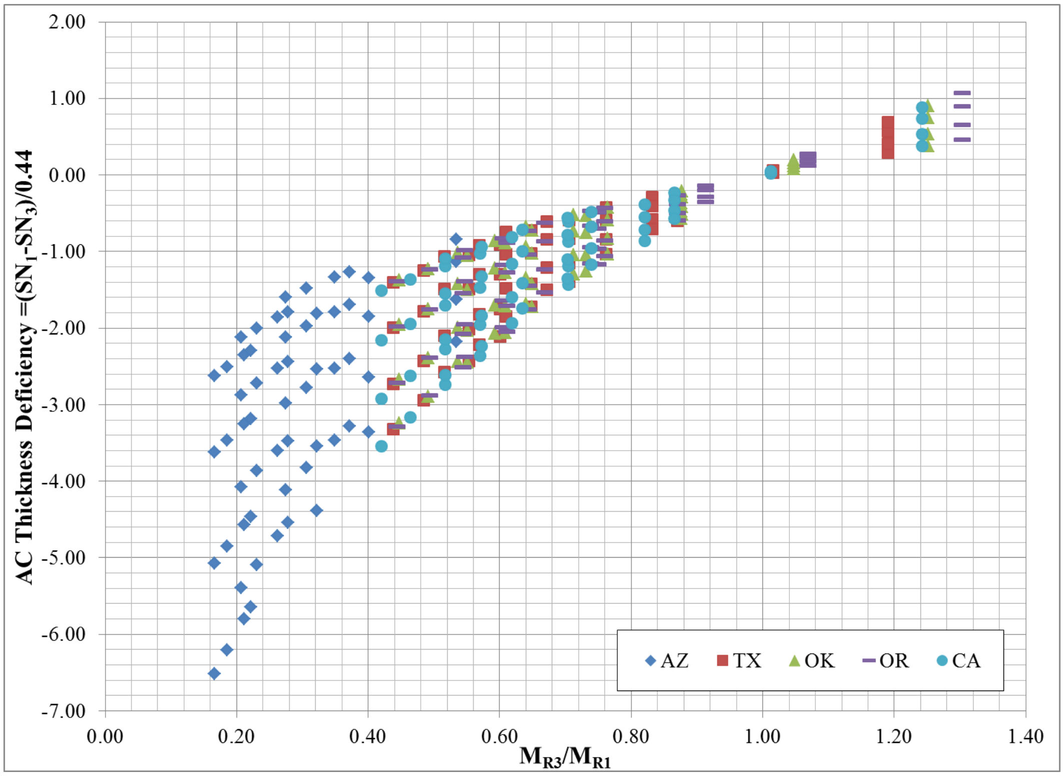

Figure 6.12: "Silty" fine grained subgrade AC deficiencies.

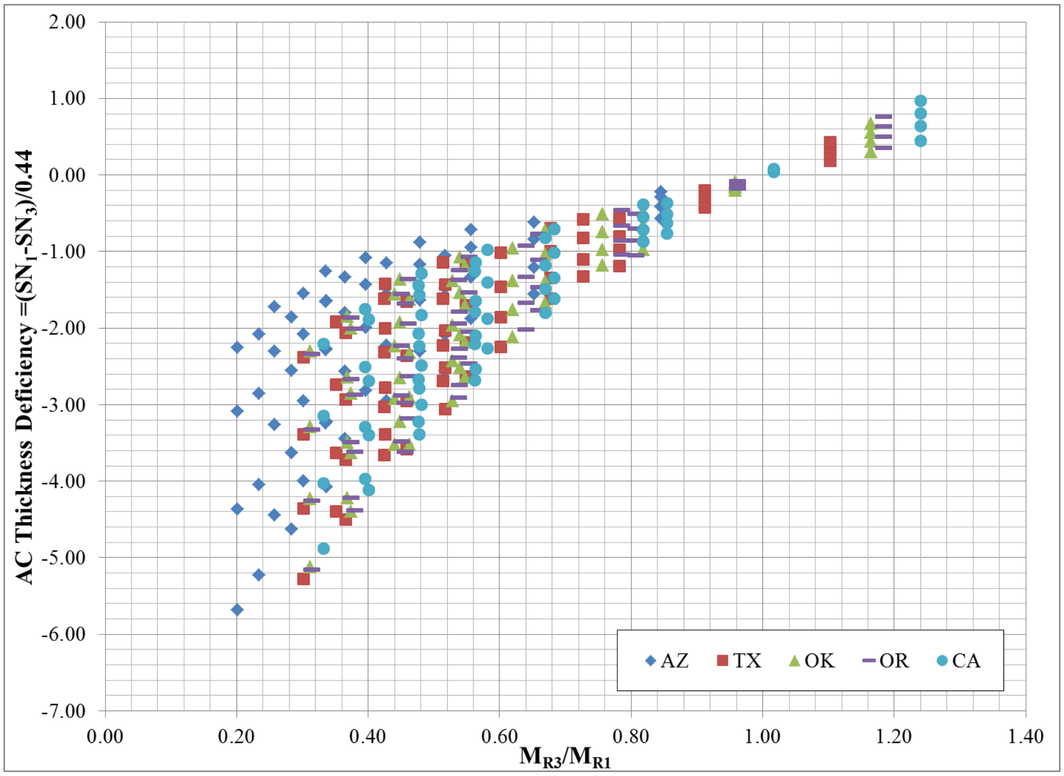

Figure 6.13: "Clayey" fine grained subgrade AC deficiencies.

As one can see in Figure 6.9, the maximum deficiency for the granular base material ranges from -2.5 inches, which Level 3B over-predicts the asphalt needed to satisfy a Level 1 design at the highest resilient moduli at equilibrium, highest level of reliability, and the highest level of traffic. On the other hand, at the lowest level of reliability, lowest level of strength, the highest level of traffic Level 3B under-predict the design by 0.5 inches of asphalt to satisfy the same traffic design.

As the unbound type material changes, the asphalt deficiency changes as well. When looking at the granular subbase material, at the highest strength, highest level of reliability, and the highest level of traffic, the asphalt deficiency is

-2.8 inches. In this case Level 3B over-predicts the needed amount of asphalt by 2.8 inches than Level 1. After the modulus ratio increases above one, for the granular subbase material, the asphalt deficiency increases to 2.4 inches, which Level 3B under-predicts the asphalt thickness by 2.4 inches less asphalt than Level 1 for the same level of traffic and level of reliability.

Once the unbound material changes from a granular material to a fine grained material, the greatest difference in the asphalt deficiencies can be seen. looking at just the fine grained subgrade material the asphalt deficiency ranges from –10.2 inches, which Level 3B will over-predict the amount of asphalt by 10.2 inches when compared to Level 1. In addition, when the level of reliability is at the lowest, strength of the material is at the lowest, and the level of traffic is at the highest, the asphalt deficiency is 2.7 inches, which Level 3B under-predicts the asphalt layer by 2.7 inches when compared to Level 1.

After determining the asphalt deficiencies of the fine grained material, it can be broken down further into the “silty” and “clayey” fine grained material. For the “silty fine grained subgrade material, the asphalt deficiency is -6.5 inches when the modulus ratio is less than one and when the modulus ratio is greater than one the asphalt deficiency is 1.1 inches of asphalt. Nevertheless, when looking at the “clayey” fine grained subgrade material, the asphalt deficiency ranges from -5.7 inches when the modulus ratio is less than one. Once the modulus ratio increases above one, the asphalt deficiency becomes 1.0 inches of asphalt, at the lowest Level 1 soil strength, the lowest level of reliability, and the highest level of traffic.

6.6 Asphalt Deficiency Equation Creation

The asphalt deficiency requires Equation 6.1 to be solved, which gives the structural number for Level 1. However, to solve this equation, it requires the structural number of Level 3B to be known as well as the modulus ratio. Then the structural number for Level 1 and Level 3B are then used to develop the asphalt deficiency by using Equation 6.2. Using Equation 6.1 requires the structural number to solved for each given level of reliability or any given level of traffic; therefore, a predictive equation is needed to determine the asphalt deficiency at any structural number of Level 3B and any modulus ratio. Figure 6.14 shows the Figure 6.7 fitted with Equation 6.1; however, in this case it used the structural numbers, for Level 1, that were used to create Figure 6.7.

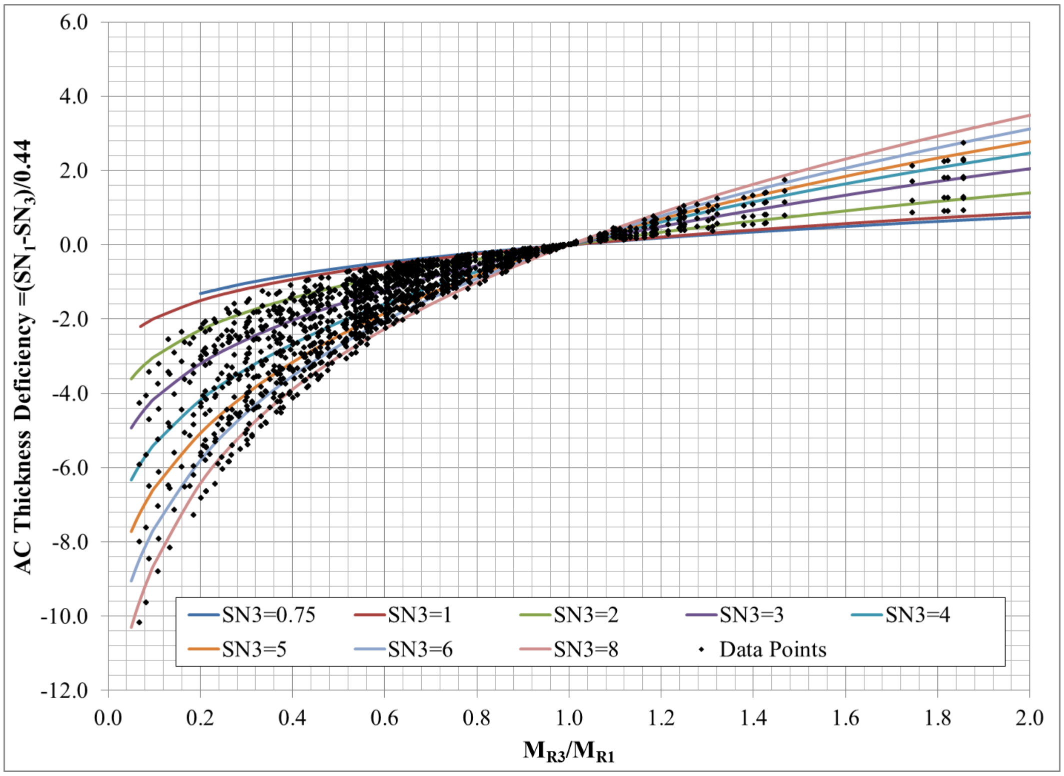

Figure 6.14: Asphalt deficiency versus structural number.

However, if a designer needs to know the asphalt deficiency for a different structural number for Level 3B versus Level 1 an equation is needed. By creating an equation that can describe the asphalt deficiency using only the structural number from Level 3B and the modulus ratio, it gives the designer an opportunity to create a what if scenario to see the potential asphalt deficiencies for any given modulus ratio.

To create an equation that will fit all the data points, first a non-linear regression was fitted through the structural number lines shown in Figure 6.14. Afterwards, the non-linear regression equation was then fitted to the 1,500 data points. The equation developed from the non-linear regression can be found in Equation 6.3.

$$\Delta AC = 2.48\left[\begin{array}{l}(\alpha)^{0.3696}(SN_3)^{0.631027} - \dfrac{(0.521)(SN_3)}{(\alpha)^{0.19074}} \\ + 0.006452(SN_3)^{2.367} + 0.0083\left(\dfrac{SN_3}{\alpha}\right) - 0.50037\end{array}\right] \text{.........}(6.3)$$

Where:

$$\alpha = \frac{M_{r3}}{M_{r1}}$$

The residuals of the non-linear regression are located in Figures 6.15 and 6.16. Figure 6.15 shows the residuals for the structural number non-linear regression. Figure 6.16, on the other hand, shows the residual of fitting the 1,500 data points.

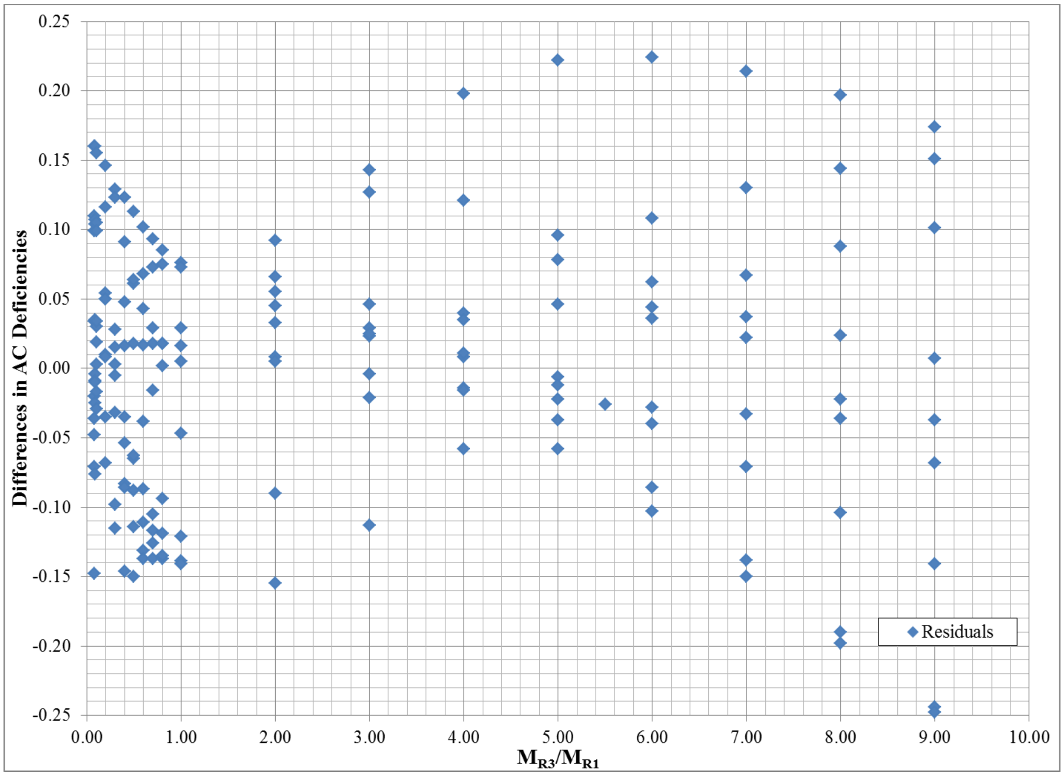

Figure 6.15: Structural number residuals.

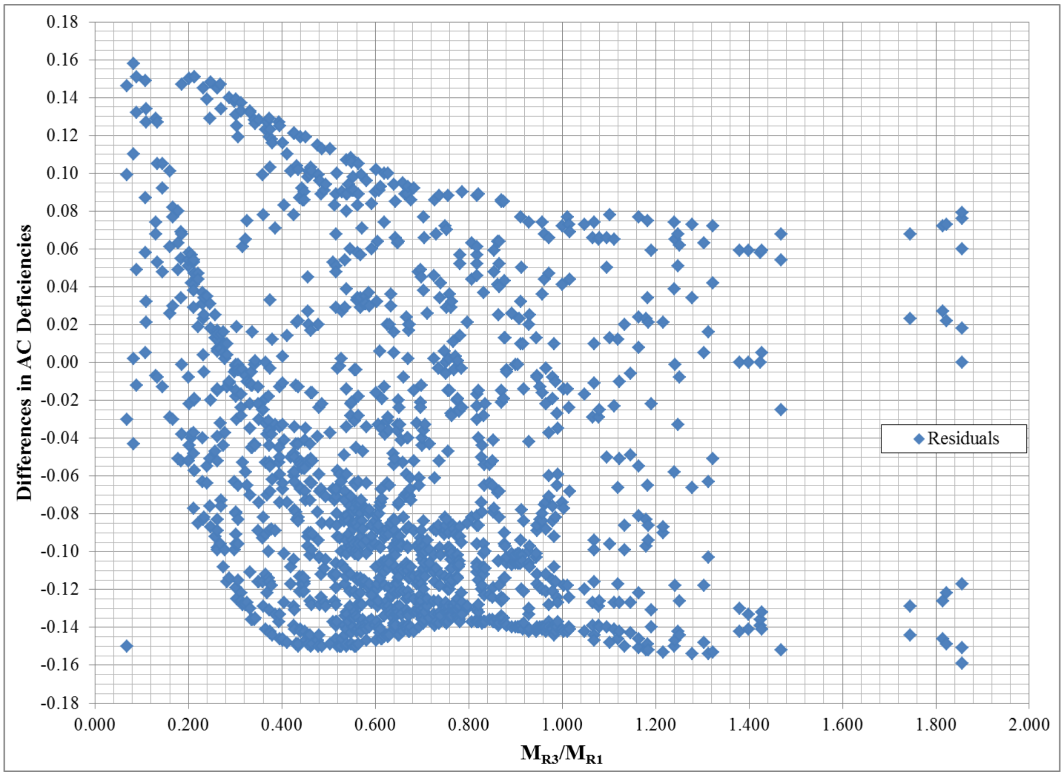

Figure 6.16: 1,500 data points residuals.

The residuals for the structural number range from 0.224 inches to -0.248 inches. The residuals for the 1,500 data points range from 0.158 inches to -0.158 inches difference in the asphalt deficiency. The predicted versus the observed values are located in Figures 6.17 and 6.18. Figure 6.17 is the predicted versus the observed values for the structural number non-linear fit, while Figure 6.18 is the predicted versus the observed values for the 1,500 data points.

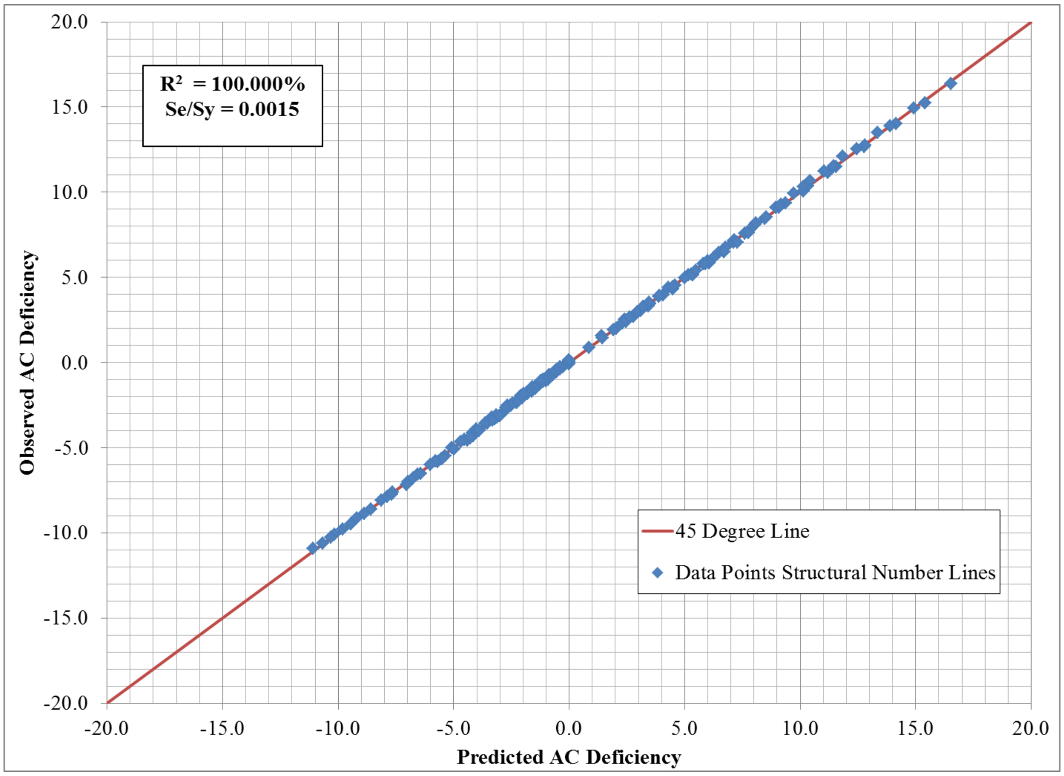

Figure 6.17: Predicted versus observed structural number lines.

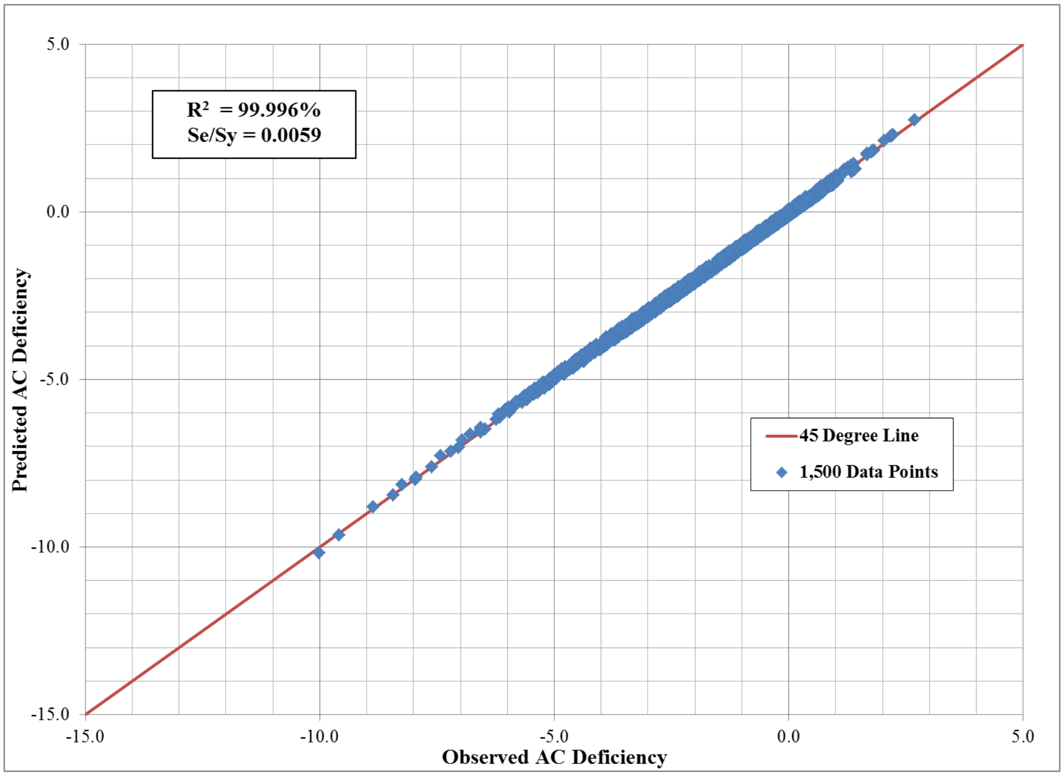

Figure 6.18: Predicted versus observed 1,500 data points.

6.7 Initial Cost per Ton Analysis

The ability to quantify the asphalt deficiency it, requires the designer to know the price per ton for the asphalt material and the tonnage of asphalt for the project. The tonnage of the asphalt is a function of the relative density of the asphalt material, the lane width, distance in mileage, and the deficiency of asphalt. The relative density of the asphalt is a function of the bulk specific gravity or the $G_{mb.}$

Therefore, the initial cost per ton for only the asphalt tonnage is a function of the lane width in feet, the distance of the project in miles, the asphalt deficiency in inches, and the G_{mb} of the in place asphalt. Equation 6.4 is a simple linear regression that uses the asphalt deficiency, the lane width, and the bulk specific gravity. The linear regression form that was selected is shown in Equation 6.5. The primary assumption with this equation is the price per ton of the asphalt material is constant regardless of the tonnage needed for the project.

$$\frac{\text{Initial Cost}}{(\text{Lane})(\text{Mile})} = 13.73(G_{mb})(L_w)\left(\frac{\text{Price of Asphalt}}{\text{ton}}\right)(\Delta\text{AC}) \quad \text{..................}(6.4)$$

Where:

G_{mb} is the Bulk specific gravity (valid between 2.0 and 2.6)

L_w is the lane width in feet (valid between 1ft and 30ft)

ΔAC is the AC deficiency (valid between -20 inches and 20 inches)

$$y = mx \quad \text{(6.5)}$$

Where

$$y = \frac{\text{Initial Per Difference}}{(\text{Lane})(\text{Mile})}$$

$$m = 13.73(G_{mb})(L_w)\left(\frac{\text{Price of Asphalt}}{\text{ton}}\right)$$

$$x = \Delta\text{AC}$$

Figure 6.19 shows the predicted versus the observed slope values for Equation 6.4. Table 6.29 shows the initial price difference for the asphalt deficiency with respect to the five different soil types. The initial price difference shown in Table 6.29 assumes a lane width of 12 feet, a bulk specific gravity of 2.404, and a 75 dollar per ton for the initial asphalt. The 12 foot lane corresponds to a high volume roadway lane width and the bulk specific gravity of 2.404 corresponds to unit weight of 150 lb/ft^3 for the asphalt.

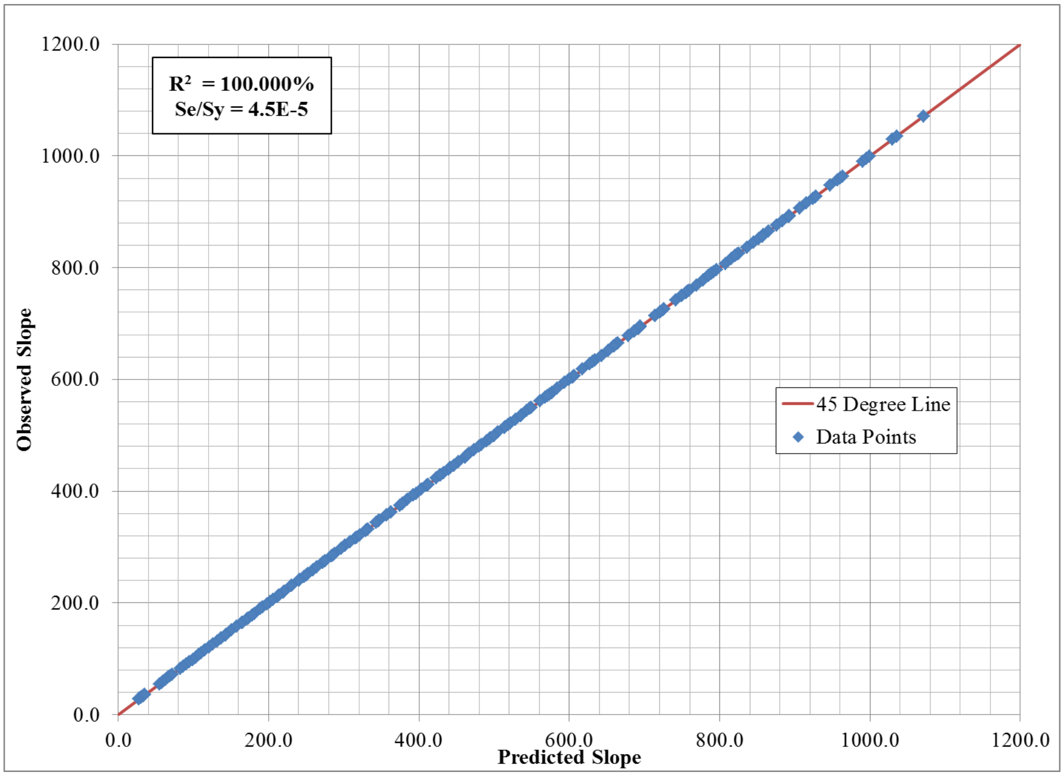

Figure 6.19: Predicted versus observed slope values for initial price per ton.

Table 6.29: Initial Price Difference for the Asphalt Deficiencies.

AC Deficiency (inches)					
Highest Deficiency	GB	GSB	FGM	SFGM	CFGM
Ratio < 1	-2.50	-2.80	-10.20	-6.50	-5.70
Ratio > 1	0.50	2.40	2.70	1.10	1.00
Initial Price Difference per Lane Mile					
Highest Deficiency	GB	GSB	FGM	SFGM	CFGM
Ratio < 1	$74,266	$ 83,177	$303,004	$193,091	$169,326
Ratio > 1	$14,853	$71,295	$80,207	$32,677	$29,706

As one can see, in Table 6.29, when the modulus ratio is less than 1 the price difference is red, which corresponds to the amount of money that is wasted for a Level 3B design when compared to the Level 1 design at the same level of traffic and the same level of reliability. On the other hand, when the values are black, it is the amount money that Level 3B is under spending for the required thickness of asphalt material to satisfy a Level 1 design. The values shown in Table 6.29 only correspond to the initial cost for the asphalt deficiency per lane mile. These values might not seem significant; however, when these values are quantified on a project, the initial price for the asphalt deficiencies will begin to add up.

6.8 Summary and Conclusion

Presented in this chapter are the results of the need for hierarchical levels of design. Secondly the need to incorporate climatic regions into design, are also presented. Finally, the significance of testing the resilient modulus at optimum instead of using correlations to obtain resilient modulus at optimum was evaluated by using the difference in structural number between Level 1 and Level 3B.

The need for hierarchical levels in unbound pavement material design are apparent when the variance associated with the levels are compared within a climatic location and assuming that the mean values are statistically the same. By knowing that hierarchical levels are important in design, within a climatic location, it allows the designer of a project to either spend money on laboratory testing to reduce the variance within the project or it allows the user to use engineering correlations, which will cause a higher variance within the project. To fully address the issue with the design unbound resilient modulus at equilibrium, different unbound resilient modulus at optimum values for Level 1 are needed to be evaluated.

When evaluating the impact of climatic regions, regardless of the soil type, the climatic region has an impact in the resilient modulus at equilibrium. The climatic region changes the matric suction of the soil, which changes the degree of saturation. Then the degree of saturation changes the environmental factor, which the environmental factor reflects the shift of the degree of saturation by the increase or reduction of the environmental factor depending if the soil is gaining or losing moisture respectively. Therefore, the need of the climatic information, regardless of the hierarchical level, is needed when designing any unbound pavement material.

Finally looking at the AC deficiency, the AC deficiency ranged from -10.12 inches to 2.70 inches of asphalt. This deficiency will always correspond to dollars lost on a project regardless if the AC deficiency is positive or negative since Level 1is the true design value for a given project. The AC deficiency when broken down into the soil classification the largest asphalt deficiencies are seen when the asphalt is placed on fine grained material. This is due to the strength of the material or the resilient modulus at equilibrium. The asphalt deficiency for the fine grained material ranged from -10.12 inches of asphalt to 2.7 inches of asphalt, which corresponds to Level 3B over-predicting the empirical 1993 AASHTO design by 10.12 inches more asphalt Level 1 and then under-predicting the empirical 1993 AASHTO design by 2.7 inches of asphalt for Level 3B to satisfy the same level of traffic and level of reliability.

The asphalt deficiencies for the granular material, on the other hand, ranged from -2.8 inches to 2.4 inches of asphalt. The -2.8 inches corresponds to Level 3B over-predicting the empirical 1993 AASHTO design by 2.8 inches to satisfy the same level of traffic and level reliability when compared a Level 1 design. As the modulus ratio increases above 1 the asphalt deficiency become 2.4 inches of asphalt, which corresponds to Level 3B under-predicting the empirical 1993 AASHTO design by 2.4 inches to satisfy the same level of traffic and same level reliability when compared a Level 1 design.

Chapter 7

SUMMARY AND CONCLUSIONS

7.1 Summary

The primary objectives of this study were:

- Postulate the methodologies of a stochastic evaluation of site equilibrium conditions of the resilient moduli using the MEPDG hierarchical concept approach.
- Complete a quantitative comparison of the MEPDG equilibrium resilient moduli of unbound materials based upon a reliability analysis of hierarchical inputs.
- Find the implications of different levels of reliability on the potential estimated cost of pavement design utilizing the structural number concept from the empirical AASHTO design model.

The three primary goals were successfully accomplished as follows:

- Postulate the methodologies of a stochastic evaluation of site equilibrium conditions of the resilient moduli using the MEPDG hierarchical concept approach: This goal was accomplished by completing the stochastic evaluation using the Monte Carlo Simulation, five different soil types, and five different climatic locations around the United States. Within the five soil types 30 different soils were evaluated. The 30 different soil were sub-divided into the three hierarchical levels so that Level 3B had five soil ranging across five different types of soil, Level 3A had five soil ranging across five different types of soil, and Level 1 had twenty-five soils ranging across the five different soil types. Within the twenty-five soils for Level 1, the soil were sub-divided into five soil classification and each soil classification had five different resilient modulus at optimum, while using the same mean values for the other parameters. Five different resilient moduli at optimum were used to represent different stiffness ranging from weak to strong.

- Complete a quantitative comparison of the MEPDG equilibrium resilient moduli of unbound materials based upon a reliability analysis of hierarchical inputs: This goal was accomplished by using the same mean values for Level 1, Level 3A, and Level 3B for the five different soil types and comparing the mean and variance associated with each level using the t-statistic and the F-statistic respectively. The t and F-statistic were used to show that within a given climatic region the variance between the levels were different (the F-statistic) and it was also possible to show that across different climatic regions the means were different (t-statistic). The mean and variance comparison used the Monte Carlo simulation since this method can generate all possible combinations of each independent variable.
- Find the implications of different levels of reliability on the cost of pavement design utilizing the structural number concept: This study focused on the reliability associated with the soil resilient modulus at equilibrium instead of the reliability associated with traffic loads. Five

different resilient moduli at optimum values were used, along with three levels of reliability, and four levels of traffic. By using five different optimum moduli values, three levels of reliability, and four levels of traffic. The cost of pavement design utilizing the structural number concept was found at a given resilient moduli at equilibrium, reliability and traffic level by estimating the asphalt deficiency between Level 1 and Level 3B empirical design analyses.

7.2 Conclusions

A review of the four statistical moments, was presented in Chapter 2, which includes the mean, variance (standard deviation), skewness, and the kurtosis. These four statistical moments describe the distribution of any variable; using the normal distribution. Along with the review of the four statistical moments, a review of the different statistical distributions and hypothesis testing were covered. After reviewing the statistical properties, stochastic methodologies were introduced. The stochastic methodologies included the First Order Taylor Series expansion, the Rosenblueth 2-Point estimation, the Rosenblueth 3-Point estimation, and the Monte Carlo simulation. The First Order Taylor Series expansion and the Rosenblueth 2 and 3-Point estimations are governed by the normal distribution; while the Monte Carlo simulation is govern by the beta distribution. It was determined that Monte Carlo simulation needs to be coupled with the beta distribution since the beta distribution is bounded between a minimum and maximum value, which is important when randomly simulating values that cannot be greater than 1 or 100 percent or less than 0 or 0 percent.

With the stochastic methodologies laid out, the stochastic evaluation of the EICM was postulated. Finally the empirical 1993 AASHTO structural number design concept was presented in Chapter 2. This design concept was used to determine the asphalt deficiencies in Chapter 6.

To accomplish the stochastic evaluation of the EICM, the definition of the hierarchical levels was needed. The hierarchical levels were first defined in Chapter 2 and then the definition was further refined in Chapter 3 for Level 3 analysis. The Level 3 was sub-divided into two sub classes, which relied on two very different classification systems. Level 3 was sub-divided into Level 3A and Level 3B, which Level 3A corresponds to the designer knowing that the soil used in design is an AASHTO soil and Level 3B corresponds to a general classification were the designer only knows that the soil is either a granular or fine grained material. In addition, project related variance and coefficients of variations were obtained for Level 1 using the LTPP DataPave SPS-1 sections and Zapata's dissertation. The SPS-1 sections were used to obtain project related gradation, Atterberg limits, compaction data and resilient modulus at optimum data. The gradation, Atterberg limits and the compaction data was grouped by AASHTO classification. Then the variance and coefficient of variation were obtained. After obtaining all the variances for each soil within a project, the variance was then pooled to create a "historical" project variance associated with the design parameters. The "historical" project variance and the coefficient of variation for the SWCC fitting parameters were obtained from Zapata's dissertation. In her dissertation, only three soils were used: a sand, a silt, and a clay. From these three soils, the historical project variance and coefficient of variation were obtained. The resilient modulus on the other hand, required backcalculation using a liner elastic program in order to obtain the variance and coefficient of variation within a project. Once the values from the backcalculation were obtained, the variances were pooled to create the historical project variance and the coefficients of variation for each project soil were averaged together. It was determined that there is no correlation between mean value of any soil property and the coefficient of variation or the pooled variation; therefore, it was sufficient using the pooled variance (historical project variance) or the averaged coefficient of variation.

The mathematical framework for the stochastic evaluation of the EICM was presented in Chapter 4. The stochastic evaluation of the EICM was performed by using the First Order Taylor Series expansion, Rosenblueth 2-Point and 3-Point estimation and the Monte Carlo Simulation. The stochastic evaluation used the models presented in the EICM after modification in order to satisfy the requirements of each of the stochastic methodologies. To accomplish the stochastic framework, the creation of an analytical program was required. The analytical program was developed on Microsoft Visual C++ 2008 Express edition so that the end result would create an .exe file that would be capable of the stochastic evaluation of the EICM. Using the soil variability determined in Chapter 3 along with the stochastic methodologies presented in Chapter 4 the quantitative comparison of the methodologies was possible.

The quantitative comparison of the four methodologies was presented in Chapter 5. In this chapter, the means and variances obtained with the four methodologies were compared using hypothesis testing. The hypothesis testing of the four stochastic methodologies showed whether the methodologies were statistically equal or different. Each stochastic methodology produces slightly different means and variance; therefore using the hypothesis testing to determine if the methodologies were statistically equal or different was a valid approach. In this chapter, the six of the means and variances associated with the EICM models were compared. The models that were compared include: Thornthwaite Moisture Index, matric suction, the unfrozen environmental factor, the degree of saturation, optimum saturation, the resilient modulus at optimum for Level 3A and 3B, and the resilient modulus at equilibrium. The hypothesis testing of means for the six models showed that the TMI, matric suction, degree of saturation, and the resilient modulus at equilibrium were statistically equal for the First Order Taylor Series expansion, Rosenblueth 3-Point estimation, and the Monte Carlo Simulation, at a level of significance of five percent. When the level significance was changed to one percent, the optimum saturation for Level 3A showed that the optimum saturation was statistically equal for the First Order Taylor Series expansion, Rosenblueth 3-Point estimation, and the Monte Carlo Simulation. When looking at the hypothesis testing of the variance, at a level of significance of five percent, the TMI, matric suction, degree of saturation, the unfrozen environmental factor, the resilient modulus at optimum for Level 3A and 3B, and the resilient modulus at equilibrium were found to be statistically equal for the

First Order Taylor Series expansion, Rosenblueth 3-Point estimation, and the Monte Carlo Simulation. When the level of significance was changed to one percent, no changes were observed. It was determined from the hypothesis testing of the mean and variance that the First Order Taylor Series expansion, Rosenblueth 3-Point estimation, and the Monte Carlo Simulation were statistically equal or comparable and that the Rosenblueth 2-Point estimation was statistically different. Therefore, it was concluded that a designer can use the First Order Taylor Series expansion, Rosenblueth 3-Point estimation, and the Monte Carlo Simulation with confidence that the mean and variances will be statistically the same.

From the work presented in Chapter 6, it was concluded that hierarchical levels are important for design, the climatic regions are important when design a pavement structure and the asphalt deficiency between Level 1 and Level 3B can be substantial. It was shown that the hierarchical levels are important within a particular climatic region by setting the means equal and comparing the variances by means of a hypothesis testing. The hypothesis testing was completed or applied to five different soil types that include: a granular base material, a granular subbase material, a fine grained subgrade material, a "silty fine grained subgrade material, and a "clayey" fine grained subgrade material. The hypothesis testing of the variance showed that the hierarchical levels are statistical different when designing with all five soils; however, the "silty" fine grained subgrade material showed that Level 3A and 3B are statistically the same. Recall that the Level 3B soil - "silty" fine grained material is composed of A-4 and A-5 soils and

Level 3A is an A-4 soil. The hypothesis testing showed that these two levels are statistically the same; however, if a Type II error is invoked, it will reject the null hypothesis and accept the alternative hypothesis, which states the variances are statistically different. This can be potentially true if more A-5 soil were within the Level 3B soil classification, as of now the A-4 soils govern and it is apparent when looking at the hypothesis testing results.

In order to evaluate the importance of the climatic regions in the stochastic determination of the resilient modulus, the same soil were evaluated across five different climatic regions by completing a hypothesis testing of the means, after determining that within the climatic region the variances were statistically different. The impact of the climatic regions was observed and the null hypotheses of the means (means are statistically equal) was rejected. This is apparent when looking at the degree of saturation across the climatic regions. The degree of saturation changed as the climatic regions changed, which then affected the unfrozen environmental factor. The result of the means being statistically different shows that the climatic region will impact the design greatly.

Finally, the asphalt deficiency between Level 1 and Level 3B was evaluated. The asphalt deficiency is the difference in asphalt material between Level 1 and Level 3B. When the asphalt deficiency is negative, Level 3B over-predicts the thickness when compared to Level 1 design. On the other hand, when the asphalt deficiency is positive, Level 3B under-predict the thickness of asphalt when compared to Level 1 design. The asphalt deficiency was evaluated using different levels of traffic, different initial modulus at optimum value for Level 1, and different levels of reliability with the final design value (resilient modulus at equilibrium), for a full depth asphalt design. It was determined that the asphalt deficiency ranged from -10.12 inches to 2.70 inches of asphalt. The asphalt deficiency will always correspond to dollars lost on a project regardless it the asphalt deficiency is positive or negative, since Level 1 is the true design thickness for a given project.

The asphalt deficiency for a granular material either the base or subbase, ranged from -2.8 inches to 2.4 inches of asphalt using the empirical 1993 AASHTO structural number design. When looking at the fine grained subgrade material, the asphalt deficiency ranged from -10.12 inches to 2.8 inches of asphalt using the empirical 1993 AASHTO structural number design; however, when the fine grained material is sub-divided into the “silty” or “clayey” categories, the asphalt deficiency ranged from 6.5 inches to 1.1 inches of asphalt for the “silty” fine grained subgrade material and the “clayey” fine grained subgrade material ranged from -5.7 inches to 1.0 inches of asphalt.

There was 1,500 data points that were used in determining the asphalt deficiency, which the data points were then used to create a non-linear regression equation. The non-linear equation was created so a designer can determined the structural number for Level 3B and use any modulus ratio to “what if” scenarios to determine the asphalt deficiency for a given project. The non-linear equation had an R^2 of 99.998% and Se/Sy of 0.0054 for the 1,500 data points and at the extremes it will under/over-predict at most 0.25 inches of asphalt.

Finally, the initial cost of difference in asphalt per lane mile was determined. The initial cost for the asphalt deficiency was determined by a using linear regression model. The initial cost for the asphalt deficiency is a function of the bulk specific gravity (relative density of the in place asphalt), the lane width, price per ton for the asphalt material, and the asphalt deficiency; however, this linear regression assumes that the price per ton for the asphalt material will stay constant regardless of the amount of asphalt material needed. The initial cost for the asphalt deficiency using a G_{mb} of 2.404 (corresponds to a unit weight of 150-lb/ft^3), a lane width of 12-ft, a price per ton of 75 dollars, along with the asphalt deficiencies ranged from under-design by 14,583 dollars per lane mile (granular base material) to over-design the pavement structure by $303,000 dollars per lane mile (fine grained subgrade material). Using the granular base material as an example since the asphalt is placed on top the granular base material, the over-design for Level 3B will cost the designer 74,266 dollars per lane mile, which quantified by ten mile stretch of roadway with one lane will cost the designer 742,660 dollars. The money lost is based on the empirical 1993 AASHTO structural number design.

The recommendation for future work is discussed in Chapter 8.

Chapter 8

RECOMMENDATIONS FOR FUTURE WORK

8.1 Parametric Study of Level 1 Variables

A parametric study of level 1 variables will confirm which property either has the greatest influence on the unbound resilient modulus at equilibrium. Knowing which property generates the most variability with the resilient modulus at equilibrium will lead to tighter specification for construction purposes. There will always be variability with the resilient modulus at equilibrium; however, if one can reduce the variability associated with it, the design resilient modulus at equilibrium, using any level of reliability, can increase thus decreasing the thickness of the pavement cross-section and reducing the overall cost of construction.

8.2 Updating Level 3 Models

When the soil property correlations were made with the original EICM, only a few hundred soils were used to make the correlations. With the addition of the LTPP DataPave database and the NCHRP 9-23A database the following equations can be updated:

- PI_{adj}
- w_{opt}
- S_{opt}
- $\gamma_{d\ max}$

These four parameters may not seem important in the overall scheme of calculating the resilient modulus at equilibrium; however, when looking at the S_{opt} for the soils in Appendix B the optimum saturation for the GB soil has a minimum value of 0.12 percent and a maximum of 100 percent. The minimum value of 0.12 percent occurs when the grain-size distribution is very uniform. If the cap was not in place, the estimated degree of saturation would be as high as 300 percent. This value becomes critical when determining the environmental factor. When the soil has an optimum saturation of 0.12%, $S\text{-}S_{opt}$ value becomes extremely positive and regardless of the *w*PI of the soil, the wPI curves merge and begin to approach zero. Therefore the parameters associated with the soil compaction need to be re-evaluated with the addition of more soils from the LTPP DataPave database and the NCHRP 9-23A soils database.

8.3 Re-evaluating the SWCC Parameters for Granular Soils

Currently the EICM has equations to predict the SWCC parameters for the granular materials; however, these parameters seem to be unreliable and in many instances, it causes the EICM to crash. With the addition of the NCHRP 9-23A soils database, there is multiple SWCC curves for the granular soils that can be used to update the granular model so that the volumetric water content is not calculated using correlations to the P_{200} and the site TMI.

8.4 Validate Chapter 6 results

While results in Chapter 6 are valid, it should be recalled that the results shown are based upon the assumption that all the hierarchical level means are the same. However, it is possible to find a soil within a project that will fall anywhere between the minimum and maximum range of Level 3B but has a different mean value. Therefore, actual project related soil properties either obtained from laboratory testing or field testing are needed to validate the results in Chapter 6. By using true laboratory or field testing results, it will show the true asphalt deficiency between Level 3B and Level 1.

8.5 Updating the Computer Code

The computer code was created using a statistical library from GNU software, which is allowed for academic purposes. GNU software copyright states that their software can be used in any application as long as it is free to the public to change and modify as the end user see fit. Therefore, the computer code that is shown in Appendix A needs to be changed to remove the coding from the GNU statistical library so that the code can be implemented in the EICM. The GNU statistical library was only used in the Monte Carlo Simulation to obtain the inverse of the beta function.

In addition, the computer code, presented in Appendix, needs to be updated to incorporate Level 2 analysis. The difference in the hierarchical levels can be seen in Table 2.2. Level 1 coding can be used and the coding only has to be changed for the SWCC and the M_{Ropt} properties. The change in the SWCC and the M_{Ropt} coding would be obtained from the Level 3 coding.

8.6 Life Cycle Cost Analysis

Compile a life cost analysis of the differences in Level 1 and Level 3B thickness from Chapter 6. By compiling a life cycle cost analysis of the difference between the levels, it will show the true implications of using information obtained from testing versus using engineering assumptions. The difference in money at the end of the pavement life will show the actual difference in money that any DOT will save throughout the pavement's life, which is connected to the maintenance schedule, the cost of construction, and the salvage value of the pavement structure at the end of the pavements life.

8.7 Incorporation of the Groundwater Table into Design

In the analysis presented in this body of work, it was assumed that the groundwater table was at a great depth and the unsaturated soil mechanics govern the design. Therefore, to see the full impact of the asphalt deficiencies in the empirical 1993 AASHTO design, the incorporation of the ground water table is needed. By incorporating the groundwater table in the design process, it will remove the uncertainty associated with the degree of saturation and the effects of the *w*PI and the optimum saturation will be apparent.

8.8 Incorporation of the Frozen Conditions into Design

The incorporation of the frozen conditions into the stochastic evaluation of the EICM is needed so that the frozen location can incorporate reliability into the unbound material. Currently, this body work only focused on the unfrozen condition since the environmental factor proposed by Cary and Zapata 2007 only focused on the unfrozen conditions. Therefore, the second half of the environmental factor is needed, which is frozen environmental factor.

8.9 Run the MEDPG to Determine the Difference in Design Life

The MEPDG uses reliability only as a global parameter, which does not reflect the reliability with the unbound material; therefore to incorporate the reliability into design the modulus at equilibrium values in Table 6.27 and 6.28 can be used. Along with the modulus at equilibrium values the thickness of asphalt from the structural number design can be used as the thickness into the MEPDG. The values in Table 6.27 and 6.28 can be inputted into the EICM so that the EICM will not change the input value and modulus at equilibrium in Tables 6.27 and Table 6.28 values then can be used in design. By having the thickness and the resilient modulus at equilibrium the MEPDG can be used to determine, the month at which the asphalt will fail at a given level of reliability. After the determining the month of which the failure occurred, the differences in the monthly failure can be determined.

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APPENDIX A

C++ COMPUTER CODE

```
#include <fstream> #include <iostream> #include <iomanip> #include <string> #include "math.h"
#include <cstdlib> #include <ctime> #include "gsl/gsl_randist.h" #include "gsl/gsl_sf.h"
#include "time.h" #include "gsl/gsl_cdf.h"
using namespace std;
int main()
{int Num_layer, Check;
double Jan_P, Feb_P, Mar_P, Apr_P, May_P, Jun_P, Jul_P, Aug_P, Sep_P, Oct_P, Nov_P,
Dec_P;
double Jan_T, Feb_T, Mar_T, Apr_T, May_T, Jun_T, Jul_T, Aug_T, Sep_T, Oct_T, Nov_T,
Dec_T, Simulations_T;
double Hy_PE, Jan_PE, Feb_PE, Mar_PE, Apr_PE, May_PE, Jun_PE, Jul_PE, Aug_PE, Sep_PE,
Oct_PE, Nov_PE, Dec_PE;
double Jan_L, Feb_L, Mar_L, Apr_L, May_L, Jun_L, Jul_L, Aug_L, Sep_L, Oct_L, Nov_L,
Dec_L;
double P_mean, P_sq_mean, P_var, P_stdev, summation_P_var, P_min, P_max, P_alpha, P_beta;
double Pone, summation_Pone, Pone_sq, summation_Pone_sq;
double Hy, summation_Hy, Hy_sq, summation_Hy_sq, Hy_min, Hy_max, Hy_alpha, Hy_beta;
double PE, summation_PE, PE_sq, summation_PE_sq, PE_mean, PE_sq_mean, PE_var,
summation_PE_var, PE_stdev, PE_min, PE_max, PE_alpha, PE_beta;
double Hy_mean, Hy_sq_mean, Hy_var, Hy_stdev, summation_Hy_var;
double TMI_mean, TMI_sq_mean, TMI_var, TMI_stdev, TMI_P, TMI_PE, TMI_Pi, TMI_PEi;
double summation_TMI, TMI, TMI_sq, summation_TMI_sq, summation_TMI_var, TMI_min,
TMI_max, TMI_alpha, TMI_beta;
double P_skew, summation_P_skew, P_kurt, summation_P_kurt, Hy_skew,
summation_Hy_skew, Hy_kurt, summation_Hy_kurt, PE_skew, summation_PE_skew, PE_kurt,
summation_PE_kurt, TMI_skew, summation_TMI_skew, TMI_kurt, summation_TMI_kurt;
double JanP[7], FebP[7], MarP[7], AprP[7], MayP[7], JunP[7], JulP[7],AugP[7],SepP[7],
OctP[7],NovP[7], DecP[7];
```

```
double JanT[7], FebT[7], MarT[7], AprT[7], MayT[7], JunT[7], JulT[7],AugT[7],SepT[7],
OctT[7],NovT[7], DecT[7];
double January_P, February_P, March_P, April_P, May1_P, June_P, July_P, August_P,
September_P, October_P, November_P, December_P;
double January_T, February_T, March_T, April_T, May1_T, June_T, July_T, August_T,
September_T, October_T, November_T, December_T;
double January_PE, February_PE, March_PE, April_PE, May1_PE, June_PE, July_PE,
August_PE, September_PE, October_PE, November_PE, December_PE;
double a0, a1, a2, a3, term1, term2, term3, Hy_3, Hy_2, apow,Co, C1, C1_dHy;
double alpha_base, beta_base, gamma_base, P200_3, P200_2;
double beta_non, gamma_non, delta_non, wPI_3, wPI_2;
double suction_mean1, suction_var1, suction_stdev1, suction_skew1, suction_kurt1,
suction_min1, suction_max1, suction_alpha1, suction_beta1;
double C_h, residual, af, bf, cf;
double theata_sat, theata_sat_var, theata_sat_stdev, theata_water, theata_water_var,
theata_water_stdev, gamma_water;
double gamma_dry_mean, gamma_dry_var, gamma_dry_stdev, gamma_dry_skew,
gamma_dry_kurt, gamma_dry_min, gamma_dry_max, gamma_dry_alpha, gamma_dry_beta,
summation_gamma_dry_skew, summation_gamma_dry_kurt;
double Fenv_mean1, Fenv_var1, Fenv_stdev1, Fenv_skew1, Fenv_kurt1, Fenv_min1,
Fenv_max1, Fenv_alpha1, Fenv_beta1;
double Fenv_term1, Fenv_term2, Fenv_term3, Fenv_term4, Fenv_denom, powerproduct;
double Mreq_mean1, Mreq_var1, Mreq_stdev1, Mreq_skew1, Mreq_kurt1, Mreq_min1,
Mreq_max1, Mreq_alpha1, Mreq_beta1;
double Mropt_mean1, Mropt_var1, Mropt_stdev1, Mropt_skew1, Mropt_kurt1, Mropt_min1,
Mropt_max1, Mropt_alpha1, Mropt_beta1;
double opt_sat_mean1, opt_sat_var1, opt_sat_stdev1, opt_sat_skew1, opt_sat_kurt1,
opt_sat_min1, opt_sat_max1, opt_sat_alpha1, opt_sat_beta1;
```

```
double degree_sat_mean1, degree_sat_var1, degree_sat_stdev1, degree_sat_skew1,
degree_sat_kurt1, degree_sat_min1, degree_sat_max1, degree_sat_alpha1, degree_sat_beta1;
double P200_M[72], P200_V[72], P200_S[72], P200_Min[72], P200_Max[72], P200_Alpha[72],
P200_Beta[72];
double wPI_M[72], wPI_V[72], wPI_S[72], wPI_Min[72], wPI_Max[72], wPI_Alpha[72],
wPI_Beta[72];
double Suction_Mean[72], Suction_Variance[72], Suction_Stdev[72], Suction_Skew[72],
Suction_Kurt[72], Suction_Minimum[72], Suction_Maximum[72], Suction_Alpha[72],
Suction_Beta[72];
double Gs_mean[72], Gs_var[72], Gs_stdev[72], Gs_Min[72], Gs_Max[72], Gs_Alpha[72],
Gs_Beta[72];
double Fenv_Mean[72], Fenv_Var[72], Fenv_Stdev[72], Fenv_Skew[72], Fenv_Kurt[72],
Fenv_Min[72], Fenv_Max[72], Fenv_Alpha[72], Fenv_Beta[72];
double Mreq_Mean[72], Mreq_Var[72], Mreq_Stdev[72], Mreq_Skew[72], Mreq_Kurt[72],
Mreq_Min[72], Mreq_Max[72], Mreq_Alpha[72], Mreq_Beta[72];
double Mropt_Mean[72], Mropt_Var[72], Mropt_Stdev[72], Mropt_Skew[72], Mropt_Kurt[72],
Mropt_Min[72], Mropt_Max[72], Mropt_Alpha[72], Mropt_Beta[72];
double opt_sat_mean[72], opt_sat_var[72], opt_sat_stdev[72], opt_sat_skew[72],
opt_sat_min[72], opt_sat_max[72], opt_sat_kurt[72], opt_sat_Alpha[72], opt_sat_Beta[72];
double degree_sat_mean[72], degree_sat_var[72], degree_sat_stdev[72], degree_sat_skew[72],
degree_sat_Min[72], degree_sat_Max[72], degree_sat_kurt[72], degree_sat_Alpha[72],
degree_sat_Beta[72];
double CBR_mean, CBR_var, CBR_stdev, CBR_min, CBR_max, CBR_skew, CBR_kurt,
CBR_alpha, CBR_beta, summation_CBR_var, summation_CBR_skew, summation_CBR_kurt,
CBR_Summation;;
double PI_M[72], PI_V[72], PI_S[72], PI_Min[72], PI_Max[72], PI_Alpha[72], PI_Beta[72]; // PI
double P20_M[72], P20_V[72], P20_S[72], P20_Min[72], P20_Max[72], P20_Alpha[72],
P20_Beta[72]; // 2.0" sieve
```

```
double P15_M[72], P15_V[72], P15_S[72], P15_Min[72], P15_Max[72], P15_Alpha[72],
P15_Beta[72]; // 1.5" sieve
double P10_M[72], P10_V[72], P10_S[72], P10_Min[72], P10_Max[72], P10_Alpha[72],
P10_Beta[72]; // 1.0" sieve
double P05_M[72], P05_V[72], P05_S[72], P05_Min[72], P05_Max[72], P05_Alpha[72],
P05_Beta[72]; // 0.5" sieve
double P40_M[72], P40_V[72], P40_S[72], P40_Min[72], P40_Max[72], P40_Alpha[72],
P40_Beta[72]; // #40 sieve
double P60_M[72], P60_V[72], P60_S[72], P60_Min[72], P60_Max[72], P60_Alpha[72],
P60_Beta[72]; // #60 sieve
double D60_M[72], D60_V[72], D60_S[72], D60_Min[72], D60_Max[72], D60_Alpha[72],
D60_Beta[72]; // D60
double CBR_M[72], CBR_V[72], CBR_S[72], CBR_Skew[72], CBR_Kurt[72], CBR_Min[72],
CBR_Max[72], CBR_Alpha[72], CBR_Beta[72]; // CBR value
double wopt_M[72], wopt_V[72], wopt_S[72], wopt_Skew[72], wopt_Kurt[72], wopt_Min[72],
wopt_Max[72], wopt_Alpha[72], wopt_Beta[72]; // lab optimum moisture content
double gamma_dry_M[72], gamma_dry_V[72], gamma_dry_S[72], gamma_dry_Skew[72],
gamma_dry_Kurt[72], gamma_dry_Min[72], gamma_dry_Max[72], gamma_dry_Alpha[72],
gamma_dry_Beta[72]; // lab gamma dry
double Theata_WM[72], Theata_WS[72], Theata_WV[72], Theata_WSkew[72],
Theata_WKurt[72], Theata_WMin[72], Theata_WMax[72], Theata_WAlpha[72],
Theata_WBeta[72];
double Theata_SM[72], Theata_SS[72], Theata_SV[72], Theata_SSkew[72], Theata_SKurt[72],
Theata_SMin[72], Theata_SMax[72], Theata_SAlpha[72], Theata_SBeta[72];
double SWCC_AM[72], SWCC_AS[72], SWCC_AV[72], SWCC_ASkew[72],
SWCC_AKurt[72], SWCC_AMin[72], SWCC_AMax[72], SWCC_AAlpha[72],
SWCC_ABeta[72];
```

```
double SWCC_BM[72], SWCC_BS[72], SWCC_BV[72], SWCC_BSkew[72],
SWCC_BKurt[72], SWCC_BMin[72], SWCC_BMax[72], SWCC_BAlpha[72],
SWCC_BBeta[72];
double SWCC_CM[72], SWCC_CS[72], SWCC_CV[72], SWCC_CSkew[72],
SWCC_CKurt[72], SWCC_CMin[72], SWCC_CMax[72], SWCC_CAlpha[72],
SWCC_CBeta[72], SWCC_H[72];
double SWCC_C_hM[72], SWCC_C_hS[72], SWCC_C_hV[72], SWCC_C_hSkew[72],
SWCC_C_hKurt[72], SWCC_C_hMin[72], SWCC_C_hMax[72], SWCC_C_hAlpha[72],
SWCC_C_hBeta[72];
double a_mean, a_var, a_stdev, a_skew, a_kurt, a_min, a_max, a_alpha, a_beta,
summation_a_var, summation_a_skew, summation_a_kurt, summation_a;
double b_mean, b_var, b_stdev, b_skew, b_kurt, b_min, b_max, b_alpha, b_beta,
summation_b_var, summation_b_skew, summation_b_kurt, summation_b;
double c_mean, c_var, c_stdev, c_skew, c_kurt, c_min, c_max, c_alpha, c_beta,
summation_c_var, summation_c_skew, summation_c_kurt, summation_c;
double C_h_mean, C_h_var, C_h_stdev, C_h_skew, C_h_kurt, C_h_min, C_h_max, C_h_alpha,
C_h_beta, summation_C_h_var, summation_C_h_skew, summation_C_h_kurt, summation_C_h;
double wPI_adj_mean, wPI_adj_var, PI_adj_mean, PI_adj_var, opt_moisture_mean,
opt_moisture_var, dry_gamma_mean;
double summation_theata_water_skew, summation_theata_water_kurt, theata_water_skew,
theata_water_kurt, summation_wopt_skew, summation_wopt_kurt, wopt_skew, wopt_kurt;
double summation_theata_sat_skew, summation_theata_sat_kurt, theata_sat_kurt,
theata_sat_skew;
gamma_water = 62.4;
bool TMIconstraints, Output_Sim, level[72], Layer_Type[72], Layer_Compaction[72];
clock_t tStart, tEnd;
string Rosenblueth, temp, Names[72], TMIconstraints1, Level_a[72], Layer_Type_a[72], location,
Layer_Compaction_a[72];
```

```
int random_integer = time(NULL);
//Global Variables
tStart = clock();
a0 = 0.000000675; a1 = -0.0000771; a2 = 0.01792; a3 = 0.47239; Co = ((1.6*30.4)/30);
gsl_rng * Rand_NUM_Gen = gsl_rng_alloc (gsl_rng_taus);//GSL Random Number Generator
gsl_rng_set (Rand_NUM_Gen,random_integer); // Seeds the Random Number Generator changes
the random number
gsl_rng_env_setup();
Simulations_T = 0.0;
//Initiation of all storage variables
for( int i=0; i<72; i++)
{
P200_M[i] = 0.0; P200_V[i] = 0.0; P200_S[i] = 0.0; P200_Min[i] = 0.0; P200_Max[i] = 0.0;
P200_Alpha[i] = 0.0; P200_Beta[i] = 0.0;wPI_M[i] = 0.0; wPI_V[i] = 0.0; wPI_S[i] = 0.0;
wPI_Min[i] = 0.0; wPI_Max[i] = 0.0; wPI_Alpha[i] = 0.0; wPI_Beta[i] = 0.0; Suction_Mean[i] =
0.0; Suction_Variance[i] = 0.0; Suction_Stdev[i] = 0.0; Suction_Skew[i] = 0.0; Suction_Kurt[i] =
0.0; Suction_Minimum[i] = 0.0; Suction_Maximum[i] = 0.0; Suction_Alpha[i] = 0.0;
Suction_Beta[i] = 0.0; Gs_mean[i] = 0.0; Gs_var[i] = 0.0; Gs_stdev[i] = 0.0; Gs_Min[i] = 0.0;
Gs_Max[i] = 0.0; Gs_Alpha[i] = 0.0; Gs_Beta[i] = 0.0;Fenv_Mean[i] = 0.0; Fenv_Var[i] = 0.0;
Fenv_Stdev[i] = 0.0; Fenv_Skew[i] = 0.0; Fenv_Kurt[i] = 0.0; Fenv_Min[i] = 0.0; Fenv_Max[i] =
0.0; Fenv_Alpha[i] = 0.0; Fenv_Beta[i] = 0.0;Mreq_Mean[i] = 0.0; Mreq_Var[i] = 0.0;
Mreq_Stdev[i] = 0.0; Mreq_Skew[i] = 0.0; Mreq_Kurt[i] = 0.0; Mreq_Min[i] = 0.0; Mreq_Max[i]
= 0.0; Mreq_Alpha[i] = 0.0; Mreq_Beta[i] = 0.0;Mropt_Mean[i] = 0.0; Mropt_Var[i] = 0.0;
Mropt_Stdev[i] = 0.0; Mropt_Skew[i] = 0.0; Mropt_Kurt[i] = 0.0; Mropt_Min[i] = 0.0;
Mropt_Max[i] = 0.0; Mropt_Alpha[i] = 0.0; Mropt_Beta[i] = 0.0;opt_sat_mean[i] = 0.0;
opt_sat_var[i] = 0.0; opt_sat_stdev[i] = 0.0; opt_sat_skew[i] = 0.0; opt_sat_min[i] = 0.0;
opt_sat_max[i] = 0.0; opt_sat_kurt[i] = 0.0; opt_sat_Alpha[i] = 0.0; opt_sat_Beta[i] =
0.0;degree_sat_mean[i] = 0.0; degree_sat_var[i] = 0.0; degree_sat_stdev[i] = .0;
```

```
degree_sat_skew[i] = 0.0; degree_sat_Min[i] = 0.0; degree_sat_Max[i] = 0.0; degree_sat_kurt[i] =
0.0; degree_sat_Alpha[i] = 0.0; degree_sat_Beta[i] = 0.0;PI_M[i] = 0.0; PI_V[i] = 0.0; PI_S[i] =
0.0; PI_Min[i] = 0.0; PI_Max[i] = 0.0; PI_Alpha[i] = 0.0; PI_Beta[i] = .0;P20_M[i] = 0.0;
P20_V[i] = 0.0; P20_S[i] = 0.0; P20_Min[i] = 0.0; P20_Max[i] = 0.0; P20_Alpha[i] = 0.0;
P20_Beta[i] = 0.0;P15_M[i] = 0.0; P15_V[i] = 0.0; P15_S[i] = 0.0; P15_Min[i] = 0.0; P15_Max[i]
= 0.0; P15_Alpha[i] = 0.0; P15_Beta[i] = 0.0;P10_M[i] = 0.0; P10_V[i] = 0.0; P10_S[i] = 0.0;
P10_Min[i] = 0.0; P10_Max[i] = 0.0; P10_Alpha[i] = 0.0; P10_Beta[i] = 0.0;P05_M[i] = 0.0;
P05_V[i] = 0.0; P05_S[i] = 0.0; P05_Min[i] = 0.0; P05_Max[i] = 0.0; P05_Alpha[i] = 0.0;
P05_Beta[i] = 0.0;P40_M[i] = 0.0; P40_V[i] = 0.0; P40_S[i] = 0.0; P40_Min[i] = 0.0; P40_Max[i]
= 0.0; P40_Alpha[i] = 0.0; P40_Beta[i] = 0.0;P60_M[i] = 0.0; P60_V[i] = 0.0; P60_S[i] = 0.0;
P60_Min[i] = 0.0; P60_Max[i] = 0.0; P60_Alpha[i] = 0.0; P60_Beta[i] = 0.0;D60_M[i] = 0.0;
D60_V[i] = 0.0; D60_S[i] = 0.0; D60_Min[i] = 0.0; D60_Max[i] = 0.0; D60_Alpha[i] = 0.0;
D60_Beta[i] = 0.0;CBR_M[i] = 0.0; CBR_V[i] = 0.0; CBR_S[i] = 0.0; CBR_Skew[i] = 0.0;
CBR_Kurt[i] = 0.0; CBR_Min[i] = 0.0; CBR_Max[i] = 0.0; CBR_Alpha[i] = 0.0; CBR_Beta[i] =
0.0;wopt_M[i] = 0.0; wopt_V[i] = 0.0; wopt_S[i] = 0.0; wopt_Skew[i] = 0.0; wopt_Kurt[i] = 0.0;
wopt_Min[i] = 0.0; wopt_Max[i] = 0.0; wopt_Alpha[i] = 0.0; wopt_Beta[i] =
0.0;gamma_dry_M[i] = 0.0; gamma_dry_V[i] = 0.0; gamma_dry_S[i] = 0.0; gamma_dry_Skew[i]
= 0.0; gamma_dry_Kurt[i] = 0.0; gamma_dry_Min[i] = 0.0; gamma_dry_Max[i] = 0.0;
gamma_dry_Alpha[i] = 0.0; gamma_dry_Beta[i] = 0.0;Theata_WM[i] = 0.0; Theata_WS[i] = 0.0;
Theata_WV[i] = 0.0; Theata_WSkew[i] = 0.0; Theata_WKurt[i] = 0.0; Theata_WMin[i] = 0.0;
Theata_WMax[i] = .0; Theata_WAlpha[i] = 0.0; Theata_WBeta[i] = 0.0;Theata_SM[i] = 0.0;
Theata_SS[i] = 0.0; Theata_SV[i] = 0.0; Theata_SSkew[i] = 0.0; Theata_SKurt[i] = 0.0;
Theata_SMin[i] = 0.0; Theata_SMax[i] = 0.0; Theata_SAlpha[i] = 0.0; Theata_SBeta[i] =
0.0;SWCC_AM[i] = 0.0; SWCC_AS[i] = 0.0; SWCC_AV[i] = 0.0; SWCC_ASkew[i] = 0.0;
SWCC_AKurt[i] = 0.0; SWCC_AMin[i] = 0.0; SWCC_AMax[i] = 0.0; SWCC_AAlpha[i] = 0.0;
SWCC_ABeta[i] = 0.0;SWCC_BM[i] = 0.0; SWCC_BS[i] = 0.0; SWCC_BV[i] = 0.0;
SWCC_BSkew[i] = 0.0; SWCC_BKurt[i] = 0.0; SWCC_BMin[i] = 0.0; SWCC_BMax[i] = 0.0;
SWCC_BAlpha[i] = 0.0; SWCC_BBeta[i] = 0.0;SWCC_CM[i] = 0.0; SWCC_CS[i] = 0.0;
```

```
SWCC_CV[i] = 0.0; SWCC_CSkew[i] = 0.0; SWCC_CKurt[i] = 0.0; SWCC_CMin[i] = 0.0;
SWCC_CMax[i] = 0.0; SWCC_CAlpha[i] = 0.0; SWCC_CBeta[i] = 0.0; SWCC_H[i] =
0.0;SWCC_C_hM[i] = 0.0; SWCC_C_hS[i] = 0.0; SWCC_C_hV[i] = 0.0; SWCC_C_hSkew[i] =
0.0; SWCC_C_hKurt[i] = .0; SWCC_C_hMin[i] = 0.0; WCC_C_hMax[i] = 0.0;
SWCC_C_hAlpha[i] = 0.0; SWCC_C_hBeta[i] = 0.0;}
CBR_mean = 0.0; CBR_var = 0.0;CBR_stdev = 0.0;CBR_skew = 0.0;CBR_kurt = 0.0;CBR_min
0.0;CBR_max = 0.0;CBR_alpha = 0.0;CBR_beta = 0.0;
ifstream input;string fileName = Excel_Output_Data.txt";
input.open(fileName.c_str());
if (input.fail())
{cout << "Cannot open input file: " << fileName << "\nPress Enter to exit..."; // if the file cannot
open
cin.get();
return 0;}
input >> Rosenblueth;
if(Rosenblueth.compare("Rosenblueth_2")==0)
{Check = 1;}
else if(Rosenblueth.compare("Rosenblueth_3")==0)
{Check = 2;}
else if(Rosenblueth.compare("Monte_Carlo")==0)
{input >> Simulations_T;Check = 3;}
else// (Rosenblueth.compare("Taylor_Series")==0)
{Check = 4;}
input >> temp; // Checking if Constraints for TMI are needed
if(temp.compare("1-40D_Constraints")==0)
{input >> temp;
if(temp.compare("Yes")==0)
{TMIconstraints = true;TMIconstraints1 = "Yes";}
```

```
else{TMIconstraints = false;TMIconstraints1= "No";}}

input >> temp;

if(temp.compare("Output_Simulations")==0)

{input >> temp;

if(temp.compare("Yes")==0)

{Output_Sim = true;}

else{Output_Sim = false;}

input >> temp;

if(temp.compare("Location")==0)

input >> location;

input >> temp; // January precipitation statistical information

if(temp.compare("January_P")==0){

for(int i=0;i<7;i++)

input >> JanP[i];}

input >> temp; // Februay precipitation statistical information

if(temp.compare("February_P")==0){

for(int i=0;i<7;i++)

input >> FebP[i];}

input >> temp; // March precipitation statistical information

if(temp.compare("March_P")==0){

for(int i=0;i<7;i++)

input >> MarP[i];}

input >> temp; // April precipitation statistical information

if(temp.compare("April_P")==0){

for(int i=0;i<7;i++)

input >> AprP[i];}

input >> temp; // May precipitation statistical information

if(temp.compare("May_P")==0){
```

```
for(int i=0;i<7;i++)

input >> MayP[i];}

input >> temp;  // June precipitation statistical information

if(temp.compare("June_P")==0){

for(int i=0;i<7;i++)

input >> JunP[i];}

input >> temp; // July precipitation statistical information

if(temp.compare("July_P")==0){

for(int i=0;i<7;i++)

input >> JulP[i];}

input >> temp; // August precipitation statistical information

if(temp.compare("August_P")==0){

for(int i=0;i<7;i++)

input >> AugP[i];}

input >> temp; // September precipitation statistical information

if(temp.compare("September_P")==0){

for(int i=0;i<7;i++)

input >> SepP[i];}

input >> temp; // October precipitation statistical information

if(temp.compare("October_P")==0){

for(int i=0;i<7;i++)

input >> OctP[i];}

input >> temp; // November precipitation statistical information

if(temp.compare("November_P")==0){

for(int i=0;i<7;i++)

input >> NovP[i];}

input >> temp; // December precipitation statistical information

if(temp.compare("December_P")==0){
```

```
for(int i=0;i<7;i++)

input >> DecP[i];}

input >> temp; // January Daylight Correction

if(temp.compare("January_L")==0)

input >> Jan_L;

input >> temp;// February Daylight Correction

if(temp.compare("February_L")==0)

input >> Feb_L;

input >> temp;// March Daylight Correction

if(temp.compare("March_L")==0)

input >> Mar_L;

input >> temp;// April Daylight Correction

if(temp.compare("April_L")==0)

input >> Apr_L;

input >> temp;// May Daylight Correction

if(temp.compare("May_L")==0)

input >> May_L;

input >> temp;// June Daylight Correction

if(temp.compare("June_L")==0)

input >> Jun_L;

input >> temp;// July Daylight Correction

if(temp.compare("July_L")==0)

input >> Jul_L;

input >> temp;// August Daylight Correction

if(temp.compare("August_L")==0)

input >> Aug_L;

input >> temp;// September Daylight Correction

if(temp.compare("September_L")==0)
```

```
input >> Sep_L;

input >> temp;//October Daylight Correction

if(temp.compare("October_L")==0)

input >> Oct_L;

input >> temp;//November Daylight Correction

if(temp.compare("November_L")==0)

input >> Nov_L;

input >> temp;//December Daylight Correction

if(temp.compare("December_L")==0)

input >> Dec_L;

input >> temp;//January temperature statistical information

if(temp.compare("January_T")==0){

for(int i=0;i<7;i++)

input >> JanT[i];}

input >> temp;//February temperature statistical information

if(temp.compare("February_T")==0){

for(int i=0;i<7;i++)

input >> FebT[i];}

input >> temp;//March temperature statistical information

if(temp.compare("March_T")==0){

for(int i=0;i<7;i++)

input >> MarT[i];}

input >> temp;//April temperature statistical information

if(temp.compare("April_T")==0){

for(int i=0;i<7;i++)

input >> AprT[i];}

input >> temp;//May temperature statistical information

if(temp.compare("May_T")==0){
```

```
for(int i=0;i<7;i++)
input >> MayT[i];}
input >> temp;//June temperature statistical information
if(temp.compare("June_T")==0){
for(int i=0;i<7;i++)
input >> JunT[i];}
input >> temp;//July temperature statistical information
if(temp.compare("July_T")==0){
for(int i=0;i<7;i++)
input >> JulT[i];}
input >> temp;//August temperature statistical information
if(temp.compare("August_T")==0){
for(int i=0;i<7;i++)
input >> AugT[i];}
input >> temp;//September temperature statistical information
if(temp.compare("September_T")==0){
for(int i=0;i<7;i++)
input >> SepT[i];}
input >> temp;//October temperature statistical information
if(temp.compare("October_T")==0){
for(int i=0;i<7;i++)
input >> OctT[i];}
input >> temp;//November temperature statistical information
if(temp.compare("November_T")==0){
for(int i=0;i<7;i++)
input >> NovT[i];}
input >> temp;//December temperature statistical information
if(temp.compare("December_T")==0){
```

```
for(int i=0;i<7;i++)
input >> DecT[i];}
input >> temp;// Number of Layers for statistical computations
if(temp.compare("Num_layers")==0)
input >> Num_layer;
input >> temp; //Layer Type ie Base Non-Base
if(temp.compare("Layer_Description")==0){
for(int i=0;i<Num_layer;i++)
{input >> temp;
if(temp.compare("Base")==0)
{Layer_Type[i] = true; Layer_Type_a[i] = temp;}
else
{Layer_Type[i] = false;Layer_Type_a[i] = temp;}}}
input >> temp; //Layer Compaction
if(temp.compare("Layer_Compacted")==0)
{for(int i=0;i<Num_layer;i++)
{input >> temp;if(temp.compare("Yes")==0){
Layer_Compaction[i] = true;Layer_Compaction_a[i] = "Yes";}
else{Layer_Compaction[i] = false;Layer_Compaction_a[i] = "No";}}}
input >> temp;//Name of Layer
if(temp.compare("Layer_Name")==0)
{for(int i=0;i<Num_layer; i++)
input >> Names[i];}
input >> temp;//Passing 2.0" Mean
if(temp.compare("P20_Mean")==0){
for(int i=0;i<Num_layer; i++)
input >> P20_M[i];}
input >> temp;//Passing 2.0" Variance
```

```
if(temp.compare("P20_Variance")==0){

for(int i=0;i<Num_layer; i++)

input >> P20_V[i];}

input >> temp;//Passing 2.0" Standard Deviation

if(temp.compare("P20_Stdev")==0){

for(int i=0;i<Num_layer; i++)

input >> P20_S[i];}

input >> temp;//Passing 2.0" Minimum

if(temp.compare("P20_Min")==0){

for(int i=0;i<Num_layer; i++)

input >> P20_Min[i];}

input >> temp;//Passing 2.0" Maximum

if(temp.compare("P20_Max")==0){

for(int i=0;i<Num_layer; i++)

input >> P20_Max[i];}

input >> temp;//Passing 2.0" alpha shape factor

if(temp.compare("P20_Alpha")==0){

for(int i=0;i<Num_layer; i++)

input >> P20_Alpha[i];}

input >> temp;//Passing 2.0" beta shape factor

if(temp.compare("P20_Beta")==0){

for(int i=0;i<Num_layer; i++)

input >> P20_Beta[i];}

input >> temp;//Passing 1.5" Mean

if(temp.compare("P15_Mean")==0){

for(int i=0;i<Num_layer; i++)

input >> P15_M[i];}

input >> temp;//Passing 1.5" Variance
```

```
if(temp.compare("P15_Variance")==0){
for(int i=0;i<Num_layer; i++)
input >> P15_V[i];}
input >> temp;//Passing 1.5" Standard Deviation
if(temp.compare("P15_Stdev")==0){
for(int i=0;i<Num_layer; i++)
input >> P15_S[i];}
input >> temp;//Passing 1.5" Minimum
if(temp.compare("P15_Min")==0){
for(int i=0;i<Num_layer; i++)
input >> P15_Min[i];}
input >> temp;//Passing 1.5" Maximum
if(temp.compare("P15_Max")==0){
for(int i=0;i<Num_layer; i++)
input >> P15_Max[i];}
input >> temp;//Passing 1.5" alpha shape factor
if(temp.compare("P15_Alpha")==0){
for(int i=0;i<Num_layer; i++)
input >> P15_Alpha[i];}
input >> temp;//Passing 1.5" beta shape factor
if(temp.compare("P15_Beta")==0){
for(int i=0;i<Num_layer; i++)
input >> P15_Beta[i];}
input >> temp;//Passing 1.0" Mean
if(temp.compare("P10_Mean")==0){
for(int i=0;i<Num_layer; i++)
input >> P10_M[i];}
input >> temp;//Passing 1.0" Variance
```

```
if(temp.compare("P10_Variance")==0){

for(int i=0;i<Num_layer; i++)

input >> P10_V[i];}

input >> temp;//Passing 1.0" Standard Deviation

if(temp.compare("P10_Stdev")==0){

for(int i=0;i<Num_layer; i++)

input >> P10_S[i];}

input >> temp;//Passing 1.0" Minimum

if(temp.compare("P10_Min")==0){

for(int i=0;i<Num_layer; i++)

input >> P10_Min[i];}

input >> temp;//Passing 1.0" Maximum

if(temp.compare("P10_Max")==0){

for(int i=0;i<Num_layer; i++)

input >> P10_Max[i];}

input >> temp;//Passing 1.0" alpha shape factor

if(temp.compare("P10_Alpha")==0){

for(int i=0;i<Num_layer; i++)

input >> P10_Alpha[i];}

input >> temp;//Passing 1.0" beta shape factor

if(temp.compare("P10_Beta")==0){

for(int i=0;i<Num_layer; i++)

input >> P10_Beta[i];}

input >> temp;//Passing 0.5" Mean

if(temp.compare("P05_Mean")==0){

for(int i=0;i<Num_layer; i++)

input >> P05_M[i];}

input >> temp;//Passing 0.5" Variance
```

```
if(temp.compare("P05_Variance")==0){

for(int i=0;i<Num_layer; i++)

input >> P05_V[i];}

input >> temp;//Passing 0.5" Standard Deviation

if(temp.compare("P05_Stdev")==0){

for(int i=0;i<Num_layer; i++)

input >> P05_S[i];}

input >> temp;//Passing 0.5" Minimum

if(temp.compare("P05_Min")==0){

for(int i=0;i<Num_layer; i++)

input >> P05_Min[i];}

input >> temp;//Passing 0.5" Maximum

if(temp.compare("P05_Max")==0){

for(int i=0;i<Num_layer; i++)

input >> P05_Max[i];}

input >> temp;//Passing 0.5" alpha shape factor

if(temp.compare("P05_Alpha")==0){

for(int i=0;i<Num_layer; i++)

input >> P05_Alpha[i];}

input >> temp;//Passing 0.5" beta shape factor

if(temp.compare("P05_Beta")==0){

for(int i=0;i<Num_layer; i++)

input >> P05_Beta[i];}

input >> temp;//Passing #40 Mean

if(temp.compare("P40_Mean")==0){

for(int i=0;i<Num_layer; i++)

input >> P40_M[i];}

input >> temp;//Passing #40 Variance
```

```
if(temp.compare("P40_Variance")==0){
for(int i=0;i<Num_layer; i++)
input >> P40_V[i];}
input >> temp;//Passing #40 Standard Deviation
if(temp.compare("P40_Stdev")==0){
for(int i=0;i<Num_layer; i++)
input >> P40_S[i];}
input >> temp;//Passing #40 Minimum
if(temp.compare("P40_Min")==0){
for(int i=0;i<Num_layer; i++)
input >> P40_Min[i];}
input >> temp;//Passing #40 Maximum
if(temp.compare("P40_Max")==0){
for(int i=0;i<Num_layer; i++)
input >> P40_Max[i];}
input >> temp;//Passing #40 alpha shape factor
if(temp.compare("P40_Alpha")==0){
for(int i=0;i<Num_layer; i++)
input >> P40_Alpha[i];}
input >> temp;//Passing #40 beta shape factor
if(temp.compare("P40_Beta")==0){
for(int i=0;i<Num_layer; i++)
input >> P40_Beta[i];}
input >> temp;//Passing #60 Mean
if(temp.compare("P60_Mean")==0){
for(int i=0;i<Num_layer; i++)
input >> P60_M[i];}
input >> temp;//Passing #60 Variance
```

```
if(temp.compare("P60_Variance")==0){
for(int i=0;i<Num_layer; i++)
input >> P60_V[i];}
input >> temp;//Passing #60 Standard Deviation
if(temp.compare("P60_Stdev")==0){
for(int i=0;i<Num_layer; i++)
input >> P60_S[i];}
input >> temp;//Passing #60 Minimum
if(temp.compare("P60_Min")==0){
for(int i=0;i<Num_layer; i++)
input >> P60_Min[i];}
input >> temp;//Passing #60 Maximum
if(temp.compare("P60_Max")==0){
for(int i=0;i<Num_layer; i++)
input >> P60_Max[i];}
input >> temp;//Passing #60 alpha shape factor
if(temp.compare("P60_Alpha")==0){
for(int i=0;i<Num_layer; i++)
input >> P60_Alpha[i];}
input >> temp;//Passing #60 beta shape factor
if(temp.compare("P60_Beta")==0){
for(int i=0;i<Num_layer; i++)
input >> P60_Beta[i];}
input >> temp;//D60 Mean
if(temp.compare("D60_Mean")==0){
for(int i=0;i<Num_layer; i++)
input >> D60_M[i];}
input >> temp;//D60 Variance
```

```
if(temp.compare("D60_Variance")==0){

for(int i=0;i<Num_layer; i++)

input >> D60_V[i];}

input >> temp;//D60 Standard Deviation

if(temp.compare("D60_Stdev")==0){

for(int i=0;i<Num_layer; i++)

input >> D60_S[i];}

input >> temp;//D60 Minimum

if(temp.compare("D60_Min")==0){

for(int i=0;i<Num_layer; i++)

input >> D60_Min[i];}

input >> temp;//D60 Maximum

if(temp.compare("D60_Max")==0){

for(int i=0;i<Num_layer; i++)

input >> D60_Max[i];}

input >> temp;//D60 alpha shape factor

if(temp.compare("D60_Alpha")==0){

for(int i=0;i<Num_layer; i++)

input >> D60_Alpha[i];}

input >> temp;//D60 beta shape factor

if(temp.compare("D60_Beta")==0){

for(int i=0;i<Num_layer; i++)

input >> D60_Beta[i];}

input >> temp;//Passing 200 Mean

if(temp.compare("P200_Mean")==0){

for(int i=0;i<Num_layer; i++)

input >> P200_M[i];}

input >> temp;//Passing 200 Variance
```

```
if(temp.compare("P200_Variance")==0){
for(int i=0;i<Num_layer; i++)
input >> P200_V[i];}
input >> temp;//Passing 200 Standard Deviation
if(temp.compare("P200_Stdev")==0){
for(int i=0;i<Num_layer; i++)
input >> P200_S[i];}
input >> temp;//Passing 200 Minimum
if(temp.compare("P200_Min")==0){
for(int i=0;i<Num_layer; i++)
input >> P200_Min[i];}
input >> temp;//Passing 200 Maximum
if(temp.compare("P200_Max")==0){
for(int i=0;i<Num_layer; i++)
input >> P200_Max[i];}
input >> temp;//Passing 200 alpha shape factor
if(temp.compare("P200_Alpha")==0){
for(int i=0;i<Num_layer; i++)
input >> P200_Alpha[i];}
input >> temp;//Passing 200 beta shape factor
if(temp.compare("P200_Beta")==0){
for(int i=0;i<Num_layer; i++)
input >> P200_Beta[i];}
input >> temp;//PI Mean
if(temp.compare("PI_Mean")==0){
for(int i=0;i<Num_layer; i++)
input >> PI_M[i];}
input >> temp;//PI Variance
```

```
if(temp.compare("PI_Variance")==0){
for(int i=0;i<Num_layer; i++)
input >> PI_V[i];}
input >> temp;//PI Standard Deviation
if(temp.compare("PI_Stdev")==0){
for(int i=0;i<Num_layer; i++)
input >> PI_S[i];}
input >> temp;//PI Minimum
if(temp.compare("PI_Min")==0){
for(int i=0;i<Num_layer; i++)
input >> PI_Min[i];}
input >> temp;//PI Maximum
if(temp.compare("PI_Max")==0){
for(int i=0;i<Num_layer; i++)
input >> PI_Max[i];}
input >> temp;//PI alpha shape factor
if(temp.compare("PI_Alpha")==0){
for(int i=0;i<Num_layer; i++)
input >> PI_Alpha[i];}
input >> temp;//PI beta shape factor
if(temp.compare("PI_Beta")==0){
for(int i=0;i<Num_layer; i++)
input >> PI_Beta[i];}
input >> temp;//wPI Mean
if(temp.compare("wPI_Mean")==0){
for(int i=0;i<Num_layer; i++)
input >> wPI_M[i];}
input >> temp;//wPI Variance
```

```
if(temp.compare("wPI_Variance")==0){
for(int i=0;i<Num_layer; i++)
input >> wPI_V[i];}
input >> temp;//wPI Standard Deviation
if(temp.compare("wPI_Stdev")==0){
for(int i=0;i<Num_layer; i++)
input >> wPI_S[i];}
input >> temp;//wPI Minimum
if(temp.compare("wPI_Min")==0){
for(int i=0;i<Num_layer; i++)
input >> wPI_Min[i];}
input >> temp;//wPI Maximum
if(temp.compare("wPI_Max")==0){
for(int i=0;i<Num_layer; i++)
input >> wPI_Max[i];}
input >> temp;//wPI alpha shape factor
if(temp.compare("wPI_Alpha")==0){
for(int i=0;i<Num_layer; i++)
input >> wPI_Alpha[i];}
input >> temp;//wPI beta shape factor
if(temp.compare("wPI_Beta")==0){
for(int i=0;i<Num_layer; i++)
input >> wPI_Beta[i];}
input >> temp;//Gs Mean
if(temp.compare("Gs_Mean")==0){
for(int i=0;i<Num_layer; i++)
input >> Gs_mean[i];}
input >> temp;//Gs Variance
```

```
if(temp.compare("Gs_Variance")==0){

for(int i=0;i<Num_layer; i++)

input >> Gs_var[i];}

input >> temp;//Gs Standard Deviation

if(temp.compare("Gs_Stdev")==0){

for(int i=0;i<Num_layer; i++)

input >> Gs_stdev[i];}

input >> temp;//Gs Minimum

if(temp.compare("Gs_Min")==0){

for(int i=0;i<Num_layer; i++)

input >> Gs_Min[i];}

input >> temp;//Gs Maximum

if(temp.compare("Gs_Max")==0){

for(int i=0;i<Num_layer; i++)

input >> Gs_Max[i];}

input >> temp;//Gs alpha shape factor

if(temp.compare("Gs_Alpha")==0){

for(int i=0;i<Num_layer; i++)

input >> Gs_Alpha[i];}

input >> temp;//Gs beta shape factor

if(temp.compare("Gs_Beta")==0){

for(int i=0;i<Num_layer; i++)

input >> Gs_Beta[i];}

input >> temp; // Level of analysis

if(temp.compare("Level")==0){

for(int i=0;i<Num_layer; i++){

input >> temp;

if(temp.compare("Level_1")==0){level[i] = true;Level_a[i] = "Level_1";}
```

```
else if(temp.compare("Level_1a")==0){level[i] = true;Level_a[i] = "Level_1a";}
else if(temp.compare("Level_2")==0){level[i] = false;Level_a[i] = "Level_2";}
else{level[i] = false;Level_a[i] = "Level_3";}}}
input >> temp;//wopt Mean
if(temp.compare("wopt_Mean")==0){
for(int i=0;i<Num_layer; i++)
input >> wopt_M[i];}
input >> temp;//wopt Variance
if(temp.compare("wopt_Variance")==0){
for(int i=0;i<Num_layer; i++)
input >> wopt_V[i];}
input >> temp;//wopt Standard Deviation
if(temp.compare("wopt_Stdev")==0){
for(int i=0;i<Num_layer; i++)
input >> wopt_S[i];}
input >> temp;//wopt Minimum
if(temp.compare("wopt_Min")==0){
for(int i=0;i<Num_layer; i++)
input >> wopt_Min[i];}
input >> temp;//wopt Maximum
if(temp.compare("wopt_Max")==0){
for(int i=0;i<Num_layer; i++)
input >> wopt_Max[i];}
input >> temp;//wopt alpha shape factor
if(temp.compare("wopt_Alpha")==0){
for(int i=0;i<Num_layer; i++)
input >> wopt_Alpha[i];}
input >> temp;//wopt beta shape factor
```

```
if(temp.compare("wopt_Beta")==0){

for(int i=0;i<Num_layer; i++)

input >> wopt_Beta[i];}

input >> temp;//CBR Mean

if(temp.compare("CBR_Mean")==0){

for(int i=0;i<Num_layer; i++)

input >> CBR_M[i];}

input >> temp;//CBR Variance

if(temp.compare("CBR_Variance")==0){

for(int i=0;i<Num_layer; i++)

input >> CBR_V[i];}

input >> temp;//CBR Standard Deviation

if(temp.compare("CBR_Stdev")==0){

for(int i=0;i<Num_layer; i++)

input >> CBR_S[i];}

input >> temp;//CBR Minimum

if(temp.compare("CBR_Min")==0){

for(int i=0;i<Num_layer; i++)

input >> CBR_Min[i];}

input >> temp;//CBR Maximum

if(temp.compare("CBR_Max")==0){

for(int i=0;i<Num_layer; i++)

input >> CBR_Max[i];}

input >> temp;//CBR alpha shape factor

if(temp.compare("CBR_Alpha")==0){

for(int i=0;i<Num_layer; i++)

input >> CBR_Alpha[i];}

input >> temp;//CBR beta shape factor
```

```
if(temp.compare("CBR_Beta")==0){
for(int i=0;i<Num_layer; i++)
input >> CBR_Beta[i];}
input >> temp;//gamma_dry Mean
if(temp.compare("gamma_dry_Mean")==0){
for(int i=0;i<Num_layer; i++)
input >> gamma_dry_M[i];}
input >> temp;//gamma_dry Variance
if(temp.compare("gamma_dry_Variance")==0){
for(int i=0;i<Num_layer; i++)
input >> gamma_dry_V[i];}
input >> temp;//gamma_dry Standard Deviation
if(temp.compare("gamma_dry_Stdev")==0){
for(int i=0;i<Num_layer; i++)
input >> gamma_dry_S[i];}
input >> temp;//gamma_dry Minimum
if(temp.compare("gamma_dry_Min")==0){
for(int i=0;i<Num_layer; i++)
input >> gamma_dry_Min[i];}
input >> temp;//gamma_dry Maximum
if(temp.compare("gamma_dry_Max")==0){
for(int i=0;i<Num_layer; i++)
input >> gamma_dry_Max[i];}
input >> temp;//gamma_dry alpha shape factor
if(temp.compare("gamma_dry_Alpha")==0){
for(int i=0;i<Num_layer; i++)
input >> gamma_dry_Alpha[i];}
input >> temp;//gamma_dry beta shape factor
```

```
if(temp.compare("gamma_dry_Beta")==0){
for(int i=0;i<Num_layer; i++)
input >> gamma_dry_Beta[i];}
input >> temp;//SWCCA Mean
if(temp.compare("SWCC_AMean")==0){
for(int i=0;i<Num_layer; i++)
input >> SWCC_AM[i];}
input >> temp;//SWCCA Variance
if(temp.compare("SWCC_AVariance")==0){
for(int i=0;i<Num_layer; i++)
input >> SWCC_AV[i];}
input >> temp;//SWCCA Standard Deviation
if(temp.compare("SWCC_AStdev")==0){
for(int i=0;i<Num_layer; i++)
input >> SWCC_AS[i];}
input >> temp;//SWCCA Minimum
if(temp.compare("SWCC_AMin")==0){
for(int i=0;i<Num_layer; i++)
input >> SWCC_AMin[i];}
input >> temp;//SWCCA Maximum
if(temp.compare("SWCC_AMax")==0){
for(int i=0;i<Num_layer; i++)
input >> SWCC_AMax[i];}
input >> temp;//SWCCA alpha shape factor
if(temp.compare("SWCC_AAlpha")==0){
for(int i=0;i<Num_layer; i++)
input >> SWCC_AAlpha[i];}
input >> temp;//SWCCA beta shape factor
```

```
if(temp.compare("SWCC_ABeta")==0){

for(int i=0;i<Num_layer; i++)

input >> SWCC_ABeta[i];}

input >> temp;//SWCCB Mean

if(temp.compare("SWCC_BMean")==0){

for(int i=0;i<Num_layer; i++)

input >> SWCC_BM[i];}

input >> temp;//SWCCB Variance

if(temp.compare("SWCC_BVariance")==0){

for(int i=0;i<Num_layer; i++)

input >> SWCC_BV[i];}

input >> temp;//SWCCB Standard Deviation

if(temp.compare("SWCC_BStdev")==0){

for(int i=0;i<Num_layer; i++)

input >> SWCC_BS[i];}

input >> temp;//SWCCB Minimum

if(temp.compare("SWCC_BMin")==0){

for(int i=0;i<Num_layer; i++)

input >> SWCC_BMin[i];}

input >> temp;//SWCCB Maximum

if(temp.compare("SWCC_BMax")==0){

for(int i=0;i<Num_layer; i++)

input >> SWCC_BMax[i];}

input >> temp;//SWCCB alpha shape factor

if(temp.compare("SWCC_BAlpha")==0){

for(int i=0;i<Num_layer; i++)

input >> SWCC_BAlpha[i];}

input >> temp;//SWCCB beta shape factor
```

```
if(temp.compare("SWCC_BBeta")==0){
for(int i=0;i<Num_layer; i++)
input >> SWCC_BBeta[i];}
input >> temp;//SWCCC Mean
if(temp.compare("SWCC_CMean")==0){
for(int i=0;i<Num_layer; i++)
input >> SWCC_CM[i];}
input >> temp;//SWCCC Variance
if(temp.compare("SWCC_CVariance")==0){
for(int i=0;i<Num_layer; i++)
input >> SWCC_CV[i];}
input >> temp;//SWCCC Standard Deviation
if(temp.compare("SWCC_CStdev")==0){
for(int i=0;i<Num_layer; i++)
input >> SWCC_CS[i];}
input >> temp;//SWCCC Minimum
if(temp.compare("SWCC_CMin")==0){
for(int i=0;i<Num_layer; i++)
input >> SWCC_CMin[i];}
input >> temp;//SWCCC Maximum
if(temp.compare("SWCC_CMax")==0){
for(int i=0;i<Num_layer; i++)
input >> SWCC_CMax[i];}
input >> temp;//SWCCC alpha shape factor
if(temp.compare("SWCC_CAlpha")==0){
for(int i=0;i<Num_layer; i++)
input >> SWCC_CAlpha[i];}
input >> temp;//SWCCC beta shape factor
```

```
if(temp.compare("SWCC_CBeta")==0){
for(int i=0;i<Num_layer; i++)
input >> SWCC_CBeta[i];}
input >> temp;//SWCC H Mean
if(temp.compare("SWCC_H")==0){
for(int i=0;i<Num_layer; i++)
input >> SWCC_H[i];}
input >> temp;//Mropt Mean
if(temp.compare("Mropt_Mean")==0){
for(int i=0;i<Num_layer; i++)
input >> Mropt_Mean[i];}
input >> temp;//Mropt Variance
if(temp.compare("Mropt_Variance")==0){
for(int i=0;i<Num_layer; i++)
input >> Mropt_Var[i];}
input >> temp;//Mropt Standard Deviation
if(temp.compare("Mropt_Stdev")==0){
for(int i=0;i<Num_layer; i++)
input >> Mropt_Stdev[i];}
input >> temp;//Mropt Minimum
if(temp.compare("Mropt_Min")==0){
for(int i=0;i<Num_layer; i++)
input >> Mropt_Min[i];}
input >> temp;//Mropt Maximum
if(temp.compare("Mropt_Max")==0){
for(int i=0;i<Num_layer; i++)
input >> Mropt_Max[i];}
input >> temp;//Mropt alpha shape factor
```

```
if(temp.compare("Mropt_Alpha")==0){
for(int i=0;i<Num_layer; i++)
input >> Mropt_Alpha[i];}
input >> temp;//Mropt beta shape factor
if(temp.compare("Mropt_Beta")==0){
for(int i=0;i<Num_layer; i++)
input >> Mropt_Beta[i];}
input.close();
if((JanP[0] <0) || (JanT[0]<-100) || (Jan_L < -100) || (Gs_mean[0]<0))//checks if all information is in the file{
cout << "Input File Does Not Have The Required Information."
<< "\n\nPlease review the input file. \n \nPress Enter to exit..."; // if the file cannot open does not have all the information
cin.get(); return 0;}
if(Check == 4)
{
// Taylor Series Solution
double January_V, February_V, March_V, April_V, May1_V, June_V, July_V, August_V, September_V, October_V, November_V, December_V;
double January_PE_dHy, February_PE_dHy, March_PE_dHy, April_PE_dHy, May1_PE_dHy, June_PE_dHy, July_PE_dHy, August_PE_dHy, September_PE_dHy, October_PE_dHy, November_PE_dHy, December_PE_dHy;
double January_PE_dt, February_PE_dt, March_PE_dt, April_PE_dt, May1_PE_dt, June_PE_dt, July_PE_dt, August_PE_dt, September_PE_dt, October_PE_dt, November_PE_dt, December_PE_dt;
double Janpow, Febpow, Marpow, Aprpow, Maypow, Junpow, Julpow, Augpow, Seppow, Octpow, Novpow, Decpow;
double summation_PE_dHy, PE_dHy, PE_dt;
```

```
double TMI_dP, TMI_dPE;
double d_dP200, d_dTMI, d_wPI, d_TMI;
double d_alpha_base, d_beta_base, d_gamma_base, d_beta_non, d_gamma_non, d_delta_non;
double d_Suction_theata_water, d_dry_gamma_theata_water,
d_Gs_theata_water,d_wPI_theata_water;
double d_theata_water, d_theata_sat, d_Gs_gamma, d_wopt_gamma, d_sopt_gamma;
double d_opt_moisture_opt_sat, d_gamma_dry_opt_sat, d_Gs_opt_sat;
double d_wPI_Fenv, d_Degree_Sat_Fenv, d_Optimum_Sat_Fenv, opt_moisture_stdev;
double d_Fenv_term1, d_Fenv_term2, d_Fenv_term3, d_cf_theata_water, d_bf_theata_water,
d_af_theata_water, d_theatasat, Fenv_Check;
P_mean = 0;P_var = 0;P_stdev = 0;P_skew =   0;P_kurt =   0;P_min = 0;P_max = 0;TMI_mean =
0;TMI_var = 0;TMI_stdev = 0;TMI_skew = 0;TMI_kurt = 0;TMI_min = 0;TMI_max =
0;PE_skew =  0;PE_kurt =  0;PE_min = 0;PE_max = 0;Hy_mean = 0;Hy_var = 0;Hy_skew =
0;Hy_kurt =  0;Hy_min = 0;Hy_max = 0;P_alpha = 0.0;P_beta = 0.0;Hy_alpha = 0.0;Hy_beta =
0.0;PE_alpha = 0.0;PE_beta = 0.0;TMI_alpha = 0.0;TMI_beta = 0.0;d_theata_sat =
0.0;d_Suction_theata_water = 0.0;d_dry_gamma_theata_water = 0.0; d_Gs_theata_water =
0.0;d_wPI_theata_water =0.0;theata_water_var = 0.0;d_opt_moisture_opt_sat =
0.0;d_gamma_dry_opt_sat = 0.0;d_Gs_opt_sat = 0.0;d_wPI_Fenv = 0.0;d_Degree_Sat_Fenv =
0.0; d_Optimum_Sat_Fenv = 0.0;d_theata_water = 0.0;d_Fenv_term1 = 0.0; d_Fenv_term2 = 0.0;
d_Fenv_term3 = 0.0;
//Precipitation Mean and Varaince Calculations
P_mean = JanP[0] + FebP[0] + MarP[0] + AprP[0] + MayP[0] + JunP[0] + JulP[0] + AugP[0] +
SepP[0] + OctP[0] + NovP[0] + DecP[0];
P_var = JanP[1] + FebP[1] + MarP[1] + AprP[1] + MayP[1] + JunP[1] + JulP[1] + AugP[1] +
SepP[1] + OctP[1] + NovP[1] + DecP[1];
P_stdev = pow(P_var,0.5);
//Annual Heat Index Mean and Variance Calculations
//Derviative of Annual Heat Index with respect to Temperature
```

```
January_V = pow((0.0175295 * JanT[0]),1.028) * JanT[1];
February_V = pow((0.0175295 * FebT[0]),1.028) * FebT[1];
March_V = pow((0.0175295 * MarT[0]),1.028) * MarT[1];
April_V = pow((0.0175295 * AprT[0]),1.028) * AprT[1];
May1_V = pow((0.0175295 * MayT[0]),1.028) * MayT[1];
June_V = pow((0.0175295 * JunT[0]),1.028) * JunT[1];
July_V = pow((0.0175295 * JulT[0]),1.028) * JulT[1];
August_V = pow((0.0175295 * AugT[0]),1.028) * AugT[1];
September_V = pow((0.0175295 * SepT[0]),1.028) * SepT[1];
October_V = pow((0.0175295 * OctT[0]),1.028) * OctT[1];
November_V = pow((0.0175295 * NovT[0]),1.028) * NovT[1];
December_V = pow((0.0175295 * DecT[0]),1.028) * DecT[1];
//Temperature check for Annual Heat Index
if(JanT[0] < 0.0)
JanT[0] = 1.0;
if(FebT[0] < 0.0)
FebT[0] = 1.0;
if(MarT[0] < 0.0)
MarT[0] = 1.0;
if(AprT[0] < 0.0)
AprT[0] = 1.0;
if(MayT[0] < 0.0)
MayT[0] = 1.0;
if(JunT[0] < 0.0)
JunT[0] = 1.0;
if(JulT[0] < 0.0)
JulT[0] = 1.0;
if(AugT[0] < 0.0)
```

```
AugT[0] = 1.0;
if(SepT[0] < 0.0)
SepT[0] = 1.0;
if(OctT[0] < 0.0)
OctT[0] = 1.0;
if(NovT[0] < 0.0)
NovT[0] = 1.0;
if(DecT[0] < 0.0)
DecT[0] = 1.0;
//Monthly Heat Index Equations
January_T = pow((0.2 * JanT[0]),1.514);
February_T = pow((0.2 * FebT[0]),1.514);
March_T = pow((0.2 * MarT[0]),1.514);
April_T = pow((0.2 * AprT[0]),1.514);
May1_T = pow((0.2 * MayT[0]),1.514);
June_T = pow((0.2 * JunT[0]),1.514);
July_T = pow((0.2 * JulT[0]),1.514);
August_T = pow((0.2 * AugT[0]),1.514);
September_T = pow((0.2 * SepT[0]),1.514);
October_T = pow((0.2 * OctT[0]),1.514);
November_T = pow((0.2 * NovT[0]),1.514);
December_T = pow((0.2 * DecT[0]),1.514);
Hy_mean = January_T + February_T + March_T + April_T + May1_T + June_T + July_T +
August_T + September_T + October_T + November_T + December_T;
Hy_var = January_V + February_V + March_V + April_V + May1_V + June_V + July_V +
August_V + September_V + October_V + November_V + December_V;
Hy_stdev = pow(Hy_var,0.5);
//Potential Evapotranspiration Mean and Variance Calculations
```

```
Hy_3 = pow(Hy_mean,3);

Hy_2 = pow(Hy_mean,2);

apow = a0*Hy_3 + a1*Hy_2 + a2*Hy_mean + a3;

term1 = pow(10,apow);

term2 = pow((1/Hy_mean),apow);

term3 = 0.000002025*Hy_2 -0.0001542*Hy_mean +0.01792;

C1 = Co * pow((10/Hy_mean),apow);

C1_dHy = Co * (term1 *term2 * (term3 * log(1/Hy_mean)-(apow/Hy_mean)) + term1 * term3 *

term2 * 2.3025850929940456840179914546843642076011014886287729760333);

Janpow = pow(JanT[0],apow);

Febpow = pow(FebT[0],apow);

Marpow = pow(MarT[0],apow);

Aprpow = pow(AprT[0],apow);

Maypow = pow(MayT[0],apow);

Junpow = pow(JunT[0],apow);

Julpow = pow(JulT[0],apow);

Augpow = pow(AugT[0],apow);

Seppow = pow(SepT[0],apow);

Octpow = pow(OctT[0],apow);

Novpow = pow(NovT[0],apow);

Decpow = pow(DecT[0],apow);

//PE Derivatives with respect to Annual Heat Index (Hy)

January_PE_dHy = term2 * Jan_L * Janpow * log(JanT[0]);

February_PE_dHy = term2 * Feb_L * Febpow * log(FebT[0]);

March_PE_dHy = term2 * Mar_L * Marpow * log(MarT[0]);

April_PE_dHy = term2 * Apr_L * Aprpow * log(AprT[0]);

May1_PE_dHy = term2 * May_L * Maypow * log(MayT[0]);

June_PE_dHy = term2 * Jun_L * Junpow * log(JunT[0]);
```

```
July_PE_dHy = term2 * Jul_L * Julpow * log(JulT[0]);
August_PE_dHy = term2 * Aug_L * Augpow * log(AugT[0]);
September_PE_dHy = term2 * Sep_L * Seppow * log(SepT[0]);
October_PE_dHy = term2 * Oct_L * Octpow * log(OctT[0]);
November_PE_dHy = term2 * Nov_L * Novpow * log(NovT[0]);
December_PE_dHy = term2 * Dec_L * Decpow * log(DecT[0]);
summation_PE_dHy = January_PE_dHy + February_PE_dHy + March_PE_dHy + April_PE_dHy
+ May1_PE_dHy + June_PE_dHy + July_PE_dHy + August_PE_dHy + September_PE_dHy +
October_PE_dHy + November_PE_dHy + December_PE_dHy;
PE_dHy = C1_dHy * summation_PE_dHy;
//PE Derivative with repsect to Temperature
January_PE_dt = pow((C1 * Jan_L * apow * pow(JanT[0],(apow-1))),2) * JanT[1];
February_PE_dt = pow((C1 * Feb_L * apow * pow(FebT[0],(apow-1))),2) * FebT[1];
March_PE_dt = pow((C1 * Mar_L * apow * pow(MarT[0],(apow-1))),2) * MarT[1];
April_PE_dt = pow((C1 * Apr_L * apow * pow(AprT[0],(apow-1))),2) * AprT[1];
May1_PE_dt = pow((C1 * May_L * apow * pow(MayT[0],(apow-1))),2) * MayT[1];
June_PE_dt = pow((C1 * Jun_L * apow * pow(JunT[0],(apow-1))),2) * JunT[1];
July_PE_dt = pow((C1 * Jul_L * apow * pow(JulT[0],(apow-1))),2) * JulT[1];
August_PE_dt = pow((C1 * Aug_L * apow * pow(AugT[0],(apow-1))),2) * AugT[1];
September_PE_dt = pow((C1 * Sep_L * apow * pow(SepT[0],(apow-1))),2) * SepT[1];
October_PE_dt = pow((C1 * Oct_L * apow * pow(OctT[0],(apow-1))),2) * OctT[1];
November_PE_dt = pow((C1 * Nov_L * apow * pow(NovT[0],(apow-1))),2) * NovT[1];
December_PE_dt = pow((C1 * Dec_L * apow * pow(DecT[0],(apow-1))),2) * DecT[1];
PE_dt = January_PE_dt + February_PE_dt + March_PE_dt + April_PE_dt + May1_PE_dt +
June_PE_dt + July_PE_dt + August_PE_dt + September_PE_dt + October_PE_dt +
November_PE_dt + December_PE_dt;
//Daylight Correction for PE
January_PE = Jan_L * pow(JanT[0],apow);
```

```
February_PE = Feb_L * pow(FebT[0],apow);
March_PE = Mar_L * pow(MarT[0],apow);
April_PE = Apr_L * pow(AprT[0],apow);
May1_PE = May_L * pow(MayT[0],apow);
June_PE = Jun_L * pow(JunT[0],apow);
July_PE = Jul_L * pow(JulT[0],apow);
August_PE = Aug_L * pow(AugT[0],apow);
September_PE = Sep_L * pow(SepT[0],apow);
October_PE = Oct_L * pow(OctT[0],apow);
November_PE = Nov_L * pow(NovT[0],apow);
December_PE = Dec_L * pow(DecT[0],apow);
summation_PE = January_PE + February_PE + March_PE + April_PE + May1_PE + June_PE +
July_PE + August_PE + September_PE + October_PE + November_PE + December_PE;
//PE statistical calculations
PE_mean = Co * pow((10/Hy_mean),apow)* summation_PE;
PE_var = (pow(PE_dHy,2) * Hy_var) + PE_dt;
PE_stdev = pow(PE_var,0.5);
//Thornwaite Moisture Index Mean and Variance
TMI_dP = 75/PE_mean;
TMI_dPE = (-75*P_mean)/pow(PE_mean,2);
TMI_mean = -65 + 75*(P_mean/PE_mean);
if(TMIconstraints == true)
{
//Constraints Per 1-40D Report
if(TMI_mean > 100)
TMI_mean = 100;}
TMI_var = pow(TMI_dP,2)*P_var + pow(TMI_dPE,2)*PE_var;
TMI_stdev = pow(TMI_var,0.5);
```

```
//Matric Suction Calculations

for (int layer_counter=0; layer_counter<Num_layer; layer_counter++)

{if(Layer_Type[layer_counter] == true)

{// Base Course Suction Parameters

if(P200_M[layer_counter] > 16.0)

P200_M[layer_counter] = 16.0;

//Powers of P200

P200_3 = pow(P200_M[layer_counter],3.0);P200_2 = pow(P200_M[layer_counter],2.0);

alpha_base = -0.0016*P200_3 + 0.1106*P200_2 - 0.1135*P200_M[layer_counter] + 3.8218;

beta_base = -0.0045*P200_3 + 0.1121*P200_2 - 0.3364*P200_M[layer_counter] + 3.2358;

gamma_base = 0.00003*P200_3 - 0.0009*P200_2 + 0.0061*P200_M[layer_counter] -0.0498;

// Taylor Series Derivatives for Base Course Materials

d_alpha_base = -0.1135 + 0.2212*P200_M[layer_counter] - 0.0048*P200_2;

d_beta_base = -0.3364 + 0.2242*P200_M[layer_counter] - 0.0135*P200_2;

d_gamma_base = 0.0061 - 0.0018*P200_M[layer_counter] + 0.00009*P200_2;

// Partial Derivative for Base Course

d_dP200 = d_alpha_base + exp(beta_base + (101.0 + TMI_mean)*(gamma_base))*(d_beta_base

+ (101.0 + TMI_mean)*(d_gamma_base));

d_dTMI = exp(beta_base + (gamma_base)*(101.0 + TMI_mean))*(gamma_base);

// If base course Material

suction_mean1 = alpha_base + exp(beta_base + gamma_base * ( TMI_mean + 101.0));

suction_var1 = pow(d_dP200,2.0)*P200_V[layer_counter] + pow(d_dTMI,2.0)*TMI_var;

}

else if(wPI_M[layer_counter] == 0 && layer_counter > 0)// Calcuclates the non-base with wPI or

P200

{if(P200_M[layer_counter] > 10.0)

{double beta_non1, gamma_non1, delta_non1;

beta_non1 = 2.56075*P200_M[layer_counter] + 393.4625;
```

```
gamma_non1 = 0.09625*P200_M[layer_counter] + 132.4875;
delta_non1 = 0.025*P200_M[layer_counter] + 14.75;
//Derivatives with with repsect
d_dP200 = 0.3*(0.025 + exp((beta_non1)/(TMI_mean + gamma_non1)) * (2.56075/(TMI_mean +
gamma_non1) - (0.09625*(beta_non1))/pow((TMI_mean + gamma_non1),2.0)));
d_TMI = -((0.3*exp((beta_non1)/(TMI_mean + gamma_non1))*(beta_non1))/pow((TMI_mean +
gamma_non1),2.0));
suction_mean1 = 0.3*(exp(beta_non1/(TMI_mean + gamma_non1))+delta_non1);
suction_var1 = (d_dP200 * d_dP200)*P200_V[layer_counter] + (d_TMI * d_TMI)*TMI_var;}
else if(P200_M[layer_counter] < 10.0)
{// Base Course Suction Parameters
P200_3 = pow(P200_M[layer_counter],3.0);
P200_2 = pow(P200_M[layer_counter],2.0);
alpha_base = -0.0016*P200_3 + 0.1106*P200_2 - 0.1135*P200_M[layer_counter] + 3.8218;
beta_base = -0.0045*P200_3 + 0.1121*P200_2 - 0.3364*P200_M[layer_counter] + 3.2358;
gamma_base = 0.00003*P200_3 - 0.0009*P200_2 + 0.0061*P200_M[layer_counter] -0.0498;
// Taylor Series Derivatives for Base Course Materials
d_alpha_base = -0.1135 + 0.2212*P200_M[layer_counter] - 0.0048*P200_2;
d_beta_base = -0.3364 + 0.2242*P200_M[layer_counter] - 0.0135*P200_2;
d_gamma_base = 0.0061 - 0.0018*P200_M[layer_counter] + 0.00009*P200_2;
// Partial Derivative for Base Course
d_dP200 = d_alpha_base + exp(beta_base + (101.0 + TMI_mean)*(gamma_base))*(d_beta_base
+ (101.0 + TMI_mean)*(d_gamma_base));
d_dTMI = exp(beta_base + (gamma_base)*(101.0 + TMI_mean))*(gamma_base);
// If base course Material
suction_mean1 = alpha_base + exp(beta_base + gamma_base * ( TMI_mean + 101.0));
suction_var1 = pow(d_dP200,2.0)*P200_V[layer_counter] + pow(d_dTMI,2.0)*TMI_var;
}}
```

```
else
{if(wPI_M[layer_counter] > 50.0)
wPI_M[layer_counter] = 50.0;
if(wPI_M[layer_counter] < 0.5)
wPI_M[layer_counter] = 0.5;
// Non-base Course Suction Parameters
wPI_3 = pow(wPI_M[layer_counter],3.0);wPI_2 = pow(wPI_M[layer_counter],2.0);
beta_non = 0.006235897* wPI_3 - 0.779833377* wPI_2 + 36.78648521*wPI_M[layer_counter] +
501.9511878;
gamma_non = 0.000395003* wPI_3 - 0.040423118* wPI_2 +
1.454065726*wPI_M[layer_counter] + 136.4775219;
delta_non = -0.019883827* wPI_2 + 1.273583098*wPI_M[layer_counter] + 13.91243841;
// Talyor Series derivatives for non-base layer
d_gamma_non = 1.45407 - 0.0808462*wPI_M[layer_counter] + 0.00118501*wPI_2;
d_beta_non = 36.7865 - 1.55967*wPI_M[layer_counter] + 0.0187077*wPI_2;
d_delta_non = 1.27358 - 0.0397677*wPI_M[layer_counter];
// Partial Derivative for Non-Base Course
d_wPI = 0.3*(d_delta_non + exp((beta_non)/(TMI_mean + gamma_non)) *
((d_beta_non)/(TMI_mean + gamma_non) - (d_gamma_non * beta_non)/pow((TMI_mean +
gamma_non),2.0)));
d_TMI = -((0.3*exp((beta_non)/( TMI_mean + gamma_non))*(beta_non))/pow((TMI_mean +
gamma_non),2.0));
// If non-base course Material
suction_mean1 = 0.3*(exp(beta_non/(TMI_mean + gamma_non))+ delta_non);
suction_var1 = (d_wPI * d_wPI)*wPI_V[layer_counter] + (d_TMI * d_TMI)*TMI_var;
}
suction_stdev1 = pow(suction_var1,0.5);
suction_skew1 = 0;suction_kurt1 = 0;suction_min1 = 0;suction_max1 = 0;
```

```
//Stores Each Layer's statistical Suction Information
Suction_Mean[layer_counter] = suction_mean1;Suction_Variance[layer_counter] = suction_var1;
Suction_Stdev[layer_counter] = suction_stdev1;Suction_Skew[layer_counter] = suction_skew1;
Suction_Kurt[layer_counter] = suction_kurt1;Suction_Minimum[layer_counter] = suction_min1;
Suction_Maximum[layer_counter] = suction_max1;
// Optimum Saturation and Degree of Saturation information
d_theata_water = 0.0;d_theata_sat = 0.0;d_Suction_theata_water = 0.0;
d_dry_gamma_theata_water = 0.0;  d_Gs_theata_water = 0.0;d_wPI_theata_water =0.0;
theata_water_var = 0.0;d_opt_moisture_opt_sat = 0.0;d_gamma_dry_opt_sat = 0.0;
d_Gs_opt_sat = 0.0;d_cf_theata_water = 0.0;d_bf_theata_water = 0.0;d_af_theata_water = 0.0;
d_theatasat = 0.0;
if(level[layer_counter] == true)
{residual = SWCC_H[layer_counter];
//Saturated Volumetric water content
theata_sat = (1.0 -
(gamma_dry_M[layer_counter]/(Gs_mean[layer_counter]*gamma_water)))*100;
theata_sat_var = pow((-
100.0/(gamma_water*Gs_mean[layer_counter])),2.0)*gamma_dry_V[layer_counter] +
pow(((100*gamma_dry_M[layer_counter])/pow((gamma_water*Gs_mean[layer_counter]),2.0)),2
.0)*Gs_var[layer_counter];
// Volumetric Water Content
af = SWCC_AM[layer_counter];bf = SWCC_BM[layer_counter];cf =
SWCC_CM[layer_counter];
// SWCC information
C_h = 1-(log(1+(Suction_Mean[layer_counter]/residual))/(log(1000000.0/residual)));
theata_water =
C_h*(theata_sat/pow(log(pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0)),cf));
// Derivative of SWCC with Respect to...
```

```
d_Suction_theata_water = -((1/residual)*pow(log(pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0)),cf))/(log(1000000.0/residual)*(1+(Suction_Mean[layer_counter]/residual)))+theata_water*((cf*pow((Suction_Mean[layer_counter]/af),bf)*((bf*af*(1/af))/Suction_Mean[layer_counter]))/((pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0))*log(pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0))));
d_theatasat = C_h*(1/pow(log(pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0)),cf));
d_af_theata_water = C_h*theata_sat*(bf*cf*pow((Suction_Mean[layer_counter]/af),bf))/(pow(log(pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0)),cf+1)*(af*pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0)*af));
d_bf_theata_water = C_h*theata_sat*(cf*pow((Suction_Mean[layer_counter]/af),bf)*log(Suction_Mean[layer_counter]/af))/(pow(log(pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0)),cf+1)*(pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0)));
d_cf_theata_water = C_h*theata_sat*(log(log(pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0)))/pow(log(pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0)),cf));
theata_water_var = pow(d_theatasat,2.0)*theata_sat_var+pow(d_Suction_theata_water,2.0)*Suction_Variance[layer_counter]+ pow(d_af_theata_water,2.0)*SWCC_AV[layer_counter]+ pow(d_bf_theata_water,2.0)*SWCC_BV[layer_counter]+ pow(d_cf_theata_water,2.0)*SWCC_CV[layer_counter];//+pow(d_dry_gamma_theata_water,2.0)*gamma_dry_V[layer_counter]+pow(d_Gs_theata_water,2.0)*Gs_var[layer_counter]
degree_sat_mean1 = (theata_water / theata_sat)*100.0;
degree_sat_var1 = pow((-(100*theata_water)/pow(theata_sat,2.0)),2.0)*theata_sat_var + pow((100/theata_sat),2.0)*theata_water_var;
opt_sat_mean1 = wopt_M[layer_counter]/((gamma_water/gamma_dry_M[layer_counter])-(1/Gs_mean[layer_counter]));
```

```
//derivatives with respect to ...
d_opt_moisture_opt_sat = pow((1/((gamma_water/gamma_dry_M[layer_counter])-
(1/Gs_mean[layer_counter]))),2.0)*wopt_V[layer_counter];
d_gamma_dry_opt_sat =
pow((wopt_M[layer_counter]*gamma_water)/(pow(((gamma_water/gamma_dry_M[layer_counte
r])-
(1/Gs_mean[layer_counter])),2.0)*pow(gamma_dry_M[layer_counter],2.0)),2.0)*gamma_dry_V[l
ayer_counter];
d_Gs_opt_sat = pow(-
(wopt_M[layer_counter])/(pow(((gamma_water/gamma_dry_M[layer_counter])-
(1/Gs_mean[layer_counter])),2.0)*pow(Gs_mean[layer_counter],2.0)),2.0)*Gs_var[layer_counter]
;
opt_sat_var1 = d_opt_moisture_opt_sat + d_gamma_dry_opt_sat + d_Gs_opt_sat;
theata_sat_stdev = pow(theata_sat_var,0.5);
theata_water_stdev = pow(theata_water_var,0.5);}
else // Level 2 and 3
{if(Names[layer_counter] == "A-1-a")
residual = 100;
else if(Names[layer_counter] == "A-1-b")
residual = 100;
else if(Names[layer_counter] == "A-2-4")
residual = 100;
else if(Names[layer_counter] == "A-2-5")
residual = 100;
else if(Names[layer_counter] == "A-2-6")
residual = 100;
else if(Names[layer_counter] == "A-2-7")
residual = 100;
```

```
else if(Names[layer_counter] == "A-3")
residual = 100;
else
residual = 500;
if(wPI_M[layer_counter]==0.0) {
opt_moisture_mean = -120.14-0.06766*P15_M[layer_counter]+3.7269*D60_M[layer_counter]-
0.167*P40_M[layer_counter]+0.117*P60_M[layer_counter]+142.53*exp(-
0.0389*D60_M[layer_counter]);
opt_moisture_var =
0.0045914176*P15_V[layer_counter]+0.027889*P40_V[layer_counter]+0.013689*P60_V[layer_
counter]+pow((3.7269-5.54403*exp(-
0.0389*D60_M[layer_counter])),2.0)*D60_V[layer_counter];
opt_sat_mean1 = -100.17+1.4991*P20_M[layer_counter]+0.56155*P10_M[layer_counter]-
0.36755*P05_M[layer_counter];
opt_sat_var1 =
2.24730081*P20_V[layer_counter]+0.3153384025*P10_V[layer_counter]+0.1350930025*P05_V
[layer_counter];
gamma_dry_mean =
(Gs_mean[layer_counter]*gamma_water)/(1+((opt_moisture_mean*Gs_mean[layer_counter])/opt
_sat_mean1));
if(Layer_Compaction[layer_counter] == false)
gamma_dry_mean = 1.0156*gamma_dry_mean - 2.464;
//derivatives with repsect to ...
d_Gs_gamma =
pow(((gamma_water*(1+((opt_moisture_mean*Gs_mean[layer_counter])/opt_sat_mean1))-
gamma_water*Gs_mean[layer_counter]*(opt_moisture_mean/opt_sat_mean1))/pow((1+((opt_mo
isture_mean*Gs_mean[layer_counter])/opt_sat_mean1)),2.0)),2.0);
```

```
d_wopt_gamma =
pow(((gamma_water*(pow(Gs_mean[layer_counter],2.0)/opt_sat_mean1))/pow((1+((opt_moisture_mean*Gs_mean[layer_counter])/opt_sat_mean1)),2.0)),2.0);
d_sopt_gamma =
pow(((gamma_water*opt_moisture_mean*(pow(Gs_mean[layer_counter],2.0)/pow(opt_sat_mean1,2.0)))/pow((1+((opt_moisture_mean*Gs_mean[layer_counter])/opt_sat_mean1)),2.0)),2.0);
gamma_dry_var =
d_Gs_gamma*Gs_var[layer_counter]+d_wopt_gamma*opt_moisture_var+d_sopt_gamma*opt_sat_var1;
gamma_dry_stdev = pow(gamma_dry_var,0.5);}
else
{PI_adj_mean = exp((P200_M[layer_counter]+42.13)/33.94);
if(PI_adj_mean < PI_M[layer_counter])
{wPI_adj_mean = (PI_adj_mean * P200_M[layer_counter])/100;
wPI_adj_var =
pow(((PI_adj_mean/100)+(P200_M[layer_counter]/3394.0)*PI_adj_mean),2.0)*P200_V[layer_counter];
}
else{wPI_adj_mean = wPI_M[layer_counter]; wPI_adj_var = wPI_V[layer_counter];}
if(wPI_adj_mean < 1.0)
wPI_adj_mean = 1.0;
opt_moisture_mean = 8.3932*pow(wPI_adj_mean,0.3075);
opt_moisture_var = pow((2.58091*pow(wPI_adj_mean,-0.6925)),2.0)*wPI_adj_var;
opt_moisture_stdev = pow(opt_moisture_var,0.5);
gamma_dry_mean = 142.115 - 1.959*opt_moisture_mean;
if(Layer_Compaction[layer_counter] == false)
gamma_dry_mean = 1.0156*gamma_dry_mean - 2.464;
gamma_dry_var = 3.837681*opt_moisture_var;
```

```
gamma_dry_stdev = pow(gamma_dry_var,0.5);
opt_sat_mean1 = opt_moisture_mean/((gamma_water/gamma_dry_mean)-
(1/Gs_mean[layer_counter]));
//derivatives with respect to ...
d_opt_moisture_opt_sat = pow((1/((gamma_water/gamma_dry_mean)-
(1/Gs_mean[layer_counter]))),2.0)*opt_moisture_var;
d_gamma_dry_opt_sat =
pow((opt_moisture_mean*gamma_water)/(pow(((gamma_water/gamma_dry_mean)-
(1/Gs_mean[layer_counter])),2.0)*pow(gamma_dry_mean,2.0)),2.0)*gamma_dry_var;
d_Gs_opt_sat = pow(-(opt_moisture_mean)/(pow(((gamma_water/gamma_dry_mean)-
(1/Gs_mean[layer_counter])),2.0)*pow(Gs_mean[layer_counter],2.0)),2.0)*Gs_var[layer_counter]
;
opt_sat_var1 = d_opt_moisture_opt_sat + d_gamma_dry_opt_sat + d_Gs_opt_sat;}
theata_sat = (1.0 - (gamma_dry_mean/(Gs_mean[layer_counter]*gamma_water)))*100.0;
theata_sat_var = pow((-100.0/(gamma_water*Gs_mean[layer_counter])),2.0)*gamma_dry_var +
pow(((100*gamma_dry_mean)/pow((gamma_water*Gs_mean[layer_counter]),2.0)),2.0)*Gs_var[l
ayer_counter];
if(wPI_M[layer_counter]<2.0)
{if(P200_M[layer_counter]<2.0)//1-40D Constraint{P200_M[layer_counter] = 2.0;}
theata_water = 4.0 + 1.5*pow(P200_M[layer_counter],0.6994) + 0.03*TMI_mean;
theata_water_var = pow((1.0491*pow(P200_M[layer_counter],-
0.3006)),2.0)*P200_V[layer_counter] + 0.009*TMI_var;
if(theata_water > 40.0)//1-40D Constraint{
theata_water = 40 + 0.11*(P200_M[layer_counter] - 53.0); theata_water_var =
0.0121*P200_V[layer_counter];}
if(theata_water > theata_sat)//1-40D constraint
{theata_water = theata_sat;}}
else{
```

```
// SWCC information
af = 32.835*log(wPI_M[layer_counter])+32.438;
bf = 1.421*pow(wPI_M[layer_counter],-0.3185);
cf = 0.2154*log(wPI_M[layer_counter])-0.07145;
double cf1 = -0.2154*log(wPI_M[layer_counter])+0.07145;
if(af < 5.0)
af = 5.0;
if(cf1 < 0.01)
cf1 = 0.03;
SWCC_AM[layer_counter] = af;
SWCC_AV[layer_counter] = pow(32.835/wPI_M[layer_counter],2.0)*wPI_V[layer_counter];
SWCC_AS[layer_counter] =
pow(pow(32.835/wPI_M[layer_counter],2.0)*wPI_V[layer_counter],0.5);
SWCC_BM[layer_counter] = bf;
SWCC_BV[layer_counter] =
pow(0.452589/pow(wPI_M[layer_counter],1.3185),2.0)*wPI_V[layer_counter];
SWCC_BS[layer_counter] =
pow((pow(0.452589/pow(wPI_M[layer_counter],1.3185),2.0)*wPI_V[layer_counter]),0.5);
SWCC_CM[layer_counter] = cf;
SWCC_CV[layer_counter] = pow(0.2154/wPI_M[layer_counter],2.0)*wPI_V[layer_counter];
SWCC_CS[layer_counter] =
pow(pow(0.2154/wPI_M[layer_counter],2.0)*wPI_V[layer_counter],0.5);
C_h = 1-(log(1+(Suction_Mean[layer_counter]/residual))/(log(1000000.0/residual)));
theata_water =
C_h*(theata_sat/pow(log(pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0)),cf1));
// Derivative of SWCC with Respect to...
d_Suction_theata_water = -
((1/residual)*pow(log(pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0)),cf))/(log(1000000.0/r
```

```
esidual)*(1+(Suction_Mean[layer_counter]/residual)))+theata_water*((cf*pow((Suction_Mean[layer_counter]/af),bf)*((bf*af*(1/af))/Suction_Mean[layer_counter]))/((pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0))*log(pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0))));
d_theatasat = C_h*(1.0/pow(log(pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0)),cf1));
d_wPI_theata_water =
C_h*theata_sat*pow(log(pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0)),cf)*((cf*pow((Suction_Mean[layer_counter]/af),bf)*((1.421*af*(-(32.835*Suction_Mean[layer_counter])/(wPI_M[layer_counter]*pow(af,2.0)))))/(Suction_Mean[layer_counter]*pow(wPI_M[layer_counter],0.3185)-(0.452589*log(Suction_Mean[layer_counter]/af))/pow(wPI_M[layer_counter],1.3185)))/((pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0))*log(pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0)))+(0.2154*log(log(pow((Suction_Mean[layer_counter]/af),bf)+exp(1.0))))/wPI_M[layer_counter]));
theata_water_var = pow(d_theatasat,2.0)*theata_sat_var +
pow(d_Suction_theata_water,2.0)*Suction_Variance[layer_counter]+
pow(d_wPI_theata_water,2.0)*wPI_V[layer_counter];//+pow(d_dry_gamma_theata_water,2.0)*gamma_dry_var+pow(d_Gs_theata_water,2.0)*Gs_var[layer_counter]}
if(theata_water > theata_sat)//1-40D constraint
{theata_water = theata_sat;}
degree_sat_mean1 = (theata_water / theata_sat)*100;
degree_sat_var1 = pow((-(100*theata_water)/pow(theata_sat,2.0)),2.0)*theata_sat_var +
pow((100/theata_sat),2.0)*theata_water_var;
theata_sat_stdev = pow(theata_sat_var,0.5);
theata_water_stdev = pow(theata_water_var,0.5);
//Optimum Moisture Content Storage
wopt_M[layer_counter] = opt_moisture_mean;wopt_V[layer_counter] = opt_moisture_var;
wopt_S[layer_counter] = opt_moisture_stdev;
//Dry Unit Weight Storage
```

```
gamma_dry_M[layer_counter] = gamma_dry_mean;gamma_dry_V[layer_counter] =
gamma_dry_var;gamma_dry_S[layer_counter] = gamma_dry_stdev;}
Theata_SM[layer_counter] = theata_sat;Theata_SV[layer_counter] =
theata_sat_var;Theata_SS[layer_counter] = theata_sat_stdev;
//Volumetric Water Content Storage
Theata_WM[layer_counter] = theata_water;Theata_WV[layer_counter] = theata_water_var;
Theata_WS[layer_counter] = theata_water_stdev;degree_sat_stdev1 = pow(degree_sat_var1,0.5);
degree_sat_skew1 = 0.0; degree_sat_kurt1 = 0.0; degree_sat_min1 = 0.0;degree_sat_max1 = 0.0;
degree_sat_mean[layer_counter] = degree_sat_mean1; degree_sat_var[layer_counter] =
degree_sat_var1;degree_sat_stdev[layer_counter] = degree_sat_stdev1;
degree_sat_skew[layer_counter] = degree_sat_skew1; degree_sat_kurt[layer_counter] =
degree_sat_kurt1; degree_sat_Min[layer_counter] = degree_sat_min1;
degree_sat_Max[layer_counter] = degree_sat_max1;
//Optimum Saturation Storage
opt_sat_stdev1 = pow(opt_sat_var1,0.5);opt_sat_skew1 = 0.0; opt_sat_kurt1 = 0.0;opt_sat_min1 =
0.0;
opt_sat_max1 = 0.0; opt_sat_mean[layer_counter] = opt_sat_mean1;opt_sat_var[layer_counter] =
opt_sat_var1; opt_sat_stdev[layer_counter] = opt_sat_stdev1; opt_sat_skew[layer_counter] =
opt_sat_skew1; opt_sat_kurt[layer_counter] = opt_sat_kurt1;opt_sat_min[layer_counter] =
opt_sat_min1;opt_sat_max[layer_counter] = opt_sat_max1;
//Fenv & Mropt information
d_wPI_Fenv = 0.0; d_Degree_Sat_Fenv = 0.0; d_Optimum_Sat_Fenv = 0.0; d_theata_water =
0.0;d_Fenv_term1 = 0.0;  d_Fenv_term2 = 0.0; d_Fenv_term3 = 0.0;
Fenv_term1 = (-0.6-1.87194*exp(-wPI_M[layer_counter]));
Fenv_term2 = 0.8+0.08*pow(wPI_M[layer_counter],0.5);
Fenv_term3 = pow((11.96518-10.19111*exp(-wPI_M[layer_counter])),0.5);
Fenv_term4 = ((degree_sat_mean[layer_counter]-opt_sat_mean[layer_counter])/100);
Fenv_denom = 1+ exp(log(-Fenv_term2/pow(Fenv_term1,-1.0))+ Fenv_term3*Fenv_term4);
```

```
powerproduct = 1.002*(pow(Fenv_term1,-1.0)+(Fenv_term2-pow(Fenv_term1,-
1.0))/Fenv_denom);
Fenv_mean1 = pow(10,powerproduct);
//derivatives with respect to ....
d_Fenv_term1 = -1.87194*exp(-wPI_M[layer_counter]);
d_Fenv_term2 = 0.04*pow(wPI_M[layer_counter],-0.5);
d_Fenv_term3 = -5.09556*exp(-wPI_M[layer_counter]);
d_wPI_Fenv = 1.002*log(10.0)*Fenv_mean1*(((d_Fenv_term2-d_Fenv_term1)/Fenv_denom)-
((Fenv_term2-Fenv_term1)*((((exp(log(-Fenv_term2/pow(Fenv_term1,-1.0))+
Fenv_term3*Fenv_term4-
wPI_M[layer_counter]))*10.19111*Fenv_term4)/(2*Fenv_term3))+(d_Fenv_term2*Fenv_term1*
exp(Fenv_term3*Fenv_term4))+(1.87194*Fenv_term2*exp(Fenv_term3*Fenv_term4-
wPI_M[layer_counter]))))/pow(Fenv_denom,2.0)+(d_Fenv_term1/pow(Fenv_term1,2.0)));
d_Degree_Sat_Fenv = (-1.002*log(10.0)*pow(10,-2.0)*Fenv_mean1*((Fenv_denom-
1)*Fenv_term3*(Fenv_term2-pow(Fenv_term1,-1.0)))))/pow(Fenv_denom,2.0);
d_Optimum_Sat_Fenv = (1.002*log(10.0)*pow(10,-2.0)*Fenv_mean1*((Fenv_denom-
1)*Fenv_term3*(Fenv_term2-pow(Fenv_term1,-1.0)))))/pow(Fenv_denom,2.0);
Fenv_var1 =
pow(d_wPI_Fenv,2.0)*wPI_V[layer_counter]+pow(d_Degree_Sat_Fenv,2.0)*degree_sat_var[lay
er_counter]+pow(d_Optimum_Sat_Fenv,2.0)*opt_sat_var[layer_counter];
Fenv_stdev1 = pow(Fenv_var1,0.5);
Fenv_skew1 = 0.0;Fenv_kurt1 = 0.0;Fenv_min1 = 0.0;Fenv_max1 = 0.0;
//Fenv Storage
Fenv_Mean[layer_counter] = Fenv_mean1;
Fenv_Var[layer_counter] = Fenv_var1;
Fenv_Stdev[layer_counter] = Fenv_stdev1;
Fenv_Skew[layer_counter] = Fenv_skew1;
Fenv_Kurt[layer_counter] = Fenv_kurt1;
```

```
Fenv_Min[layer_counter] = Fenv_min1;

Fenv_Max[layer_counter] = Fenv_max1;

//Mropt Information

if((level[layer_counter] == true) && (Level_a[layer_counter] == "Level_1"))

{Mropt_mean1 = Mropt_Mean[layer_counter];Mropt_var1 = Mropt_Var[layer_counter];

Mropt_stdev1 = Mropt_Stdev[layer_counter];Mropt_skew1 = 0;Mropt_kurt1 = 0;

Mropt_min1 = Mropt_Min[layer_counter];Mropt_max1 = Mropt_Max[layer_counter];

Mropt_alpha1 = Mropt_Alpha[layer_counter];Mropt_beta1 = Mropt_Beta[layer_counter];}

else if(Level_a[layer_counter] == "Level_1a")

{Mropt_mean1 = (2555*pow(CBR_M[layer_counter],0.64))*(2.11-2.78*pow(10,-

5.0)*(2555*pow(CBR_M[layer_counter],0.64)));

Mropt_var1 = 2.11-0.0000556*CBR_M[layer_counter];}

else

{if(wPI_M[layer_counter] == 0.0){

Mropt_mean1 = 2555*pow(28.09*pow(D60_M[layer_counter],0.358),0.64)*(2.11-2.78*pow(10,-

5.0)*2555*pow(28.09*pow(D60_M[layer_counter],0.358),0.64));

Mropt_var1 = pow(((10442.6/pow(D60_M[layer_counter],0.77088))-

(5943.82/pow(D60_M[layer_counter],0.51476))),2.0)*D60_V[layer_counter];

CBR_mean = 28.09*pow(D60_M[layer_counter],0.358);

CBR_var = pow(10.0562*pow(D60_M[layer_counter],-0.642),2.0)*D60_V[layer_counter];}

else

{Mropt_mean1 = 2555*pow((75/(1+0.728*wPI_M[layer_counter])),0.64)*(2.11-2.78*pow(10,-

5.0)*2555*pow((75/(1+0.728*wPI_M[layer_counter])),0.64));

Mropt_var1 = pow((42486.1*pow((1/(1+0.728*wPI_M[layer_counter])),2.28)-

39812.9*pow((1/(1+0.728*wPI_M[layer_counter])),1.64)),2.0)*wPI_V[layer_counter];

CBR_mean = 75/(1+0.728*wPI_M[layer_counter]);

CBR_var = pow(-54.6/pow((1+0.728*wPI_M[layer_counter]),2.0),2.0)*wPI_V[layer_counter];}}

Mropt_stdev1 = pow(Mropt_var1,0.5);Mropt_skew1 = 0.0;Mropt_kurt1 = 0.0;Mropt_min1 = 0.0;
```

```
Mropt_max1 = 0.0;Mropt_alpha1 = 0.0;Mropt_beta1 = 0.0;CBR_stdev = pow(CBR_var,0.5);
CBR_skew = 0.0;CBR_kurt = 0.0;CBR_min = 0.0;CBR_max = 0.0;Fenv_Check = 0.0;
//Mropt Storage
Mropt_Mean[layer_counter] = Mropt_mean1;Mropt_Var[layer_counter] = Mropt_var1;
Mropt_Stdev[layer_counter] = Mropt_stdev1;Mropt_Skew[layer_counter] = Mropt_skew1;
Mropt_Kurt[layer_counter] = Mropt_kurt1; Mropt_Min[layer_counter] = Mropt_min1;
Mropt_Max[layer_counter] = Mropt_max1;
//CBR Storage
CBR_M[layer_counter] = CBR_mean; CBR_V[layer_counter] = CBR_var;CBR_S[layer_counter]
= CBR_stdev;CBR_Skew[layer_counter] = CBR_skew;CBR_Kurt[layer_counter] = CBR_kurt;
CBR_Min[layer_counter] = CBR_min;CBR_Max[layer_counter] = CBR_max;
// Mr equilibrium
if(Fenv_Mean[layer_counter] <= 0.20)
{Fenv_Check = 0.20;}
else
{Fenv_Check = Fenv_Mean[layer_counter];}
Mreq_mean1 = log(Mropt_Mean[layer_counter]*Fenv_Check)/log(10.0);
Mreq_var1 = pow(1/Mropt_Mean[layer_counter],2.0)*Mropt_Var[layer_counter] +
pow(1/Fenv_Mean[layer_counter],2.0)*Fenv_Var[layer_counter];
Mreq_stdev1 = pow(Mreq_var1,0.5);
Mreq_skew1 = 0.0;Mreq_kurt1 = 0.0;Mreq_min1 = 0.0;Mreq_max1 = 0.0;
//Mr equilibrium storage
Mreq_Mean[layer_counter] = Mreq_mean1;Mreq_Var[layer_counter] =
Mreq_var1;Mreq_Stdev[layer_counter] = Mreq_stdev1;
Mreq_Skew[layer_counter] = Mreq_skew1; Mreq_Kurt[layer_counter] = Mreq_kurt1;
Mreq_Min[layer_counter] = Mreq_min1;Mreq_Max[layer_counter] = Mreq_max1;}
cout << "Taylor Series Solution" << endl; }
else if (Check == 1){
```

```
// Rosenblueth 2 Point Solution
double Rosenblueth2P[4096], Rosenblueth2Temp[4096],
Rosenblueth2PE[8192],RosenbluethTMI[9];
double January_R, February_R, March_R, April_R, May1_R, June_R, July_R, August_R,
September_R, October_R, November_R, December_R;
double Hy_PER, January_PER, February_PER, March_PER, April_PER, May1_PER, June_PER,
July_PER, August_PER, September_PER, October_PER, November_PER, December_PER;
double suction_TMI_Num, suction_P200_Num, suction_wPI_Num, summation_suction_skew,
summation_suction_kurt,summation_suction_var;
double Rosenblueth2Suction[72][4], P200_Rosen, TMI_Rosen, wPI_Rosen, suction, suction_sq,
summation_suction, summation_suction_sq, suction_sq_mean;
double R2_theata_sat[72][4], Rosen_gamma_dry, Rosen_Gs, theata_sat_sq,
summation_theata_sat_sq, summation_theata_sat,theata_sat_sq_mean, R2_gamma_dry1, R2_Gs;
double R2_theata_water[72][4], Rosen_theata_P200, Rosen_theata_TMI, Rosen_theata_wPI,
Rosen_theata_Suction, theata_water_sq, summation_theata_water_sq, summation_theata_water,
theata_water_sq_mean, R2_P200_theata_water, R2_TMI_theata_water,  R2_wPI_theata_water,
R2_Suction_theata_water;
double R2_degree_sat[72][4], Rosen_theata_sat, Rosen_theata_water, degree_sat_sq,
summation_degree_sat, summation_degree_sat_sq, degree_sat_sq_mean, R2_theata_sat_dsat,
R2_theata_water_dsat, summation_degree_sat_skew, summation_degree_sat_kurt;
double R2_opt_sat[72][8], Rosen_opt_wopt, Rosen_opt_gamma, Rosen_opt_Gs, Rosen_opt_P20,
Rosen_opt_P10, Rosen_opt_P05, opt_sat_sq , summation_opt_sat, summation_opt_sat_sq,
opt_sat_sq_mean, R2_P20, R2_P10, R2_P05, R2_opt_wopt, R2_opt_gamma, R2_opt_Gs,
summation_opt_sat_skew, summation_opt_sat_kurt;
double R2_gamma_dry[72][8], Rosen_gamma_wopt, Rosen_gamma_Gs, Rosen_gamma_Sopt,
summation_gamma_dry, summation_gamma_dry_sq, gamma_dry_sq, gamma_dry_sq_mean,
R2_gamma_wopt, R2_gamma_Gs, R2_gamma_Sopt;
```

```
double R2_wopt[72][16], Rosen_wopt_wPIadj, Rosen_wopt_P15, Rosen_wopt_P40,
Rosen_wopt_P60, Rosen_wopt_D60, summation_wopt, summation_wopt_sq, wopt_sq,
wopt_sq_mean,R2_wopt_P15, R2_wopt_P40, R2_wopt_P60, R2_wopt_D60;
double R2_PIadj[72][2], Rosen_PIadj_P200, PIadj_sq, summation_PIadj, summation_PIadj_sq,
PIadj_sq_mean, R2_PIadj_P200,R2_theata_sat_water,Rosen_theata_sat_water;
double R2_wPIadj[72][4], Rosen_wPIadj_PIadj, Rosen_wPIadj_P200, wPIadj_sq,
summation_wPIadj, summation_wPIadj_sq, wPIadj_sq_mean, R2_wPIadj_PIadj,
R2_wPIadj_P200, R2_wPI_adj;
double R2_Fenv[72][8], Rosen_Fenv_wPI, Rosen_Fenv_degree_sat, Rosen_Fenv_opt_sat,
summation_Fenv, summation_Fenv_sq, Fenv_sq, Fenv_sq_mean, summation_Fenv_kurt,
summation_Fenv_skew, R2_Fenv_wPI, R2_Fenv_dsat, R2_Fenv_osat;
double R2_Mropt[72][2], Rosen_Mropt_CBR, Rosen_Mropt_D60, Rosen_Mropt_wPI, Mropt_sq,
Mropt_sq_mean, summation_Mropt, summation_Mropt_sq, summation_Mropt_kurt,
summation_Mropt_skew, R2_Mropt_CBR, R2_Mropt_D60, R2_Mropt_wPI;
double R2_Mreq[72][4], Rosen_Mreq_Fenv, Rosen_Mreq_Mropt, Mreq_sq, Mreq_sq_mean,
summation_Mreq, summation_Mreq_sq, summation_Mreq_kurt, summation_Mreq_skew,
R2_Mreq_Fenv, R2_Mreq_Mropt;
double R2_CBR[72][2], summation_CBR, summation_CBR_sq, CBR_sq, CBR_sq_mean, CBR1,
Rosen_theata_af, Rosen_theata_bf, Rosen_theata_cf, R2_sat_theata_water;
double wopt_var, wopt_stdev, wopt_min, wopt_max, summation_wopt_skew,
summation_wopt_kurt, theata_sat_min, theata_sat_max, summation_theata_sat_skew,
summation_theata_sat_kurt;
double theata_water_min, theata_water_max;
bool checker;
double Rosenblueth1[72][3][9];
double mean_a, mean_b, mean_c;
double summation_a, summation_b, summation_c, summation_a_sq, summation_b_sq,
summation_c_sq;
```

```
double var_a, var_b, var_c, stdev_a, stdev_b, stdev_c, min_a, min_b, min_c, max_a, max_b,
max_c;
for(int i=0; i<72; i++){for(int j=0; j<3; j++){for(int k=0; k<9; k++){Rosenblueth1[i][j][k] =
0.0;}}}
//Variable Initialization
suction = 0.0;suction_sq = 0.0;summation_suction = 0.0;summation_suction_sq = 0.0;
summation_suction_skew = 0.0; summation_suction_kurt = 0.0;summation_suction_var =
0.0;P_skew = 0;summation_P_skew =0;P_kurt = 0;summation_P_kurt = 0;Hy_skew = 0;
summation_Hy_skew = 0;Hy_kurt = 0;summation_Hy_kurt = 0;PE_skew =
0;summation_PE_skew = 0; PE_kurt = 0;summation_PE_kurt = 0;TMI_skew =
0;summation_TMI_skew = 0;TMI_kurt = 0;summation_TMI_kurt = 0;Jan_P = 1;Feb_P =
1;Mar_P = 1;Apr_P = 1;May_P = 1;Jun_P = 1;Jul_P = 1;Aug_P = 1;Sep_P = 1;Oct_P = 1;Nov_P
= 1;Dec_P = 1;summation_Pone = 0;summation_Pone_sq = 0;Pone = 0;Pone_sq = 0;January_R =
0;February_R = 0;March_R = 0;April_R = 0;May1_R = 0;June_R = 0;July_R = 0; August_R =
0;September_R = 0;October_R = 0;November_R = 0;December_R = 0;Hy_PER = 0;January_PER
= 0;February_PER = 0;March_PER = 0;April_PER = 0;May1_PER = 0;June_PER = 0;July_PER
= 0;
August_PER = 0;September_PER = 0;October_PER = 0;November_PER = 0;December_PER = 0;
Jan_T = 1;Feb_T = 1;Mar_T = 1;Apr_T = 1;May_T = 1;Jun_T = 1;Jul_T = 1;Aug_T = 1;
Sep_T 1= 1;Oct_T = 1;Nov_T = 1;Dec_T = 1;summation_Hy = 0;summation_Hy_sq = 0;
Hy = 0;Hy_sq = 0;Hy_PE = 1;Jan_PE = 1;Feb_PE = 1;Mar_PE = 1;Apr_PE = 1;May_PE = 1;
Jun_PE = 1; Jul_PE = 1;Aug_PE = 1;Sep_PE = 1;Oct_PE = 1;Nov_PE = 1;Dec_PE = 1;
summation_PE = 0; summation_PE_sq = 0;PE = 0;PE_sq = 0;TMI_Pi = 1;TMI_PEi = 1;
summation_TMI = 0;TMI = 0;summation_TMI_sq = 0;TMI_mean = 0;TMI_var = 0;TMI_stdev =
0;CBR_Summation = 0;
// Precipitation Mean, Variance, Skewness, and Kurtosis Calculations
for (int i=1; i<=4096;i++){
January_P = (JanP[0] + (Jan_P * JanP[2]));
```

```
if (January_P < 0)
January_P = 0;
February_P = (FebP[0] + (Feb_P * FebP[2]));
if(February_P < 0)
February_P = 0;
March_P = (MarP[0] + (Mar_P * MarP[2]));
if (March_P < 0)
March_P = 0;
April_P = (AprP[0] + (Apr_P * AprP[2]));
if(April_P < 0)
April_P = 0;
May1_P = (MayP[0] + (May_P * MayP[2]));
if(May1_P < 0)
May1_P = 0;
June_P = (JunP[0] + (Jun_P * JunP[2]));
if(June_P < 0)
June_P = 0;
July_P = (JulP[0] + (Jul_P * JulP[2]));
if(July_P < 0)
July_P = 0;
August_P = (AugP[0] + (Aug_P * AugP[2]));
if(August_P < 0)
August_P = 0;
September_P = (SepP[0] + (Sep_P * SepP[2]));
if(September_P < 0)
September_P = 0;
October_P = (OctP[0] + (Oct_P * OctP[2]));
if(October_P < 0)
```

```
October_P = 0;

November_P = (NovP[0] + (Nov_P * NovP[2]));

if(November_P < 0)

November_P = 0;

December_P = (DecP[0] + (Dec_P * DecP[2]));

if(December_P < 0)

December_P = 0;

Pone = January_P + February_P + March_P + April_P + May1_P + June_P + July_P + August_P

+ September_P + October_P + November_P + December_P;

Pone_sq = Pone * Pone;

summation_Pone += Pone;

summation_Pone_sq += Pone_sq;

Rosenblueth2P[i-1] = Pone;

// modifiers

Dec_P = -Dec_P;

if(i% 2 == 0)

Nov_P = - Nov_P;

if(i % 4 == 0)

Oct_P = -Oct_P;

if(i % 8 == 0)

Sep_P = - Sep_P;

if(i % 16 == 0)

Aug_P = -Aug_P;

if(i % 32 == 0)

Jul_P = -Jul_P;

if(i % 64 == 0)

Jun_P = -Jun_P;

if(i % 128 == 0)
```

```
May_P = -May_P;
if(i % 256 == 0)
Apr_P = -Apr_P;
if(i % 512 == 0)
Mar_P = -Mar_P;
if(i % 1024 == 0)
Feb_P = -Feb_P;
if(i % 2048 == 0)
Jan_P = -Jan_P;}
P_mean = summation_Pone / 4096;
P_var = (summation_Pone_sq - pow(summation_Pone,2.0)/4096.0)/4095.0;
P_stdev = pow(P_var,0.5); P_min = 1000000000;P_max =0;
//Skewness, Kurtosis, Minimum, and Maximum
for( int y=0;y<4096;y++)
{P_skew = pow(((Rosenblueth2P[y]-P_mean)/P_stdev),3);
summation_P_skew += P_skew;
P_kurt = pow(((Rosenblueth2P[y]-P_mean)/P_stdev),4);
summation_P_kurt +=P_kurt;
if(P_min > Rosenblueth2P[y])
P_min = Rosenblueth2P[y];
if(P_max < Rosenblueth2P[y])
P_max = Rosenblueth2P[y];}
P_skew = 0.00024431954085 *summation_P_skew;
P_kurt = (0.00024455830903*summation_P_kurt)-3.00219905516239;
//Annual Heat Index Mean, Variance, Skewness, and Kurtosis Calculations
for (int i=1; i<=4096;i++)
{January_T = (JanT[0] + (Jan_T * JanT[2]));
if (January_T < 0)
```

```
January_T = 0;
January_R = pow((0.2*January_T),1.514);
February_T = (FebT[0] + (Feb_T * FebT[2]));
if(February_T < 0)
February_T = 0;
February_R = pow((0.2*February_T),1.514);
March_T = (MarT[0] + (Mar_T * MarT[2]));
if (March_T < 0)
March_T = 0;
March_R = pow((0.2*March_T),1.514);
April_T = (AprT[0] + (Apr_T * AprT[2]));
if(April_T < 0)
April_T = 0;
April_R = pow((0.2*April_T),1.514);
May1_T = (MayT[0] + (May_T * MayT[2]));
if(May1_T < 0)
May1_T = 0;
May1_R = pow((0.2*May1_T),1.514);
June_T = (JunT[0] + (Jun_T * JunT[2]));
if(June_T < 0)
June_T = 0;
June_R = pow((0.2*June_T),1.514);
July_T = (JulT[0] + (Jul_T * JulT[2]));
if(July_T < 0)
July_T = 0;
July_R = pow((0.2*July_T),1.514);
August_T = (AugT[0] + (Aug_T * AugT[2]));
if(August_T < 0)
```

```
August_T = 0;
August_R = pow((0.2*August_T),1.514);
September_T = (SepT[0] + (Sep_T * SepT[2]));
if(September_T < 0)
September_T = 0;
September_R = pow((0.2*September_T),1.514);
October_T = (OctT[0] + (Oct_T * OctT[2]));
if(October_T < 0)
October_T = 0;
October_R = pow((0.2*October_T),1.514);
November_T = (NovT[0] + (Nov_T * NovT[2]));
if(November_T < 0)
November_T = 0;
November_R = pow((0.2*November_T),1.514);
December_T = (DecT[0] + (Dec_T * DecT[2]));
if(December_T < 0)
December_T = 0;
December_R = pow((0.2*December_T),1.514);
Hy = January_R + February_R + March_R + April_R + May1_R + June_R + July_R + August_R
+ September_R + October_R + November_R + December_R;
Hy_sq = Hy * Hy;
summation_Hy += Hy;
summation_Hy_sq += Hy_sq;
Rosenblueth2Temp[i-1] = Hy;
// modifiers
Dec_T = -Dec_T;
if(i% 2 == 0)
Nov_T = - Nov_T;
```

```
if(i % 4 == 0)
Oct_T = -Oct_T;
if(i % 8 == 0)
Sep_T = - Sep_T;
if(i % 16 == 0)
Aug_T = -Aug_T;
if(i % 32 == 0)
Jul_T = -Jul_T;
if(i % 64 == 0)
Jun_T = -Jun_T;
if(i % 128 == 0)
May_T = -May_T;
if(i % 256 == 0)
Apr_T = -Apr_T;
if(i % 512 == 0)
Mar_T = -Mar_T;
if(i % 1024 == 0)
Feb_T = -Feb_T;
if(i % 2048 == 0)
Jan_T = -Jan_T;}
Hy_mean = summation_Hy / 4096;
Hy_var = (summation_Hy_sq - pow(summation_Hy,2.0)/4096.0)/4095.0;
Hy_stdev = pow(Hy_var,0.5);Hy_min = 1000.0;Hy_max = -1.0;
//Skewness, Kurtosis, Minimum, and Maximum
for(int f=0; f<4096;f++)
{Hy_skew = pow(((Rosenblueth2Temp[f]-Hy_mean)/Hy_stdev),3);
summation_Hy_skew += Hy_skew;
Hy_kurt = pow(((Rosenblueth2Temp[f]-Hy_mean)/Hy_stdev),4);
```

```
summation_Hy_kurt += Hy_kurt;
if(Hy_min > Rosenblueth2Temp[f])
Hy_min = Rosenblueth2Temp[f];
if(Hy_max < Rosenblueth2Temp[f])
Hy_max = Rosenblueth2Temp[f];}
Hy_skew = 0.00024431954085 *summation_Hy_skew;
Hy_kurt = (0.00024455830903*summation_Hy_kurt)-3.00219905516239;
//Potential Evapotranspiration Mean, Variance, Skewness, and Kurtosis Calculations
for (int i=1; i<=8192;i++)
{Hy_3 = pow((Hy_mean + Hy_PE * Hy_stdev),3);
Hy_2 = pow((Hy_mean + Hy_PE * Hy_stdev),2);
apow = a0*Hy_3 + a1*Hy_2 + a2*(Hy_mean + Hy_PE * Hy_stdev) + a3;
Hy_PER = pow((10/(Hy_mean + Hy_PE * Hy_stdev)),apow);
January_PE = (JanT[0] + (Jan_PE * JanT[2]));
if (January_PE < 0)
January_PE = 0;
January_PER = Co * Hy_PER * Jan_L * pow(January_PE, apow);
February_PE = (FebT[0] + (Feb_PE * FebT[2]));
if(February_PE < 0)
February_PE = 0;
February_PER = Co * Hy_PER * Feb_L * pow(February_PE, apow);
March_PE = (MarT[0] + (Mar_PE * MarT[2]));
if (March_PE < 0)
March_PE = 0;
March_PER = Co * Hy_PER * Mar_L * pow(March_PER, apow);
April_PE = (AprT[0] + (Apr_PE * AprT[2]));
if(April_PE < 0)
April_PE = 0;
```

```
April_PER = Co * Hy_PER * Apr_L * pow(April_PE, apow);

May1_PE = (MayT[0] + (May_PE * MayT[2]));

if(May1_PE < 0)

May1_PE = 0;

May1_PER = Co * Hy_PER * May_L * pow(May1_PE, apow);

June_PE = (JunT[0] + (Jun_PE * JunT[2]));

if(June_PE < 0)

June_PE = 0;

June_PER = Co * Hy_PER * Jun_L * pow(June_PE, apow);

July_PE = (JulT[0] + (Jul_PE * JulT[2]));

if(July_PE < 0)

July_PE = 0;

July_PER = Co * Hy_PER * Jul_L * pow(July_PE, apow);

August_PE = (AugT[0] + (Aug_PE * AugT[2]));

if(August_PE < 0)

August_PE = 0;

August_PER = Co * Hy_PER * Aug_L * pow(August_PE, apow);

September_PE = (SepT[0] + (Sep_PE * SepT[2]));

if(September_PE < 0)

September_PE = 0;

September_PER = Co * Hy_PER * Sep_L * pow(September_PE, apow);

October_PE = (OctT[0] + (Oct_PE * OctT[2]));

if(October_PE < 0)

October_PE = 0;

October_PER = Co * Hy_PER * Oct_L * pow(October_PE, apow);

November_PE = (NovT[0] + (Nov_PE * NovT[2]));

if(November_PE < 0)

November_PE = 0;
```

```
November_PER = Co * Hy_PER * Nov_L * pow(November_PE, apow);
December_PE = (DecT[0] + (Dec_PE * DecT[2]));
if(December_PE < 0)
December_PE = 0;
December_PER = Co * Hy_PER * Dec_L * pow(December_PE, apow);
PE = January_PER + February_PER + March_PER + April_PER + May1_PER + June_PER +
July_PER + August_PER + September_PER + October_PER + November_PER +
December_PER;PE_sq = PE * PE;summation_PE += PE;summation_PE_sq += PE_sq;
Rosenblueth2PE[i-1] = PE;
// modifiers
Dec_PE = -Dec_PE;
if(i% 2 == 0)
Nov_PE = - Nov_PE;
if(i % 4 == 0)
Oct_PE = -Oct_PE;
if(i % 8 == 0)
Sep_PE = - Sep_PE;
if(i % 16 == 0)
Aug_PE = -Aug_PE;
if(i % 32 == 0)
Jul_PE = -Jul_PE;
if(i % 64 == 0)
Jun_PE = -Jun_PE;
if(i % 128 == 0)
May_PE = -May_PE;
if(i % 256 == 0)
Apr_PE = -Apr_PE;
if(i % 512 == 0)
```

```
Mar_PE = -Mar_PE;
if(i % 1024 == 0)
Feb_PE = -Feb_PE;
if(i % 2028 == 0)
Jan_PE = -Jan_PE;
if(i % 4096 == 0)
Hy_PE = -Hy_PE;}
PE_mean = summation_PE / 8192;
PE_var = (summation_PE_sq - pow(summation_PE,2.0)/8192.0)/8191.0;PE_stdev =
pow(PE_var,0.5);PE_min = 1000.0;PE_max = -1.0;
//Skewness, Kurtosis, Minimum, and Maximum
for(int k=0;k<8192;k++)
{PE_skew = pow(((Rosenblueth2PE[k]-PE_mean)/PE_stdev),3);
summation_PE_skew += PE_skew;
PE_kurt = pow(((Rosenblueth2PE[k]-PE_mean)/PE_stdev),4);
summation_PE_kurt += PE_kurt;
if(PE_min > Rosenblueth2PE[k])
PE_min = Rosenblueth2PE[k];
if(PE_max < Rosenblueth2PE[k])
PE_max = Rosenblueth2PE[k];}
PE_skew = 0.00012211502872*summation_PE_skew;
PE_kurt = (0.00012217467704*summation_PE_kurt)-3.00109908002203;
//Thornwaite Moisture Index Mean, Variance, Skewness, and Kurtosis Calculations
for(int i =1; i<=4;i++)
{TMI_P = P_mean + P_stdev * TMI_Pi;
TMI_PE = PE_mean + PE_stdev * TMI_PEi;
TMI = -65 + 75*(TMI_P/TMI_PE);
if(TMIconstraints == true)
```

```
{//Constraints Per 1-40D Reportif(TMI > 100)
TMI = 100;}
summation_TMI += TMI;TMI_sq = TMI * TMI; summation_TMI_sq += TMI_sq;
RosenbluethTMI[i-1] = TMI; TMI_PEi = -TMI_PEi;
if(i % 2 ==0)
TMI_Pi = -TMI_Pi;}
TMI_mean = summation_TMI/4; TMI_var = (summation_TMI_sq -
pow(summation_TMI,2.0)/4.0)/3.0;TMI_stdev = pow(TMI_var,0.5);
TMI_min = 1000.0;TMI_max = -1000.0;
//Skewness, Kurtosis, Minimum, and Maximum
for(int i=0; i<4; i++)
{TMI_skew = pow(((RosenbluethTMI[i]-TMI_mean)/TMI_stdev),3);
summation_TMI_skew += TMI_skew;
TMI_kurt = pow(((RosenbluethTMI[i]-TMI_mean)/TMI_stdev),4);
summation_TMI_kurt += TMI_kurt;
if(TMI_min > RosenbluethTMI[i])
TMI_min = RosenbluethTMI[i];
if(TMI_max < RosenbluethTMI[i])
TMI_max = RosenbluethTMI[i];}
TMI_skew = (4/6)*summation_TMI_skew;
TMI_kurt = ((20/6)*summation_TMI_kurt)-13.5;
//Matric Suction Mean, Variance, Skewness, and Kurtosis Calculations for N layers
for (int layer_counter=0; layer_counter<Num_layer; layer_counter++)
{suction_TMI_Num = 1;suction_P200_Num = 1;suction_wPI_Num = 1;suction = 0.0;suction_sq
= 0.0;summation_suction = 0.0;summation_suction_sq = 0.0;summation_suction_skew = 0.0;
summation_suction_kurt = 0.0;summation_suction_var = 0.0;
if(Layer_Type[layer_counter] == true)
{// Base Course Suction Parameters
```

```
for (int i=1; i<=4; i++)
{P200_Rosen = P200_M[layer_counter] + suction_P200_Num * P200_S[layer_counter];
//Constraints Per 1-40D Report
if(P200_Rosen > 16.0)
P200_Rosen = 16.0;
if(P200_Rosen < 0.0)
P200_Rosen = 0.0;
TMI_Rosen = TMI_mean + suction_TMI_Num * TMI_stdev;
//Constraints Per 1-40D Report
if(TMI_Rosen > 100.0)
TMI_Rosen = 100.0;
//Powers of P200
P200_3 = pow(P200_Rosen,3.0);
P200_2 = pow(P200_Rosen,2.0);
alpha_base = -0.0016*P200_3 + 0.1106*P200_2 - 0.1135*P200_Rosen + 3.8218;
beta_base = -0.0045*P200_3 + 0.1121*P200_2 - 0.3364*P200_Rosen + 3.2358;
gamma_base = 0.00003*P200_3 - 0.0009*P200_2 + 0.0061*P200_Rosen -0.0498;
// If base course Material
suction = alpha_base + exp(beta_base + gamma_base * ( TMI_Rosen + 101.0));
suction_sq = suction * suction;
summation_suction += suction;
summation_suction_sq += suction_sq;
Rosenblueth2Suction[layer_counter][i-1] = suction;
// modifiers
suction_TMI_Num = -suction_TMI_Num;
if(i% 2 == 0)
suction_P200_Num = - suction_P200_Num;}}
```

```
else if(wPI_M[layer_counter] == 0 && layer_counter > 0)// Calcuclates the non-base with wPI or P200
{if(P200_M[layer_counter] > 10.0){
for( int i=1; i<=4;i++)
{P200_Rosen = P200_M[layer_counter] + suction_P200_Num * P200_S[layer_counter];
//Constraints Per 1-40D Report
if(P200_Rosen > 50.0)
P200_Rosen = 50.0;
if(P200_Rosen < 10.0)
P200_Rosen = 10.0;
TMI_Rosen = TMI_mean + suction_TMI_Num * TMI_stdev;
//Constraints Per 1-40D Report
if(TMI_Rosen > 100.0)
TMI_Rosen = 100.0;
double beta_non1, gamma_non1, delta_non1;
beta_non1 = 2.56075*P200_Rosen + 393.4625;
gamma_non1 = 0.09625*P200_Rosen + 132.4875;
delta_non1 = 0.025*P200_Rosen + 14.75;
suction_mean1 = 0.3*(exp(beta_non1/(TMI_Rosen + gamma_non1))+delta_non1);
suction_sq = suction * suction;
summation_suction += suction_mean1;
summation_suction_sq += suction_sq;
Rosenblueth2Suction[layer_counter][i-1] = suction_mean1;
// modifiers
suction_TMI_Num = -suction_TMI_Num;
if(i% 2 == 0)
suction_P200_Num = - suction_P200_Num;}}
else if(P200_M[layer_counter] < 10.0)
```

```
{for (int i=1; i<=4; i++){
P200_Rosen = P200_M[layer_counter] + suction_P200_Num * P200_S[layer_counter];
//Constraints Per 1-40D Report
if(P200_Rosen > 16.0)
P200_Rosen = 16.0;
if(P200_Rosen < 0.0)
P200_Rosen = 0.0;
TMI_Rosen = TMI_mean + suction_TMI_Num * TMI_stdev;
//Constraints Per 1-40D Report
if(TMI_Rosen > 100.0)
TMI_Rosen = 100.0;
//Powers of P200
P200_3 = pow(P200_Rosen,3.0);
P200_2 = pow(P200_Rosen,2.0);
alpha_base = -0.0016*P200_3 + 0.1106*P200_2 - 0.1135*P200_Rosen + 3.8218;
beta_base = -0.0045*P200_3 + 0.1121*P200_2 - 0.3364*P200_Rosen + 3.2358;
gamma_base = 0.00003*P200_3 - 0.0009*P200_2 + 0.0061*P200_Rosen -0.0498;
// If base course Material
suction = alpha_base + exp(beta_base + gamma_base * ( TMI_Rosen + 101.0));
suction_sq = suction * suction;
summation_suction += suction;
summation_suction_sq += suction_sq;
Rosenblueth2Suction[layer_counter][i-1] = suction;
// modifiers
suction_TMI_Num = -suction_TMI_Num;
if(i% 2 == 0)
suction_P200_Num = - suction_P200_Num;}}}
else
```

```
{for (int i=1; i<=4; i++){
wPI_Rosen = wPI_M[layer_counter] + suction_wPI_Num * wPI_S[layer_counter];
//Constraints Per 1-40D Report
if(wPI_Rosen > 50.0)
wPI_Rosen = 50.0;
if(wPI_Rosen < 0.5)
wPI_Rosen = 0.5;
TMI_Rosen = TMI_mean + suction_TMI_Num * TMI_stdev;
//Constraints Per 1-40D Report
if(TMI_Rosen > 100.0)
TMI_Rosen = 100.0;
// Non-base Course Suction Parameters
wPI_3 = pow(wPI_Rosen,3.0);
wPI_2 = pow(wPI_Rosen,2.0);
beta_non = 0.006235897* wPI_3 - 0.779833377* wPI_2 + 36.78648521*wPI_Rosen +
501.9511878;
gamma_non = 0.000395003* wPI_3 - 0.040423118* wPI_2 + 1.454065726*wPI_Rosen +
136.4775219;
delta_non = -0.019883827* wPI_2 + 1.273583098*wPI_Rosen + 13.91243841;
// If non-base course Material
suction_mean1 = 0.3*(exp(beta_non/(TMI_Rosen + gamma_non))+ delta_non);
suction_sq = suction * suction;
summation_suction += suction_mean1;
summation_suction_sq += suction_sq;
Rosenblueth2Suction[layer_counter][i-1] = suction_mean1;
// modifiers
suction_TMI_Num = -suction_TMI_Num;
if(i% 2 == 0)
```

```
suction_wPI_Num = - suction_wPI_Num;}}
suction_mean1 = summation_suction / 4.0;
for(int i=0; i<4;i++)
{suction_var1 = pow((Rosenblueth2Suction[layer_counter][i] - suction_mean1),2.0);
summation_suction_var += suction_var1;}
suction_var1 = summation_suction_var/3.0;suction_stdev1 = pow(suction_var1,0.5);
suction_min1 = 1000000000.0;suction_max1 = -1.0;
//Skewness, Kurtosis, Minimum, and Maximum
for(int f=0; f<4;f++)
{suction_skew1 = pow(((Rosenblueth2Suction[layer_counter][f]-
suction_mean1)/suction_stdev1),3.0);
summation_suction_skew += suction_skew1;
suction_kurt1 = pow(((Rosenblueth2Suction[layer_counter][f]-
suction_mean1)/suction_stdev1),4.0);
summation_suction_kurt += suction_kurt1;
if(suction_min1 > Rosenblueth2Suction[layer_counter][f])
suction_min1 = Rosenblueth2Suction[layer_counter][f];
if(suction_max1 < Rosenblueth2Suction[layer_counter][f])
suction_max1 = Rosenblueth2Suction[layer_counter][f];}
suction_skew1 = (1/3.0)*summation_suction_skew;
suction_kurt1 = ((1/3.0)*summation_suction_kurt)-3.0;
//Stores Each Layer's statistical Suction Information
Suction_Mean[layer_counter] = suction_mean1;Suction_Variance[layer_counter] = suction_var1;
Suction_Stdev[layer_counter] = suction_stdev1;Suction_Skew[layer_counter] = suction_skew1;
Suction_Kurt[layer_counter] = suction_kurt1;Suction_Minimum[layer_counter] = suction_min1;
Suction_Maximum[layer_counter] = suction_max1;
// Optimum Saturation and Degree of Saturation information
if(level[layer_counter] == true)
```

```
{residual = SWCC_H[layer_counter];
//Saturated Volumetric water content
Rosen_gamma_dry = 1.0;Rosen_Gs = 1.0;theata_sat_sq = 0.0;summation_theata_sat_sq = 0.0;
summation_theata_sat = 0.0;R2_gamma_dry1 = 0.0;R2_Gs = 0.0;
for(int i=1; i<=4; i++)
{R2_gamma_dry1 = gamma_dry_M[layer_counter] +
Rosen_gamma_dry*gamma_dry_S[layer_counter];
R2_Gs = Gs_mean[layer_counter] + Rosen_Gs*Gs_stdev[layer_counter];
theata_sat = (1.0 - (R2_gamma_dry1/(R2_Gs*gamma_water)))*100;
theata_sat_sq = theata_sat * theata_sat;
summation_theata_sat += theata_sat;
summation_theata_sat_sq += theata_sat_sq;
R2_theata_sat[layer_counter][i-1] = theata_sat;
//modifiers
Rosen_gamma_dry = -Rosen_gamma_dry;
if(i% 2 == 0)
Rosen_Gs = - Rosen_Gs;}
theata_sat_sq = summation_theata_sat_sq/4.0;
theata_sat_var = (summation_theata_sat_sq - pow(summation_theata_sat,2.0)/4.0)/3.0;
theata_sat_stdev = pow(theata_sat_var,0.5);  theata_sat_min = 1000.0;theata_sat_max = -1000.0;
summation_theata_sat_skew = 0.0;summation_theata_sat_kurt = 0.0;
for( int w=0; w<4; w++)
{theata_sat_kurt = pow(((R2_theata_sat[layer_counter][w]- theata_sat)/theata_sat_stdev),4.0);
summation_theata_sat_kurt += theata_sat_kurt;
theata_sat_skew = pow(((R2_theata_sat[layer_counter][w]- theata_sat)/theata_sat_stdev),3.0);
summation_theata_sat_skew += theata_sat_skew;
if(theata_sat_min > R2_theata_sat[layer_counter][w])
theata_sat_min = R2_theata_sat[layer_counter][w];
```

```
if(theata_sat_max < R2_theata_sat[layer_counter][w])
theata_sat_max = R2_theata_sat[layer_counter][w];}
theata_sat_skew = (1/3.0)*summation_theata_sat_skew;
theata_sat_kurt = ((1/3.0)*summation_theata_sat_kurt)-3.0;
// Volumetric Water Content
Rosen_theata_sat = 1.0;Rosen_theata_Suction = 1.0;Rosen_theata_af = 1.0;Rosen_theata_bf =
1.0;Rosen_theata_cf = 1.0;theata_water_sq = 0.0;summation_theata_water_sq = 0.0;
summation_theata_water = 0.0;R2_sat_theata_water = 0.0;R2_Suction_theata_water = 0.0;
// SWCC information
for(int i =1; i<=32; i++)
{R2_sat_theata_water =  theata_sat + Rosen_theata_sat* theata_sat_stdev;
R2_Suction_theata_water = Suction_Mean[layer_counter] +
Rosen_theata_Suction*Suction_Stdev[layer_counter];
af = SWCC_AM[layer_counter] + Rosen_theata_af * SWCC_AS[layer_counter];
bf = SWCC_BM[layer_counter] + Rosen_theata_bf * SWCC_BS[layer_counter];
cf = SWCC_CM[layer_counter] + Rosen_theata_cf * SWCC_CS[layer_counter];
C_h = 1-(log(1+(R2_Suction_theata_water/residual))/(log(1000000.0/residual)));
theata_water =
C_h*(R2_sat_theata_water/pow(log(pow((R2_Suction_theata_water/af),bf)+exp(1.0)),cf));
theata_water_sq = theata_water * theata_water;
summation_theata_water += theata_water;
summation_theata_water_sq += theata_water_sq;
R2_theata_water[layer_counter][i-1] = theata_water;
//modifier
Rosen_theata_Suction = -Rosen_theata_Suction;
if(i % 2 == 0)
Rosen_theata_sat = -Rosen_theata_sat;
if(i % 4 == 0)
```

```
Rosen_theata_af = -Rosen_theata_af;

if(i % 8 == 0)

Rosen_theata_bf = -Rosen_theata_bf;

if(i % 16 == 0)

Rosen_theata_cf = -Rosen_theata_cf;}

theata_water = summation_theata_water/32.0;

theata_water_var = (summation_theata_water_sq - pow(summation_theata_water,2.0)/32.0)/31.0;

theata_water_stdev = pow(theata_water_var, 0.5); theata_water_min = 1000.0;

theata_water_max = -1000.0;theata_water_skew = 0.0; theata_water_kurt = 0.0;

summation_theata_water_kurt = 0.0;summation_theata_water_skew = 0.0;

for( int w=0; w<32; w++)

{theata_water_kurt = pow(((R2_theata_water[layer_counter][w]-

theata_water)/theata_water_stdev),4.0);

summation_theata_water_kurt += theata_water_kurt;

theata_water_skew = pow(((R2_theata_water[layer_counter][w]-

theata_water)/theata_water_stdev),3.0);

summation_theata_water_skew += theata_water_skew;

if(theata_water_min > R2_theata_water[layer_counter][w])

theata_water_min = R2_theata_water[layer_counter][w];

if(theata_water_max < R2_theata_water[layer_counter][w])

theata_water_max = R2_theata_water[layer_counter][w];}

theata_water_skew = (1/31.0)*summation_theata_water_skew;

theata_water_kurt = ((1/31.0)*summation_theata_water_kurt)-3.0;

//Degree of Saturation

Rosen_theata_sat = 1.0;Rosen_theata_water = 1.0;degree_sat_sq = 0.0;

summation_degree_sat = 0.0;summation_degree_sat_sq = 0.0;R2_theata_water_dsat = 0.0;

R2_theata_sat_dsat = 0.0;

for(int i=1; i<=4; i++)
```

```
{R2_theata_water_dsat = theata_water + Rosen_theata_water* theata_water_stdev;
R2_theata_sat_dsat = theata_sat + Rosen_theata_sat* theata_sat_stdev;
degree_sat_mean1 = (R2_theata_water_dsat / R2_theata_sat_dsat)*100;
if(degree_sat_mean1 > 100.0)
degree_sat_mean1 = degree_sat_mean1;
if(degree_sat_mean1 < 0.0)
degree_sat_mean1 = 0.0;
degree_sat_sq = degree_sat_mean1*degree_sat_mean1;
summation_degree_sat += degree_sat_mean1;
summation_degree_sat_sq += degree_sat_sq;
R2_degree_sat[layer_counter][i-1] = degree_sat_mean1;
//modifiers
Rosen_theata_sat = -Rosen_theata_sat;
if(i%2==0)
Rosen_theata_water = -Rosen_theata_water;}
degree_sat_mean1 = summation_degree_sat/4.0;
degree_sat_var1 = (summation_degree_sat_sq - pow(summation_degree_sat,2.0)/4.0)/3.0;
degree_sat_stdev1 = pow(degree_sat_var1,0.5);
degree_sat_min1 = 1000.0;degree_sat_max1 = -100.0; summation_degree_sat_skew =
0.0;summation_degree_sat_kurt = 0.0;
for(int f=0; f<4;f++)
{degree_sat_skew1 = pow(((R2_degree_sat[layer_counter][f]-
degree_sat_mean1)/degree_sat_stdev1),3.0);
summation_degree_sat_skew += degree_sat_skew1;
degree_sat_kurt1 = pow(((R2_degree_sat[layer_counter][f]-
degree_sat_mean1)/degree_sat_stdev1),4.0);
summation_degree_sat_kurt += degree_sat_kurt1;
if(degree_sat_min1 > R2_degree_sat[layer_counter][f])
```

```
degree_sat_min1 = R2_degree_sat[layer_counter][f];
if(degree_sat_max1 < R2_degree_sat[layer_counter][f])
degree_sat_max1 = R2_degree_sat[layer_counter][f];}
degree_sat_skew1 = (1/3.0)*summation_degree_sat_skew;
degree_sat_kurt1 = ((1/3.0)*summation_degree_sat_kurt)-3.0;
//Optimum Saturation
Rosen_opt_wopt = 1.0; Rosen_opt_gamma = 1.0; Rosen_opt_Gs = 1.0; summation_opt_sat = 0.0;
summation_opt_sat_sq = 0.0; opt_sat_sq_mean = 0.0; R2_opt_wopt = 0.0; R2_opt_gamma = 0.0;
R2_opt_Gs = 0.0;
for(int i=1; i<=8; i++)
{R2_opt_wopt = wopt_M[layer_counter] +Rosen_opt_wopt*wopt_S[layer_counter];
R2_opt_gamma = gamma_dry_M[layer_counter] +
Rosen_opt_gamma*gamma_dry_S[layer_counter];
R2_opt_Gs = Gs_mean[layer_counter] + Rosen_opt_Gs*Gs_stdev[layer_counter];
opt_sat_mean1 = R2_opt_wopt/((gamma_water/R2_opt_gamma)-(1/R2_opt_Gs));
if(opt_sat_mean1 > 100.0)
opt_sat_mean1 = 100.0;
if(opt_sat_mean1 < 0.0)
opt_sat_mean1 = 0.0;
opt_sat_sq = opt_sat_mean1 * opt_sat_mean1;
summation_opt_sat += opt_sat_mean1;
summation_opt_sat_sq += opt_sat_sq;
R2_opt_sat[layer_counter][i-1] = opt_sat_mean1;
//modifiers
Rosen_opt_Gs = -Rosen_opt_Gs;
if(i%2==0)
Rosen_opt_gamma = -Rosen_opt_gamma;
if(i%4==0)
```

```
Rosen_opt_wopt = -Rosen_opt_wopt;}

opt_sat_mean1 = summation_opt_sat/8.0;

opt_sat_var1 = (summation_opt_sat_sq - pow(summation_opt_sat,2.0)/8.0)/7.0;

opt_sat_stdev1 = pow(opt_sat_var1,0.5);opt_sat_min1 = 1000.0; opt_sat_max1 = -1.0;

summation_opt_sat_skew = 0.0;summation_opt_sat_kurt = 0.0;

for(int f=0; f<8;f++)

{opt_sat_skew1 = pow(((R2_opt_sat[layer_counter][f]-opt_sat_mean1)/opt_sat_stdev1),3.0);

summation_opt_sat_skew += opt_sat_skew1;

opt_sat_kurt1 = pow(((R2_opt_sat[layer_counter][f]-opt_sat_mean1)/opt_sat_stdev1),4.0);

summation_opt_sat_kurt += opt_sat_kurt1;

if(opt_sat_min1 > R2_opt_sat[layer_counter][f])

opt_sat_min1 = R2_opt_sat[layer_counter][f];

if(opt_sat_max1 < R2_opt_sat[layer_counter][f])

opt_sat_max1 = R2_opt_sat[layer_counter][f];}

opt_sat_skew1 = (1/7.0)*summation_opt_sat_skew;

opt_sat_kurt1 = ((1/7.0)*summation_opt_sat_kurt)-3.0;}

else // Level 2 and 3

{if(Names[layer_counter] == "A-1-a")

residual = 100;

else if(Names[layer_counter] == "A-1-b")

residual = 100;

else if(Names[layer_counter] == "A-2-4")

residual = 100;

else if(Names[layer_counter] == "A-2-5")

residual = 100;

else if(Names[layer_counter] == "A-2-6")

residual = 100;

else if(Names[layer_counter] == "A-2-7")
```

```
residual = 100;
else if(Names[layer_counter] == "A-3")
residual = 100;
else
residual = 500;
if(wPI_M[layer_counter]==0.0)
{//Optimum Moisture Content
Rosen_wopt_P15 = 1.0;Rosen_wopt_P40 = 1.0;Rosen_wopt_P60 = 1.0;Rosen_wopt_D60 =
1.0;summation_wopt = 0.0;summation_wopt_sq = 0.0;R2_wopt_P15 = 0.0;R2_wopt_P40 =
0.0;R2_wopt_P60 = 0.0;R2_wopt_D60 = 0.0;wopt_sq = 0.0;
for(int i=1; i<=16; i++)
{R2_wopt_P15 = P15_M[layer_counter] + Rosen_wopt_P15*P15_S[layer_counter];
R2_wopt_P40 = P40_M[layer_counter] + Rosen_wopt_P40*P40_S[layer_counter];
R2_wopt_P60 = P60_M[layer_counter] + Rosen_wopt_P60*P60_S[layer_counter];
R2_wopt_D60 = D60_M[layer_counter] + Rosen_wopt_D60*D60_S[layer_counter];
opt_moisture_mean = -120.14-0.06766*R2_wopt_P15+3.7269*R2_wopt_D60-
0.167*R2_wopt_P40+0.117*R2_wopt_P60+142.53*exp(-0.0389*R2_wopt_D60);
wopt_sq = opt_moisture_mean * opt_moisture_mean;
summation_wopt += opt_moisture_mean;
summation_wopt_sq += wopt_sq;
//modifiers
Rosen_wopt_D60 = -Rosen_wopt_D60;
if(i%2==0)
Rosen_wopt_P60 = -Rosen_wopt_P60;
if(i%4==0)
Rosen_wopt_P40 = -Rosen_wopt_P40;
if(i%8==0)
Rosen_wopt_P15 = -Rosen_wopt_P15;}
```

```
opt_moisture_mean = summation_wopt/16.0;
opt_moisture_var = (summation_wopt_sq - pow(summation_wopt,2.0)/16.0)/15.0;
wopt_var = opt_moisture_var;wopt_stdev = pow(opt_moisture_var,0.5);
wopt_min = 1000.0;wopt_max =-1000.0;summation_wopt_skew = 0.0;
summation_wopt_kurt = 0.0;
for(int w=0; w<16; w++)
{summation_wopt_skew += pow(((R2_wopt[layer_counter][w]-
opt_moisture_mean)/wopt_stdev),3.0);
summation_wopt_kurt += pow(((R2_wopt[layer_counter][w]-
opt_moisture_mean)/wopt_stdev),4.0);
if(wopt_min > R2_wopt[layer_counter][w])
wopt_min = R2_wopt[layer_counter][w];
if(wopt_max < R2_wopt[layer_counter][w])
wopt_max = R2_wopt[layer_counter][w];}
wopt_skew = (1/15.0)*summation_wopt_skew;
wopt_kurt =((1/15.0)*summation_wopt_kurt)-3.0;
//Optimum Saturation
Rosen_opt_P20 = 1.0;Rosen_opt_P10 = 1.0;Rosen_opt_P05 = 1.0;R2_P20 = 0.0;
R2_P10 = 0.0;R2_P05 = 0.0;opt_sat_sq = 0.0;summation_opt_sat = 0.0;
summation_opt_sat_sq = 0.0;
for(int i=1; i<=8; i++)
{R2_P20 = P20_M[layer_counter] + Rosen_opt_P20*P20_S[layer_counter];
R2_P10 = P10_M[layer_counter] + Rosen_opt_P10*P10_S[layer_counter];
R2_P05 = P05_M[layer_counter] + Rosen_opt_P05*P05_S[layer_counter];
opt_sat_mean1 = -100.17+1.4991*R2_P20+0.56155*R2_P10-0.36755*R2_P05;
if(opt_sat_mean1 > 100.0)
opt_sat_mean1 = 100.0;
if(opt_sat_mean1 < 0.0)
```

```
opt_sat_mean1 = 0.0;

opt_sat_sq = opt_sat_mean1*opt_sat_mean1;

summation_opt_sat += opt_sat_mean1;

summation_opt_sat_sq += opt_sat_sq;

R2_opt_sat[layer_counter][i-1] = opt_sat_mean1;

//modifiers

Rosen_opt_P05 = -Rosen_opt_P05;

if(i%2==0)

Rosen_opt_P10 = -Rosen_opt_P10;

if(i%4==0)

Rosen_opt_P20 = -Rosen_opt_P20;}

opt_sat_mean1 = summation_opt_sat/8.0;

opt_sat_var1 = (summation_opt_sat_sq - pow(summation_opt_sat,2.0)/8.0)/7.0;

opt_sat_stdev1 = pow(opt_sat_var1,0.5);

opt_sat_min1 = 1000.0;opt_sat_max1 = -1.0;summation_opt_sat_skew = 0.0;

summation_opt_sat_kurt = 0.0;

for(int f=0; f<8;f++)

{opt_sat_skew1 = pow(((R2_opt_sat[layer_counter][f]-opt_sat_mean1)/opt_sat_stdev1),3.0);

summation_opt_sat_skew += opt_sat_skew1;

opt_sat_kurt1 = pow(((R2_opt_sat[layer_counter][f]-opt_sat_mean1)/opt_sat_stdev1),4.0);

summation_opt_sat_kurt += opt_sat_kurt1;

if(opt_sat_min1 > R2_opt_sat[layer_counter][f])

opt_sat_min1 = R2_opt_sat[layer_counter][f];

if(opt_sat_max1 < R2_opt_sat[layer_counter][f])

opt_sat_max1 = R2_opt_sat[layer_counter][f];}

opt_sat_skew1 = (1/7.0)*summation_opt_sat_skew;

opt_sat_kurt1 = ((1/7.0)*summation_opt_sat_kurt)-3.0;

//wPI = 0.0 Gamma Dry Maximum
```

```
Rosen_gamma_wopt = 1.0; Rosen_gamma_Gs = 1.0; Rosen_gamma_Sopt = 1.0;
summation_gamma_dry = 0.0; summation_gamma_dry_sq = 0.0; gamma_dry_sq = 0.0;
R2_gamma_wopt = 0.0; R2_gamma_Gs = 0.0; R2_gamma_Sopt = 0.0;
for(int i=1; i<=8; i++)
{R2_gamma_wopt = opt_moisture_mean + Rosen_gamma_wopt*pow(opt_moisture_var,0.5);
R2_gamma_Gs = Gs_mean[layer_counter] + Rosen_gamma_Gs*Gs_stdev[layer_counter];
R2_gamma_Sopt = opt_sat_mean1 + Rosen_gamma_Sopt*opt_sat_stdev1;
gamma_dry_mean =
(R2_gamma_Gs*gamma_water)/(1+((R2_gamma_wopt*R2_gamma_Gs)/R2_gamma_Sopt));
if(Layer_Compaction[layer_counter] == false)
gamma_dry_mean = 1.0156*gamma_dry_mean - 2.464;
gamma_dry_sq = gamma_dry_mean * gamma_dry_mean;
summation_gamma_dry += gamma_dry_mean;
summation_gamma_dry_sq += gamma_dry_sq;
R2_gamma_dry[layer_counter][i-1]= gamma_dry_mean;
//modifiers
Rosen_gamma_Sopt = -Rosen_gamma_Sopt;
if(i%2==0)
Rosen_gamma_Gs = -Rosen_gamma_Gs;
if(i%4==0)
Rosen_gamma_wopt = -Rosen_gamma_wopt;}
gamma_dry_mean = summation_gamma_dry/8.0;
gamma_dry_var = (summation_gamma_dry_sq - pow(summation_gamma_dry,2.0)/8.0)/7.0;
gamma_dry_stdev = pow(gamma_dry_var,0.5);
gamma_dry_min = 1000.0; gamma_dry_max =-1000.0; summation_gamma_dry_kurt = 0.0;
summation_gamma_dry_skew = 0.0;
for(int w=0; w<8; w++)
```

```
{summation_gamma_dry_skew += pow(((R2_gamma_dry[layer_counter][w]-
gamma_dry_mean)/gamma_dry_stdev),3.0);
summation_gamma_dry_kurt += pow(((R2_gamma_dry[layer_counter][w]-
gamma_dry_mean)/gamma_dry_stdev),4.0);
if(gamma_dry_min > R2_gamma_dry[layer_counter][w])
gamma_dry_min = R2_gamma_dry[layer_counter][w];
if(gamma_dry_max < R2_gamma_dry[layer_counter][w])
gamma_dry_max = R2_gamma_dry[layer_counter][w];}
gamma_dry_skew = (1.0/7.0)*summation_gamma_dry_skew;
gamma_dry_kurt = ((1.0/7.0)*summation_gamma_dry_kurt)-3.0;}
else // wPI > 2.0
{//adjusted PI
Rosen_PIadj_P200 = 1.0;
R2_PIadj_P200 = 0.0;
PIadj_sq = 0.0;
summation_PIadj = 0.0;
summation_PIadj_sq = 0.0;
for(int i=1; i<=2; i++)
{R2_PIadj_P200 = P200_M[layer_counter] + Rosen_PIadj_P200*P200_S[layer_counter];
PI_adj_mean = exp((R2_PIadj_P200+42.13)/33.94);
PIadj_sq = PI_adj_mean * PI_adj_mean;
summation_PIadj += PI_adj_mean;
summation_PIadj_sq += PIadj_sq;
//modifer
Rosen_PIadj_P200 = -Rosen_PIadj_P200;}
PI_adj_mean = summation_PIadj/2.0;
PI_adj_var = (summation_PIadj_sq - pow(summation_PIadj,2.0)/2.0);
if(PI_adj_mean < PI_M[layer_counter])
```

```
{Rosen_wPIadj_PIadj = 1.0;Rosen_wPIadj_P200 = 1.0; R2_wPIadj_PIadj = 0.0;
R2_wPIadj_P200 = 0.0;wPIadj_sq = 0.0; summation_wPIadj = 0.0; summation_wPIadj_sq = 0.0;
for(int i=1; i<=4; i++)
{R2_wPIadj_PIadj = PI_adj_mean + Rosen_wPIadj_PIadj*pow(PI_adj_var,0.5);
R2_wPIadj_P200 = P200_M[layer_counter] + Rosen_wPIadj_P200*P200_S[layer_counter];
wPI_adj_mean = (R2_wPIadj_PIadj * R2_wPIadj_P200)/100;
wPIadj_sq = wPI_adj_mean * wPI_adj_mean;
summation_wPIadj += wPI_adj_mean;
summation_wPIadj_sq += wPIadj_sq;
//modifiers
Rosen_wPIadj_P200 = -Rosen_wPIadj_P200;
if(i%2==0)
Rosen_wPIadj_PIadj = -Rosen_wPIadj_PIadj;}
wPI_adj_mean = summation_wPIadj/4.0;
wPI_adj_var = (summation_wPIadj_sq - pow(summation_wPIadj,2.0)/4.0)/3.0;}
else
{wPI_adj_mean = wPI_M[layer_counter]; wPI_adj_var = wPI_V[layer_counter];}
if(wPI_adj_mean < 1.0)
wPI_adj_mean = 1.0;
//wPI >0 Optimum Moisture Content
Rosen_wopt_wPIadj = 1.0; R2_wPI_adj = 0.0; summation_wopt = 0.0; summation_wopt_sq =
0.0; wopt_sq = 0.0;
for(int i=1; i<=2; i++)
{R2_wPI_adj = wPI_adj_mean + Rosen_wopt_wPIadj*pow(wPI_adj_var,0.5);
if(R2_wPI_adj<0)
R2_wPI_adj=0.0;
opt_moisture_mean = 8.3932*pow(R2_wPI_adj,0.3075);
wopt_sq = opt_moisture_mean * opt_moisture_mean;
```

```
R2_wopt[layer_counter][i-1] = opt_moisture_mean;
summation_wopt += opt_moisture_mean;
summation_wopt_sq += wopt_sq;
//modifiers
Rosen_wopt_wPIadj = -Rosen_wopt_wPIadj;}
opt_moisture_mean = summation_wopt/2.0;
opt_moisture_var = (summation_wopt_sq - pow(summation_wopt,2.0)/2.0);
wopt_var = opt_moisture_var; wopt_stdev = pow(opt_moisture_var,0.5); wopt_min = 1000.0;
wopt_max =-1000.0; summation_wopt_skew = 0.0;summation_wopt_kurt = 0.0;
for(int w=0; w<2; w++)
{summation_wopt_skew += pow(((R2_wopt[layer_counter][w]-
opt_moisture_mean)/wopt_stdev),3.0);
summation_wopt_kurt += pow(((R2_wopt[layer_counter][w]-
opt_moisture_mean)/wopt_stdev),4.0);
if(wopt_min > R2_wopt[layer_counter][w])
wopt_min = R2_wopt[layer_counter][w];
if(wopt_max < R2_wopt[layer_counter][w])
wopt_max = R2_wopt[layer_counter][w];}
wopt_skew = (1/2.0)*summation_wopt_skew;
wopt_kurt =((1/2.0)*summation_wopt_kurt)-3.0;
Rosen_gamma_wopt = 1.0; summation_gamma_dry = 0.0; summation_gamma_dry_sq = 0.0;
gamma_dry_sq = 0.0; gamma_dry_sq_mean = 0.0; R2_gamma_wopt = 0.0;
for(int i=1; i<=2; i++)
{R2_gamma_wopt = opt_moisture_mean + Rosen_gamma_wopt*pow(opt_moisture_var,0.5);
gamma_dry_mean = 142.115 - 1.959*R2_gamma_wopt;
if(Layer_Compaction[layer_counter] == false)
gamma_dry_mean = 1.0156*gamma_dry_mean - 2.464;
gamma_dry_sq = gamma_dry_mean * gamma_dry_mean;
```

```
summation_gamma_dry += gamma_dry_mean;
summation_gamma_dry_sq += gamma_dry_sq;
R2_gamma_dry[layer_counter][i-1] = gamma_dry_mean;
//modifier
Rosen_gamma_wopt = -Rosen_gamma_wopt;}
gamma_dry_mean = summation_gamma_dry/2.0;
gamma_dry_var = (summation_gamma_dry_sq - pow(summation_gamma_dry,2.0)/2.0);
gamma_dry_stdev = pow(gamma_dry_var,0.5); gamma_dry_min = 1000.0; gamma_dry_max =-
1000.0; summation_gamma_dry_kurt = 0.0;summation_gamma_dry_skew = 0.0;
for(int w=0; w<2; w++)
{summation_gamma_dry_skew += pow(((R2_gamma_dry[layer_counter][w]-
gamma_dry_mean)/gamma_dry_stdev),3.0);
summation_gamma_dry_kurt += pow(((R2_gamma_dry[layer_counter][w]-
gamma_dry_mean)/gamma_dry_stdev),4.0);
if(gamma_dry_min > R2_gamma_dry[layer_counter][w])
gamma_dry_min = R2_gamma_dry[layer_counter][w];
if(gamma_dry_max < R2_gamma_dry[layer_counter][w])
gamma_dry_max = R2_gamma_dry[layer_counter][w];}
gamma_dry_skew = summation_gamma_dry_skew;
gamma_dry_kurt = (summation_gamma_dry_kurt)-3.0;
//Optimum Saturation
Rosen_opt_wopt = 1.0; Rosen_opt_gamma = 1.0;Rosen_opt_Gs = 1.0; R2_opt_wopt = 0.0;
R2_opt_gamma = 0.0; R2_opt_Gs = 0.0; opt_sat_sq = 0.0; summation_opt_sat = 0.0;
summation_opt_sat_sq = 0.0; opt_sat_sq_mean = 0.0;
for(int i=1; i<=8; i++)
{R2_opt_wopt = opt_moisture_mean +Rosen_opt_wopt*wopt_stdev;
R2_opt_gamma = gamma_dry_mean + Rosen_opt_gamma*gamma_dry_stdev;
R2_opt_Gs = Gs_mean[layer_counter] + Rosen_opt_Gs*Gs_stdev[layer_counter];
```

```
opt_sat_mean1 = R2_opt_wopt/((gamma_water/R2_opt_gamma)-(1/R2_opt_Gs));

if(opt_sat_mean1 > 100.0)

opt_sat_mean1 = 100.0;

if(opt_sat_mean1 < 0.0)

opt_sat_mean1 = 0.0;

opt_sat_sq = opt_sat_mean1 * opt_sat_mean1;

summation_opt_sat += opt_sat_mean1;

summation_opt_sat_sq += opt_sat_sq;

R2_opt_sat[layer_counter][i-1] = opt_sat_mean1;

//modifiers

Rosen_opt_wopt = -Rosen_opt_wopt;

if(i%2==0)

Rosen_opt_gamma = -Rosen_opt_gamma;

if(i%4==0)

Rosen_opt_Gs = -Rosen_opt_Gs;}

opt_sat_mean1 = summation_opt_sat/8.0;

opt_sat_var1 = (summation_opt_sat_sq - pow(summation_opt_sat,2.0)/8.0)/7.0;

opt_sat_stdev1 = pow(opt_sat_var1,0.5); opt_sat_min1 = 1000.0;opt_sat_max1 = -1.0;

summation_opt_sat_skew = 0.0;summation_opt_sat_kurt = 0.0;

for(int f=0; f<8;f++)

{opt_sat_skew1 = pow(((R2_opt_sat[layer_counter][f]-opt_sat_mean1)/opt_sat_stdev1),3.0);

summation_opt_sat_skew += opt_sat_skew1;

opt_sat_kurt1 = pow(((R2_opt_sat[layer_counter][f]-opt_sat_mean1)/opt_sat_stdev1),4.0);

summation_opt_sat_kurt += opt_sat_kurt1;

if(opt_sat_min1 > R2_opt_sat[layer_counter][f])

opt_sat_min1 = R2_opt_sat[layer_counter][f];

if(opt_sat_max1 < R2_opt_sat[layer_counter][f])

opt_sat_max1 = R2_opt_sat[layer_counter][f];}
```

```
opt_sat_skew1 = (1/7.0)*summation_opt_sat_skew;

opt_sat_kurt1 = ((1/7.0)*summation_opt_sat_kurt)-3.0;}

//Saturated Volumetric water content

Rosen_gamma_dry = 1.0; Rosen_Gs = 1.0; theata_sat_sq = 0.0; summation_theata_sat_sq = 0.0;

summation_theata_sat = 0.0; R2_gamma_dry1 = 0.0; R2_Gs = 0.0;

for(int i=1; i<=4; i++)

{R2_gamma_dry1 = gamma_dry_mean + Rosen_gamma_dry*pow(gamma_dry_var,0.5);

R2_Gs = Gs_mean[layer_counter] + Rosen_Gs*Gs_stdev[layer_counter];

theata_sat = (1.0 - (R2_gamma_dry1/(R2_Gs*gamma_water)))*100;

if(theata_sat > 100.0)

theata_sat = 100.0;

if(theata_sat < 0.0)

theata_sat = 0.0;

theata_sat_sq = theata_sat * theata_sat;

summation_theata_sat += theata_sat;

summation_theata_sat_sq += theata_sat_sq;

R2_theata_sat[layer_counter][i-1] = theata_sat;

//modifiers

Rosen_gamma_dry = -Rosen_gamma_dry;

if(i% 2 == 0)

Rosen_Gs = - Rosen_Gs;}

theata_sat = summation_theata_sat / 4.0;

theata_sat_var = (summation_theata_sat_sq - pow(summation_theata_sat,2.0)/4.0)/3.0;

theata_sat_stdev = pow(theata_sat_var,0.5);theata_sat_min = 1000.0; theata_sat_max = -1000.0;

summation_theata_sat_skew = 0.0; summation_theata_sat_kurt = 0.0;

for( int w=0; w<4; w++)

{theata_sat_kurt = pow(((R2_theata_sat[layer_counter][w]- theata_sat)/theata_sat_stdev),4.0);

summation_theata_sat_kurt += theata_sat_kurt;
```

```
theata_sat_skew = pow(((R2_theata_sat[layer_counter][w]- theata_sat)/theata_sat_stdev),3.0);
summation_theata_sat_skew += theata_sat_skew;
if(theata_sat_min > R2_theata_sat[layer_counter][w])
theata_sat_min = R2_theata_sat[layer_counter][w];
if(theata_sat_max < R2_theata_sat[layer_counter][w])
theata_sat_max = R2_theata_sat[layer_counter][w];}
theata_sat_skew = (1/3.0)*summation_theata_sat_skew;
theata_sat_kurt = ((1/3.0)*summation_theata_sat_kurt)-3.0;
//wPI <2.0
if(wPI_M[layer_counter]<2.0){
if(P200_M[layer_counter]<2.0)//1-40D Constraint{P200_M[layer_counter] = 2.0;}
Rosen_theata_P200 = 1.0;Rosen_theata_TMI = 1.0;theata_water_sq = 0.0;
summation_theata_water_sq = 0.0;summation_theata_water = 0.0; theata_water_sq_mean =
0.0;R2_P200_theata_water = 0.0; R2_TMI_theata_water = 0.0;
for(int i=1; i <=4; i++)
{R2_P200_theata_water = P200_M[layer_counter] + Rosen_theata_P200 *
P200_S[layer_counter];
R2_TMI_theata_water = TMI_mean + Rosen_theata_TMI * TMI_stdev;
theata_water = 4.0 + 1.5*pow(R2_P200_theata_water,0.6994) + 0.03*R2_TMI_theata_water;
if(theata_water > 100.0)
theata_water = 100.0;
if(theata_water < 0.0)
theata_water = 0.0;
theata_water_sq = theata_water * theata_water;
summation_theata_water += theata_water;
summation_theata_water_sq += theata_water_sq;
R2_theata_water[layer_counter][i-1] = theata_water;
//modifiers
```

```
Rosen_theata_TMI = -Rosen_theata_TMI;
if(i % 2 ==0)
Rosen_theata_P200 = -Rosen_theata_P200;}
if(theata_water > 40.0)//1-40D Constraint{
for(int i=1; i<=2; i++)
{R2_P200_theata_water = P200_M[layer_counter] + Rosen_theata_P200 *
P200_S[layer_counter];
theata_water = 40 + 0.11*(R2_P200_theata_water - 53.0);
if(theata_water > 100.0)
theata_water = 100.0;
if(theata_water < 0.0)
theata_water = 0.0;
theata_water_sq = theata_water * theata_water;
summation_theata_water += theata_water;
summation_theata_water_sq += theata_water_sq;
R2_theata_water[layer_counter][i-1] = theata_water;
//modifier
Rosen_theata_P200 = -Rosen_theata_P200;}}
if(theata_water < 40.0)//1-40D Constraint
{theata_water = summation_theata_water/4.0;
theata_water_var = (summation_theata_water_sq - pow(summation_theata_water,2.0)/4.0)/3.0;}
else
{theata_water = summation_theata_water/2.0;
theata_water_var = (summation_theata_water_sq - pow(summation_theata_water,2.0)/2.0);}
theata_water_stdev = pow(theata_water_var, 0.5);
theata_water_skew = 0.0;theata_water_kurt = 0.0; summation_theata_water_kurt = 0.0;
summation_theata_water_skew = 0.0; theata_water_min = 1000.0; theata_water_max = -1000.0;
for( int w=0; w<2; w++)
```

```
{theata_water_kurt = pow(((R2_theata_water[layer_counter][w]-
theata_water)/theata_water_stdev),4.0);
summation_theata_water_kurt += theata_water_kurt;
theata_water_skew = pow(((R2_theata_water[layer_counter][w]-
theata_water)/theata_water_stdev),3.0);
summation_theata_water_skew += theata_water_skew;
if(theata_water_min > R2_theata_water[layer_counter][w])
theata_water_min = R2_theata_water[layer_counter][w];
if(theata_water_max < R2_theata_water[layer_counter][w])
theata_water_max = R2_theata_water[layer_counter][w];}
theata_water_skew = summation_theata_water_skew;
theata_water_kurt = (summation_theata_water_kurt)-3.0;
if(theata_water > theata_sat)//1-40D constraint
{theata_water = theata_sat; theata_water_var = theata_sat_var; theata_water_stdev =
theata_sat_stdev;}}
else
{Rosen_theata_wPI = 1.0; Rosen_theata_Suction = 1.0; Rosen_theata_sat_water = 1.0;
theata_water_sq = 0.0; summation_theata_water_sq = 0.0;summation_theata_water = 0.0;
R2_wPI_theata_water = 0.0; R2_Suction_theata_water = 0.0;R2_theata_sat_water = 0.0;
theata_water_min = 0.0; theata_water_max = 0.0;var_a = 0.0; var_b = 0.0;var_c = 0.0;
stdev_a = 0.0; stdev_b = 0.0; stdev_c = 0.0;min_a = 10000.0;min_b = 100000.0;min_c =
100000.0;
max_a = 0.0;max_b = 0.0;max_c = 0.0;mean_a = 0.0;mean_b = 0.0;mean_c = 0.0;
summation_a = 0.0; summation_b = 0.0;summation_c = 0.0;summation_a_sq = 0.0;
summation_b_sq = 0.0;summation_c_sq = 0.0;
// SWCC information
for(int i =1; i<=8; i++)
{checker = true;
```

```
R2_wPI_theata_water = wPI_M[layer_counter] + Rosen_theata_wPI* wPI_S[layer_counter];
if(R2_wPI_theata_water < 0)
R2_wPI_theata_water = 0.0;
if(R2_wPI_theata_water > 100.0)
R2_wPI_theata_water = 100.0;
R2_theata_sat_water = theata_sat + Rosen_theata_sat_water*theata_sat_stdev;
if(R2_theata_sat_water < 0)
R2_theata_sat_water = 0.0;
if(R2_theata_sat_water > 100.0)
R2_theata_sat_water = 100.0;
R2_Suction_theata_water = Suction_Mean[layer_counter] +
Rosen_theata_Suction*Suction_Stdev[layer_counter];
if(R2_Suction_theata_water < 0.0)
R2_Suction_theata_water= 0.0;
if(R2_Suction_theata_water > 1000000.0)
R2_Suction_theata_water = 1000000.0;
af = 32.835*log(R2_wPI_theata_water)+32.438;
bf = 1.421*pow(R2_wPI_theata_water,-0.3185);
cf = -0.2154*log(R2_wPI_theata_water)+0.7145;
if(af < 5.0)
af = 5.0;
if(cf < 0.01)
cf = 0.03;
summation_a += af;summation_b += bf;summation_c += cf; summation_a_sq += af*af;
summation_b_sq += bf*bf;summation_c_sq += cf*cf;Rosenblueth1[layer_counter][0][i-1] = af;
Rosenblueth1[layer_counter][1][i-1] = bf; Rosenblueth1[layer_counter][2][i-1] = cf;
C_h = 1-(log(1+(R2_Suction_theata_water/residual))/(log(1000000.0/residual)));
```

```
theata_water =
C_h*(R2_theata_sat_water/pow(log(pow((R2_Suction_theata_water/af),bf)+exp(1.0)),cf));
if(theata_water > 100.0)
theata_water = 100.0;
if(theata_water < 0.0)
theata_water = 0.0;
R2_theata_water[layer_counter][i-1]=theata_water;
theata_water_sq = theata_water * theata_water;
summation_theata_water += theata_water;
summation_theata_water_sq += theata_water_sq;
//modifier
Rosen_theata_Suction = -Rosen_theata_Suction;
if(i % 2 ==0)
Rosen_theata_wPI = -Rosen_theata_wPI;
if(i % 4 == 0)
Rosen_theata_sat_water = -Rosen_theata_sat_water;
}
theata_water = summation_theata_water/8.0;
theata_water_var = (summation_theata_water_sq - pow(summation_theata_water,2.0)/8.0)/7.0;
theata_water_stdev = pow(theata_water_var, 0.5);theata_water_skew = 0.0;
theata_water_kurt = 0.0; summation_theata_water_kurt = 0.0;summation_theata_water_skew =
0.0;theata_water_min = 1000.0;theata_water_max = -1000.0;
if(checker == true)
{mean_a = summation_a/8.0;mean_b = summation_b/8.0;mean_c = summation_c/8.0;
var_a = (summation_a_sq - pow(summation_a,2.0)/8.0)/7.0;
var_b = (summation_b_sq - pow(summation_b,2.0)/8.0)/7.0;
var_c = (summation_c_sq - pow(summation_c,2.0)/8.0)/7.0;
stdev_a = pow(var_a,0.5); stdev_b = pow(var_b,0.5); stdev_c = pow(var_c,0.5);
```

```
for( int w=0; w<4; w++)
{theata_water_kurt = pow(((R2_theata_water[layer_counter][w]-
theata_water)/theata_water_stdev),4.0);
summation_theata_water_kurt += theata_water_kurt;
theata_water_skew = pow(((R2_theata_water[layer_counter][w]-
theata_water)/theata_water_stdev),3.0);
summation_theata_water_skew += theata_water_skew;
if(theata_water_min > R2_theata_water[layer_counter][w])
theata_water_min = R2_theata_water[layer_counter][w];
if(theata_water_max < R2_theata_water[layer_counter][w])
theata_water_max = R2_theata_water[layer_counter][w];
if(max_a < Rosenblueth1[layer_counter][0][w])
max_a = Rosenblueth1[layer_counter][0][w];
if(max_b < Rosenblueth1[layer_counter][1][w])
max_b = Rosenblueth1[layer_counter][1][w];
if(max_c < Rosenblueth1[layer_counter][2][w])
max_c = Rosenblueth1[layer_counter][2][w];
if(min_a > Rosenblueth1[layer_counter][0][w])
min_a = Rosenblueth1[layer_counter][0][w];
if(min_b > Rosenblueth1[layer_counter][1][w])
min_b = Rosenblueth1[layer_counter][1][w];
if(min_c > Rosenblueth1[layer_counter][2][w])
min_c = Rosenblueth1[layer_counter][2][w];}
theata_water_skew = (1/7.0)*summation_theata_water_skew;
theata_water_kurt = ((1/7.0)*summation_theata_water_kurt)-3.0;
SWCC_AM[layer_counter] = mean_a;SWCC_BM[layer_counter] = mean_b;
SWCC_CM[layer_counter] = mean_c;SWCC_AV[layer_counter] = var_a;
SWCC_BV[layer_counter] = var_b;SWCC_CV[layer_counter] = var_c;
```

```
SWCC_AS[layer_counter] = stdev_a;SWCC_BS[layer_counter] = stdev_b;
SWCC_CS[layer_counter] = stdev_c;SWCC_AMax[layer_counter] = max_a;
SWCC_BMax[layer_counter] = max_b;SWCC_CMax[layer_counter] = max_c;
SWCC_AMin[layer_counter] = min_a;SWCC_BMin[layer_counter] = min_b;
SWCC_CMin[layer_counter] = min_c;}
else{for( int w=0; w<2; w++)
{theata_water_kurt = pow(((R2_theata_water[layer_counter][w]-
theata_water)/theata_water_stdev),4.0);
summation_theata_water_kurt += theata_water_kurt;
theata_water_skew = pow(((R2_theata_water[layer_counter][w]-
theata_water)/theata_water_stdev),3.0);
summation_theata_water_skew += theata_water_skew;
if(theata_water_min > R2_theata_water[layer_counter][w])
theata_water_min = R2_theata_water[layer_counter][w];
if(theata_water_max < R2_theata_water[layer_counter][w])
theata_water_max = R2_theata_water[layer_counter][w];}
theata_water_skew = summation_theata_water_skew;
theata_water_kurt = (summation_theata_water_kurt)-3.0;}}
//Degree of Saturation
Rosen_theata_sat = 1.0;Rosen_theata_water = 1.0;degree_sat_sq = 0.0;summation_degree_sat =
0.0;
summation_degree_sat_sq = 0.0;R2_theata_water_dsat = 0.0;R2_theata_sat_dsat = 0.0;
for(int i=1; i<=4; i++)
{R2_theata_water_dsat = theata_water + Rosen_theata_water* theata_water_stdev;
R2_theata_sat_dsat = theata_sat + Rosen_theata_sat* theata_sat_stdev;
degree_sat_mean1 = (R2_theata_water_dsat / R2_theata_sat_dsat) *100;
if(degree_sat_mean1 > 100.0)
degree_sat_mean1 = 100.0;
```

```
if(degree_sat_mean1 < 0.0)

degree_sat_mean1 = 0.0;

degree_sat_sq = degree_sat_mean1*degree_sat_mean1;

summation_degree_sat += degree_sat_mean1;

summation_degree_sat_sq += degree_sat_sq;

R2_degree_sat[layer_counter][i-1] = degree_sat_mean1;

//modifiers

Rosen_theata_sat = -Rosen_theata_sat;

if(i%2==0)

Rosen_theata_water = -Rosen_theata_water;}

degree_sat_mean1 = summation_degree_sat/4.0;

degree_sat_var1 = (summation_degree_sat_sq - pow(summation_degree_sat,2.0)/4.0)/3.0;

degree_sat_stdev1 = pow(degree_sat_var1,0.5);degree_sat_min1 = 1000.0;degree_sat_max1 = -

100.0;summation_degree_sat_skew = 0.0; summation_degree_sat_kurt = 0.0;

for(int f=0; f<4;f++)

{degree_sat_skew1 = pow(((R2_degree_sat[layer_counter][f]-

degree_sat_mean1)/degree_sat_stdev1),3.0);

summation_degree_sat_skew += degree_sat_skew1;

degree_sat_kurt1 = pow(((R2_degree_sat[layer_counter][f]-

degree_sat_mean1)/degree_sat_stdev1),4.0);

summation_degree_sat_kurt += degree_sat_kurt1;

if(degree_sat_min1 > R2_degree_sat[layer_counter][f])

degree_sat_min1 = R2_degree_sat[layer_counter][f];

if(degree_sat_max1 < R2_degree_sat[layer_counter][f])

degree_sat_max1 = R2_degree_sat[layer_counter][f];}

degree_sat_skew1 = (1/3.0)*summation_degree_sat_skew;

degree_sat_kurt1 = ((1/3.0)*summation_degree_sat_kurt)-3.0;

//Optimum Moisture Content Storage
```

```
wopt_M[layer_counter] = opt_moisture_mean; wopt_V[layer_counter] = wopt_var;
wopt_S[layer_counter] = wopt_stdev;wopt_Skew[layer_counter] = wopt_skew;
wopt_Kurt[layer_counter] = wopt_kurt;wopt_Min[layer_counter] = wopt_min;
wopt_Max[layer_counter] = wopt_max;
//Dry Unit Weight Storage
gamma_dry_M[layer_counter] = gamma_dry_mean;gamma_dry_V[layer_counter] =
gamma_dry_var;gamma_dry_S[layer_counter] = gamma_dry_stdev;
gamma_dry_Skew[layer_counter] = gamma_dry_skew; gamma_dry_Kurt[layer_counter] =
gamma_dry_kurt;gamma_dry_Min[layer_counter] = gamma_dry_min;
gamma_dry_Max[layer_counter] = gamma_dry_max;}
//Saturated Volumetric Water Content Storage
Theata_SM[layer_counter] = theata_sat;Theata_SV[layer_counter] = theata_sat_var;
Theata_SS[layer_counter] = theata_sat_stdev;Theata_SSkew[layer_counter] = theata_sat_skew;
Theata_SKurt[layer_counter] = theata_sat_kurt;
//Volumetric Water Content Storage
Theata_WM[layer_counter] = theata_water; Theata_WV[layer_counter] = theata_water_var;
Theata_WS[layer_counter] = theata_water_stdev; Theata_WSkew[layer_counter] =
theata_water_skew; Theata_WKurt[layer_counter] = theata_water_kurt;
//Degree of Saturation Storage
degree_sat_mean[layer_counter] = degree_sat_mean1; degree_sat_var[layer_counter] =
degree_sat_var1; degree_sat_stdev[layer_counter] = degree_sat_stdev1;
degree_sat_skew[layer_counter] = degree_sat_skew1; degree_sat_kurt[layer_counter] =
degree_sat_kurt1; degree_sat_Min[layer_counter] = degree_sat_min1;
degree_sat_Max[layer_counter] = degree_sat_max1;
//Optimum Saturation Storage
opt_sat_mean[layer_counter] = opt_sat_mean1; opt_sat_var[layer_counter] = opt_sat_var1;
opt_sat_stdev[layer_counter] = opt_sat_stdev1; opt_sat_skew[layer_counter] = opt_sat_skew1;
opt_sat_kurt[layer_counter] = opt_sat_kurt1; opt_sat_min[layer_counter] = opt_sat_min1;
```

```
opt_sat_max[layer_counter] = opt_sat_max1;
//Fenv information
Rosen_Fenv_wPI = 1.0; Rosen_Fenv_degree_sat = 1.0; Rosen_Fenv_opt_sat = 1.0;
R2_Fenv_wPI = 0.0; R2_Fenv_dsat = 0.0; R2_Fenv_osat = 0.0; summation_Fenv = 0.0;
summation_Fenv_sq = 0.0; Fenv_sq = 0.0;
for(int i=1; i<=8; i++)
{R2_Fenv_wPI = wPI_M[layer_counter] + Rosen_Fenv_wPI*wPI_S[layer_counter];
if(R2_Fenv_wPI < 0)
R2_Fenv_wPI= 0.0;
R2_Fenv_dsat = degree_sat_mean[layer_counter] +
Rosen_Fenv_degree_sat*degree_sat_stdev[layer_counter];
if(R2_Fenv_dsat < 0)
R2_Fenv_dsat = 0.0;
if(R2_Fenv_dsat > 100)
R2_Fenv_dsat = 100.0;
R2_Fenv_osat = opt_sat_mean[layer_counter] +
Rosen_Fenv_opt_sat*opt_sat_stdev[layer_counter];
if(R2_Fenv_osat < 0)
R2_Fenv_osat = 0.0;
if(R2_Fenv_osat > 100.0)
R2_Fenv_osat = 100.0;
Fenv_term1 = (-0.6-1.87194*exp(-R2_Fenv_wPI));
Fenv_term2 = 0.8+0.08*pow(R2_Fenv_wPI,0.5);
Fenv_term3 = pow((11.96518-10.19111*exp(-R2_Fenv_wPI)),0.5);
Fenv_term4 = ((R2_Fenv_dsat-R2_Fenv_osat)/100);
Fenv_denom = 1+ exp(log(-Fenv_term2/pow(Fenv_term1,-1.0))+ Fenv_term3*Fenv_term4);
powerproduct = 1.002*(pow(Fenv_term1,-1.0)+(Fenv_term2-pow(Fenv_term1,-
1.0))/Fenv_denom);
```

```
Fenv_mean1 = pow(10,powerproduct);

Fenv_sq = Fenv_mean1 * Fenv_mean1;

summation_Fenv += Fenv_mean1;

summation_Fenv_sq +=Fenv_sq;

R2_Fenv[layer_counter][i-1] = Fenv_mean1;

//modifers

Rosen_Fenv_opt_sat = -Rosen_Fenv_opt_sat;

if(i%2==0)

Rosen_Fenv_degree_sat = -Rosen_Fenv_degree_sat;

if(i%4==0)

Rosen_Fenv_wPI = -Rosen_Fenv_wPI;}

Fenv_mean1 = summation_Fenv/8.0;

Fenv_var1 = (summation_Fenv_sq - pow(summation_Fenv,2.0)/8.0)/7.0; Fenv_stdev1 =

pow(Fenv_var1,0.5);Fenv_min1 = 100.0;Fenv_max1 = -1.0;summation_Fenv_skew =

0.0;summation_Fenv_kurt = 0.0;

for(int f=0; f<8;f++)

{Fenv_skew1 = pow(((R2_Fenv[layer_counter][f]-Fenv_mean1)/Fenv_stdev1),3.0);

summation_Fenv_skew += Fenv_skew1;

Fenv_kurt1 = pow(((R2_Fenv[layer_counter][f]-Fenv_mean1)/Fenv_stdev1),4.0);

summation_Fenv_kurt += Fenv_kurt1;

if(Fenv_min1 > R2_Fenv[layer_counter][f])

Fenv_min1 = R2_Fenv[layer_counter][f];

if(Fenv_max1 < R2_Fenv[layer_counter][f])

Fenv_max1 = R2_Fenv[layer_counter][f];}

Fenv_skew1 = (1/7.0)*summation_Fenv_skew;

Fenv_kurt1 = ((1/7.0)*summation_Fenv_kurt)-3.0;

Fenv_Mean[layer_counter] = Fenv_mean1; Fenv_Var[layer_counter] = Fenv_var1;

Fenv_Stdev[layer_counter] = Fenv_stdev1; Fenv_Skew[layer_counter] = Fenv_skew1;
```

```
Fenv_Kurt[layer_counter] = Fenv_kurt1; Fenv_Min[layer_counter] = Fenv_min1;
Fenv_Max[layer_counter] = Fenv_max1;
// Mropt
if((level[layer_counter] == true) && (Level_a[layer_counter] == "Level_1"))
{Mropt_mean1 = Mropt_Mean[layer_counter]; Mropt_var1 = Mropt_Var[layer_counter];
Mropt_stdev1 = Mropt_Stdev[layer_counter]; Mropt_skew1 = 0; Mropt_kurt1 = 0; Mropt_min1 =
Mropt_Min[layer_counter]; Mropt_max1 = Mropt_Max[layer_counter];}
else if(Level_a[layer_counter] == "Level_1a")
{Rosen_Mropt_CBR = 1.0; R2_Mropt_CBR = 0.0; Mropt_sq = 0.0;Mropt_sq_mean = 0.0;
summation_Mropt = 0.0; summation_Mropt_sq = 0.0;
for(int i=1; i<=2; i++){
R2_Mropt_CBR = CBR_M[layer_counter] + Rosen_Mropt_CBR*CBR_S[layer_counter];
R2_Mropt_CBR = 2555*pow(R2_Mropt_CBR,0.64);
Mropt_mean1 = R2_Mropt_CBR*(2.11-2.78*pow(10,-5.0)*R2_Mropt_CBR);
Mropt_sq = Mropt_mean1 * Mropt_mean1;
summation_Mropt += Mropt_mean1;
summation_Mropt_sq += Mropt_sq;
R2_Mropt[layer_counter][i-1] = Mropt_mean1;
//modifer
Rosen_Mropt_CBR = -Rosen_Mropt_CBR;}
Mropt_mean1 = summation_Mropt/2.0;
Mropt_var1 = (summation_Mropt_sq - pow(summation_Mropt,2.0)/2.0);
Mropt_stdev1 = pow(Mropt_var1,0.5); Mropt_min1 = 1000000000000.0; Mropt_max1 = -1.0;
summation_Mropt_skew = 0.0; summation_CBR_skew = 0.0;summation_Mropt_kurt = 0.0;
summation_CBR_kurt = 0.0;
for(int f=0; f<2;f++)
{Mropt_skew1 = pow(((R2_Mropt[layer_counter][f]-Mropt_mean1)/Mropt_stdev1),3.0);
summation_Mropt_skew += Mropt_skew1;
```

```
Mropt_kurt1 = pow(((R2_Mropt[layer_counter][f]-Mropt_mean1)/Mropt_stdev1),2.0);
summation_Mropt_kurt += Mropt_kurt1;
if(Mropt_min1 > R2_Mropt[layer_counter][f])
Mropt_min1 = R2_Mropt[layer_counter][f];
if(Mropt_max1 < R2_Mropt[layer_counter][f])
Mropt_max1 = R2_Mropt[layer_counter][f];}
Mropt_skew1 = summation_Mropt_skew;
Mropt_kurt1 = (summation_Mropt_kurt)-3.0;}
else
{summation_CBR = 0.0;summation_CBR_sq = 0.0;CBR_sq = 0.0; CBR1 = 0.0;
Rosen_Mropt_D60 = 1.0; Rosen_Mropt_wPI = 1.0; R2_Mropt_D60 = 0.0; R2_Mropt_wPI = 0.0;
Mropt_sq = 0.0; summation_Mropt = 0.0; summation_Mropt_sq = 0.0;
if(wPI_M[layer_counter] == 0.00)
{for(int i=1; i<=2.0; i++)
{R2_Mropt_D60 = D60_M[layer_counter] + Rosen_Mropt_D60*D60_S[layer_counter];
if(R2_Mropt_D60 <0.0)
R2_Mropt_D60 = 0.0;
CBR1 = 28.09*pow(R2_Mropt_D60,0.358);
if(R2_Mropt_D60 < 0.01)
CBR1 = 5.0;
if(R2_Mropt_D60 > 30.0)
CBR1 = 95.0;
Mropt_mean1 = 2555*pow(CBR1,0.64)*(2.11-2.78*pow(10,-5.0)*2555*pow(CBR1,0.64));
CBR_sq_mean = CBR1 * CBR1;
Mropt_sq = Mropt_mean1 * Mropt_mean1;
summation_CBR +=CBR1; summation_CBR_sq += CBR_sq_mean;
summation_Mropt += Mropt_mean1; summation_Mropt_sq += Mropt_sq;
R2_Mropt[layer_counter][i-1] = Mropt_mean1; R2_CBR[layer_counter][i-1] = CBR1;
```

```
//modifer
Rosen_Mropt_D60 = -Rosen_Mropt_D60;}}
else
{for(int i=1; i<=2; i++)
{R2_Mropt_wPI = wPI_M[layer_counter] + Rosen_Mropt_wPI*wPI_S[layer_counter];
if(R2_Mropt_wPI<0)
R2_Mropt_wPI = 0.0;
if(R2_Mropt_wPI>100.0)
R2_Mropt_wPI = 100.0;
CBR1 = 75/(1+0.728*R2_Mropt_wPI);
Mropt_mean1 = 2555*pow(CBR1,0.64)*(2.11-2.78*pow(10,-5.0)*2555*pow(CBR1,0.64));
Mropt_sq = Mropt_mean1 * Mropt_mean1;
CBR_sq_mean = CBR1 * CBR1;
summation_CBR +=CBR1; summation_CBR_sq += CBR_sq_mean; summation_Mropt +=
Mropt_mean1; summation_Mropt_sq += Mropt_sq;R2_Mropt[layer_counter][i-1] =
Mropt_mean1; R2_CBR[layer_counter][i-1] = CBR1;
//modifer
Rosen_Mropt_wPI = -Rosen_Mropt_wPI;
}}}
if(level[layer_counter]==false)
{CBR_mean = summation_CBR/2.0;Mropt_mean1 = summation_Mropt/2.0;
Mropt_var1 = (summation_Mropt_sq - pow(summation_Mropt,2.0)/2.0);
Mropt_stdev1 = pow(Mropt_var1,0.5); CBR_var = (summation_CBR_sq -
pow(summation_CBR,2.0)/2.0); CBR_stdev = pow(CBR_var,0.5);
Mropt_min1 = 1000000000000.0; Mropt_max1 = -1.0;
CBR_max = -1.0; CBR_min = 1000.0; summation_Mropt_skew = 0.0; summation_CBR_skew =
0.0; summation_Mropt_kurt = 0.0; summation_CBR_kurt = 0.0;
for(int f=0; f<2;f++)
```

```
{Mropt_skew1 = pow(((R2_Mropt[layer_counter][f]-Mropt_mean1)/Mropt_stdev1),3.0);

summation_Mropt_skew += Mropt_skew1;

Mropt_kurt1 = pow(((R2_Mropt[layer_counter][f]-Mropt_mean1)/Mropt_stdev1),2.0);

summation_Mropt_kurt += Mropt_kurt1;

if(Mropt_min1 > R2_Mropt[layer_counter][f])

Mropt_min1 = R2_Mropt[layer_counter][f];

if(Mropt_max1 < R2_Mropt[layer_counter][f])

Mropt_max1 = R2_Mropt[layer_counter][f];

CBR_skew = pow(((R2_CBR[layer_counter][f]-CBR_mean)/CBR_stdev),3.0);

summation_CBR_skew += CBR_skew;

CBR_kurt = pow(((R2_CBR[layer_counter][f]-CBR_mean)/CBR_stdev),2.0);

summation_CBR_kurt += CBR_kurt;

if(CBR_min > R2_CBR[layer_counter][f])

CBR_min = R2_CBR[layer_counter][f];

if(CBR_max < R2_CBR[layer_counter][f])

CBR_max = R2_CBR[layer_counter][f];}

Mropt_skew1 = summation_Mropt_skew;Mropt_kurt1 = (summation_Mropt_kurt)-3.0;

CBR_skew = summation_CBR_skew;CBR_kurt = (summation_CBR_kurt)-3.0;}

//Mr Optimum

Mropt_Mean[layer_counter] = Mropt_mean1; Mropt_Var[layer_counter] = Mropt_var1;

Mropt_Stdev[layer_counter] = Mropt_stdev1; Mropt_Skew[layer_counter] = Mropt_skew1;

Mropt_Kurt[layer_counter] = Mropt_kurt1; Mropt_Min[layer_counter] = Mropt_min1;

Mropt_Max[layer_counter] = Mropt_max1;

//CBR Storage

CBR_M[layer_counter] = CBR_mean; CBR_V[layer_counter] = CBR_var;

CBR_S[layer_counter] = CBR_stdev; CBR_Skew[layer_counter] = CBR_skew;

CBR_Kurt[layer_counter] = CBR_kurt; CBR_Min[layer_counter] = CBR_min;

CBR_Max[layer_counter] = CBR_max;
```

```
// Mr equilibrium
Rosen_Mreq_Fenv = 1.0; Rosen_Mreq_Mropt = 1.0; R2_Mreq_Fenv = 0.0; R2_Mreq_Mropt =
0.0; Mreq_sq = 0.0; summation_Mreq = 0.0; summation_Mreq_sq = 0.0;
for(int i=1; i<=4; i++)
{R2_Mreq_Fenv = Fenv_Mean[layer_counter] + Rosen_Mreq_Fenv*Fenv_Stdev[layer_counter];
if(R2_Mreq_Fenv < 0.20)
R2_Mreq_Fenv = 0.20;
R2_Mreq_Mropt = Mropt_Mean[layer_counter] +
Rosen_Mreq_Mropt*Mropt_Stdev[layer_counter];
Mreq_mean1 = log(R2_Mreq_Mropt*R2_Mreq_Fenv)/log(10.0);
Mreq_sq = Mreq_mean1 * Mreq_mean1; summation_Mreq += Mreq_mean1;
summation_Mreq_sq += Mreq_sq; R2_Mreq[layer_counter][i-1] = Mreq_mean1;
//modifers
if(i%2==0)
Rosen_Mreq_Fenv = -Rosen_Mreq_Fenv;
Rosen_Mreq_Mropt = -Rosen_Mreq_Mropt; }
Mreq_mean1 = summation_Mreq/4.0;
Mreq_var1 = (summation_Mreq_sq - pow(summation_Mreq,2.0)/4.0)/3.0;
Mreq_stdev1 = pow(Mreq_var1,0.5);Mreq_min1 = 1000000000000.0; Mreq_max1 = -1.0;
summation_Mreq_skew = 0.0;summation_Mreq_kurt = 0.0;
for(int f=0; f<4;f++)
{Mreq_skew1 = pow(((R2_Mreq[layer_counter][f]-Mreq_mean1)/Mreq_stdev1),3.0);
summation_Mreq_skew += Mreq_skew1;
Mreq_kurt1 = pow(((R2_Mreq[layer_counter][f]-Mreq_mean1)/Mreq_stdev1),4.0);
summation_Mreq_kurt += Mreq_kurt1;
if(Mreq_min1 > R2_Mreq[layer_counter][f])
Mreq_min1 = R2_Mreq[layer_counter][f];
if(Mreq_max1 < R2_Mreq[layer_counter][f])
```

```
Mreq_max1 = R2_Mreq[layer_counter][f];}
Mreq_skew1 = (1/3.0)*summation_Mreq_skew;
Mreq_kurt1 = ((1/3.0)*summation_Mreq_kurt)-3.0;
Mreq_Mean[layer_counter] = Mreq_mean1; Mreq_Var[layer_counter] = Mreq_var1;
Mreq_Stdev[layer_counter] = Mreq_stdev1; Mreq_Skew[layer_counter] = Mreq_skew1;
Mreq_Kurt[layer_counter] = Mreq_kurt1; Mreq_Min[layer_counter] = Mreq_min1;
Mreq_Max[layer_counter] = Mreq_max1;}
if(Output_Sim == true)
{//Precipitation Output
ofstream output_P;
output_P.open("Precipitation_Rosenblueth_2_Point.txt");
for (int j=0; j<4096;j++)
output_P << Rosenblueth2P[j] << endl;
output_P.close();
//Annual Heat Index Output
ofstream output_T;
output_T.open("Temperature_Rosenblueth_2_Point.txt");
for (int j=0; j<4096;j++)
output_T << Rosenblueth2Temp[j] << endl;
output_T.close();
//PE outputs
ofstream output_PE;
output_PE.open("PE_Rosenblueth_2_Point.txt");
for (int j=0; j<8192;j++)
output_PE << Rosenblueth2PE[j] << endl;
output_PE.close();
//TMI output
ofstream output_TMI;
```

```
output_TMI.open("TMI_Rosenblueth_2_Point.txt");
for (int i=0;i<4;i++)
output_TMI << RosenbluethTMI[i] << endl;
output_TMI.close();
//Output Suction
ofstream output_Suction;
output_Suction.open("Rosenblueth_2Point_Suction.txt");
for( int w=0; w<4; w++)
{for(int layer =0;layer<Num_layer;layer++){
output_Suction << Rosenblueth2Suction[layer][w] << "\t";}
output_Suction << endl;}
output_Suction.close();}
cout << "Rosenblueth 2 Point" << endl;}
else if (Check == 2){cout << "Initializing Variables" << endl;
//Rosenblueth 3-point Information
double January_R, February_R, March_R, April_R, May1_R, June_R, July_R, August_R,
September_R, October_R, November_R, December_R,theata_sat_max,
theata_sat_min,theata_sat_alpha, theata_sat_beta;
double Hy_PER, January_PER, February_PER, March_PER, April_PER, May1_PER, June_PER,
July_PER, August_PER, September_PER, October_PER, November_PER, December_PER;
double suction_TMI_Num, suction_P200_Num, suction_wPI_Num, summation_suction_skew,
summation_suction_kurt,summation_suction_var;
double Rosenblueth3Suction[72][9], RosenbluethTMI[9], P200_Rosen, TMI_Rosen, wPI_Rosen,
suction, suction_sq, summation_suction, summation_suction_sq;
double *Rosenblueth3P = new double[531441]; double *Rosenblueth3Temp = new
double[531441]; double *Rosenblueth3PE = new double[1594323];
double R3_theata_sat[72][9], Rosen_gamma_dry, Rosen_Gs, theata_sat_sq,
summation_theata_sat_sq, summation_theata_sat, R3_gamma_dry1, R3_Gs;
```

```
double R3_theata_water[72][243], Rosen_theata_P200, Rosen_theata_TMI, Rosen_theata_wPI,
Rosen_theata_Suction, theata_water_sq, summation_theata_water_sq, summation_theata_water,
R3_P200_theata_water, R3_TMI_theata_water,  R3_wPI_theata_water,
R3_Suction_theata_water;
double R3_degree_sat[72][9], Rosen_theata_sat, Rosen_theata_water, degree_sat_sq,
summation_degree_sat, summation_degree_sat_sq, degree_sat_sq_mean, R3_theata_sat_dsat,
R3_theata_water_dsat, summation_degree_sat_skew, summation_degree_sat_kurt;
double R3_opt_sat[72][27], Rosen_opt_wopt, Rosen_opt_gamma, Rosen_opt_Gs,
Rosen_opt_P20, Rosen_opt_P10, Rosen_opt_P05, opt_sat_sq , summation_opt_sat,
summation_opt_sat_sq, R3_P20, R3_P10, R3_P05, R3_opt_wopt, R3_opt_gamma, R3_opt_Gs,
summation_opt_sat_skew, summation_opt_sat_kurt;
double R3_gamma_dry[72][27], Rosen_gamma_wopt, Rosen_gamma_Gs, Rosen_gamma_Sopt,
summation_gamma_dry, summation_gamma_dry_sq, gamma_dry_sq, gamma_dry_sq_mean,
R3_gamma_wopt, R3_gamma_Gs, R3_gamma_Sopt, R3_theata_sat_water,
Rosen_theata_sat_water;
double R3_wopt[72][81], Rosen_wopt_wPIadj, Rosen_wopt_P15, Rosen_wopt_P40,
Rosen_wopt_P60, Rosen_wopt_D60, summation_wopt, summation_wopt_sq, wopt_sq,
R3_wopt_P15, R3_wopt_P40, R3_wopt_P60, R3_wopt_D60;
double R3_PIadj[72][3], Rosen_PIadj_P200, PIadj_sq, summation_PIadj, summation_PIadj_sq,
R3_PIadj_P200;
double R3_wPIadj[72][9], Rosen_wPIadj_PIadj, Rosen_wPIadj_P200, wPIadj_sq,
summation_wPIadj, summation_wPIadj_sq, R3_wPIadj_PIadj, R3_wPIadj_P200, R3_wPIadj1;
double R3_Fenv[72][27], Rosen_Fenv_wPI, Rosen_Fenv_degree_sat, Rosen_Fenv_opt_sat,
summation_Fenv, summation_Fenv_sq, Fenv_sq, summation_Fenv_kurt, summation_Fenv_skew,
R3_Fenv_wPI, R3_Fenv_dsat, R3_Fenv_osat;
double R3_Mropt[72][3], Rosen_Mropt_CBR, Rosen_Mropt_D60, Rosen_Mropt_wPI, Mropt_sq,
summation_Mropt, summation_Mropt_sq, summation_Mropt_kurt, summation_Mropt_skew,
R3_Mropt_CBR, R3_Mropt_D60, R3_Mropt_wPI;
```

```
double R3_Mreq[72][9], Rosen_Mreq_Fenv, Rosen_Mreq_Mropt, Mreq_sq, summation_Mreq,
summation_Mreq_sq, summation_Mreq_kurt, summation_Mreq_skew, R3_Mreq_Fenv,
R3_Mreq_Mropt;
double R3_CBR[72][9], summation_CBR, summation_CBR_sq, CBR_sq, CBR1,
Rosen_theata_af, Rosen_theata_bf, Rosen_theata_cf, R3_sat_theata_water;
double theata_water_min, theata_water_max, theata_water_alpha, theata_water_beta;
double wopt_var, wopt_stdev, wopt_skew, wopt_kurt, wopt_min, wopt_max, wopt_alpha,
wopt_beta; bool checker; double Rosenblueth1[72][3][9];
double mean_a, mean_b, mean_c; double summation_a, summation_b, summation_c,
summation_a_sq, summation_b_sq, summation_c_sq;
double var_a, var_b, var_c, stdev_a, stdev_b, stdev_c, min_a, min_b, min_c, max_a, max_b,
max_c;
//Initializing Variables
suction = 0.0; suction_sq = 0.0; summation_suction = 0.0; summation_suction_sq = 0.0;
summation_suction_skew = 0.0; summation_suction_kurt = 0.0; summation_suction_var = 0.0;
P_skew = 0; summation_P_skew =0; P_kurt = 0;summation_P_kurt = 0; Hy_skew = 0;
summation_Hy_skew = 0;Hy_kurt = 0;summation_Hy_kurt = 0;PE_skew = 0;
summation_PE_skew = 0;PE_kurt = 0;summation_PE_kurt = 0;TMI_skew = 0;
summation_TMI_skew = 0; TMI_kurt = 0; summation_TMI_kurt = 0; Jan_P = 1;Feb_P = 1;
Mar_P = 1;Apr_P = 1; May_P = 1;Jun_P = 1;Jul_P = 1;Aug_P = 1;Sep_P = 1;Oct_P = 1;Nov_P =
1;Dec_P = 1;summation_Pone = 0;summation_Pone_sq = 0;Pone = 0;Pone_sq = 0;January_R = 0;
February_R = 0;March_R = 0;April_R = 0;May1_R = 0;June_R = 0;July_R = 0;August_R = 0;
September_R = 0; October_R = 0; November_R = 0; December_R = 0;Hy_PER = 0;January_PER
= 0; February_PER = 0;March_PER = 0; April_PER = 0; May1_PER = 0; June_PER = 0;
July_PER = 0; August_PER = 0;September_PER = 0; October_PER = 0; November_PER = 0;
December_PER = 0; Jan_T = 1; Feb_T = 1;Mar_T = 1; Apr_T = 1; May_T = 1; Jun_T = 1; Jul_T
= 1; Aug_T = 1; Sep_T = 1;Oct_T = 1; Nov_T = 1; Dec_T = 1; summation_Hy = 0;
summation_Hy_sq = 0; Hy = 0; Hy_sq = 0;  Hy_PE = 1; Jan_PE = 1; Feb_PE = 1;Mar_PE = 1;
```

```
Apr_PE = 1;May_PE = 1; Jun_PE = 1;Jul_PE = 1;Aug_PE = 1;Sep_PE = 1;Oct_PE = 1;Nov_PE
= 1;Dec_PE = 1;summation_PE = 0;summation_PE_sq = 0;PE = 0;PE_sq = 0;TMI_Pi = 1;
TMI_PEi = 1;summation_TMI = 0;TMI = 0;summation_TMI_sq = 0;CBR_Summation = 0;
cout << "\nStarting TMI calculations for " << location << endl;
// Precipitation Mean, Variance, Skewness, Kurtosis Calculations
for (int i=1; i<=531441;i++)
{January_P = (JanP[0] + (Jan_P * JanP[2]));
if (January_P < 0)
January_P = 0;
February_P = (FebP[0] + (Feb_P * FebP[2]));
if(February_P < 0)
February_P = 0;
March_P = (MarP[0] + (Mar_P * MarP[2]));
if (March_P < 0)
March_P = 0;
April_P = (AprP[0] + (Apr_P * AprP[2]));
if(April_P < 0)
April_P = 0;
May1_P = (MayP[0] + (May_P * MayP[2]));
if(May1_P < 0)
May1_P = 0;
June_P = (JunP[0] + (Jun_P * JunP[2]));
if(June_P < 0)
June_P = 0;
July_P = (JulP[0] + (Jul_P * JulP[2]));
if(July_P < 0)
July_P = 0;
August_P = (AugP[0] + (Aug_P * AugP[2]));
```

```
if(August_P < 0)

August_P = 0;

September_P = (SepP[0] + (Sep_P * SepP[2]));

if(September_P < 0)

September_P = 0;

October_P = (OctP[0] + (Oct_P * OctP[2]));

if(October_P < 0)

October_P = 0;

November_P = (NovP[0] + (Nov_P * NovP[2]));

if(November_P < 0)

November_P = 0;

December_P = (DecP[0] + (Dec_P * DecP[2]));

if(December_P < 0)

December_P = 0;

Pone = January_P + February_P + March_P + April_P + May1_P + June_P + July_P + August_P

+ September_P + October_P + November_P + December_P;

Pone_sq = Pone * Pone;

summation_Pone += Pone;

summation_Pone_sq += Pone_sq;

Rosenblueth3P[i-1] = Pone;

// modifiers

Dec_P--;if(Dec_P < -1){Dec_P = 1;}

if(i% 3 == 0){Nov_P--;}if(Nov_P < -1){Nov_P = 1;}

if(i % 9 == 0){Oct_P--;}if(Oct_P < -1){Oct_P = 1;}

if(i % 27 == 0){Sep_P--;}if(Sep_P <-1){Sep_P = 1;}

if(i % 81 == 0){Aug_P--;}if(Aug_P < -1){Aug_P = 1;}

if(i % 243 == 0){Jul_P--;}if(Jul_P < -1){Jul_P = 1;}

if(i % 729 == 0){Jun_P--;}if(Jun_P < -1){Jun_P = 1;}
```

```
if(i % 2187 == 0){May_P--;}if(May_P < -1){May_P = 1;}
if(i % 6561 == 0){Apr_P--;}if(Apr_P < -1){Apr_P = 1;}
if(i % 19683 == 0){Mar_P--;}if(Mar_P < -1){Mar_P = 1;}
if(i % 59049 == 0){Feb_P--;}if(Feb_P < -1){Feb_P = 1;}
if(i % 177147 == 0){Jan_P--;}if(Jan_P < -1){Jan_P = 1;}}
P_mean = summation_Pone / 531441;
P_var = (summation_Pone_sq - pow(summation_Pone,2.0)/531441.0)/531440.0;
P_stdev = pow(P_var,0.5);P_min = 100000000000000000;P_max =0;
for( int y=0;y<531441;y++){
P_skew = pow(((Rosenblueth3P[y]-P_mean)/P_stdev),3);
summation_P_skew += P_skew;
P_kurt = pow(((Rosenblueth3P[y]-P_mean)/P_stdev),4);
summation_P_kurt +=P_kurt;
if(P_min > Rosenblueth3P[y])
P_min = Rosenblueth3P[y];
if(P_max < Rosenblueth3P[y])
P_max = Rosenblueth3P[y];}
P_skew = 0.00000188168705*summation_P_skew;
P_kurt = (0.00000188170121*summation_P_kurt)-3.00001693519403;
// Annual Heat Index Mean, Variance, Skewness, and Kurtosis Calculations
for (int i=1; i<=531441;i++)
{January_T = (JanT[0] + (Jan_T * JanT[2]));
if (January_T < 0)
January_T = 0;
January_R = pow((0.2*January_T),1.514);
February_T = (FebT[0] + (Feb_T * FebT[2]));
if(February_T < 0)
February_T = 0;
```

```
February_R = pow((0.2*February_T),1.514);
March_T = (MarT[0] + (Mar_T * MarT[2]));
if (March_T < 0)
March_T = 0;
March_R = pow((0.2*March_T),1.514);
April_T = (AprT[0] + (Apr_T * AprT[2]));
if(April_T < 0)
April_T = 0;
April_R = pow((0.2*April_T),1.514);
May1_T = (MayT[0] + (May_T * MayT[2]));
if(May1_T < 0)
May1_T = 0;
May1_R = pow((0.2*May1_T),1.514);
June_T = (JunT[0] + (Jun_T * JunT[2]));
if(June_T < 0)
June_T = 0;
June_R = pow((0.2*June_T),1.514);
July_T = (JulT[0] + (Jul_T * JulT[2]));
if(July_T < 0)
July_T = 0;
July_R = pow((0.2*July_T),1.514);
August_T = (AugT[0] + (Aug_T * AugT[2]));
if(August_T < 0)
August_T = 0;
August_R = pow((0.2*August_T),1.514);
September_T = (SepT[0] + (Sep_T * SepT[2]));
if(September_T < 0)
September_T = 0;
```

```
September_R = pow((0.2*September_T),1.514);

October_T = (OctT[0] + (Oct_T * OctT[2]));

if(October_T < 0)

October_T = 0;

October_R = pow((0.2*October_T),1.514);

November_T = (NovT[0] + (Nov_T * NovT[2]));

if(November_T < 0)

November_T = 0;

November_R = pow((0.2*November_T),1.514);

December_T = (DecT[0] + (Dec_T * DecT[2]));

if(December_T < 0)

December_T = 0;

December_R = pow((0.2*December_T),1.514);

Hy = January_R + February_R + March_R + April_R + May1_R + June_R + July_R + August_R

+ September_R + October_R + November_R + December_R;

Hy_sq = Hy * Hy;

summation_Hy += Hy;

summation_Hy_sq += Hy_sq;

Rosenblueth3Temp[i-1] = Hy;

// modifiers

Dec_T--;if(Dec_T < -1){Dec_T = 1;}

if(i% 3 == 0){Nov_T--;}if(Nov_T < -1){Nov_T = 1;}

if(i % 9 == 0){Oct_T--;}if(Oct_T < -1){Oct_T = 1;}

if(i % 27 == 0){Sep_T--;}if(Sep_T <-1){Sep_T = 1;}

if(i % 81 == 0){Aug_T--;}if(Aug_T < -1){Aug_T = 1;}

if(i % 243 == 0){Jul_T--;}if(Jul_T < -1){Jul_T = 1;}

if(i % 729 == 0){Jun_T--;}if(Jun_T < -1){Jun_T = 1;}

if(i % 2187 == 0){May_T--;}if(May_T < -1){May_T = 1;}
```

```
if(i % 6561 == 0){Apr_T--;}if(Apr_T < -1){Apr_T = 1;}

if(i % 19683 == 0){Mar_T--;}if(Mar_T < -1){Mar_T = 1;}

if(i % 59049 == 0){Feb_T--;}if(Feb_T < -1){Feb_T = 1;}

if(i % 177147 == 0){Jan_T--;}if(Jan_T < -1){Jan_T = 1;}}

Hy_mean = summation_Hy / 531441;

Hy_var = (summation_Hy_sq - pow(summation_Hy,2.0)/531441.0)/531440.0;

Hy_stdev = pow(Hy_var,0.5);Hy_min = 1000.0;Hy_max = -1.0;

//Skewness, Kurtosis, Minimum, and Maximum

for(int f=0; f<531441;f++)

{Hy_skew = pow(((Rosenblueth3Temp[f]-Hy_mean)/Hy_stdev),3);

summation_Hy_skew += Hy_skew;

Hy_kurt = pow(((Rosenblueth3Temp[f]-Hy_mean)/Hy_stdev),4);

summation_Hy_kurt += Hy_kurt;

if(Hy_min > Rosenblueth3Temp[f])

Hy_min = Rosenblueth3Temp[f];

if(Hy_max < Rosenblueth3Temp[f])

Hy_max = Rosenblueth3Temp[f];}

Hy_skew = 0.00000188168705*summation_Hy_skew;

Hy_kurt = (0.00000188170121*summation_Hy_kurt)-3.00001693519403;

//Potential Evapotranspiration Mean, Variance, Skewness, and Kurtosis Calculations

for (int i=1; i<=1594323;i++){Hy_3 = pow((Hy_mean + Hy_PE * Hy_stdev),3);

Hy_2 = pow((Hy_mean + Hy_PE * Hy_stdev),2);

apow = a0*Hy_3 + a1*Hy_2 + a2*(Hy_mean + Hy_PE * Hy_stdev) + a3;

Hy_PER = pow((10/(Hy_mean + Hy_PE * Hy_stdev)),apow);

January_PE = (JanT[0] + (Jan_PE * JanT[2]));

if (January_PE < 0)

January_PE = 0;

January_PER = Co * Hy_PER * Jan_L * pow(January_PE, apow);
```

```
February_PE = (FebT[0] + (Feb_PE * FebT[2]));
if(February_PE < 0)
February_PE = 0;
February_PER = Co * Hy_PER * Feb_L * pow(February_PE, apow);
March_PE = (MarT[0] + (Mar_PE * MarT[2]));
if (March_PE < 0)
March_PE = 0;
March_PER = Co * Hy_PER * Mar_L * pow(March_PER, apow);
April_PE = (AprT[0] + (Apr_PE * AprT[2]));
if(April_PE < 0)
April_PE = 0;
April_PER = Co * Hy_PER * Apr_L * pow(April_PE, apow);
May1_PE = (MayT[0] + (May_PE * MayT[2]));
if(May1_PE < 0)
May1_PE = 0;
May1_PER = Co * Hy_PER * May_L * pow(May1_PE, apow);
June_PE = (JunT[0] + (Jun_PE * JunT[2]));
if(June_PE < 0)
June_PE = 0;
June_PER = Co * Hy_PER * Jun_L * pow(June_PE, apow);
July_PE = (JulT[0] + (Jul_PE * JulT[2]));
if(July_PE < 0)
July_PE = 0;
July_PER = Co * Hy_PER * Jul_L * pow(July_PE, apow);
August_PE = (AugT[0] + (Aug_PE * AugT[2]));
if(August_PE < 0)
August_PE = 0;
August_PER = Co * Hy_PER * Aug_L * pow(August_PE, apow);
```

```
September_PE = (SepT[0] + (Sep_PE * SepT[2]));
if(September_PE < 0)
September_PE = 0;
September_PER = Co * Hy_PER * Sep_L * pow(September_PE, apow);
October_PE = (OctT[0] + (Oct_PE * OctT[2]));
if(October_PE < 0)
October_PE = 0;
October_PER = Co * Hy_PER * Oct_L * pow(October_PE, apow);
November_PE = (NovT[0] + (Nov_PE * NovT[2]));
if(November_PE < 0)
November_PE = 0;
November_PER = Co * Hy_PER * Nov_L * pow(November_PE, apow);
December_PE = (DecT[0] + (Dec_PE * DecT[2]));
if(December_PE < 0)
December_PE = 0;
December_PER = Co * Hy_PER * Dec_L * pow(December_PE, apow);
PE = January_PER + February_PER + March_PER + April_PER + May1_PER + June_PER +
July_PER + August_PER + September_PER + October_PER + November_PER +
December_PER;
PE_sq = PE * PE;
summation_PE += PE;
summation_PE_sq += PE_sq;
Rosenblueth3PE[i-1] = PE;
// modifiers
Dec_PE--;if(Dec_PE < -1){Dec_PE = 1;}
if(i% 3 == 0){Nov_PE--;}if(Nov_PE < -1){Nov_PE = 1;}
if(i % 9 == 0){Oct_PE--;}if(Oct_PE < -1){Oct_PE = 1;}
if(i % 27 == 0){Sep_PE--;}if(Sep_PE <-1){Sep_PE = 1;}
```

```
if(i % 81 == 0){Aug_PE--;}if(Aug_PE < -1){Aug_PE = 1;}
if(i % 243 == 0){Jul_PE--;}if(Jul_PE < -1){Jul_PE = 1;}
if(i % 729 == 0){Jun_PE--;}if(Jun_PE < -1){Jun_PE = 1;}
if(i % 2187 == 0){May_PE--;}if(May_PE < -1){May_PE = 1;}
if(i % 6561 == 0){Apr_PE--;}if(Apr_PE < -1){Apr_PE = 1;}
if(i % 19683 == 0){Mar_PE--;}if(Mar_PE < -1){Mar_PE = 1;}
if(i % 59049 == 0){Feb_PE--;}if(Feb_PE < -1){Feb_PE = 1;}
if(i % 177147 == 0){Jan_PE--;}if(Jan_PE < -1){Jan_PE = 1;}
if(i % 531441 == 0){Hy_PE--;}if(Hy_PE < -1){Hy_PE = 1;}}
PE_mean = summation_PE / 1594323;
PE_var = (summation_PE_sq - pow(summation_PE,2.0)/1594323.0)/1594322.0;
PE_stdev = pow(PE_var,0.5);PE_min = 1000.0;PE_max = -1.0;
//Skewness, Kurtosis, Minimum, and Maximum
for(int k=0;k<1594323;k++)
{PE_skew = pow(((Rosenblueth3PE[k]-PE_mean)/PE_stdev),3);
summation_PE_skew += PE_skew;
PE_kurt = pow(((Rosenblueth3PE[k]-PE_mean)/PE_stdev),4);
summation_PE_kurt += PE_kurt;
if(PE_min > Rosenblueth3PE[k])
PE_min = Rosenblueth3PE[k];
if(PE_max < Rosenblueth3PE[k])
PE_max = Rosenblueth3PE[k];}
PE_skew = 0.00000062722665*summation_PE_skew;
PE_kurt = (0.00000062722823*summation_PE_kurt)-3.00000564504107;
//Thornwaite Moisture Index Mean, Variance, Skewness, and Kurtosis Calculations
for (int i =1; i<=9;i++)
{TMI_P = P_mean + P_stdev * TMI_Pi;
TMI_PE = PE_mean + PE_stdev * TMI_PEi;
```

```
TMI = -65 + 75*(TMI_P/TMI_PE);

if(TMIconstraints == true)

{//Constraints Per 1-40D Report

if(TMI > 100)

TMI = 100;}

summation_TMI += TMI;TMI_sq = TMI * TMI; summation_TMI_sq += TMI_sq;

RosenbluethTMI[i-1] = TMI;

//modifiers

TMI_Pi--;if(TMI_Pi < -1){TMI_Pi = 1;}

if(i% 3 == 0){TMI_PEi--;}if(TMI_PEi < -1){TMI_PEi = 1;}}

TMI_mean = summation_TMI/9.0;

TMI_var = (summation_TMI_sq - pow(summation_TMI,2.0)/9.0)/8.0;

TMI_stdev = pow(TMI_var,0.5);TMI_min = 1000.0; TMI_max = -100.0;

for(int i=0; i<9; i++)

{TMI_skew = pow(((RosenbluethTMI[i]-TMI_mean)/TMI_stdev),3);

summation_TMI_skew += TMI_skew;

TMI_kurt = pow(((RosenbluethTMI[i]-TMI_mean)/TMI_stdev),4);

summation_TMI_kurt += TMI_kurt;

if(TMI_min > RosenbluethTMI[i])

TMI_min = RosenbluethTMI[i];

if(TMI_max < RosenbluethTMI[i])

TMI_max = RosenbluethTMI[i];}

TMI_skew = 0.16071428571429*summation_TMI_skew;

TMI_kurt = (0.26785714285714*summation_TMI_kurt)-4.57142857142857;

cout << "\nFinished with TMI calculations" << endl;

cout << "\nStarting layer calculations" << endl << endl;

// Matric Suction Mean, Variance, Skewness, and Kurtosis Calculations for N layers
```

```
for (int layer_counter=0; layer_counter<Num_layer; layer_counter++)
{suction_TMI_Num = 1;suction_P200_Num = 1;suction_wPI_Num = 1;suction = 0.0;suction_sq
= 0.0;summation_suction = 0.0; summation_suction_sq = 0.0;summation_suction_skew = 0.0;
summation_suction_kurt = 0.0;summation_suction_var = 0.0;
if(Layer_Type[layer_counter] == true)
{// Base Course Suction Parameters
for (int i=1; i<=9; i++)
{P200_Rosen = P200_M[layer_counter] + suction_P200_Num * P200_S[layer_counter];
if(P200_Rosen > 16.0)
P200_Rosen = 16.0;
if(P200_Rosen < 0.0)
P200_Rosen = 0.0;
TMI_Rosen = TMI_mean + suction_TMI_Num * TMI_stdev;
if(TMI_Rosen > 100.0)
TMI_Rosen = 100.0;
//Powers of P200
P200_3 = pow(P200_Rosen,3.0); P200_2 = pow(P200_Rosen,2.0);
alpha_base = -0.0016*P200_3 + 0.1106*P200_2 - 0.1135*P200_Rosen + 3.8218;
beta_base = -0.0045*P200_3 + 0.1121*P200_2 - 0.3364*P200_Rosen + 3.2358;
gamma_base = 0.00003*P200_3 - 0.0009*P200_2 + 0.0061*P200_Rosen -0.0498;
// If base course Material
suction = alpha_base + exp(beta_base + gamma_base * ( TMI_Rosen + 101.0));
suction_sq = suction * suction;
summation_suction += suction;
summation_suction_sq += suction_sq;
Rosenblueth3Suction[layer_counter][i-1] = suction;
// modifiers
suction_TMI_Num--;if(suction_TMI_Num < -1){suction_TMI_Num = 1;}
```

```
if(i% 3 == 0){suction_P200_Num--;}if(suction_P200_Num < -1){suction_P200_Num = 1;}}}
else if(wPI_M[layer_counter] == 0 && layer_counter > 0)// Calcuclates the non-base with wPI or P200
{P200_Rosen = 0;
if(P200_M[layer_counter] > 10.0){
for( int i=1; i<=9;i++)
{P200_Rosen = P200_M[layer_counter] + suction_P200_Num * P200_S[layer_counter];
if(P200_Rosen > 50.0)
P200_Rosen = 50.0;
if(P200_Rosen < 10.0)
P200_Rosen = 10.0;
TMI_Rosen = TMI_mean + suction_TMI_Num * TMI_stdev;
if(TMI_Rosen > 100.0)
TMI_Rosen = 100.0;
// Insert P200 equations
double beta_non1, gamma_non1, delta_non1;
beta_non1 = 2.56075*P200_Rosen + 393.4625;
gamma_non1 = 0.09625*P200_Rosen + 132.4875;
delta_non1 = 0.025*P200_Rosen + 14.75;
suction_mean1 = 0.3*(exp(beta_non1/(TMI_Rosen + gamma_non1))+delta_non1);
suction_sq = suction * suction;summation_suction += suction;
summation_suction_sq += suction_sq;
Rosenblueth3Suction[layer_counter][i-1] = suction;
// modifiers
suction_TMI_Num--;if(suction_TMI_Num < -1){suction_TMI_Num = 1;}
if(i% 3 == 0){suction_P200_Num--;}if(suction_P200_Num < -1){suction_P200_Num = 1;}}}
else if(P200_M[layer_counter] < 10.0)
{for (int i=1; i<=9; i++)
```

```
{P200_Rosen = P200_M[layer_counter] + suction_P200_Num * P200_S[layer_counter];
if(P200_Rosen > 16.0)
P200_Rosen = 16.0;
if(P200_Rosen < 0.0)
P200_Rosen = 0.0;
TMI_Rosen = TMI_mean + suction_TMI_Num * TMI_stdev;
if(TMI_Rosen > 100.0)
TMI_Rosen = 100.0;
//Powers of P200
P200_3 = pow(P200_Rosen,3.0);P200_2 = pow(P200_Rosen,2.0);
alpha_base = -0.0016*P200_3 + 0.1106*P200_2 - 0.1135*P200_Rosen + 3.8218;
beta_base = -0.0045*P200_3 + 0.1121*P200_2 - 0.3364*P200_Rosen + 3.2358;
gamma_base = 0.00003*P200_3 - 0.0009*P200_2 + 0.0061*P200_Rosen - 0.0498;
// If base course Material
suction = alpha_base + exp(beta_base + gamma_base * ( TMI_Rosen + 101.0));
suction_sq = suction * suction;summation_suction += suction;
summation_suction_sq += suction_sq; Rosenblueth3Suction[layer_counter][i-1] = suction;
// modifiers
suction_TMI_Num--;if(suction_TMI_Num < -1){suction_TMI_Num = 1;}
if(i% 3 == 0){suction_P200_Num--;}if(suction_P200_Num < -1){suction_P200_Num = 1;}}}}
else //if(wPI_M[layer_counter] > 0.0 && layer_counter > 0) // Calcs the non-base suction using
wPI parameters
{for (int i=1; i<=9; i++)
{wPI_Rosen = wPI_M[layer_counter] + suction_wPI_Num * wPI_S[layer_counter];
if(wPI_Rosen > 50.0)
wPI_Rosen = 50.0;
if(wPI_Rosen < 0.5)
wPI_Rosen = 0.5;
```

```
TMI_Rosen = TMI_mean + suction_TMI_Num * TMI_stdev;
if(TMI_Rosen > 100.0)
TMI_Rosen = 100.0;
// Non-base Course Suction Parameters
wPI_3 = pow(wPI_Rosen,3.0); wPI_2 = pow(wPI_Rosen,2.0);
beta_non = 0.006235897* wPI_3 - 0.779833377* wPI_2 + 36.78648521*wPI_Rosen +
501.9511878;
gamma_non = 0.000395003* wPI_3 - 0.040423118* wPI_2 + 1.454065726*wPI_Rosen +
136.4775219;
delta_non = -0.019883827* wPI_2 + 1.273583098*wPI_Rosen + 13.91243841;
// If non-base course Material
suction_mean1 = 0.3*(exp(beta_non/(TMI_Rosen + gamma_non))+ delta_non);
suction_sq = suction * suction; summation_suction += suction_mean1;
summation_suction_sq += suction_sq; Rosenblueth3Suction[layer_counter][i-1] = suction_mean1;
// modifiers
suction_TMI_Num--;if(suction_TMI_Num < -1){suction_TMI_Num = 1;}
if(i% 3 == 0){suction_wPI_Num--;}if(suction_wPI_Num < -1){suction_wPI_Num = 1;}}}
suction_mean1 = summation_suction / 9.0;
for(int i=0; i<9;i++)
{suction_var1 = pow((Rosenblueth3Suction[layer_counter][i] - suction_mean1),2.0);
summation_suction_var += suction_var1;}
suction_var1 = summation_suction_var/8.0;
suction_stdev1 = pow(suction_var1,0.5);suction_min1 = 1000000000.0;
suction_max1 = 0.0;
for(int f=0; f<9;f++)
{suction_skew1 = pow(((Rosenblueth3Suction[layer_counter][f]-
suction_mean1)/suction_stdev1),3.0);
summation_suction_skew += suction_skew1;
```

```
suction_kurt1 = pow(((Rosenblueth3Suction[layer_counter][f]-
suction_mean1)/suction_stdev1),4.0);summation_suction_kurt += suction_kurt1;
if(suction_min1 > Rosenblueth3Suction[layer_counter][f])
suction_min1 = Rosenblueth3Suction[layer_counter][f];
if(suction_max1 < Rosenblueth3Suction[layer_counter][f])
suction_max1 = Rosenblueth3Suction[layer_counter][f];}
suction_skew1 = (1/8.0)*summation_suction_skew;
suction_kurt1 = ((1/8.0)*summation_suction_kurt)-3.0;
//Stores Each Layer's statistical Suction Information
Suction_Mean[layer_counter] = suction_mean1; Suction_Variance[layer_counter] = suction_var1;
Suction_Stdev[layer_counter] = suction_stdev1; Suction_Skew[layer_counter] = suction_skew1;
Suction_Kurt[layer_counter] = suction_kurt1; Suction_Minimum[layer_counter] = suction_min1;
Suction_Maximum[layer_counter] = suction_max1;
// Optimum Saturation and Degree of Saturation information
if(level[layer_counter] == true)
{//Saturated Volumetric water content
Rosen_gamma_dry = 1.0; Rosen_Gs = 1.0; theata_sat_sq = 0.0; summation_theata_sat_sq = 0.0;
summation_theata_sat = 0.0; R3_gamma_dry1 = 0.0; R3_Gs = 0.0;
for(int i=1; i<=9; i++)
{R3_gamma_dry1 = gamma_dry_M[layer_counter] +
Rosen_gamma_dry*gamma_dry_S[layer_counter];
R3_Gs = Gs_mean[layer_counter] + Rosen_Gs*Gs_stdev[layer_counter];
theata_sat = (1.0 - (R3_gamma_dry1/(R3_Gs*gamma_water)))*100;
if(theata_sat > 100.0)
theata_sat = 100.0;
if(theata_sat < 0.0)
theata_sat = 0.0;
```

```
theata_sat_sq = theata_sat * theata_sat; summation_theata_sat += theata_sat;
summation_theata_sat_sq += theata_sat_sq; R3_theata_sat[layer_counter][i-1] = theata_sat;
//modifiers
Rosen_gamma_dry--;if(Rosen_gamma_dry < -1){Rosen_gamma_dry = 1.0;}
if(i% 3 == 0){Rosen_Gs--;}if(Rosen_Gs < -1){Rosen_Gs = 1.0;}}
theata_sat = summation_theata_sat / 9.0;
theata_sat_var = (summation_theata_sat_sq - pow(summation_theata_sat,2.0)/9.0)/8.0;
theata_sat_stdev = pow(theata_sat_var,0.5);theata_sat_min = 1000.0; theata_sat_max = -1000.0;
summation_theata_sat_skew = 0.0; summation_theata_sat_kurt = 0.0;
for( int w=0; w<9; w++)
{theata_sat_kurt = pow(((R3_theata_sat[layer_counter][w]- theata_sat)/theata_sat_stdev),4.0);
summation_theata_sat_kurt += theata_sat_kurt;
theata_sat_skew = pow(((R3_theata_sat[layer_counter][w]- theata_sat)/theata_sat_stdev),3.0);
summation_theata_sat_skew += theata_sat_skew;
if(theata_sat_min > R3_theata_sat[layer_counter][w])
theata_sat_min = R3_theata_sat[layer_counter][w];
if(theata_sat_max < R3_theata_sat[layer_counter][w])
theata_sat_max = R3_theata_sat[layer_counter][w];}
theata_sat_skew = (1/8.0)*summation_theata_sat_skew;
theata_sat_kurt = ((1/8.0)*summation_theata_sat_kurt)-3.0;
// Volumetric Water Content
Rosen_theata_sat = 1.0; Rosen_theata_Suction = 1.0; Rosen_theata_af = 1.0; Rosen_theata_bf =
1.0; Rosen_theata_cf = 1.0; theata_water_sq = 0.0; summation_theata_water_sq = 0.0;
summation_theata_water = 0.0; R3_wPI_theata_water = 0.0; R3_Suction_theata_water = 0.0;
// SWCC information
for(int i =1; i<=243; i++)
{residual = SWCC_H[layer_counter];
R3_sat_theata_water =  theata_sat + Rosen_theata_sat* theata_sat_stdev;
```

```
if(R3_sat_theata_water > 100.0)
R3_sat_theata_water = 100.0;
if(R3_sat_theata_water < 0.0)
R3_sat_theata_water = 0.0;
R3_Suction_theata_water = Suction_Mean[layer_counter] +
Rosen_theata_Suction*Suction_Stdev[layer_counter];
if(R3_Suction_theata_water < 0.0)
R3_Suction_theata_water = 0.0;
if(R3_Suction_theata_water > 1000000.0)
R3_Suction_theata_water = 1000000.0;
af = SWCC_AM[layer_counter] + Rosen_theata_af * SWCC_AS[layer_counter];
bf = SWCC_BM[layer_counter] + Rosen_theata_bf * SWCC_BS[layer_counter];
cf = SWCC_CM[layer_counter] + Rosen_theata_cf * SWCC_CS[layer_counter];
C_h = 1-(log(1+(R3_Suction_theata_water/residual))/(log(1000000.0/residual)));
theata_water =
C_h*(R3_sat_theata_water/pow(log(pow((R3_Suction_theata_water/af),bf)+exp(1.0)),cf));
if(theata_water > 100.0)
theata_water = 100.0;
if(theata_water < 0.0)
theata_water = 0.0;
theata_water_sq = theata_water * theata_water;
summation_theata_water += theata_water;
summation_theata_water_sq += theata_water_sq;
R3_theata_water[layer_counter][i-1] = theata_water;
//modifier
Rosen_theata_Suction--;if(Rosen_theata_Suction < -1){Rosen_theata_Suction = 1.0;}
if(i%3==0){Rosen_theata_sat--;}if(Rosen_theata_sat < -1){Rosen_theata_sat = 1.0;}
if(i%9==0){Rosen_theata_af--;}if(Rosen_theata_af < -1){Rosen_theata_af = 1.0;}
```

```
if(i%27==0){Rosen_theata_bf--;}if(Rosen_theata_bf < -1){Rosen_theata_bf = 1.0;}
if(i%81==0){Rosen_theata_cf--;}if(Rosen_theata_cf < -1){Rosen_theata_cf = 1.0;}}
theata_water = summation_theata_water/243.0;theata_water_var = (summation_theata_water_sq -
pow(summation_theata_water,2.0)/243.0)/242.0;theata_water_stdev = pow(theata_water_var,
0.5);theata_water_min = 1000.0;theata_water_max =-1000.0;
summation_theata_water_skew = 0.0;  summation_theata_water_kurt = 0.0;
for( int w=0; w<243; w++)
{theata_water_skew = pow(((R3_theata_water[layer_counter][w]-
theata_water)/theata_water_stdev),3.0);
theata_water_kurt = pow(((R3_theata_water[layer_counter][w]-
theata_water)/theata_water_stdev),4.0);
summation_theata_water_skew += theata_water_skew;
summation_theata_water_kurt += theata_water_kurt;
if(theata_water_min > R3_theata_water[layer_counter][w])
theata_water_min = R3_theata_water[layer_counter][w];
if(theata_water_max < R3_theata_water[layer_counter][w])
theata_water_max = R3_theata_water[layer_counter][w];}
theata_water_skew = (1.0/242.0)*summation_theata_water_skew;
theata_water_kurt = ((1.0/242.0)*summation_theata_water_kurt)-3.0;
//Degree of Saturation
Rosen_theata_sat = 1.0; Rosen_theata_water = 1.0; degree_sat_sq = 0.0; summation_degree_sat =
0.0; summation_degree_sat_sq = 0.0; R3_theata_water_dsat = 0.0;R3_theata_sat_dsat = 0.0;
for(int i=1; i<=9; i++)
{R3_theata_water_dsat = theata_water + Rosen_theata_water* theata_water_stdev;
R3_theata_sat_dsat = theata_sat + Rosen_theata_sat* theata_sat_stdev;
degree_sat_mean1 = (R3_theata_water_dsat / R3_theata_sat_dsat)*100.0;
if(degree_sat_mean1 > 100.0)
degree_sat_mean1 = 100.0;
```

```
if(degree_sat_mean1 < 0.0)
degree_sat_mean1 = 0.0;
degree_sat_sq = degree_sat_mean1*degree_sat_mean1;
summation_degree_sat += degree_sat_mean1;
summation_degree_sat_sq += degree_sat_sq;
R3_degree_sat[layer_counter][i-1] = degree_sat_mean1;
//modifiers
Rosen_theata_sat--;if(Rosen_theata_sat < -1.0){Rosen_theata_sat = 1.0;}
if(i%3==0){Rosen_theata_water--;}if(Rosen_theata_water < -1){Rosen_theata_water = 1.0;}}
degree_sat_mean1 = summation_degree_sat/9.0;
degree_sat_var1 = (summation_degree_sat_sq - pow(summation_degree_sat,2.0)/9.0)/8.0;
degree_sat_stdev1 = pow(degree_sat_var1,0.5); degree_sat_min1 = 1000.0; degree_sat_max1 = -
1.0; summation_degree_sat_skew = 0.0; summation_degree_sat_kurt = 0.0;
for(int f=0; f<9;f++)
{degree_sat_skew1 = pow(((R3_degree_sat[layer_counter][f]-
degree_sat_mean1)/degree_sat_stdev1),3.0);
summation_degree_sat_skew += degree_sat_skew1;
degree_sat_kurt1 = pow(((R3_degree_sat[layer_counter][f]-
degree_sat_mean1)/degree_sat_stdev1),4.0);
summation_degree_sat_kurt += degree_sat_kurt1;
if(degree_sat_min1 > R3_degree_sat[layer_counter][f])
degree_sat_min1 = R3_degree_sat[layer_counter][f];
if(degree_sat_max1 < R3_degree_sat[layer_counter][f])
degree_sat_max1 = R3_degree_sat[layer_counter][f];}
degree_sat_skew1 = (1/8.0)*summation_degree_sat_skew;
degree_sat_kurt1 = ((1/8.0)*summation_degree_sat_kurt)-3.0;
//Optimum Saturation
```

```
Rosen_opt_wopt = 1.0; Rosen_opt_gamma = 1.0; Rosen_opt_Gs = 1.0; opt_sat_sq = 0.0;
summation_opt_sat = 0.0; summation_opt_sat_sq = 0.0;R3_opt_wopt = 0.0; R3_opt_gamma =
0.0; R3_opt_Gs = 0.0;
for(int i=1; i<=27; i++)
{R3_opt_wopt = wopt_M[layer_counter] +Rosen_opt_wopt*wopt_S[layer_counter];
R3_opt_gamma = gamma_dry_M[layer_counter] +
Rosen_opt_gamma*gamma_dry_S[layer_counter];
R3_opt_Gs = Gs_mean[layer_counter] + Rosen_opt_Gs*Gs_stdev[layer_counter];
opt_sat_mean1 = R3_opt_wopt/((gamma_water/R3_opt_gamma)-(1/R3_opt_Gs));
if(opt_sat_mean1 > 100.0)
opt_sat_mean1 = 100.0;
if(opt_sat_mean1 < 0.0)
opt_sat_mean1 = 0.0;
opt_sat_sq = opt_sat_mean1 * opt_sat_mean1;
summation_opt_sat += opt_sat_mean1;
summation_opt_sat_sq += opt_sat_sq;
R3_opt_sat[layer_counter][i-1] = opt_sat_mean1;
//modifiers
Rosen_opt_Gs--;if(Rosen_opt_Gs < -1){Rosen_opt_Gs = 1.0;}
if(i%3==0){Rosen_opt_gamma--;}if(Rosen_opt_gamma < -1){Rosen_opt_gamma = 1.0;}
if(i%9==0){Rosen_opt_wopt--;}if(Rosen_opt_wopt < -1){Rosen_opt_wopt = 1.0;}}
opt_sat_mean1 = summation_opt_sat/27.0;
opt_sat_var1 = (summation_opt_sat_sq - pow(summation_opt_sat,2.0)/27.0)/26.0;
opt_sat_stdev1 = pow(opt_sat_var1,0.5); opt_sat_min1 = 1000.0; opt_sat_max1 = -1.0;
summation_opt_sat_skew = 0.0; summation_opt_sat_kurt = 0.0;
for(int f=0; f<27;f++)
{opt_sat_skew1 = pow(((R3_opt_sat[layer_counter][f]-opt_sat_mean1)/opt_sat_stdev1),3.0);
summation_opt_sat_skew += opt_sat_skew1;
```

```
opt_sat_kurt1 = pow(((R3_opt_sat[layer_counter][f]-opt_sat_mean1)/opt_sat_stdev1),4.0);

summation_opt_sat_kurt += opt_sat_kurt1;

if(opt_sat_min1 > R3_opt_sat[layer_counter][f])

opt_sat_min1 = R3_opt_sat[layer_counter][f];

if(opt_sat_max1 < R3_opt_sat[layer_counter][f])

opt_sat_max1 = R3_opt_sat[layer_counter][f];}

opt_sat_skew1 = (1/26.0)*summation_opt_sat_skew;

opt_sat_kurt1 = ((1/26.0)*summation_opt_sat_kurt)-3.0;}

else // Level 2 and 3

{if(Names[layer_counter] == "A-1-a")

residual = 100;

else if(Names[layer_counter] == "A-1-b")

residual = 100;

else if(Names[layer_counter] == "A-2-4")

residual = 100;

else if(Names[layer_counter] == "A-2-5")

residual = 100;

else if(Names[layer_counter] == "A-2-6")

residual = 100;

else if(Names[layer_counter] == "A-2-7")

residual = 100;

else if(Names[layer_counter] == "A-3")

residual = 100;

else

residual = 500;

if(wPI_M[layer_counter]==0.0)

{//Optimum Moisture Content

Rosen_wopt_P15 = 1.0; Rosen_wopt_P40 = 1.0; Rosen_wopt_P60 = 1.0;Rosen_wopt_D60 = 1.0;
```

```
summation_wopt = 0.0;summation_wopt_sq = 0.0;R3_wopt_P15 = 0.0;R3_wopt_P40 = 0.0;
R3_wopt_P60 = 0.0;
R3_wopt_D60 = 0.0;wopt_sq = 0.0;
for(int i=1; i<=81; i++)
{R3_wopt_P15 = P15_M[layer_counter] + Rosen_wopt_P15*P15_S[layer_counter];
R3_wopt_P40 = P40_M[layer_counter] + Rosen_wopt_P40*P40_S[layer_counter];
R3_wopt_P60 = P60_M[layer_counter] + Rosen_wopt_P60*P60_S[layer_counter];
R3_wopt_D60 = D60_M[layer_counter] + Rosen_wopt_D60*D60_S[layer_counter];
opt_moisture_mean = -120.14-0.06766*R3_wopt_P15+3.7269*R3_wopt_D60-
0.167*R3_wopt_P40+0.117*R3_wopt_P60+142.53*exp(-0.0389*R3_wopt_D60);
if(opt_moisture_mean > 100.0)
opt_moisture_mean = 100.0;
if(opt_moisture_mean < 0.0)
opt_moisture_mean = 0.0;
wopt_sq = opt_moisture_mean * opt_moisture_mean;
summation_wopt += opt_moisture_mean;
summation_wopt_sq += wopt_sq;
R3_wopt[layer_counter][i-1]=opt_moisture_mean;
//modifiers
Rosen_wopt_D60--;if(Rosen_wopt_D60 < -1){Rosen_wopt_D60 = 1.0;}
if(i%3==0)Rosen_wopt_P60--;if(Rosen_wopt_P60 < -1){Rosen_wopt_P60 = 1.0;}
if(i%9==0){Rosen_wopt_P40--;}if(Rosen_wopt_P40 < -1){Rosen_wopt_P40 = 1.0;}
if(i%27==0){Rosen_wopt_P15--;}if(Rosen_wopt_P15 < -1){Rosen_wopt_P15 = 1.0;}}
opt_moisture_mean = summation_wopt/81.0;
opt_moisture_var = (summation_wopt_sq - pow(summation_wopt,2.0)/81.0)/80.0;
wopt_var = opt_moisture_var;wopt_stdev = pow(opt_moisture_var,0.5);
wopt_min = 1000.0;wopt_max =-1000.0;summation_wopt_skew = 0.0;
summation_wopt_kurt = 0.0;
```

```
for(int w=0; w<81; w++)
{summation_wopt_skew += pow(((R3_wopt[layer_counter][w]-
opt_moisture_mean)/wopt_stdev),3.0);
summation_wopt_kurt += pow(((R3_wopt[layer_counter][w]-
opt_moisture_mean)/wopt_stdev),4.0);
if(wopt_min > R3_wopt[layer_counter][w])
wopt_min = R3_wopt[layer_counter][w];
if(wopt_max < R3_wopt[layer_counter][w])
wopt_max = R3_wopt[layer_counter][w];}
wopt_skew = (1/81.0)*summation_wopt_skew;
wopt_kurt =((1/81.0)*summation_wopt_kurt)-3.0;
//Optimum Saturation
Rosen_opt_P20 = 1.0; Rosen_opt_P10 = 1.0;Rosen_opt_P05 = 1.0; R3_P20 = 0.0;
R3_P10 = 0.0; R3_P05 = 0.0; opt_sat_sq = 0.0; summation_opt_sat = 0.0;
summation_opt_sat_sq = 0.0;
for(int i=1; i<=27; i++)
{R3_P20 = P20_M[layer_counter] + Rosen_opt_P20*P20_S[layer_counter];
R3_P10 = P10_M[layer_counter] + Rosen_opt_P10*P10_S[layer_counter];
R3_P05 = P05_M[layer_counter] + Rosen_opt_P05*P05_S[layer_counter];
opt_sat_mean1 = -100.17+1.4991*R3_P20+0.56155*R3_P10-0.36755*R3_P05;
if(opt_sat_mean1 > 100.0)
opt_sat_mean1 = 100.0;
if(opt_sat_mean1 < 0.0)
opt_sat_mean1 = 0.0;
opt_sat_sq = opt_sat_mean1 * opt_sat_mean1;
summation_opt_sat += opt_sat_mean1;
summation_opt_sat_sq += opt_sat_sq;
R3_opt_sat[layer_counter][i-1] = opt_sat_mean1;
```

```
//modifiers

Rosen_opt_P05--; if(Rosen_opt_P05 < -1){Rosen_opt_P05 = 1.0;}

if(i%3==0){Rosen_opt_P10--;}if(Rosen_opt_P10 < -1){Rosen_opt_P10 = 1.0;}

if(i%9==0){Rosen_opt_P20--;}if(Rosen_opt_P20 < -1){Rosen_opt_P20 = 1.0;}}

opt_sat_mean1 = summation_opt_sat/27.0;

opt_sat_var1 = (summation_opt_sat_sq - pow(summation_opt_sat,2.0)/27.0)/26.0;

opt_sat_stdev1 = pow(opt_sat_var1,0.5); opt_sat_min1 = 1000.0; opt_sat_max1 = -1.0;

summation_opt_sat_skew = 0.0; summation_opt_sat_kurt = 0.0;

for(int f=0; f<27;f++)

{opt_sat_skew1 = pow(((R3_opt_sat[layer_counter][f]-opt_sat_mean1)/opt_sat_stdev1),3.0);

summation_opt_sat_skew += opt_sat_skew1;

opt_sat_kurt1 = pow(((R3_opt_sat[layer_counter][f]-opt_sat_mean1)/opt_sat_stdev1),4.0);

summation_opt_sat_kurt += opt_sat_kurt1;

if(opt_sat_min1 > R3_opt_sat[layer_counter][f])

opt_sat_min1 = R3_opt_sat[layer_counter][f];

if(opt_sat_max1 < R3_opt_sat[layer_counter][f])

opt_sat_max1 = R3_opt_sat[layer_counter][f];}

opt_sat_skew1 = (1/26.0)*summation_opt_sat_skew;

opt_sat_kurt1 = ((1/26.0)*summation_opt_sat_kurt)-3.0;

//wPI = 0.0 Gamma Dry Maximum

Rosen_gamma_wopt = 1.0; Rosen_gamma_Gs = 1.0; Rosen_gamma_Sopt = 1.0;

summation_gamma_dry = 0.0; summation_gamma_dry_sq = 0.0; gamma_dry_sq = 0.0;

R3_gamma_wopt = 0.0; R3_gamma_Gs = 0.0;R3_gamma_Sopt = 0.0;

for(int i=1; i<=27; i++)

{R3_gamma_wopt = opt_moisture_mean + Rosen_gamma_wopt*pow(opt_moisture_var,0.5);

R3_gamma_Gs = Gs_mean[layer_counter] + Rosen_gamma_Gs*Gs_stdev[layer_counter];

R3_gamma_Sopt = opt_sat_mean1 + Rosen_gamma_Sopt*opt_sat_stdev1;
```

```
gamma_dry_mean =
(R3_gamma_Gs*gamma_water)/(1+((R3_gamma_wopt*R3_gamma_Gs)/R3_gamma_Sopt));
if(Layer_Compaction[layer_counter] == false)
gamma_dry_mean = 1.0156*gamma_dry_mean - 2.464;
gamma_dry_sq = gamma_dry_mean * gamma_dry_mean;
summation_gamma_dry += gamma_dry_mean;
summation_gamma_dry_sq += gamma_dry_sq;
//modifiers
Rosen_gamma_Sopt--;if(Rosen_gamma_Sopt < -1.0){Rosen_gamma_Sopt = 1.0;}
if(i%3==0){Rosen_gamma_Gs--;}if(Rosen_gamma_Gs < -1.0){Rosen_gamma_Gs = 1.0;}
if(i%9==0){Rosen_gamma_wopt--;}if(Rosen_gamma_wopt < -1.0){Rosen_gamma_wopt =
1.0;}}
gamma_dry_mean = summation_gamma_dry/27.0;
gamma_dry_var = (summation_gamma_dry_sq - pow(summation_gamma_dry,2.0)/27.0)/26.0;
gamma_dry_stdev = pow(gamma_dry_var,0.5);gamma_dry_min = 1000.0;
gamma_dry_max =-1000.0; summation_gamma_dry_kurt = 0.0;
summation_gamma_dry_skew = 0.0;
for(int w=0; w<27; w++)
{summation_gamma_dry_skew += pow(((R3_gamma_dry[layer_counter][w]-
gamma_dry_mean)/gamma_dry_stdev),3.0);
summation_gamma_dry_kurt += pow(((R3_gamma_dry[layer_counter][w]-
gamma_dry_mean)/gamma_dry_stdev),4.0);
if(gamma_dry_min > R3_gamma_dry[layer_counter][w])
gamma_dry_min = R3_gamma_dry[layer_counter][w];
if(gamma_dry_max < R3_gamma_dry[layer_counter][w])
gamma_dry_max = R3_gamma_dry[layer_counter][w];}
gamma_dry_skew = (1.0/26.0)*summation_gamma_dry_skew;
gamma_dry_kurt = ((1.0/26.0)*summation_gamma_dry_kurt)-3.0;}
```

```
else // wPI > 2.0
{//adjusted PI
Rosen_PIadj_P200 = 1.0; R3_PIadj_P200 = 0.0; PIadj_sq = 0.0; summation_PIadj = 0.0;
summation_PIadj_sq = 0.0;
for(int i=1; i<=3; i++)
{R3_PIadj_P200 = P200_M[layer_counter] + Rosen_PIadj_P200*P200_S[layer_counter];
PI_adj_mean = exp((R3_PIadj_P200+42.13)/33.94);
PIadj_sq = PI_adj_mean * PI_adj_mean;
summation_PIadj += PI_adj_mean;
summation_PIadj_sq += PIadj_sq;
//modifer
Rosen_PIadj_P200--;if(Rosen_PIadj_P200 < -1.0){Rosen_PIadj_P200 = 1.0;}}
PI_adj_mean = summation_PIadj/3.0;
PI_adj_var = (summation_PIadj_sq - pow(summation_PIadj,2.0)/3.0)/2.0;
if(PI_adj_mean < PI_M[layer_counter])
{Rosen_wPIadj_PIadj = 1.0; Rosen_wPIadj_P200 = 1.0; R3_wPIadj_PIadj = 0.0;
R3_wPIadj_P200 = 0.0; wPIadj_sq = 0.0; summation_wPIadj = 0.0; summation_wPIadj_sq = 0.0;
for(int i=1; i<=9; i++)
{R3_wPIadj_PIadj = PI_adj_mean + Rosen_wPIadj_PIadj*pow(PI_adj_var,0.5);
R3_wPIadj_P200 = P200_M[layer_counter] + Rosen_wPIadj_P200*P200_S[layer_counter];
wPI_adj_mean = (R3_wPIadj_PIadj * R3_wPIadj_P200)/100;
wPIadj_sq = wPI_adj_mean * wPI_adj_mean;
summation_wPIadj += wPI_adj_mean;
summation_wPIadj_sq += wPIadj_sq;
//modifiers
Rosen_wPIadj_P200--;if(Rosen_wPIadj_P200 < -1.0){Rosen_wPIadj_P200 = 1.0;}
if(i%3==0){Rosen_wPIadj_PIadj--;}if(Rosen_wPIadj_PIadj < -1.0){Rosen_wPIadj_PIadj =
 1.0;}}
```

```
wPI_adj_mean = summation_wPIadj/9.0;
wPI_adj_var = (summation_wPIadj_sq - pow(summation_wPIadj,2.0)/9.0)/8.0;}
else
{wPI_adj_mean = wPI_M[layer_counter]; wPI_adj_var = wPI_V[layer_counter];}
if(wPI_adj_mean < 1.0)
wPI_adj_mean = 1.0;
//wPI >0 Optimum Moisture Content
Rosen_wopt_wPIadj = 1.0; R3_wPIadj1 = 0.0; summation_wopt = 0.0; summation_wopt_sq =
0.0; wopt_sq = 0.0;
for(int i=1; i<=3; i++)
{R3_wPIadj1 = wPI_adj_mean + Rosen_wopt_wPIadj*pow(wPI_adj_var,0.5);
if(R3_wPIadj1<0)
R3_wPIadj1 = 1.0;
opt_moisture_mean = 8.3932*pow(R3_wPIadj1,0.3075);
if(opt_moisture_mean > 100.0)
opt_moisture_mean = 100.0;
if(opt_moisture_mean < 0.0)
opt_moisture_mean = 0.0;
wopt_sq = opt_moisture_mean * opt_moisture_mean;
summation_wopt += opt_moisture_mean;
summation_wopt_sq += wopt_sq;
R3_wopt[layer_counter][i-1]=opt_moisture_mean;
//modifers
Rosen_wopt_wPIadj--;if(Rosen_wopt_wPIadj < -1.0){Rosen_wopt_wPIadj = 1.0;}}
opt_moisture_mean = summation_wopt/3.0;
opt_moisture_var = (summation_wopt_sq - pow(summation_wopt,2.0)/3.0)/2.0;
wopt_var = opt_moisture_var;wopt_stdev = pow(opt_moisture_var,0.5);
wopt_min = 1000.0; wopt_max =-1000.0;summation_wopt_skew = 0.0;
```

```
summation_wopt_kurt = 0.0;
for(int w=0; w<3; w++)
{summation_wopt_skew += pow(((R3_wopt[layer_counter][w]-
opt_moisture_mean)/wopt_stdev),3.0);
summation_wopt_kurt += pow(((R3_wopt[layer_counter][w]-
opt_moisture_mean)/wopt_stdev),4.0);
if(wopt_min > R3_wopt[layer_counter][w])
wopt_min = R3_wopt[layer_counter][w];
if(wopt_max < R3_wopt[layer_counter][w])
wopt_max = R3_wopt[layer_counter][w];}
wopt_skew = (1/2.0)*summation_wopt_skew;
wopt_kurt =((1/2.0)*summation_wopt_kurt)-3.0;
Rosen_gamma_wopt = 1.0; summation_gamma_dry = 0.0; summation_gamma_dry_sq = 0.0;
gamma_dry_sq = 0.0; R3_gamma_wopt = 0.0;
for(int i=1; i<=3; i++)
{R3_gamma_wopt = opt_moisture_mean + Rosen_gamma_wopt*pow(opt_moisture_var,0.5);
gamma_dry_mean = 142.115 - 1.959*R3_gamma_wopt;
if(Layer_Compaction[layer_counter] == false)
gamma_dry_mean = 1.0156*gamma_dry_mean - 2.464;
gamma_dry_sq = gamma_dry_mean * gamma_dry_mean;
summation_gamma_dry += gamma_dry_mean;
summation_gamma_dry_sq += gamma_dry_sq;
R3_gamma_dry[layer_counter][i-1]=gamma_dry_mean;
//modifiers
Rosen_gamma_wopt--; if(Rosen_gamma_wopt < -1.0){Rosen_gamma_wopt = 1.0;}}
gamma_dry_mean = summation_gamma_dry/3.0;
gamma_dry_var = (summation_gamma_dry_sq - pow(summation_gamma_dry,2.0)/3.0)/2.0;
```

```
gamma_dry_stdev = pow(gamma_dry_var,0.5); gamma_dry_min = 1000.0; gamma_dry_max =-
1000.0;summation_gamma_dry_kurt = 0.0; summation_gamma_dry_skew = 0.0;
for(int w=0; w<3; w++)
{summation_gamma_dry_skew += pow(((R3_gamma_dry[layer_counter][w]-
gamma_dry_mean)/gamma_dry_stdev),3.0);
summation_gamma_dry_kurt += pow(((R3_gamma_dry[layer_counter][w]-
gamma_dry_mean)/gamma_dry_stdev),4.0);
if(gamma_dry_min > R3_gamma_dry[layer_counter][w])
gamma_dry_min = R3_gamma_dry[layer_counter][w];
if(gamma_dry_max < R3_gamma_dry[layer_counter][w])
gamma_dry_max = R3_gamma_dry[layer_counter][w];}
gamma_dry_skew = (1.0/2.0)*summation_gamma_dry_skew;
gamma_dry_kurt = ((1.0/2.0)*summation_gamma_dry_kurt)-3.0;
//Optimum Saturation
Rosen_opt_wopt = 1.0; Rosen_opt_gamma = 1.0; Rosen_opt_Gs = 1.0; R3_opt_wopt = 0.0;
R3_opt_gamma = 0.0; R3_opt_Gs = 0.0; opt_sat_sq = 0.0;summation_opt_sat = 0.0;
summation_opt_sat_sq = 0.0;
for(int i=1; i<=27; i++)
{R3_opt_wopt = opt_moisture_mean +Rosen_opt_wopt*pow(opt_moisture_var,0.5);
R3_opt_gamma = gamma_dry_mean + Rosen_opt_gamma*pow(gamma_dry_var,0.5);
R3_opt_Gs = Gs_mean[layer_counter] + Rosen_opt_Gs*Gs_stdev[layer_counter];
opt_sat_mean1 = R3_opt_wopt/((gamma_water/R3_opt_gamma)-(1/R3_opt_Gs));
if(opt_sat_mean1 > 100.0)
opt_sat_mean1 = 100.0;
if(opt_sat_mean1 < 0.0)
opt_sat_mean1 = 0.0; opt_sat_sq = opt_sat_mean1 * opt_sat_mean1; summation_opt_sat +=
opt_sat_mean1; summation_opt_sat_sq += opt_sat_sq; R3_opt_sat[layer_counter][i-1] =
opt_sat_mean1;
```

```
//modifiers
Rosen_opt_Gs--; if(Rosen_opt_Gs < -1.0){Rosen_opt_Gs = 1.0;}
if(i%3==0){Rosen_opt_gamma--;}if(Rosen_opt_gamma < -1.0){Rosen_opt_gamma = 1.0;}
if(i%9==0){Rosen_opt_wopt--;}if(Rosen_opt_wopt < -1.0){Rosen_opt_wopt = 1.0;}}
opt_sat_mean1 = summation_opt_sat/27.0;
opt_sat_var1 = (summation_opt_sat_sq - pow(summation_opt_sat,2.0)/27.0)/26.0;
opt_sat_stdev1 = pow(opt_sat_var1,0.5); opt_sat_min1 = 1000.0; opt_sat_max1 = -1.0;
summation_opt_sat_skew = 0.0; summation_opt_sat_kurt = 0.0;
for(int f=0; f<27;f++)
{opt_sat_skew1 = pow(((R3_opt_sat[layer_counter][f]-opt_sat_mean1)/opt_sat_stdev1),3.0);
summation_opt_sat_skew += opt_sat_skew1;
opt_sat_kurt1 = pow(((R3_opt_sat[layer_counter][f]-opt_sat_mean1)/opt_sat_stdev1),4.0);
summation_opt_sat_kurt += opt_sat_kurt1;
if(opt_sat_min1 > R3_opt_sat[layer_counter][f])
opt_sat_min1 = R3_opt_sat[layer_counter][f];
if(opt_sat_max1 < R3_opt_sat[layer_counter][f])
opt_sat_max1 = R3_opt_sat[layer_counter][f];}
opt_sat_skew1 = (1/26.0)*summation_opt_sat_skew; opt_sat_kurt1 =
((1/26.0)*summation_opt_sat_kurt)-3.0;}
//Saturated Volumetric water content
Rosen_gamma_dry = 1.0; Rosen_Gs = 1.0; theata_sat = 0.0; theata_sat_sq = 0.0;
summation_theata_sat_sq = 0.0; summation_theata_sat = 0.0; R3_gamma_dry1 = 0.0;
R3_Gs = 0.0;
for(int i=1; i<=9; i++)
{R3_gamma_dry1 = gamma_dry_mean + Rosen_gamma_dry*pow(gamma_dry_var,0.5);
R3_Gs = Gs_mean[layer_counter] + Rosen_Gs*Gs_stdev[layer_counter];
theata_sat = (1.0 - (R3_gamma_dry1/(R3_Gs*gamma_water)))*100;
if(theata_sat > 100.0)
```

```
theata_sat = 100.0;
if(theata_sat < 0.0)
theata_sat = 0.0; theata_sat_sq = theata_sat * theata_sat; summation_theata_sat += theata_sat;
summation_theata_sat_sq += theata_sat_sq; R3_theata_sat[layer_counter][i-1] = theata_sat;
//modifiers
Rosen_gamma_dry--;if(Rosen_gamma_dry < -1.0){Rosen_gamma_dry = 1.0;}
if(i%3==0){Rosen_Gs--;}if(Rosen_Gs < -1.0){Rosen_Gs = 1.0;}}
theata_sat = summation_theata_sat / 9.0;
theata_sat_var = (summation_theata_sat_sq - pow(summation_theata_sat,2.0)/9.0)/8.0;
theata_sat_stdev = pow(theata_sat_var,0.5); theata_sat_min = 1000.0; theata_sat_max = -1000.0;
summation_theata_sat_skew = 0.0; summation_theata_sat_kurt = 0.0;
for( int w=0; w<9; w++)
{theata_sat_kurt = pow(((R3_theata_sat[layer_counter][w]- theata_sat)/theata_sat_stdev),4.0);
summation_theata_sat_kurt += theata_sat_kurt;
theata_sat_skew = pow(((R3_theata_sat[layer_counter][w]- theata_sat)/theata_sat_stdev),3.0);
summation_theata_sat_skew += theata_sat_skew;
if(theata_sat_min > R3_theata_sat[layer_counter][w])
theata_sat_min = R3_theata_sat[layer_counter][w];
if(theata_sat_max < R3_theata_sat[layer_counter][w])
theata_sat_max = R3_theata_sat[layer_counter][w];}
theata_sat_skew = (1/8.0)*summation_theata_sat_skew;
theata_sat_kurt = ((1/8.0)*summation_theata_sat_kurt)-3.0;
//wPI <2.0
if(wPI_M[layer_counter]<2.0)
{if(P200_M[layer_counter]<2.0){P200_M[layer_counter] = 2.0;}
Rosen_theata_P200 = 1.0; Rosen_theata_TMI = 1.0; theata_water_sq = 0.0;
summation_theata_water_sq = 0.0; summation_theata_water = 0.0; R3_P200_theata_water = 0.0;
R3_TMI_theata_water = 0.0;
```

```
for(int i=1; i <=9; i++)

{checker = true;

R3_P200_theata_water = P200_M[layer_counter] + Rosen_theata_P200 * P200_S[layer_counter];

R3_TMI_theata_water = TMI_mean + Rosen_theata_TMI * TMI_stdev;

theata_water = 4.0 + 1.5*pow(R3_P200_theata_water,0.6994) + 0.03*R3_TMI_theata_water;

if(theata_water > 100.0)

theata_water = 100.0;

if(theata_water < 0.0)

theata_water = 0.0;

theata_water_sq = theata_water * theata_water;

summation_theata_water += theata_water;

summation_theata_water_sq += theata_water_sq;

R3_theata_water[layer_counter][i-1] = theata_water;

//modifiers

Rosen_theata_TMI--;if(Rosen_theata_TMI < -1.0){Rosen_theata_TMI = 1.0;}

if(i%3==0){Rosen_theata_P200--;}if(Rosen_theata_P200 < -1.0){Rosen_theata_P200 = 1.0;}}


if(theata_water > 40.0)//1-40D Constraint

{for(int i=1; i<=3; i++){

checker = false;

R3_P200_theata_water = P200_M[layer_counter] + Rosen_theata_P200 * P200_S[layer_counter];

theata_water = 40 + 0.11*(R3_P200_theata_water - 53.0);

if(theata_water > 100.0)

theata_water = 100.0;

if(theata_water < 0.0)

theata_water = 0.0;

theata_water_sq = theata_water * theata_water; summation_theata_water += theata_water;
```

```
summation_theata_water_sq += theata_water_sq;R3_theata_water[layer_counter][i-1] =
theata_water;
//modifier
Rosen_theata_P200--;if(Rosen_theata_P200 < -1.0){Rosen_theata_P200 = 1.0;}}}
if(theata_water < 40.0)//1-40D Constraint
{theata_water = summation_theata_water/9.0; theata_water_var = (summation_theata_water_sq -
pow(summation_theata_water,2.0)/9.0)/8.0;}
else
{theata_water = summation_theata_water/3.0; theata_water_var = (summation_theata_water_sq -
pow(summation_theata_water,2.0)/3.0)/2.0;}
theata_water_stdev = pow(theata_water_var, 0.5);
if(theata_water > theata_sat)//1-40D constraint
{theata_water = theata_sat; theata_water_var = theata_sat_var; theata_water_stdev =
theata_sat_stdev;}}
else
{Rosen_theata_wPI = 1.0; Rosen_theata_Suction = 1.0; Rosen_theata_sat_water = 1.0;
theata_water_sq = 0.0; summation_theata_water_sq = 0.0; summation_theata_water = 0.0;
R3_wPI_theata_water = 0.0;R3_Suction_theata_water = 0.0; R3_theata_sat_water = 0.0;
var_a = 0.0; var_b = 0.0;var_c = 0.0; stdev_a = 0.0; stdev_b = 0.0; stdev_c = 0.0; min_a = 1000.0;
min_b = 1000.0; min_c = 1000.0; max_a = 0.0; max_b = 0.0; max_c = 0.0; mean_a = 0.0; mean_b
= 0.0; mean_c = 0.0; summation_a = 0.0; summation_b = 0.0; summation_c = 0.0;
summation_a_sq = 0.0; summation_b_sq = 0.0; summation_c_sq = 0.0;
// SWCC information
for(int i =1; i<=27; i++)
{checker = true;
R3_wPI_theata_water = wPI_M[layer_counter] + Rosen_theata_wPI* wPI_S[layer_counter];
if(R3_wPI_theata_water < 0)
R3_wPI_theata_water = 0.0;
```

```
if(R3_wPI_theata_water > 100.0)
R3_wPI_theata_water = 100.0;
R3_theata_sat_water = theata_sat + Rosen_theata_sat_water*theata_sat_stdev;
if(R3_theata_sat_water < 0)
R3_theata_sat_water = 0.0;
if(R3_theata_sat_water > 100.0)
R3_theata_sat_water = 100.0;
R3_Suction_theata_water = Suction_Mean[layer_counter] +
Rosen_theata_Suction*Suction_Stdev[layer_counter];
if(R3_Suction_theata_water < 0.0)
R3_Suction_theata_water= 0.0;
if(R3_Suction_theata_water > 1000000.0)
R3_Suction_theata_water = 1000000.0;
af = 32.835*log(R3_wPI_theata_water)+32.438;
bf = 1.421*pow(R3_wPI_theata_water,-0.3185);
cf = -0.2154*log(R3_wPI_theata_water)+0.7145;
if(af < 5.0)
af = 5.0;
if(cf < 0.01)
cf = 0.03;
summation_a += af; summation_b += bf; summation_c += cf;
summation_a_sq += af*af; summation_b_sq += bf*bf; summation_c_sq += cf*cf;
Rosenblueth1[layer_counter][0][i-1] = af; Rosenblueth1[layer_counter][1][i-1] = bf;
Rosenblueth1[layer_counter][2][i-1] = cf;
C_h = 1-(log(1+(R3_Suction_theata_water/residual))/(log(1000000.0/residual)));
theata_water =
C_h*(R3_theata_sat_water/pow(log(pow((R3_Suction_theata_water/af),bf)+exp(1.0)),cf));
if(theata_water > 100.0)
```

```
theata_water = 100.0;
if(theata_water < 0.0)
theata_water = 0.0;
theata_water_sq = theata_water * theata_water;
summation_theata_water += theata_water;
summation_theata_water_sq += theata_water_sq;
R3_theata_water[layer_counter][i-1] = theata_water;
//modifier
Rosen_theata_Suction--;if(Rosen_theata_Suction < -1.0){Rosen_theata_Suction = 1.0;}
if(i%3==0){Rosen_theata_wPI--;}if(Rosen_theata_wPI < -1.0){Rosen_theata_wPI = 1.0;}
if(i%9==0){Rosen_theata_sat_water--;}if(Rosen_theata_sat_water < -
1.0){Rosen_theata_sat_water = 1.0;}}
theata_water = summation_theata_water/27.0;
theata_water_var = (summation_theata_water_sq - pow(summation_theata_water,2.0)/27.0)/26.0;
theata_water_stdev = pow(theata_water_var, 0.5);
theata_water_min = 1000.0;theata_water_max = -1000.0;
summation_theata_water_skew = 0.0; summation_theata_water_kurt = 0.0;
if(checker == true)
{mean_a = summation_a/27.0;mean_b = summation_b/27.0;mean_c = summation_c/27.0;
var_a = (summation_a_sq - pow(summation_a,2.0)/27.0)/26.0;
var_b = (summation_b_sq - pow(summation_b,2.0)/27.0)/26.0;
var_c = (summation_c_sq - pow(summation_c,2.0)/27.0)/26.0;
stdev_a = pow(var_a,0.5); stdev_b = pow(var_b,0.5); stdev_c = pow(var_c,0.5);
for( int w=0; w<9; w++)
{theata_water_kurt = pow(((R3_theata_water[layer_counter][w]-
theata_water)/theata_water_stdev),4.0);
summation_theata_water_kurt += theata_water_kurt;
```

```
theata_water_skew = pow(((R3_theata_water[layer_counter][w]-
theata_water)/theata_water_stdev),3.0);
summation_theata_water_skew += theata_water_skew;}
theata_water_skew = (1/26.0)*summation_theata_water_skew;
theata_water_kurt = ((1/26.0)*summation_theata_water_kurt)-3.0;
for( int w=0; w<9; w++)
{if(theata_water_min > R3_theata_water[layer_counter][w])
theata_water_min = R3_theata_water[layer_counter][w];
if(theata_water_max < R3_theata_water[layer_counter][w])
theata_water_max = R3_theata_water[layer_counter][w];
if(max_a < Rosenblueth1[layer_counter][0][w])
max_a = Rosenblueth1[layer_counter][0][w];
if(max_b < Rosenblueth1[layer_counter][1][w])
max_b = Rosenblueth1[layer_counter][1][w];
if(max_c < Rosenblueth1[layer_counter][2][w])
max_c = Rosenblueth1[layer_counter][2][w];
if(min_a > Rosenblueth1[layer_counter][0][w])
min_a = Rosenblueth1[layer_counter][0][w];
if(min_b > Rosenblueth1[layer_counter][1][w])
min_b = Rosenblueth1[layer_counter][1][w];
if(min_c > Rosenblueth1[layer_counter][2][w])
min_c = Rosenblueth1[layer_counter][2][w];}
SWCC_AM[layer_counter] = mean_a; SWCC_BM[layer_counter] = mean_b;
SWCC_CM[layer_counter] = mean_c; SWCC_AV[layer_counter] = var_a;
SWCC_BV[layer_counter] = var_b; SWCC_CV[layer_counter] = var_c;
SWCC_AS[layer_counter] = stdev_a; SWCC_BS[layer_counter] = stdev_b;
SWCC_CS[layer_counter] = stdev_c; SWCC_AMax[layer_counter] = max_a;
SWCC_BMax[layer_counter] = max_b; SWCC_CMax[layer_counter] = max_c;
```

```
SWCC_AMin[layer_counter] = min_a; SWCC_BMin[layer_counter] = min_b;
SWCC_CMin[layer_counter] = min_c;}
else
{for( int w=0; w<3; w++)
{theata_water_kurt = pow(((R3_theata_water[layer_counter][w]-
theata_water)/theata_water_stdev),4.0);
summation_theata_water_kurt += theata_water_kurt;
theata_water_skew = pow(((R3_theata_water[layer_counter][w]-
theata_water)/theata_water_stdev),3.0);
summation_theata_water_skew += theata_water_skew;}
theata_water_skew = (1/2.0)*summation_theata_water_skew;
theata_water_kurt = ((1/2.0)*summation_theata_water_kurt)-3.0;
for( int w=0; w<3; w++)
{if(theata_water_min > R3_theata_water[layer_counter][w])
theata_water_min = R3_theata_water[layer_counter][w];
if(theata_water_max < R3_theata_water[layer_counter][w])
theata_water_max = R3_theata_water[layer_counter][w];
}}}
//Degree of Saturation
Rosen_theata_sat = 1.0; Rosen_theata_water = 1.0; degree_sat_sq = 0.0; summation_degree_sat =
0.0;summation_degree_sat_sq = 0.0; R3_theata_water_dsat = 0.0; R3_theata_sat_dsat = 0.0;
for(int i=1; i<=9; i++)
{R3_theata_water_dsat = theata_water + Rosen_theata_water* theata_water_stdev;
R3_theata_sat_dsat = theata_sat + Rosen_theata_sat* theata_sat_stdev;
degree_sat_mean1 = (R3_theata_water_dsat / R3_theata_sat_dsat)*100;
if(degree_sat_mean1 > 100.0)
degree_sat_mean1 = 100.0;
if(degree_sat_mean1 < 0.0)
```

```
degree_sat_mean1 = 0.0;
degree_sat_sq = degree_sat_mean1*degree_sat_mean1;
summation_degree_sat += degree_sat_mean1;
summation_degree_sat_sq += degree_sat_sq;
R3_degree_sat[layer_counter][i-1] = degree_sat_mean1;
//modifiers
Rosen_theata_sat--;if(Rosen_theata_sat < -1.0){Rosen_theata_sat = 1.0;}
if(i%3==0){Rosen_theata_water--;}if(Rosen_theata_water < -1.0){Rosen_theata_water = 1.0;}}
degree_sat_mean1 = summation_degree_sat/9.0;
degree_sat_var1 = (summation_degree_sat_sq - pow(summation_degree_sat,2.0)/9.0)/8.0;
degree_sat_stdev1 = pow(degree_sat_var1,0.5);
degree_sat_min1 = 10000;degree_sat_max1 = -10;
summation_degree_sat_skew = 0.0; summation_degree_sat_kurt = 0.0;
for(int f=0; f<9;f++)
{degree_sat_skew1 = pow(((R3_degree_sat[layer_counter][f]-
degree_sat_mean1)/degree_sat_stdev1),3.0);
summation_degree_sat_skew += degree_sat_skew1;
degree_sat_kurt1 = pow(((R3_degree_sat[layer_counter][f]-
degree_sat_mean1)/degree_sat_stdev1),4.0);
summation_degree_sat_kurt += degree_sat_kurt1;
if(degree_sat_min1 > R3_degree_sat[layer_counter][f])
degree_sat_min1 = R3_degree_sat[layer_counter][f];
if(degree_sat_max1 < R3_degree_sat[layer_counter][f])
degree_sat_max1 = R3_degree_sat[layer_counter][f];}
degree_sat_skew1 = (1/8.0)*summation_degree_sat_skew;
degree_sat_kurt1 = ((1/8.0)*summation_degree_sat_kurt)-3.0;
//Optimum Moisture Content Storage
```

```
wopt_M[layer_counter] = opt_moisture_mean; wopt_V[layer_counter] = wopt_var;
wopt_S[layer_counter] = wopt_stdev; wopt_Skew[layer_counter] = wopt_skew;
wopt_Kurt[layer_counter] = wopt_kurt; wopt_Min[layer_counter] = wopt_min;
wopt_Max[layer_counter] = wopt_max;
//Dry Unit Weight Storage
gamma_dry_M[layer_counter] = gamma_dry_mean; gamma_dry_V[layer_counter] =
gamma_dry_var; gamma_dry_S[layer_counter] = gamma_dry_stdev;
gamma_dry_Skew[layer_counter] = gamma_dry_skew; gamma_dry_Kurt[layer_counter] =
gamma_dry_kurt; gamma_dry_Min[layer_counter] = gamma_dry_min;
gamma_dry_Max[layer_counter] = gamma_dry_max;}
//Saturated Volumetric Water Content Storage
Theata_SM[layer_counter] = theata_sat; Theata_SV[layer_counter] = theata_sat_var;
Theata_SS[layer_counter] = theata_sat_stdev; Theata_SSkew[layer_counter] = theata_sat_skew;
Theata_SKurt[layer_counter] = theata_sat_kurt; Theata_SMin[layer_counter] = theata_sat_min;
Theata_SMax[layer_counter] = theata_sat_max;
//Volumetric Water Content Storage
Theata_WM[layer_counter] = theata_water; Theata_WV[layer_counter] = theata_water_var;
Theata_WS[layer_counter] = theata_water_stdev; Theata_WSkew[layer_counter] =
theata_water_skew; Theata_WKurt[layer_counter] = theata_water_kurt;
Theata_WMin[layer_counter] = theata_water_min; Theata_WMax[layer_counter] =
theata_water_max;
//Degree Saturation Storage
degree_sat_mean[layer_counter] = degree_sat_mean1; degree_sat_var[layer_counter] =
degree_sat_var1; degree_sat_stdev[layer_counter] = degree_sat_stdev1;
degree_sat_skew[layer_counter] = degree_sat_skew1; degree_sat_kurt[layer_counter] =
degree_sat_kurt1; degree_sat_Min[layer_counter] = degree_sat_min1;
degree_sat_Max[layer_counter] = degree_sat_max1;
//Optimum Saturation Storage
```

```
opt_sat_mean[layer_counter] = opt_sat_mean1; opt_sat_var[layer_counter] = opt_sat_var1;
opt_sat_stdev[layer_counter] = opt_sat_stdev1; opt_sat_skew[layer_counter] = opt_sat_skew1;
opt_sat_kurt[layer_counter] = opt_sat_kurt1; opt_sat_min[layer_counter] = opt_sat_min1;
opt_sat_max[layer_counter] = opt_sat_max1;
//Fenv information
Rosen_Fenv_wPI = 1.0; Rosen_Fenv_degree_sat = 1.0;Rosen_Fenv_opt_sat = 1.0;
R3_Fenv_wPI = 0.0; R3_Fenv_dsat = 0.0; R3_Fenv_osat = 0.0;summation_Fenv = 0.0;
summation_Fenv_sq = 0.0; Fenv_sq = 0.0;
for(int i=1; i<=27; i++)
{R3_Fenv_wPI = wPI_M[layer_counter] + Rosen_Fenv_wPI*wPI_S[layer_counter];
if(R3_Fenv_wPI < 0)
R3_Fenv_wPI = 0.0;
if(R3_Fenv_wPI > 100.0)
R3_Fenv_wPI = 100.0;
R3_Fenv_dsat = degree_sat_mean[layer_counter] +
Rosen_Fenv_degree_sat*degree_sat_stdev[layer_counter];
if(R3_Fenv_dsat > 100.0)
R3_Fenv_dsat = 100.0;
if(R3_Fenv_dsat < 0.0)
R3_Fenv_dsat = 0.0;
R3_Fenv_osat = opt_sat_mean[layer_counter] +
Rosen_Fenv_opt_sat*opt_sat_stdev[layer_counter];
if(R3_Fenv_osat > 100.0)
R3_Fenv_osat = 100.0;
if(R3_Fenv_osat < 0.0)
R3_Fenv_osat = 0.0;
Fenv_term1 = (-0.6-1.87194*exp(-R3_Fenv_wPI));
Fenv_term2 = 0.8+0.08*pow(R3_Fenv_wPI,0.5);
```

```
Fenv_term3 = pow((11.96518-10.19111*exp(-R3_Fenv_wPI)),0.5);
Fenv_term4 = ((R3_Fenv_dsat-R3_Fenv_osat)/100);
Fenv_denom = 1+ exp(log(-Fenv_term2/pow(Fenv_term1,-1.0))+ Fenv_term3*Fenv_term4);
powerproduct = 1.002*(pow(Fenv_term1,-1.0)+(Fenv_term2-pow(Fenv_term1,-
1.0))/Fenv_denom);
Fenv_mean1 = pow(10,powerproduct);
Fenv_sq = Fenv_mean1 * Fenv_mean1;
summation_Fenv += Fenv_mean1;
summation_Fenv_sq +=Fenv_sq;
R3_Fenv[layer_counter][i-1] = Fenv_mean1;
//modifers
Rosen_Fenv_opt_sat--;if(Rosen_Fenv_opt_sat < -1.0){Rosen_Fenv_opt_sat = 1.0;}
if(i%3==0){Rosen_Fenv_degree_sat--;}if(Rosen_Fenv_degree_sat < -
1.0){Rosen_Fenv_degree_sat = 1.0;}
if(i%9==0){Rosen_Fenv_wPI--;}if(Rosen_Fenv_wPI < -1.0){Rosen_Fenv_wPI = 1.0;}}
Fenv_mean1 = summation_Fenv/27.0;
Fenv_var1 = (summation_Fenv_sq - pow(summation_Fenv,2.0)/27.0)/26.0;
Fenv_stdev1 = pow(Fenv_var1,0.5); Fenv_min1 = 1000.0; Fenv_max1 = -1.0;
summation_Fenv_skew = 0.0; summation_Fenv_kurt = 0.0;
for(int f=0; f<27;f++)
{Fenv_skew1 = pow(((R3_Fenv[layer_counter][f]-Fenv_mean1)/Fenv_stdev1),3.0);
summation_Fenv_skew += Fenv_skew1;
Fenv_kurt1 = pow(((R3_Fenv[layer_counter][f]-Fenv_mean1)/Fenv_stdev1),4.0);
summation_Fenv_kurt += Fenv_kurt1;
if(Fenv_min1 > R3_Fenv[layer_counter][f])
Fenv_min1 = R3_Fenv[layer_counter][f];
if(Fenv_max1 < R3_Fenv[layer_counter][f])
Fenv_max1 = R3_Fenv[layer_counter][f];}
```

```
Fenv_skew1 = (1/26.0)*summation_Fenv_skew;
Fenv_kurt1 = ((1/26.0)*summation_Fenv_kurt)-3.0;
//Fenv Storage
Fenv_Mean[layer_counter] = Fenv_mean1; Fenv_Var[layer_counter] = Fenv_var1;
Fenv_Stdev[layer_counter] = Fenv_stdev1; Fenv_Skew[layer_counter] = Fenv_skew1;
Fenv_Kurt[layer_counter] = Fenv_kurt1; Fenv_Min[layer_counter] = Fenv_min1;
Fenv_Max[layer_counter] = Fenv_max1;
// Mropt
if((level[layer_counter] == true) && (Level_a[layer_counter] == "Level_1"))
{Mropt_mean1 = Mropt_Mean[layer_counter]; Mropt_var1 = Mropt_Var[layer_counter];
Mropt_stdev1 = Mropt_Stdev[layer_counter]; Mropt_skew1 = 0; Mropt_kurt1 = 0;
Mropt_min1 = Mropt_Min[layer_counter]; Mropt_max1 = Mropt_Max[layer_counter];}
else if(Level_a[layer_counter] == "Level_1a")
{Rosen_Mropt_CBR = 1.0; R3_Mropt_CBR = 0.0; Mropt_sq = 0.0;summation_Mropt = 0.0;
summation_Mropt_sq = 0.0;
for(int i=1; i<=3; i++)
{R3_Mropt_CBR = CBR_M[layer_counter] + Rosen_Mropt_CBR*CBR_S[layer_counter];
R3_Mropt_CBR = 2555*pow(R3_Mropt_CBR,0.64);
Mropt_mean1 = R3_Mropt_CBR*(2.11-2.78*pow(10,-5.0)*R3_Mropt_CBR);
Mropt_sq = Mropt_mean1 * Mropt_mean1;
summation_Mropt += Mropt_mean1;
summation_Mropt_sq += Mropt_sq;
R3_Mropt[layer_counter][i-1] = Mropt_mean1;
//modifer
Rosen_Mropt_CBR--;if(Rosen_Mropt_CBR < -1.0){Rosen_Mropt_CBR = 1.0;}}
Mropt_mean1 = summation_Mropt/3.0;
Mropt_var1 = (summation_Mropt_sq - pow(summation_Mropt,2.0)/3.0)/2.0;
```

```
Mropt_stdev1 = pow(Mropt_var1,0.5);Mropt_min1 = 10000000000000;Mropt_max1 = -100;
summation_Mropt_skew = 0.0;summation_Mropt_kurt = 0.0;CBR_mean = summation_CBR/3.0;
CBR_var = (summation_CBR_sq - pow(summation_CBR,2.0)/3.0)/2.0;
CBR_min = 1000.0; CBR_max = -1.0; summation_CBR_skew = 0.0; summation_CBR_kurt =
0.0;
for(int f=0; f<3;f++){
Mropt_skew1 = pow(((R3_Mropt[layer_counter][f]-Mropt_mean1)/Mropt_stdev1),3.0);
summation_Mropt_skew += Mropt_skew1;
Mropt_kurt1 = pow(((R3_Mropt[layer_counter][f]-Mropt_mean1)/Mropt_stdev1),2.0);
summation_Mropt_kurt += Mropt_kurt1;
if(Mropt_min1 > R3_Mropt[layer_counter][f])
Mropt_min1 = R3_Mropt[layer_counter][f];
if(Mropt_max1 < R3_Mropt[layer_counter][f])
Mropt_max1 = R3_Mropt[layer_counter][f];
CBR_skew = pow(((R3_CBR[layer_counter][f]-CBR_mean)/CBR_stdev),3.0);
summation_CBR_skew += CBR_skew;
CBR_kurt = pow(((R3_CBR[layer_counter][f]-CBR_mean)/CBR_stdev),2.0);
summation_CBR_kurt += CBR_kurt;
if(CBR_min > R3_CBR[layer_counter][f])
CBR_min = R3_CBR[layer_counter][f];
if(CBR_max < R3_CBR[layer_counter][f])
CBR_max = R3_CBR[layer_counter][f];}
Mropt_skew1 = (1/2.0)*summation_Mropt_skew;
Mropt_kurt1 = ((1/2.0)*summation_Mropt_kurt)-3.0;}
else
{Rosen_Mropt_D60 = 1.0; Rosen_Mropt_wPI = 1.0; R3_Mropt_D60 = 0.0; R3_Mropt_wPI = 0.0;
Mropt_sq = 0.0; summation_Mropt = 0.0; summation_Mropt_sq = 0.0; summation_CBR = 0.0;
summation_CBR_sq = 0.0; CBR_sq = 0.0;
```

```
if(wPI_M[layer_counter] == 0.0)
{for(int i=1; i<=3.0; i++){
R3_Mropt_D60 = D60_M[layer_counter] + Rosen_Mropt_D60*D60_S[layer_counter];
CBR_mean = 28.09*pow(R3_Mropt_D60,0.358);
if(R3_Mropt_D60 < 0.01)
CBR_mean = 5.0;
if(R3_Mropt_D60 > 30.0)
CBR_mean = 95.0;
Mropt_mean1 = 2555*pow(CBR_mean,0.64)*(2.11-2.78*pow(10,-
5.0)*2555*pow(CBR_mean,0.64));
Mropt_sq = Mropt_mean1 * Mropt_mean1;
summation_Mropt += Mropt_mean1;
summation_Mropt_sq += Mropt_sq;
R3_Mropt[layer_counter][i-1] = Mropt_mean1;
CBR_sq = CBR_mean * CBR_mean; summation_CBR += CBR_mean; summation_CBR_sq
+=CBR_sq;R3_CBR[layer_counter][i-1] = CBR_mean;
//modifer
Rosen_Mropt_D60--;if(Rosen_Mropt_D60 < -1.0){Rosen_Mropt_D60 = 1.0;}}}
else
{for(int i=1; i<=3; i++)
{R3_Mropt_wPI = wPI_M[layer_counter] + Rosen_Mropt_wPI*wPI_S[layer_counter];
if(R3_Mropt_wPI < 0)
R3_Mropt_wPI = 0.0;
CBR_mean = 75/(1+0.728*R3_Mropt_wPI);
Mropt_mean1 = 2555*pow(CBR_mean,0.64)*(2.11-2.78*pow(10,-
5.0)*2555*pow(CBR_mean,0.64));
Mropt_sq = Mropt_mean1 * Mropt_mean1;
```

```
summation_Mropt += Mropt_mean1; summation_Mropt_sq += Mropt_sq;
R3_Mropt[layer_counter][i-1] = Mropt_mean1; CBR_sq = CBR_mean * CBR_mean;
summation_CBR += CBR_mean; summation_CBR_sq +=CBR_sq;
R3_CBR[layer_counter][i-1] = CBR_mean;
//modifer
Rosen_Mropt_wPI--;if(Rosen_Mropt_wPI < -1.0){Rosen_Mropt_wPI = 1.0;}}}}
if(level[layer_counter]==false)
{Mropt_mean1 = summation_Mropt/3.0;
Mropt_var1 = (summation_Mropt_sq - pow(summation_Mropt,2.0)/3.0)/2.0;
Mropt_stdev1 = pow(Mropt_var1,0.5); Mropt_min1 = 10000000000000; Mropt_max1 = -10;
summation_Mropt_skew = 0.0; summation_Mropt_kurt = 0.0; CBR_mean =
summation_CBR/3.0; CBR_var = (summation_CBR_sq - pow(summation_CBR,2.0)/3.0)/2.0;
CBR_stdev = pow(CBR_var,0.5); CBR_min = 1000.0; CBR_max = -1.0; summation_CBR_skew
= 0.0; summation_CBR_kurt = 0.0;
for(int f=0; f<3;f++)
{Mropt_skew1 = pow(((R3_Mropt[layer_counter][f]-Mropt_mean1)/Mropt_stdev1),3.0);
summation_Mropt_skew += Mropt_skew1;
Mropt_kurt1 = pow(((R3_Mropt[layer_counter][f]-Mropt_mean1)/Mropt_stdev1),2.0);
summation_Mropt_kurt += Mropt_kurt1;
if(Mropt_min1 > R3_Mropt[layer_counter][f])
Mropt_min1 = R3_Mropt[layer_counter][f];
if(Mropt_max1 < R3_Mropt[layer_counter][f])
Mropt_max1 = R3_Mropt[layer_counter][f];
CBR_skew = pow(((R3_CBR[layer_counter][f]-CBR_mean)/CBR_stdev),3.0);
summation_CBR_skew += CBR_skew;
CBR_kurt = pow(((R3_CBR[layer_counter][f]-CBR_mean)/CBR_stdev),2.0);
summation_CBR_kurt += CBR_kurt;
if(CBR_min > R3_CBR[layer_counter][f])
```

```
CBR_min = R3_CBR[layer_counter][f];

if(CBR_max < R3_CBR[layer_counter][f])

CBR_max = R3_CBR[layer_counter][f];}

Mropt_skew1 = (1/2.0)*summation_Mropt_skew;

Mropt_kurt1 = ((1/2.0)*summation_Mropt_kurt)-3.0;

CBR_skew = (1/2.0)*summation_CBR_skew;

CBR_kurt = ((1/2.0)*summation_CBR_kurt)-3.0;}

//Mropt Storage

Mropt_Mean[layer_counter] = Mropt_mean1; Mropt_Var[layer_counter] = Mropt_var1;

Mropt_Stdev[layer_counter] = Mropt_stdev1; Mropt_Skew[layer_counter] = Mropt_skew1;

Mropt_Kurt[layer_counter] = Mropt_kurt1; Mropt_Min[layer_counter] = Mropt_min1;

Mropt_Max[layer_counter] = Mropt_max1;

//CBR Storage

CBR_M[layer_counter] = CBR_mean; CBR_V[layer_counter] = CBR_var;

CBR_S[layer_counter] = CBR_stdev; CBR_Skew[layer_counter] = CBR_skew;

CBR_Kurt[layer_counter] = CBR_kurt; CBR_Min[layer_counter] = CBR_min;

CBR_Max[layer_counter] = CBR_max;

// Mr equilibrium

Rosen_Mreq_Fenv = 1.0; Rosen_Mreq_Mropt = 1.0; R3_Mreq_Fenv = 0.0;

R3_Mreq_Mropt = 0.0; Mreq_sq = 0.0; summation_Mreq = 0.0; summation_Mreq_sq = 0.0;

for(int i=1; i<=9; i++)

{R3_Mreq_Fenv = Fenv_Mean[layer_counter] + Rosen_Mreq_Fenv*Fenv_Stdev[layer_counter];

if(R3_Mreq_Fenv < 0.20)

R3_Mreq_Fenv = 0.20;

R3_Mreq_Mropt = Mropt_Mean[layer_counter] +

Rosen_Mreq_Mropt*Mropt_Stdev[layer_counter];

Mreq_mean1 = log(R3_Mreq_Mropt*R3_Mreq_Fenv)/log(10.0);

Mreq_sq = Mreq_mean1 * Mreq_mean1; summation_Mreq += Mreq_mean1;
```

```
summation_Mreq_sq += Mreq_sq; R3_Mreq[layer_counter][i-1] = Mreq_mean1;
//modifiers
Rosen_Mreq_Fenv--;if(Rosen_Mreq_Fenv < -1.0){Rosen_Mreq_Fenv = 1.0;}
if(i%3==0){Rosen_Mreq_Mropt--;}if(Rosen_Mreq_Mropt < -1.0){Rosen_Mreq_Mropt = 1.0;}}
Mreq_mean1 = summation_Mreq/9.0;
Mreq_var1 = (summation_Mreq_sq - pow(summation_Mreq,2.0)/9.0)/8.0;
Mreq_stdev1 = pow(Mreq_var1,0.5);Mreq_min1 = 1000000000000.0;Mreq_max1 = -1.0;
summation_Mreq_skew = 0.0; summation_Mreq_kurt = 0.0;
for(int f=0; f<9;f++)
{Mreq_skew1 = pow(((R3_Mreq[layer_counter][f]-Mreq_mean1)/Mreq_stdev1),3.0);
summation_Mreq_skew += Mreq_skew1;
Mreq_kurt1 = pow(((R3_Mreq[layer_counter][f]-Mreq_mean1)/Mreq_stdev1),4.0);
summation_Mreq_kurt += Mreq_kurt1;
if(Mreq_min1 > R3_Mreq[layer_counter][f])
Mreq_min1 = R3_Mreq[layer_counter][f];
if(Mreq_max1 < R3_Mreq[layer_counter][f])
Mreq_max1 = R3_Mreq[layer_counter][f];}
Mreq_skew1 = (1/8.0)*summation_Mreq_skew;
Mreq_kurt1 = ((1/8.0)*summation_Mreq_kurt)-3.0;
Mreq_Mean[layer_counter] = Mreq_mean1;Mreq_Var[layer_counter] = Mreq_var1;
Mreq_Stdev[layer_counter] = Mreq_stdev1; Mreq_Skew[layer_counter] = Mreq_skew1;
Mreq_Kurt[layer_counter] = Mreq_kurt1; Mreq_Min[layer_counter] = Mreq_min1;
Mreq_Max[layer_counter] = Mreq_max1;
cout << "Finish with Layer " << layer_counter + 1 << endl;
cout << Num_layer - layer_counter - 1 << " Layers Remaining" << endl << endl;}
if(Output_Sim == true)
{//Py Output
ofstream output_P;
```

```
output_P.open("Precipitation_Rosenblueth_3_Point.txt");
for (int j=0; j<531441;j++)
output_P << Rosenblueth3P[j] << endl;
output_P.close();
//Temperature Output
ofstream output_T;
output_T.open("Temperature_Rosenblueth_3_Point.txt");
for (int j=0; j<531441;j++)
output_T << Rosenblueth3Temp[j] << endl;
output_T.close();
//PE output
ofstream output_PE;
output_PE.open("PE_Rosenblueth_3_Point.txt");
for (int j=0; j<1594323;j++)
output_PE << Rosenblueth3PE[j] << endl;
output_PE.close();
//TMI Output
ofstream output_TMI;
output_TMI.open("TMI_Rosenblueth_3_Point.txt");
for (int i=0;i<9;i++)
output_TMI << RosenbluethTMI[i] << endl;
output_TMI.close();
ofstream output_Suction;
output_Suction.open("Rosenblueth_3Point_Suction.txt");
for( int w=0; w<9; w++){for(int layer =0;layer<Num_layer;layer++)
{output_Suction << Rosenblueth3Suction[layer][w] << "\t";}output_Suction <<
endl;}output_Suction.close();}
cout << "Rosenblueth 3 Point" << endl;}
```

```
else if (Check == 3) // Monte Carlo Solution
{int str, str1, str2, SWCC_checker;
double endloop;
endloop = Simulations_T;
cout << endl << "Monte Carlo Simulation" << endl;
cout << "Number of Simulations" << "\t" << Simulations_T << endl << endl;
double *MonteCarloP = new double[endloop];
double *MonteCarloT = new double[endloop];
double *MonteCarloPE = new double[endloop];
double *MonteCarloTMI = new double[endloop];
double **MonteCarloSuction = new double*[72];
for (int i=0; i<72; i++)
MonteCarloSuction[i] = new double [endloop];
double **Monte_theata_sat = new double*[72];
for (int i=0; i<72; i++)
Monte_theata_sat[i] = new double [endloop];
double **Monte_theata_water = new double*[72];
for (int i=0; i<72; i++)
Monte_theata_water[i] = new double [endloop];
double **Monte_degree_sat = new double*[72];
for (int i=0; i<72; i++)
Monte_degree_sat[i] = new double [endloop];
double **Monte_opt_sat = new double*[72];
for (int i=0; i<72; i++)
Monte_opt_sat[i] = new double [endloop];
double **Monte_gamma_dry = new double*[72];
for (int i=0; i<72; i++)
Monte_gamma_dry[i] = new double [endloop];
```

```
double **Monte_wopt = new double*[72];

for (int i=0; i<72; i++)

Monte_wopt[i] = new double [endloop];

double **Monte_PIadj = new double*[72];

for (int i=0; i<72; i++)

Monte_PIadj[i] = new double [endloop];

double **Monte_wPIadj = new double*[72];

for (int i=0; i<72; i++)

Monte_wPIadj[i] = new double [endloop];

double **Monte_Fenv = new double*[72];

for (int i=0; i<72; i++)

Monte_Fenv[i] = new double [endloop];

double **Monte_Mropt = new double*[72];

for (int i=0; i<72; i++)

Monte_Mropt[i] = new double [endloop];

double **Monte_Mreq = new double*[72];

for (int i=0; i<72; i++)

Monte_Mreq[i] = new double [endloop];

double **TMIStorage = new double*[3];

for (int i=0; i<3; i++)

TMIStorage[i] = new double [endloop];

double ***SWCC_Parameters = new double**[72];

for (int i=0; i<72; i++)

{SWCC_Parameters[i] = new double *[endloop];

for(int j=0; j<endloop; j++)

{SWCC_Parameters[i][j] = new double[4];

for(int k=0; k<4; k++){SWCC_Parameters[i][j][k] = 0.0;}}}

double **CBRStorage = new double*[72];
```

```
for (int i=0; i<72; i++)
CBRStorage[i] = new double [endloop];
double **Model_Storage = new double *[72];
for(int i=0; i<72; i++)
Model_Storage[i] = new double[endloop];
int **woptModelStorage = new int *[72];
for(int i=0; i<72; i++)
woptModelStorage[i] = new int[endloop];

for (int i=0; i<72; i++){for(int j=0; j<endloop; j++)
{MonteCarloSuction[i][j] = 0.0;Monte_theata_sat[i][j] = 0.0;Monte_theata_water[i][j] =
0.0;Monte_degree_sat[i][j] = 0.0;Monte_opt_sat[i][j] = 0.0;Monte_gamma_dry[i][j] =
0.0;Monte_wopt[i][j] = 0.0;Monte_PIadj[i][j] = 0.0;Monte_wPIadj[i][j] = 0.0;Monte_Fenv[i][j] =
0.0;Monte_Mropt[i][j] = 0.0;Monte_Mreq[i][j] = 0.0;CBRStorage[i][j] = 0.0;Model_Storage[i][j]
= 0.0;woptModelStorage[i][j] = 0.0;}}
for(int i=0; i<endloop; i++)
{MonteCarloP[i] = 0.0;MonteCarloT[i] = 0.0; MonteCarloPE[i] = 0.0; MonteCarloTMI[i] = 0.0;}
double MonteCarlo_gamma_dry, MonteCarlo_Gs, Monte_gamma_dry1, Monte_Gs,
summation_theata_sat, summation_theata_sat_var, theata_sat_var, theata_sat_stdev,
theata_sat_min, theata_sat_max, theata_sat_alpha, theata_sat_beta, theata_water_check;
double MonteCarlo_theata_P200, MonteCarlo_theata_TMI, MonteCarlo_theata_wPI,
MonteCarlo_theata_Suction, Monte_P200_theata_water, Monte_TMI_theata_water,
Monte_wPI_theata_water, Monte_Suction_theata_water, summation_theata_water,
summation_theata_water_var, theata_water_var, theata_water_stdev, theata_water_min,
theata_water_max, theata_water_alpha, theata_water_beta;
double MonteCarlo_theata_sat, MonteCarlo_theata_water, Monte_theata_sat_dsat,
Monte_theata_water_dsat, summation_degree_sat, summation_degree_sat_var,
summation_degree_sat_skew, summation_degree_sat_kurt;
```

```
double MonteCarlo_opt_wopt, MonteCarlo_opt_gamma, MonteCarlo_opt_Gs,
MonteCarlo_opt_P20, MonteCarlo_opt_P10, MonteCarlo_opt_P05,Monte_P20, Monte_P10,
Monte_P05, Monte_opt_wopt, Monte_opt_gamma, Monte_opt_Gs, summation_opt_sat_var,
summation_opt_sat_skew, summation_opt_sat_kurt, Monte_sat_theata_water;
double MonteCarlo_gamma_wopt, MonteCarlo_gamma_Gs, MonteCarlo_gamma_Sopt,
Monte_gamma_wopt, Monte_gamma_Gs, Monte_gamma_Sopt, gamma_dry_min,
gamma_dry_max, summation_gamma_dry_var, gamma_dry_alpha, gamma_dry_beta;
double MonteCarlo_wopt_wPIadj, MonteCarlo_wopt_P15, MonteCarlo_wopt_P40,
MonteCarlo_wopt_P60, MonteCarlo_wopt_D60, Monte_wopt_P15, Monte_wopt_P40,
Monte_wopt_P60, Monte_wopt_D60, wopt_min, wopt_max, summation_wopt_var, wopt_alpha,
wopt_beta;
double MonteCarlo_PIadj_P200, Monte_PIadj_P200, PI_adj_min, PI_adj_max,
summation_PI_adj_var, PI_adj_alpha, PI_adj_beta;
double MonteCarlo_wPIadj_PIadj, MonteCarlo_wPIadj_P200, Monte_wPIadj_PIadj,
Monte_wPIadj_P200, Monte_wPIadj1, wPIadj_min, wPIadj_max, summation_wPIadj_var,
wPIadj_alpha, wPIadj_beta, summation_wPIadj;
double MonteCarlo_Fenv_wPI, MonteCarlo_Fenv_degree_sat, MonteCarlo_Fenv_opt_sat,
summation_Fenv_kurt, summation_Fenv_skew, Monte_Fenv_wPI, Monte_Fenv_dsat,
Monte_Fenv_osat, summation_Fenv_var, summation_Fenv;
double MonteCarlo_Mropt_CBR, MonteCarlo_Mropt_D60, MonteCarlo_Mropt_wPI,
summation_Mropt_kurt, summation_Mropt_skew, Monte_Mropt_CBR, Monte_Mropt_D60,
Monte_Mropt_wPI, summation_Mropt, summation_Mropt_var;
double MonteCarlo_Mreq_Fenv, MonteCarlo_Mreq_Mropt, summation_Mreq_kurt,
summation_Mreq_skew, Monte_Mreq_Fenv, Monte_Mreq_Mropt, summation_Mreq_var,
summation_Mreq;
double suction_TMI_Num, summation_suction_kurt, summation_suction_skew, Hy_Monte,
summation_opt_sat, summation_wopt, wopt_var, wopt_stdev, Monte_wPI_theata_water1,
Monte_wPI_theata_water2;
```

```
double P200_Monte, TMI_Monte, wPI_Monte, suction, summation_suction,
summation_suction_var, prob, prob1, prob2, prob3, summation_gamma_dry;
double January_R, February_R, March_R, April_R, May1_R, June_R, July_R, August_R,
September_R, October_R, November_R, December_R, summation_PIadj, wPIadj_var,
wPIadj_stdev;
double Hy_PER, January_PER, February_PER, March_PER, April_PER, May1_PER, June_PER,
July_PER, August_PER, September_PER, October_PER, November_PER, December_PER,
PI_adj_stdev;
//Initializing Variables
P_skew = 0;summation_P_skew =0;P_kurt = 0;summation_P_kurt = 0; Hy_skew = 0;
summation_Hy_skew = 0; Hy_kurt = 0;summation_Hy_kurt = 0; PE_skew =
0;summation_PE_skew = 0;PE_kurt = 0;summation_PE_kurt = 0;TMI_skew =
0;summation_TMI_skew = 0;TMI_kurt = 0;summation_TMI_kurt = 0;summation_suction =
0.0;summation_suction_var = 0.0;summation_suction_skew = 0.0;summation_suction_kurt =
0.0;suction_mean1 = 0.0;January_R = 0;February_R = 0;March_R = 0;April_R = 0;May1_R =
0;June_R = 0;July_R = 0;August_R = 0;September_R = 0;October_R = 0;November_R =
0;December_R = 0;Hy_PER = 0;January_PER = 0;February_PER = 0;March_PER = 0;April_PER
= 0;May1_PER = 0;June_PER = 0;July_PER = 0;August_PER = 0;September_PER =
0;October_PER = 0;November_PER = 0;December_PER = 0;summation_Hy =
0;summation_Hy_var = 0;Hy = 0;summation_PE = 0;summation_PE_var = 0;PE =
0;summation_Pone = 0;summation_P_var = 0;Pone = 0;summation_TMI = 0;TMI =
0;summation_TMI_var = 0;TMI_mean = 0;TMI_var = 0;TMI_stdev = 0;MonteCarlo_gamma_dry
= 0.0;MonteCarlo_Gs = 0.0;Monte_gamma_dry1 = 0.0;Monte_Gs = 0.0;summation_theata_sat =
0.0;summation_theata_sat_var = 0.0;theata_sat_var = 0.0;theata_sat_stdev = 0.0;theata_sat_min =
0.0;theata_sat_max = 0.0;theata_sat_alpha = 0.0;theata_sat_beta = 0.0;theata_water_check =
0.0;MonteCarlo_theata_P200 = 0.0;MonteCarlo_theata_TMI = 0.0;MonteCarlo_theata_wPI =
0.0;MonteCarlo_theata_Suction = 0.0;Monte_P200_theata_water = 0.0;Monte_TMI_theata_water
= 0.0;Monte_wPI_theata_water = 0.0;Monte_Suction_theata_water =
```

```
0.0;summation_theata_water = 0.0;summation_theata_water_var = 0.0;theata_water_var =
0.0;theata_water_stdev = 0.0;theata_water_min = 0.0;theata_water_max = 0.0;theata_water_alpha
= 0.0;theata_water_beta = 0.0;MonteCarlo_theata_sat = 0.0;MonteCarlo_theata_water =
0.0;Monte_theata_sat_dsat = 0.0;Monte_theata_water_dsat = 0.0;summation_degree_sat =
0.0;summation_degree_sat_var = 0.0;summation_degree_sat_skew =
0.0;summation_degree_sat_kurt = 0.0;MonteCarlo_opt_wopt = 0.0;MonteCarlo_opt_gamma =
0.0;MonteCarlo_opt_Gs = 0.0;MonteCarlo_opt_P20 = 0.0;MonteCarlo_opt_P10 =
0.0;MonteCarlo_opt_P05 = 0.0;Monte_P20 = 0.0;Monte_P10 = 0.0;Monte_P05 =
0.0;Monte_opt_wopt = 0.0;Monte_opt_gamma = 0.0;Monte_opt_Gs =
0.0;summation_opt_sat_var = 0.0;summation_opt_sat_skew = 0.0;summation_opt_sat_kurt =
0.0;MonteCarlo_gamma_wopt = 0.0;MonteCarlo_gamma_Gs = 0.0;MonteCarlo_gamma_Sopt =
0.0;Monte_gamma_wopt = 0.0;Monte_gamma_Gs = 0.0;Monte_gamma_Sopt =
0.0;gamma_dry_min = 0.0;gamma_dry_max = 0.0;summation_gamma_dry_var =
0.0;gamma_dry_alpha = 0.0;gamma_dry_beta = 0.0;MonteCarlo_wopt_wPIadj =
0.0;MonteCarlo_wopt_P15 = 0.0;MonteCarlo_wopt_P40 = 0.0;MonteCarlo_wopt_P60 =
0.0;MonteCarlo_wopt_D60 = 0.0;Monte_wopt_P15 = 0.0;Monte_wopt_P40 =
0.0;Monte_wopt_P60 = 0.0;Monte_wopt_D60 = 0.0;wopt_min = 0.0;wopt_max =
0.0;summation_wopt_var = 0.0;wopt_alpha = 0.0;wopt_beta = 0.0;MonteCarlo_PIadj_P200 =
0.0;Monte_PIadj_P200 = 0.0;PI_adj_min = 0.0;PI_adj_max = 0.0; summation_PI_adj_var =
0.0;PI_adj_alpha = 0.0;PI_adj_beta = 0.0;MonteCarlo_wPIadj_PIadj =
0.0;MonteCarlo_wPIadj_P200 = 0.0;Monte_wPIadj_PIadj = 0.0;Monte_wPIadj_P200 =
0.0;Monte_wPIadj1 = 0.0;wPIadj_min = 0.0;wPIadj_max = 0.0;summation_wPIadj_var =
0.0;wPIadj_alpha = 0.0;wPIadj_beta = 0.0;summation_wPIadj = 0.0;MonteCarlo_Fenv_wPI =
0.0;MonteCarlo_Fenv_degree_sat = 0.0;MonteCarlo_Fenv_opt_sat = 0.0;summation_Fenv_kurt =
0.0; summation_Fenv_skew = 0.0;Monte_Fenv_wPI = 0.0;Monte_Fenv_dsat =
0.0;Monte_Fenv_osat = 0.0;summation_Fenv_var = 0.0;summation_Fenv =
0.0;MonteCarlo_Mropt_CBR = 0.0;MonteCarlo_Mropt_D60 = 0.0;MonteCarlo_Mropt_wPI =
0.0;summation_Mropt_kurt = 0.0;summation_Mropt_skew = 0.0;Monte_Mropt_CBR =
```

```
0.0;Monte_Mropt_D60 = 0.0;Monte_Mropt_wPI = 0.0;summation_Mropt =
0.0;summation_Mropt_var = 0.0;MonteCarlo_Mreq_Fenv = 0.0;MonteCarlo_Mreq_Mropt =
0.0;summation_Mreq_kurt = 0.0;summation_Mreq_skew = 0.0;Monte_Mreq_Fenv =
0.0;Monte_Mreq_Mropt = 0.0;summation_Mreq_var = 0.0;summation_Mreq =
0.0;suction_TMI_Num = 0.0;summation_suction_kurt = 0.0;summation_suction_skew =
0.0;Hy_Monte = 0.0;summation_opt_sat = 0.0;summation_wopt = 0.0;wopt_var = 0.0;wopt_stdev
= 0.0;P200_Monte = 0.0;TMI_Monte = 0.0;wPI_Monte = 0.0;suction = 0.0;summation_suction =
0.0;summation_suction_var = 0.0;prob = 0.0;prob1 = 0.0;prob2 = 0.0;prob3 =
0.0;summation_gamma_dry = 0.0;January_R = 0.0;February_R = 0.0;March_R = 0.0;April_R =
0.0;May1_R = 0.0;June_R = 0.0;July_R = 0.0;August_R = 0.0;September_R = 0.0;October_R =
0.0;November_R = 0.0;December_R = 0.0;summation_PIadj = 0.0;wPIadj_var =
0.0;wPIadj_stdev = 0.0;Hy_PER = 0.0;January_PER = 0.0;February_PER = 0.0;March_PER =
0.0;April_PER = 0.0;May1_PER = 0.0;June_PER = 0.0;July_PER = 0.0;August_PER =
0.0;September_PER = 0.0;October_PER = 0.0;November_PER = 0.0;December_PER =
0.0;PI_adj_stdev = 0.0;CBR_Summation = 0.0;
cout << "Starting TMI Calculations" << endl;
//Precipitation Mean, Variance, Skewness, and Kurtosis Calculations
for (int q=0; q < endloop; q++)
{
Jan_P = gsl_rng_uniform_pos(Rand_NUM_Gen);Feb_P =
gsl_rng_uniform_pos(Rand_NUM_Gen);Mar_P =
gsl_rng_uniform_pos(Rand_NUM_Gen);Apr_P =
gsl_rng_uniform_pos(Rand_NUM_Gen);May_P =
gsl_rng_uniform_pos(Rand_NUM_Gen);Jun_P = gsl_rng_uniform_pos(Rand_NUM_Gen);Jul_P
= gsl_rng_uniform_pos(Rand_NUM_Gen);Aug_P =
gsl_rng_uniform_pos(Rand_NUM_Gen);Sep_P = gsl_rng_uniform_pos(Rand_NUM_Gen);Oct_P
= gsl_rng_uniform_pos(Rand_NUM_Gen);Nov_P =
gsl_rng_uniform_pos(Rand_NUM_Gen);Dec_P = gsl_rng_uniform_pos(Rand_NUM_Gen);
```

```
January_P = gsl_cdf_beta_Pinv(Jan_P,JanP[5],JanP[6]);
str = static_cast<int>(January_P);
if (str != 0)
{do{Jan_P = gsl_rng_uniform_pos(Rand_NUM_Gen);
January_P = gsl_cdf_beta_Pinv(Jan_P,JanP[5],JanP[6]);
str = static_cast<int>(January_P);} while (str != 0);}
January_P = (JanP[3] + (January_P * (JanP[4] - JanP[3])));
if (January_P < 0)
January_P = 0;
February_P = gsl_cdf_beta_Pinv(Feb_P,FebP[5],FebP[6]);
str = static_cast<int>(February_P);
if (str != 0)
{do{Feb_P = gsl_rng_uniform_pos(Rand_NUM_Gen);
February_P = gsl_cdf_beta_Pinv(Feb_P,FebP[5],FebP[6]);
str = static_cast<int>(February_P);} while (str != 0);}
February_P = (FebP[3] + (February_P * (FebP[4] - FebP[3])));
if(February_P < 0)
February_P = 0;
March_P = gsl_cdf_beta_Pinv(Mar_P,MarP[5],MarP[6]);
str = static_cast<int>(March_P);
if (str != 0)
{do{Mar_P = gsl_rng_uniform_pos(Rand_NUM_Gen);
March_P = gsl_cdf_beta_Pinv(Mar_P,MarP[5],MarP[6]);
str = static_cast<int>(March_P);} while (str != 0);}
March_P = (MarP[3] + (March_P * (MarP[4] - MarP[3])));
if (March_P < 0)
March_P = 0;
April_P = gsl_cdf_beta_Pinv(Apr_P,AprP[5],AprP[6]);
```

```
str = static_cast<int>(April_P);

if (str != 0)

{do{Apr_P = gsl_rng_uniform_pos(Rand_NUM_Gen);

April_P = gsl_cdf_beta_Pinv(Apr_P,AprP[5],AprP[6]);

str = static_cast<int>(April_P);} while (str != 0);}

April_P = (AprP[3] + (April_P * (AprP[4] - AprP[3])));

if(April_P < 0)

April_P = 0;

May1_P = gsl_cdf_beta_Pinv(May_P,MayP[5],MayP[6]);

str = static_cast<int>(May1_P);

if (str != 0)

{do{May_P = gsl_rng_uniform_pos(Rand_NUM_Gen);

May1_P = gsl_cdf_beta_Pinv(May_P,MayP[5],MayP[6]);

str = static_cast<int>(May1_P);} while (str != 0);}

May1_P = (MayP[3] + (May1_P * (MayP[4] - MayP[3])));

if(May1_P < 0)

May1_P = 0;

June_P = gsl_cdf_beta_Pinv(Jun_P,JunP[5],JunP[6]);

str = static_cast<int>(June_P);

if (str != 0)

{do{Jun_P = gsl_rng_uniform_pos(Rand_NUM_Gen);

June_P = gsl_cdf_beta_Pinv(Jun_P,JunP[5],JunP[6]);

str = static_cast<int>(June_P);} while (str != 0);}

June_P = (JunP[3] + (June_P * (JunP[4] - JunP[3])));

if(June_P < 0)

June_P = 0;

July_P = gsl_cdf_beta_Pinv(Jul_P,JulP[5],JulP[6]);

str = static_cast<int>(July_P);
```

```
if (str != 0)
{do{Jul_P = gsl_rng_uniform_pos(Rand_NUM_Gen);
July_P = gsl_cdf_beta_Pinv(Jul_P,JulP[5],JulP[6]);
str = static_cast<int>(July_P);} while (str != 0);}
July_P = (JulP[3] + (July_P * (JulP[4] - JulP[3])));
if(July_P < 0)
July_P = 0;
August_P = gsl_cdf_beta_Pinv(Aug_P,AugP[5],AugP[6]);
str = static_cast<int>(August_P);
if (str != 0)
{do{Aug_P = gsl_rng_uniform_pos(Rand_NUM_Gen);
August_P = gsl_cdf_beta_Pinv(Aug_P,AugP[5],AugP[6]);
str = static_cast<int>(August_P);} while (str != 0);}
August_P = (AugP[3] + (August_P * (AugP[4] - AugP[3])));
if(August_P < 0)
August_P = 0;
September_P = gsl_cdf_beta_Pinv(Sep_P,SepP[5],SepP[6]);
str = static_cast<int>(September_P);
if (str != 0)
{do{Sep_P = gsl_rng_uniform_pos(Rand_NUM_Gen);
September_P = gsl_cdf_beta_Pinv(Sep_P,SepP[5],SepP[6]);
str = static_cast<int>(September_P);} while (str != 0);}
September_P = (SepP[3] + (September_P * (SepP[4] - SepP[3])));
if(September_P < 0)
September_P = 0;
October_P = gsl_cdf_beta_Pinv(Oct_P,OctP[5],OctP[6]);
str = static_cast<int>(October_P);
if (str != 0)
```

```
{do{Oct_P = gsl_rng_uniform_pos(Rand_NUM_Gen);
October_P = gsl_cdf_beta_Pinv(Oct_P,OctP[5],OctP[6]);
str = static_cast<int>(October_P);} while (str != 0);}
October_P = (OctP[3] + (October_P * (OctP[4] - OctP[3])));
if(October_P < 0)
October_P = 0;
November_P = gsl_cdf_beta_Pinv(Nov_P,NovP[5],NovP[6]);
str = static_cast<int>(November_P);
if (str != 0)
{do{Nov_P = gsl_rng_uniform_pos(Rand_NUM_Gen);
November_P = gsl_cdf_beta_Pinv(Nov_P,NovP[5],NovP[6]);
str = static_cast<int>(November_P);} while (str != 0);}
November_P = (NovP[3] + (November_P * (NovP[4] - NovP[3])));
if(November_P < 0)
November_P = 0;
December_P = gsl_cdf_beta_Pinv(Dec_P,DecP[5],DecP[6]);
str = static_cast<int>(December_P);
if (str != 0)
{do{Dec_P = gsl_rng_uniform_pos(Rand_NUM_Gen);
December_P = gsl_cdf_beta_Pinv(Dec_P,DecP[5],DecP[6]);
str = static_cast<int>(December_P);} while (str != 0);}
December_P = (DecP[3] + (December_P * (DecP[4] - DecP[3])));
if(December_P < 0)
December_P = 0;
Pone = January_P + February_P + March_P + April_P + May1_P + June_P + July_P + August_P
+ September_P + October_P + November_P + December_P;
summation_Pone += Pone;
MonteCarloP[q]=Pone;
```

```
}
P_mean = summation_Pone/endloop;
for( int w=0; w<endloop; w++)
{
P_var = pow((MonteCarloP[w]-P_mean),2.0);
summation_P_var += P_var;
}
P_var = summation_P_var/endloop;P_stdev = pow(P_var,0.5);P_min = 1000.0;P_max = 0.0;
for( int y=0;y<endloop;y++)
{
P_skew = pow(((MonteCarloP[y]-P_mean)/P_stdev),3.0);
summation_P_skew += P_skew;
P_kurt = pow(((MonteCarloP[y]-P_mean)/P_stdev),4.0);
summation_P_kurt +=P_kurt;
if(P_min > MonteCarloP[y])
P_min = MonteCarloP[y];
if(P_max < MonteCarloP[y])
P_max = MonteCarloP[y];
}
P_skew = (1/endloop)*summation_P_skew;
P_kurt = ((1/endloop)*summation_P_kurt)-3.0;
P_alpha = ((P_mean-P_min)/(P_max-P_min))*(((P_mean-P_min)*(P_max-P_mean)/P_var)-1.0);
P_beta = ((P_max-P_mean)/(P_mean-P_min))*P_alpha;
// Annual Heat Index Mean, Variance, Skewness, and Kurtosis Calculations
for (int q=0; q < endloop; q++)
{
Jan_T = gsl_rng_uniform_pos(Rand_NUM_Gen);Feb_T =
gsl_rng_uniform_pos(Rand_NUM_Gen);Mar_T =
```

```
gsl_rng_uniform_pos(Rand_NUM_Gen);Apr_T =
gsl_rng_uniform_pos(Rand_NUM_Gen);May_T =
gsl_rng_uniform_pos(Rand_NUM_Gen);Jun_T = gsl_rng_uniform_pos(Rand_NUM_Gen);Jul_T
= gsl_rng_uniform_pos(Rand_NUM_Gen);Aug_T =
gsl_rng_uniform_pos(Rand_NUM_Gen);Sep_T = gsl_rng_uniform_pos(Rand_NUM_Gen);Oct_T
= gsl_rng_uniform_pos(Rand_NUM_Gen);Nov_T =
gsl_rng_uniform_pos(Rand_NUM_Gen);Dec_T = gsl_rng_uniform_pos(Rand_NUM_Gen);
January_T = gsl_cdf_beta_Pinv(Jan_T,JanT[5],JanT[6]);
str = static_cast<int>(January_T);
if (str != 0)
{do{Jan_T = gsl_rng_uniform_pos(Rand_NUM_Gen);
January_T = gsl_cdf_beta_Pinv(Jan_T,JanT[5],JanT[6]);
str = static_cast<int>(January_T);} while (str != 0);}
January_T = (JanT[3] + (January_T * (JanT[4] - JanT[3])));
if (January_T < 0)
January_T = 0;
January_R = pow((0.2*January_T),1.514);
February_T = gsl_cdf_beta_Pinv(Feb_T,FebT[5],FebT[6]);
str = static_cast<int>(February_T);
if (str != 0)
{do{Feb_T = gsl_rng_uniform_pos(Rand_NUM_Gen);
February_T = gsl_cdf_beta_Pinv(Feb_T,FebT[5],FebT[6]);
str = static_cast<int>(February_T);} while (str != 0);}
February_T = (FebT[3] + (February_T * (FebT[4] - FebT[3])));
if(February_T < 0)
February_T = 0;
February_R = pow((0.2*February_T),1.514);
March_T = gsl_cdf_beta_Pinv(Mar_T,MarT[5],MarT[6]);
```

```
str = static_cast<int>(March_T);

if (str != 0)

{do{Mar_T = gsl_rng_uniform_pos(Rand_NUM_Gen);

March_T = gsl_cdf_beta_Pinv(Mar_T,MarT[5],MarT[6]);

str = static_cast<int>(March_T);} while (str != 0);}

March_T = (MarT[3] + (March_T * (MarT[4] - MarT[3])));

if (March_T < 0)

March_T = 0;

March_R = pow((0.2*March_T),1.514);

April_T = gsl_cdf_beta_Pinv(Apr_T,AprT[5],AprT[6]);

str = static_cast<int>(April_T);

if (str != 0)

{do{Apr_T = gsl_rng_uniform_pos(Rand_NUM_Gen);

April_T = gsl_cdf_beta_Pinv(Apr_T,AprT[5],AprT[6]);

str = static_cast<int>(April_T);} while (str != 0);}

April_T = (AprT[3] + (April_T * (AprT[4] - AprT[3])));

if(April_T < 0)

April_T = 0;

April_R = pow((0.2*April_T),1.514);

May1_T = gsl_cdf_beta_Pinv(May_T,MayT[5],MayT[6]);

str = static_cast<int>(May1_T);

if (str != 0)

{do{May_T = gsl_rng_uniform_pos(Rand_NUM_Gen);

May1_T = gsl_cdf_beta_Pinv(May_T,MayT[5],MayT[6]);

str = static_cast<int>(May1_T);} while (str != 0);}

May1_T = (MayT[3] + (May1_T * (MayT[4] - MayT[3])));

if(May1_T < 0)

May1_T = 0;
```

```
May1_R = pow((0.2*May1_T),1.514);
June_T = gsl_cdf_beta_Pinv(Jun_T,JunT[5],JunT[6]);
str = static_cast<int>(June_T);
if (str != 0)
{do{Jun_T = gsl_rng_uniform_pos(Rand_NUM_Gen);
June_T = gsl_cdf_beta_Pinv(Jun_T,JunT[5],JunT[6]);
str = static_cast<int>(June_T);} while (str != 0);}
June_T = (JunT[3] + (June_T * (JunT[4] - JunT[3])));
if(June_T < 0)
June_T = 0;
June_R = pow((0.2*June_T),1.514);
July_T = gsl_cdf_beta_Pinv(Jul_T,JulT[5],JulT[6]);
str = static_cast<int>(July_T);
if (str != 0)
{do{Jul_T = gsl_rng_uniform_pos(Rand_NUM_Gen);
July_T = gsl_cdf_beta_Pinv(Jul_T,JulT[5],JulT[6]);
str = static_cast<int>(July_T);} while (str != 0);}
July_T = (JulT[3] + (July_T * (JulT[4] - JulT[3])));
if(July_T < 0)
July_T = 0;
July_R = pow((0.2*July_T),1.514);
August_T = gsl_cdf_beta_Pinv(Aug_T,AugT[5],AugT[6]);
str = static_cast<int>(August_T);
if (str != 0)
{do{Aug_T = gsl_rng_uniform_pos(Rand_NUM_Gen);
August_T = gsl_cdf_beta_Pinv(Aug_T,AugT[5],AugT[6]);
str = static_cast<int>(August_T);} while (str != 0);}
August_T = (AugT[3] + (August_T * (AugT[4] - AugT[3])));
```

```
if(August_T < 0)
August_T = 0;
August_R = pow((0.2*August_T),1.514);
September_T = gsl_cdf_beta_Pinv(Sep_T,SepT[5],SepT[6]);
str = static_cast<int>(September_T);
if (str != 0)
{do{Sep_T = gsl_rng_uniform_pos(Rand_NUM_Gen);
September_T = gsl_cdf_beta_Pinv(Sep_T,SepT[5],SepT[6]);
str = static_cast<int>(September_T);} while (str != 0);}
September_T = (SepT[3] + (September_T * (SepT[4] - SepT[3])));
if(September_T < 0)
September_T = 0;
September_R = pow((0.2*September_T),1.514);
October_T = gsl_cdf_beta_Pinv(Oct_T,OctT[5],OctT[6]);
str = static_cast<int>(October_T);
if (str != 0)
{do{Oct_T = gsl_rng_uniform_pos(Rand_NUM_Gen);
October_T = gsl_cdf_beta_Pinv(Oct_T,OctT[5],OctT[6]);
str = static_cast<int>(October_T);} while (str != 0);}
October_T = (OctT[3] + (October_T * (OctT[4] - OctT[3])));
if(October_T < 0)
October_T = 0;
October_R = pow((0.2*October_T),1.514);
November_T = gsl_cdf_beta_Pinv(Nov_T,NovT[5],NovT[6]);
str = static_cast<int>(November_T);
if (str != 0)
{do{Nov_T = gsl_rng_uniform_pos(Rand_NUM_Gen);
November_T = gsl_cdf_beta_Pinv(Nov_T,NovT[5],NovT[6]);
```

```
str = static_cast<int>(November_T);} while (str != 0);}
November_T = (NovT[3] + (November_T * (NovT[4] - NovT[3])));
if(November_T < 0)
November_T = 0;
November_R = pow((0.2*November_T),1.514);
December_T = gsl_cdf_beta_Pinv(Dec_T,DecT[5],DecT[6]);
str = static_cast<int>(December_T);
if (str != 0)
{do{Dec_T = gsl_rng_uniform_pos(Rand_NUM_Gen);
December_T = gsl_cdf_beta_Pinv(Dec_T,DecT[5],DecT[6]);
str = static_cast<int>(December_T);} while (str != 0);}
December_T = (DecT[3] + (December_T * (DecT[4] - DecT[3])));
if(December_T < 0)
December_T = 0;
December_R = pow((0.2*December_T),1.514);
Hy = January_R + February_R + March_R + April_R + May1_R + June_R + July_R + August_R
+ September_R + October_R + November_R + December_R;
summation_Hy += Hy;
MonteCarloT[q] = Hy;
}
Hy_mean = summation_Hy/endloop;
for( int w=0; w<endloop; w++)
{
Hy_var = pow((MonteCarloT[w]- Hy_mean),2.0);
summation_Hy_var += Hy_var;
}
Hy_var = summation_Hy_var / endloop;
Hy_stdev = pow(Hy_var,0.5);Hy_min = 1000.0;Hy_max = 0.0;
```

```
for(int f=0; f<endloop;f++)
{
Hy_skew = pow(((MonteCarloT[f]-Hy_mean)/Hy_stdev),3.0);
summation_Hy_skew += Hy_skew;
Hy_kurt = pow(((MonteCarloT[f]-Hy_mean)/Hy_stdev),4.0);
summation_Hy_kurt += Hy_kurt;
if(Hy_min > MonteCarloT[f])
Hy_min = MonteCarloT[f];
if(Hy_max < MonteCarloT[f])
Hy_max = MonteCarloT[f];
}
Hy_skew = (1/endloop)*summation_Hy_skew;
Hy_kurt = ((1/endloop)*summation_Hy_kurt)-3.0;
Hy_alpha = ((Hy_mean-Hy_min)/(Hy_max-Hy_min))*(((Hy_mean-Hy_min)*(Hy_max-
Hy_mean)/Hy_var)-1.0);
Hy_beta = ((Hy_max-Hy_mean)/(Hy_mean-Hy_min))*Hy_alpha;
// Potential Evapotranspiration Mean, Variance, Skewness, and Kurtosis Calculations
for (int q=0; q < endloop; q++)
{
Hy_PE = gsl_rng_uniform_pos(Rand_NUM_Gen);Jan_PE =
gsl_rng_uniform_pos(Rand_NUM_Gen);Feb_PE =
gsl_rng_uniform_pos(Rand_NUM_Gen);Mar_PE =
gsl_rng_uniform_pos(Rand_NUM_Gen);Apr_PE =
gsl_rng_uniform_pos(Rand_NUM_Gen);May_PE =
gsl_rng_uniform_pos(Rand_NUM_Gen);Jun_PE =
gsl_rng_uniform_pos(Rand_NUM_Gen);Jul_PE =
gsl_rng_uniform_pos(Rand_NUM_Gen);Aug_PE =
gsl_rng_uniform_pos(Rand_NUM_Gen);Sep_PE =
```

```
gsl_rng_uniform_pos(Rand_NUM_Gen);Oct_PE =
gsl_rng_uniform_pos(Rand_NUM_Gen);Nov_PE =
gsl_rng_uniform_pos(Rand_NUM_Gen);Dec_PE = gsl_rng_uniform_pos(Rand_NUM_Gen);
Hy_Monte = gsl_cdf_beta_Pinv(Hy_PE,Hy_alpha,Hy_beta);
str = static_cast<int>(Hy_Monte);
if (str != 0)
{do{Hy_PE = gsl_rng_uniform_pos(Rand_NUM_Gen);
Hy_Monte = gsl_cdf_beta_Pinv(Hy_PE,Hy_alpha,Hy_beta);
str = static_cast<int>(Hy_Monte);} while (str != 0);}
Hy_Monte = (Hy_min + (Hy_Monte * (Hy_max - Hy_min)));
Hy_3 = pow(Hy_Monte,3.0);Hy_2 = pow(Hy_Monte,2.0);
apow = a0*Hy_3 + a1*Hy_2 + a2*Hy_Monte + a3;
Hy_PER = pow((10.0/Hy_Monte),apow);
January_PE = gsl_cdf_beta_Pinv(Jan_PE,JanT[5],JanT[6]);
str = static_cast<int>(January_PE);
if (str != 0)
{do{Jan_PE = gsl_rng_uniform_pos(Rand_NUM_Gen);
January_PE = gsl_cdf_beta_Pinv(Jan_PE,JanT[5],JanT[6]);
str = static_cast<int>(January_PE);} while (str != 0);}
January_PE = (JanT[3] + (January_PE * (JanT[4] - JanT[3])));
if (January_PE < 0)
January_PE = 0;
January_PER = Co * Hy_PER * Jan_L * pow(January_PE, apow);
February_PE = gsl_cdf_beta_Pinv(Feb_PE,FebT[5],FebT[6]);
str = static_cast<int>(February_PE);
if (str != 0)
{do{Feb_PE = gsl_rng_uniform_pos(Rand_NUM_Gen);
February_PE = gsl_cdf_beta_Pinv(Feb_PE,FebT[5],FebT[6]);
```

```
str = static_cast<int>(February_PE);} while (str != 0);}
February_PE = (FebT[3] + (February_PE * (FebT[4] - FebT[3])));
if(February_PE < 0)
February_PE = 0;
February_PER = Co * Hy_PER * Feb_L * pow(February_PE, apow);
March_PE = gsl_cdf_beta_Pinv(Mar_PE,MarT[5],MarT[6]);
str = static_cast<int>(March_PE);
if (str != 0)
{do{Mar_PE = gsl_rng_uniform_pos(Rand_NUM_Gen);
March_PE = gsl_cdf_beta_Pinv(Mar_PE,MarT[5],MarT[6]);
str = static_cast<int>(March_PE);} while (str != 0);}
March_PE = (MarT[3] + (March_PE * (MarT[4] - MarT[3])));
if (March_PE < 0)
March_PE = 0;
March_PER = Co * Hy_PER * Mar_L * pow(March_PER, apow);
April_PE = gsl_cdf_beta_Pinv(Apr_PE,AprT[5],AprT[6]);
str = static_cast<int>(April_PE);
if (str != 0)
{do{Apr_PE = gsl_rng_uniform_pos(Rand_NUM_Gen);
April_PE = gsl_cdf_beta_Pinv(Apr_PE,AprT[5],AprT[6]);
str = static_cast<int>(April_PE);} while (str != 0);}
April_PE = (AprT[3] + (April_PE * (AprT[4] - AprT[3])));
if(April_PE < 0)
April_PE = 0;
April_PER = Co * Hy_PER * Apr_L * pow(April_PE, apow);
May1_PE = gsl_cdf_beta_Pinv(May_PE,MayT[5],MayT[6]);
str = static_cast<int>(May1_PE);
if (str != 0)
```

```
{do{May_PE = gsl_rng_uniform_pos(Rand_NUM_Gen);
May1_PE = gsl_cdf_beta_Pinv(May_PE,MayT[5],MayT[6]);
str = static_cast<int>(May1_PE);} while (str != 0);}
May1_PE = (MayT[3] + (May1_PE * (MayT[4] - MayT[3])));
if(May1_PE < 0)
May1_PE = 0;
May1_PER = Co * Hy_PER * May_L * pow(May1_PE, apow);
June_PE = gsl_cdf_beta_Pinv(Jun_PE,JunT[5],JunT[6]);
str = static_cast<int>(June_PE);
if (str != 0)
{do{Jun_PE = gsl_rng_uniform_pos(Rand_NUM_Gen);
June_PE = gsl_cdf_beta_Pinv(Jun_PE,JunT[5],JunT[6]);
str = static_cast<int>(June_PE);} while (str != 0);}
June_PE = (JunT[3] + (June_PE * (JunT[4] - JunT[3])));
if(June_PE < 0)
June_PE = 0;
June_PER = Co * Hy_PER * Jun_L * pow(June_PE, apow);
July_PE = gsl_cdf_beta_Pinv(Jul_PE,JulT[5],JulT[6]);
str = static_cast<int>(July_PE);
if (str != 0)
{do{Jul_PE = gsl_rng_uniform_pos(Rand_NUM_Gen);
July_PE = gsl_cdf_beta_Pinv(Jul_PE,JulT[5],JulT[6]);
str = static_cast<int>(July_PE);} while (str != 0);}
July_PE = (JulT[3] + (July_PE * (JulT[4] - JulT[3])));
if(July_PE < 0)
July_PE = 0;
July_PER = Co * Hy_PER * Jul_L * pow(July_PE, apow);
August_PE = gsl_cdf_beta_Pinv(Aug_PE,AugT[5],AugT[6]);
```

```
str = static_cast<int>(August_PE);

if (str != 0)

{do{Aug_PE = gsl_rng_uniform_pos(Rand_NUM_Gen);

August_PE = gsl_cdf_beta_Pinv(Aug_PE,AugT[5],AugT[6]);

str = static_cast<int>(August_PE);} while (str != 0);}

August_PE = (AugT[3] + (August_PE * (AugT[4] - AugT[3])));

if(August_PE < 0)

August_PE = 0;

August_PER = Co * Hy_PER * Aug_L * pow(August_PE, apow);

September_PE = gsl_cdf_beta_Pinv(Sep_PE,SepT[5],SepT[6]);

str = static_cast<int>(September_PE);

if (str != 0)

{do{Sep_PE = gsl_rng_uniform_pos(Rand_NUM_Gen);

September_PE = gsl_cdf_beta_Pinv(Sep_PE,SepT[5],SepT[6]);

str = static_cast<int>(September_PE);} while (str != 0);}

September_PE = (SepT[3] + (September_PE * (SepT[4] - SepT[3])));

if(September_PE < 0)

September_PE = 0;

September_PER = Co * Hy_PER * Sep_L * pow(September_PE, apow);

October_PE = gsl_cdf_beta_Pinv(Oct_PE,OctT[5],OctT[6]);

str = static_cast<int>(October_PE);

if (str != 0)

{do{Oct_PE = gsl_rng_uniform_pos(Rand_NUM_Gen);

October_PE = gsl_cdf_beta_Pinv(Oct_PE,OctT[5],OctT[6]);

str = static_cast<int>(October_PE);} while (str != 0);}

October_PE = (OctT[3] + (October_PE * (OctT[4] - OctT[3])));

if(October_PE < 0)

October_PE = 0;
```

```
October_PER = Co * Hy_PER * Oct_L * pow(October_PE, apow);
November_PE = gsl_cdf_beta_Pinv(Nov_PE,NovT[5],NovT[6]);
str = static_cast<int>(November_PE);
if (str != 0)
{do{Nov_PE = gsl_rng_uniform_pos(Rand_NUM_Gen);
November_PE = gsl_cdf_beta_Pinv(Nov_PE,NovT[5],NovT[6]);
str = static_cast<int>(November_PE);} while (str != 0);}
November_PE = (NovT[3] + (November_PE * (NovT[4] - NovT[3])));
if(November_PE < 0)
November_PE = 0;
November_PER = Co * Hy_PER * Nov_L * pow(November_PE, apow);
December_PE = gsl_cdf_beta_Pinv(Dec_PE,DecT[5],DecT[6]);
str = static_cast<int>(December_T);
if (str != 0)
{do{Dec_PE = gsl_rng_uniform_pos(Rand_NUM_Gen);
December_T = gsl_cdf_beta_Pinv(Dec_PE,DecT[5],DecT[6]);
str = static_cast<int>(December_PE);} while (str != 0);}
December_PE = (DecT[3] + (December_PE * (DecT[4] - DecT[3])));
if(December_PE < 0)
December_PE = 0;
December_PER = Co * Hy_PER * Dec_L * pow(December_PE, apow);
PE = January_PER + February_PER + March_PER + April_PER + May1_PER + June_PER +
July_PER + August_PER + September_PER + October_PER + November_PER +
December_PER;summation_PE += PE;MonteCarloPE[q] = PE;
}
PE_mean = summation_PE/endloop;
for( int w=0; w<endloop; w++)
{
```

```
PE_var = pow((MonteCarloPE[w]- PE_mean),2.0);
summation_PE_var += PE_var;
}
PE_var = summation_PE_var / endloop;
PE_stdev = pow(PE_var,0.5);PE_min = 1000.0;PE_max = 0.0;
for(int k=0;k<endloop;k++)
{
PE_skew = pow(((MonteCarloPE[k]-PE_mean)/PE_stdev),3.0);
summation_PE_skew += PE_skew;
PE_kurt = pow(((MonteCarloPE[k]-PE_mean)/PE_stdev),4.0);
summation_PE_kurt += PE_kurt;
if(PE_min > MonteCarloPE[k])
PE_min = MonteCarloPE[k];
if(PE_max < MonteCarloPE[k])
PE_max = MonteCarloPE[k];
}
PE_skew = (1/endloop)*summation_PE_skew;
PE_kurt = ((1/endloop)*summation_PE_kurt)-3.0;
PE_alpha = ((PE_mean-PE_min)/(PE_max-PE_min))*(((PE_mean-PE_min)*(PE_max-
PE_mean)/PE_var)-1.0);
PE_beta = ((PE_max-PE_mean)/(PE_mean-PE_min))*PE_alpha;
// Thornwaite Moisture Index Mean, Variance, Skewness, and Kurtosis Calculations
for (int q=0; q < endloop; q++)
{
TMI_Pi = gsl_rng_uniform_pos(Rand_NUM_Gen);
TMI_PEi = gsl_rng_uniform_pos(Rand_NUM_Gen);

TMI_Pi = gsl_cdf_beta_Pinv(TMI_Pi,P_alpha,P_beta);
```

```
str = static_cast<int>(TMI_Pi);
if (str != 0)
{do{TMI_Pi = gsl_rng_uniform_pos(Rand_NUM_Gen);
TMI_Pi = gsl_cdf_beta_Pinv(TMI_Pi,P_alpha,P_beta);
str = static_cast<int>(TMI_Pi);} while (str != 0);}
TMI_P = (P_min + (TMI_Pi * (P_max - P_min)));
TMI_PEi = gsl_cdf_beta_Pinv(TMI_PEi,PE_alpha,PE_beta);
str = static_cast<int>(TMI_PEi);
if (str != 0)
{do{TMI_PEi = gsl_rng_uniform_pos(Rand_NUM_Gen);
TMI_PEi = gsl_cdf_beta_Pinv(TMI_PEi,PE_alpha,PE_beta);
str = static_cast<int>(TMI_PEi);} while (str != 0);}
TMI_PE = (PE_min + (TMI_PEi * (PE_max - PE_min)));
TMI = 75*(TMI_P/TMI_PE) - 65;
if(TMIconstraints == true)
{
if(TMI > 100)
TMI = 100;
}
summation_TMI += TMI;MonteCarloTMI[q] = TMI;TMIStorage[0][q] =
TMI_P;TMIStorage[1][q] = TMI_PE;TMIStorage[2][q] = TMI;
}
TMI_mean = summation_TMI / endloop;
for ( int i=0; i < endloop; i++)
{
TMI_var = pow((MonteCarloTMI[i]-TMI_mean),2.0);
summation_TMI_var += TMI_var;
}
```

```
TMI_var = summation_TMI_var / endloop;
TMI_stdev = pow(TMI_var,0.5);TMI_min = 1000.0;TMI_max =-1000.0;
for(int i=0; i<endloop; i++)
{
TMI_skew = pow(((MonteCarloTMI[i]-TMI_mean)/TMI_stdev),3.0);
summation_TMI_skew += TMI_skew;
TMI_kurt = pow(((MonteCarloTMI[i]-TMI_mean)/TMI_stdev),4.0);
summation_TMI_kurt += TMI_kurt;
if(TMI_min > MonteCarloTMI[i])
TMI_min = MonteCarloTMI[i];
if(TMI_max < MonteCarloTMI[i])
TMI_max = MonteCarloTMI[i];
}
TMI_skew = (1/endloop)*summation_TMI_skew;
TMI_kurt = ((1/endloop)*summation_TMI_kurt)-3.0;
TMI_alpha = ((TMI_mean-TMI_min)/(TMI_max-TMI_min))*(((TMI_mean-
TMI_min)*(TMI_max-TMI_mean)/TMI_var)-1.0);
TMI_beta = ((TMI_max-TMI_mean)/(TMI_mean-TMI_min))*TMI_alpha;
//Matric Suction Mean, Variance, Skewness, and Kutosis Calculations for N Layers
cout << "Finished with TMI for " << location << endl;
cout << endl << "Starting simulations for Layer 1." << endl;
for (int layer_counter=0; layer_counter<Num_layer; layer_counter++)
{suction = 0.0;summation_suction = 0.0; summation_suction_var = 0.0;summation_suction_skew
= 0.0;summation_suction_kurt = 0.0;suction_mean1 = 0.0;
if(Layer_Type[layer_counter] == true)
{
// Base Course Suction Parameters
for (int i=0; i<=endloop; i++)
```

```
{
prob = gsl_rng_uniform_pos(Rand_NUM_Gen);
P200_Monte = gsl_cdf_beta_Pinv(prob,P200_Alpha[layer_counter],P200_Beta[layer_counter]);
str = static_cast<int>(P200_Monte);
if (str != 0)
{do{prob = gsl_rng_uniform_pos(Rand_NUM_Gen);
P200_Monte = gsl_cdf_beta_Pinv(prob,wPI_Alpha[layer_counter],wPI_Beta[layer_counter]);
str = static_cast<int>(P200_Monte);} while (str != 0);}
P200_Monte = (P200_Min[layer_counter] + (P200_Monte * (P200_Max[layer_counter] -
P200_Min[layer_counter])));
if(P200_Monte > 16.0)
P200_Monte = 16.0;
if(P200_Monte < 0.0)
P200_Monte = 0.0;
suction_TMI_Num = gsl_rng_uniform_pos(Rand_NUM_Gen);
TMI_Monte = gsl_cdf_beta_Pinv(suction_TMI_Num,TMI_alpha,TMI_beta);
str = static_cast<int>(TMI_Monte);
if (str != 0)
{do{suction_TMI_Num = gsl_rng_uniform_pos(Rand_NUM_Gen);
TMI_Monte = gsl_cdf_beta_Pinv(suction_TMI_Num,TMI_alpha,TMI_beta);
str = static_cast<int>(TMI_Monte);} while (str != 0);}
TMI_Monte = (TMI_min + (TMI_Monte * (TMI_max - TMI_min)));
P200_3 = pow(P200_Monte,3.0);
P200_2 = pow(P200_Monte,2.0);
alpha_base = -0.0016*P200_3 + 0.1106*P200_2 - 0.1135*P200_Monte + 3.8218;
beta_base = -0.0045*P200_3 + 0.1121*P200_2 - 0.3364*P200_Monte + 3.2358;
gamma_base = 0.00003*P200_3 - 0.0009*P200_2 + 0.0061*P200_Monte -0.0498;
suction = alpha_base + exp(beta_base + gamma_base * (TMI_Monte + 101.0));
```

```
summation_suction += suction;
MonteCarloSuction[layer_counter][i] = suction;}}
else if(wPI_M[layer_counter] == 0.0 && layer_counter > 0)// Calcuclates the non-base with wPI
or P200{
if(P200_M[layer_counter] > 10.0)
{
for( int i=0; i<=endloop;i++)
{
prob1 = gsl_rng_uniform_pos(Rand_NUM_Gen);
P200_Monte = gsl_cdf_beta_Pinv(prob1,P200_Alpha[layer_counter],P200_Beta[layer_counter]);
str = static_cast<int>(P200_Monte);
if (str != 0)
{do{prob1 = gsl_rng_uniform_pos(Rand_NUM_Gen);
P200_Monte = gsl_cdf_beta_Pinv(prob1,wPI_Alpha[layer_counter],wPI_Beta[layer_counter]);
str = static_cast<int>(P200_Monte);} while (str != 0);}
P200_Monte = (P200_Min[layer_counter] + (P200_Monte * (P200_Max[layer_counter] -
P200_Min[layer_counter])));
if(P200_Monte > 50.0)
P200_Monte = 50.0;
if(P200_Monte < 10.0)
P200_Monte = 10.0;
suction_TMI_Num = gsl_rng_uniform_pos(Rand_NUM_Gen);
TMI_Monte = gsl_cdf_beta_Pinv(suction_TMI_Num,TMI_alpha,TMI_beta);
str = static_cast<int>(TMI_Monte);
if (str != 0)
{do{suction_TMI_Num = gsl_rng_uniform_pos(Rand_NUM_Gen);
TMI_Monte = gsl_cdf_beta_Pinv(suction_TMI_Num,TMI_alpha,TMI_beta);
str = static_cast<int>(TMI_Monte);} while (str != 0);}
```

```
TMI_Monte = (TMI_min + (TMI_Monte * (TMI_max - TMI_min)));
//P200 equations
double beta_non1, gamma_non1, delta_non1;
beta_non1 = 2.56075*P200_Monte + 393.4625;
gamma_non1 = 0.09625*P200_Monte + 132.4875;
delta_non1 = 0.025*P200_Monte + 14.75;
suction_mean1 = 0.3*(exp(beta_non1/(TMI_Monte + gamma_non1))+delta_non1);
summation_suction += suction_mean1;
MonteCarloSuction[layer_counter][i] = suction_mean1;}}
else if(P200_M[layer_counter] < 10.0)
{
for (int i=0; i<=endloop; i++)
{
prob2 = gsl_rng_uniform_pos(Rand_NUM_Gen);
P200_Monte = gsl_cdf_beta_Pinv(prob2,P200_Alpha[layer_counter],P200_Beta[layer_counter]);
str = static_cast<int>(P200_Monte);
if (str != 0)
{do{prob2 = gsl_rng_uniform_pos(Rand_NUM_Gen);
P200_Monte = gsl_cdf_beta_Pinv(prob2,wPI_Alpha[layer_counter],wPI_Beta[layer_counter]);
str = static_cast<int>(P200_Monte);} while (str != 0);}
P200_Monte = (P200_Min[layer_counter] + (P200_Monte * (P200_Max[layer_counter] -
P200_Min[layer_counter])));
if(P200_Monte > 16.0)
P200_Monte = 16.0;
if(P200_Monte < 0.0)
P200_Monte = 0.0;
suction_TMI_Num = gsl_rng_uniform_pos(Rand_NUM_Gen);
TMI_Monte = gsl_cdf_beta_Pinv(suction_TMI_Num,TMI_alpha,TMI_beta);
```

```
str = static_cast<int>(TMI_Monte);
if (str != 0)
{do{suction_TMI_Num = gsl_rng_uniform_pos(Rand_NUM_Gen);
TMI_Monte = gsl_cdf_beta_Pinv(suction_TMI_Num,TMI_alpha,TMI_beta);
str = static_cast<int>(TMI_Monte);} while (str != 0);}
else{TMI_Monte = TMI_Monte;}
TMI_Monte = (TMI_min + (TMI_Monte * (TMI_max - TMI_min)));
P200_3 = pow(P200_Monte,3.0);P200_2 = pow(P200_Monte,2.0);
alpha_base = -0.0016*P200_3 + 0.1106*P200_2 - 0.1135*P200_Monte + 3.8218;
beta_base = -0.0045*P200_3 + 0.1121*P200_2 - 0.3364*P200_Monte + 3.2358;
gamma_base = 0.00003*P200_3 - 0.0009*P200_2 + 0.0061*P200_Monte - 0.0498;

suction = alpha_base + exp(beta_base + gamma_base * ( TMI_Monte + 101.0));
summation_suction += suction;
MonteCarloSuction[layer_counter][i] = suction;}}}
else
{
for (int i=0; i<=endloop; i++)
{
prob3 = gsl_rng_uniform_pos(Rand_NUM_Gen);
wPI_Monte = gsl_cdf_beta_Pinv(prob3,wPI_Alpha[layer_counter],wPI_Beta[layer_counter]);
str = static_cast<int>(wPI_Monte);
if (str != 0)
{do{prob3 = gsl_rng_uniform_pos(Rand_NUM_Gen);
wPI_Monte = gsl_cdf_beta_Pinv(prob3,wPI_Alpha[layer_counter],wPI_Beta[layer_counter]);
str = static_cast<int>(wPI_Monte);} while (str != 0);}
(double)wPI_Monte = (wPI_Min[layer_counter] + (wPI_Monte * (wPI_Max[layer_counter] -
wPI_Min[layer_counter])));
```

```
if(wPI_Monte > 50.0)
wPI_Monte = 50.0;
if(wPI_Monte < 0.5)
wPI_Monte = 0.5;
suction_TMI_Num = gsl_rng_uniform_pos(Rand_NUM_Gen);
TMI_Monte = gsl_cdf_beta_Pinv(suction_TMI_Num,TMI_alpha,TMI_beta);
str = static_cast<int>(TMI_Monte);
if (str != 0)
{do{suction_TMI_Num = gsl_rng_uniform_pos(Rand_NUM_Gen);
TMI_Monte = gsl_cdf_beta_Pinv(suction_TMI_Num,TMI_alpha,TMI_beta);
str = static_cast<int>(TMI_Monte);} while (str != 0);}
TMI_Monte = (TMI_min + (TMI_Monte * (TMI_max - TMI_min)));
// Non-base Course Suction Parameters
wPI_3 = pow(wPI_Monte,3.0);wPI_2 = pow(wPI_Monte,2.0);
beta_non = 0.006235897* wPI_3 - 0.779833377* wPI_2 + 36.78648521*wPI_Monte +
501.9511878;
gamma_non = 0.000395003* wPI_3 - 0.040423118* wPI_2 + 1.454065726*wPI_Monte +
136.4775219;
delta_non = -0.019883827* wPI_2 + 1.273583098*wPI_Monte + 13.91243841;
// If non-base course Material
suction_mean1 = 0.3*(exp(beta_non/(TMI_Monte + gamma_non))+ delta_non);
summation_suction += suction_mean1;
MonteCarloSuction[layer_counter][i] = suction_mean1;}}
suction_mean1 = summation_suction / endloop;
for(int i=0; i<endloop;i++)
{
suction_var1 = pow((MonteCarloSuction[layer_counter][i] - suction_mean1),2.0);
summation_suction_var += suction_var1;
```

```
}
suction_var1 = summation_suction_var/endloop;
suction_stdev1 = pow(suction_var1,0.5);
suction_min1 = 1000000000.0;suction_max1 = 0.0;
for(int f=0; f<endloop;f++)
{
suction_skew1 = pow(((MonteCarloSuction[layer_counter][f]-
suction_mean1)/suction_stdev1),3.0);
summation_suction_skew += suction_skew1;
suction_kurt1 = pow(((MonteCarloSuction[layer_counter][f]-
suction_mean1)/suction_stdev1),4.0);
summation_suction_kurt += suction_kurt1;
if(suction_min1 > MonteCarloSuction[layer_counter][f])
suction_min1 = MonteCarloSuction[layer_counter][f];
if(suction_max1 < MonteCarloSuction[layer_counter][f])
suction_max1 = MonteCarloSuction[layer_counter][f];
}
suction_skew1 = (1/endloop)*summation_suction_skew;
suction_kurt1 = ((1/endloop)*summation_suction_kurt)-3.0;
suction_alpha1 = ((suction_mean1-suction_min1)/(suction_max1-
suction_min1))*(((suction_mean1-suction_min1)*(suction_max1-suction_mean1)/suction_var1)-
1);
suction_beta1 = ((suction_max1-suction_mean1)/(suction_mean1-suction_min1))*suction_alpha1;
//Stores Each Layer's statistical Suction Information
Suction_Mean[layer_counter] = suction_mean1;Suction_Variance[layer_counter] =
suction_var1;Suction_Stdev[layer_counter] = suction_stdev1;Suction_Skew[layer_counter] =
suction_skew1;Suction_Kurt[layer_counter] = suction_kurt1;Suction_Minimum[layer_counter] =
```

```
suction_min1;Suction_Maximum[layer_counter] = suction_max1;Suction_Alpha[layer_counter] =
suction_alpha1;Suction_Beta[layer_counter] = suction_beta1;
// Optimum Saturation and Degree of Saturation information
if(level[layer_counter] == true)
{
//Saturated Volumetric water content
MonteCarlo_gamma_dry = 0.0;MonteCarlo_Gs = 0.0;Monte_gamma_dry1 = 0.0;Monte_Gs =
0.0;summation_theata_sat = 0.0;
for(int i=0; i<endloop; i++)
{
MonteCarlo_gamma_dry = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_gamma_dry1 =
gsl_cdf_beta_Pinv(MonteCarlo_gamma_dry,gamma_dry_Alpha[layer_counter],gamma_dry_Beta
[layer_counter]);
str = static_cast<int>(Monte_gamma_dry1);
if (str != 0)
{do{MonteCarlo_gamma_dry = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_gamma_dry1 =
gsl_cdf_beta_Pinv(MonteCarlo_gamma_dry,gamma_dry_Alpha[layer_counter],gamma_dry_Beta
[layer_counter]);
str = static_cast<int>(Monte_gamma_dry1);} while (str != 0);}
(double)Monte_gamma_dry1 = (gamma_dry_Min[layer_counter] + (Monte_gamma_dry1 *
(gamma_dry_Max[layer_counter] - gamma_dry_Min[layer_counter])));
MonteCarlo_Gs = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Gs =
gsl_cdf_beta_Pinv(MonteCarlo_Gs,Gs_Alpha[layer_counter],Gs_Beta[layer_counter]);
str = static_cast<int>(Monte_Gs);
if (str != 0)
```

```
{do{MonteCarlo_Gs = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Gs =
gsl_cdf_beta_Pinv(MonteCarlo_Gs,Gs_Alpha[layer_counter],Gs_Beta[layer_counter]);
str = static_cast<int>(Monte_Gs);} while (str != 0);}
(double)Monte_Gs = (Gs_Min[layer_counter] + (Monte_Gs * (Gs_Max[layer_counter] -
Gs_Min[layer_counter])));
theata_sat = (1.0 - (Monte_gamma_dry1/(Monte_Gs*gamma_water)))*100;
summation_theata_sat += theata_sat;
Monte_theata_sat[layer_counter][i] = theata_sat;
}
theata_sat = summation_theata_sat / endloop;
theata_sat_min = 1000.0;theata_sat_max = -1000.0;theata_sat_var =
0.0;summation_theata_sat_var = 0.0;summation_theata_sat_skew =
0.0;summation_theata_sat_kurt = 0.0;
for( int w=0; w<endloop; w++)
{
theata_sat_var = pow((Monte_theata_sat[layer_counter][w]- theata_sat),2.0);
summation_theata_sat_var +=theata_sat_var;
if(theata_sat_min > Monte_theata_sat[layer_counter][w])
theata_sat_min = Monte_theata_sat[layer_counter][w];
if(theata_sat_max < Monte_theata_sat[layer_counter][w])
theata_sat_max = Monte_theata_sat[layer_counter][w];
}
theata_sat_var = summation_theata_sat_var / endloop;
theata_sat_stdev = pow(theata_sat_var,0.5);
for( int w=0; w<endloop; w++)
{
theata_sat_kurt = pow(((Monte_theata_sat[layer_counter][w]- theata_sat)/theata_sat_stdev),4.0);
```

```
summation_theata_sat_kurt += theata_sat_kurt;
theata_sat_skew = pow(((Monte_theata_sat[layer_counter][w]- theata_sat)/theata_sat_stdev),3.0);
summation_theata_sat_skew += theata_sat_skew;
}
theata_sat_skew = (1/endloop)*summation_theata_sat_skew;
theata_sat_kurt = ((1/endloop)*summation_theata_sat_kurt)-3.0;
if(theata_sat_min == theata_sat_max)
{theata_sat_alpha = 1.0;theata_sat_beta = 1.0;}
else
{
theata_sat_alpha = ((theata_sat-theata_sat_min)/(theata_sat_max-theata_sat_min))*(((theata_sat-
theata_sat_min)*(theata_sat_max-theata_sat)/theata_sat_var)-1.0);
theata_sat_beta = ((theata_sat_max-theata_sat)/(theata_sat-theata_sat_min))*theata_sat_alpha;
}
// Volumetric Water Content
MonteCarlo_theata_wPI = 1.0;MonteCarlo_theata_Suction = 1.0;summation_theata_water =
0.0;Monte_wPI_theata_water = 0.0;Monte_Suction_theata_water = 0.0;summation_C_h = 0.0;
// SWCC information
for(int i =0; i<endloop; i++)
{
residual = SWCC_H[layer_counter];
MonteCarlo_theata_wPI = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wPI_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_wPI,SWCC_AAlpha[layer_counter],SWCC_ABeta[layer_
counter]);
Monte_wPI_theata_water1 = gsl_cdf_beta_Pinv((1-
MonteCarlo_theata_wPI),SWCC_BAlpha[layer_counter],SWCC_BBeta[layer_counter]);
```

```
Monte_wPI_theata_water2 =
gsl_cdf_beta_Pinv(MonteCarlo_theata_wPI,SWCC_CAlpha[layer_counter],SWCC_CBeta[layer_
counter]);
str = static_cast<int>(Monte_wPI_theata_water);
str1 = static_cast<int>(Monte_wPI_theata_water1);
str2 = static_cast<int>(Monte_wPI_theata_water2);
if ((str != 0)||(str1 !=0)||(str2 !=0)){do{MonteCarlo_theata_wPI =
gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wPI_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_wPI,SWCC_AAlpha[layer_counter],SWCC_ABeta[layer_
counter]);
Monte_wPI_theata_water1 = gsl_cdf_beta_Pinv((1-
MonteCarlo_theata_wPI),SWCC_BAlpha[layer_counter],SWCC_BBeta[layer_counter]);
Monte_wPI_theata_water2 =
gsl_cdf_beta_Pinv(MonteCarlo_theata_wPI,SWCC_CAlpha[layer_counter],SWCC_CBeta[layer_
counter]);
str = static_cast<int>(Monte_wPI_theata_water);
str1 = static_cast<int>(Monte_wPI_theata_water1);
str2 = static_cast<int>(Monte_wPI_theata_water2);} while ((str != 0)||(str1 !=0)||(str2 !=0));}
af = (SWCC_AMin[layer_counter] + (Monte_wPI_theata_water * (SWCC_AMax[layer_counter]
- SWCC_AMin[layer_counter])));
bf = (SWCC_BMin[layer_counter] + (Monte_wPI_theata_water1 *
(SWCC_BMax[layer_counter] - SWCC_BMin[layer_counter])));
cf = (SWCC_CMin[layer_counter] + (Monte_wPI_theata_water2 * (SWCC_CMax[layer_counter]
- SWCC_CMin[layer_counter])));
MonteCarlo_theata_sat = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_sat_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_sat,theata_sat_alpha,theata_sat_beta);
```

```
str = static_cast<int>(Monte_sat_theata_water);
if (str != 0)
{do{MonteCarlo_theata_sat = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_sat_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_sat,theata_sat_alpha,theata_sat_beta);
str = static_cast<int>(Monte_sat_theata_water);} while (str != 0);}
(double)Monte_sat_theata_water = (theata_sat_min + (Monte_sat_theata_water * (theata_sat_max
- theata_sat_min)));
MonteCarlo_theata_Suction = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Suction_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_Suction,Suction_Alpha[layer_counter],Suction_Beta[layer
_counter]);
str = static_cast<int>(Monte_Suction_theata_water);
if (str != 0)
{do{MonteCarlo_theata_Suction = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Suction_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_Suction,Suction_Alpha[layer_counter],Suction_Beta[layer
_counter]);
str = static_cast<int>(Monte_Suction_theata_water);} while (str != 0);}
(double)Monte_Suction_theata_water = (Suction_Minimum[layer_counter] +
(Monte_Suction_theata_water * (Suction_Maximum[layer_counter] -
Suction_Minimum[layer_counter])));
C_h = 1-(log(1+(Monte_Suction_theata_water/residual))/(log(1+(1000000.0/residual))));
theata_water =
C_h*(Monte_sat_theata_water/pow(log(pow((Monte_Suction_theata_water/af),bf)+exp(1.0)),cf));
summation_theata_water += theata_water;
Monte_theata_water[layer_counter][i] = theata_water;
}
```

```
theata_water = summation_theata_water/endloop;
theata_water_min = 1000.0;theata_water_max =-1000.0;summation_theata_water_var =
0.0;summation_theata_water_skew = 0.0;summation_theata_water_kurt = 0.0;
for( int w=0; w<endloop; w++)
{
theata_water_var = pow((Monte_theata_water[layer_counter][w]- theata_water),2.0);
summation_theata_water_var += theata_water_var;
if(theata_water_min > Monte_theata_water[layer_counter][w])
theata_water_min = Monte_theata_water[layer_counter][w];
if(theata_water_max < Monte_theata_water[layer_counter][w])
theata_water_max = Monte_theata_water[layer_counter][w];
}
theata_water_var = summation_theata_water_var / endloop;
theata_water_stdev = pow(theata_water_var,0.5);
for( int w=0; w<endloop; w++)
{
theata_water_skew = pow(((Monte_theata_water[layer_counter][w]-
theata_water)/theata_water_stdev),3.0);
theata_water_kurt = pow(((Monte_theata_water[layer_counter][w]-
theata_water)/theata_water_stdev),4.0);
summation_theata_water_skew += theata_water_skew;
summation_theata_water_kurt += theata_water_kurt;
}
theata_water_skew = (1.0/endloop)*summation_theata_water_skew;
theata_water_kurt = ((1.0/endloop)*summation_theata_water_kurt)-3.0;
if(theata_water_min == theata_water_max)
{theata_water_alpha = 1.0;theata_water_beta = 1.0;}
else
```

```
{
theata_water_alpha = ((theata_water-theata_water_min)/(theata_water_max-
theata_water_min))*(((theata_water-theata_water_min)*(theata_water_max-
theata_water)/theata_water_var)-1.0);
theata_water_beta = ((theata_water_max-theata_water)/(theata_water-
theata_water_min))*theata_water_alpha;
}
//Degree of Saturation
MonteCarlo_theata_sat = 1.0;MonteCarlo_theata_water = 1.0;summation_degree_sat =
0.0;summation_degree_sat_var = 0.0;Monte_theata_water_dsat = 0.0;Monte_theata_sat_dsat =
0.0;
for(int i=0; i<endloop; i++)
{MonteCarlo_theata_water = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_theata_water_dsat =
gsl_cdf_beta_Pinv(MonteCarlo_theata_water,theata_water_alpha,theata_water_beta);
str = static_cast<int>(Monte_theata_water_dsat);
if (str != 0)
{do{MonteCarlo_theata_water = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_theata_water_dsat =
gsl_cdf_beta_Pinv(MonteCarlo_theata_water,theata_water_alpha,theata_water_beta);
str = static_cast<int>(Monte_theata_water_dsat);} while (str != 0);}
(double)Monte_theata_water_dsat = (theata_water_min + (Monte_theata_water_dsat *
(theata_water_max - theata_water_min)));
MonteCarlo_theata_sat = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_theata_sat_dsat =
gsl_cdf_beta_Pinv(MonteCarlo_theata_sat,theata_sat_alpha,theata_sat_beta);
str = static_cast<int>(Monte_theata_sat_dsat);
if (str != 0)
```

```
{do{MonteCarlo_theata_sat = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_theata_sat_dsat =
gsl_cdf_beta_Pinv(MonteCarlo_theata_sat,theata_sat_alpha,theata_sat_beta);
str = static_cast<int>(Monte_theata_sat_dsat);} while (str != 0);}
else{Monte_theata_sat_dsat = Monte_theata_sat_dsat;}
(double)Monte_theata_sat_dsat = (theata_sat_min + (Monte_theata_sat_dsat * (theata_sat_max -
theata_sat_min)));
degree_sat_mean1 = (Monte_theata_water_dsat / Monte_theata_sat_dsat)*100;
if(degree_sat_mean1 > 100)
degree_sat_mean1 = 100;
summation_degree_sat += degree_sat_mean1;
Monte_degree_sat[layer_counter][i] = degree_sat_mean1;
}
degree_sat_mean1 = summation_degree_sat/endloop;
for( int w=0; w<endloop; w++)
{
degree_sat_var1 = pow((Monte_degree_sat[layer_counter][w]- degree_sat_mean1),2.0);
summation_degree_sat_var += degree_sat_var1;
}
degree_sat_var1 = summation_degree_sat_var/endloop;
degree_sat_stdev1 = pow(degree_sat_var1,0.5);degree_sat_min1 = 1000.0;degree_sat_max1 = -
1000.0;summation_degree_sat_skew = 0.0;summation_degree_sat_kurt = 0.0;
for(int f=0; f<endloop;f++)
{
degree_sat_skew1 = pow(((Monte_degree_sat[layer_counter][f]-
degree_sat_mean1)/degree_sat_stdev1),3.0);
summation_degree_sat_skew += degree_sat_skew1;
```

```
degree_sat_kurt1 = pow(((Monte_degree_sat[layer_counter][f]-
degree_sat_mean1)/degree_sat_stdev1),4.0);
summation_degree_sat_kurt += degree_sat_kurt1;
if(degree_sat_min1 > Monte_degree_sat[layer_counter][f])
degree_sat_min1 = Monte_degree_sat[layer_counter][f];
if(degree_sat_max1 < Monte_degree_sat[layer_counter][f])
degree_sat_max1 = Monte_degree_sat[layer_counter][f];
}
degree_sat_skew1 = (1/endloop)*summation_degree_sat_skew;
degree_sat_kurt1 = ((1/endloop)*summation_degree_sat_kurt)-3.0;
if(degree_sat_min1 == degree_sat_max1)
{degree_sat_alpha1 = 1.0;degree_sat_beta1 = 1.0;}
else
{
degree_sat_alpha1 = ((degree_sat_mean1-degree_sat_min1)/(degree_sat_max1-
degree_sat_min1))*(((degree_sat_mean1-degree_sat_min1)*(degree_sat_max1-
degree_sat_mean1)/degree_sat_var1)-1);
degree_sat_beta1 = ((degree_sat_max1-degree_sat_mean1)/(degree_sat_mean1-
degree_sat_min1))*degree_sat_alpha1;
}
//Optimum Saturation
MonteCarlo_opt_wopt = 1.0;MonteCarlo_opt_gamma = 1.0;MonteCarlo_opt_Gs =
1.0;summation_opt_sat = 0.0;Monte_opt_wopt = 0.0;Monte_opt_gamma = 0.0;Monte_opt_Gs =
0.0;
for(int i=0; i<endloop; i++)
{
MonteCarlo_opt_wopt = gsl_rng_uniform_pos(Rand_NUM_Gen);
MonteCarlo_opt_gamma = 1.0 - MonteCarlo_opt_wopt;
```

```
MonteCarlo_opt_Gs = MonteCarlo_opt_wopt;
Monte_opt_wopt =
gsl_cdf_beta_Pinv(MonteCarlo_opt_wopt,wopt_Alpha[layer_counter],wopt_Beta[layer_counter])
;
Monte_opt_gamma =
gsl_cdf_beta_Pinv(MonteCarlo_opt_gamma,gamma_dry_Alpha[layer_counter],gamma_dry_Beta
[layer_counter]);
Monte_opt_Gs =
gsl_cdf_beta_Pinv(MonteCarlo_opt_Gs,Gs_Alpha[layer_counter],Gs_Beta[layer_counter]);
str = static_cast<int>(Monte_opt_gamma); str1 = static_cast<int>(Monte_opt_wopt);
if ((str != 0)||(str1 !=0)||(str2 !=0))
{do{MonteCarlo_opt_wopt = gsl_rng_uniform_pos(Rand_NUM_Gen);
MonteCarlo_opt_gamma = 1.0 - MonteCarlo_opt_wopt;
MonteCarlo_opt_Gs = MonteCarlo_opt_wopt;
Monte_opt_wopt =
gsl_cdf_beta_Pinv(MonteCarlo_opt_wopt,wopt_Alpha[layer_counter],wopt_Beta[layer_counter])
;
Monte_opt_gamma =
gsl_cdf_beta_Pinv(MonteCarlo_opt_gamma,gamma_dry_Alpha[layer_counter],gamma_dry_Beta
[layer_counter]);
Monte_opt_Gs =
gsl_cdf_beta_Pinv(MonteCarlo_opt_Gs,Gs_Alpha[layer_counter],Gs_Beta[layer_counter]);
str = static_cast<int>(Monte_opt_gamma);
str1 = static_cast<int>(Monte_opt_wopt);
str2 = static_cast<int>(Monte_opt_Gs);} while ((str != 0)||(str1 !=0)||(str2 !=0));}
(double)Monte_opt_wopt = (wopt_Min[layer_counter] + (Monte_opt_wopt *
(wopt_Max[layer_counter] - wopt_Min[layer_counter])));
```

```
(double)Monte_opt_gamma = (gamma_dry_Min[layer_counter] + (Monte_opt_gamma * (gamma_dry_Max[layer_counter] - gamma_dry_Min[layer_counter])));
(double)Monte_opt_Gs = (Gs_Min[layer_counter] + (Monte_opt_Gs * (Gs_Max[layer_counter] - Gs_Min[layer_counter])));
opt_sat_mean1 = Monte_opt_wopt/((gamma_water/Monte_opt_gamma)-(1/Monte_opt_Gs));
if(opt_sat_mean1 > 100)
opt_sat_mean1 = 100.0;
summation_opt_sat += opt_sat_mean1;
Monte_opt_sat[layer_counter][i] = opt_sat_mean1;
}
opt_sat_mean1 = summation_opt_sat/endloop;
summation_opt_sat_var = 0.0;
for( int w=0; w<endloop; w++)
{
opt_sat_var1 = pow((Monte_opt_sat[layer_counter][w]- opt_sat_mean1),2.0);
summation_opt_sat_var += opt_sat_var1;
}
opt_sat_var1 = summation_opt_sat_var/endloop;
opt_sat_min1 = 1000.0;opt_sat_max1 = -100.0;summation_opt_sat_skew = 0.0;
opt_sat_stdev1 = pow(opt_sat_var1,0.5);
summation_opt_sat_kurt = 0.0;
for(int f=0; f<endloop;f++)
{
opt_sat_skew1 = pow(((Monte_opt_sat[layer_counter][f]-opt_sat_mean1)/opt_sat_stdev1),3.0);
summation_opt_sat_skew += opt_sat_skew1;
opt_sat_kurt1 = pow(((Monte_opt_sat[layer_counter][f]-opt_sat_mean1)/opt_sat_stdev1),4.0);
summation_opt_sat_kurt += opt_sat_kurt1;
if(opt_sat_min1 > Monte_opt_sat[layer_counter][f])
```

```
opt_sat_min1 = Monte_opt_sat[layer_counter][f];
if(opt_sat_max1 < Monte_opt_sat[layer_counter][f])
opt_sat_max1 = Monte_opt_sat[layer_counter][f];
}
opt_sat_skew1 = (1/endloop)*summation_opt_sat_skew;
opt_sat_kurt1 = ((1/endloop)*summation_opt_sat_kurt)-3.0;
if(opt_sat_min1 == opt_sat_max1)
{opt_sat_alpha1 = 1.0;opt_sat_beta1 = 1.0;}
else
{
opt_sat_alpha1 = ((opt_sat_mean1-opt_sat_min1)/(opt_sat_max1-
opt_sat_min1))*(((opt_sat_mean1-opt_sat_min1)*(opt_sat_max1-opt_sat_mean1)/opt_sat_var1)-
1);
opt_sat_beta1 = ((opt_sat_max1-opt_sat_mean1)/(opt_sat_mean1-opt_sat_min1))*opt_sat_alpha1;
}
//moisture content
opt_moisture_mean = wopt_M[layer_counter]; wopt_var = wopt_V[layer_counter];wopt_stdev =
wopt_S[layer_counter];wopt_skew = 0.0;wopt_kurt = 0.0;wopt_min =
wopt_Min[layer_counter];wopt_max = wopt_Max[layer_counter]; wopt_alpha =
wopt_Alpha[layer_counter]; wopt_beta = wopt_Beta[layer_counter];
//Unit Weight
gamma_dry_mean = gamma_dry_M[layer_counter];gamma_dry_var =
gamma_dry_V[layer_counter];gamma_dry_stdev =
gamma_dry_S[layer_counter];gamma_dry_skew = 0.0; gamma_dry_kurt = 0.0;gamma_dry_min =
gamma_dry_Min[layer_counter];gamma_dry_max =
gamma_dry_Max[layer_counter];gamma_dry_alpha = gamma_dry_Alpha[layer_counter];
gamma_dry_beta = gamma_dry_Beta[layer_counter];
}
```

```
else // Level 2 and 3
{
if(Names[layer_counter] == "A-1-a")
residual = 100;
else if(Names[layer_counter] == "A-1-b")
residual = 100;
else if(Names[layer_counter] == "A-2-4")
residual = 100;
else if(Names[layer_counter] == "A-2-5")
residual = 100;
else if(Names[layer_counter] == "A-2-6")
residual = 100;
else if(Names[layer_counter] == "A-2-7")
residual = 100;
else if(Names[layer_counter] == "A-3")
residual = 100;
else
residual = 500;
if(wPI_M[layer_counter] == 0.0)//changed
{
//Optimum Moisture Content
MonteCarlo_wopt_P15 = 1.0;MonteCarlo_wopt_P40 = 1.0;MonteCarlo_wopt_P60 =
1.0;MonteCarlo_wopt_D60 = 1.0;summation_wopt = 0.0;Monte_wopt_P15 =
0.0;Monte_wopt_P40 = 0.0;Monte_wopt_P60 = 0.0;Monte_wopt_D60 = 0.0;
for(int i=0; i<endloop; i++)
{
MonteCarlo_wopt_P15 = gsl_rng_uniform_pos(Rand_NUM_Gen);
```

```
Monte_wopt_P15 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_P15,P15_Alpha[layer_counter],P15_Beta[layer_counter]);
str = static_cast<int>(Monte_wopt_P15);
if ((str != 0))
{do{MonteCarlo_wopt_P15 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wopt_P15 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_P15,P15_Alpha[layer_counter],P15_Beta[layer_counter]);
str = static_cast<int>(Monte_wopt_P15);} while ((str != 0));}
(double)Monte_wopt_P15 = (P15_Min[layer_counter] + (Monte_wopt_P15 *
(P15_Max[layer_counter] - P15_Min[layer_counter])));
Monte_wopt_P40 = MonteCarlo_wopt_P15;
do{MonteCarlo_wopt_P40 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wopt_P40 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_P40,P40_Alpha[layer_counter],P40_Beta[layer_counter]);
str = static_cast<int>(Monte_wopt_P40);
if (str != 0)
{do{MonteCarlo_wopt_P40 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wopt_P40 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_P40,P40_Alpha[layer_counter],P40_Beta[layer_counter]);
str = static_cast<int>(Monte_wopt_P40);} while (str != 0);}
(double)Monte_wopt_P40 = (P40_Min[layer_counter] + (Monte_wopt_P40 *
(P40_Max[layer_counter] - P40_Min[layer_counter])));} while (MonteCarlo_wopt_P40 >
Monte_wopt_P15);
Monte_wopt_P60 = MonteCarlo_wopt_P40;do{MonteCarlo_wopt_P60 =
gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wopt_P60 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_P60,P60_Alpha[layer_counter],P60_Beta[layer_counter]);
str = static_cast<int>(Monte_wopt_P60);
```

```
if (str != 0)
{do{MonteCarlo_wopt_P60 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wopt_P60 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_P60,P60_Alpha[layer_counter],P60_Beta[layer_counter]);
str = static_cast<int>(Monte_wopt_P60);} while (str != 0);}
(double)Monte_wopt_P60 = (P60_Min[layer_counter] + (Monte_wopt_P60 *
(P60_Max[layer_counter] - P60_Min[layer_counter])));} while(MonteCarlo_wopt_P60 >
Monte_wopt_P40);
do{MonteCarlo_wopt_D60 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wopt_D60 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_D60,D60_Alpha[layer_counter],D60_Beta[layer_counter]);
str1 = static_cast<int>(Monte_wopt_D60);
if ((str1 !=0))
{do{MonteCarlo_wopt_D60 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wopt_D60 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_D60,D60_Alpha[layer_counter],D60_Beta[layer_counter]);
str1 = static_cast<int>(Monte_wopt_D60);} while ((str1 !=0));}
else{Monte_wopt_D60 = Monte_wopt_D60;}
(double)Monte_wopt_D60 = (D60_Min[layer_counter] + (Monte_wopt_D60 *
(D60_Max[layer_counter] - D60_Min[layer_counter])));
if((Monte_wopt_D60 < 37.50) && (Monte_wopt_P15 < 60.0)) // 1.5" Comparison{str = 0.0;}
else if((Monte_wopt_D60 > 0.425) && (Monte_wopt_P40 < 60.0)||((Monte_wopt_D60 > 0.425)
&& (Monte_wopt_P40 > 60.0)))// #40 Comparison{str = 0.0;}
else if((Monte_wopt_D60 > 0.250)&&(Monte_wopt_P60 <60)||((Monte_wopt_D60 >
0.250)&&(Monte_wopt_P60 >60))) // #60 Comparison{str = 0.0;}
else
{str = 1.0;}} while(str !=0.0);
```

```
opt_moisture_mean = -120.14-0.06766*Monte_wopt_P15+3.7269*Monte_wopt_D60-
0.167*Monte_wopt_P40+0.117*Monte_wopt_P60+142.53*exp(-0.0389*Monte_wopt_D60);
summation_wopt += opt_moisture_mean;
Monte_wopt[layer_counter][i]=opt_moisture_mean;
}
opt_moisture_mean = summation_wopt/endloop;
summation_wopt_var = 0.0;wopt_min = 1000.0;wopt_max =-1000.0;
for( int w=0; w<endloop; w++)
{
wopt_var = pow((Monte_wopt[layer_counter][w]- opt_moisture_mean),2.0);
summation_wopt_var += wopt_var;
if(wopt_min > Monte_wopt[layer_counter][w])
wopt_min = Monte_wopt[layer_counter][w];
if(wopt_max < Monte_wopt[layer_counter][w])
wopt_max = Monte_wopt[layer_counter][w];
}
wopt_var = summation_wopt_var / endloop;
wopt_stdev = pow(wopt_var,0.5);summation_wopt_skew = 0.0;summation_wopt_kurt = 0.0;
for(int w=0; w<endloop; w++)
{
summation_wopt_skew += pow(((Monte_wopt[layer_counter][w]-
opt_moisture_mean)/wopt_stdev),3.0);
summation_wopt_kurt += pow(((Monte_wopt[layer_counter][w]-
opt_moisture_mean)/wopt_stdev),4.0);
}
wopt_skew = (1/endloop)*summation_wopt_skew;
wopt_kurt =((1/endloop)*summation_wopt_kurt)-3.0;
```

```
wopt_alpha = ((opt_moisture_mean-wopt_min)/(wopt_max-wopt_min))*(((opt_moisture_mean-
wopt_min)*(wopt_max-opt_moisture_mean)/wopt_var)-1.0);
wopt_beta = ((wopt_max-opt_moisture_mean)/(opt_moisture_mean-wopt_min))*wopt_alpha;
//Optimum Saturation
MonteCarlo_opt_P20 = 1.0;MonteCarlo_opt_P10 = 1.0;MonteCarlo_opt_P05 = 1.0;Monte_P20 =
0.0;Monte_P10 = 0.0;Monte_P05 = 0.0;summation_opt_sat = 0.0;
for(int i=0; i<endloop; i++)
{
MonteCarlo_opt_P20 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P20 = 0.0;
Monte_P20 =
gsl_cdf_beta_Pinv(MonteCarlo_opt_P20,P20_Alpha[layer_counter],P20_Beta[layer_counter]);
str = static_cast<int>(Monte_P20);
if (str != 0)
{do{MonteCarlo_opt_P20 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P20 =
gsl_cdf_beta_Pinv(MonteCarlo_opt_P20,P20_Alpha[layer_counter],P20_Beta[layer_counter]);
str = static_cast<int>(Monte_P20);} while (str != 0);}
(double)Monte_P20 = (P20_Min[layer_counter] + (Monte_P20 * (P20_Max[layer_counter] -
P20_Min[layer_counter])));
Monte_P10 = Monte_P20;
do{MonteCarlo_opt_P10 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P10 =
gsl_cdf_beta_Pinv(MonteCarlo_opt_P10,P10_Alpha[layer_counter],P10_Beta[layer_counter]);
str = static_cast<int>(Monte_P10);
if (str != 0)
{do{MonteCarlo_opt_P10 = gsl_rng_uniform_pos(Rand_NUM_Gen);
```

```
Monte_P10 =
gsl_cdf_beta_Pinv(MonteCarlo_opt_P10,P10_Alpha[layer_counter],P10_Beta[layer_counter]);
str = static_cast<int>(Monte_P10);} while (str != 0);}
(double)Monte_P10 = (P10_Min[layer_counter] + (Monte_P10 * (P10_Max[layer_counter] -
P10_Min[layer_counter])));} while (Monte_P10 > Monte_P20);
Monte_P05 = Monte_P10;
do{MonteCarlo_opt_P05 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P05 =
gsl_cdf_beta_Pinv(MonteCarlo_opt_P05,P05_Alpha[layer_counter],P05_Beta[layer_counter]);
str = static_cast<int>(Monte_P05);
if (str != 0)
{do{MonteCarlo_opt_P05 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P05 =
gsl_cdf_beta_Pinv(MonteCarlo_opt_P05,P05_Alpha[layer_counter],P05_Beta[layer_counter]);
str = static_cast<int>(Monte_P05);} while (str != 0);}
(double)Monte_P05 = (P05_Min[layer_counter] + (Monte_P05 * (P05_Max[layer_counter] -
P05_Min[layer_counter])));} while (Monte_P05 > Monte_P10);
opt_sat_mean1 = -100.17+1.4991*Monte_P20+0.56155*Monte_P10-0.36755*Monte_P05;
if(opt_sat_mean1 > 100)
opt_sat_mean1 = 100.0;
summation_opt_sat += opt_sat_mean1;
Monte_opt_sat[layer_counter][i] = opt_sat_mean1;
}
opt_sat_mean1 = summation_opt_sat/endloop;
summation_opt_sat_var = 0.0;
for( int w=0; w<endloop; w++)
{
opt_sat_var1 = pow((Monte_opt_sat[layer_counter][w]- opt_sat_mean1),2.0);
```

```
summation_opt_sat_var += opt_sat_var1;
}
opt_sat_var1 = summation_opt_sat_var/endloop;
opt_sat_stdev1 = pow(opt_sat_var1,0.5);
opt_sat_min1 = 1000.0;opt_sat_max1 =-1000.0;summation_opt_sat_skew =
0.0;summation_opt_sat_kurt = 0.0;
for(int f=0; f<endloop;f++)
{
opt_sat_skew1 = pow(((Monte_opt_sat[layer_counter][f]-opt_sat_mean1)/opt_sat_stdev1),3.0);
summation_opt_sat_skew += opt_sat_skew1;
opt_sat_kurt1 = pow(((Monte_opt_sat[layer_counter][f]-opt_sat_mean1)/opt_sat_stdev1),4.0);
summation_opt_sat_kurt += opt_sat_kurt1;
if(opt_sat_min1 > Monte_opt_sat[layer_counter][f])
opt_sat_min1 = Monte_opt_sat[layer_counter][f];
if(opt_sat_max1 < Monte_opt_sat[layer_counter][f])
opt_sat_max1 = Monte_opt_sat[layer_counter][f];
}
if(opt_sat_min1 < 0.0)
opt_sat_min1 = 0.0;
opt_sat_skew1 = (1/endloop)*summation_opt_sat_skew;
opt_sat_kurt1 = ((1/endloop)*summation_opt_sat_kurt)-3.0;
opt_sat_alpha1 = ((opt_sat_mean1-opt_sat_min1)/(opt_sat_max1-
opt_sat_min1))*(((opt_sat_mean1-opt_sat_min1)*(opt_sat_max1-opt_sat_mean1)/opt_sat_var1)-
1);
opt_sat_beta1 = ((opt_sat_max1-opt_sat_mean1)/(opt_sat_mean1-opt_sat_min1))*opt_sat_alpha1;
//wPI = 0.0 Gamma Dry Maximum
```

```
MonteCarlo_gamma_wopt = 1.0;MonteCarlo_gamma_Gs = 1.0;MonteCarlo_gamma_Sopt =
1.0;summation_gamma_dry = 0.0;Monte_gamma_wopt = 0.0;Monte_gamma_Gs =
0.0;Monte_gamma_Sopt = 0.0;
for(int i=0; i<endloop; i++)
{
MonteCarlo_gamma_wopt = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_gamma_wopt = gsl_cdf_beta_Pinv(MonteCarlo_gamma_wopt,wopt_alpha,wopt_beta);
str = static_cast<int>(Monte_gamma_wopt);
if (str != 0)
{do{MonteCarlo_gamma_wopt = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_gamma_wopt = gsl_cdf_beta_Pinv(MonteCarlo_gamma_wopt,wopt_alpha,wopt_beta);
str = static_cast<int>(Monte_gamma_wopt);} while (str != 0);}
(double)Monte_gamma_wopt = (wopt_min + (Monte_gamma_wopt * (wopt_max - wopt_min)));
MonteCarlo_gamma_Gs = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_gamma_Gs =
gsl_cdf_beta_Pinv(MonteCarlo_gamma_Gs,Gs_Alpha[layer_counter],Gs_Beta[layer_counter]);
str = static_cast<int>(Monte_gamma_Gs);
if (str != 0)
{do{MonteCarlo_gamma_Gs = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_gamma_Gs =
gsl_cdf_beta_Pinv(MonteCarlo_gamma_Gs,Gs_Alpha[layer_counter],Gs_Beta[layer_counter]);
str = static_cast<int>(Monte_gamma_Gs);} while (str != 0);}
(double)Monte_gamma_Gs = (Gs_Min[layer_counter] + (Monte_gamma_Gs *
(Gs_Max[layer_counter] - Gs_Min[layer_counter])));
MonteCarlo_gamma_Sopt = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_gamma_Sopt =
gsl_cdf_beta_Pinv(MonteCarlo_gamma_Sopt,opt_sat_alpha1,opt_sat_beta1);
str = static_cast<int>(Monte_gamma_Sopt);
```

```
if (str != 0)
{do{MonteCarlo_gamma_Sopt = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_gamma_Sopt =
gsl_cdf_beta_Pinv(MonteCarlo_gamma_Sopt,opt_sat_alpha1,opt_sat_beta1);
str = static_cast<int>(Monte_gamma_Sopt);} while (str != 0);}
(double)Monte_gamma_Sopt = (opt_sat_min1 + (Monte_gamma_Sopt * (opt_sat_max1 -
opt_sat_min1)));
gamma_dry_mean =
(Monte_gamma_Gs*gamma_water)/(1+((Monte_gamma_wopt*Monte_gamma_Gs)/Monte_gam
ma_Sopt));
if(Layer_Compaction[layer_counter] == false)
gamma_dry_mean = 1.0156*gamma_dry_mean - 2.464;
if(gamma_dry_mean >150)
gamma_dry_mean = 150;
summation_gamma_dry += gamma_dry_mean;
Monte_gamma_dry[layer_counter][i] = gamma_dry_mean;
}
gamma_dry_mean = summation_gamma_dry/endloop;
gamma_dry_min = 1000.0;gamma_dry_max =-1000.0;summation_gamma_dry_var = 0.0;
for( int w=0; w<endloop; w++)
{
gamma_dry_var = pow((Monte_gamma_dry[layer_counter][w]- gamma_dry_mean),2.0);
summation_gamma_dry_var += gamma_dry_var;
if(gamma_dry_min > Monte_gamma_dry[layer_counter][w])
gamma_dry_min = Monte_gamma_dry[layer_counter][w];
if(gamma_dry_max < Monte_gamma_dry[layer_counter][w])
gamma_dry_max = Monte_gamma_dry[layer_counter][w];
}
```

```
gamma_dry_var = summation_gamma_dry_var / endloop;

gamma_dry_stdev = pow(gamma_dry_var,0.5);

summation_gamma_dry_kurt = 0.0;

summation_gamma_dry_skew = 0.0;

for(int w=0; w<endloop; w++)

{

summation_gamma_dry_skew += pow(((Monte_gamma_dry[layer_counter][w]-

gamma_dry_mean)/gamma_dry_stdev),3.0);

summation_gamma_dry_kurt += pow(((Monte_gamma_dry[layer_counter][w]-

gamma_dry_mean)/gamma_dry_stdev),4.0);

}

gamma_dry_skew = (1.0/endloop)*summation_gamma_dry_skew;

gamma_dry_kurt = ((1.0/endloop)*summation_gamma_dry_kurt)-3.0;

gamma_dry_alpha = ((gamma_dry_mean-gamma_dry_min)/(gamma_dry_max-

gamma_dry_min))*(((gamma_dry_mean-gamma_dry_min)*(gamma_dry_max-

gamma_dry_mean)/gamma_dry_var)-1.0);

gamma_dry_beta = ((gamma_dry_max-gamma_dry_mean)/(gamma_dry_mean-

gamma_dry_min))*gamma_dry_alpha;

}

else // wPI != 0.0

{

//adjusted PI

MonteCarlo_PIadj_P200 = 1.0;Monte_PIadj_P200 = 0.0;summation_PIadj = 0.0;

for(int i=0; i<endloop; i++)

{

MonteCarlo_PIadj_P200 = gsl_rng_uniform_pos(Rand_NUM_Gen);
```

```
Monte_PIadj_P200 =
gsl_cdf_beta_Pinv(MonteCarlo_PIadj_P200,P200_Alpha[layer_counter],P200_Beta[layer_counte
r]);
str = static_cast<int>(Monte_PIadj_P200);
if (str != 0)
{do{MonteCarlo_PIadj_P200 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_PIadj_P200 =
gsl_cdf_beta_Pinv(MonteCarlo_PIadj_P200,P200_Alpha[layer_counter],P200_Beta[layer_counte
r]);
str = static_cast<int>(Monte_PIadj_P200);} while (str != 0);}
(double)Monte_PIadj_P200 = (P200_Min[layer_counter] + (Monte_PIadj_P200 *
(P200_Max[layer_counter] - P200_Min[layer_counter])));
PI_adj_mean = exp((Monte_PIadj_P200+42.13)/33.94);
summation_PIadj += PI_adj_mean;
Monte_PIadj[layer_counter][i] = PI_adj_mean;}
PI_adj_mean = summation_PIadj/endloop;
PI_adj_min = 1000.0;PI_adj_max =-1.0;summation_PI_adj_var = 0.0;
for( int w=0; w<endloop; w++)
{
PI_adj_var = pow((Monte_PIadj[layer_counter][w]- PI_adj_mean),2.0);
summation_PI_adj_var += PI_adj_var;
if(PI_adj_min > Monte_PIadj[layer_counter][w])
PI_adj_min = Monte_PIadj[layer_counter][w];
if(PI_adj_max < Monte_PIadj[layer_counter][w])
PI_adj_max = Monte_PIadj[layer_counter][w];
}
PI_adj_var = summation_PI_adj_var / endloop;
PI_adj_stdev = pow(PI_adj_var,0.5);
```

```
PI_adj_alpha = ((PI_adj_mean-PI_adj_min)/(PI_adj_max-PI_adj_min))*(((PI_adj_mean-
PI_adj_min)*(PI_adj_max-PI_adj_mean)/PI_adj_var)-1.0);
PI_adj_beta = ((PI_adj_max-PI_adj_mean)/(PI_adj_mean-PI_adj_min))*PI_adj_alpha;
if(PI_adj_mean < PI_M[layer_counter])
{
MonteCarlo_wPIadj_PIadj = 1.0;MonteCarlo_wPIadj_P200 = 1.0;Monte_wPIadj_PIadj =
0.0;Monte_wPIadj_P200 = 0.0;summation_wPIadj = 0.0;
for(int i=0; i<endloop; i++)
{MonteCarlo_wPIadj_PIadj = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wPIadj_PIadj = gsl_cdf_beta_Pinv(MonteCarlo_wPIadj_PIadj,PI_adj_alpha,PI_adj_beta);
str = static_cast<int>(Monte_wPIadj_PIadj);
if (str != 0)
{do{MonteCarlo_wPIadj_PIadj = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wPIadj_PIadj = gsl_cdf_beta_Pinv(MonteCarlo_wPIadj_PIadj,PI_adj_alpha,PI_adj_beta);
str = static_cast<int>(Monte_wPIadj_PIadj);} while (str != 0);}
(double)Monte_wPIadj_PIadj = (PI_adj_min + (Monte_wPIadj_PIadj * (PI_adj_max -
PI_adj_min)));
MonteCarlo_wPIadj_P200 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wPIadj_P200 =
gsl_cdf_beta_Pinv(MonteCarlo_wPIadj_P200,P200_Alpha[layer_counter],P200_Beta[layer_coun
ter]);
str = static_cast<int>(Monte_wPIadj_P200);
if (str != 0)
{do{MonteCarlo_wPIadj_P200 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wPIadj_P200 =
gsl_cdf_beta_Pinv(MonteCarlo_wPIadj_P200,P200_Alpha[layer_counter],P200_Beta[layer_coun
ter]); str = static_cast<int>(Monte_wPIadj_P200);} while (str != 0);}
```

```
(double)Monte_wPIadj_P200 = (P200_Min[layer_counter] + (Monte_wPIadj_P200 *
(P200_Max[layer_counter] - P200_Min[layer_counter])));
wPI_adj_mean = (Monte_wPIadj_PIadj * Monte_wPIadj_P200)/100.0;
summation_wPIadj += wPI_adj_mean;
Monte_wPIadj[layer_counter][i] = wPI_adj_mean;
}
wPI_adj_mean = summation_wPIadj/endloop;
wPIadj_min = 1000.0;wPIadj_max =-1.0;summation_wPIadj_var = 0.0;
for( int w=0; w<endloop; w++)
{
wPIadj_var = pow((Monte_wPIadj[layer_counter][w]- wPI_adj_mean),2.0);
summation_wPIadj_var += wPIadj_var;
if(wPIadj_min > Monte_wPIadj[layer_counter][w])
wPIadj_min = Monte_wPIadj[layer_counter][w];
if(wPIadj_max < Monte_wPIadj[layer_counter][w])
wPIadj_max = Monte_wPIadj[layer_counter][w];
}
wPIadj_var = summation_wPIadj_var / endloop;
wPIadj_stdev = pow(wPIadj_var,0.5);
wPIadj_alpha = ((wPI_adj_mean-wPIadj_min)/(wPIadj_max-wPIadj_min))*(((wPI_adj_mean-
wPIadj_min)*(wPIadj_max-wPI_adj_mean)/wPIadj_var)-1.0);
wPIadj_beta = ((wPIadj_max-wPI_adj_mean)/(wPI_adj_mean-wPIadj_min))*wPIadj_alpha;
}
else{wPI_adj_mean = wPI_M[layer_counter];wPIadj_var = wPI_V[layer_counter];wPIadj_stdev
= wPI_S[layer_counter];wPIadj_min = wPI_Min[layer_counter];wPIadj_max =
wPI_Max[layer_counter];wPIadj_alpha = wPI_Alpha[layer_counter];wPIadj_beta =
wPI_Beta[layer_counter];}
//wPI >0 Optimum Moisture Content
```

```
MonteCarlo_wopt_P15 = 1.0;MonteCarlo_wopt_P40 = 1.0; MonteCarlo_wopt_P60 =
1.0;MonteCarlo_wopt_D60 = 1.0;MonteCarlo_wopt_wPIadj = 1.0;Monte_wopt_P15 =
0.0;Monte_wopt_P40 = 0.0;Monte_wopt_P60 = 0.0;Monte_wopt_D60 = 0.0;Monte_wPIadj1 =
0.0;summation_wopt = 0.0;
for(int i=0; i<endloop; i++)
{MonteCarlo_wopt_wPIadj = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wPIadj1 = gsl_cdf_beta_Pinv(MonteCarlo_wopt_wPIadj,wPIadj_alpha,wPIadj_beta);
str = static_cast<int>(Monte_wPIadj1);
if (str != 0)
{do{MonteCarlo_wopt_wPIadj = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wPIadj1 = gsl_cdf_beta_Pinv(MonteCarlo_wopt_wPIadj,wPIadj_alpha,wPIadj_beta);
str = static_cast<int>(Monte_wPIadj1);} while (str != 0);}
(double)Monte_wPIadj1 = (wPIadj_min + (Monte_wPIadj1 * (wPIadj_max - wPIadj_min)));
if(Monte_wPIadj1 <0.001)
{woptModelStorage[layer_counter][i] = 0.0;
do{MonteCarlo_wopt_P15 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wopt_P15 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_P15,P15_Alpha[layer_counter],P15_Beta[layer_counter]);
str = static_cast<int>(Monte_wopt_P15);
if ((str != 0))
{do{MonteCarlo_wopt_P15 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wopt_P15 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_P15,P15_Alpha[layer_counter],P15_Beta[layer_counter]);
str = static_cast<int>(Monte_wopt_P15);} while ((str != 0));}
(double)Monte_wopt_P15 = (P15_Min[layer_counter] + (Monte_wopt_P15 *
(P15_Max[layer_counter] - P15_Min[layer_counter])));
Monte_wopt_P40 = MonteCarlo_wopt_P15;
do{MonteCarlo_wopt_P40 = gsl_rng_uniform_pos(Rand_NUM_Gen);
```

```
Monte_wopt_P40 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_P40,P40_Alpha[layer_counter],P40_Beta[layer_counter]);
str = static_cast<int>(Monte_wopt_P40);
if (str != 0)
{do{MonteCarlo_wopt_P40 = gsl_rng_uniform_pos(Rand_NUM_Gen);
        Monte_wopt_P40 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_P40,P40_Alpha[layer_counter],P40_Beta[layer_counter]);
        str = static_cast<int>(Monte_wopt_P40);} while (str != 0);}
(double)Monte_wopt_P40 = (P40_Min[layer_counter] + (Monte_wopt_P40 *
(P40_Max[layer_counter] - P40_Min[layer_counter])));} while (Monte_wopt_P40 >
Monte_wopt_P15);
Monte_wopt_P60 = MonteCarlo_wopt_P40;
do{MonteCarlo_wopt_P60 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wopt_P60 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_P60,P60_Alpha[layer_counter],P60_Beta[layer_counter]);
str = static_cast<int>(Monte_wopt_P60);
if (str != 0)
{do{MonteCarlo_wopt_P60 = gsl_rng_uniform_pos(Rand_NUM_Gen);
        Monte_wopt_P60 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_P60,P60_Alpha[layer_counter],P60_Beta[layer_counter]);
        str = static_cast<int>(Monte_wopt_P60);} while (str != 0);}
(double)Monte_wopt_P60 = (P60_Min[layer_counter] + (Monte_wopt_P60 *
(P60_Max[layer_counter] - P60_Min[layer_counter])));} while(Monte_wopt_P60 >
Monte_wopt_P40);
do{MonteCarlo_wopt_D60 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wopt_D60 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_D60,D60_Alpha[layer_counter],D60_Beta[layer_counter]);
str1 = static_cast<int>(Monte_wopt_D60);
```

```
if ((str1 !=0))
{do{MonteCarlo_wopt_D60 = gsl_rng_uniform_pos(Rand_NUM_Gen);
        Monte_wopt_D60 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_D60,D60_Alpha[layer_counter],D60_Beta[layer_counter]);
        str1 = static_cast<int>(Monte_wopt_D60);} while ((str1 !=0));}
else{Monte_wopt_D60 = Monte_wopt_D60;}
(double)Monte_wopt_D60 = (D60_Min[layer_counter] + (Monte_wopt_D60 *
(D60_Max[layer_counter] - D60_Min[layer_counter])));
if((Monte_wopt_D60 < 37.50) && (Monte_wopt_P15 < 60.0)) // 1.5" Comparison{str = 0.0;}
else if((Monte_wopt_D60 > 0.425) && (Monte_wopt_P40 < 60.0)||((Monte_wopt_D60 > 0.425)
&& (Monte_wopt_P40 > 60.0)))// #40 Comparison{str = 0.0;}
else if((Monte_wopt_D60 > 0.250)&&(Monte_wopt_P60 <60))||((Monte_wopt_D60 >
0.250)&&(Monte_wopt_P60 >60))) // #60 Comparison{str = 0.0;}
else
{str = 1.0;}} while(str !=0.0);
opt_moisture_mean = -120.14-0.06766*Monte_wopt_P15+3.7269*Monte_wopt_D60-
0.167*Monte_wopt_P40+0.117*Monte_wopt_P60+142.53*exp(-0.0389*Monte_wopt_D60);
}while(opt_moisture_mean <0);}
else
{
woptModelStorage[layer_counter][i] = 1;
if(Monte_wPIadj1 <1.0)
Monte_wPIadj1 = 1.0;
opt_moisture_mean = 8.3932*pow(Monte_wPIadj1,0.3075);
}
summation_wopt += opt_moisture_mean;
Monte_wopt[layer_counter][i] = opt_moisture_mean;
}
```

```
opt_moisture_mean = summation_wopt/endloop;
summation_wopt_var = 0.0;
wopt_min = 1000.0;
wopt_max =-1.0;
for( int w=0; w<endloop; w++)
{
wopt_var = pow((Monte_wopt[layer_counter][w]- opt_moisture_mean),2.0);
summation_wopt_var += wopt_var;
if(wopt_min > Monte_wopt[layer_counter][w])
wopt_min = Monte_wopt[layer_counter][w];
if(wopt_max < Monte_wopt[layer_counter][w])
wopt_max = Monte_wopt[layer_counter][w];
}
wopt_var = summation_wopt_var / endloop;
wopt_stdev = pow(wopt_var,0.5);
summation_wopt_skew = 0.0;
summation_wopt_kurt = 0.0;
for(int w=0; w<endloop; w++)
{
summation_wopt_skew += pow(((Monte_wopt[layer_counter][w]-
opt_moisture_mean)/wopt_stdev),3.0);
summation_wopt_kurt += pow(((Monte_wopt[layer_counter][w]-
opt_moisture_mean)/wopt_stdev),4.0);}
wopt_skew = (1/endloop)*summation_wopt_skew;
wopt_kurt =((1/endloop)*summation_wopt_kurt)-3.0;
if(wopt_max == wopt_min)
{wopt_alpha = 1.0;wopt_beta = 1.0;}
else
```

```
{wopt_alpha = ((opt_moisture_mean-wopt_min)/(wopt_max-wopt_min))*(((opt_moisture_mean-
wopt_min)*(wopt_max-opt_moisture_mean)/wopt_var)-1.0);
wopt_beta = ((wopt_max-opt_moisture_mean)/(opt_moisture_mean-wopt_min))*wopt_alpha;}
MonteCarlo_gamma_wopt = 1.0;summation_gamma_dry = 0.0;Monte_gamma_wopt = 0.0;
for(int i=0; i<endloop; i++)
{if(woptModelStorage[layer_counter][i] ==0.0)
{do{do{MonteCarlo_wopt_P15 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wopt_P15 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_P15,P15_Alpha[layer_counter],P15_Beta[layer_counter]);
str = static_cast<int>(Monte_wopt_P15);
if ((str != 0))
{do{MonteCarlo_wopt_P15 = gsl_rng_uniform_pos(Rand_NUM_Gen);
        Monte_wopt_P15 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_P15,P15_Alpha[layer_counter],P15_Beta[layer_counter]);
        str = static_cast<int>(Monte_wopt_P15);} while ((str != 0));}
(double)Monte_wopt_P15 = (P15_Min[layer_counter] + (Monte_wopt_P15 *
(P15_Max[layer_counter] - P15_Min[layer_counter])));
Monte_wopt_P40 = MonteCarlo_wopt_P15;
do{MonteCarlo_wopt_P40 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wopt_P40 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_P40,P40_Alpha[layer_counter],P40_Beta[layer_counter]);
str = static_cast<int>(Monte_wopt_P40);
if (str != 0)
{do{MonteCarlo_wopt_P40 = gsl_rng_uniform_pos(Rand_NUM_Gen);
                Monte_wopt_P40 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_P40,P40_Alpha[layer_counter],P40_Beta[layer_counter]);
                str = static_cast<int>(Monte_wopt_P40);} while (str != 0);}
```

```
(double)Monte_wopt_P40 = (P40_Min[layer_counter] + (Monte_wopt_P40 *
(P40_Max[layer_counter] - P40_Min[layer_counter])));} while (Monte_wopt_P40 >
Monte_wopt_P15);
Monte_wopt_P60 = MonteCarlo_wopt_P40;
do{MonteCarlo_wopt_P60 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wopt_P60 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_P60,P60_Alpha[layer_counter],P60_Beta[layer_counter]);
str = static_cast<int>(Monte_wopt_P60);
if (str != 0)
{do{MonteCarlo_wopt_P60 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wopt_P60 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_P60,P60_Alpha[layer_counter],P60_Beta[layer_counter]);
                str = static_cast<int>(Monte_wopt_P60);} while (str != 0);}
(double)Monte_wopt_P60 = (P60_Min[layer_counter] + (Monte_wopt_P60 *
(P60_Max[layer_counter] - P60_Min[layer_counter])));} while(Monte_wopt_P60 >
Monte_wopt_P40);
do{MonteCarlo_wopt_D60 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wopt_D60 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_D60,D60_Alpha[layer_counter],D60_Beta[layer_counter]);
str1 = static_cast<int>(Monte_wopt_D60);
if ((str1 !=0))
{do{MonteCarlo_wopt_D60 = gsl_rng_uniform_pos(Rand_NUM_Gen);
                Monte_wopt_D60 =
gsl_cdf_beta_Pinv(MonteCarlo_wopt_D60,D60_Alpha[layer_counter],D60_Beta[layer_counter]);
                str1 = static_cast<int>(Monte_wopt_D60);} while ((str1 !=0));}
else
{Monte_wopt_D60 = Monte_wopt_D60;}
```

```
(double)Monte_wopt_D60 = (D60_Min[layer_counter] + (Monte_wopt_D60 *
(D60_Max[layer_counter] - D60_Min[layer_counter])));
if((Monte_wopt_D60 < 37.50) && (Monte_wopt_P15 < 60.0)) // 1.5" Comparison
{str = 0.0;}
else if((Monte_wopt_D60 > 0.425) && (Monte_wopt_P40 < 60.0)||((Monte_wopt_D60 > 0.425)
&& (Monte_wopt_P40 > 60.0)))// #40 Comparison
{str = 0.0;}
else if((Monte_wopt_D60 > 0.250)&&(Monte_wopt_P60 <60)||((Monte_wopt_D60 >
0.250)&&(Monte_wopt_P60 >60))) // #60 Comparison
{str = 0.0;}
else
{str = 1.0;}}while(str !=0.0);
opt_moisture_mean = -120.14-0.06766*Monte_wopt_P15+3.7269*Monte_wopt_D60-
0.167*Monte_wopt_P40+0.117*Monte_wopt_P60+142.53*exp(-0.0389*Monte_wopt_D60);
}while(opt_moisture_mean <0);
do{MonteCarlo_opt_P20 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P20 = 0.0;
Monte_P20 =
gsl_cdf_beta_Pinv(MonteCarlo_opt_P20,P20_Alpha[layer_counter],P20_Beta[layer_counter]);
str = static_cast<int>(Monte_P20);
if (str != 0)
{do{MonteCarlo_opt_P20 = gsl_rng_uniform_pos(Rand_NUM_Gen);
        Monte_P20 =
gsl_cdf_beta_Pinv(MonteCarlo_opt_P20,P20_Alpha[layer_counter],P20_Beta[layer_counter]);
        str = static_cast<int>(Monte_P20);} while (str != 0);}
(double)Monte_P20 = (P20_Min[layer_counter] + (Monte_P20 * (P20_Max[layer_counter] -
P20_Min[layer_counter])));
Monte_P10 = Monte_P20;
```

```
do{MonteCarlo_opt_P10 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P10 =
gsl_cdf_beta_Pinv(MonteCarlo_opt_P10,P10_Alpha[layer_counter],P10_Beta[layer_counter]);
str = static_cast<int>(Monte_P10);
if (str != 0)
{do{MonteCarlo_opt_P10 = gsl_rng_uniform_pos(Rand_NUM_Gen);
                Monte_P10 =
gsl_cdf_beta_Pinv(MonteCarlo_opt_P10,P10_Alpha[layer_counter],P10_Beta[layer_counter]);
                str = static_cast<int>(Monte_P10);} while (str != 0);}
(double)Monte_P10 = (P10_Min[layer_counter] + (Monte_P10 * (P10_Max[layer_counter] -
P10_Min[layer_counter])));} while (Monte_P10 > Monte_P20);

Monte_P05 = Monte_P10;
do{MonteCarlo_opt_P05 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P05 =
gsl_cdf_beta_Pinv(MonteCarlo_opt_P05,P05_Alpha[layer_counter],P05_Beta[layer_counter]);
str = static_cast<int>(Monte_P05);
if (str != 0)
{do{MonteCarlo_opt_P05 = gsl_rng_uniform_pos(Rand_NUM_Gen);
                Monte_P05 =
gsl_cdf_beta_Pinv(MonteCarlo_opt_P05,P05_Alpha[layer_counter],P05_Beta[layer_counter]);
                str = static_cast<int>(Monte_P05);  } while (str != 0);}
(double)Monte_P05 = (P05_Min[layer_counter] + (Monte_P05 * (P05_Max[layer_counter] -
P05_Min[layer_counter])));
} while (Monte_P05 > Monte_P10);
opt_sat_mean1 = -100.17+1.4991*Monte_P20+0.56155*Monte_P10-0.36755*Monte_P05;

}while(opt_sat_mean1<0);
```

```
MonteCarlo_gamma_Gs = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_gamma_Gs =
gsl_cdf_beta_Pinv(MonteCarlo_gamma_Gs,Gs_Alpha[layer_counter],Gs_Beta[layer_counter]);
str = static_cast<int>(Monte_gamma_Gs);
if (str != 0)
{do{MonteCarlo_gamma_Gs = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_gamma_Gs =
gsl_cdf_beta_Pinv(MonteCarlo_gamma_Gs,Gs_Alpha[layer_counter],Gs_Beta[layer_counter]);
str = static_cast<int>(Monte_gamma_Gs);} while (str != 0);}
(double)Monte_gamma_Gs = (Gs_Min[layer_counter] + (Monte_gamma_Gs *
(Gs_Max[layer_counter] - Gs_Min[layer_counter])));

gamma_dry_mean =
(Monte_gamma_Gs*gamma_water)/(1+((opt_moisture_mean*Monte_gamma_Gs)/opt_sat_mean
1));
}while(gamma_dry_mean>150);//Remoeving Impropable Maximum Dry density's
gamma_dry_mean<70||
}
else
{
MonteCarlo_gamma_wopt = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_gamma_wopt = gsl_cdf_beta_Pinv(MonteCarlo_gamma_wopt,wopt_alpha,wopt_beta);
str = static_cast<int>(Monte_gamma_wopt);
if (str != 0)
{do{MonteCarlo_gamma_wopt = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_gamma_wopt = gsl_cdf_beta_Pinv(MonteCarlo_gamma_wopt,wopt_alpha,wopt_beta);
str = static_cast<int>(Monte_gamma_wopt);} while (str != 0); }
(double)Monte_gamma_wopt = (wopt_min + (Monte_gamma_wopt * (wopt_max - wopt_min)));
```

```
if(Monte_gamma_wopt<8.3932)

Monte_gamma_wopt = 8.3932;

gamma_dry_mean = 142.115-1.959*Monte_gamma_wopt;

}

if(gamma_dry_mean >150)

gamma_dry_mean = 150;

if(Layer_Compaction[layer_counter] == false)

gamma_dry_mean = 1.0156*gamma_dry_mean - 2.464;

summation_gamma_dry += gamma_dry_mean;

Monte_gamma_dry[layer_counter][i] = gamma_dry_mean;

}

gamma_dry_mean = summation_gamma_dry/endloop;

gamma_dry_min = 1000.0;

gamma_dry_max =-1.0;

summation_gamma_dry_var = 0.0;

for( int w=0; w<endloop; w++)

{

gamma_dry_var = pow((Monte_gamma_dry[layer_counter][w]- gamma_dry_mean),2.0);

summation_gamma_dry_var += gamma_dry_var;

if(gamma_dry_min > Monte_gamma_dry[layer_counter][w])

gamma_dry_min = Monte_gamma_dry[layer_counter][w];

if(gamma_dry_max < Monte_gamma_dry[layer_counter][w])

gamma_dry_max = Monte_gamma_dry[layer_counter][w];

}

gamma_dry_var = summation_gamma_dry_var / endloop;

gamma_dry_stdev = pow(gamma_dry_var,0.5);

summation_gamma_dry_kurt = 0.0;

summation_gamma_dry_skew = 0.0;
```

```
for(int w=0; w<endloop; w++)
{
summation_gamma_dry_skew += pow(((Monte_gamma_dry[layer_counter][w]-
gamma_dry_mean)/gamma_dry_stdev),3.0);
summation_gamma_dry_kurt += pow(((Monte_gamma_dry[layer_counter][w]-
gamma_dry_mean)/gamma_dry_stdev),4.0);
}
gamma_dry_skew = (1.0/endloop)*summation_gamma_dry_skew;
gamma_dry_kurt = ((1.0/endloop)*summation_gamma_dry_kurt)-3.0;

if(gamma_dry_min == gamma_dry_max)
{ gamma_dry_alpha = 1.0; gamma_dry_beta = 1.0;}
else
{
gamma_dry_alpha = ((gamma_dry_mean-gamma_dry_min)/(gamma_dry_max-
gamma_dry_min))*(((gamma_dry_mean-gamma_dry_min)*(gamma_dry_max-
gamma_dry_mean)/gamma_dry_var)-1.0);
gamma_dry_beta = ((gamma_dry_max-gamma_dry_mean)/(gamma_dry_mean-
gamma_dry_min))*gamma_dry_alpha;
}
//Optimum Saturation
MonteCarlo_opt_wopt = 1.0; MonteCarlo_opt_gamma = 1.0; MonteCarlo_opt_Gs = 1.0;
MonteCarlo_wopt_P15 = 1.0;MonteCarlo_wopt_P40 = 1.0; MonteCarlo_wopt_P60 =
1.0;MonteCarlo_wopt_D60 = 1.0;MonteCarlo_opt_P20 = 1.0; MonteCarlo_opt_P10 =
1.0;MonteCarlo_opt_P05 = 1.0;Monte_P20 = 0.0;Monte_P10 = 0.0; Monte_P05 =
0.0;Monte_wopt_P15 = 0.0;Monte_wopt_P40 = 0.0;Monte_wopt_P60 = 0.0;Monte_wopt_D60 =
0.0;Monte_opt_wopt = 0.0;Monte_opt_gamma = 0.0;Monte_opt_Gs = 0.0;summation_opt_sat =
0.0;
```

```
for(int i=0; i<endloop; i++)
{do{if(woptModelStorage[layer_counter][i]==0.0)
{MonteCarlo_opt_P20 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P20 = 0.0;
Monte_P20 =
gsl_cdf_beta_Pinv(MonteCarlo_opt_P20,P20_Alpha[layer_counter],P20_Beta[layer_counter]);
str = static_cast<int>(Monte_P20);
if (str != 0)
{do{MonteCarlo_opt_P20 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P20 =
gsl_cdf_beta_Pinv(MonteCarlo_opt_P20,P20_Alpha[layer_counter],P20_Beta[layer_counter]);
str = static_cast<int>(Monte_P20);} while (str != 0);}
(double)Monte_P20 = (P20_Min[layer_counter] + (Monte_P20 * (P20_Max[layer_counter] -
P20_Min[layer_counter])));
Monte_P10 = Monte_P20;
do{MonteCarlo_opt_P10 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P10 =
gsl_cdf_beta_Pinv(MonteCarlo_opt_P10,P10_Alpha[layer_counter],P10_Beta[layer_counter]);
str = static_cast<int>(Monte_P10);
if (str != 0)
{do{MonteCarlo_opt_P10 = gsl_rng_uniform_pos(Rand_NUM_Gen);
        Monte_P10 =
gsl_cdf_beta_Pinv(MonteCarlo_opt_P10,P10_Alpha[layer_counter],P10_Beta[layer_counter]);
        str = static_cast<int>(Monte_P10);} while (str != 0);}
(double)Monte_P10 = (P10_Min[layer_counter] + (Monte_P10 * (P10_Max[layer_counter] -
P10_Min[layer_counter])));} while (Monte_P10 > Monte_P20);
Monte_P05 = Monte_P10;
do{MonteCarlo_opt_P05 = gsl_rng_uniform_pos(Rand_NUM_Gen);
```

```
Monte_P05 =
gsl_cdf_beta_Pinv(MonteCarlo_opt_P05,P05_Alpha[layer_counter],P05_Beta[layer_counter]);
str = static_cast<int>(Monte_P05);
if (str != 0)
{do{MonteCarlo_opt_P05 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P05 =
gsl_cdf_beta_Pinv(MonteCarlo_opt_P05,P05_Alpha[layer_counter],P05_Beta[layer_counter]);
        str = static_cast<int>(Monte_P05);} while (str != 0);}
(double)Monte_P05 = (P05_Min[layer_counter] + (Monte_P05 * (P05_Max[layer_counter] -
P05_Min[layer_counter])));
} while (Monte_P05 > Monte_P10);
opt_sat_mean1 = -100.17+1.4991*Monte_P20+0.56155*Monte_P10-0.36755*Monte_P05;}
else
{MonteCarlo_opt_wopt = gsl_rng_uniform_pos(Rand_NUM_Gen);
MonteCarlo_opt_gamma = 1.0 - MonteCarlo_opt_wopt;
MonteCarlo_opt_Gs = MonteCarlo_opt_wopt;
Monte_opt_wopt = gsl_cdf_beta_Pinv(MonteCarlo_opt_wopt,wopt_alpha,wopt_beta);
Monte_opt_gamma =
gsl_cdf_beta_Pinv(MonteCarlo_opt_gamma,gamma_dry_alpha,gamma_dry_beta);
Monte_opt_Gs =
gsl_cdf_beta_Pinv(MonteCarlo_opt_Gs,Gs_Alpha[layer_counter],Gs_Beta[layer_counter]);
str = static_cast<int>(Monte_opt_gamma);
str1 = static_cast<int>(Monte_opt_wopt);
if ((str != 0)||(str1 !=0)||(str2 !=0))
{do{MonteCarlo_opt_wopt = gsl_rng_uniform_pos(Rand_NUM_Gen);
MonteCarlo_opt_gamma = 1.0 - MonteCarlo_opt_wopt;
MonteCarlo_opt_Gs = MonteCarlo_opt_wopt;
Monte_opt_wopt = gsl_cdf_beta_Pinv(MonteCarlo_opt_wopt,wopt_alpha,wopt_beta);
```

```
Monte_opt_gamma =
gsl_cdf_beta_Pinv(MonteCarlo_opt_gamma,gamma_dry_alpha,gamma_dry_beta);
Monte_opt_Gs =
gsl_cdf_beta_Pinv(MonteCarlo_opt_Gs,Gs_Alpha[layer_counter],Gs_Beta[layer_counter]);
str = static_cast<int>(Monte_opt_gamma);
str1 = static_cast<int>(Monte_opt_wopt);
str2 = static_cast<int>(Monte_opt_Gs);} while ((str != 0)||(str1 !=0)||(str2 !=0));}
(double)Monte_opt_wopt = (wopt_min + (Monte_opt_wopt * (wopt_max - wopt_min)));
(double)Monte_opt_gamma = (gamma_dry_min + (Monte_opt_gamma * (gamma_dry_max -
gamma_dry_min)));
(double)Monte_opt_Gs = (Gs_Min[layer_counter] + (Monte_opt_Gs * (Gs_Max[layer_counter] -
Gs_Min[layer_counter])));
opt_sat_mean1 = Monte_opt_wopt/((gamma_water/Monte_opt_gamma)-(1/Monte_opt_Gs));
}
}while(opt_sat_mean1<0);
if(opt_sat_mean1 > 100.0)
opt_sat_mean1 = 100.0;
summation_opt_sat += opt_sat_mean1;
Monte_opt_sat[layer_counter][i] = opt_sat_mean1;
}
opt_sat_mean1 = summation_opt_sat/endloop;
summation_opt_sat_var = 0.0;
for( int w=0; w<endloop; w++)
{
opt_sat_var1 = pow((Monte_opt_sat[layer_counter][w]- opt_sat_mean1),2.0);
summation_opt_sat_var += opt_sat_var1;
}
opt_sat_var1 = summation_opt_sat_var/endloop;
```

```
opt_sat_stdev1 = pow(opt_sat_var1,0.5);

opt_sat_min1 = 1000.0;

opt_sat_max1 = -1.0;

summation_opt_sat_skew = 0.0;

summation_opt_sat_kurt = 0.0;

for(int f=0; f<endloop; f++)

{

opt_sat_skew1 = pow(((Monte_opt_sat[layer_counter][f]-opt_sat_mean1)/opt_sat_stdev1),3.0);

summation_opt_sat_skew += opt_sat_skew1;

opt_sat_kurt1 = pow(((Monte_opt_sat[layer_counter][f]-opt_sat_mean1)/opt_sat_stdev1),4.0);

summation_opt_sat_kurt += opt_sat_kurt1;

if(opt_sat_min1 > Monte_opt_sat[layer_counter][f])

opt_sat_min1 = Monte_opt_sat[layer_counter][f];

if(opt_sat_max1 < Monte_opt_sat[layer_counter][f])

opt_sat_max1 = Monte_opt_sat[layer_counter][f];

}

opt_sat_skew1 = (1/endloop)*summation_opt_sat_skew;

opt_sat_kurt1 = ((1/endloop)*summation_opt_sat_kurt)-3.0;

opt_sat_alpha1 = ((opt_sat_mean1-opt_sat_min1)/(opt_sat_max1-

opt_sat_min1))*(((opt_sat_mean1-opt_sat_min1)*(opt_sat_max1-opt_sat_mean1)/opt_sat_var1)-

1);

opt_sat_beta1 = ((opt_sat_max1-opt_sat_mean1)/(opt_sat_mean1-opt_sat_min1))*opt_sat_alpha1;

}

//Saturated Volumetric water content

MonteCarlo_gamma_dry = 1.0;MonteCarlo_Gs = 1.0;summation_theata_sat =

0.0;Monte_gamma_dry1 = 0.0;Monte_Gs = 0.0;

for(int i=0; i<endloop; i++)

{
```

```
MonteCarlo_Gs = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Gs =
gsl_cdf_beta_Pinv(MonteCarlo_Gs,Gs_Alpha[layer_counter],Gs_Beta[layer_counter]);
str = static_cast<int>(Monte_Gs);
if (str != 0)
{do{MonteCarlo_Gs = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Gs =
gsl_cdf_beta_Pinv(MonteCarlo_Gs,Gs_Alpha[layer_counter],Gs_Beta[layer_counter]);
str = static_cast<int>(Monte_Gs);} while (str != 0);}
(double)Monte_Gs = (Gs_Min[layer_counter] + (Monte_Gs * (Gs_Max[layer_counter] -
Gs_Min[layer_counter])));
MonteCarlo_gamma_dry = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_gamma_dry1 =
gsl_cdf_beta_Pinv(MonteCarlo_gamma_dry,gamma_dry_alpha,gamma_dry_beta);
str = static_cast<int>(Monte_gamma_dry1);
if (str != 0)
{do{MonteCarlo_gamma_dry = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_gamma_dry1 =
gsl_cdf_beta_Pinv(MonteCarlo_gamma_dry,gamma_dry_alpha,gamma_dry_beta);
str = static_cast<int>(Monte_gamma_dry1);} while (str != 0);}
(double)Monte_gamma_dry1 = (gamma_dry_min + (Monte_gamma_dry1 * (gamma_dry_max -
gamma_dry_min)));
theata_sat = (1.0-(Monte_gamma_dry1/(Monte_Gs*gamma_water)))*100;
if(theata_sat<0)
{
MonteCarlo_Gs = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Gs =
gsl_cdf_beta_Pinv(MonteCarlo_Gs,Gs_Alpha[layer_counter],Gs_Beta[layer_counter]);
```

```
str = static_cast<int>(Monte_Gs);
if (str != 0)
{do{
MonteCarlo_Gs = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Gs =
gsl_cdf_beta_Pinv(MonteCarlo_Gs,Gs_Alpha[layer_counter],Gs_Beta[layer_counter]);
str = static_cast<int>(Monte_Gs);} while (str != 0);}
(double)Monte_Gs = (Gs_Min[layer_counter] + (Monte_Gs * (Gs_Max[layer_counter] -
Gs_Min[layer_counter])));
MonteCarlo_gamma_dry = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_gamma_dry1 =
gsl_cdf_beta_Pinv(MonteCarlo_gamma_dry,gamma_dry_alpha,gamma_dry_beta);
str = static_cast<int>(Monte_gamma_dry1);
if (str != 0)
{do{
MonteCarlo_gamma_dry = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_gamma_dry1 =
gsl_cdf_beta_Pinv(MonteCarlo_gamma_dry,gamma_dry_alpha,gamma_dry_beta);
str = static_cast<int>(Monte_gamma_dry1);} while (str != 0);}
(double)Monte_gamma_dry1 = (gamma_dry_min + (Monte_gamma_dry1 * (gamma_dry_max -
gamma_dry_min)));
theata_sat = (1.0-(Monte_gamma_dry1/(Monte_Gs*gamma_water)))*100;
}
summation_theata_sat += theata_sat; Monte_theata_sat[layer_counter][i] = theata_sat;
}
theata_sat = summation_theata_sat / endloop;
theata_sat_min = 1000.0; theata_sat_max =-1.0; theata_sat_var = 0.0; summation_theata_sat_var
= 0.0; summation_theata_sat_skew = 0.0; summation_theata_sat_kurt = 0.0;
```

```
for( int w=0; w<endloop; w++)

{

theata_sat_var = pow((Monte_theata_sat[layer_counter][w]- theata_sat),2.0);

if(theata_sat_min > Monte_theata_sat[layer_counter][w])

theata_sat_min = Monte_theata_sat[layer_counter][w];

if(theata_sat_max < Monte_theata_sat[layer_counter][w])

theata_sat_max = Monte_theata_sat[layer_counter][w];

summation_theata_sat_var += theata_sat_var;

}

theata_sat_var = summation_theata_sat_var / endloop;

theata_sat_stdev = pow(theata_sat_var,0.5);

for( int w=0; w<endloop; w++)

{

theata_sat_kurt = pow(((Monte_theata_sat[layer_counter][w]- theata_sat)/theata_sat_stdev),4.0);

summation_theata_sat_kurt += theata_sat_kurt;

theata_sat_skew = pow(((Monte_theata_sat[layer_counter][w]- theata_sat)/theata_sat_stdev),3.0);

summation_theata_sat_skew += theata_sat_skew;

}

theata_sat_skew = (1/endloop)*summation_theata_sat_skew;

theata_sat_kurt = ((1/endloop)*summation_theata_sat_kurt)-3.0;

theata_sat_alpha = ((theata_sat-theata_sat_min)/(theata_sat_max-theata_sat_min))*(((theata_sat-
theata_sat_min)*(theata_sat_max-theata_sat)/theata_sat_var)-1.0);

theata_sat_beta = ((theata_sat_max-theata_sat)/(theata_sat-theata_sat_min))*theata_sat_alpha;


//wPI <2.0

if(wPI_Max[layer_counter]<2.0)

{
```

```
MonteCarlo_theata_P200 = 1.0; MonteCarlo_theata_TMI = 1.0; Monte_P200_theata_water = 0.0;
Monte_TMI_theata_water = 0.0; summation_theata_water = 0.0;
for(int i=0; i <endloop; i++)
{
MonteCarlo_theata_P200 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P200_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_P200,P200_Alpha[layer_counter],P200_Beta[layer_counter]);
str = static_cast<int>(Monte_P200_theata_water);
if (str != 0)
{do{
MonteCarlo_theata_P200 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P200_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_P200,P200_Alpha[layer_counter],P200_Beta[layer_counter]);
str = static_cast<int>(Monte_P200_theata_water);} while (str != 0);}
(double)Monte_P200_theata_water = (P200_Min[layer_counter] + (Monte_P200_theata_water *
(P200_Max[layer_counter] - P200_Min[layer_counter])));
if(Monte_P200_theata_water < 2.0)
Monte_P200_theata_water = 2.0;
MonteCarlo_theata_TMI = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_TMI_theata_water = gsl_cdf_beta_Pinv(MonteCarlo_theata_TMI,TMI_alpha,TMI_beta);
str = static_cast<int>(Monte_TMI_theata_water);
if (str != 0)
{do{
MonteCarlo_theata_TMI = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_TMI_theata_water = gsl_cdf_beta_Pinv(MonteCarlo_theata_TMI,TMI_alpha,TMI_beta);
str = static_cast<int>(Monte_TMI_theata_water);} while (str != 0);}
```

```
(double)Monte_TMI_theata_water = (TMI_min + (Monte_TMI_theata_water * (TMI_max -
TMI_min)));
theata_water = 4.0 + 1.5*pow(Monte_P200_theata_water,0.6994) +
0.03*Monte_TMI_theata_water;
if(theata_water > 40.0)//1-40D Constraint
{
MonteCarlo_theata_P200 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P200_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_P200,P200_Alpha[layer_counter],P200_Beta[layer_count
er]);
str = static_cast<int>(Monte_P200_theata_water);
if (str != 0)
{do{
MonteCarlo_theata_P200 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P200_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_P200,P200_Alpha[layer_counter],P200_Beta[layer_count
er]);
str = static_cast<int>(Monte_P200_theata_water);} while (str != 0);}
(double)Monte_P200_theata_water = (P200_Min[layer_counter] + (Monte_P200_theata_water *
(P200_Max[layer_counter] - P200_Min[layer_counter])));
theata_water = 40 + 0.11*(Monte_P200_theata_water - 53.0);}
summation_theata_water += theata_water;
Monte_theata_water[layer_counter][i] = theata_water;}}
else
{
MonteCarlo_theata_P200 = 1.0;MonteCarlo_theata_TMI = 1.0;Monte_P200_theata_water =
0.0;Monte_TMI_theata_water = 0.0;summation_theata_water = 0.0;summation_a =
0.0;summation_b = 0.0;summation_c = 0.0;summation_C_h = 0.0; MonteCarlo_theata_wPI =
```

```
1.0;MonteCarlo_theata_Suction = 1.0;summation_theata_water = 0.0;Monte_wPI_theata_water =
0.0;Monte_Suction_theata_water = 0.0;SWCC_checker = 0.0;
// SWCC information
for(int i =0; i<endloop; i++)
{
MonteCarlo_theata_wPI = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wPI_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_wPI,wPI_Alpha[layer_counter],wPI_Beta[layer_counter]);
str = static_cast<int>(Monte_wPI_theata_water);
if (str != 0)
{do{
MonteCarlo_theata_wPI = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_wPI_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_wPI,wPI_Alpha[layer_counter],wPI_Beta[layer_counter]);
str = static_cast<int>(Monte_wPI_theata_water);} while (str != 0);
}
(double)Monte_wPI_theata_water = (wPI_Min[layer_counter] + (Monte_wPI_theata_water *
(wPI_Max[layer_counter] - wPI_Min[layer_counter])));
if(Monte_wPI_theata_water > 2.0)
{
MonteCarlo_theata_sat = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_sat_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_sat,theata_sat_alpha,theata_sat_beta);
str = static_cast<int>(Monte_sat_theata_water);
if (str != 0)
{do{
MonteCarlo_theata_sat = gsl_rng_uniform_pos(Rand_NUM_Gen);
```

```
Monte_sat_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_sat,theata_sat_alpha,theata_sat_beta);
str = static_cast<int>(Monte_sat_theata_water);} while (str != 0);
}
(double)Monte_sat_theata_water = (theata_sat_min + (Monte_sat_theata_water * (theata_sat_max
- theata_sat_min)));
MonteCarlo_theata_Suction = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Suction_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_Suction,Suction_Alpha[layer_counter],Suction_Beta[layer
_counter]);
str = static_cast<int>(Monte_Suction_theata_water);
if (str != 0)
{
do
{
MonteCarlo_theata_Suction = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Suction_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_Suction,Suction_Alpha[layer_counter],Suction_Beta[layer
_counter]);
str = static_cast<int>(Monte_Suction_theata_water);} while (str != 0);
}
(double)Monte_Suction_theata_water = (Suction_Minimum[layer_counter] +
(Monte_Suction_theata_water * (Suction_Maximum[layer_counter] -
Suction_Minimum[layer_counter])));
af = 32.835*log(Monte_wPI_theata_water)+32.438;
if(af < 5.0)
af = 5.0;
bf = 1.421*pow(Monte_wPI_theata_water,-0.3185);
```

```
cf = -0.2154*log(Monte_wPI_theata_water)+0.7145;
if(cf < 0.01)
cf = 0.03;
C_h = 1-(log(1+(Monte_Suction_theata_water/residual))/(log(1+(1000000.0/residual))));
theata_water =
C_h*(Monte_sat_theata_water/pow(log(pow((Monte_Suction_theata_water/af),bf)+exp(1.0)),cf));
summation_theata_water += theata_water;
Monte_theata_water[layer_counter][i] = theata_water;
SWCC_Parameters[layer_counter][i-SWCC_checker][0] = af;
SWCC_Parameters[layer_counter][i-SWCC_checker][1] = bf;
SWCC_Parameters[layer_counter][i-SWCC_checker][2] = cf;
summation_a += af; summation_b += bf; summation_c += cf;
}
else
{
SWCC_checker += 1.0;
MonteCarlo_theata_P200 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P200_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_P200,P200_Alpha[layer_counter],P200_Beta[layer_count
er]);
str = static_cast<int>(Monte_P200_theata_water);
if (str != 0)
{do{
MonteCarlo_theata_P200 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P200_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_P200,P200_Alpha[layer_counter],P200_Beta[layer_count
er]);
str = static_cast<int>(Monte_P200_theata_water);} while (str != 0);
```

```
}
(double)Monte_P200_theata_water = (P200_Min[layer_counter] + (Monte_P200_theata_water *
(P200_Max[layer_counter] - P200_Min[layer_counter])));
if(Monte_P200_theata_water < 2.0)
Monte_P200_theata_water = 2.0;
MonteCarlo_theata_TMI = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_TMI_theata_water = gsl_cdf_beta_Pinv(MonteCarlo_theata_TMI,TMI_alpha,TMI_beta);
str = static_cast<int>(Monte_TMI_theata_water);
if (str != 0)
{do{
MonteCarlo_theata_TMI = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_TMI_theata_water = gsl_cdf_beta_Pinv(MonteCarlo_theata_TMI,TMI_alpha,TMI_beta);
str = static_cast<int>(Monte_TMI_theata_water);} while (str != 0);
}
(double)Monte_TMI_theata_water = (TMI_min + (Monte_TMI_theata_water * (TMI_max -
TMI_min)));
theata_water = 4.0 + 1.5*pow(Monte_P200_theata_water,0.6994) +
0.03*Monte_TMI_theata_water;
if(theata_water > 40.0)//1-40D Constraint
{
MonteCarlo_theata_P200 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_P200_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_P200,P200_Alpha[layer_counter],P200_Beta[layer_count
er]);
str = static_cast<int>(Monte_P200_theata_water);
if (str != 0)
{do{
MonteCarlo_theata_P200 = gsl_rng_uniform_pos(Rand_NUM_Gen);
```

```
Monte_P200_theata_water =
gsl_cdf_beta_Pinv(MonteCarlo_theata_P200,P200_Alpha[layer_counter],P200_Beta[layer_count
er]);
str = static_cast<int>(Monte_P200_theata_water);} while (str != 0);
}
(double)Monte_P200_theata_water = (P200_Min[layer_counter] + (Monte_P200_theata_water *
(P200_Max[layer_counter] - P200_Min[layer_counter])));
theata_water = 40 + 0.11*(Monte_P200_theata_water - 53.0);
}
summation_theata_water += theata_water;
Monte_theata_water[layer_counter][i] = theata_water;}}
a_mean = summation_a/(endloop-SWCC_checker);
b_mean = summation_b/(endloop-SWCC_checker);
c_mean = summation_c/(endloop-SWCC_checker);
summation_a_var = 0.0; summation_b_var = 0.0; summation_c_var = 0.0; summation_C_h_var =
0.0; summation_a_skew = 0.0; summation_b_skew = 0.0; summation_c_skew = 0.0;
summation_a_kurt = 0.0; summation_b_kurt = 0.0; summation_c_kurt = 0.0; a_max =-10000.0;
a_min = 10000.0; b_max =-10000.0; b_min =10000.0; c_max =-10000.0; c_min = 10000.0;
for(int w=0; w<endloop-SWCC_checker; w++)
{
summation_a_var += pow((SWCC_Parameters[layer_counter][w][0]-a_mean),2.0);
if((a_min >
SWCC_Parameters[layer_counter][w][0])&&(SWCC_Parameters[layer_counter][w][0] != 0.0))
a_min = SWCC_Parameters[layer_counter][w][0];
if(a_max < SWCC_Parameters[layer_counter][w][0])
a_max = SWCC_Parameters[layer_counter][w][0];
summation_b_var += pow((SWCC_Parameters[layer_counter][w][1]-b_mean),2.0);
```

```
if((b_min >
SWCC_Parameters[layer_counter][w][1])&&(SWCC_Parameters[layer_counter][w][1] != 0.0))
b_min = SWCC_Parameters[layer_counter][w][1];
if(b_max < SWCC_Parameters[layer_counter][w][1])
b_max = SWCC_Parameters[layer_counter][w][1];
summation_c_var += pow((SWCC_Parameters[layer_counter][w][2]-c_mean),2.0);
if((c_min >
SWCC_Parameters[layer_counter][w][2])&&(SWCC_Parameters[layer_counter][w][2] != 0.0))
c_min = SWCC_Parameters[layer_counter][w][2];
if(c_max < SWCC_Parameters[layer_counter][w][2])
c_max = SWCC_Parameters[layer_counter][w][2];
}
a_var = summation_a_var/(endloop-SWCC_checker);
b_var = summation_b_var/(endloop-SWCC_checker);
c_var = summation_c_var/(endloop-SWCC_checker);
a_stdev = pow(a_var,0.5);
b_stdev = pow(b_var,0.5);
c_stdev = pow(c_var,0.5);
for(int w=0; w<endloop-SWCC_checker; w++)
{
summation_a_skew += pow(((SWCC_Parameters[layer_counter][w][0]-a_mean)/a_stdev),3.0);
summation_b_skew += pow(((SWCC_Parameters[layer_counter][w][1]-b_mean)/b_stdev),3.0);
summation_c_skew += pow(((SWCC_Parameters[layer_counter][w][2]-c_mean)/c_stdev),3.0);
summation_a_kurt += pow(((SWCC_Parameters[layer_counter][w][0]-a_mean)/a_stdev),4.0);
summation_b_kurt += pow(((SWCC_Parameters[layer_counter][w][1]-b_mean)/b_stdev),4.0);
summation_c_kurt += pow(((SWCC_Parameters[layer_counter][w][2]-c_mean)/c_stdev),4.0);
}
a_skew = (1.0/(endloop-SWCC_checker))*summation_a_skew;
```

```
b_skew = (1.0/(endloop-SWCC_checker))*summation_b_skew;
c_skew = (1.0/(endloop-SWCC_checker))*summation_c_skew;
a_kurt = ((1.0/(endloop-SWCC_checker))*summation_a_kurt)-3.0;
b_kurt = ((1.0/(endloop-SWCC_checker))*summation_b_kurt)-3.0;
c_kurt = ((1.0/(endloop-SWCC_checker))*summation_c_kurt)-3.0;
a_alpha = ((a_mean-a_min)/(a_max-a_min))*(((a_mean-a_min)*(a_max-a_mean)/a_var)-1.0);
a_beta = ((a_max-a_mean)/(a_mean-a_min))*a_alpha;
b_alpha = ((b_mean-b_min)/(b_max-b_min))*(((b_mean-b_min)*(b_max-b_mean)/b_var)-1.0);
b_beta = ((b_max-b_mean)/(b_mean-b_min))*b_alpha;
c_alpha = ((c_mean-c_min)/(c_max-c_min))*(((c_mean-c_min)*(c_max-c_mean)/c_var)-1.0);
c_beta = ((c_max-c_mean)/(c_mean-c_min))*c_alpha;
SWCC_AM[layer_counter] = a_mean; SWCC_AV[layer_counter] = a_var;
SWCC_AS[layer_counter] = a_stdev; SWCC_ASkew[layer_counter] = a_skew;
SWCC_AKurt[layer_counter] = a_kurt; SWCC_AMin[layer_counter] = a_min;
SWCC_AMax[layer_counter] = a_max; SWCC_AAlpha[layer_counter] = a_alpha;
SWCC_ABeta[layer_counter] = a_beta; SWCC_BM[layer_counter] = b_mean;
SWCC_BV[layer_counter] = b_var;SWCC_BS[layer_counter] =
b_stdev;SWCC_BSkew[layer_counter] = b_skew; SWCC_BKurt[layer_counter] =
b_kurt;SWCC_BMin[layer_counter] = b_min; SWCC_BMax[layer_counter] = b_max;
SWCC_BAlpha[layer_counter] = b_alpha; SWCC_BBeta[layer_counter] =
b_beta;SWCC_CM[layer_counter] = c_mean; SWCC_CV[layer_counter] = c_var;
SWCC_CS[layer_counter] = c_stdev; SWCC_CSkew[layer_counter] = c_skew;
SWCC_CKurt[layer_counter] = c_kurt; SWCC_CMin[layer_counter] =
c_min;SWCC_CMax[layer_counter] = c_max; SWCC_CAlpha[layer_counter] = c_alpha;
SWCC_CBeta[layer_counter] = c_beta;
}
theata_water = summation_theata_water/endloop;
```

```
theata_water_min = 1000.0; theata_water_max =-1.0; summation_theata_water_var = 0.0;
summation_theata_water_skew = 0.0; summation_theata_water_kurt = 0.0;
for( int w=0; w<endloop; w++)
{
theata_water_var = pow((Monte_theata_water[layer_counter][w]- theata_water),2.0);
summation_theata_water_var += theata_water_var;
if(theata_water_min > Monte_theata_water[layer_counter][w])
theata_water_min = Monte_theata_water[layer_counter][w];
if(theata_water_max < Monte_theata_water[layer_counter][w])
theata_water_max = Monte_theata_water[layer_counter][w];
}
theata_water_var = summation_theata_water_var / endloop;
theata_water_stdev = pow(theata_water_var,0.5);
for( int w=0; w<endloop; w++)
{
theata_water_skew = pow(((Monte_theata_water[layer_counter][w]-
theata_water)/theata_water_stdev),3.0);
theata_water_kurt = pow(((Monte_theata_water[layer_counter][w]-
theata_water)/theata_water_stdev),4.0);
summation_theata_water_skew += theata_water_skew;
summation_theata_water_kurt += theata_water_kurt;
}
theata_water_skew = (1.0/endloop)*summation_theata_water_skew;
theata_water_kurt = ((1.0/endloop)*summation_theata_water_kurt)-3.0;
theata_water_alpha = ((theata_water-theata_water_min)/(theata_water_max-
theata_water_min))*(((theata_water-theata_water_min)*(theata_water_max-
theata_water)/theata_water_var)-1.0);
```

```
theata_water_beta = ((theata_water_max-theata_water)/(theata_water-
theata_water_min))*theata_water_alpha;
//Degree of Saturation
MonteCarlo_theata_sat = 1.0; MonteCarlo_theata_water = 1.0; summation_degree_sat = 0.0;
summation_degree_sat_var = 0.0; Monte_theata_water_dsat = 0.0; Monte_theata_sat_dsat = 0.0;
for(int i=0; i<endloop; i++)
{
MonteCarlo_theata_water = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_theata_water_dsat =
gsl_cdf_beta_Pinv(MonteCarlo_theata_water,theata_water_alpha,theata_water_beta);
str = static_cast<int>(Monte_theata_water_dsat);
if (str != 0)
{do{
MonteCarlo_theata_water = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_theata_water_dsat =
gsl_cdf_beta_Pinv(MonteCarlo_theata_water,theata_water_alpha,theata_water_beta);
str = static_cast<int>(Monte_theata_water_dsat);} while (str != 0);
}
(double)Monte_theata_water_dsat = (theata_water_min + (Monte_theata_water_dsat *
(theata_water_max - theata_water_min)));
MonteCarlo_theata_sat = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_theata_sat_dsat =
gsl_cdf_beta_Pinv(MonteCarlo_theata_sat,theata_sat_alpha,theata_sat_beta);
str = static_cast<int>(Monte_theata_sat_dsat);
if (str != 0)
{do{
MonteCarlo_theata_sat = gsl_rng_uniform_pos(Rand_NUM_Gen);
```

```
Monte_theata_sat_dsat =
gsl_cdf_beta_Pinv(MonteCarlo_theata_sat,theata_sat_alpha,theata_sat_beta);
str = static_cast<int>(Monte_theata_sat_dsat);} while (str != 0);
}
(double)Monte_theata_sat_dsat = (theata_sat_min + (Monte_theata_sat_dsat * (theata_sat_max -
theata_sat_min)));
if(Monte_theata_water_dsat > Monte_theata_sat_dsat)
Monte_theata_water_dsat = Monte_theata_sat_dsat;
degree_sat_mean1 = (Monte_theata_water_dsat / Monte_theata_sat_dsat)*100.0;
if(degree_sat_mean1 > 100.0)
degree_sat_mean1 = 100.0;
summation_degree_sat += degree_sat_mean1;
Monte_degree_sat[layer_counter][i] = degree_sat_mean1;
}
degree_sat_mean1 = summation_degree_sat/endloop;
for( int w=0; w<endloop; w++)
{
degree_sat_var1 = pow((Monte_degree_sat[layer_counter][w]- degree_sat_mean1),2.0);
summation_degree_sat_var += degree_sat_var1;
}
degree_sat_var1 = summation_degree_sat_var/endloop;
degree_sat_stdev1 = pow(degree_sat_var1,0.5);
degree_sat_min1 = 1000.0; degree_sat_max1 = -1.0; summation_degree_sat_skew =
0.0;summation_degree_sat_kurt = 0.0;
for(int f=0; f<endloop;f++)
{
degree_sat_skew1 = pow(((Monte_degree_sat[layer_counter][f]-
degree_sat_mean1)/degree_sat_stdev1),3.0);
```

```
summation_degree_sat_skew += degree_sat_skew1;
degree_sat_kurt1 = pow(((Monte_degree_sat[layer_counter][f]-
degree_sat_mean1)/degree_sat_stdev1),4.0);
summation_degree_sat_kurt += degree_sat_kurt1;
if(degree_sat_min1 > Monte_degree_sat[layer_counter][f])
degree_sat_min1 = Monte_degree_sat[layer_counter][f];
if(degree_sat_max1 < Monte_degree_sat[layer_counter][f])
degree_sat_max1 = Monte_degree_sat[layer_counter][f];
}
degree_sat_skew1 = (1/endloop)*summation_degree_sat_skew;
degree_sat_kurt1 = ((1/endloop)*summation_degree_sat_kurt)-3.0;
degree_sat_alpha1 = ((degree_sat_mean1-degree_sat_min1)/(degree_sat_max1-
degree_sat_min1))*(((degree_sat_mean1-degree_sat_min1)*(degree_sat_max1-
degree_sat_mean1)/degree_sat_var1)-1);
degree_sat_beta1 = ((degree_sat_max1-degree_sat_mean1)/(degree_sat_mean1-
degree_sat_min1))*degree_sat_alpha1;
}
//Optimum Moisture Content Storage
wopt_M[layer_counter] = opt_moisture_mean; wopt_V[layer_counter] =
wopt_var;wopt_S[layer_counter] = wopt_stdev;wopt_Skew[layer_counter] =
wopt_skew;wopt_Kurt[layer_counter] = wopt_kurt;wopt_Min[layer_counter] =
wopt_min;wopt_Max[layer_counter] = wopt_max; wopt_Alpha[layer_counter] = wopt_alpha;
wopt_Beta[layer_counter] = wopt_beta;
//Dry Unit Weight Storage
gamma_dry_M[layer_counter] = gamma_dry_mean;gamma_dry_V[layer_counter] =
gamma_dry_var;gamma_dry_S[layer_counter] =
gamma_dry_stdev;gamma_dry_Skew[layer_counter] =
gamma_dry_skew;gamma_dry_Kurt[layer_counter] =
```

```
gamma_dry_kurt;gamma_dry_Min[layer_counter] =
gamma_dry_min;gamma_dry_Max[layer_counter] =
gamma_dry_max;gamma_dry_Alpha[layer_counter] =
gamma_dry_alpha;gamma_dry_Beta[layer_counter] = gamma_dry_beta;
//Saturated Volumetric Water Content Storage
Theata_SM[layer_counter] = theata_sat;Theata_SV[layer_counter] = theata_sat_var;
Theata_SS[layer_counter] = theata_sat_stdev;Theata_SSkew[layer_counter] =
theata_sat_skew;Theata_SKurt[layer_counter] = theata_sat_kurt;Theata_SMin[layer_counter] =
theata_sat_min;Theata_SMax[layer_counter] = theata_sat_max;Theata_SAlpha[layer_counter] =
theata_sat_alpha;Theata_SBeta[layer_counter] = theata_sat_beta;
//Volumetric Water Content Storage
Theata_WM[layer_counter] = theata_water;Theata_WV[layer_counter] =
theata_water_var;Theata_WS[layer_counter] =
theata_water_stdev;Theata_WSkew[layer_counter] =
theata_water_skew;Theata_WKurt[layer_counter] =
theata_water_kurt;Theata_WMin[layer_counter] =
theata_water_min;Theata_WMax[layer_counter] =
theata_water_max;Theata_WAlpha[layer_counter] =
theata_water_alpha;Theata_WBeta[layer_counter] = theata_water_beta;
//Degree Saturation Storage
degree_sat_mean[layer_counter] = degree_sat_mean1; degree_sat_var[layer_counter] =
degree_sat_var1;degree_sat_stdev[layer_counter] =
degree_sat_stdev1;degree_sat_skew[layer_counter] =
degree_sat_skew1;degree_sat_kurt[layer_counter] =
degree_sat_kurt1;degree_sat_Min[layer_counter] =
degree_sat_min1;degree_sat_Max[layer_counter] =
degree_sat_max1;degree_sat_Alpha[layer_counter] =
degree_sat_alpha1;degree_sat_Beta[layer_counter] = degree_sat_beta1;
```

```
//Optimum Saturation Storage
opt_sat_mean[layer_counter] = opt_sat_mean1;opt_sat_var[layer_counter] =
opt_sat_var1;opt_sat_stdev[layer_counter] = opt_sat_stdev1;opt_sat_skew[layer_counter] =
opt_sat_skew1;opt_sat_kurt[layer_counter] = opt_sat_kurt1;opt_sat_min[layer_counter] =
opt_sat_min1;opt_sat_max[layer_counter] = opt_sat_max1;opt_sat_Alpha[layer_counter] =
opt_sat_alpha1; opt_sat_Beta[layer_counter] = opt_sat_beta1;
//Fenv information
MonteCarlo_Fenv_wPI = 1.0; MonteCarlo_Fenv_degree_sat = 1.0; MonteCarlo_Fenv_opt_sat =
1.0; Monte_Fenv_wPI = 0.0; Monte_Fenv_dsat = 0.0; Monte_Fenv_osat = 0.0; summation_Fenv
= 0.0;
for(int i=0; i<endloop; i++)
{
MonteCarlo_Fenv_wPI = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Fenv_wPI =
gsl_cdf_beta_Pinv(MonteCarlo_Fenv_wPI,wPI_Alpha[layer_counter],wPI_Beta[layer_counter]);
str = static_cast<int>(Monte_Fenv_wPI);
if (str != 0)
{do{
MonteCarlo_Fenv_wPI = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Fenv_wPI =
gsl_cdf_beta_Pinv(MonteCarlo_Fenv_wPI,wPI_Alpha[layer_counter],wPI_Beta[layer_counter]);
str = static_cast<int>(Monte_Fenv_wPI);} while (str != 0);
}
(double)Monte_Fenv_wPI =
(wPI_Min[layer_counter]+Monte_Fenv_wPI*(wPI_Max[layer_counter]-
wPI_Min[layer_counter]));
MonteCarlo_Fenv_degree_sat = gsl_rng_uniform_pos(Rand_NUM_Gen);
```

```
Monte_Fenv_dsat =
gsl_cdf_beta_Pinv(MonteCarlo_Fenv_degree_sat,degree_sat_Alpha[layer_counter],degree_sat_Beta[layer_counter]);
str = static_cast<int>(Monte_Fenv_dsat);
if (str != 0)
{do{
MonteCarlo_Fenv_degree_sat = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Fenv_dsat =
gsl_cdf_beta_Pinv(MonteCarlo_Fenv_degree_sat,degree_sat_Alpha[layer_counter],degree_sat_Beta[layer_counter]);
str = static_cast<int>(Monte_Fenv_dsat);} while (str != 0);
}
(double)Monte_Fenv_dsat = (degree_sat_Min[layer_counter] + (Monte_Fenv_dsat *
(degree_sat_Max[layer_counter] - degree_sat_Min[layer_counter])));
MonteCarlo_Fenv_opt_sat = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Fenv_osat =
gsl_cdf_beta_Pinv(MonteCarlo_Fenv_opt_sat,opt_sat_Alpha[layer_counter],opt_sat_Beta[layer_counter]);
str = static_cast<int>(Monte_Fenv_osat);
if (str != 0)
{do{
MonteCarlo_Fenv_opt_sat = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Fenv_osat =
gsl_cdf_beta_Pinv(MonteCarlo_Fenv_opt_sat,opt_sat_Alpha[layer_counter],opt_sat_Beta[layer_counter]);
str = static_cast<int>(Monte_Fenv_osat);} while (str != 0);
}
```

```
(double)Monte_Fenv_osat = (opt_sat_min[layer_counter] + (Monte_Fenv_osat *
(opt_sat_max[layer_counter] - opt_sat_min[layer_counter])));
Fenv_term1 = (-0.6-1.87194*exp(-Monte_Fenv_wPI));
Fenv_term2 = 0.8+0.08*pow(Monte_Fenv_wPI,0.5);
Fenv_term3 = pow((11.96518-10.19111*exp(-Monte_Fenv_wPI)),0.5);
Fenv_term4 = ((Monte_Fenv_dsat-Monte_Fenv_osat)/100);
Fenv_denom = 1+ exp(log(-Fenv_term2/pow(Fenv_term1,-1.0))+ Fenv_term3*Fenv_term4);
powerproduct = 1.002*(pow(Fenv_term1,-1.0)+(Fenv_term2-pow(Fenv_term1,-
1.0))/Fenv_denom);
Fenv_mean1 = pow(10,powerproduct);
summation_Fenv += Fenv_mean1;
Monte_Fenv[layer_counter][i] = Fenv_mean1;
}
Fenv_mean1 = summation_Fenv/endloop;
summation_Fenv_var = 0.0;
for(int w=0; w<endloop; w++)
{
Fenv_var1 = pow((Monte_Fenv[layer_counter][w]- Fenv_mean1),2.0);
summation_Fenv_var += Fenv_var1;
}
Fenv_var1 = summation_Fenv_var/endloop;Fenv_stdev1 = pow(Fenv_var1,0.5);Fenv_min1 =
1000.0;Fenv_max1 = -1000.0;summation_Fenv_skew = 0.0;summation_Fenv_kurt = 0.0;
for(int f=0; f<endloop;f++)
{
Fenv_skew1 = pow(((Monte_Fenv[layer_counter][f]-Fenv_mean1)/Fenv_stdev1),3.0);
summation_Fenv_skew += Fenv_skew1;
Fenv_kurt1 = pow(((Monte_Fenv[layer_counter][f]-Fenv_mean1)/Fenv_stdev1),4.0);
summation_Fenv_kurt += Fenv_kurt1;
```

```
if(Fenv_min1 > Monte_Fenv[layer_counter][f])

Fenv_min1 = Monte_Fenv[layer_counter][f];

if(Fenv_max1 < Monte_Fenv[layer_counter][f])

Fenv_max1 = Monte_Fenv[layer_counter][f];

}

Fenv_skew1 = (1/endloop)*summation_Fenv_skew;

Fenv_kurt1 = ((1/endloop)*summation_Fenv_kurt)-3.0;

Fenv_alpha1 = ((Fenv_mean1-Fenv_min1)/(Fenv_max1-Fenv_min1))*(((Fenv_mean1-
Fenv_min1)*(Fenv_max1-Fenv_mean1)/Fenv_var1)-1);

Fenv_beta1 = ((Fenv_max1-Fenv_mean1)/(Fenv_mean1-Fenv_min1))*Fenv_alpha1;


//Environmental Factor Storage

Fenv_Mean[layer_counter] = Fenv_mean1;Fenv_Var[layer_counter] =
Fenv_var1;Fenv_Stdev[layer_counter] = Fenv_stdev1;Fenv_Skew[layer_counter] =
Fenv_skew1;Fenv_Kurt[layer_counter] = Fenv_kurt1;Fenv_Min[layer_counter] =
Fenv_min1;Fenv_Max[layer_counter] = Fenv_max1;Fenv_Alpha[layer_counter] =
Fenv_alpha1;Fenv_Beta[layer_counter] = Fenv_beta1;

// Mropt

if((level[layer_counter] == true) && (Level_a[layer_counter] == "Level_1"))

{

Mropt_mean1 = Mropt_Mean[layer_counter];Mropt_var1 =
Mropt_Var[layer_counter];Mropt_stdev1 = Mropt_Stdev[layer_counter];Mropt_skew1 =
0;Mropt_kurt1 = 0;Mropt_min1 = Mropt_Min[layer_counter];Mropt_max1 =
Mropt_Max[layer_counter];Mropt_alpha1 = Mropt_Alpha[layer_counter];Mropt_beta1 =
Mropt_Beta[layer_counter];

}

else if(Level_a[layer_counter] == "Level_1a")

{
```

```
MonteCarlo_Mropt_CBR = 1.0;
Monte_Mropt_CBR = 0.0;
summation_Mropt = 0.0;
for(int i=0; i<endloop; i++)
{
MonteCarlo_Mropt_CBR = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Mropt_CBR =
gsl_cdf_beta_Pinv(MonteCarlo_Mropt_CBR,CBR_Alpha[layer_counter],CBR_Beta[layer_counte
r]);
str = static_cast<int>(Monte_Mropt_CBR);
if (str != 0)
{do{
MonteCarlo_Mropt_CBR = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Mropt_CBR =
gsl_cdf_beta_Pinv(MonteCarlo_Mropt_CBR,CBR_Alpha[layer_counter],CBR_Beta[layer_counte
r]);
str = static_cast<int>(Monte_Mropt_CBR);} while (str != 0);
}
(double)Monte_Mropt_CBR = (CBR_Min[layer_counter] + (Monte_Mropt_CBR *
(CBR_Max[layer_counter] - CBR_Min[layer_counter])));
Monte_Mropt_CBR = 2555*pow(Monte_Mropt_CBR,0.64);
Mropt_mean1 = Monte_Mropt_CBR*(2.11-2.78*pow(10,-5.0)*Monte_Mropt_CBR);
summation_Mropt += Mropt_mean1;
Monte_Mropt[layer_counter][i] = Mropt_mean1;
}
CBR_mean = CBR_M[layer_counter];CBR_var = CBR_V[layer_counter];CBR_stdev =
CBR_S[layer_counter];CBR_skew = 0;CBR_kurt = 0;CBR_min =
```

```
CBR_Min[layer_counter];CBR_max = CBR_Max[layer_counter];CBR_alpha =
CBR_Alpha[layer_counter]; CBR_beta = CBR_Beta[layer_counter];
}
else
{
MonteCarlo_Mropt_D60 = 1.0;
MonteCarlo_Mropt_wPI = 1.0;
Monte_Mropt_D60 = 0.0;
Monte_Mropt_wPI = 0.0;
summation_Mropt = 0.0;
CBR_Summation = 0.0;
if(wPI_M[layer_counter] == 0.00)
{
for(int i=0; i<endloop; i++)
{
MonteCarlo_Mropt_D60 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Mropt_D60 =
gsl_cdf_beta_Pinv(MonteCarlo_Mropt_D60,D60_Alpha[layer_counter],D60_Beta[layer_counter]
);
str = static_cast<int>(Monte_Mropt_D60);
if (str != 0)
{do{
MonteCarlo_Mropt_D60 = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Mropt_D60 =
gsl_cdf_beta_Pinv(MonteCarlo_Mropt_D60,D60_Alpha[layer_counter],D60_Beta[layer_counter]
);
str = static_cast<int>(Monte_Mropt_D60);} while (str != 0);
}
```

```
(double)Monte_Mropt_D60 = (D60_Min[layer_counter] + (Monte_Mropt_D60 *
(D60_Max[layer_counter] - D60_Min[layer_counter])));
CBR_mean = 28.09*pow(Monte_Mropt_D60,0.358);
if(Monte_Mropt_D60 < 0.01)
CBR_mean = 5.0;
if(Monte_Mropt_D60 > 30.0)
CBR_mean = 95.0;
CBR_Summation += 28.09*pow(Monte_Mropt_D60,0.358);
CBRStorage[layer_counter][i] = 28.09*pow(Monte_Mropt_D60,0.358);
Model_Storage[layer_counter][i] = 0.0;
Mropt_mean1 = 2555*pow(CBR_mean,0.64)*(2.11-2.78*pow(10,-
5.0)*2555*pow(CBR_mean,0.64));
summation_Mropt += Mropt_mean1;
Monte_Mropt[layer_counter][i] = Mropt_mean1;
}
}
else
{
for(int i=0; i<endloop; i++)
{
MonteCarlo_Mropt_wPI = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Mropt_wPI =
gsl_cdf_beta_Pinv(MonteCarlo_Mropt_wPI,wPI_Alpha[layer_counter],wPI_Beta[layer_counter])
;
str = static_cast<int>(Monte_Mropt_wPI);
if (str != 0)
{do{
MonteCarlo_Mropt_wPI = gsl_rng_uniform_pos(Rand_NUM_Gen);
```

```
Monte_Mropt_wPI =

gsl_cdf_beta_Pinv(MonteCarlo_Mropt_wPI,wPI_Alpha[layer_counter],wPI_Beta[layer_counter])

;

str = static_cast<int>(Monte_Mropt_wPI);} while (str != 0);

}

(double)Monte_Mropt_wPI = (wPI_Min[layer_counter] + (Monte_Mropt_wPI *

(wPI_Max[layer_counter] - wPI_Min[layer_counter])));

if(Monte_Mropt_wPI < 0.1)

{

MonteCarlo_Mropt_D60 = gsl_rng_uniform_pos(Rand_NUM_Gen);

Monte_Mropt_D60 =

gsl_cdf_beta_Pinv(MonteCarlo_Mropt_D60,D60_Alpha[layer_counter],D60_Beta[layer_counter]

);

str = static_cast<int>(Monte_Mropt_D60);

if (str != 0)

{do{

MonteCarlo_Mropt_D60 = gsl_rng_uniform_pos(Rand_NUM_Gen);

Monte_Mropt_D60 =

gsl_cdf_beta_Pinv(MonteCarlo_Mropt_D60,D60_Alpha[layer_counter],D60_Beta[layer_counter]

);

str = static_cast<int>(Monte_Mropt_D60); } while (str != 0);

}

(double)Monte_Mropt_D60 = (D60_Min[layer_counter] + (Monte_Mropt_D60 *

(D60_Max[layer_counter] - D60_Min[layer_counter])));

CBR_mean = 28.09*pow(Monte_Mropt_D60,0.358);

if(Monte_Mropt_D60 < 0.01)

CBR_mean = 5.0;

if(Monte_Mropt_D60 > 30.0)
```

```
CBR_mean = 95.0;
CBR_Summation += 28.09*pow(Monte_Mropt_D60,0.358);
CBR_mean = 28.09*pow(Monte_Mropt_D60,0.358);
Model_Storage[layer_counter][i] = 0.0;
CBRStorage[layer_counter][i] = 28.09*pow(Monte_Mropt_D60,0.358);
Mropt_mean1 = 2555*pow(CBR_mean,0.64)*(2.11-2.78*pow(10,-5.0)*2555*pow(CBR_mean,0.64));
summation_Mropt += Mropt_mean1;
Monte_Mropt[layer_counter][i] = Mropt_mean1;
}
else
{
CBR_Summation += (75/(1+0.728*Monte_Mropt_wPI));
CBR_mean = (75/(1+0.728*Monte_Mropt_wPI));
CBRStorage[layer_counter][i] = (75/(1+0.728*Monte_Mropt_wPI));
Model_Storage[layer_counter][i] = 1.0;
Mropt_mean1 = 2555*pow(CBR_mean,0.64)*(2.11-2.78*pow(10,-5.0)*2555*pow(CBR_mean,0.64));
summation_Mropt += Mropt_mean1;
Monte_Mropt[layer_counter][i] = Mropt_mean1;
}}}
CBR_mean = CBR_Summation/endloop;
summation_CBR_var = 0.0;
for( int w=0; w<endloop; w++)
{
CBR_var = pow((CBRStorage[layer_counter][w]-CBR_mean),2.0);
summation_CBR_var += CBR_var;
}
```

```
CBR_var = summation_CBR_var/endloop; CBR_stdev = pow(CBR_var,0.5); CBR_min =
1000.0; CBR_max =-1.0; summation_CBR_skew = 0.0; summation_CBR_kurt = 0.0;
for(int f=0; f<endloop;f++)
{
CBR_skew = pow(((CBRStorage[layer_counter][f]-CBR_mean)/CBR_stdev),3.0);
summation_CBR_skew += CBR_skew;
CBR_kurt = pow(((CBRStorage[layer_counter][f]-CBR_mean)/CBR_stdev),2.0);
summation_CBR_kurt += CBR_kurt;
if(CBR_min > CBRStorage[layer_counter][f])
CBR_min = CBRStorage[layer_counter][f];
if(CBR_max < CBRStorage[layer_counter][f])
CBR_max = CBRStorage[layer_counter][f];
}
CBR_skew = (1/endloop)*summation_CBR_skew;
CBR_kurt = ((1/endloop)*summation_CBR_kurt)-3.0;
CBR_alpha = ((CBR_mean-CBR_min)/(CBR_max-CBR_min))*(((CBR_mean-
CBR_min)*(CBR_max-CBR_mean)/CBR_var)-1.0);
CBR_beta = ((CBR_max-CBR_mean)/(CBR_mean-CBR_min))*CBR_alpha;

}
if(level[layer_counter] == false)
{
Mropt_mean1 = summation_Mropt/endloop;
summation_Mropt_var = 0.0;
for( int w=0; w<endloop; w++)
{
Mropt_var1 = pow((Monte_Mropt[layer_counter][w]- Mropt_mean1),2.0);
summation_Mropt_var += Mropt_var1;
```

```
}
Mropt_var1 = summation_Mropt_var/endloop;
Mropt_stdev1 = pow(Mropt_var1,0.5);
Mropt_max1 = -1.0; Mropt_min1 = 100000000.0; summation_Mropt_kurt = 0.0;
summation_Mropt_skew = 0.0;
for(int f=0; f<endloop;f++)
{
Mropt_skew1 = pow(((Monte_Mropt[layer_counter][f]-Mropt_mean1)/Mropt_stdev1),3.0);
summation_Mropt_skew += Mropt_skew1;
Mropt_kurt1 = pow(((Monte_Mropt[layer_counter][f]-Mropt_mean1)/Mropt_stdev1),2.0);
summation_Mropt_kurt += Mropt_kurt1;
if(Mropt_min1 > Monte_Mropt[layer_counter][f])
Mropt_min1 = Monte_Mropt[layer_counter][f];
if(Mropt_max1 < Monte_Mropt[layer_counter][f])
Mropt_max1 = Monte_Mropt[layer_counter][f];
}
Mropt_skew1 = (1/endloop)*summation_Mropt_skew;
Mropt_kurt1 = ((1/endloop)*summation_Mropt_kurt)-3.0;
Mropt_alpha1 = ((Mropt_mean1-Mropt_min1)/(Mropt_max1-Mropt_min1))*(((Mropt_mean1-
Mropt_min1)*(Mropt_max1-Mropt_mean1)/Mropt_var1)-1);
Mropt_beta1 = ((Mropt_max1-Mropt_mean1)/(Mropt_mean1-Mropt_min1))*Mropt_alpha1;
}}
//Resilient Modulus at Optimum Storage
Mropt_Mean[layer_counter] = Mropt_mean1; Mropt_Var[layer_counter] =
Mropt_var1;Mropt_Stdev[layer_counter] = Mropt_stdev1; Mropt_Skew[layer_counter] =
Mropt_skew1; Mropt_Kurt[layer_counter] = Mropt_kurt1; Mropt_Min[layer_counter] =
Mropt_min1; Mropt_Max[layer_counter] = Mropt_max1; Mropt_Alpha[layer_counter] =
Mropt_alpha1; Mropt_Beta[layer_counter] = Mropt_beta1;
```

```
//CBR Storage
CBR_M[layer_counter] = CBR_mean; CBR_V[layer_counter] = CBR_var;
CBR_S[layer_counter] = CBR_stdev; CBR_Skew[layer_counter] = CBR_skew;
CBR_Kurt[layer_counter] = CBR_kurt; CBR_Min[layer_counter] = CBR_min;
CBR_Max[layer_counter] = CBR_max; CBR_Alpha[layer_counter] =
CBR_alpha;CBR_Beta[layer_counter] = CBR_beta;
// Resilient Modulus at Equilibrium
MonteCarlo_Mreq_Fenv = 1.0;
MonteCarlo_Mreq_Mropt = 1.0;
Monte_Mreq_Fenv = 0.0;
Monte_Mreq_Mropt = 0.0;
summation_Mreq = 0.0;
double Fenv_check;
for(int i=0; i<endloop; i++)
{
MonteCarlo_Mreq_Fenv = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Mreq_Fenv =
gsl_cdf_beta_Pinv(MonteCarlo_Mreq_Fenv,Fenv_Alpha[layer_counter],Fenv_Beta[layer_counter
]);
str = static_cast<int>(Monte_Mreq_Fenv);
Fenv_check = (Fenv_Min[layer_counter] + (Monte_Mreq_Fenv * (Fenv_Max[layer_counter] -
Fenv_Min[layer_counter])));
if ((str != 0)||(Fenv_check < 0.20))
{do
{
MonteCarlo_Mreq_Fenv = gsl_rng_uniform_pos(Rand_NUM_Gen);
```

```
Monte_Mreq_Fenv =
gsl_cdf_beta_Pinv(MonteCarlo_Mreq_Fenv,Fenv_Alpha[layer_counter],Fenv_Beta[layer_counter
]);
Fenv_check = Monte_Mreq_Fenv;
str = static_cast<int>(Monte_Mreq_Fenv);
} while ((str != 0)||(Fenv_check < 0.20));
}
(double)Monte_Mreq_Fenv = (Fenv_Min[layer_counter] + (Monte_Mreq_Fenv *
(Fenv_Max[layer_counter] - Fenv_Min[layer_counter])));
MonteCarlo_Mreq_Mropt = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Mreq_Mropt =
gsl_cdf_beta_Pinv(MonteCarlo_Mreq_Mropt,Mropt_Alpha[layer_counter],Mropt_Beta[layer_cou
nter]);
str = static_cast<int>(Monte_Mreq_Mropt);
if (str != 0)
{do
{
MonteCarlo_Mreq_Mropt = gsl_rng_uniform_pos(Rand_NUM_Gen);
Monte_Mreq_Mropt =
gsl_cdf_beta_Pinv(MonteCarlo_Mreq_Mropt,Mropt_Alpha[layer_counter],Mropt_Beta[layer_cou
nter]);
str = static_cast<int>(Monte_Mreq_Mropt);
} while (str != 0);
}
(double)Monte_Mreq_Mropt = (Mropt_Min[layer_counter] + (Monte_Mreq_Mropt *
(Mropt_Max[layer_counter] - Mropt_Min[layer_counter])));
Mreq_mean1 = log(Monte_Mreq_Mropt*Monte_Mreq_Fenv)/log(10.0);//log change
summation_Mreq += Mreq_mean1;
```

```
Monte_Mreq[layer_counter][i] = Mreq_mean1;
}
Mreq_mean1 = summation_Mreq/endloop;
summation_Mreq_var = 0.0;
for( int w=0; w<endloop; w++)
{
Mreq_var1 = pow((Monte_Mreq[layer_counter][w]- Mreq_mean1),2.0);
summation_Mreq_var += Mreq_var1;
}
Mreq_var1 = summation_Mreq_var/endloop; Mreq_stdev1 = pow(Mreq_var1,0.5); Mreq_min1 =
10000000.0;Mreq_max1 = -1.0; summation_Mreq_skew = 0.0; summation_Mreq_kurt = 0.0;
for(int f=0; f<endloop;f++)
{Mreq_skew1 = pow(((Monte_Mreq[layer_counter][f]-Mreq_mean1)/Mreq_stdev1),3.0);
summation_Mreq_skew += Mreq_skew1;
Mreq_kurt1 = pow(((Monte_Mreq[layer_counter][f]-Mreq_mean1)/Mreq_stdev1),4.0);
summation_Mreq_kurt += Mreq_kurt1;
if(Mreq_min1 > Monte_Mreq[layer_counter][f])
Mreq_min1 = Monte_Mreq[layer_counter][f];
if(Mreq_max1 < Monte_Mreq[layer_counter][f])
Mreq_max1 = Monte_Mreq[layer_counter][f];}
Mreq_skew1 = (1/endloop)*summation_Mreq_skew;
Mreq_kurt1 = ((1/endloop)*summation_Mreq_kurt)-3.0;
Mreq_alpha1 = ((Mreq_mean1-Mreq_min1)/(Mreq_max1-Mreq_min1))*(((Mreq_mean1-
Mreq_min1)*(Mreq_max1-Mreq_mean1)/Mreq_var1)-1);
Mreq_beta1 = ((Mreq_max1-Mreq_mean1)/(Mreq_mean1-Mreq_min1))*Mreq_alpha1;
//Resilient Modulus at Equilibrium Storage
Mreq_Mean[layer_counter] = Mreq_mean1; Mreq_Var[layer_counter] =
Mreq_var1;Mreq_Stdev[layer_counter] = Mreq_stdev1;Mreq_Skew[layer_counter] =
```

```
Mreq_skew1;Mreq_Kurt[layer_counter] = Mreq_kurt1;Mreq_Min[layer_counter] =
Mreq_min1;Mreq_Max[layer_counter] = Mreq_max1; Mreq_Alpha[layer_counter] =
Mreq_alpha1; Mreq_Beta[layer_counter] = Mreq_beta1;
cout << endl << "Finish with Layer " << layer_counter + 1<< endl;
if (Num_layer-1-layer_counter > 1)
cout << Num_layer-1-layer_counter << " layers remaining" << endl;
else if((Num_layer-1-layer_counter)==0)
cout << "No remaining layers" << endl;
else
cout <<Num_layer-1-layer_counter << " layer remaining" << endl;}
if(Output_Sim == true)
{//Py Output
ofstream output_P;
output_P.open("P_MonteCarlo_Simulation.txt");
for( int w=0; w<endloop; w++){output_P << MonteCarloP[w] << endl;}
output_P.close();
//HY output
ofstream output_T;
output_T.open("Temperature_MonteCarlo_Simulation.txt");
for( int w=0; w<endloop; w++){output_T << MonteCarloT[w] << endl;}
output_T.close();
//PE Output
ofstream output_PE;
output_PE.open("PE_MonteCarlo_Simulation.txt");
for( int w=0; w<endloop; w++){output_PE << MonteCarloPE[w] << endl;}
output_PE.close();
//Output TMI Data
ofstream output_TMI;
```

```
output_TMI.open("TMI_Monte_Carlo_Simulation.txt");
for ( int i=0; i < endloop; i++){for(int j =0; j<3; j++){output_TMI << TMIStorage[j][i] << "\t";}
output_TMI << endl;}
output_TMI.close();
//Output of Matric Suction
ofstream output_Suction;
output_Suction.open("Suction_Monte_Carlo.txt");
for( int w=0; w<endloop; w++)
{for(int layer =0;layer<Num_layer;layer++){output_Suction << MonteCarloSuction[layer][w] <<
"\t";}output_Suction << endl;}
output_Suction.close();
//Ouput of Resilient Modulus at Equilibrium
ofstream MREQ;
MREQ.open("Equilibrium_Modulus.csv");
for(int i=0; i<endloop; i++)
{for(int f=0; f<Num_layer; f++){MREQ << Monte_Mreq[f][i] << ",";}MREQ << endl;}
MREQ.close();
ofstream CBRStuff;
CBRStuff.open("CBR_Values.txt");
for(int i=0; i<endloop; i++){for(int j=0; j<Num_layer; j++){CBRStuff << CBRStorage[j][i] <<
"\t" << "\t" << Model_Storage[j][i] << "\t";
}CBRStuff << endl;}}}
tEnd = clock();//Clocks at end of the program
double EndTime = ((double)(tEnd-tStart))/((double)(CLOCKS_PER_SEC));//Calculates amount
of Time from clocks
ofstream output_Final;
output_Final.open("Mean and Variances.csv");
if(Check == 1)
```

```
output_Final << "Rosenblueth 2-Point Solution" << endl;
else if(Check ==2)
output_Final << "Rosenblueth 3-Point Solution" << endl;
else if(Check ==3)
{output_Final << "Monte Carlo Solution" << endl;
output_Final << "Number of Simulations " << "," << Simulations_T << endl;
output_Final << "Location," << location << endl;
output_Final << "1-40D Constraints for TMI" << "," << TMIconstraints1 << endl;
output_Final << "Time Required" << "," << EndTime << ",Seconds" << endl;
output_Final << "Variable" << "," << "Mean" << "," << "Variance" << "," << "Std Dev" << ","
<< "Skewness" << "," << "Kurtosis" << "," << "Minimum" << "," << "Maximum" << "," <<
"Shape Alpha" << "," << "Shape Beta" << endl;
output_Final << "Precipitation" << "," << P_mean << "," << P_var << "," << P_stdev << "," <<
P_skew << "," << P_kurt << "," << P_min << "," << P_max  << "," << P_alpha << "," << P_beta
<< endl;
output_Final << "Annual Heat Index" << "," << Hy_mean << "," << Hy_var << "," << Hy_stdev
<< "," <<  Hy_skew << "," << Hy_kurt << "," << Hy_min << "," << Hy_max << "," << Hy_alpha
<< "," << Hy_beta << endl;
output_Final << "Potential Evapotranspiration" << "," << PE_mean << "," << PE_var << "," <<
PE_stdev << "," << PE_skew << "," << PE_kurt << "," << PE_min << "," << PE_max  << "," <<
PE_alpha << "," << PE_beta << endl;
output_Final << "Thornthwaite Moisture Index" << "," << TMI_mean << "," << TMI_var << ","
<< TMI_stdev << "," << TMI_skew << "," << TMI_kurt << "," << TMI_min << "," << TMI_max
<< "," << TMI_alpha << "," << TMI_beta << endl << endl;
for (int i=0; i<Num_layer; i++)//Outputs Each Soil Layer Information
{output_Final << "Layer Number" << "," << i+1 << endl;
output_Final << "Layer Description" << "," << Layer_Type_a[i] << endl;
output_Final << "Compacted Layer" << "," << Layer_Compaction_a[i] << endl;
```

```
output_Final << "Soil Layer Name" << "," << Names[i]<< endl;
output_Final << "Level of Analysis" << "," << Level_a[i] << endl;
output_Final << "Soil Properties" << "," << "Mean" << "," << "Variance" << "," << "Std Dev" <<
"," << "Skewness" << "," << "Kurtosis" << "," << "Minimum" << "," << "Maximum"  << "," <<
"Shape Alpha" << "," << "Shape Beta" << endl;
if((wPI_Max[i]<2.0)&&(level[i]==false))
{output_Final << "Percent Passing_#200 (%)"  << "," << P200_M[i] << "," << P200_V[i] << ","
<< P200_S[i] << "," << "N/A" << "," << "N/A" << "," << P200_Min[i] << "," << P200_Max[i]
<< "," << P200_Alpha[i] << "," << P200_Beta[i] << endl;
output_Final << "Plasticity Index (%)" << "," << PI_M[i] << "," << PI_V[i] << "," << PI_S[i] <<
"," << "N/A" << "," << "N/A" << "," << PI_Min[i] << "," << PI_Max[i] << "," << PI_Alpha[i] <<
"," << PI_Beta[i] << endl;
output_Final << "wPI parameter" << "," << wPI_M[i] << "," << wPI_V[i] << "," << wPI_S[i] <<
"," << "N/A" << "," << "N/A" << "," << wPI_Min[i] << "," << wPI_Max[i] << "," <<
wPI_Alpha[i] << "," << wPI_Beta[i] << endl;
output_Final << "Optimum Moisture Content (%)" << "," << wopt_M[i] << "," << wopt_V[i] <<
"," << wopt_S[i] << "," << wopt_Skew[i] << "," << wopt_Kurt[i] << "," << wopt_Min[i] << ","
<< wopt_Max[i] << "," << wopt_Alpha[i] << "," << wopt_Beta[i] << endl;
output_Final << "Maximum Dry Density (pcf)" << "," << gamma_dry_M[i] << "," <<
gamma_dry_V[i] << "," << gamma_dry_S[i] << "," << gamma_dry_Skew[i] << "," <<
gamma_dry_Kurt[i] << "," << gamma_dry_Min[i] << "," << gamma_dry_Max[i] << "," <<
gamma_dry_Alpha[i] << "," << gamma_dry_Beta[i] << endl;
output_Final << "Matric Suction (kPa)" << "," << Suction_Mean[i] << "," << Suction_Variance[i]
<< "," << Suction_Stdev[i] << "," << Suction_Skew[i] << "," << Suction_Kurt[i] << "," <<
Suction_Minimum[i] << "," << Suction_Maximum[i] << "," << Suction_Alpha[i] << ","
<<Suction_Beta[i] << endl;
output_Final << "Volumetric Water Content" << "," << Theata_WM[i] << "," << Theata_WS[i]
<< "," << Theata_WV[i] << "," << Theata_WSkew[i] << "," << Theata_WKurt[i] << "," <<
```

```
Theata_WMin[i] << "," << Theata_WMax[i] << "," << Theata_WAlpha[i] << "," <<
Theata_WBeta[i] << endl;
output_Final << "Sat'd Volumetric Water Content" << "," << Theata_SM[i] << "," <<
Theata_SS[i] << "," << Theata_SV[i] << "," << Theata_SSkew[i] << "," << Theata_SKurt[i] <<
"," << Theata_SMin[i] << "," << Theata_SMax[i] << "," << Theata_SAlpha[i] << "," <<
Theata_SBeta[i] << endl;
output_Final << "Degree of Saturation (%)" << "," << degree_sat_mean[i] << "," <<
degree_sat_var[i] << "," << degree_sat_stdev[i] << "," << degree_sat_skew[i] << "," <<
degree_sat_kurt[i] << "," << degree_sat_Min[i] << "," << degree_sat_Max[i] << "," <<
degree_sat_Alpha[i] << "," <<degree_sat_Beta[i] << endl;
output_Final << "Optimum Saturation (%)" << "," << opt_sat_mean[i] << "," << opt_sat_var[i]
<< "," << opt_sat_stdev[i] << "," << opt_sat_skew[i] << "," << opt_sat_kurt[i] << "," <<
opt_sat_min[i] << "," << opt_sat_max[i] << "," << opt_sat_Alpha[i] << "," <<opt_sat_Beta[i] <<
endl;
output_Final << "Environmental Factor" << "," << Fenv_Mean[i] << "," << Fenv_Var[i] << ","
<< Fenv_Stdev[i] << "," << Fenv_Skew[i] << "," << Fenv_Kurt[i] << "," << Fenv_Min[i] << ","
<< Fenv_Max[i] << "," << Fenv_Alpha[i] << "," <<Fenv_Beta[i] << endl;
output_Final << "California Bearing Ratio (%)" << "," << CBR_M[i] << "," << CBR_V[i] << ","
<< CBR_S[i] << "," << CBR_Skew[i] << "," << CBR_Kurt[i] << "," << CBR_Min[i] << "," <<
CBR_Max[i] << "," << CBR_Alpha[i] << "," << CBR_Beta[i] << endl;
output_Final << "Modulus at Optimum(Psi)" << "," << Mropt_Mean[i] << "," << Mropt_Var[i]
<< "," << Mropt_Stdev[i] << "," << Mropt_Skew[i] << "," << Mropt_Kurt[i] << "," <<
Mropt_Min[i] << "," << Mropt_Max[i] << "," << Mropt_Alpha[i] << "," <<Mropt_Beta[i] <<
endl;
output_Final << "Modulus at Equilibrium_(Psi)" << "," << Mreq_Mean[i] << "," << Mreq_Var[i]
<< "," << Mreq_Stdev[i] << "," << Mreq_Skew[i] << "," << Mreq_Kurt[i] << "," << Mreq_Min[i]
<< "," << Mreq_Max[i] << "," << Mreq_Alpha[i] << "," <<Mreq_Beta[i] << endl << endl << endl
<< endl;}
```

```
else if((wPI_Max[i]>2.0)&&(level[i]==false)|| ((level[i]==true)&&(Level_a[i]=="Level_1a")))
{output_Final << "Percent Passing #200 (%)"  << "," << P200_M[i] << "," << P200_V[i] << ","
<< P200_S[i] << "," << "N/A" << "," << "N/A" << "," << P200_Min[i] << "," << P200_Max[i]
<< "," << P200_Alpha[i] << "," << P200_Beta[i] << endl;
output_Final << "Plasticity Index (%)" << "," << PI_M[i] << "," << PI_V[i] << "," << PI_S[i] <<
"," << "N/A" << "," << "N/A" << "," << PI_Min[i] << "," << PI_Max[i] << "," << PI_Alpha[i] <<
"," << PI_Beta[i] << endl;
output_Final << "wPI parameter" << "," << wPI_M[i] << "," << wPI_V[i] << "," << wPI_S[i] <<
"," << "N/A" << "," << "N/A" << "," << wPI_Min[i] << "," << wPI_Max[i] << "," <<
wPI_Alpha[i] << "," << wPI_Beta[i] << endl;
output_Final << "Optimum Moisture Content (%)" << "," << wopt_M[i] << "," << wopt_V[i] <<
"," << wopt_S[i] << "," << wopt_Skew[i] << "," << wopt_Kurt[i] << "," << wopt_Min[i] << ","
<< wopt_Max[i] << "," << wopt_Alpha[i] << "," << wopt_Beta[i] << endl;
output_Final << "Maximum Dry Density (pcf)" << "," << gamma_dry_M[i] << "," <<
gamma_dry_V[i] << "," << gamma_dry_S[i] << "," << gamma_dry_Skew[i] << "," <<
gamma_dry_Kurt[i] << "," << gamma_dry_Min[i] << "," << gamma_dry_Max[i] << "," <<
gamma_dry_Alpha[i] << "," << gamma_dry_Beta[i] << endl;
output_Final << "Matric Suction (kPa)" << "," << Suction_Mean[i] << "," << Suction_Variance[i]
<< "," << Suction_Stdev[i] << "," << Suction_Skew[i] << "," << Suction_Kurt[i] << "," <<
Suction_Minimum[i] << "," << Suction_Maximum[i] << "," << Suction_Alpha[i] << ","
<<Suction_Beta[i] << endl;
output_Final << "SWCC Fitting Parameter A" << "," << SWCC_AM[i] << "," << SWCC_AV[i]
<< "," << SWCC_AS[i] << "," << SWCC_ASkew[i] << "," << SWCC_AKurt[i] << "," <<
SWCC_AMin[i] << "," << SWCC_AMax[i] << "," << SWCC_AAlpha[i] << "," <<
SWCC_ABeta[i] << endl;
output_Final << "SWCC Fitting Parameter B" << "," << SWCC_BM[i] << "," << SWCC_BV[i]
<< "," << SWCC_BS[i] << "," << SWCC_BSkew[i] << "," << SWCC_BKurt[i] << "," <<
```

```
SWCC_BMin[i] << "," << SWCC_BMax[i] << "," << SWCC_BAlpha[i] << "," <<
SWCC_BBeta[i] << endl;
output_Final << "SWCC Fitting Parameter C" << "," << SWCC_CM[i] << "," << SWCC_CV[i]
<< "," << SWCC_CS[i] << "," << SWCC_CSkew[i] << "," << SWCC_CKurt[i] << "," <<
SWCC_CMin[i] << "," << SWCC_CMax[i] << "," << SWCC_CAlpha[i] << "," <<
SWCC_CBeta[i] << endl;
output_Final << "Volumetric Water Content" << "," << Theata_WM[i] << "," << Theata_WV[i]
<< "," << Theata_WS[i] << "," << Theata_WSkew[i] << "," << Theata_WKurt[i] << "," <<
Theata_WMin[i] << "," << Theata_WMax[i] << "," << Theata_WAlpha[i] << "," <<
Theata_WBeta[i] << endl;
output_Final << "Sat'd_Volumetric Water Content" << "," << Theata_SM[i] << "," <<
Theata_SV[i] << "," << Theata_SS[i] << "," << Theata_SSkew[i] << "," << Theata_SKurt[i] <<
"," << Theata_SMin[i] << "," << Theata_SMax[i] << "," << Theata_SAlpha[i] << "," <<
Theata_SBeta[i] << endl;
output_Final << "Degree of Saturation (%)" << "," << degree_sat_mean[i] << "," <<
degree_sat_var[i] << "," << degree_sat_stdev[i] << "," << degree_sat_skew[i] << "," <<
degree_sat_kurt[i] << "," << degree_sat_Min[i] << "," << degree_sat_Max[i] << "," <<
degree_sat_Alpha[i] << "," <<degree_sat_Beta[i] << endl;
output_Final << "Optimum Saturation (%)" << "," << opt_sat_mean[i] << "," << opt_sat_var[i]
<< "," << opt_sat_stdev[i] << "," << opt_sat_skew[i] << "," << opt_sat_kurt[i] << "," <<
opt_sat_min[i] << "," << opt_sat_max[i] << "," << opt_sat_Alpha[i] << "," <<opt_sat_Beta[i] <<
endl;
output_Final << "Environmental Factor" << "," << Fenv_Mean[i] << "," << Fenv_Var[i] << ","
<< Fenv_Stdev[i] << "," << Fenv_Skew[i] << "," << Fenv_Kurt[i] << "," << Fenv_Min[i] << ","
<< Fenv_Max[i] << "," << Fenv_Alpha[i] << "," <<Fenv_Beta[i] << endl;
output_Final << "California Bearing Ratio (%)" << "," << CBR_M[i] << "," << CBR_V[i] << ","
<< CBR_S[i] << "," << CBR_Skew[i] << "," << CBR_Kurt[i] << "," << CBR_Min[i] << "," <<
CBR_Max[i] << "," << CBR_Alpha[i] << "," << CBR_Beta[i] << endl;
```

```
output_Final << "Modulus at Optimum (Psi)" << "," << Mropt_Mean[i] << "," << Mropt_Var[i]
<< "," << Mropt_Stdev[i] << "," << Mropt_Skew[i] << "," << Mropt_Kurt[i] << "," <<
Mropt_Min[i] << "," << Mropt_Max[i] << "," << Mropt_Alpha[i] << "," <<Mropt_Beta[i] <<
endl;
output_Final << "Modulus at Equilibrium (Psi)" << "," << Mreq_Mean[i] << "," << Mreq_Var[i]
<< "," << Mreq_Stdev[i] << "," << Mreq_Skew[i] << "," << Mreq_Kurt[i] << "," << Mreq_Min[i]
<< "," << Mreq_Max[i] << "," << Mreq_Alpha[i] << "," <<Mreq_Beta[i] << endl << endl;}
else if((wPI_M[i]>=0.0)&&(level[i]==true)&&(Level_a[i]=="Level_1"))
{output_Final << "Percent_Passing_#200_(%)"  << "," << P200_M[i] << "," << P200_V[i] << ","
<< P200_S[i] << "," << "N/A" << "," << "N/A" << "," << P200_Min[i] << "," << P200_Max[i]
<< "," << P200_Alpha[i] << "," << P200_Beta[i] << endl;
output_Final << "Plasticity_Index_(%)" << "," << PI_M[i] << "," << PI_V[i] << "," << PI_S[i] <<
"," << "N/A" << "," << "N/A" << "," << PI_Min[i] << "," << PI_Max[i] << "," << PI_Alpha[i] <<
"," << PI_Beta[i] << endl;
output_Final << "wPI_parameter" << "," << wPI_M[i] << "," << wPI_V[i] << "," << wPI_S[i] <<
"," << "N/A" << "," << "N/A" << "," << wPI_Min[i] << "," << wPI_Max[i] << "," <<
wPI_Alpha[i] << "," << wPI_Beta[i] << endl;
output_Final << "Optimum Moisture Content (%)" << "," << wopt_M[i] << "," << wopt_V[i] <<
"," << wopt_S[i] << "," << "N/A" << "," << "N/A" << "," << wopt_Min[i] << "," << wopt_Max[i]
<< "," << wopt_Alpha[i] << "," << wopt_Beta[i] << endl;
output_Final << "Maximum Dry Density (pcf)" << "," << gamma_dry_M[i] << "," <<
gamma_dry_V[i] << "," << gamma_dry_S[i] << "," << "N/A" << "," << "N/A" << "," <<
gamma_dry_Min[i] << "," << gamma_dry_Max[i] << "," << gamma_dry_Alpha[i] << "," <<
gamma_dry_Beta[i] << endl;
output_Final << "Matric Suction (kPa)" << "," << Suction_Mean[i] << "," << Suction_Variance[i]
<< "," << Suction_Stdev[i] << "," << Suction_Skew[i] << "," << Suction_Kurt[i] << "," <<
Suction_Minimum[i] << "," << Suction_Maximum[i] << "," << Suction_Alpha[i] << ","
<<Suction_Beta[i] << endl;
```

```
output_Final << "SWCC Fitting Parameter A" << "," << SWCC_AM[i] << "," << SWCC_AV[i]
<< "," << SWCC_AS[i] << "," << "N/A" << "," << "N/A" << "," << SWCC_AMin[i] << "," <<
SWCC_AMax[i] << "," << SWCC_AAlpha[i] << "," << SWCC_ABeta[i] << endl;
output_Final << "SWCC Fitting Parameter B" << "," << SWCC_BM[i] << "," << SWCC_BV[i]
<< "," << SWCC_BS[i] << "," << "N/A" << "," << "N/A" << "," << SWCC_BMin[i] << "," <<
SWCC_BMax[i] << "," << SWCC_BAlpha[i] << "," << SWCC_BBeta[i] << endl;
output_Final << "SWCC Fitting Parameter C" << "," << SWCC_CM[i] << "," << SWCC_CV[i]
<< "," << SWCC_CS[i] << "," << "N/A" << "," << "N/A" << "," << SWCC_CMin[i] << "," <<
SWCC_CMax[i] << "," << SWCC_CAlpha[i] << "," << SWCC_CBeta[i] << endl;
output_Final << "Volumetric Water Content_(%)" << "," << Theata_WM[i] << "," <<
Theata_WV[i] << "," << Theata_WS[i] << "," << Theata_WSkew[i] << "," << Theata_WKurt[i]
<< "," << Theata_WMin[i] << "," << Theata_WMax[i] << "," << Theata_WAlpha[i] << "," <<
Theata_WBeta[i] << endl;
output_Final << "Sat'd_Volumetric Water Content_(%)" << "," << Theata_SM[i] << "," <<
Theata_SV[i] << "," << Theata_SS[i] << "," << Theata_SSkew[i] << "," << Theata_SKurt[i] <<
"," << Theata_SMin[i] << "," << Theata_SMax[i] << "," << Theata_SAlpha[i] << "," <<
Theata_SBeta[i] << endl;
output_Final << "Degree of Saturation (%)" << "," << degree_sat_mean[i] << "," <<
degree_sat_var[i] << "," << degree_sat_stdev[i] << "," << degree_sat_skew[i] << "," <<
degree_sat_kurt[i] << "," << degree_sat_Min[i] << "," << degree_sat_Max[i] << "," <<
degree_sat_Alpha[i] << "," <<degree_sat_Beta[i] << endl;
output_Final << "Optimum Saturation (%)" << "," << opt_sat_mean[i] << "," << opt_sat_var[i]
<< "," << opt_sat_stdev[i] << "," << opt_sat_skew[i] << "," << opt_sat_kurt[i] << "," <<
opt_sat_min[i] << "," << opt_sat_max[i] << "," << opt_sat_Alpha[i] << "," <<opt_sat_Beta[i] <<
endl;
output_Final << "Environmental Factor" << "," << Fenv_Mean[i] << "," << Fenv_Var[i] << ","
<< Fenv_Stdev[i] << "," << Fenv_Skew[i] << "," << Fenv_Kurt[i] << "," << Fenv_Min[i] << ","
<< Fenv_Max[i] << "," << Fenv_Alpha[i] << "," <<Fenv_Beta[i] << endl;
```

```
output_Final << "California Bearing Ratio (%)" << "," << "CBR is not required since Modulus at
Optimum was given." << endl;
output_Final << "Modulus at Optimum (Psi)" << "," << Mropt_Mean[i] << "," << Mropt_Var[i]
<< "," << Mropt_Stdev[i] << "," << "N/A" << "," << "N/A" << "," << Mropt_Min[i] << "," <<
Mropt_Max[i] << "," << Mropt_Alpha[i] << "," <<Mropt_Beta[i] << endl;
output_Final << "Modulus at Equilibrium (Psi)" << "," << Mreq_Mean[i] << "," << Mreq_Var[i]
<< "," << Mreq_Stdev[i] << "," << Mreq_Skew[i] << "," << Mreq_Kurt[i] << "," << Mreq_Min[i]
<< "," << Mreq_Max[i] << "," << Mreq_Alpha[i] << "," <<Mreq_Beta[i] << endl << endl;}}}
else
output_Final << left << "Taylor Series Solution" << endl;
if((Check == 1)||(Check == 2)||(Check == 4))
{output_Final << "Location," << location << endl;
output_Final << "1-40D Constraints for TMI," << TMIconstraints1 << endl;
output_Final << "Time_Required" << "," << EndTime << ",Seconds" << endl;
output_Final << "Variable" << "," << "Mean" << "," << "Variance" << "," << "Std_Dev" << ","
<< "Skewness" << "," << "Kurtosis" << "," << "Minimum" << "," << "Maximum" <<  endl;
output_Final << "Precipitation" << "," << P_mean << "," << P_var << "," << P_stdev << "," <<
P_skew << "," << P_kurt << "," << P_min << "," << P_max  << endl;
output_Final << "Annual Heat Index" << "," << Hy_mean << "," << Hy_var << "," << Hy_stdev
<< "," <<  Hy_skew << "," << Hy_kurt << "," << Hy_min << "," << Hy_max << endl;
output_Final << "Potential Evapotranspiration"<< "," << PE_mean << "," << PE_var << "," <<
PE_stdev << "," << PE_skew << "," << PE_kurt << "," << PE_min << "," << PE_max << endl;
output_Final << "Thornthwaite Moisture Index" << "," << TMI_mean << "," << TMI_var << ","
<< TMI_stdev << "," << TMI_skew << "," << TMI_kurt << "," << TMI_min << "," << TMI_max
<< endl << endl;
for (int i=0; i<Num_layer; i++)//Outputs Each Soil Layer Matric Suction Information
{output_Final << "Layer Number" << "," << i+1 << endl;
output_Final << "Layer Description" << "," << Layer_Type_a[i] << endl;
```

```
output_Final << "Compacted Layer" << "," << Layer_Compaction_a[i] << endl;
output_Final << "Soil Layer Name" << "," << Names[i]<< endl;
output_Final << "Level of Analysis" << "," << Level_a[i] << endl;
output_Final << "Soil Properties" << "," << "Mean" << "," << "Variance" << "," << "Std_Dev"
<< "," << "Skewness" << "," << "Kurtosis" << "," << "Minimum" << "," << "Maximum"  <<
endl;
if((wPI_Max[i]<2.0)&&(level[i]==false))
{output_Final << "Percent Passing #200 (%)"  << "," << P200_M[i] << "," << P200_V[i] << ","
<< P200_S[i] << "," << "N/A" << "," << "N/A" << "," << P200_Min[i] << "," << P200_Max[i]
<< endl;
output_Final << "Plasticity Index (%)" << "," << PI_M[i] << "," << PI_V[i] << "," << PI_S[i] <<
"," << "N/A" << "," << "N/A" << "," << PI_Min[i] << "," << PI_Max[i] << endl;
output_Final << "wPI parameter" << "," << wPI_M[i] << "," << wPI_V[i] << "," << wPI_S[i] <<
"," << "N/A" << "," << "N/A" << "," << wPI_Min[i] << "," << wPI_Max[i] << endl;
output_Final << "Optimum Moisture Content (%)" << "," << wopt_M[i] << "," << wopt_V[i] <<
"," << wopt_S[i] << "," << wopt_Skew[i] << "," << wopt_Kurt[i] << "," << wopt_Min[i] << ","
<< wopt_Max[i] << endl;
output_Final << "Maximum Dry Density (pcf)" << "," << gamma_dry_M[i] << "," <<
gamma_dry_V[i] << "," << gamma_dry_S[i] << "," << gamma_dry_Skew[i] << "," <<
gamma_dry_Kurt[i] << "," << gamma_dry_Min[i] << "," << gamma_dry_Max[i] << endl;
output_Final << "Matric Suction (kPa)" << "," << Suction_Mean[i] << "," << Suction_Variance[i]
<< "," << Suction_Stdev[i] << "," << Suction_Skew[i] << "," << Suction_Kurt[i] << "," <<
Suction_Minimum[i] << "," << Suction_Maximum[i] << endl;
output_Final << "Volumetric Water Content" << "," << Theata_WM[i] << "," << Theata_WS[i]
<< "," << Theata_WV[i] << "," << Theata_WSkew[i] << "," << Theata_WKurt[i] << "," <<
Theata_WMin[i] << "," << Theata_WMax[i] << endl;
```

```
output_Final << "Sat'd_Volumetric Water Content" << "," << Theata_SM[i] << "," <<
Theata_SS[i] << "," << Theata_SV[i] << "," << Theata_SSkew[i] << "," << Theata_SKurt[i] <<
"," << Theata_SMin[i] << "," << Theata_SMax[i] << endl;
output_Final << "Degree of Saturation (%)" << "," << degree_sat_mean[i] << "," <<
degree_sat_var[i] << "," << degree_sat_stdev[i] << "," << degree_sat_skew[i] << "," <<
degree_sat_kurt[i] << "," << degree_sat_Min[i] << "," << degree_sat_Max[i] << endl;
output_Final << "Optimum Saturation (%)" << "," << opt_sat_mean[i] << "," << opt_sat_var[i]
<< "," << opt_sat_stdev[i] << "," << opt_sat_skew[i] << "," << opt_sat_kurt[i] << "," <<
opt_sat_min[i] << "," << opt_sat_max[i] << endl;
output_Final << "Environmental Factor" << "," << Fenv_Mean[i] << "," << Fenv_Var[i] << ","
<< Fenv_Stdev[i] << "," << Fenv_Skew[i] << "," << Fenv_Kurt[i] << "," << Fenv_Min[i] << ","
<< Fenv_Max[i] << endl;
output_Final << "California Bearing Ratio (%)" << "," << CBR_M[i] << "," << CBR_V[i] << ","
<< CBR_S[i] << "," << CBR_Skew[i] << "," << CBR_Kurt[i] << "," << CBR_Min[i] << "," <<
CBR_Max[i] << endl;
output_Final << "Modulus at Optimum (Psi)" << "," << Mropt_Mean[i] << "," << Mropt_Var[i]
<< "," << Mropt_Stdev[i] << "," << Mropt_Skew[i] << "," << Mropt_Kurt[i] << "," <<
Mropt_Min[i] << "," << Mropt_Max[i] << endl;
output_Final << "Modulus at Equilibrium (Psi)" << "," << Mreq_Mean[i] << "," << Mreq_Var[i]
<< "," << Mreq_Stdev[i] << "," << Mreq_Skew[i] << "," << Mreq_Kurt[i] << "," << Mreq_Min[i]
<< "," << Mreq_Max[i] << endl << endl << endl << endl;}
else if((wPI_Max[i]>2.0)&&(level[i]==false)|| ((level[i]==true)&&(Level_a[i]=="Level_1a")))
{output_Final << "Percent Passing #200 (%)"  << "," << P200_M[i] << "," << P200_V[i] << ","
<< P200_S[i] << "," << "N/A" << "," << "N/A" << "," << P200_Min[i] << "," << P200_Max[i]
<< endl;
output_Final << "Plasticity Index (%)" << "," << PI_M[i] << "," << PI_V[i] << "," << PI_S[i] <<
"," << "N/A" << "," << "N/A" << "," << PI_Min[i] << "," << PI_Max[i] << endl;
```

```
output_Final << "wPI_parameter" << "," << wPI_M[i] << "," << wPI_V[i] << "," << wPI_S[i] <<
"," << "N/A" << "," << "N/A" << "," << wPI_Min[i] << "," << wPI_Max[i] << endl;
output_Final << "Optimum Moisture Content (%)" << "," << wopt_M[i] << "," << wopt_V[i] <<
"," << wopt_S[i] << "," << wopt_Skew[i] << "," << wopt_Kurt[i] << "," << wopt_Min[i] << ","
<< wopt_Max[i] << endl;
output_Final << "Maximum Dry Density (pcf)" << "," << gamma_dry_M[i] << "," <<
gamma_dry_V[i] << "," << gamma_dry_S[i] << "," << gamma_dry_Skew[i] << "," <<
gamma_dry_Kurt[i] << "," << gamma_dry_Min[i] << "," << gamma_dry_Max[i] << endl;
output_Final << "Matric Suction (kPa)" << "," << Suction_Mean[i] << "," << Suction_Variance[i]
<< "," << Suction_Stdev[i] << "," << Suction_Skew[i] << "," << Suction_Kurt[i] << "," <<
Suction_Minimum[i] << "," << Suction_Maximum[i] << endl;
output_Final << "SWCC Fitting Parameter A" << "," << SWCC_AM[i] << "," << SWCC_AV[i]
<< "," << SWCC_AS[i] << "," << SWCC_ASkew[i] << "," << SWCC_AKurt[i] << "," <<
SWCC_AMin[i] << "," << SWCC_AMax[i] << endl;
output_Final << "SWCC Fitting Parameter B" << "," << SWCC_BM[i] << "," << SWCC_BV[i]
<< "," << SWCC_BS[i] << "," << SWCC_BSkew[i] << "," << SWCC_BKurt[i] << "," <<
SWCC_BMin[i] << "," << SWCC_BMax[i] << endl;
output_Final << "SWCC Fitting Parameter C" << "," << SWCC_CM[i] << "," << SWCC_CV[i]
<< "," << SWCC_CS[i] << "," << SWCC_CSkew[i] << "," << SWCC_CKurt[i] << "," <<
SWCC_CMin[i] << "," << SWCC_CMax[i] << endl;
output_Final << "Volumetric Water Content" << "," << Theata_WM[i] << "," << Theata_WV[i]
<< "," << Theata_WS[i] << "," << Theata_WSkew[i] << "," << Theata_WKurt[i] << "," <<
Theata_WMin[i] << "," << Theata_WMax[i] << endl;
output_Final << "Sat'd Volumetric Water Content" << "," << Theata_SM[i] << "," <<
Theata_SV[i] << "," << Theata_SS[i] << "," << Theata_SSkew[i] << "," << Theata_SKurt[i] <<
"," << Theata_SMin[i] << "," << Theata_SMax[i] << endl;
```

```
output_Final << "Degree of Saturation (%)" << "," << degree_sat_mean[i] << "," <<
degree_sat_var[i] << "," << degree_sat_stdev[i] << "," << degree_sat_skew[i] << "," <<
degree_sat_kurt[i] << "," << degree_sat_Min[i] << "," << degree_sat_Max[i] << endl;
output_Final << "Optimum Saturation (%)" << "," << opt_sat_mean[i] << "," << opt_sat_var[i]
<< "," << opt_sat_stdev[i] << "," << opt_sat_skew[i] << "," << opt_sat_kurt[i] << "," <<
opt_sat_min[i] << "," << opt_sat_max[i] << endl;
output_Final << "Environmental Factor" << "," << Fenv_Mean[i] << "," << Fenv_Var[i] << ","
<< Fenv_Stdev[i] << "," << Fenv_Skew[i] << "," << Fenv_Kurt[i] << "," << Fenv_Min[i] << ","
<< Fenv_Max[i] << endl;
output_Final << "California Bearing Ratio (%)" << "," << CBR_M[i] << "," << CBR_V[i] << ","
<< CBR_S[i] << "," << CBR_Skew[i] << "," << CBR_Kurt[i] << "," << CBR_Min[i] << "," <<
CBR_Max[i] << endl;
output_Final << "Modulus at Optimum (Psi)" << "," << Mropt_Mean[i] << "," << Mropt_Var[i]
<< "," << Mropt_Stdev[i] << "," << Mropt_Skew[i] << "," << Mropt_Kurt[i] << "," <<
Mropt_Min[i] << "," << Mropt_Max[i] << endl;
output_Final << "Modulus at Equilibrium (Psi)" << "," << Mreq_Mean[i] << "," << Mreq_Var[i]
<< "," << Mreq_Stdev[i] << "," << Mreq_Skew[i] << "," << Mreq_Kurt[i] << "," << Mreq_Min[i]
<< "," << Mreq_Max[i] << endl << endl;}
else if((wPI_M[i]>=0.0)&&(level[i]==true)&&(Level_a[i]=="Level_1"))
{output_Final << "Percent Passing #200 (%)"  << "," << P200_M[i] << "," << P200_V[i] << ","
<< P200_S[i] << "," << "N/A" << "," << "N/A" << "," << P200_Min[i] << "," << P200_Max[i]
<< endl;
output_Final << "Plasticity Index (%)" << "," << PI_M[i] << "," << PI_V[i] << "," << PI_S[i] <<
"," << "N/A" << "," << "N/A" << "," << PI_Min[i] << "," << PI_Max[i] << endl;
output_Final << "wPI parameter" << "," << wPI_M[i] << "," << wPI_V[i] << "," << wPI_S[i] <<
"," << "N/A" << "," << "N/A" << "," << wPI_Min[i] << "," << wPI_Max[i] << endl;
```

```
output_Final << "Optimum Moisture Content (%)" << "," << wopt_M[i] << "," << wopt_V[i] << "," << wopt_S[i] << "," << "N/A" << "," << "N/A" << "," << wopt_Min[i] << "," << wopt_Max[i] << endl;
output_Final << "Maximum Dry Density (pcf)" << "," << gamma_dry_M[i] << "," << gamma_dry_V[i] << "," << gamma_dry_S[i] << "," << "N/A" << "," << "N/A" << "," << gamma_dry_Min[i] << "," << gamma_dry_Max[i] << endl;
output_Final << "Matric Suction (kPa)" << "," << Suction_Mean[i] << "," << Suction_Variance[i] << "," << Suction_Stdev[i] << "," << Suction_Skew[i] << "," << Suction_Kurt[i] << "," << Suction_Minimum[i] << "," << Suction_Maximum[i] << endl;
output_Final << "SWCC Fitting Parameter A" << "," << SWCC_AM[i] << "," << SWCC_AV[i] << "," << SWCC_AS[i] << "," << "N/A" << "," << "N/A" << "," << SWCC_AMin[i] << "," << SWCC_AMax[i] << endl;
output_Final << "SWCC Fitting Parameter B" << "," << SWCC_BM[i] << "," << SWCC_BV[i] << "," << SWCC_BS[i] << "," << "N/A" << "," << "N/A" << "," << SWCC_BMin[i] << "," << SWCC_BMax[i] << endl;
output_Final << "SWCC Fitting Parameter C" << "," << SWCC_CM[i] << "," << SWCC_CV[i] << "," << SWCC_CS[i] << "," << "N/A" << "," << "N/A" << "," << SWCC_CMin[i] << "," << SWCC_CMax[i] << endl;
output_Final << "Volumetric Water Content (%)" << "," << Theata_WM[i] << "," << Theata_WV[i] << "," << Theata_WS[i] << "," << Theata_WSkew[i] << "," << Theata_WKurt[i] << "," << Theata_WMin[i] << "," << Theata_WMax[i] << endl;
output_Final << "Sat'd Volumetric Water Content (%)" << "," << Theata_SM[i] << "," << Theata_SV[i] << "," << Theata_SS[i] << "," << Theata_SSkew[i] << "," << Theata_SKurt[i] << "," << Theata_SMin[i] << "," << Theata_SMax[i] << endl;
output_Final << "Degree of Saturation (%)" << "," << degree_sat_mean[i] << "," << degree_sat_var[i] << "," << degree_sat_stdev[i] << "," << degree_sat_skew[i] << "," << degree_sat_kurt[i] << "," << degree_sat_Min[i] << "," << degree_sat_Max[i] << endl;
```

```
output_Final << "Optimum Saturation (%)" << "," << opt_sat_mean[i] << "," << opt_sat_var[i]
<< "," << opt_sat_stdev[i] << "," << opt_sat_skew[i] << "," << opt_sat_kurt[i] << "," <<
opt_sat_min[i] << "," << opt_sat_max[i] << endl;
output_Final << "Environmental Factor" << "," << Fenv_Mean[i] << "," << Fenv_Var[i] << ","
<< Fenv_Stdev[i] << "," << Fenv_Skew[i] << "," << Fenv_Kurt[i] << "," << Fenv_Min[i] << ","
<< Fenv_Max[i] << endl;
output_Final << "California Bearing Ratio (%)" << "," << "CBR is not required since Modulus at
Optimum was given." << endl;
output_Final << "Modulus at Optimum (Psi)" << "," << Mropt_Mean[i] << "," << Mropt_Var[i]
<< "," << Mropt_Stdev[i] << "," << "N/A" << "," << "N/A" << "," << Mropt_Min[i] << "," <<
Mropt_Max[i] << endl;
output_Final << "Modulus at Equilibrium (Psi)" << "," << Mreq_Mean[i] << "," << Mreq_Var[i]
<< "," << Mreq_Stdev[i] << "," << Mreq_Skew[i] << "," << Mreq_Kurt[i] << "," << Mreq_Min[i]
<< "," << Mreq_Max[i] << endl << endl;}}}
output_Final.close();
cout << endl << "Final Output file created" << endl << endl;
EndTime = ((double)(tEnd-tStart))/((double)(CLOCKS_PER_SEC));
cout << left << "Time Required\t" << EndTime << endl;
cout << "\n" << "Program Complete.\n\n";system("pause");gsl_rng_free (Rand_NUM_Gen);
// Releases GSL's Memory
return 0;}
```

APPENDIX B

PROGRAM RESULTS

Location	Phoenix AZ								
Time	162.82	Sec							
Variable	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
Py	16.2	32.231	5.677	0.36	-0.1	1.59	40.17	3.729	6.133
Hy	134.2	10.432	3.23	-0.05	-0.08	122.24	146.29	6.417	6.44
PE	179.7	70.657	8.406	0	-0.11	149.94	210.86	5.929	6.193
TMI	-58.2	5.767	2.402	0.33	-0.3	-63.99	-48.31	3.278	5.628

Soil Name	GB								
Analysis	L3B								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	42.979	6.556	N/A	N/A	0	25	1.36	1.27
PI	1.159	3.084	1.756	N/A	N/A	0	6	0.16	0.66
wPI	0.206	0.117	0.342	N/A	N/A	0	1.5	0.18	1.1
Wopt	5.302	3.341	1.828	2.39	33.4	0.03	39.44	16.51	60.1
Gamma	124.6	60.943	7.807	-2.73	32.8	0.3	149.9	42.06	8.57
Suction	181.9	15661	125.1	-0.22	-1.56	6	425	0.73	1.01
Vol Cont	11.02	10.94	3.31	-0.29	-0.96	4.5	16.7	1.25	1.09
Sat Vol Cont	25.43	30.28	5.5	0.18	0.06	6.7	50.5	6.2	8.3
%S	45.5	307.752	17.543	0.65	0.21	11.53	100	1.92	3.09
Sopt	69.8	121.059	11.003	0.11	2.42	0.12	100	11.43	4.96
Fenv	1.439	0.279	0.528	2.14	6.63	0.3	5.11	3.29	10.7
CBR	49.6	234.792	15.323	0.15	-2	23	114.1	1.84	4.46
Mropt	37510	8054690	2838	-1.15	-2	30075	40037	0.99	0.34
Mreq	4.701	0.029	0.169	-0.32	-0.18	4.048	5.176	5.68	4.12

Soil Name	GSB								
Analysis	L3B								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24.004	76.382	8.74	N/A	N/A	0.3	35.4	1.71	0.82
PI	4.632	33.302	5.771	N/A	N/A	0	50	0.49	4.82
wPI	1.272	2.77	1.664	N/A	N/A	0	16.95	0.47	5.74
Wopt	4.643	3.553	1.885	1.4	2.74	0.01	23.88	14.77	22.6
Gamma	123	11.537	3.397	0.48	8.89	84.47	149.99	52.45	36.7
Suction	342.8	71576	267.538	4.42	29.3	121	4260	0.6	10.5
SWCC A	73.942	170.88	13.072	0.59	-0.4	55.2	122.4	1.2	3.11
SWCC B	0.958	0.014	0.117	-0.37	-0.76	0.594	1.139	2.55	1.28
SWCC C	0.442	0.007	0.086	-0.59	-0.4	0.125	0.565	3.11	1.2
Vol Cont	16.441	15.127	3.889	-0.68	0.27	4.5	28.3	4.16	4.14
Sat Vol Cont	26.242	7.755	2.785	-0.03	-0.07	13.9	38	9.06	8.68
%S	63.117	264.003	16.248	0.16	-0.49	19.3	100	2.78	2.34
Sopt	70.514	3.961	1.99	-3.05	88	9.2	90.7	233.9	76.8
Fenv	1.302	0.413	0.642	1.93	4.94	0.22	5.71	2.09	8.51
CBR	37.477	341.75	18.487	0.21	-2	6.84	96.43	1.47	2.82
Mropt	33561	3.70E+07	6155	-0.63	-2	16327	40037	1.41	0.53
Mreq	4.579	0.059	0.243	-0.36	-0.16	3.631	5.23	5.6	3.85
Soil Name	FGM								
Analysis	L3B								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.454	330.286	18.174	N/A	N/A	35.5	100	1.06	1.08
PI	13.801	103.596	10.178	N/A	N/A	0	75	1.32	5.84
wPI	10.179	83.614	9.144	N/A	N/A	0	66.24	0.89	4.93
Wopt	9.879	22.423	4.735	0.14	-0.86	8.28	29.37	1.23	2.28
Gamma	111.4	86.61	9.306	-0.48	-0.61	85.08	148.51	4.27	6.01
Suction	4545.9	5.30E+07	7248.7	2.89	10.3	133	68375	0.28	4.08
SWCC A	105.43	612.626	24.751	-0.09	-0.87	55.2	167.4	1.83	2.25
SWCC B	0.721	0.031	0.175	0.48	-0.65	0.384	1.139	1.61	2.01
SWCC C	0.241	0.024	0.154	0.27	-1.01	0.01	0.565	0.9	1.26
Vol Cont	23.617	68.272	8.263	-0.07	-0.8	2.8	45.9	2.81	3
Sat Vol Cont	33.322	33.605	5.797	-0.21	-0.3	10.9	49.5	5.71	4.12
%S	69.46	549.536	23.442	-0.26	-1.01	7.8	100	1.62	0.8
Sopt	82.222	16.491	4.061	2.48	7.74	69.1	100	5.57	7.56
Fenv	2.223	4.285	2.07	1.56	2.2	0.21	14.3	0.67	4.01
CBR	16.869	224.552	14.985	1.55	-2	1.78	69.9	0.57	2
Mropt	22819	7.80E+07	8834	0.4	-2	7409	40037	1.13	1.27
Mreq	4.469	0.231	0.481	-0.15	-0.71	3.206	5.678	2.87	2.75

Soil Name SFGM

Analysis L3B

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.023	295.422	17.188	N/A	N/A	35.5	99	0.86	1.37
PI	5.873	8.413	2.901	N/A	N/A	0	10	1.1	0.78
wPI	3.634	4.981	2.232	N/A	N/A	0	9.76	1.29	2.18
Wopt	10.084	5.666	2.38	-0.06	-1.14	8.39	16.86	0.9	1.2
Gamma	118.5	21.607	4.648	-0.24	-1.1	109.09	125.67	1.21	0.91
Suction	665.5	197494	444.403	1.5	2.57	118	3466	1.11	5.66
SWCC A	80.394	169.39	13.015	-0.09	-1	55.2	107	1.44	1.52
SWCC B	0.9	0.013	0.114	0.28	-0.94	0.689	1.139	1.34	1.53
SWCC C	0.4	0.007	0.085	0.09	-1	0.225	0.565	1.52	1.44
Vol Cont	21.822	34.581	5.881	0.72	0.29	8.7	39.6	2.45	3.3
Sat Vol Cont	29.004	11.188	3.345	0.1	-0.6	19.9	38.6	3.29	3.48
%S	74.181	358.18	18.926	-0.18	-1.05	26.5	100	1.58	0.86
Sopt	78.33	0.764	0.874	2.26	15	67.6	87.1	67.71	55.2
Fenv	1.451	1.238	1.113	1.36	1.2	0.29	5.99	0.67	2.6
CBR	25.532	176.622	13.29	1.17	-2	2.97	69.9	1.57	3.09
Mropt	29682	3.20E+07	5697	0.09	-2	10086	40037	3.44	1.82
Mreq	4.501	0.126	0.354	-0.03	-0.95	3.523	5.354	3.01	2.63

Soil Name CFGM

Analysis L3B

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.209	266.317	16.319	N/A	N/A	35.6	100	1.64	1.1
PI	20.999	81.069	9.004	N/A	N/A	10.5	75	0.98	5.02
wPI	16.124	80.837	8.991	N/A	N/A	3.89	66.24	1.29	5.29
Wopt	19.085	10.974	3.313	0.21	-0.68	12.74	29.12	1.86	2.94
Gamma	104.7	42.373	6.509	-0.32	-0.63	86.44	117.07	2.58	1.75
Suction	8117	8.10E+07	9003	2.06	5	360	76900	0.57	5.02
SWCC A	118.63	348.255	18.662	-0.1	-0.76	77	167.9	2.24	2.65
SWCC B	0.626	0.013	0.114	0.43	-0.57	0.382	0.922	2.04	2.48
SWCC C	0.158	0.012	0.109	0.46	-0.88	0.01	0.422	0.82	1.46
Vol Cont	22.622	43.485	6.594	0.26	-0.52	5.5	44	3.3	4.13
Sat Vol Cont	37.439	17.418	4.174	0.21	-0.57	26.6	50.8	3.29	4.04
%S	61.001	350.512	18.722	0.19	-0.64	13.9	100	2.32	1.92
Sopt	85.241	7.466	2.732	-0.41	-0.24	75.4	93.6	5.43	4.6
Fenv	3.439	4.801	2.191	0.79	0.05	0.31	14.23	1.35	4.67
CBR	7.638	15.363	3.92	0.9	-2	1.78	19.58	1.17	2.38
Mropt	16679	2.10E+07	4650	0.4	-2	7423	28003	1.73	2.12
Mreq	4.639	0.119	0.344	-0.44	-0.24	3.406	5.478	4.59	3.13

Soil Name A-1-b(GB)

Analysis L3A

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	39.35	6.27	N/A	N/A	0.2	25	1.5	1.41
PI	1.159	3.59	1.89	N/A	N/A	0	6	0.11	0.46
wPI	0.206	0.17	0.41	N/A	N/A	0	1.5	0.08	0.51
Wopt	8.826	2.679	1.637	-0.86	0.84	0.7	13.71	7.92	6.76
Gamma	128.5	51.201	7.155	0.82	0.68	95.6	149.99	7.75	5.07
Suction	235	2492	50	0.62	0.59	120	482	3.29	7.06
Vol Cont	11.01	3.158	9.975	-0.28	-0.92	4.53	16.59	1.41	1.21
Sat Vol Cont	23.14	5.2	27.037	-0.04	-0.12	3.54	40.73	6.19	5.56
%S	49.9	356.407	18.879	0.63	0.02	13.5	100	1.73	2.38
Sopt	71.3	97.936	9.896	0.62	1.18	35.6	100	5.26	4.22
Fenv	1.397	0.297	0.545	2.39	8.17	0.27	5.55	3.15	11.6
CBR	52.19	94.037	9.697	-0.1	-2	24.93	70.15	2.54	1.67
Mropt	38632	2045860	1430.3	-1.16	-2	31093	40037	3.52	0.66
Mreq	4.697	0.032	0.178	-0.32	-0.23	4.021	5.177	5.44	3.86

Soil Name A-2-4(GSB)

Analysis L3A

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24.004	46.64	6.83	N/A	N/A	2.8	35.4	2.72	1.46
PI	4.632	10.48	3.24	N/A	N/A	0	10	0.63	0.73
wPI	1.272	0.84	0.92	N/A	N/A	0	3.5	0.85	1.49
Wopt	8.925	1.438	1.199	0.79	-0.36	0.23	12.86	15.32	5.83
Gamma	123.4	3.647	1.91	-0.96	18.8	74.21	146.22	209.6	96.89
Suction	308	11730	108.31	1.1	1.12	122	851	1.94	5.66
SWCC A	63.328	23.972	4.896	0.16	-1.05	55.2	73.6	1.09	1.37
SWCC B	1.054	0.002	0.05	-0.1	-1.08	0.954	1.139	1.32	1.12
SWCC C	0.512	0.001	0.032	-0.16	-1.05	0.445	0.565	1.37	1.09
Vol Cont	16.211	7.477	2.734	-0.64	0.15	5.8	25.1	6.1	5.21
Sat Vol Cont	25.985	5.061	2.25	-0.03	-0.27	18.5	34.5	5.35	6.09
%S	62.982	143.743	11.989	0.14	-0.19	26.2	100	4.23	4.25
Sopt	71.39	1.428	1.195	-2.45	12.52	56.7	86.3	75.55	76.6
Fenv	1.335	0.25	0.5	1.25	1.9	0.35	4.16	2.64	7.53
CBR	40.407	206.45	14.368	0.26	-2	12.32	88.5	2.04	3.5
Mropt	35515	16632500	4078	-1.17	-2	22376	40037	1.91	0.66
Mreq	4.641	0.032	0.178	-0.26	-0.31	4.013	5.121	4.85	3.7

Soil Name A-4(SFGM)
Analysis L3A

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.023	295.249	17.183	N/A	N/A	35.5	99	0.86	1.37
PI	5.873	7.96	2.821	N/A	N/A	0	10	1.2	0.84
wPI	3.634	4.852	2.203	N/A	N/A	0	9.76	1.34	2.25
Wopt	12.049	5.507	2.347	-0.09	-1.12	8.39	16.81	0.94	1.22
Gamma	118.5	21.144	4.598	-0.22	-1.11	109.18	125.67	1.22	0.94
Suction	662	195242	441.86	1.49	2.39	125	3290	1.06	5.17
SWCC A	80.152	166.261	12.894	-0.08	-1	55.2	106.7	1.44	1.54
SWCC B	0.902	0.013	0.113	0.26	-0.94	0.692	1.14	1.36	1.54
SWCC C	0.401	0.007	0.085	0.08	-1	0.228	0.565	1.54	1.44
Vol Cont	21.881	34.931	5.91	0.72	0.24	8.3	39.7	2.56	3.35
Sat Vol Cont	29.076	11.041	3.323	0.08	-0.61	20.4	38.6	3.1	3.39
%S	74.076	357.478	18.907	-0.18	-1.04	25.8	100	1.63	0.87
Sopt	78.341	0.672	0.82	2.32	15.17	73.9	86.3	18.2	32.9
Fenv	1.44	1.224	1.106	1.4	1.36	0.29	5.99	0.66	2.61
CBR	25.402	171.49	13.095	1.17	-2	0	69.84	2.03	3.55
Mropt	29646	32630900	5712	-0.04	-2	0	40037	6.25	2.19
Mreq	4.497	0.124	0.353	-0.02	-0.94	3.35	5.331	3.87	2.82

Soil Name A-6(CFGM)
Analysis L3A

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.209	269	16.39	N/A	N/A	35.6	98.2	1.51	0.94
PI	20.999	8.83	2.97	N/A	N/A	10.5	29	4.84	3.69
wPI	16.124	11.5	3.39	N/A	N/A	3.89	24.38	4.65	3.14
Wopt	19.656	1.77	1.33	-0.62	0.16	13.58	22.33	5.68	2.51
Gamma	103.6	6.742	2.596	0.5	-0.17	98.43	114.08	2.33	4.71
Suction	6531	10176600	3190.08	0.83	0.65	682	23950	2.26	6.75
SWCC A	122.956	56.342	7.506	-0.82	0.58	85.7	137.1	6.05	2.29
SWCC B	0.592	0.002	0.044	1.04	1.28	0.515	0.848	2.08	6.89
SWCC C	0.121	0.002	0.049	0.82	0.58	0.028	0.365	2.29	6.05
Vol Cont	22.673	9.136	3.023	0.31	0	12.1	34.2	5.87	6.45
Sat Vol Cont	38.055	4.402	2.098	-0.17	-0.13	29.9	45.2	6.46	5.67
%S	59.754	75.357	8.681	0.16	-0.22	34.2	93.8	4.52	6.02
Sopt	85.918	8.582	2.929	-0.11	-0.53	76.2	92.7	3.95	2.76
Fenv	3.453	1.241	1.114	0.28	-0.42	0.61	7.49	3.42	4.85
CBR	6.15	1.914	1.384	1.39	-2	4.04	16.61	1.76	8.75
Mropt	15277	3374850	1837	1	-2	12098	25945	2.08	6.97
Mreq	4.694	0.025	0.16	-0.5	0.18	3.992	5.12	6.68	4.05

Soil Name A-6(FGM)
Analysis L3A

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.454	269	16.39	N/A	N/A	35.6	98.2	1.35	1.3
PI	13.801	8.83	2.97	N/A	N/A	10.5	29	0.84	3.85
wPI	10.179	11.5	3.39	N/A	N/A	3.885	24.375	2.08	4.69
Wopt	16.935	3.047	1.746	0.04	-0.63	12.761	21.919	2.66	3.17
Gamma	108.952	11.767	3.43	-0.11	-0.68	99.708	116.927	2.83	2.44
Suction	2797	3846640	1961	1.83	4.74	395.979	17812.6	1.15	7.22
SWCC A	106.821	121.811	11.037	-0.17	-0.61	77.251	135.612	3.03	2.95
SWCC B	0.695	0.006	0.075	0.39	-0.46	0.522	0.92	2.55	3.34
SWCC C	0.227	0.005	0.072	0.17	-0.61	0.038	0.421	2.95	3.03
Vol Cont	22.189	14.874	3.857	0.15	-0.33	9.944	34.961	4.66	4.86
Sat Vol Cont	34.84	6.384	2.527	0.05	-0.35	26.415	43.658	5.2	5.44
%S	63.948	147.212	12.133	0.17	-0.28	29.78	100	3.59	3.78
Sopt	85.015	5.987	2.447	-0.07	-0.32	76.368	94.054	5.89	6.16
Fenv	2.758	1.498	1.224	0.5	-0.33	0.426	7.546	2.11	4.34
CBR	9.72	8.403	2.899	0.66	-2	4.298	19.487	1.89	3.41
Mropt	19493	9320060	3052.88	0.28	-2	12534	27944	2.4	2.91
Mreq	4.679	0.049	0.222	-0.47	-0.08	3.818	5.24	5.31	3.46

Soil Name (GB)5
Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	237.61	6343	80	-0.22	-0.94	63.18	421.81	1.98	2.09
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	10.11	1.86	1.3625	0.67	0.61	6.48	17.02	4.32	8.21
Sat Vol Cont	25	2.85	1.6891	-0.02	-0.69	20.6	29.22	2.82	2.7
%S	40.64	37.34	6.11	0.41	-0.04	24.17	66.77	4.07	6.45
Sopt	67.55	0.911	0.955	0.06	-1.01	65.72	69.49	1.4	1.48
Fenv	1.46	0.018	0.134	0.1	-0.33	1.05	1.94	4.57	5.3
Mropt	31443	762430	873	N/A	N/A	29732	33154	1.42	1.42
Mreq	4.661	0.00173	0.0416	-0.11	-0.37	4.523	4.785	4.69	4.21

Soil Name (GB)35

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	236.67	6310	79	-0.21	-0.95	63.51	425.02	2	2.17
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	10.1	1.81	1.3443	0.66	0.63	6.48	16.53	4.27	7.61
Sat Vol Cont	25	2.79	1.6716	-0.02	-0.68	20.64	29.3	2.87	2.83
%S	40.61	36.69	6.06	0.39	-0.06	25.11	69.71	3.92	7.37
Sopt	67.55	0.915	0.956	0.05	-1.02	65.72	69.48	1.39	1.47
Fenv	1.46	0.018	0.134	0.06	-0.31	1.04	1.92	4.75	5
Mropt	37260	1070630	1035	N/A	N/A	35232	39288	1.42	1.42
Mreq	4.735	0.00175	0.0418	-0.15	-0.37	4.584	4.857	5.29	4.27

Soil Name (GB)50

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	237.94	6293	79	-0.23	-0.93	65.7	427.45	1.99	2.19
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	10.09	1.76	1.3279	0.65	0.58	6.67	17.3	4.18	8.81
Sat Vol Cont	25.01	2.82	1.6786	-0.04	-0.69	20.64	29.32	2.86	2.82
%S	40.57	36.1	6.01	0.45	0.08	25.29	67.55	3.77	6.65
Sopt	67.55	0.917	0.957	0.05	-1.02	65.72	69.48	1.39	1.46
Fenv	1.46	0.018	0.133	0.06	-0.34	1.06	1.9	4.31	4.72
Mropt	37262	1070740	1035	N/A	N/A	35234	39290	1.42	1.42
Mreq	4.735	0.00169	0.0411	-0.13	-0.38	4.586	4.86	5.43	4.6

Soil Name	(GB)75								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	236.67	6385	80	-0.2	-0.96	63.86	423.94	1.95	2.12
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	10.12	1.85	1.3607	0.67	0.64	6.57	16.99	4.14	8.02
Sat Vol Cont	25.01	2.83	1.6815	-0.05	-0.7	20.67	29.2	2.76	2.66
%S	40.69	37.87	6.15	0.43	0	24.62	67.21	3.87	6.39
Sopt	67.55	0.907	0.952	0.06	-1.01	65.72	69.49	1.41	1.49
Fenv	1.46	0.018	0.136	0.09	-0.38	1.05	1.9	4.26	4.61
Mropt	39880	1226480	1107	N/A	N/A	37709	42051	1.42	1.42
Mreq	4.764	0.0018	0.0424	-0.16	-0.39	4.62	4.883	4.67	3.87

Soil Name	(GB)95								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	237.13	6367	80	-0.22	-0.95	65.02	422.74	1.93	2.08
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	10.11	1.83	1.352	0.63	0.48	6.41	16.33	4.32	7.27
Sat Vol Cont	25.01	2.81	1.6763	-0.03	-0.69	20.66	29.23	2.81	2.73
%S	40.6	37.14	6.09	0.37	-0.08	24.74	66.66	3.83	6.3
Sopt	67.55	0.906	0.952	0.07	-1.01	65.72	69.49	1.41	1.5
Fenv	1.46	0.018	0.134	0.08	-0.32	1.07	1.92	4.16	4.73
Mropt	40036	1236100	1112	N/A	N/A	37857	42215	1.42	1.42
Mreq	4.766	0.00174	0.0418	-0.13	-0.39	4.626	4.886	4.68	3.99

Soil Name	(GSM)5								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	293.86	4331	66	0.44	-0.11	130.43	561.97	3.45	5.66
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	18.84	2.85	1.6874	0.04	-0.26	13.33	24.83	5.08	5.51
Sat Vol Cont	26.57	2.7	1.6441	-0.01	-0.69	22.33	30.59	2.72	2.58
%S	71.24	60.78	7.8	0.22	-0.16	48.78	100	4.22	5.41
Sopt	70.39	0.21	0.459	-0.24	-0.99	69.39	71.17	1.51	1.18
Fenv	1	0.056	0.237	0.41	-0.16	0.42	1.96	3.39	5.57
Mropt	21095	343171	586	N/A	N/A	19947	22243	1.42	1.42
Mreq	4.313	0.01136	0.1066	-0.25	-0.39	3.954	4.589	4.37	3.36

Soil Name	(GSM)35								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	294.22	4356	66	0.43	-0.13	129.07	560.53	3.48	5.62
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	18.84	2.87	1.6933	0.02	-0.28	13.51	24.42	4.58	4.79
Sat Vol Cont	26.58	2.68	1.638	-0.02	-0.68	22.22	30.73	2.94	2.8
%S	71.19	60.81	7.8	0.22	-0.21	48.85	99.18	4.12	5.16
Sopt	70.4	0.211	0.46	-0.26	-0.99	69.39	71.17	1.5	1.16
Fenv	1	0.056	0.237	0.42	-0.16	0.42	1.94	3.35	5.34
Mropt	32449	811997	901	N/A	N/A	30683	34215	1.42	1.42
Mreq	4.5	0.01136	0.1066	-0.26	-0.37	4.131	4.782	4.62	3.52

Soil Name (GSM)50

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	293.82	4313	66	0.45	-0.1	130.83	560.09	3.44	5.62
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	18.84	2.78	1.6679	0.04	-0.26	13.11	24.44	5.33	5.22
Sat Vol Cont	26.58	2.65	1.6284	-0.01	-0.7	22.3	30.73	2.89	2.8
%S	71.17	58.59	7.65	0.2	-0.17	48.2	98.69	4.46	5.34
Sopt	70.4	0.211	0.46	-0.26	-0.99	69.39	71.17	1.5	1.16
Fenv	1.01	0.055	0.235	0.49	-0.01	0.42	1.94	3.45	5.48
Mropt	33653	873377	935	N/A	N/A	31821	35485	1.42	1.42
Mreq	4.515	0.01115	0.1056	-0.25	-0.39	4.16	4.792	4.39	3.41

Soil Name (GSM)75

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	294.38	4332	66	0.45	-0.09	123.89	558.12	3.68	5.7
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	18.84	2.86	1.6918	0.03	-0.28	12.96	24.88	5.64	5.78
Sat Vol Cont	26.57	2.68	1.6371	-0.02	-0.7	22.25	30.69	2.89	2.76
%S	71.14	59.9	7.74	0.17	-0.21	47.24	100	4.76	5.75
Sopt	70.39	0.211	0.459	-0.24	-0.99	69.39	71.17	1.51	1.17
Fenv	1	0.056	0.237	0.46	-0.04	0.43	1.99	3.38	5.78
Mropt	38901	1167010	1080	N/A	N/A	36784	41018	1.42	1.42
Mreq	4.58	0.01115	0.1056	-0.24	-0.39	4.235	4.866	4.28	3.55

Soil Name	(GSM)95								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	293.6	4357	66	0.45	-0.08	129.42	560.24	3.45	5.6
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	18.84	2.85	1.6886	0.03	-0.31	13.15	24.71	5.27	5.44
Sat Vol Cont	26.58	2.68	1.6364	-0.01	-0.7	22.3	30.77	2.88	2.81
%S	71.18	60.8	7.8	0.18	-0.19	46.93	100	4.79	5.7
Sopt	70.39	0.213	0.461	-0.24	-1.01	69.39	71.17	1.49	1.16
Fenv	1	0.057	0.238	0.49	0.04	0.42	2.05	3.54	6.33
Mropt	39984	1232890	1110	N/A	N/A	37808	42160	1.42	1.42
Mreq	4.591	0.01121	0.1059	-0.21	-0.36	4.243	4.884	4.41	3.7
Soil Name	(FGM)5								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	2684.45	2070390	1439	0.93	0.55	441.37	9050.42	1.54	4.36
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	20.81	6.14	2.4783	0.34	-0.35	14.21	29.72	3.65	4.93
Sat Vol Cont	33.16	2.23	1.4932	-0.01	-0.7	29.33	36.9	2.75	2.68
%S	62.9	65.46	8.09	0.25	-0.32	39.89	91.56	4.04	5.03
Sopt	83.6	1.865	1.366	-0.41	-0.84	80.37	85.74	1.63	1.08
Fenv	2.65	0.664	0.815	0.29	-0.46	0.74	5.5	2.89	4.32
Mropt	9227	65656	256	N/A	N/A	8725	9729	1.42	1.42
Mreq	4.366	0.02024	0.1423	-0.43	-0.23	3.861	4.703	4.44	2.96

Soil Name (FGM)35

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	2691.38	2085500	1444	0.93	0.52	453.29	9516.58	1.56	4.76
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	20.79	6.08	2.4653	0.31	-0.37	14.14	29.23	3.63	4.61
Sat Vol Cont	33.15	2.23	1.4929	-0.02	-0.69	29.22	36.92	2.88	2.77
%S	62.9	63.67	7.98	0.23	-0.32	40.37	93.41	4.16	5.64
Sopt	83.6	1.863	1.365	-0.41	-0.86	80.37	85.74	1.63	1.08
Fenv	2.66	0.643	0.802	0.22	-0.48	0.7	5.43	3.07	4.35
Mropt	18357	259869	510	N/A	N/A	17358	19356	1.42	1.42
Mreq	4.667	0.01949	0.1396	-0.5	-0.1	4.162	4.988	4.48	2.85

Soil Name (FGM)50

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	2677.69	2043430	1429	0.93	0.56	416.06	9391.19	1.62	4.81
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	20.82	6.25	2.4992	0.36	-0.31	14.13	29.56	3.63	4.74
Sat Vol Cont	33.17	2.25	1.4985	-0.03	-0.7	29.26	36.97	2.85	2.78
%S	62.83	64.54	8.03	0.23	-0.35	40.68	91.37	3.84	4.95
Sopt	83.6	1.861	1.364	-0.41	-0.86	80.37	85.74	1.63	1.08
Fenv	2.66	0.654	0.808	0.29	-0.47	0.73	5.5	2.98	4.41
Mropt	22927	405361	637	N/A	N/A	21679	24175	1.42	1.42
Mreq	4.763	0.02	0.1414	-0.46	-0.18	4.235	5.084	4.65	2.83

Soil Name (FGM)75

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	2693.8	2075040	1441	0.92	0.51	438.48	9222.87	1.57	4.53
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	20.8	6.2	2.4908	0.35	-0.32	14.17	29.53	3.59	4.73
Sat Vol Cont	33.18	2.25	1.4986	-0.04	-0.71	29.36	36.96	2.72	2.69
%S	62.93	65.49	8.09	0.21	-0.38	41.49	91.29	3.57	4.72
Sopt	83.61	1.852	1.361	-0.44	-0.82	80.37	85.74	1.65	1.08
Fenv	2.65	0.66	0.812	0.25	-0.51	0.75	5.23	2.72	3.69
Mropt	30347	710204	843	N/A	N/A	28695	31999	1.42	1.42
Mreq	4.884	0.02029	0.1424	-0.5	-0.19	4.379	5.197	4.2	2.6

Soil Name (FGM)95

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	2677.39	2032080	1426	0.92	0.53	475.97	8821.03	1.49	4.16
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	20.81	6.07	2.4633	0.32	-0.35	14.24	30.02	3.74	5.24
Sat Vol Cont	33.17	2.24	1.497	-0.02	-0.7	29.36	36.94	2.72	2.7
%S	62.96	63.97	8	0.25	-0.32	41.44	95.09	3.93	5.87
Sopt	83.59	1.873	1.369	-0.41	-0.86	80.37	85.74	1.62	1.08
Fenv	2.64	0.634	0.797	0.2	-0.49	0.61	5.29	3.26	4.24
Mropt	37431	1080470	1039	N/A	N/A	35394	39468	1.42	1.42
Mreq	4.974	0.02022	0.1422	-0.57	0.06	4.413	5.3	5.1	2.97

Soil Name	(SFGM)5								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	599.91	43630	209	0.74	0.28	177.28	1474.23	2.43	5.04
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	20.57	3.11	1.7631	0.23	-0.24	15.3	26.87	4.41	5.27
Sat Vol Cont	30.95	2.38	1.5418	-0.01	-0.7	26.93	34.83	2.84	2.73
%S	66.62	44.11	6.64	0.22	-0.21	47.63	93.87	4.41	6.32
Sopt	78.68	0.594	0.771	-0.56	-0.72	76.74	79.76	1.62	0.91
Fenv	1.72	0.2	0.448	0.29	-0.37	0.58	3.28	3.33	4.57
Mropt	19408	290478	539	N/A	N/A	18352	20464	1.42	1.42
Mreq	4.507	0.01414	0.1189	-0.4	-0.25	4.078	4.805	4.74	3.29

Soil Name	(SFGM)35								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	601.15	44354	211	0.74	0.27	179.67	1505.31	2.41	5.18
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	20.56	3.12	1.7665	0.25	-0.22	15.43	27.22	4.33	5.61
Sat Vol Cont	30.97	2.35	1.5344	-0.02	-0.68	27.02	34.91	2.81	2.8
%S	66.57	43.51	6.6	0.21	-0.23	47.55	90.86	4.23	5.4
Sopt	78.68	0.594	0.771	-0.57	-0.69	76.75	79.76	1.62	0.91
Fenv	1.72	0.2	0.447	0.31	-0.38	0.64	3.32	3.1	4.58
Mropt	27760	594279	771	N/A	N/A	26249	29271	1.42	1.42
Mreq	4.664	0.0139	0.1179	-0.36	-0.31	4.262	4.96	4.35	3.21

Soil Name	(SFGM)50								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	600.7	44465	211	0.73	0.23	187.81	1535.53	2.35	5.33
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	20.56	3.13	1.7696	0.19	-0.31	15.07	27.04	4.74	5.61
Sat Vol Cont	30.97	2.36	1.5361	-0.01	-0.68	26.98	34.88	2.84	2.78
%S	66.56	43.97	6.63	0.2	-0.2	46.15	92.28	4.84	6.1
Sopt	78.68	0.587	0.766	-0.57	-0.69	76.74	79.76	1.65	0.92
Fenv	1.72	0.203	0.45	0.34	-0.31	0.59	3.38	3.32	4.9
Mropt	29725	681394	825	N/A	N/A	28107	31343	1.42	1.42
Mreq	4.693	0.01425	0.1194	-0.37	-0.27	4.261	4.989	4.74	3.26

Soil Name	(SFGM)75								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	600.23	44669	211	0.74	0.24	193.54	1512.99	2.25	5.06
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	20.58	3.1	1.761	0.21	-0.27	15.26	26.75	4.44	5.14
Sat Vol Cont	30.98	2.34	1.529	-0.02	-0.66	27	34.86	2.83	2.77
%S	66.67	43.87	6.62	0.19	-0.22	46.68	92.18	4.67	5.95
Sopt	78.69	0.589	0.767	-0.58	-0.67	76.75	79.76	1.64	0.91
Fenv	1.71	0.201	0.448	0.32	-0.34	0.59	3.38	3.29	4.95
Mropt	34157	899728	949	N/A	N/A	32298	36016	1.42	1.42
Mreq	4.75	0.01426	0.1194	-0.35	-0.28	4.327	5.038	4.49	3.06

Soil Name (SFGM)95

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	602.07	45206	213	0.75	0.28	170.9	1581.11	2.55	5.79
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	20.55	3.19	1.7852	0.25	-0.18	15.46	27.11	4.14	5.34
Sat Vol Cont	30.96	2.39	1.5446	-0.03	-0.71	26.99	34.81	2.74	2.66
%S	66.6	45.03	6.71	0.24	-0.21	47.21	92.24	4.32	5.72
Sopt	78.68	0.587	0.766	-0.57	-0.7	76.75	79.76	1.65	0.92
Fenv	1.72	0.208	0.456	0.3	-0.38	0.58	3.36	3.29	4.71
Mropt	37849	1104740	1051	N/A	N/A	35789	39909	1.42	1.42
Mreq	4.798	0.0146	0.1208	-0.39	-0.25	4.369	5.093	4.55	3.12

Soil Name (CFGM)5

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	6814.24	17217200	4149	0.93	0.52	749.81	26314.3	1.39	4.48
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	22.07	10.34	3.2157	0.41	-0.4	14.33	33.53	3.05	4.52
Sat Vol Cont	37.55	1.92	1.3847	-0.04	-0.71	33.92	40.98	2.82	2.67
%S	58.84	78.65	8.87	0.28	-0.38	36.41	90.94	3.35	4.8
Sopt	85.7	5.382	2.32	-0.29	-0.94	80.48	89.61	1.6	1.2
Fenv	3.52	1.259	1.122	0.2	-0.49	0.7	7.32	3.21	4.32
Mropt	9476	69247	263	N/A	N/A	8960	9992	1.42	1.42
Mreq	4.498	0.02277	0.1509	-0.59	0.12	3.831	4.831	5.83	2.92

Soil Name	(CFGM)35								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	6770.37	17131500	4139	0.94	0.51	750.82	27200.7	1.41	4.77
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	22.07	10.24	3.1994	0.38	-0.37	14.42	33.92	3.08	4.78
Sat Vol Cont	37.52	1.95	1.3962	-0.02	-0.71	33.98	40.98	2.67	2.61
%S	58.89	77.95	8.83	0.29	-0.36	37.1	91.62	3.26	4.89
Sopt	85.73	5.399	2.324	-0.31	-0.92	80.47	89.61	1.6	1.18
Fenv	3.53	1.257	1.121	0.17	-0.54	0.75	7.06	3	3.81
Mropt	14357	158957	399	N/A	N/A	13576	15138	1.42	1.42
Mreq	4.68	0.02273	0.1508	-0.59	0	4.061	5.005	5.15	2.7

Soil Name	(CFGM)50								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	6757.65	17083700	4133	0.97	0.64	794.3	27384.7	1.39	4.81
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	22.09	10.19	3.1917	0.39	-0.37	14.61	32.94	2.84	4.12
Sat Vol Cont	37.54	1.94	1.3938	-0.02	-0.71	33.93	41.09	2.82	2.77
%S	58.88	77.15	8.78	0.26	-0.43	38.36	89.96	2.89	4.38
Sopt	85.75	5.364	2.316	-0.32	-0.91	80.48	89.61	1.61	1.18
Fenv	3.52	1.25	1.118	0.15	-0.56	0.73	7.52	3.25	4.67
Mropt	16656	213948	463	N/A	N/A	15750	17563	1.42	1.42
Mreq	4.744	0.0225	0.15	-0.56	0.04	4.154	5.087	5.06	2.94

Soil Name	(CFGM)75								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	6752.89	17230900	4151	0.95	0.57	777.44	25771.8	1.34	4.26
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	22.07	10.34	3.2159	0.4	-0.39	14.52	33.11	2.87	4.19
Sat Vol Cont	37.54	1.92	1.3865	0	-0.68	33.95	41.04	2.81	2.74
%S	58.83	78.91	8.88	0.27	-0.4	37.65	91.76	3.07	4.77
Sopt	85.71	5.425	2.329	-0.3	-0.95	80.48	89.61	1.58	1.18
Fenv	3.52	1.277	1.13	0.17	-0.52	0.8	7.31	2.95	4.11
Mropt	20166	313611	560	N/A	N/A	19068	21264	1.42	1.42
Mreq	4.827	0.02249	0.15	-0.57	0.01	4.246	5.163	4.87	2.81

Soil Name	(CFGM)95								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	6745.38	16972400	4120	0.95	0.57	814.74	27041.3	1.38	4.71
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	22.11	10.29	3.2073	0.37	-0.43	14.29	32.59	2.98	3.99
Sat Vol Cont	37.52	1.92	1.3855	0	-0.71	33.95	41.07	2.81	2.79
%S	59.13	79.3	8.9	0.19	-0.48	37.11	89.66	3.13	4.34
Sopt	85.73	5.36	2.315	-0.3	-0.93	80.48	89.61	1.61	1.19
Fenv	3.49	1.282	1.132	0.21	-0.52	0.71	7.32	3.08	4.25
Mropt	24558	465091	682	N/A	N/A	23221	25895	1.42	1.42
Mreq	4.906	0.02418	0.1555	-0.6	0.08	4.301	5.261	4.97	2.92

Location	Amarillo TX								
Time	164.789	Sec							
Variable	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
Py	50.671	173.502	13.172	0.21	-0.1	11	103.67	4.76	6.359
Hy	65.376	8.616	2.935	0.04	-0.13	54.5	75.94	6.256	6.078
PE	76.443	12.271	3.503	0.01	-0.17	63.99	89.44	5.964	6.225
TMI	-15.122	176.678	13.292	0.21	-0.29	-50.89	32.63	3.711	4.955
Soil Name	GB								
Analysis	L3B								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.973	42.979	6.556	N/A	N/A	0	25	1.36	1.27
PI	1.159	3.084	1.756	N/A	N/A	0	6	0.16	0.66
wPI	0.206	0.117	0.342	N/A	N/A	0	1.5	0.18	1.1
Wopt	6.555	3.572	1.89	3.82	76.6	0.12	60.87	16.68	104.8
Gamma	124.6	60.406	7.772	-2.63	30.9	7.4	150	39.65	8.59
Suction	34.365	628.561	25.071	1.16	1.74	4	176	1.04	4.82
Vol Cont	12.29	11.15	3.34	-0.28	-0.95	5	18.6	1.69	1.47
Sat Vol Cont	25.53	29.95	5.47	0.17	0.06	5.6	48.6	6.64	7.7
%S	50.518	326.27	18.063	0.61	0.02	13.49	100	1.98	2.64
Sopt	69.793	114.43	10.697	0.27	2.33	1.16	100	11.89	5.23
Fenv	1.353	0.237	0.487	2.16	6.98	0.29	5.132	3.49	12.42
CBR	49.566	230.382	15.178	0.12	-2	23	114.1	1.88	4.56
Mropt	37524	8074220	2842	-1.17	-2	30075	40037	0.99	0.33
Mreq	4.677	0.027	0.165	-0.31	-0.15	4.062	5.146	5.47	4.17

Soil Name	GSB								
Analysis	L3B								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24.004	76.382	8.74	N/A	N/A	0.3	35.4	1.71	0.82
PI	4.632	33.302	5.771	N/A	N/A	0	50	0.49	4.82
wPI	1.272	2.77	1.664	N/A	N/A	0	16.95	0.47	5.74
Wopt	11.799	3.548	1.884	1.42	2.59	0.02	18.81	12	11.9
Gamma	123	11.33	3.366	0	15	55.86	149.99	113.4	45.6
Suction	38.2	775.262	27.844	4.32	35.9	11	631	0.85	18.77
SWCC A	73.715	165.092	12.849	0.61	-0.34	55.2	115.3	1.13	2.54
SWCC B	0.959	0.013	0.115	-0.38	-0.72	0.636	1.139	2.18	1.21
SWCC C	0.444	0.007	0.084	-0.61	-0.34	0.171	0.565	2.54	1.13
Vol Cont	18.71	21.915	4.681	-0.26	0.04	5	33.7	3.98	4.36
Sat Vol Cont	26.264	7.682	2.772	0.01	-0.09	13.5	37.2	9.22	7.89
%S	71.272	319.878	17.885	-0.1	-0.81	20.9	100	2.24	1.28
Sopt	70.425	5.673	2.382	-2.67	36.5	7.1	90.5	169.2	53.47
Fenv	1.098	0.36	0.6	2.11	6.33	0.16	6	1.87	9.83
CBR	37.841	339.6	18.43	0.17	-2	6.31	87.57	1.4	2.21
Mropt	33696	3.70E+07	6117	-0.66	-2	15605	40037	1.53	0.54
Mreq	4.498	0.07	0.264	-0.29	-0.33	3.55	5.209	4.96	3.71
Soil Name	FGM								
Analysis	L3B								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.454	330.286	18.174	N/A	N/A	35.5	100	1.06	1.08
PI	13.801	103.596	10.178	N/A	N/A	0	75	1.32	5.84
wPI	10.179	83.614	9.144	N/A	N/A	0	66.24	0.89	4.93
Wopt	10.392	22.921	4.788	0.14	-0.87	5.75	29.02	2.04	2.74
Gamma	111.3	84.255	9.179	-0.26	-0.77	86.09	139.68	3.52	3.97
Suction	241.5	182965	427.744	5.41	48.4	12	9811	0.26	10.74
SWCC A	105.82	613.81	24.775	-0.12	-0.85	55.2	165.3	1.79	2.11
SWCC B	0.718	0.031	0.175	0.52	-0.61	0.392	1.14	1.52	1.97
SWCC C	0.239	0.024	0.154	0.31	-0.99	0.01	0.565	0.89	1.27
Vol Cont	30.658	39.126	6.255	-0.14	-0.34	8.4	47.5	4.89	3.69
Sat Vol Cont	33.501	32.905	5.736	-0.1	-0.47	15.4	49.8	4.18	3.75
%S	86.327	236.696	15.385	-0.93	-0.12	28.1	100	1.91	0.45
Sopt	81.522	3.247	1.802	0.53	6.97	69.1	100	28.16	41.75
Fenv	1.027	0.95	0.974	2.58	7.75	0.27	9.34	0.47	5.18
CBR	17.075	229.582	15.152	1.53	-2	1.8	69.88	0.56	1.95
Mropt	22932	7.80E+07	8867	0.39	-2	7474	40037	1.12	1.24
Mreq	4.182	0.159	0.398	0.29	-0.53	3.304	5.427	2.44	3.46

Soil Name	SFGM								
Analysis	L3B								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.023	295.422	17.188	N/A	N/A	35.5	99	0.86	1.37
PI	5.873	8.413	2.901	N/A	N/A	0	10	1.1	0.78
wPI	3.634	4.981	2.232	N/A	N/A	0	9.76	1.29	2.18
Wopt	12.011	5.643	2.375	-0.06	-1.13	8.39	16.85	0.9	1.2
Gamma	118.6	21.641	4.652	-0.25	-1.1	109.1	125.67	1.2	0.9
Suction	62.4	2404	49.035	2.97	15.5	12	784	0.92	13.23
SWCC A	80.362	169.91	13.035	-0.1	-1.01	55.2	107	1.43	1.51
SWCC B	0.9	0.013	0.114	0.28	-0.94	0.689	1.139	1.33	1.52
SWCC C	0.4	0.007	0.086	0.1	-1.01	0.225	0.565	1.51	1.43
Vol Cont	27.218	19.076	4.368	0.62	0.29	14	44.9	4.83	6.46
Sat Vol Cont	29.022	11.399	3.376	0.11	-0.62	20	39.2	3.33	3.76
%S	89.541	134.78	11.61	-0.9	-0.19	43.6	100	2.09	0.48
Sopt	78.318	0.74	0.86	2.57	16.6	74	87.3	16.41	34.32
Fenv	0.725	0.231	0.481	2.28	6.23	0.28	4.14	0.64	4.94
CBR	25.542	175.423	13.245	1.16	-2	2.97	69.8	1.59	3.11
Mropt	29696	3.20E+07	5696	0.07	-2	10086	40037	3.44	1.81
Mreq	4.245	0.071	0.267	0.37	-0.57	3.57	5.145	3.23	4.31

Soil Name	CFGM								
Analysis	L3B								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.209	266.317	16.319	N/A	N/A	35.6	100	1.64	1.1
PI	20.999	81.069	9.004	N/A	N/A	10.5	75	0.98	5.02
wPI	16.124	80.837	8.991	N/A	N/A	3.89	66.24	1.29	5.29
Wopt	19.104	10.933	3.307	0.22	-0.66	12.75	29.46	1.91	3.11
Gamma	104.7	42.586	6.526	-0.35	-0.59	84.78	117.13	2.96	1.85
Suction	406	317589	564	4.48	32	20	9271	0.41	9.35
SWCC A	118.702	346.811	18.623	-0.12	-0.75	77.1	166.2	2.2	2.51
SWCC B	0.626	0.013	0.114	0.45	-0.56	0.388	0.922	1.95	2.43
SWCC C	0.158	0.012	0.109	0.47	-0.87	0.01	0.422	0.81	1.46
Vol Cont	33.127	27.024	5.198	-0.14	-0.18	14.1	48.6	5.44	4.43
Sat Vol Cont	37.375	17.309	4.16	0.25	-0.51	26.5	51	3.33	4.17
%S	86.53	166.572	12.906	-0.7	-0.42	36.5	100	2.4	0.65
Sopt	85.359	8.052	2.838	-0.62	0.16	74.1	93.7	6.1	4.5
Fenv	1.155	0.931	0.965	2.21	5.57	0.27	8.11	0.63	4.96
CBR	7.654	15.35	3.918	0.88	-2	1.77	19.58	1.18	2.39
Mropt	16699	2.10E+07	4655	0.38	-2	7393	28006	1.74	2.12
Mreq	4.136	0.129	0.359	0.22	-0.73	3.312	5.172	2.49	3.13

Soil Name	A-1-b(GB)								
Analysis	L3A								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.973	39.35	6.27	N/A	N/A	0.2	25	1.5	1.41
PI	1.159	3.59	1.89	N/A	N/A	0	6	0.11	0.46
wPI	0.206	0.17	0.41	N/A	N/A	0	1.5	0.08	0.51
Wopt	6.321	2.668	1.633	-0.87	0.84	0.684	13.327	7.68	6.1
Gamma	128.50	51.264	7.16	0.84	0.66	95.02	149.988	7.94	5.09
Suction	30	190	14	1.59	3.39	11	151	1.49	9.57
Vol Cont	12.286	3.189	10.169	-0.27	-0.89	5.05	18.602	1.86	1.63
Sat Vol Cont	23.096	5.195	26.98	-0.02	-0.18	3.087	40.924	6.46	5.76
%S	55.61	373.12	19.316	0.53	-0.31	15.02	100	1.83	2
Sopt	71.379	97.894	9.894	0.6	1.19	35.9	100	5.19	4.18
Fenv	1.301	0.253	0.503	2.44	9.03	0.269	5.291	3.13	12.11
CBR	52.191	95.415	9.768	-0.1	-2	24.38	69.91	2.54	1.62
Mropt	38626	2.0E6	1440	-1.16	-2	30807	40037	3.66	0.66
Mreq	4.669	0.03	0.174	-0.28	-0.22	4.048	5.159	5.06	3.99
Soil Name	A-2-4(GSB)								
Analysis	L3A								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24.004	46.64	6.83	N/A	N/A	2.8	35.4	2.72	1.46
PI	4.632	10.48	3.24	N/A	N/A	0	10	0.63	0.73
wPI	1.272	0.84	0.92	N/A	N/A	0	3.5	0.85	1.49
Wopt	5.924	1.446	1.202	0.76	-0.45	0.76	13.13	14.89	6.46
Gamma	123.4	3.626	1.904	-0.24	1.44	110.7	144.84	27.4	46.41
Suction	36	365	19.1	1.98	5.99	12	198	1.31	8.57
SWCC A	63.308	24.446	4.944	0.16	-1.09	55.2	73.5	1.06	1.34
SWCC B	1.055	0.003	0.05	-0.09	-1.12	0.954	1.139	1.29	1.09
SWCC C	0.512	0.001	0.032	-0.16	-1.09	0.445	0.565	1.34	1.06
Vol Cont	18.816	15.124	3.889	0.04	-0.13	6.7	31.7	4.49	4.78
Sat Vol Cont	25.988	5.081	2.254	-0.05	-0.24	17.4	35.3	7.14	7.71
%S	72.673	244.165	15.62	-0.04	-0.72	25.8	100	2.68	1.56
Sopt	71.344	0.783	0.885	-1.9	24.62	58.2	86.5	117.45	135.87
Fenv	1.062	0.281	0.53	1.59	3.3	0.26	4.18	1.61	6.28
CBR	40.346	210.341	14.50	0.25	-2	12.32	94.91	2.13	4.14
Mropt	35468	1.72E7	4154	-1.18	-2	22376	40037	1.83	0.64
Mreq	4.517	0.052	0.228	-0.15	-0.56	3.826	5.132	3.8	3.39

Soil Name A-4(SFGM)
Analysis L3A

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.023	295.249	17.183	N/A	N/A	35.5	99	0.86	1.37
PI	5.873	7.96	2.821	N/A	N/A	0	10	1.2	0.84
wPI	3.634	4.852	2.203	N/A	N/A	0	9.76	1.34	2.25
Wopt	12.046	5.559	2.358	-0.08	-1.12	8.39	16.86	0.93	1.23
Gamma	118.5	21.391	4.625	-0.23	-1.1	109.09	125.67	1.22	0.93
Suction	62	2225	47.17	2.78	13.04	12	678	0.94	11.76
SWCC A	80.236	167.559	12.945	-0.09	-1	55.2	107	1.45	1.55
SWCC B	0.901	0.013	0.114	0.28	-0.94	0.69	1.139	1.36	1.54
SWCC C	0.401	0.007	0.085	0.09	-1	0.226	0.565	1.55	1.45
Vol Cont	27.245	18.651	4.319	0.63	0.38	14	44.9	4.92	6.58
Sat Vol Cont	29.064	11.12	3.335	0.1	-0.59	20.1	39.7	3.46	4.11
%S	89.544	135.345	11.634	-0.91	-0.17	45.4	100	1.95	0.46
Sopt	78.319	0.699	0.836	2.67	17.28	74.1	86.3	16.57	31.14
Fenv	0.71	0.214	0.463	2.23	5.94	0.28	3.7	0.62	4.33
CBR	25.559	173.499	13.172	1.17	-2	0	69.89	2.02	3.51
Mropt	29719	32410500	5693	-0.04	-2	129	40037	6.24	2.18
Mreq	4.241	0.07	0.265	0.35	-0.51	3.259	5.047	5.67	4.65

Soil Name A-6(CFGM)
Analysis L3A

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.209	269	16.39	N/A	N/A	35.6	98.2	1.51	0.94
PI	20.999	8.83	2.97	N/A	N/A	10.5	29	4.84	3.69
wPI	16.124	11.5	3.39	N/A	N/A	3.89	24.38	4.65	3.14
Wopt	19.635	1.791	1.338	-0.61	0.05	13.79	22.32	5.32	2.44
Gamma	103.7	6.859	2.619	0.47	-0.26	98.44	112.99	2.18	3.91
Suction	365	102789	320.61	2.71	11.37	32	4423	0.92	11.25
SWCC A	122.942	56.205	7.497	-0.83	0.63	82.9	137	6.65	2.33
SWCC B	0.592	0.002	0.044	1.05	1.36	0.516	0.871	2.12	7.69
SWCC C	0.121	0.002	0.049	0.83	0.63	0.029	0.383	2.33	6.65
Vol Cont	33.988	8.183	2.861	-0.19	-0.17	23	42.1	5.7	4.2
Sat Vol Cont	38.039	4.274	2.067	-0.12	-0.2	30.3	45	6.07	5.49
%S	89.062	64.94	8.059	-0.38	-0.63	59.3	100	2.93	1.08
Sopt	85.908	8.675	2.945	-0.18	-0.59	76.2	91.8	3.47	2.1
Fenv	0.927	0.223	0.472	1.59	2.84	0.29	3.79	1.31	5.88
CBR	6.155	1.913	1.383	1.4	-2	4.03	14.85	1.69	6.94
Mropt	15285	3366510	1835	1.01	-2	12081	24569	2.01	5.83
Mreq	4.094	0.05	0.224	0.02	-0.7	3.568	4.76	2.65	3.36

Soil Name A-6(FGM)
Analysis L3A

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.454	269	16.39	N/A	N/A	35.6	98.2	1.35	1.3
PI	13.801	8.83	2.97	N/A	N/A	10.5	29	0.84	3.85
wPI	10.179	11.5	3.39	N/A	N/A	3.885	24.375	2.08	4.69
Wopt	16.93	3.053	1.747	0.04	-0.63	12.77	22.065	2.68	3.31
Gamma	108.934	11.686	3.418	-0.14	-0.63	99.08	116.97	3.18	2.6
Suction	186	30365	174	3.41	19.65	19.90	2523.8	0.78	11.01
SWCC A	106.755	124.461	11.156	-0.16	-0.61	77.28	136.18	2.99	2.98
SWCC B	0.695	0.006	0.076	0.38	-0.46	0.519	0.92	2.56	3.28
SWCC C	0.227	0.005	0.073	0.16	-0.61	0.034	0.42	2.98	2.99
Vol Cont	31.17	9.762	3.124	-0.17	-0.1	19.01	40.852	6.15	4.9
Sat Vol Cont	34.825	6.29	2.508	0.08	-0.34	26.13	44.21	5.75	6.21
%S	88.837	85.803	9.263	-0.52	-0.56	55.90	100	2.45	0.83
Sopt	84.931	5.856	2.42	-0.11	-0.17	75.5	93.381	6.65	5.96
Fenv	0.909	0.264	0.514	1.68	2.93	0.316	3.925	0.95	4.83
CBR	9.726	8.562	2.926	0.66	-2	4.321	19.351	1.83	3.25
Mropt	19495	9466960	3076.84	0.29	-2	12574	27855	2.32	2.8
Mreq	4.179	0.058	0.242	0.19	-0.73	3.612	4.91	2.67	3.44

Soil Name (GB)5
Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.1	128.86	1.42	1.42
Suction	42.31	446	21	1.67	3.72	13.35	189.23	1.41	7.14
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	15.71	6.87	2.6218	0.11	-0.45	8.18	24.08	3.87	4.3
Sat Vol Cont	25.01	2.83	1.6821	-0.02	-0.69	20.62	29.21	2.83	2.7
%S	63.18	128.97	11.36	0.2	-0.33	32.5	100	3.53	4.23
Sopt	67.54	0.914	0.956	0.06	-1.02	65.72	69.49	1.39	1.48
Fenv	1.08	0.028	0.166	0.34	-0.39	0.68	1.7	3.09	4.88
Mropt	31443	762430	873	N/A	N/A	29732	33154	1.42	1.42
Mreq	4.523	0.00462	0.068	-0.06	-0.51	4.326	4.723	3.74	3.78

Soil Name (GB)35

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	42.27	436	21	1.68	3.9	13.05	188.88	1.47	7.36
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	15.75	6.76	2.5992	0.12	-0.42	7.82	24.23	4.33	4.63
Sat Vol Cont	25.01	2.87	1.6933	-0.02	-0.71	20.68	29.19	2.7	2.61
%S	63.27	128.76	11.35	0.18	-0.31	32.38	100	3.57	4.24
Sopt	67.55	0.913	0.955	0.05	-1.01	65.72	69.48	1.4	1.48
Fenv	1.08	0.028	0.166	0.36	-0.35	0.69	1.65	2.85	4.17
Mropt	37260	1070630	1035	N/A	N/A	35232	39288	1.42	1.42
Mreq	4.598	0.00472	0.0687	-0.07	-0.55	4.399	4.788	3.57	3.42

Soil Name (GB)50

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	42.57	455	21	1.65	3.51	13.29	185.76	1.4	6.83
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	15.75	6.91	2.6292	0.12	-0.46	8.26	24.12	3.81	4.26
Sat Vol Cont	25.02	2.83	1.6825	-0.02	-0.71	20.62	29.29	2.86	2.78
%S	63.33	130.77	11.44	0.2	-0.31	31.17	100	3.75	4.27
Sopt	67.54	0.914	0.956	0.07	-1.02	65.72	69.48	1.39	1.48
Fenv	1.07	0.028	0.167	0.4	-0.32	0.69	1.73	2.96	5.09
Mropt	37262	1070740	1035	N/A	N/A	35234	39290	1.42	1.42
Mreq	4.597	0.00479	0.0692	-0.01	-0.54	4.403	4.796	3.49	3.58

Soil Name (GB)75

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	42.51	444	21	1.66	3.53	13.24	180.53	1.42	6.69
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	15.7	6.73	2.5944	0.12	-0.46	7.98	23.96	4.09	4.38
Sat Vol Cont	25.03	2.82	1.6805	-0.03	-0.7	20.66	29.28	2.83	2.75
%S	63.05	126.81	11.26	0.16	-0.32	30.6	100	3.95	4.5
Sopt	67.55	0.905	0.952	0.04	-1	65.72	69.48	1.42	1.49
Fenv	1.08	0.027	0.166	0.39	-0.3	0.7	1.67	2.88	4.42
Mropt	39880	1226480	1107	N/A	N/A	37709	42051	1.42	1.42
Mreq	4.629	0.00458	0.0677	-0.04	-0.54	4.44	4.824	3.47	3.59

Soil Name (GB)95

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	42.2	435	21	1.65	3.59	12.75	190.26	1.5	7.53
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	15.7	6.77	2.6023	0.12	-0.45	8.22	24.41	3.98	4.64
Sat Vol Cont	24.99	2.78	1.6668	-0.01	-0.68	20.67	29.22	2.82	2.76
%S	63.14	128.29	11.33	0.22	-0.33	33.1	100	3.43	4.2
Sopt	67.54	0.91	0.954	0.06	-1.01	65.72	69.48	1.4	1.49
Fenv	1.08	0.027	0.165	0.33	-0.38	0.67	1.65	3.16	4.45
Mropt	40036	1236100	1112	N/A	N/A	37857	42215	1.42	1.42
Mreq	4.629	0.00463	0.068	-0.12	-0.5	4.428	4.819	3.72	3.51

Soil Name	(GSM)5								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	35.48	289	17	1.67	3.81	12.32	161.06	1.41	7.64
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	24.42	3.35	1.8312	-0.17	-0.25	17.06	29.66	6.13	4.37
Sat Vol Cont	26.58	2.66	1.632	-0.03	-0.72	22.24	30.65	2.91	2.73
%S	91.19	55.1	7.42	-0.55	-0.53	62.87	100	2.69	0.84
Sopt	70.39	0.212	0.46	-0.24	-1.01	69.39	71.17	1.49	1.16
Fenv	0.56	0.02	0.14	1.16	1.46	0.33	1.23	1.73	5.08
Mropt	21095	343171	586	N/A	N/A	19947	22243	1.42	1.42
Mreq	4.058	0.01138	0.1067	0.2	-0.64	3.824	4.388	2.41	3.39

Soil Name	(GSM)35								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	35.16	284	17	1.64	3.5	12.44	145.51	1.33	6.48
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	24.47	3.34	1.8278	-0.14	-0.3	16.79	29.72	6.57	4.48
Sat Vol Cont	26.59	2.67	1.6355	-0.03	-0.68	22.33	30.65	2.79	2.67
%S	91.33	54.77	7.4	-0.55	-0.53	61.13	100	2.94	0.84
Sopt	70.39	0.21	0.458	-0.24	-0.98	69.4	71.17	1.51	1.17
Fenv	0.56	0.02	0.142	1.28	1.98	0.33	1.34	1.72	6.03
Mropt	32449	811997	901	N/A	N/A	30683	34215	1.42	1.42
Mreq	4.242	0.01158	0.1076	0.29	-0.58	4.016	4.6	2.32	3.68

Soil Name	(GSM)50								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	35.33	280	17	1.6	3.35	11.91	142.58	1.43	6.55
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	24.44	3.32	1.822	-0.14	-0.26	17.14	29.53	6.01	4.18
Sat Vol Cont	26.58	2.67	1.6338	-0.02	-0.68	22.26	30.71	2.91	2.78
%S	91.2	54.8	7.4	-0.53	-0.56	62.72	100	2.73	0.84
Sopt	70.39	0.211	0.459	-0.24	-0.99	69.39	71.17	1.5	1.17
Fenv	0.56	0.02	0.14	1.18	1.59	0.33	1.25	1.78	5.36
Mropt	33653	873377	935	N/A	N/A	31821	35485	1.42	1.42
Mreq	4.26	0.01142	0.1069	0.21	-0.63	4.029	4.58	2.29	3.17

Soil Name	(GSM)75								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	35.33	289	17	1.68	3.75	12.2	154.85	1.39	7.17
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	24.46	3.33	1.8245	-0.12	-0.3	17.64	29.63	5.45	4.13
Sat Vol Cont	26.59	2.67	1.6341	-0.03	-0.68	22.31	30.72	2.86	2.76
%S	91.29	54.09	7.35	-0.55	-0.51	64.5	100	2.5	0.81
Sopt	70.4	0.213	0.461	-0.26	-0.99	69.39	71.17	1.49	1.14
Fenv	0.56	0.019	0.137	1.1	1.2	0.33	1.21	1.73	5.08
Mropt	38901	1167010	1080	N/A	N/A	36784	41018	1.42	1.42
Mreq	4.323	0.01118	0.1058	0.21	-0.65	4.094	4.664	2.41	3.57

Soil Name	(GSM)95								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	35.55	295	17	1.7	3.99	12.04	164.73	1.43	7.86
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	24.46	3.33	1.825	-0.13	-0.29	17.15	29.58	6.01	4.22
Sat Vol Cont	26.59	2.69	1.6406	-0.03	-0.7	22.28	30.73	2.88	2.76
%S	91.28	54.57	7.39	-0.55	-0.54	63.9	100	2.56	0.82
Sopt	70.39	0.213	0.461	-0.25	-0.99	69.39	71.17	1.49	1.16
Fenv	0.56	0.019	0.138	1.14	1.38	0.33	1.21	1.71	5.02
Mropt	39984	1232890	1110	N/A	N/A	37808	42160	1.42	1.42
Mreq	4.335	0.0112	0.1058	0.21	-0.64	4.102	4.648	2.35	3.15
Soil Name	(FGM)5								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	181.56	22634	150	2.57	10.09	22.77	1806.96	0.93	9.48
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	29.62	4.72	2.172	-0.18	-0.31	22.28	35.85	4.7	3.99
Sat Vol Cont	33.18	2.21	1.4875	-0.03	-0.7	29.37	36.99	2.78	2.78
%S	89.1	51.43	7.17	-0.26	-0.66	65.95	100	2.66	1.25
Sopt	83.59	1.86	1.364	-0.41	-0.84	80.37	85.74	1.63	1.09
Fenv	0.8	0.111	0.333	1.22	1.2	0.35	2.36	1.2	4.14
Mropt	9227	65656	256	N/A	N/A	8725	9729	1.42	1.42
Mreq	3.834	0.03093	0.1759	0.16	-0.82	3.49	4.309	1.8	2.48

Soil Name (FGM)35
Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	180.26	22412	150	2.76	12.2	23.95	1832.93	0.91	9.62
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	29.64	4.7	2.167	-0.18	-0.32	22.33	35.69	4.6	3.81
Sat Vol Cont	33.19	2.21	1.488	-0.04	-0.68	29.32	36.95	2.82	2.74
%S	89.14	51.15	7.15	-0.25	-0.67	65.23	100	2.8	1.27
Sopt	83.61	1.849	1.36	-0.42	-0.83	80.37	85.74	1.65	1.08
Fenv	0.8	0.111	0.334	1.27	1.39	0.35	2.37	1.18	4.12
Mropt	18357	259869	510	N/A	N/A	17358	19356	1.42	1.42
Mreq	4.133	0.0311	0.1763	0.17	-0.82	3.789	4.612	1.79	2.5

Soil Name (FGM)50
Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	183.02	22559	150	2.61	10.44	23.95	1755.12	0.93	9.16
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	29.59	4.69	2.1668	-0.17	-0.31	22.31	35.98	4.74	4.17
Sat Vol Cont	33.18	2.23	1.4945	-0.03	-0.72	29.3	36.97	2.83	2.77
%S	88.98	51.26	7.16	-0.23	-0.67	65.48	100	2.76	1.29
Sopt	83.6	1.873	1.368	-0.42	-0.84	80.37	85.74	1.62	1.07
Fenv	0.81	0.113	0.336	1.24	1.3	0.35	2.48	1.22	4.5
Mropt	22927	405361	637	N/A	N/A	21679	24175	1.42	1.42
Mreq	4.232	0.03061	0.175	0.18	-0.79	3.889	4.732	1.87	2.73

Soil Name (FGM)75
Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	180.82	22426	150	2.57	10.13	24.31	1806.33	0.91	9.44
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	29.6	4.66	2.1591	-0.17	-0.27	21.6	35.74	5.4	4.14
Sat Vol Cont	33.17	2.23	1.4942	-0.03	-0.71	29.31	36.94	2.79	2.73
%S	89.14	50.84	7.13	-0.27	-0.62	64.19	100	3.02	1.31
Sopt	83.61	1.854	1.362	-0.41	-0.86	80.37	85.74	1.64	1.08
Fenv	0.8	0.112	0.335	1.3	1.58	0.35	2.56	1.25	4.84
Mropt	30347	710204	843	N/A	N/A	28695	31999	1.42	1.42
Mreq	4.352	0.03032	0.1741	0.17	-0.76	4.005	4.841	1.9	2.69

Soil Name (FGM)95
Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	180.72	22724	151	2.73	12	22.69	1762.15	0.91	9.09
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	29.61	4.67	2.1612	-0.15	-0.35	21.81	35.61	5.1	3.93
Sat Vol Cont	33.18	2.22	1.4912	-0.04	-0.7	29.28	36.9	2.82	2.7
%S	89.2	50.95	7.14	-0.27	-0.61	63.37	100	3.15	1.32
Sopt	83.6	1.871	1.368	-0.42	-0.85	80.37	85.74	1.62	1.07
Fenv	0.8	0.113	0.336	1.35	1.78	0.35	2.55	1.21	4.74
Mropt	37431	1080470	1039	N/A	N/A	35394	39468	1.42	1.42
Mreq	4.439	0.0307	0.1752	0.2	-0.78	4.099	4.941	1.84	2.72

Soil Name (SFGM)5

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	58.71	1221	35	2.02	6.02	15.26	340.86	1.21	7.83
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	28.09	3.29	1.8137	-0.09	-0.33	21.57	33.14	5.08	3.94
Sat Vol Cont	30.97	2.36	1.537	-0.03	-0.68	26.98	34.77	2.78	2.64
%S	90.5	44.62	6.68	-0.32	-0.64	67.83	100	2.7	1.13
Sopt	78.69	0.584	0.764	-0.58	-0.67	76.74	79.76	1.66	0.92
Fenv	0.6	0.046	0.214	1.24	1.29	0.3	1.59	1.29	4.2
Mropt	19408	290478	539	N/A	N/A	18352	20464	1.42	1.42
Mreq	4.044	0.02192	0.1481	0.2	-0.77	3.747	4.463	1.94	2.74

Soil Name (SFGM)35

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	59.16	1233	35	2.04	6.42	14.84	355.68	1.26	8.4
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	28.09	3.33	1.8255	-0.09	-0.33	21.33	33.38	5.47	4.28
Sat Vol Cont	30.97	2.39	1.5458	-0.03	-0.69	26.87	34.9	2.93	2.81
%S	90.54	45.44	6.74	-0.34	-0.66	68.02	100	2.6	1.09
Sopt	78.68	0.589	0.767	-0.57	-0.69	76.74	79.76	1.64	0.92
Fenv	0.61	0.047	0.216	1.25	1.35	0.31	1.6	1.24	4.13
Mropt	27760	594279	771	N/A	N/A	26249	29271	1.42	1.42
Mreq	4.199	0.022	0.1483	0.23	-0.77	3.91	4.635	1.88	2.84

Soil Name	(SFGM)50								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	58.95	1236	35	2.04	6.15	13.89	344.44	1.28	8.12
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	28.12	3.31	1.8196	-0.09	-0.36	21.85	33.34	4.85	4.04
Sat Vol Cont	30.98	2.36	1.5357	-0.04	-0.7	26.94	34.84	2.88	2.74
%S	90.6	44.26	6.65	-0.32	-0.67	68.21	100	2.65	1.11
Sopt	78.69	0.582	0.763	-0.58	-0.66	76.75	79.76	1.67	0.93
Fenv	0.6	0.044	0.21	1.22	1.29	0.31	1.57	1.26	4.14
Mropt	29725	681394	825	N/A	N/A	28107	31343	1.42	1.42
Mreq	4.227	0.02146	0.1465	0.22	-0.78	3.942	4.669	1.9	2.95

Soil Name	(SFGM)75								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	58.94	1259	35	2.07	6.44	14.32	385.55	1.27	9.3
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	28.1	3.38	1.8378	-0.04	-0.35	21.43	33.56	5.38	4.41
Sat Vol Cont	30.97	2.41	1.5514	-0.02	-0.71	26.99	34.93	2.78	2.77
%S	90.51	45.15	6.72	-0.33	-0.64	66.93	100	2.82	1.14
Sopt	78.68	0.591	0.769	-0.57	-0.69	76.75	79.76	1.63	0.91
Fenv	0.61	0.047	0.216	1.28	1.53	0.31	1.68	1.26	4.55
Mropt	34157	899728	949	N/A	N/A	32298	36016	1.42	1.42
Mreq	4.29	0.02179	0.1476	0.27	-0.7	4.004	4.743	1.91	3.04

Soil Name (SFGM)95

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	59	1228	35	2.04	6.46	14.12	372.9	1.31	9.17
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	28.1	3.4	1.8438	-0.06	-0.35	21.65	33.48	5.03	4.19
Sat Vol Cont	30.97	2.38	1.5438	-0.03	-0.69	26.96	34.9	2.83	2.78
%S	90.51	45.49	6.74	-0.33	-0.67	67.13	100	2.76	1.12
Sopt	78.69	0.586	0.766	-0.58	-0.67	76.75	79.76	1.65	0.91
Fenv	0.61	0.047	0.217	1.29	1.51	0.31	1.68	1.22	4.49
Mropt	37849	1104740	1051	N/A	N/A	35789	39909	1.42	1.42
Mreq	4.336	0.02246	0.1499	0.28	-0.73	4.051	4.771	1.79	2.73

Soil Name (CFGM)5

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	374.38	133753	366	3.21	16.97	30.03	5303.09	0.76	10.93
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	33.16	7.16	2.6751	-0.32	-0.32	22.53	40.01	5.57	3.59
Sat Vol Cont	37.55	1.94	1.3917	-0.03	-0.71	33.96	41.02	2.76	2.68
%S	88.17	55.9	7.48	-0.32	-0.49	61.66	100	3.19	1.42
Sopt	85.7	5.434	2.331	-0.3	-0.94	80.47	89.61	1.58	1.18
Fenv	0.95	0.186	0.431	1.33	1.83	0.34	3.44	1.4	5.74
Mropt	9476	69247	263	N/A	N/A	8960	9992	1.42	1.42
Mreq	3.911	0.03731	0.1932	0.08	-0.74	3.495	4.451	2.19	2.84

Soil Name	(CFGM)35								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	376.68	132508	364	2.97	13.53	31.66	4819.37	0.76	9.81
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	33.13	7.05	2.6556	-0.29	-0.31	23.22	40.06	5.14	3.6
Sat Vol Cont	37.54	1.94	1.3941	-0.04	-0.7	33.91	41.03	2.82	2.71
%S	88.21	54.79	7.4	-0.28	-0.56	62.06	100	3.19	1.44
Sopt	85.7	5.484	2.342	-0.29	-0.96	80.47	89.61	1.56	1.16
Fenv	0.94	0.178	0.422	1.31	1.73	0.34	3.2	1.39	5.22
Mropt	14357	158957	399	N/A	N/A	13576	15138	1.42	1.42
Mreq	4.091	0.03642	0.1908	0.03	-0.76	3.676	4.597	2.15	2.62

Soil Name	(CFGM)50								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	377.92	133823	366	2.99	13.83	28.76	4720.21	0.77	9.56
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	33.14	7.22	2.6863	-0.29	-0.36	23.77	40.25	4.68	3.55
Sat Vol Cont	37.55	1.94	1.3945	-0.01	-0.7	33.9	41.04	2.83	2.71
%S	88.23	56.19	7.5	-0.26	-0.64	63.31	100	2.87	1.35
Sopt	85.74	5.345	2.312	-0.31	-0.91	80.47	89.6	1.62	1.19
Fenv	0.95	0.183	0.428	1.28	1.52	0.35	3.17	1.33	4.92
Mropt	16656	213948	463	N/A	N/A	15750	17563	1.42	1.42
Mreq	4.155	0.03753	0.1937	0.06	-0.79	3.746	4.676	2.06	2.62

Soil Name	(CFGM)75								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	373.01	124212	352	2.95	14.37	34.26	5521.66	0.81	12.24
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	33.12	6.84	2.6148	-0.31	-0.32	23.74	39.96	4.85	3.53
Sat Vol Cont	37.55	1.94	1.3932	-0.03	-0.72	33.93	41	2.78	2.66
%S	88.18	53.64	7.32	-0.24	-0.59	63.15	100	3.07	1.45
Sopt	85.72	5.374	2.318	-0.3	-0.93	80.48	89.6	1.6	1.18
Fenv	0.95	0.174	0.417	1.25	1.55	0.34	3.24	1.46	5.51
Mropt	20166	313611	560	N/A	N/A	19068	21264	1.42	1.42
Mreq	4.238	0.03571	0.189	0.03	-0.75	3.821	4.76	2.27	2.83

Soil Name	(CFGM)95								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	367.96	124604	353	3.03	14.42	30.41	5082.45	0.79	10.98
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	33.19	6.89	2.6255	-0.29	-0.33	23.8	40.04	4.82	3.51
Sat Vol Cont	37.56	1.94	1.3936	-0.04	-0.7	33.93	41.04	2.81	2.7
%S	88.28	54.69	7.4	-0.27	-0.58	62.24	100	3.16	1.42
Sopt	85.71	5.344	2.312	-0.3	-0.93	80.48	89.61	1.61	1.2
Fenv	0.94	0.178	0.422	1.32	1.81	0.35	3.23	1.38	5.28
Mropt	24558	465091	682	N/A	N/A	23221	25895	1.42	1.42
Mreq	4.32	0.03605	0.1899	0.06	-0.74	3.907	4.859	2.25	2.93

Location	McAlester OK								
Time	157.293	Sec							
Variable	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
Py	78.275	238.807	15.453	0.17	-0.06	26.07	138.64	5.656	6.541
Hy	81.728	10.04	3.169	0.08	-0.14	70.11	93.85	6.37	6.647
PE	88.724	16.382	4.047	0.09	-0.17	75.5	103.5	5.159	5.765
TMI	1.392	180.281	13.427	0.12	-0.31	-39.7	52.37	4.739	5.88
Soil Name	GB								
Analysis	L3B								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.973	42.979	6.556	N/A	N/A	0	25	1.36	1.27
PI	1.159	3.084	1.756	N/A	N/A	0	6	0.16	0.66
wPI	0.206	0.117	0.342	N/A	N/A	0	1.5	0.18	1.1
Wopt	6.312	3.656	1.912	3.97	78.5	0.37	66.35	15.57	111.4
Gamma	124.8	56.828	7.538	-1.89	22.4	18.6	150	37.27	8.85
Suction	23.298	172.147	13.121	0.42	0.11	4	91	1.49	5.22
Vol Cont	12.76	11.09	3.33	-0.26	-0.96	5.4	19.5	1.84	1.67
Sat Vol Cont	25.33	29.08	5.39	0.15	0	6.7	48.8	6.2	7.84
%S	52.517	325.122	18.031	0.56	-0.09	14.65	100	2.01	2.52
Sopt	69.813	107.165	10.352	0.16	3.2	0.12	100	13	5.63
Fenv	1.316	0.217	0.466	2.21	7.53	0.249	5.167	3.9	14.06
CBR	49.532	233.577	15.283	0.15	-2	23	109.8	1.78	4.05
Mropt	37504	8102470	2846.4	-1.16	-2	30075	40037	0.99	0.34
Mreq	4.664	0.026	0.162	-0.33	-0.09	3.969	5.113	6.6	4.25

Soil Name GSB

Analysis L3B

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24.004	76.382	8.74	N/A	N/A	0.3	35.4	1.71	0.82
PI	4.632	33.302	5.771	N/A	N/A	0	50	0.49	4.82
wPI	1.272	2.77	1.664	N/A	N/A	0	16.95	0.47	5.74
Wopt	11.803	3.656	1.912	1.42	2.55	0.24	18.9	11.29	11.5
Gamma	123	11.744	3.427	-1.75	69.6	4.27	149.69	219.7	49.4
Suction	23	157.147	12.536	4.6	56.6	9	400	1.09	30.3
SWCC A	73.695	165.291	12.857	0.63	-0.34	55.2	115.3	1.12	2.53
SWCC B	0.96	0.013	0.115	-0.4	-0.71	0.636	1.139	2.18	1.21
SWCC C	0.444	0.007	0.084	-0.63	-0.34	0.171	0.565	2.53	1.12
Vol Cont	19.255	21.903	4.68	-0.27	0.03	5.5	33.7	3.93	4.14
Sat Vol Cont	26.241	7.667	2.769	0.02	-0.06	15.7	37	6.83	7
%S	73.128	317.235	17.811	-0.17	-0.84	23.4	100	2.08	1.13
Sopt	70.47	6.201	2.49	-2.82	30.8	20.4	91	116.8	47.97
Fenv	1.051	0.332	0.576	2.22	7.22	0.17	5.32	1.76	8.56
CBR	37.825	341.798	18.488	0.17	-2	7	97.5	1.49	2.89
Mropt	33676	37598000	6132	-0.65	-2	16545	40037	1.38	0.51
Mreq	4.473	0.068	0.262	-0.27	-0.37	3.575	5.192	4.68	3.75

Soil Name FGM

Analysis L3B

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.454	330.286	18.174	N/A	N/A	35.5	100	1.06	1.08
PI	13.801	103.596	10.178	N/A	N/A	0	75	1.32	5.84
wPI	10.179	83.614	9.144	N/A	N/A	0	66.24	0.89	4.93
Wopt	5.556	22.779	4.773	0.15	-0.88	8.15	29.34	1.23	2.27
Gamma	111.5	88.551	9.41	-0.49	-0.62	85	135.71	3.27	2.98
Suction	108.2	23512	153.337	4.42	31.84	10	2661	0.36	9.31
SWCC A	106.02	609.789	24.694	-0.13	-0.85	55.2	166.2	1.84	2.18
SWCC B	0.716	0.03	0.174	0.53	-0.6	0.388	1.139	1.56	2.01
SWCC C	0.237	0.024	0.153	0.32	-0.98	0.01	0.565	0.89	1.28
Vol Cont	31.134	36.659	6.055	-0.03	-0.53	10.9	47.7	4.47	3.66
Sat Vol Cont	33.352	34.677	5.889	0.01	-0.54	16.4	49.7	3.54	3.42
%S	87.553	211.999	14.56	-0.99	-0.01	31.6	100	1.87	0.42
Sopt	82.117	8.934	2.989	3.4	15.27	69.1	100	10.5	14.47
Fenv	0.987	0.833	0.913	2.65	8.32	0.23	8.39	0.53	5.17
CBR	16.939	230.017	15.166	1.56	-2	1.73	69.91	0.56	1.94
Mropt	22815	78776800	8876	0.4	-2	7296	40037	1.13	1.26
Mreq	4.165	0.162	0.403	0.2	-0.6	3.233	5.361	2.58	3.3

Soil Name	SFGM								
Analysis	L3B								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.023	295.422	17.188	N/A	N/A	35.5	99	0.86	1.37
PI	5.873	8.413	2.901	N/A	N/A	0	10	1.1	0.78
wPI	3.634	4.981	2.232	N/A	N/A	0	9.76	1.29	2.18
Wopt	8.789	5.685	2.384	-0.08	-1.14	8.39	16.9	0.91	1.21
Gamma	118.5	21.895	4.679	-0.25	-1.1	109	125.67	1.21	0.9
Suction	34.7	411	20.262	2.29	8.5	10	254	1.22	10.88
SWCC A	80.252	170.66	13.064	-0.09	-1.01	55.2	107	1.41	1.51
SWCC B	0.901	0.013	0.115	0.27	-0.95	0.69	1.139	1.33	1.5
SWCC C	0.401	0.007	0.086	0.09	-1.01	0.226	0.565	1.51	1.41
Vol Cont	28.037	17.555	4.19	0.62	0.27	16.8	45	3.94	5.92
Sat Vol Cont	29.027	11.383	3.374	0.1	-0.58	19.8	38.7	3.32	3.47
%S	91.239	111.918	10.579	-1.04	0.09	51.6	100	1.72	0.38
Sopt	78.423	0.702	0.838	2.28	16.43	69.1	86.5	57.35	49.42
Fenv	0.654	0.157	0.396	2.24	5.94	0.28	3.19	0.64	4.35
CBR	25.508	176.769	13.296	1.18	-2	2.97	69.88	1.57	3.09
Mropt	29672	32286100	5682	0.1	-2	10086	40037	3.46	1.83
Mreq	4.214	0.06	0.246	0.39	-0.48	3.542	5.045	3.69	4.56
Soil Name	CFGM								
Analysis	L3B								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.209	266.317	16.319	N/A	N/A	35.6	100	1.64	1.1
PI	20.999	81.069	9.004	N/A	N/A	10.5	75	0.98	5.02
wPI	16.124	80.837	8.991	N/A	N/A	3.89	66.24	1.29	5.29
Wopt	19.117	10.887	3.299	0.23	-0.63	12.74	29.1	1.89	2.96
Gamma	104.7	41.099	6.411	-0.32	-0.63	85.99	117.11	2.8	1.85
Suction	174	36278	190	3.59	21.85	17	2986	0.59	10.54
SWCC A	118.753	347.297	18.636	-0.12	-0.75	77	167.3	2.23	2.6
SWCC B	0.625	0.013	0.114	0.46	-0.55	0.384	0.922	2.01	2.46
SWCC C	0.157	0.012	0.109	0.48	-0.86	0.01	0.422	0.81	1.45
Vol Cont	34.501	19.979	4.47	0.01	-0.26	19.2	48.8	5.15	4.82
Sat Vol Cont	37.414	16.75	4.093	0.19	-0.56	26.4	50.7	3.54	4.26
%S	89.59	116.766	10.806	-0.8	-0.33	49.1	100	2.08	0.53
Sopt	85.463	6.829	2.613	-0.57	0.07	75.2	93.8	6.36	5.14
Fenv	0.952	0.496	0.705	2.16	5.06	0.28	5.49	0.66	4.47
CBR	7.626	15.456	3.931	0.9	-2	1.68	19.58	1.19	2.4
Mropt	16658	21823300	4672	0.39	-2	7171	28007	1.79	2.14
Mreq	4.076	0.103	0.321	0.23	-0.66	3.318	5.039	2.67	3.39

Soil Name A-1-b(GB)

Analysis L3A

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.973	39.35	6.27	N/A	N/A	0.2	25	1.5	1.41
PI	1.159	3.59	1.89	N/A	N/A	0	6	0.11	0.46
wPI	0.206	0.17	0.41	N/A	N/A	0	1.5	0.08	0.51
Wopt	7.135	2.771	1.665	-0.8	0.79	0.824	13.631	7.37	6.35
Gamma	128.59	52.042	7.214	0.78	0.61	95.17	149.9	7.77	4.98
Suction	19	36	6	1.44	2.99	10	73	1.95	11.21
Vol Cont	12.787	3.183	10.131	-0.27	-0.87	5.49	19.215	1.93	1.7
Sat Vol Cont	23.013	5.2	27.039	-0.02	-0.2	5.001	43.264	5.88	6.61
%S	58.036	376.325	19.399	0.44	-0.49	16.284	100	1.82	1.83
Sopt	71.217	96.006	9.798	0.6	1.28	31.447	100	6.34	4.59
Fenv	1.253	0.224	0.474	2.5	9.83	0.273	5.255	3.24	13.24
CBR	52.121	94.956	9.745	-0.1	-2	24.353	70.607	2.65	1.76
Mropt	38618	2087240	1444.7	-1.15	-2	30793	40037	3.66	0.66
Mreq	4.654	0.029	0.17	-0.27	-0.25	4.032	5.134	5.27	4.06

Soil Name A-2-4(GSB)

Analysis L3A

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24.004	46.64	6.83	N/A	N/A	2.8	35.4	2.72	1.46
PI	4.632	10.48	3.24	N/A	N/A	0	10	0.63	0.73
wPI	1.272	0.84	0.92	N/A	N/A	0	3.5	0.85	1.49
Wopt	12.435	1.451	1.205	0.81	-0.61	2.16	13.09	11.53	5.91
Gamma	123.4	3.697	1.923	-0.23	2.9	105.81	147.11	47.75	64.11
Suction	22	70	8.39	1.76	5.1	10	103	1.81	11.62
SWCC A	63.415	24.397	4.939	0.15	-1.07	55.2	73.5	1.08	1.33
SWCC B	1.053	0.003	0.05	-0.08	-1.09	0.954	1.14	1.29	1.11
SWCC C	0.511	0.001	0.032	-0.15	-1.07	0.445	0.565	1.33	1.08
Vol Cont	19.402	15.925	3.991	0.06	-0.23	7.3	31.3	4.05	3.98
Sat Vol Cont	25.996	5.019	2.24	-0.04	-0.2	18	33.9	5.84	5.73
%S	74.729	245.989	15.684	-0.14	-0.77	30.1	100	2.29	1.3
Sopt	71.391	0.626	0.792	-1.79	11.65	63.1	82.6	62.47	84.46
Fenv	1.017	0.266	0.516	1.58	3.12	0.27	3.94	1.48	5.78
CBR	40.505	207.988	14.422	0.25	-2	12.32	91.52	2.1	3.81
Mropt	35533	16652100	4081	-1.16	-2	22376	40037	1.91	0.65
Mreq	4.498	0.054	0.231	-0.11	-0.64	3.839	5.116	3.41	3.19

Soil Name	A-4(SFGM)								
Analysis	L3A								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.023	295.249	17.183	N/A	N/A	35.5	99	0.86	1.37
PI	5.873	7.96	2.821	N/A	N/A	0	10	1.2	0.84
wPI	3.634	4.852	2.203	N/A	N/A	0	9.76	1.34	2.25
Wopt	12.043	5.561	2.358	-0.07	-1.12	8.39	16.86	0.93	1.23
Gamma	118.6	21.336	4.619	-0.25	-1.09	109.08	125.67	1.23	0.93
Suction	35	415	20.38	2.33	9.19	10	238	1.22	10
SWCC A	80.123	166.035	12.886	-0.08	-0.99	55.2	107.1	1.46	1.58
SWCC B	0.902	0.013	0.113	0.27	-0.93	0.689	1.139	1.39	1.55
SWCC C	0.402	0.007	0.085	0.08	-0.99	0.225	0.565	1.58	1.46
Vol Cont	27.979	17.259	4.154	0.69	0.46	17.4	45	3.6	5.78
Sat Vol Cont	29.04	11.022	3.32	0.09	-0.58	20.1	39.3	3.39	3.88
%S	91.206	109.768	10.477	-1.01	-0.02	52.2	100	1.74	0.39
Sopt	78.443	0.667	0.817	2.25	15.4	73.6	87.5	22.96	42.62
Fenv	0.662	0.156	0.395	2.15	5.43	0.29	2.99	0.64	3.95
CBR	25.621	173.011	13.153	1.14	-2	0	69.9	2.04	3.52
Mropt	29755	32418500	5694	-0.04	-2	24	40037	6.26	2.17
Mreq	4.221	0.062	0.248	0.34	-0.45	3.288	5.013	5.95	5.05
Soil Name	A-6(CFGM)								
Analysis	L3A								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.209	269	16.39	N/A	N/A	35.6	98.2	1.51	0.94
PI	20.999	8.83	2.97	N/A	N/A	10.5	29	4.84	3.69
wPI	16.124	11.5	3.39	N/A	N/A	3.89	24.38	4.65	3.14
Wopt	19.63	1.783	1.335	-0.61	0.12	13.33	22.35	6.02	2.6
Gamma	103.7	6.852	2.618	0.5	-0.17	98.45	114.58	2.36	4.95
Suction	164	12320	111	2.23	7.77	22	1194	1.31	9.54
SWCC A	122.934	57.35	7.573	-0.84	0.68	86.1	137	5.82	2.23
SWCC B	0.592	0.002	0.045	1.07	1.46	0.515	0.844	2.02	6.6
SWCC C	0.121	0.002	0.05	0.84	0.68	0.028	0.362	2.23	5.82
Vol Cont	35.412	5.424	2.329	-0.07	-0.23	26.8	43.3	6	5.52
Sat Vol Cont	38.047	4.384	2.094	-0.19	-0.1	29.9	45.2	6.58	5.72
%S	92.434	42.015	6.482	-0.56	-0.54	68.3	100	2.55	0.8
Sopt	85.929	8.756	2.959	-0.07	-0.52	76.4	92.9	3.78	2.77
Fenv	0.758	0.112	0.335	1.64	3.16	0.29	2.86	1.43	6.37
CBR	6.143	1.916	1.384	1.41	-2	4.04	16.09	1.73	8.18
Mropt	15267	3377000	1838	1.01	-2	12094	25549	2.04	6.62
Mreq	4.019	0.037	0.193	0.11	-0.62	3.56	4.625	2.78	3.66

Soil Name	A-6(FGM)								
Analysis	L3A								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.454	269	16.39	N/A	N/A	35.6	98.2	1.35	1.3
PI	13.801	8.83	2.97	N/A	N/A	10.5	29	0.84	3.85
wPI	10.179	11.5	3.39	N/A	N/A	3.885	24.375	2.08	4.69
Wopt	16.919	3.102	1.761	0.06	-0.65	12.775	21.966	2.59	3.15
Gamma	108.98	11.951	3.457	-0.15	-0.68	99.635	116.916	2.82	2.39
Suction	90	4222	65	2.91	15.7	17.706	1005.22	1.06	13.54
SWCC A	106.81	122.779	11.081	-0.14	-0.63	77.458	135.365	2.95	2.87
SWCC B	0.695	0.006	0.075	0.36	-0.49	0.524	0.918	2.49	3.25
SWCC C	0.227	0.005	0.073	0.14	-0.63	0.039	0.419	2.87	2.95
Vol Cont	32.33	7.17	2.678	0.07	-0.2	22.598	42.716	6.34	6.76
Sat Vol Cont	34.823	6.385	2.527	0.06	-0.34	27.311	44.636	4.57	5.97
%S	91.676	61.261	7.827	-0.67	-0.45	62.187	100	2.34	0.66
Sopt	84.951	5.904	2.43	-0.04	-0.35	76.883	92.605	4.85	4.61
Fenv	0.764	0.151	0.389	1.88	3.98	0.313	3.139	0.97	5.12
CBR	9.747	8.589	2.931	0.66	-2	4.284	19.535	1.87	3.35
Mropt	19517	9481620	3079.22	0.28	-2	12511	27976	2.38	2.87
Mreq	4.117	0.048	0.219	0.27	-0.61	3.618	4.823	2.64	3.74

Soil Name	(GB)5								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	27.42	87	9	1.44	3.33	11.93	96.4	2.07	9.2
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	17.11	5.67	2.3812	-0.13	-0.34	9.31	24.62	4.75	4.57
Sat Vol Cont	25.01	2.82	1.6794	-0.03	-0.69	20.64	29.24	2.83	2.73
%S	68.81	113.38	10.65	0.14	-0.33	36.94	100	3.93	3.84
Sopt	67.55	0.914	0.956	0.06	-1.01	65.72	69.48	1.39	1.48
Fenv	1	0.02	0.142	0.45	-0.25	0.67	1.52	2.89	4.62
Mropt	31443	762430	873	N/A	N/A	29732	33154	1.42	1.42
Mreq	4.492	0.00395	0.0629	0	-0.55	4.314	4.678	3.61	3.79

Soil Name (GB)35

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	27.43	87	9	1.45	3.28	12.03	88.9	1.98	7.9
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	17.13	5.66	2.38	-0.13	-0.37	9.75	24.76	4.39	4.54
Sat Vol Cont	25.01	2.83	1.6835	-0.03	-0.71	20.66	29.22	2.77	2.68
%S	68.82	113.98	10.68	0.16	-0.33	38.77	100	3.54	3.68
Sopt	67.56	0.911	0.955	0.07	-1	65.72	69.48	1.41	1.48
Fenv	1	0.02	0.142	0.4	-0.35	0.68	1.53	2.83	4.68
Mropt	37260	1070630	1035	N/A	N/A	35232	39288	1.42	1.42
Mreq	4.566	0.004	0.0632	0.01	-0.55	4.384	4.748	3.63	3.65

Soil Name (GB)50

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	27.44	85	9	1.4	3.08	12.06	95.72	2.09	9.27
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	17.12	5.52	2.3502	-0.12	-0.31	9.23	24.54	4.95	4.65
Sat Vol Cont	25	2.81	1.6757	-0.03	-0.69	20.65	29.2	2.81	2.71
%S	68.79	111.75	10.57	0.16	-0.25	37.39	100	3.9	3.87
Sopt	67.55	0.912	0.955	0.05	-1.02	65.72	69.49	1.4	1.48
Fenv	1	0.02	0.141	0.44	-0.25	0.67	1.55	3.07	5.17
Mropt	37262	1070740	1035	N/A	N/A	35234	39290	1.42	1.42
Mreq	4.565	0.00387	0.0622	0	-0.52	4.394	4.752	3.47	3.79

Soil Name (GB)75

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	27.53	89	9	1.48	3.45	12.22	91.37	1.93	8.03
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	17.08	5.68	2.3825	-0.12	-0.3	9.21	24.32	4.71	4.33
Sat Vol Cont	25.01	2.84	1.6855	-0.04	-0.69	20.54	29.23	2.9	2.74
%S	68.77	113.89	10.67	0.11	-0.34	38.22	100	3.65	3.73
Sopt	67.54	0.912	0.955	0.06	-1	65.72	69.48	1.39	1.49
Fenv	1	0.02	0.142	0.43	-0.26	0.68	1.58	2.94	5.36
Mropt	39880	1226480	1107	N/A	N/A	37709	42051	1.42	1.42
Mreq	4.595	0.00392	0.0626	0.04	-0.49	4.421	4.793	3.65	4.14

Soil Name (GB)95

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	27.48	87	9	1.46	3.4	12.2	89.57	1.96	7.94
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	17.09	5.57	2.3607	-0.13	-0.28	9.32	24.59	4.81	4.65
Sat Vol Cont	25	2.83	1.683	-0.02	-0.69	20.63	29.27	2.82	2.76
%S	68.65	112.41	10.6	0.14	-0.29	36.62	100	4.01	3.92
Sopt	67.55	0.921	0.96	0.05	-1.01	65.72	69.49	1.38	1.46
Fenv	1	0.02	0.141	0.44	-0.2	0.67	1.56	3.09	5.25
Mropt	40036	1236100	1112	N/A	N/A	37857	42215	1.42	1.42
Mreq	4.597	0.0039	0.0625	0.02	-0.5	4.419	4.779	3.63	3.69

Soil Name (GSM)5

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	21.59	53	7	1.5	3.34	9.75	78.09	2.02	9.62
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	25.12	2.88	1.6971	-0.09	-0.48	19	29.74	5.03	3.79
Sat Vol Cont	26.58	2.66	1.6307	-0.02	-0.69	22.29	30.62	2.84	2.68
%S	93.23	42.92	6.55	-0.73	-0.35	66.39	100	2.58	0.65
Sopt	70.39	0.211	0.46	-0.25	-1	69.39	71.17	1.5	1.17
Fenv	0.52	0.014	0.12	1.18	1.66	0.33	1.11	1.73	5.24
Mropt	21095	343171	586	N/A	N/A	19947	22243	1.42	1.42
Mreq	4.033	0.00948	0.0974	0.25	-0.61	3.823	4.347	2.39	3.58

Soil Name (GSM)35

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	21.59	53	7	1.48	3.08	10.39	75.96	1.79	8.67
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	25.11	2.85	1.6883	-0.06	-0.49	18.83	29.69	5.25	3.83
Sat Vol Cont	26.59	2.68	1.6372	-0.03	-0.71	22.31	30.72	2.84	2.75
%S	93.25	42.88	6.55	-0.75	-0.29	66.91	100	2.5	0.64
Sopt	70.4	0.211	0.459	-0.25	-0.99	69.39	71.17	1.51	1.16
Fenv	0.52	0.014	0.119	1.16	1.51	0.33	1.11	1.76	5.3
Mropt	32449	811997	901	N/A	N/A	30683	34215	1.42	1.42
Mreq	4.219	0.00923	0.0961	0.26	-0.59	4.01	4.528	2.41	3.58

Soil Name	(GSM)50								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	21.65	54	7	1.51	3.35	10.01	75.39	1.88	8.7
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	25.07	2.87	1.6946	-0.07	-0.46	18.5	29.59	5.54	3.81
Sat Vol Cont	26.55	2.7	1.6423	-0.01	-0.7	22.33	30.78	2.8	2.81
%S	93.15	44.12	6.64	-0.76	-0.27	67.85	100	2.3	0.62
Sopt	70.39	0.21	0.458	-0.25	-0.99	69.39	71.17	1.51	1.18
Fenv	0.53	0.015	0.121	1.11	1.29	0.33	1.1	1.77	5.1
Mropt	33653	873377	935	N/A	N/A	31821	35485	1.42	1.42
Mreq	4.236	0.00959	0.0979	0.25	-0.6	4.022	4.56	2.5	3.76

Soil Name	(GSM)75								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	21.68	54	7	1.47	3.05	9.97	81.49	1.96	10.03
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	25.11	2.84	1.6843	-0.07	-0.45	19.18	29.63	4.8	3.66
Sat Vol Cont	26.58	2.68	1.6372	-0.03	-0.7	22.28	30.64	2.84	2.68
%S	93.3	42.57	6.52	-0.74	-0.36	68.39	100	2.3	0.62
Sopt	70.39	0.211	0.459	-0.24	-0.99	69.39	71.17	1.51	1.17
Fenv	0.52	0.014	0.119	1.09	1.25	0.33	1.08	1.72	4.9
Mropt	38901	1167010	1080	N/A	N/A	36784	41018	1.42	1.42
Mreq	4.299	0.00934	0.0967	0.24	-0.59	4.086	4.606	2.45	3.54

Soil Name	(GSM)95								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	21.59	53	7	1.46	2.99	10.17	74.57	1.86	8.62
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	25.1	2.86	1.6901	-0.04	-0.49	18.95	29.7	5.1	3.81
Sat Vol Cont	26.58	2.68	1.6385	-0.03	-0.69	22.3	30.78	2.88	2.83
%S	93.21	43.24	6.58	-0.74	-0.34	66.61	100	2.53	0.65
Sopt	70.4	0.209	0.457	-0.27	-0.97	69.39	71.17	1.53	1.17
Fenv	0.52	0.014	0.118	1.12	1.48	0.33	1.1	1.77	5.2
Mropt	39984	1232890	1110	N/A	N/A	37808	42160	1.42	1.42
Mreq	4.311	0.00927	0.0963	0.25	-0.61	4.101	4.626	2.45	3.68
Soil Name	(FGM)5								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	88.44	3221	57	2.27	8.55	18.18	774.1	1.3	12.66
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	30.73	2.97	1.7235	-0.06	-0.34	24.54	35.99	5.39	4.58
Sat Vol Cont	33.17	2.24	1.4973	-0.03	-0.7	29.33	36.92	2.74	2.67
%S	92.29	33.8	5.81	-0.39	-0.67	72.86	100	2.46	0.98
Sopt	83.62	1.851	1.36	-0.42	-0.84	80.37	85.74	1.65	1.08
Fenv	0.66	0.055	0.235	1.3	1.46	0.35	1.84	1.21	4.52
Mropt	9227	65656	256	N/A	N/A	8725	9729	1.42	1.42
Mreq	3.761	0.02133	0.146	0.3	-0.72	3.486	4.183	1.75	2.68

Soil Name (FGM)35
Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	88.1	3215	57	2.28	8.56	18.1	684.47	1.26	10.73
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	30.76	2.93	1.7131	-0.06	-0.36	24.64	35.79	5.21	4.28
Sat Vol Cont	33.18	2.24	1.4959	-0.04	-0.71	29.2	36.9	2.91	2.72
%S	92.37	33.84	5.82	-0.43	-0.6	70.87	100	2.84	1.01
Sopt	83.61	1.852	1.361	-0.42	-0.84	80.37	85.74	1.65	1.08
Fenv	0.66	0.056	0.237	1.41	1.95	0.35	1.93	1.21	4.85
Mropt	18357	259869	510	N/A	N/A	17358	19356	1.42	1.42
Mreq	4.06	0.02183	0.1478	0.31	-0.68	3.789	4.53	1.77	3.07

Soil Name (FGM)50
Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	87.86	3095	56	2.17	7.4	17.76	666.76	1.31	10.8
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	30.73	2.94	1.7146	-0.06	-0.35	24.81	35.76	4.93	4.2
Sat Vol Cont	33.15	2.22	1.4908	-0.02	-0.69	29.28	36.97	2.84	2.8
%S	92.36	33.63	5.8	-0.39	-0.68	72.5	100	2.54	0.98
Sopt	83.61	1.846	1.359	-0.41	-0.84	80.38	85.74	1.64	1.08
Fenv	0.66	0.055	0.234	1.36	1.7	0.35	1.84	1.2	4.51
Mropt	22927	405361	637	N/A	N/A	21679	24175	1.42	1.42
Mreq	4.156	0.02111	0.1453	0.31	-0.68	3.881	4.598	1.82	2.93

Soil Name (FGM)75
Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	87.84	3205	57	2.31	9.05	16.84	688.98	1.3	11.02
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	30.74	2.95	1.7169	-0.04	-0.37	24.88	35.9	4.91	4.34
Sat Vol Cont	33.17	2.23	1.4946	-0.04	-0.69	29.3	36.89	2.77	2.67
%S	92.36	33.89	5.82	-0.41	-0.65	72.29	100	2.55	0.97
Sopt	83.61	1.834	1.354	-0.42	-0.83	80.37	85.74	1.67	1.09
Fenv	0.66	0.055	0.234	1.36	1.73	0.34	1.82	1.24	4.49
Mropt	30347	710204	843	N/A	N/A	28695	31999	1.42	1.42
Mreq	4.276	0.02157	0.1469	0.27	-0.73	3.994	4.705	1.82	2.78

Soil Name (FGM)95
Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	87.71	3148	56	2.25	8.38	18.28	694.27	1.27	11.11
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	30.75	2.96	1.7197	-0.04	-0.38	25.06	35.9	4.67	4.23
Sat Vol Cont	33.17	2.26	1.5027	-0.03	-0.72	29.31	36.91	2.74	2.65
%S	92.38	33.5	5.79	-0.39	-0.66	71.09	100	2.83	1.01
Sopt	83.61	1.852	1.361	-0.43	-0.83	80.37	85.74	1.64	1.08
Fenv	0.66	0.055	0.234	1.41	1.98	0.34	1.95	1.28	5.22
Mropt	37431	1080470	1039	N/A	N/A	35394	39468	1.42	1.42
Mreq	4.366	0.02144	0.1464	0.32	-0.65	4.092	4.852	1.89	3.34

Soil Name	(SFGM)5								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	33.29	210	14	1.78	4.91	11.3	159.33	1.82	10.4
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	29.04	2.46	1.57	-0.02	-0.48	24.05	33.77	4.4	4.18
Sat Vol Cont	30.98	2.37	1.5392	-0.04	-0.67	26.91	34.92	2.92	2.84
%S	93.11	32.95	5.74	-0.5	-0.63	73.42	100	2.31	0.81
Sopt	78.68	0.591	0.768	-0.57	-0.71	76.75	79.76	1.63	0.91
Fenv	0.53	0.026	0.162	1.32	1.6	0.3	1.29	1.23	4.19
Mropt	19408	290478	539	N/A	N/A	18352	20464	1.42	1.42
Mreq	3.99	0.01629	0.1276	0.31	-0.7	3.749	4.381	1.82	2.96

Soil Name	(SFGM)35								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	33.23	206	14	1.7	4.38	12.02	163.75	1.74	10.69
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	29.02	2.52	1.5879	0.02	-0.51	24.02	33.55	4.18	3.79
Sat Vol Cont	30.96	2.41	1.5522	-0.02	-0.71	26.94	34.87	2.8	2.72
%S	93.19	33.14	5.76	-0.53	-0.59	72.96	100	2.36	0.8
Sopt	78.68	0.591	0.768	-0.59	-0.68	76.75	79.76	1.63	0.91
Fenv	0.53	0.027	0.165	1.35	1.62	0.31	1.3	1.14	4.01
Mropt	27760	594279	771	N/A	N/A	26249	29271	1.42	1.42
Mreq	4.146	0.01676	0.1295	0.35	-0.69	3.91	4.551	1.73	2.98

Soil Name (SFGM)50
Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	33.25	210	14	1.78	4.96	12.23	155.3	1.65	9.59
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	29.05	2.5	1.5812	0	-0.53	24.19	33.48	3.98	3.62
Sat Vol Cont	30.98	2.4	1.5489	-0.04	-0.68	26.9	34.82	2.84	2.68
%S	93.18	32.74	5.72	-0.52	-0.58	73.5	100	2.3	0.8
Sopt	78.69	0.583	0.764	-0.58	-0.68	76.75	79.76	1.66	0.92
Fenv	0.53	0.027	0.163	1.33	1.52	0.31	1.26	1.16	3.89
Mropt	29725	681394	825	N/A	N/A	28107	31343	1.42	1.42
Mreq	4.176	0.0167	0.1292	0.32	-0.72	3.941	4.572	1.71	2.87

Soil Name (SFGM)75
Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	33.4	213	15	1.75	4.73	12.23	155.42	1.65	9.5
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	29.04	2.48	1.5758	-0.01	-0.5	23.62	33.46	4.76	3.89
Sat Vol Cont	30.98	2.39	1.5467	-0.03	-0.69	26.96	34.85	2.8	2.7
%S	93.19	33	5.74	-0.54	-0.55	72.59	100	2.44	0.81
Sopt	78.68	0.58	0.762	-0.57	-0.68	76.74	79.76	1.68	0.94
Fenv	0.53	0.028	0.167	1.38	1.79	0.31	1.36	1.17	4.43
Mropt	34157	899728	949	N/A	N/A	32298	36016	1.42	1.42
Mreq	4.236	0.01698	0.1303	0.39	-0.65	4.002	4.675	1.75	3.29

Soil Name	(SFGM)95								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	33.15	210	15	1.79	5.05	11.62	164.65	1.75	10.7
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	29.04	2.5	1.5799	-0.01	-0.52	24.17	33.53	4.04	3.72
Sat Vol Cont	30.97	2.38	1.5419	-0.04	-0.69	26.99	34.85	2.78	2.72
%S	93.17	32.75	5.72	-0.51	-0.61	73.3	100	2.34	0.8
Sopt	78.68	0.583	0.763	-0.56	-0.7	76.75	79.76	1.66	0.94
Fenv	0.53	0.027	0.164	1.31	1.51	0.3	1.3	1.22	4.21
Mropt	37849	1104740	1051	N/A	N/A	35789	39909	1.42	1.42
Mreq	4.283	0.01669	0.1292	0.32	-0.71	4.041	4.669	1.76	2.82

Soil Name	(CFGM)5								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	166.59	15806	126	2.5	10.44	23.2	1688.49	1.1	11.7
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	34.6	3.58	1.8925	-0.1	-0.29	27.91	40.14	5.11	4.23
Sat Vol Cont	37.54	1.94	1.394	-0.01	-0.72	33.92	41.07	2.82	2.76
%S	92.06	31.04	5.57	-0.35	-0.61	72.52	100	2.84	1.16
Sopt	85.71	5.337	2.31	-0.28	-0.93	80.47	89.6	1.62	1.2
Fenv	0.74	0.071	0.266	1.26	1.66	0.34	2.15	1.59	5.5
Mropt	9476	69247	263	N/A	N/A	8960	9992	1.42	1.42
Mreq	3.823	0.02277	0.1509	0.1	-0.7	3.488	4.267	2.38	3.15

Soil Name (CFGM)35

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	166.19	16061	127	2.6	11.2	21.47	1544.29	1.09	10.33
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	34.59	3.63	1.904	-0.13	-0.25	27.71	40.3	5.37	4.45
Sat Vol Cont	37.54	1.94	1.3913	-0.02	-0.71	33.86	41.06	2.91	2.79
%S	91.96	31.14	5.58	-0.33	-0.61	72.44	100	2.86	1.18
Sopt	85.74	5.322	2.307	-0.31	-0.91	80.48	89.6	1.63	1.19
Fenv	0.75	0.072	0.268	1.23	1.53	0.35	2.3	1.61	6.14
Mropt	14357	158957	399	N/A	N/A	13576	15138	1.42	1.42
Mreq	4.009	0.02265	0.1505	0.13	-0.67	3.677	4.478	2.43	3.43

Soil Name (CFGM)50

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	164.01	15034	123	2.4	9.1	23.51	1510.86	1.09	10.49
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	34.57	3.52	1.8766	-0.11	-0.28	27.54	40.17	5.67	4.51
Sat Vol Cont	37.52	1.95	1.3977	-0.02	-0.7	33.93	40.95	2.72	2.59
%S	91.99	31.22	5.59	-0.35	-0.6	72.56	100	2.82	1.16
Sopt	85.73	5.355	2.314	-0.3	-0.93	80.47	89.6	1.61	1.19
Fenv	0.75	0.07	0.265	1.24	1.6	0.35	2.05	1.53	4.94
Mropt	16656	213948	463	N/A	N/A	15750	17563	1.42	1.42
Mreq	4.067	0.02293	0.1514	0.13	-0.73	3.745	4.497	2.16	2.88

Soil Name	(CFGM)75								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	164.81	14635	121	2.36	8.87	23.49	1353.15	1.11	9.36
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	34.59	3.51	1.8738	-0.09	-0.31	27.85	40.06	5.24	4.26
Sat Vol Cont	37.53	1.93	1.3876	-0.01	-0.7	33.94	41.03	2.79	2.72
%S	92	30.3	5.5	-0.31	-0.61	71.56	100	3.16	1.24
Sopt	85.74	5.465	2.338	-0.32	-0.92	80.47	89.61	1.57	1.16
Fenv	0.75	0.07	0.264	1.26	1.71	0.35	2.24	1.61	5.98
Mropt	20166	313611	560	N/A	N/A	19068	21264	1.42	1.42
Mreq	4.152	0.02209	0.1486	0.15	-0.66	3.826	4.649	2.51	3.82

Soil Name	(CFGM)95								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	164.89	15422	124	2.46	9.83	23.59	1835.26	1.12	13.19
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	34.6	3.57	1.8887	-0.13	-0.27	27.63	39.9	5.31	4.03
Sat Vol Cont	37.55	1.94	1.3924	-0.03	-0.71	33.93	40.97	2.77	2.62
%S	92.01	31.6	5.62	-0.35	-0.62	72.36	100	2.82	1.15
Sopt	85.73	5.351	2.313	-0.31	-0.92	80.48	89.61	1.61	1.19
Fenv	0.75	0.073	0.271	1.24	1.45	0.35	2.07	1.48	4.81
Mropt	24558	465091	682	N/A	N/A	23221	25895	1.42	1.42
Mreq	4.241	0.02365	0.1538	0.12	-0.75	3.914	4.675	2.16	2.86

Location	Salem OR								
Time	166.564	Sec							
Variable	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
Py	106.096	356.108	18.871	0.15	-0.17	46.35	185.11	5.277	6.979
Hy	47.184	2.441	1.562	0.04	-0.18	41.64	53.51	6.254	7.135
PE	64.674	3.816	1.954	0.04	-0.15	57.98	71.89	5.609	6.051
TMI	57.678	464.991	21.564	0.02	-0.6	-5.77	100	2.864	1.911
Soil Name	GB								
Analysis	L3B								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.973	42.979	6.556	N/A	N/A	0	25	1.36	1.27
PI	1.159	3.084	1.756	N/A	N/A	0	6	0.16	0.66
wPI	0.206	0.117	0.342	N/A	N/A	0	1.5	0.18	1.1
Wopt	8.73	3.898	1.974	4.43	81.59	0	61.69	15.71	98.83
Gamma	124.6	58.308	7.636	-2.29	29.26	1.4	149.9	43.62	8.99
Suction	16.633	60.088	7.752	-0.34	-1.44	4	34	1.13	1.5
Vol Cont	14.46	11.38	3.37	-0.27	-0.9	6.4	21	2.03	1.65
Sat Vol Cont	25.46	29.52	5.43	0.16	-0.02	6.7	47.9	6.07	7.25
%S	59.18	349.23	18.688	0.41	-0.49	17.17	100	1.98	1.93
Sopt	69.511	103.592	10.178	0.05	3.81	0.02	100	13.52	5.93
Fenv	1.202	0.175	0.418	2.23	8.33	0.279	4.985	3.72	15.25
CBR	49.6	233.123	15.268	0.13	-2	23	109.9	1.8	4.08
Mropt	37517	8075490	2841.7	-1.17	-2	30075	40037	0.99	0.33
Mreq	4.627	0.025	0.158	-0.26	-0.22	4.056	5.114	5.44	4.64

Soil Name GSB

Analysis L3B

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24.004	76.382	8.74	N/A	N/A	0.3	35.4	1.71	0.82
PI	4.632	33.302	5.771	N/A	N/A	0	50	0.49	4.82
wPI	1.272	2.77	1.664	N/A	N/A	0	16.95	0.47	5.74
Wopt	8.051	3.563	1.888	1.47	2.57	0.06	22.44	13.98	19.28
Gamma	123	10.836	3.292	-0.38	18.65	44.77	149.8	143.3	49.15
Suction	10.4	11.114	3.334	3.37	22.41	7	58	0.87	12.28
SWCC A	73.814	163.84	12.8	0.58	-0.45	55.2	119.9	1.22	3.02
SWCC B	0.958	0.013	0.115	-0.36	-0.78	0.608	1.139	2.51	1.3
SWCC C	0.443	0.007	0.084	-0.58	-0.45	0.141	0.565	3.02	1.22
Vol Cont	20.696	19.729	4.442	-0.44	0.12	6.7	34.4	4.39	4.31
Sat Vol Cont	26.267	7.533	2.745	0	-0.09	15.5	38.4	7.71	8.63
%S	78.017	266.655	16.33	-0.31	-0.82	26.5	100	2.28	0.97
Sopt	70.514	5.182	2.276	-2.12	36.93	8.5	92.2	191.7	67.03
Fenv	0.923	0.21	0.458	2.16	7.94	0.18	4.49	2.03	9.67
CBR	37.678	343.075	18.522	0.19	-2	6.82	89.95	1.37	2.33
Mropt	33621	3.70E+07	6138	-0.63	-2	16303	40037	1.42	0.53
Mreq	4.433	0.058	0.24	-0.27	-0.33	3.594	5.152	5.1	4.37

Soil Name FGM

Analysis L3B

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.454	330.286	18.174	N/A	N/A	35.5	100	1.06	1.08
PI	13.801	103.596	10.178	N/A	N/A	0	75	1.32	5.84
wPI	10.179	83.614	9.144	N/A	N/A	0	66.24	0.89	4.93
Wopt	9.497	22.639	4.758	0.15	-0.85	8.39	29.58	1.19	2.28
Gamma	111.4	86.812	9.317	-0.51	-0.59	84.31	125.67	2.26	1.19
Suction	26.6	619	24.879	4	29.56	7	462	0.55	12.19
SWCC A	105.864	612.294	24.745	-0.12	-0.85	55.2	165.7	1.81	2.14
SWCC B	0.718	0.03	0.175	0.52	-0.6	0.39	1.139	1.54	1.99
SWCC C	0.238	0.024	0.154	0.31	-0.98	0.01	0.565	0.89	1.27
Vol Cont	32.546	32.324	5.685	0.25	-0.59	17.7	50.8	3.3	4.06
Sat Vol Cont	33.358	33.728	5.808	0.41	-0.56	21	52.9	2.38	3.76
%S	90.223	159.692	12.637	-1.15	0.29	40.3	100	1.72	0.34
Sopt	82.071	2.183	1.477	-1.02	1.24	69.1	85.8	16.53	4.83
Fenv	0.832	0.51	0.714	2.8	9.23	0.27	6.77	0.49	5.1
CBR	17.081	229.582	15.152	1.54	-2	1.75	69.9	0.57	1.96
Mropt	22944	7.80E+07	8848	0.39	-2	7353	40037	1.15	1.26
Mreq	4.123	0.132	0.363	0.29	-0.47	3.299	5.246	2.54	3.46

Soil Name	SFGM								
Analysis	L3B								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.023	295.422	17.188	N/A	N/A	35.5	99	0.86	1.37
PI	5.873	8.413	2.901	N/A	N/A	0	10	1.1	0.78
wPI	3.634	4.981	2.232	N/A	N/A	0	9.76	1.29	2.18
Wopt	12.046	5.622	2.371	-0.08	-1.13	8.39	16.9	0.92	1.23
Gamma	118.5	21.706	4.659	-0.25	-1.09	109	125.67	1.22	0.92
Suction	13.5	26	5.104	2.12	7.5	7	66	1.31	10.61
SWCC A	80.358	171.68	13.103	-0.08	-1.01	55.2	107.1	1.41	1.5
SWCC B	0.9	0.013	0.115	0.27	-0.95	0.689	1.14	1.33	1.5
SWCC C	0.4	0.007	0.086	0.08	-1.01	0.225	0.565	1.5	1.41
Vol Cont	29.187	17.892	4.23	0.68	0.35	19.4	45	2.9	4.71
Sat Vol Cont	29.069	11.268	3.357	0.1	-0.59	19.9	39.2	3.41	3.78
%S	93.28	84.99	9.219	-1.27	0.6	55.4	100	1.69	0.3
Sopt	78.386	0.729	0.854	2.64	16.73	73.7	87.4	19.62	37.67
Fenv	0.59	0.107	0.327	2.3	6.54	0.28	2.69	0.65	4.38
CBR	25.677	177.482	13.322	1.16	-2	2.97	69.91	1.58	3.08
Mropt	29754	3.20E+07	5690	0.07	-2	10086	40037	3.45	1.8
Mreq	4.183	0.052	0.228	0.41	-0.39	3.512	4.906	4.02	4.33
Soil Name	CFGM								
Analysis	L3B								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.209	266.317	16.319	N/A	N/A	35.6	100	1.64	1.1
PI	20.999	81.069	9.004	N/A	N/A	10.5	75	0.98	5.02
wPI	16.124	80.837	8.991	N/A	N/A	3.89	66.24	1.29	5.29
Wopt	19.106	10.999	3.316	0.22	-0.66	12.74	28.95	1.84	2.85
Gamma	104.7	42.459	6.516	-0.32	-0.63	85.67	117.12	2.76	1.8
Suction	38	877	30	3.32	18.67	10	455	0.78	11.59
SWCC A	118.762	348.983	18.681	-0.12	-0.76	77.1	167.1	2.21	2.56
SWCC B	0.625	0.013	0.115	0.46	-0.55	0.385	0.922	1.98	2.44
SWCC C	0.157	0.012	0.109	0.48	-0.86	0.01	0.422	0.81	1.45
Vol Cont	36.235	16.934	4.115	0.18	-0.46	23.6	49.5	4.35	4.59
Sat Vol Cont	37.37	17.105	4.136	0.22	-0.56	26.8	51.7	3.35	4.55
%S	92.795	81.185	9.01	-1.14	0.37	53.9	100	2.06	0.38
Sopt	85.388	7.475	2.734	-0.66	0.18	74.2	93.4	6.41	4.57
Fenv	0.764	0.273	0.522	2.65	8.25	0.26	4.71	0.7	5.53
CBR	7.62	15.309	3.913	0.89	-2	1.68	19.59	1.21	2.43
Mropt	16656	2.10E+07	4657	0.39	-2	7167	28009	1.81	2.16
Mreq	4.002	0.087	0.295	0.26	-0.54	3.297	4.931	2.82	3.72

Soil Name A-1-b(GB)
Analysis L3A

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.973	39.35	6.27	N/A	N/A	0.2	25	1.5	1.41
PI	1.159	3.59	1.89	N/A	N/A	0	6	0.11	0.46
wPI	0.206	0.17	0.41	N/A	N/A	0	1.5	0.08	0.51
Wopt	7.401	2.715	1.648	-0.82	0.75	1.093	13.484	6.98	6.09
Gamma	128.442	50.884	7.133	0.8	0.83	89.76	149.99	9.88	5.5
Suction	9	3	2	1.69	3.72	7	21	1.08	6.06
Vol Cont	14.471	3.221	10.377	-0.26	-0.83	6.494	21.012	2.21	1.82
Sat Vol Cont	23.115	5.144	26.461	0.05	-0.12	2.672	42.947	7.27	7.05
%S	64.595	367.268	19.164	0.25	-0.77	19.88	100	1.85	1.46
Sopt	71.144	95.245	9.759	0.56	1.21	34.34	100	5.69	4.46
Fenv	1.153	0.176	0.419	2.55	11.15	0.279	4.997	3.35	14.76
CBR	52.13	95.538	9.774	-0.09	-2	23.99	69.907	2.6	1.64
Mropt	386167	2.1E5	1448	-1.17	-2	30601	40037	3.76	0.67
Mreq	4.619	0.026	0.162	-0.23	-0.26	4.048	5.119	5.27	4.62

Soil Name A-2-4(GSB)
Analysis L3A

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24.004	46.64	6.83	N/A	N/A	2.8	35.4	2.72	1.46
PI	4.632	10.48	3.24	N/A	N/A	0	10	0.63	0.73
wPI	1.272	0.84	0.92	N/A	N/A	0	3.5	0.85	1.49
Wopt	5.711	1.433	1.197	0.74	-0.33	0.58	14.56	19.4	11.4
Gamma	123.4	3.842	1.96	-0.21	3.07	109.69	146.95	30.67	52.45
Suction	10	6	2.41	1.7	4.15	7	29	1.29	7.84
SWCC A	63.352	24.011	4.9	0.15	-1.07	55.2	73.5	1.09	1.36
SWCC B	1.054	0.002	0.05	-0.08	-1.09	0.954	1.14	1.31	1.12
SWCC C	0.512	0.001	0.032	-0.15	-1.07	0.445	0.565	1.36	1.09
Vol Cont	20.851	13.849	3.721	-0.1	-0.17	8.8	31.9	4.47	4.1
Sat Vol Cont	25.984	5.101	2.259	-0.03	-0.21	16.8	34	7.13	6.21
%S	79.732	204.863	14.313	-0.28	-0.78	35.7	100	2.3	1.06
Sopt	71.44	0.515	0.717	-5.33	305.24	34.4	86.7	778.4	320.9
Fenv	0.879	0.174	0.417	1.61	3.81	0.24	3.44	1.68	6.72
CBR	40.434	208.2	14.43	0.25	-2	12.32	88.73	2.03	3.49
Mropt	35510	1.67E7	4098	-1.17	-2	22376	40037	1.89	0.65
Mreq	4.444	0.046	0.214	-0.12	-0.55	3.771	5.032	4.09	3.58

Soil Name	A-4(SFGM)								
Analysis	L3A								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.023	295.249	17.183	N/A	N/A	35.5	99	0.86	1.37
PI	5.873	7.96	2.821	N/A	N/A	0	10	1.2	0.84
wPI	3.634	4.852	2.203	N/A	N/A	0	9.76	1.34	2.25
Wopt	12.079	5.484	2.342	-0.09	-1.1	8.39	16.82	0.96	1.23
Gamma	118.5	21.155	4.599	-0.23	-1.1	109.	125.	1.22	0.94
Suction	14	26	5.09	2.12	7.38	7	59	1.27	8.96
SWCC A	80.244	167.594	12.946	-0.07	-0.99	55.2	107	1.45	1.55
SWCC B	0.901	0.013	0.114	0.25	-0.94	0.689	1.139	1.37	1.55
SWCC C	0.401	0.007	0.085	0.07	-0.99	0.225	0.565	1.55	1.45
Vol Cont	29.205	17.588	4.194	0.69	0.4	19.5	45	2.93	4.78
Sat Vol Cont	29.109	11.163	3.341	0.06	-0.61	20	39.3	3.47	3.87
%S	93.26	84.946	9.217	-1.25	0.54	56.4	100	1.63	0.3
Sopt	78.52	0.646	0.804	2.07	15.07	73.9	86.2	20.4	33.74
Fenv	0.592	0.106	0.326	2.23	6	0.28	2.66	0.68	4.46
CBR	25.658	178.674	13.36	1.17	-2	0	69.9	1.96	3.39
Mropt	29731	3.27E7	5719	0	-2	27	40037	6.21	2.15
Mreq	4.181	0.052	0.227	0.34	-0.3	3.085	4.937	8.91	6.14

Soil Name	A-6(CFGM)								
Analysis	L3A								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.209	269	16.39	N/A	N/A	35.6	98.2	1.51	0.94
PI	20.999	8.83	2.97	N/A	N/A	10.5	29	4.84	3.69
wPI	16.124	11.5	3.39	N/A	N/A	3.89	24.38	4.65	3.14
Wopt	19.621	1.813	1.347	-0.63	0.12	13.59	22.34	5.54	2.5
Gamma	103.7	6.953	2.637	0.47	-0.25	98.43	113.6	2.27	4.28
Suction	38	400	20.01	2.39	8.54	12	239	1.4	10.7
SWCC A	122.924	55.59	7.456	-0.8	0.62	82.9	136.9	6.71	2.35
SWCC B	0.592	0.002	0.044	1.03	1.37	0.516	0.871	2.14	7.78
SWCC C	0.121	0.002	0.049	0.8	0.62	0.029	0.383	2.35	6.71
Vol Cont	36.975	4.35	2.086	-0.09	-0.36	29.6	43.4	5.23	4.57
Sat Vol Cont	38.001	4.359	2.088	-0.14	-0.15	29.6	45	6.77	5.62
%S	95.543	25.849	5.084	-1.03	0.24	72.7	100	2.47	0.48
Sopt	85.96	8.655	2.942	-0.15	-0.56	76.5	92.2	3.5	2.3
Fenv	0.628	0.057	0.239	1.91	4.64	0.28	2.16	1.51	6.71
CBR	6.153	1.981	1.407	1.44	-2	4.04	16.73	1.71	8.56
Mropt	15278	3.47E6	1863	1.03	-2	12096	26033	2.02	6.84
Mreq	3.95	0.028	0.168	0.19	-0.54	3.546	4.532	3.03	4.36

Soil Name A-6(FGM)

Analysis L3A

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.454	269	16.39	N/A	N/A	35.6	98.2	1.35	1.3
PI	13.801	8.83	2.97	N/A	N/A	10.5	29	0.84	3.85
wPI	10.179	11.5	3.39	N/A	N/A	3.885	24.375	2.08	4.69
Wopt	16.933	3.075	1.754	0.05	-0.62	12.75	21.957	2.65	3.18
Gamma	108.9	11.671	3.416	-0.13	-0.64	99.3	116.9	3.02	2.5
Suction	25	160	13	2.64	11.44	9.988	168.37	1.21	11.43
SWCC A	106.8	122.156	11.052	-0.16	-0.61	77.198	135.788	3.05	2.98
SWCC B	0.695	0.006	0.075	0.38	-0.45	0.521	0.921	2.57	3.35
SWCC C	0.227	0.005	0.073	0.16	-0.61	0.037	0.421	2.98	3.05
Vol Cont	33.731	6.144	2.479	0.05	-0.45	26.16	41.769	4.32	4.59
Sat Vol Cont	34.83	6.24	2.498	0.08	-0.33	27.04	43.529	4.66	5.2
%S	94.508	40.995	6.403	-1.04	0.22	66.14	100	2.35	0.45
Sopt	85.024	5.558	2.357	-0.14	-0.22	76.192	93.638	6.42	6.27
Fenv	0.652	0.086	0.293	2.22	5.99	0.3	2.682	1.09	6.26
CBR	9.724	8.357	2.891	0.66	-2	4.374	19.385	1.85	3.34
Mropt	19499	9253630	3041.98	0.29	-2	12663	27878	2.33	2.86
Mreq	4.058	0.037	0.192	0.28	-0.54	3.599	4.69	2.88	3.98

Soil Name (GB)5

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	18.26	14	4	0.17	-0.82	11.26	32.2	2.07	4.11
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	18.52	4.96	2.2262	-0.31	-0.16	10.97	24.64	4.59	3.73
Sat Vol Cont	25	2.85	1.688	-0.02	-0.7	20.67	29.29	2.77	2.74
%S	74.42	104.52	10.22	0.06	-0.38	44.57	100	3.4	2.91
Sopt	67.55	0.909	0.953	0.05	-1.01	65.72	69.49	1.41	1.49
Fenv	0.93	0.015	0.124	0.52	-0.22	0.66	1.38	2.58	4.36
Mropt	31443	762430	873	N/A	N/A	29732	33154	1.42	1.42
Mreq	4.46	0.00348	0.059	0.06	-0.58	4.305	4.634	3.19	3.55

Soil Name (GB)35

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	18.28	14	4	0.15	-0.85	11.28	32.52	2.09	4.25
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	18.53	4.92	2.2184	-0.28	-0.2	10.9	24.72	4.74	3.86
Sat Vol Cont	25.02	2.86	1.6898	-0.03	-0.72	20.67	29.28	2.77	2.72
%S	74.32	103.71	10.18	0.08	-0.33	43.44	100	3.63	3.02
Sopt	67.56	0.916	0.957	0.05	-1.02	65.72	69.48	1.39	1.46
Fenv	0.93	0.015	0.124	0.52	-0.17	0.66	1.4	2.63	4.66
Mropt	37260	1070630	1035	N/A	N/A	35232	39288	1.42	1.42
Mreq	4.535	0.00346	0.0588	0.08	-0.55	4.378	4.722	3.43	4.08

Soil Name (GB)50

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	18.29	13	4	0.14	-0.84	11.22	32.8	2.17	4.45
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	18.51	4.92	2.219	-0.3	-0.17	10.96	24.9	4.76	4.04
Sat Vol Cont	25.01	2.85	1.6869	-0.03	-0.7	20.73	29.31	2.73	2.75
%S	74.34	102.73	10.14	0.1	-0.36	45.03	100	3.37	2.95
Sopt	67.55	0.91	0.954	0.05	-1.01	65.72	69.48	1.4	1.48
Fenv	0.93	0.015	0.123	0.48	-0.26	0.66	1.4	2.66	4.64
Mropt	37262	1070740	1035	N/A	N/A	35234	39290	1.42	1.42
Mreq	4.535	0.00347	0.0589	0.07	-0.56	4.376	4.721	3.45	4.06

Soil Name (GB)75

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	18.29	13	4	0.15	-0.81	11.29	32.88	2.16	4.5
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	18.5	4.9	2.2125	-0.3	-0.2	10.2	24.6	5.38	3.96
Sat Vol Cont	25	2.83	1.6836	-0.04	-0.69	20.59	29.12	2.8	2.62
%S	74.46	105.28	10.26	0.05	-0.34	40.74	100	4.09	3.09
Sopt	67.55	0.916	0.957	0.05	-1.02	65.72	69.48	1.39	1.47
Fenv	0.93	0.015	0.124	0.61	0	0.66	1.44	2.61	5.08
Mropt	39880	1226480	1107	N/A	N/A	37709	42051	1.42	1.42
Mreq	4.563	0.00349	0.0591	0.11	-0.55	4.412	4.757	3.22	4.16

Soil Name (GB)95

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.5	0.67	0.82	N/A	N/A	6.9	10.1	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	18.3	14	4	0.14	-0.85	11.28	32.39	2.09	4.19
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.0001	0.0108	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.0021	0.0453	N/A	N/A	0.7	0.88	1.42	1.42
Vol Cont	18.49	4.92	2.2177	-0.3	-0.16	10.55	24.95	5.2	4.22
Sat Vol Cont	24.99	2.86	1.6907	-0.02	-0.7	20.6	29.33	2.85	2.81
%S	74.31	104.25	10.21	0.06	-0.32	42.49	100	3.78	3.06
Sopt	67.54	0.912	0.955	0.06	-1.01	65.72	69.49	1.39	1.48
Fenv	0.93	0.016	0.125	0.54	-0.12	0.66	1.4	2.63	4.6
Mropt	40036	1236100	1112	N/A	N/A	37857	42215	1.42	1.42
Mreq	4.566	0.00358	0.0598	0.07	-0.55	4.404	4.75	3.44	3.9

Soil Name	(GSM)5								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	10.05	4	2	1.68	3.58	7.25	23.24	1.28	6.02
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	25.79	2.65	1.6267	-0.01	-0.64	20.52	30.02	4.11	3.31
Sat Vol Cont	26.58	2.67	1.6343	-0.02	-0.68	22.31	30.74	2.87	2.78
%S	95.05	32.81	5.73	-1.02	0.13	71.47	100	2.11	0.44
Sopt	70.4	0.214	0.463	-0.25	-1.01	69.39	71.17	1.48	1.14
Fenv	0.5	0.011	0.105	1.1	1.34	0.33	0.97	1.67	4.66
Mropt	21095	343171	586	N/A	N/A	19947	22243	1.42	1.42
Mreq	4.011	0.00803	0.0896	0.27	-0.6	3.824	4.304	2.27	3.54
Soil Name	(GSM)35								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	10.06	4	2	1.61	3.27	7.23	22.6	1.32	5.83
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	25.8	2.63	1.6223	-0.05	-0.61	20.83	29.94	3.72	3.09
Sat Vol Cont	26.58	2.69	1.6406	-0.02	-0.71	22.31	30.65	2.79	2.66
%S	95.04	32.23	5.68	-1.01	0.12	72.28	100	2.05	0.45
Sopt	70.39	0.213	0.461	-0.24	-1	69.39	71.17	1.49	1.16
Fenv	0.5	0.01	0.102	1.08	1.29	0.33	0.93	1.69	4.34
Mropt	32449	811997	901	N/A	N/A	30683	34215	1.42	1.42
Mreq	4.197	0.00775	0.0881	0.24	-0.64	4.008	4.466	2.31	3.28

Soil Name	(GSM)50								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	10.06	4	2	1.63	3.25	7.19	23.19	1.34	6.13
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	25.77	2.68	1.638	-0.04	-0.66	20.89	29.92	3.54	3.01
Sat Vol Cont	26.55	2.71	1.6464	-0.01	-0.7	22.26	30.62	2.79	2.65
%S	94.95	33.4	5.78	-0.99	0.05	72.77	100	1.92	0.44
Sopt	70.4	0.211	0.46	-0.24	-0.98	69.39	71.17	1.5	1.16
Fenv	0.5	0.011	0.105	1.04	1.02	0.33	0.94	1.62	4.24
Mropt	33653	873377	935	N/A	N/A	31821	35485	1.42	1.42
Mreq	4.216	0.00813	0.0902	0.25	-0.66	4.023	4.488	2.25	3.19

Soil Name	(GSM)75								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	10.06	4	2	1.63	3.21	7.24	22.69	1.28	5.75
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	25.8	2.63	1.6217	-0.01	-0.62	20.71	30.03	3.92	3.26
Sat Vol Cont	26.58	2.66	1.6324	-0.03	-0.69	22.32	30.71	2.85	2.76
%S	95.02	32.33	5.69	-1.01	0.13	72.19	100	2.07	0.45
Sopt	70.4	0.21	0.459	-0.24	-0.99	69.39	71.17	1.51	1.17
Fenv	0.5	0.011	0.103	1.03	1.12	0.33	0.95	1.75	4.57
Mropt	38901	1167010	1080	N/A	N/A	36784	41018	1.42	1.42
Mreq	4.277	0.00781	0.0884	0.23	-0.62	4.084	4.577	2.52	3.89

Soil Name (GSM)95

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24	11.5	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.1	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.5	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	10.08	4	2	1.62	3.3	7.25	23.81	1.33	6.45
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.0001	0.0098	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.0006	0.0252	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	25.75	2.71	1.6466	-0.01	-0.65	20.18	30.06	4.43	3.43
Sat Vol Cont	26.56	2.7	1.6446	-0.02	-0.69	22.31	30.71	2.8	2.73
%S	94.92	33.58	5.8	-1	0.1	71.24	100	2.13	0.46
Sopt	70.4	0.208	0.456	-0.25	-0.97	69.4	71.17	1.53	1.17
Fenv	0.5	0.011	0.105	1.1	1.38	0.33	0.98	1.68	4.77
Mropt	39984	1232890	1110	N/A	N/A	37808	42160	1.42	1.42
Mreq	4.291	0.00802	0.0895	0.26	-0.63	4.099	4.579	2.36	3.55

Soil Name (FGM)5

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	25.04	128	11	2.3	8.54	10.67	132.39	1.31	9.79
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	32.04	2.29	1.5147	-0.03	-0.6	27.67	36.18	3.53	3.35
Sat Vol Cont	33.16	2.22	1.4912	-0.02	-0.68	29.24	36.93	2.88	2.77
%S	95.53	21.03	4.59	-0.81	-0.27	77.31	100	2.31	0.57
Sopt	83.61	1.864	1.365	-0.42	-0.83	80.37	85.74	1.64	1.07
Fenv	0.55	0.026	0.161	1.74	3.34	0.35	1.43	1.09	4.81
Mropt	9227	65656	256	N/A	N/A	8725	9729	1.42	1.42
Mreq	3.686	0.01431	0.1196	0.49	-0.49	3.481	4.073	1.58	2.98

Soil Name (FGM)35

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	25.14	127	11	2.22	7.65	10.75	125.78	1.3	9.1
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	32.02	2.29	1.5141	0	-0.58	27.34	36.14	3.94	3.46
Sat Vol Cont	33.16	2.24	1.4973	-0.01	-0.71	29.29	36.97	2.81	2.76
%S	95.45	21.74	4.66	-0.83	-0.21	77.57	100	2.19	0.56
Sopt	83.61	1.857	1.363	-0.41	-0.84	80.37	85.74	1.64	1.08
Fenv	0.55	0.028	0.167	1.71	3.04	0.35	1.46	1.05	4.63
Mropt	18357	259869	510	N/A	N/A	17358	19356	1.42	1.42
Mreq	3.988	0.01511	0.1229	0.52	-0.49	3.782	4.4	1.55	3.09

Soil Name (FGM)50

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	25.1	127	11	2.27	8.16	10.78	127.87	1.29	9.27
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	32.04	2.29	1.5125	-0.02	-0.58	27.4	36.17	3.9	3.47
Sat Vol Cont	33.17	2.22	1.4916	-0.04	-0.7	29.29	36.92	2.82	2.73
%S	95.45	21.38	4.62	-0.79	-0.3	77.52	100	2.25	0.57
Sopt	83.61	1.852	1.361	-0.41	-0.85	80.37	85.74	1.64	1.08
Fenv	0.55	0.027	0.164	1.68	2.92	0.34	1.39	1.1	4.42
Mropt	22927	405361	637	N/A	N/A	21679	24175	1.42	1.42
Mreq	4.084	0.01479	0.1216	0.46	-0.58	3.873	4.487	1.64	3.12

Soil Name	(FGM)75								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	25.21	127	11	2.14	7.06	10.64	134.18	1.36	10.16
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	32.02	2.3	1.5163	-0.03	-0.58	27.29	36.04	3.93	3.34
Sat Vol Cont	33.16	2.24	1.4959	-0.01	-0.7	29.26	36.87	2.8	2.66
%S	95.44	22.07	4.7	-0.83	-0.23	77.17	100	2.22	0.55
Sopt	83.6	1.853	1.361	-0.41	-0.85	80.37	85.74	1.65	1.09
Fenv	0.55	0.028	0.167	1.68	2.98	0.34	1.48	1.09	4.81
Mropt	30347	710204	843	N/A	N/A	28695	31999	1.42	1.42
Mreq	4.206	0.01493	0.1222	0.48	-0.54	3.997	4.624	1.61	3.23

Soil Name	(FGM)95								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.8	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.5	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.3	1.42	1.42
Suction	25.26	128	11	2.21	7.6	10.63	134.79	1.36	10.17
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.0191	0.138	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.0037	0.0605	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	32.01	2.28	1.5095	0.01	-0.6	27.22	36.23	4.18	3.69
Sat Vol Cont	33.16	2.24	1.4971	-0.01	-0.69	29.31	36.92	2.76	2.69
%S	95.44	21.63	4.65	-0.82	-0.21	77.26	100	2.26	0.57
Sopt	83.6	1.857	1.363	-0.4	-0.85	80.37	85.74	1.64	1.09
Fenv	0.55	0.028	0.167	1.71	3.13	0.35	1.48	1.08	4.83
Mropt	37431	1080470	1039	N/A	N/A	35394	39468	1.42	1.42
Mreq	4.299	0.0151	0.1229	0.5	-0.51	4.09	4.702	1.56	3.02

Soil Name	(SFGM)5								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	13.29	14	4	1.78	4.6	8.04	40.8	1.54	8.07
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	30.04	2.32	1.5242	-0.04	-0.67	25.97	34	3.01	2.93
Sat Vol Cont	30.96	2.39	1.5469	-0.02	-0.71	26.91	34.84	2.85	2.72
%S	95.55	23.21	4.82	-0.9	-0.1	77.4	100	1.99	0.49
Sopt	78.68	0.592	0.769	-0.57	-0.7	76.74	79.76	1.63	0.91
Fenv	0.47	0.016	0.127	1.58	2.5	0.3	1.09	1.08	4.15
Mropt	19408	290478	539	N/A	N/A	18352	20464	1.42	1.42
Mreq	3.94	0.01243	0.1115	0.49	-0.54	3.749	4.311	1.6	3.1
Soil Name	(SFGM)35								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	13.31	14	4	1.85	5.16	8.1	43.56	1.54	8.93
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	30.02	2.25	1.4996	0.01	-0.64	25.71	33.97	3.44	3.14
Sat Vol Cont	30.98	2.36	1.536	-0.03	-0.68	27	34.91	2.83	2.8
%S	95.57	23.03	4.8	-0.91	-0.08	77.35	100	2.02	0.49
Sopt	78.69	0.589	0.768	-0.57	-0.68	76.74	79.76	1.64	0.91
Fenv	0.47	0.016	0.128	1.57	2.38	0.3	1.08	1.08	4.08
Mropt	27760	594279	771	N/A	N/A	26249	29271	1.42	1.42
Mreq	4.097	0.01271	0.1127	0.48	-0.55	3.903	4.452	1.56	2.86

Soil Name (SFGM)50

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	13.36	14	4	1.87	5.28	8.02	42.53	1.52	8.33
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	30.03	2.29	1.5124	0	-0.66	25.59	34.06	3.57	3.25
Sat Vol Cont	30.97	2.38	1.5433	-0.02	-0.7	26.94	34.88	2.85	2.76
%S	95.54	23.17	4.81	-0.89	-0.12	76.72	100	2.12	0.5
Sopt	78.69	0.583	0.764	-0.59	-0.66	76.75	79.76	1.66	0.92
Fenv	0.47	0.017	0.129	1.59	2.58	0.3	1.1	1.07	4.15
Mropt	29725	681394	825	N/A	N/A	28107	31343	1.42	1.42
Mreq	4.129	0.01282	0.1132	0.48	-0.55	3.933	4.485	1.57	2.86

Soil Name (SFGM)75

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	13.31	14	4	1.78	4.53	7.97	41.64	1.58	8.37
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	30.04	2.33	1.5276	-0.02	-0.68	25.7	34.01	3.34	3.05
Sat Vol Cont	30.96	2.39	1.5465	-0.02	-0.71	26.97	34.88	2.79	2.75
%S	95.6	23.06	4.8	-0.91	-0.09	75.57	100	2.32	0.51
Sopt	78.68	0.589	0.767	-0.59	-0.67	76.75	79.76	1.64	0.92
Fenv	0.47	0.017	0.129	1.67	3.03	0.31	1.17	1.09	4.72
Mropt	34157	899728	949	N/A	N/A	32298	36016	1.42	1.42
Mreq	4.187	0.01263	0.1124	0.54	-0.43	3.994	4.598	1.68	3.58

Soil Name (SFGM)95

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.4	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.8	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.3	N/A	N/A	110.49	119.51	1.42	1.42
Suction	13.28	14	4	1.88	5.19	8.05	41.45	1.5	8.1
SWCC A	80.27	122.5	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.9	0	0.0041	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.4	0.0014	0.0372	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	30.06	2.28	1.5089	-0.02	-0.68	25.64	33.93	3.48	3.05
Sat Vol Cont	30.98	2.39	1.5456	-0.03	-0.7	26.93	34.85	2.84	2.71
%S	95.61	22.86	4.78	-0.92	-0.06	77.38	100	2.02	0.49
Sopt	78.68	0.585	0.765	-0.57	-0.69	76.75	79.76	1.66	0.93
Fenv	0.47	0.016	0.127	1.59	2.51	0.31	1.08	1.04	4.05
Mropt	37849	1104740	1051	N/A	N/A	35789	39909	1.42	1.42
Mreq	4.23	0.01233	0.111	0.5	-0.54	4.043	4.592	1.53	2.96

Soil Name (CFGM)5

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	38.56	506	22	2.69	11.03	12.92	243.99	1.04	8.36
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	36.21	2.31	1.5204	-0.06	-0.46	31.14	40.72	4.71	4.18
Sat Vol Cont	37.54	1.94	1.3933	-0.01	-0.72	33.91	41.05	2.84	2.74
%S	95.69	17.39	4.17	-0.74	-0.3	79.59	100	2.36	0.63
Sopt	85.71	5.395	2.323	-0.3	-0.93	80.48	89.61	1.59	1.19
Fenv	0.6	0.031	0.175	1.42	2.34	0.34	1.58	1.58	5.85
Mropt	9476	69247	263	N/A	N/A	8960	9992	1.42	1.42
Mreq	3.739	0.01476	0.1215	0.27	-0.62	3.489	4.128	2.18	3.41

Soil Name (CFGM)35

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	38.3	465	22	2.4	8.46	13	221.78	1.09	7.89
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	36.23	2.29	1.5138	-0.01	-0.48	31.44	40.58	4.23	3.85
Sat Vol Cont	37.54	1.95	1.3959	-0.02	-0.71	33.96	41.09	2.77	2.75
%S	95.78	17.11	4.14	-0.76	-0.29	80.03	100	2.28	0.61
Sopt	85.72	5.328	2.308	-0.3	-0.92	80.48	89.6	1.62	1.2
Fenv	0.6	0.03	0.174	1.45	2.49	0.34	1.55	1.55	5.69
Mropt	14357	158957	399	N/A	N/A	13576	15138	1.42	1.42
Mreq	3.916	0.01471	0.1213	0.27	-0.62	3.663	4.314	2.27	3.58

Soil Name (CFGM)50

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	38.53	493	22	2.52	9.65	12.7	267.71	1.12	9.9
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	36.22	2.26	1.5047	-0.04	-0.46	31.37	40.52	4.35	3.86
Sat Vol Cont	37.54	1.95	1.3972	-0.02	-0.72	33.96	41.02	2.74	2.65
%S	95.74	17.09	4.13	-0.74	-0.34	79.84	100	2.34	0.63
Sopt	85.72	5.358	2.315	-0.31	-0.92	80.47	89.61	1.61	1.19
Fenv	0.6	0.029	0.17	1.41	2.37	0.34	1.51	1.61	5.64
Mropt	16656	213948	463	N/A	N/A	15750	17563	1.42	1.42
Mreq	3.979	0.01419	0.1191	0.25	-0.62	3.728	4.374	2.33	3.66

Soil Name (CFGM)75

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	38.2	464	22	2.53	10.02	12.99	274.96	1.14	10.72
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	36.21	2.28	1.5092	-0.03	-0.51	31.22	40.45	4.48	3.8
Sat Vol Cont	37.55	1.93	1.3902	-0.04	-0.68	33.91	41.01	2.82	2.68
%S	95.67	17.11	4.14	-0.73	-0.33	79.13	100	2.52	0.66
Sopt	85.71	5.394	2.323	-0.3	-0.93	80.48	89.61	1.59	1.19
Fenv	0.6	0.03	0.174	1.46	2.58	0.34	1.66	1.63	6.58
Mropt	20166	313611	560	N/A	N/A	19068	21264	1.42	1.42
Mreq	4.066	0.01422	0.1193	0.27	-0.58	3.81	4.47	2.43	3.84

Soil Name (CFGM)95

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	38.33	478	22	2.51	9.6	12.94	244.06	1.09	8.84
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.0567	0.2381	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.0043	0.0658	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	36.2	2.28	1.5088	-0.02	-0.48	31.65	40.44	3.88	3.61
Sat Vol Cont	37.54	1.95	1.3959	-0.03	-0.73	33.98	41.1	2.75	2.75
%S	95.71	17.14	4.14	-0.73	-0.34	80.36	100	2.22	0.62
Sopt	85.73	5.401	2.324	-0.31	-0.92	80.47	89.61	1.6	1.18
Fenv	0.6	0.03	0.174	1.42	2.29	0.34	1.56	1.57	5.78
Mropt	24558	465091	682	N/A	N/A	23221	25895	1.42	1.42
Mreq	4.149	0.01469	0.1212	0.28	-0.6	3.9	4.534	2.17	3.35

Location	Arcata/Eureka CA	
Time	164.372	Sec

Variable	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
Py	124.87	447.563	21.156	0.21	-0.25	64.94	208.6	4.26	5.962
Hy	39.331	1.974	1.405	0	-0.16	34.27	44.16	5.82	5.558
PE	58.629	3.437	1.854	0.01	-0.14	52.16	65.25	5.65	5.789
TMI	85.993	287.322	16.951	-1.04	0.05	21.67	100	1.75	0.382

Soil Name	GB
Analysis	L3B

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	42.98	6.56	N/A	N/A	0.00	25.00	1.36	1.27
PI	1.16	3.08	1.76	N/A	N/A	0.00	6.00	0.16	0.66
wPI	0.21	0.12	0.34	N/A	N/A	0.00	1.50	0.18	1.10
Wopt	8.95	3.70	1.92	3.83	73.97	0.24	61.64	15.66	101.39
Gamma	124.6	60.426	7.77	-2.65	33.58	1.70	149.90	41.80	8.60
Suction	16.224	56.738	7.53	-0.35	-1.48	4.00	26.00	0.63	0.49
Vol Cont	15.33	11.07	3.33	-0.28	-0.91	7.20	21.20	1.94	1.41
Sat Vol Cont	25.37	30.43	5.52	0.19	0.06	6.20	51.00	6.50	8.66
%S	62.788	351.947	18.76	0.30	-0.66	18.48	100.00	2.00	1.68
Sopt	69.613	113.9	10.67	0.08	3.15	0.34	100.00	12.15	5.33
Fenv	1.153	0.152	0.39	2.25	9.10	0.24	4.72	4.15	16.21
CBR	49.581	233.975	15.30	0.14	-2.00	23.00	106.60	1.74	3.74
Mropt	37510	8.1E6	2844.00	-1.16	-2.00	30075	40037	0.99	0.34
Mreq	4.61	0.024	0.15	-0.25	-0.13	4.01	5.10	6.21	5.07

Soil Name	GSB								
Analysis	L3B								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24.00	76.38	8.74	N/A	N/A	0.30	35.40	1.71	0.82
PI	4.63	33.30	5.77	N/A	N/A	0.00	50.00	0.49	4.82
wPI	1.27	2.77	1.66	N/A	N/A	0.00	16.95	0.47	5.74
Wopt	9.66	3.53	1.88	1.48	2.52	0.08	18.49	11.72	11.29
Gamma	123	11.317	3.36	-0.83	31.82	39.79	149.23	145.84	45.92
Suction	8.4	3.298	1.82	2.99	15.52	7.00	35.00	0.48	9.45
SWCC A	73.72	162.96	12.77	0.62	-0.31	55.20	119.80	1.21	3.02
SWCC B	0.96	0.01	0.11	-0.39	-0.70	0.61	1.14	2.52	1.30
SWCC C	0.44	0.01	0.08	-0.62	-0.31	0.14	0.57	3.02	1.21
Vol Cont	21.40	18.04	4.25	-0.53	0.22	7.70	34.80	4.65	4.54
Sat Vol Cont	26.222	7.706	2.78	0.00	-0.12	16.80	36.90	5.62	6.39
%S	80.282	243.159	15.59	-0.39	-0.80	29.90	100.00	2.22	0.87
Sopt	70.556	5.4	2.33	-2.22	22.96	18.90	92.40	145.37	61.47
Fenv	0.873	0.179	0.42	2.05	7.71	0.18	4.81	2.14	12.12
CBR	37.894	344.3	18.56	0.18	-2.00	6.94	85.84	1.30	2.01
Mropt	33683	3.8E+07	6138.00	-0.65	-2.00	16463	40037	1.39	0.51
Mreq	4.408	0.054	0.23	-0.22	-0.27	3.59	5.06	4.90	3.93
Soil Name	FGM								
Analysis	L3B								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	330.29	18.17	N/A	N/A	35.50	100.00	1.06	1.08
PI	13.80	103.60	10.18	N/A	N/A	0.00	75.00	1.32	5.84
wPI	10.18	83.61	9.14	N/A	N/A	0.00	66.24	0.89	4.93
Wopt	11.70	22.54	4.75	0.15	-0.84	1.72	29.38	3.76	3.72
Gamma	111.3	80.096	8.95	-0.16	-0.78	86.00	139.75	3.75	4.23
Suction	17.5	128	11.34	2.75	14.57	7.00	163.00	0.73	10.12
SWCC A	105.91	616.18	24.82	-0.09	-0.86	55.20	164.10	1.76	2.02
SWCC B	0.72	0.03	0.18	0.50	-0.63	0.40	1.14	1.49	1.96
SWCC C	0.24	0.02	0.15	0.29	-1.00	0.01	0.57	0.89	1.27
Vol Cont	33.01	30.57	5.53	-0.07	-0.51	15.40	48.70	4.23	3.78
Sat Vol Cont	33.435	31.425	5.61	-0.10	-0.45	14.90	49.80	4.61	4.07
%S	90.956	145.429	12.06	-1.25	0.64	38.00	100.00	1.96	0.33
Sopt	81.09	14.3	3.78	-2.94	11.10	49.80	83.60	4.06	0.32
Fenv	0.764	0.433	0.66	3.10	12.07	0.11	6.89	0.80	7.46
CBR	16.897	228.221	15.11	1.55	-2.00	1.68	69.90	0.57	1.97
Mropt	22798	7.9E+07	8866.00	0.41	-2.00	7150	40037	1.16	1.27
Mreq	4.239	0.143	0.38	-0.12	-0.65	3.17	5.24	3.34	3.13

Soil Name	SFGM								
Analysis	L3B								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	295.42	17.19	N/A	N/A	35.50	99.00	0.86	1.37
PI	5.87	8.41	2.90	N/A	N/A	0.00	10.00	1.10	0.78
wPI	3.63	4.98	2.23	N/A	N/A	0.00	9.76	1.29	2.18
Wopt	8.26	5.70	2.39	-0.06	-1.13	8.39	16.90	0.90	1.21
Gamma	118.5	21.965	4.69	-0.24	-1.11	109.02	127.53	1.49	1.41
Suction	10.6	8	2.74	1.64	5.13	7.00	36.00	1.31	9.58
SWCC A	80.10	169.57	13.02	-0.07	-1.00	55.20	107.10	1.42	1.54
SWCC B	0.90	0.01	0.11	0.26	-0.95	0.69	1.14	1.36	1.51
SWCC C	0.40	0.01	0.09	0.07	-1.00	0.23	0.57	1.54	1.42
Vol Cont	29.53	19.29	4.39	0.68	0.43	18.80	45.00	3.10	4.47
Sat Vol Cont	29.02	11.518	3.39	-0.02	-0.51	18.90	38.70	3.86	3.70
%S	93.732	82.04	9.06	-1.40	1.03	54.40	100.00	1.73	0.28
Sopt	78.299	3.5	1.87	3.13	13.71	69.30	94.10	14.25	25.13
Fenv	0.577	0.106	0.33	2.44	7.66	0.24	3.11	0.81	6.14
CBR	25.59	178.49	13.36	1.16	-2.00	2.97	69.89	1.56	3.05
Mropt	29698	3.3E+07	5709.00	0.09	-2.00	10086	40037	3.42	1.80
Mreq	4.166	0.055	0.24	0.32	-0.45	3.48	4.95	4.05	4.62
Soil Name	CFGM								
Analysis	L3B								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	266.32	16.32	N/A	N/A	35.60	100.00	1.64	1.10
PI	21.00	81.07	9.00	N/A	N/A	10.50	75.00	0.98	5.02
wPI	16.12	80.84	8.99	N/A	N/A	3.89	66.24	1.29	5.29
Wopt	19.11	10.87	3.30	0.22	-0.64	12.75	29.33	1.91	3.07
Gamma	104.7	41.383	6.43	-0.33	-0.59	85.61	117.09	2.86	1.86
Suction	24	155	12.00	2.57	11.81	10.00	162.00	1.10	10.64
SWCC A	118.58	353.26	18.80	-0.11	-0.78	77.00	166.70	2.16	2.50
SWCC B	0.63	0.01	0.12	0.44	-0.59	0.39	0.92	1.94	2.39
SWCC C	0.16	0.01	0.11	0.46	-0.89	0.01	0.42	0.81	1.43
Vol Cont	36.48	16.33	4.04	0.11	-0.53	26.00	49.10	3.20	3.87
Sat Vol Cont	37.376	16.716	4.09	0.24	-0.53	26.40	50.50	3.49	4.17
%S	93.194	73.377	8.57	-1.14	0.36	56.30	100.00	2.04	0.38
Sopt	85.308	7.0	2.65	-0.53	0.07	75.00	93.80	6.30	5.18
Fenv	0.74	0.232	0.48	2.59	7.85	0.28	4.43	0.72	5.68
CBR	7.62	15.35	3.92	0.91	-2.00	1.72	19.57	1.19	2.41
Mropt	16656	2.2E+07	4650.00	0.41	-2.00	7255	28000	1.78	2.15
Mreq	3.995	0.077	0.28	0.30	-0.47	3.31	4.92	3.07	4.14

Soil Name	A-1-b(GB)								
Analysis	L3A								
Properties	Mean	Var	Std Dev	Skew	Kurt	Min	Max	Alpha	Beta
P#200	12.973	39.35	6.27	N/A	N/A	0.2	25	1.5	1.41
PI	1.159	3.59	1.89	N/A	N/A	0	6	0.11	0.46
wPI	0.206	0.17	0.41	N/A	N/A	0	1.5	0.08	0.51
Wopt	9.151	2.644	1.626	-0.85	0.91	0.855	13.529	7.65	6.42
Gamma	128.509	51.093	7.148	0.83	0.68	95.74	149.99	7.72	5.06
Suction	8	1	1	2.29	5.98	7	13	0.37	3.57
Vol Cont	15.375	3.189	10.17	-0.29	-0.85	7.26	21.219	2.13	1.53
Sat Vol Cont	23.094	5.131	26.332	-0.02	-0.17	3.678	41.155	6.38	5.94
%S	68.387	360.373	18.984	0.14	-0.91	22.22	100	1.81	1.24
Sopt	71.327	98.596	9.93	0.64	1.23	35.5	100	5.23	4.19
Fenv	1.097	0.149	0.387	2.48	10.78	0.229	4.489	3.81	14.88
CBR	52.064	95.769	9.786	-0.11	-2	24.75	69.898	2.47	1.61
Mropt	38606	2132920	1460.45	-1.15	-2	31000	40037	3.45	0.65
Mreq	4.598	0.025	0.157	-0.29	-0.16	3.994	5.109	6.21	5.24

Soil Name	A-2-4(GSB)								
Analysis	L3A								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24.00	46.64	6.83	N/A	N/A	2.80	35.40	2.72	1.46
PI	4.63	10.48	3.24	N/A	N/A	0.00	10.00	0.63	0.73
wPI	1.27	0.84	0.92	N/A	N/A	0.00	3.50	0.85	1.49
Wopt	8.59	1.45	1.20	0.78	-0.51	1.18	12.33	11.56	4.14
Gamma	123.4	3.475	1.86	-0.11	1.39	109.	143.09	33.07	46.0
Suction	8	2	1.23	1.83	5.08	7.00	18.00	0.82	6.18
SWCC A	63.32	23.72	4.87	0.17	-1.05	55.20	73.60	1.11	1.40
SWCC B	1.05	0.00	0.05	-0.10	-1.07	0.95	1.14	1.35	1.14
SWCC C	0.51	0.00	0.03	-0.17	-1.05	0.45	0.57	1.40	1.11
Vol Cont	21.53	12.21	3.49	-0.22	-0.1	10.00	31.80	4.59	4.09
Sat Vol Cont	26.02	4.941	2.22	-0.05	-0.2	17.80	33.60	5.99	5.56
%S	82.237	177.34	13.32	-0.37	-0.7	39.00	100.00	2.36	0.97
Sopt	71.355	1.5	1.22	-2.32	13.5	55.20	90.50	94.47	111
Fenv	0.808	0.131	0.36	1.50	3.4	0.24	3.03	1.76	6.86
CBR	40.571	210.876	14.52	0.25	-2.0	12.32	94.01	2.13	4.03
Mropt	35532	1.7E+7	4106	-1.17	-2.0	22376	40037	1.87	0.64
Mreq	4.412	0.041	0.20	-0.12	-0.53	3.80	4.98	3.87	3.58

Soil Name A-4(SFGM)

Analysis L3A

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	295.25	17.18	N/A	N/A	35.50	99.00	0.86	1.37
PI	5.87	7.96	2.82	N/A	N/A	0.00	10.00	1.20	0.84
wPI	3.63	4.85	2.20	N/A	N/A	0.00	9.76	1.34	2.25
Wopt	12.04	5.49	2.34	-0.08	-1.10	8.39	16.85	0.95	1.25
Gamma	118.5	21.122	4.60	-0.23	-1.10	109.13	125.67	1.24	0.95
Suction	11	7	2.69	1.57	4.47	7.00	35.00	1.34	9.22
SWCC A	80.07	165.96	12.88	-0.07	-0.98	55.20	106.60	1.44	1.54
SWCC B	0.90	0.01	0.11	0.26	-0.93	0.69	1.14	1.36	1.53
SWCC C	0.40	0.01	0.09	0.07	-0.98	0.23	0.57	1.54	1.44
Vol Cont	29.46	18.45	4.30	0.71	0.46	19.70	45.00	2.80	4.44
Sat Vol Cont	29.069	11.03	3.32	0.07	-0.60	19.70	39.10	3.63	3.88
%S	93.665	81.471	9.03	-1.37	0.92	55.60	100.00	1.68	0.28
Sopt	78.308	0.7	0.84	2.54	16.28	73.50	87.20	20.97	38.95
Fenv	0.575	0.101	0.32	2.39	7.23	0.27	2.73	0.67	4.78
CBR	25.519	171.643	13.10	1.15	-2.00	0.00	69.83	2.04	3.55
Mropt	29706	3.3E+07	5723.00	-0.09	-2.00	62	40037	6.19	2.16
Mreq	4.17	0.052	0.23	0.36	-0.27	3.34	4.94	5.83	5.41

Soil Name A-6(CFGM)

Analysis L3A

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	269.00	16.39	N/A	N/A	35.60	98.20	1.51	0.94
PI	21.00	8.83	2.97	N/A	N/A	10.50	29.00	4.84	3.69
wPI	16.12	11.50	3.39	N/A	N/A	3.89	24.38	4.65	3.14
Wopt	19.66	1.75	1.32	-0.59	0.07	13.55	22.31	5.76	2.49
Gamma	103.6	6.848	2.62	0.50	-0.22	98.45	113.54	2.22	4.27
Suction	24	64	8.02	2.55	9.92	11.00	100.00	2.34	12.84
SWCC A	122.94	56.61	7.52	-0.83	0.60	86.80	136.70	5.64	2.15
SWCC B	0.59	0.00	0.05	1.05	1.30	0.52	0.84	1.96	6.38
SWCC C	0.12	0.00	0.05	0.83	0.60	0.03	0.36	2.15	5.64
Vol Cont	37.25	4.23	2.06	-0.02	-0.35	30.50	43.50	4.73	4.39
Sat Vol Cont	38.051	4.293	2.07	-0.16	-0.14	30.00	46.00	7.04	6.89
%S	95.866	24.036	4.90	-1.09	0.36	74.40	100.00	2.25	0.43
Sopt	85.979	9.2	3.03	-0.16	-0.58	75.20	92.30	4.01	2.34
Fenv	0.612	0.051	0.23	1.90	4.66	0.28	2.06	1.57	6.84
CBR	6.128	1.915	1.38	1.43	-2.00	4.05	15.68	1.67	7.69
Mropt	15246	3.4E+06	1839.00	1.02	-2.00	12108	25233	1.98	6.29
Mreq	3.94	0.026	0.16	0.16	-0.58	3.55	4.48	2.93	4.09

Soil Name	A-6(FGM)								
Analysis	L3A								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	269.00	16.39	N/A	N/A	35.60	98.20	1.35	1.30
PI	13.80	8.83	2.97	N/A	N/A	10.50	29.00	0.84	3.85
wPI	10.18	11.50	3.39	N/A	N/A	3.89	24.38	2.08	4.69
Wopt	16.95	3.07	1.75	0.04	-0.64	12.75	21.92	2.66	3.14
Gamma	108.915	11.855	3.44	-0.13	-0.66	99.49	116.93	2.90	2.47
Suction	18	33	6.00	2.30	9.23	9.75	77.53	1.53	11.71
SWCC A	106.87	124.64	11.16	-0.16	-0.60	77.19	135.08	2.93	2.79
SWCC B	0.69	0.01	0.08	0.39	-0.44	0.53	0.92	2.42	3.23
SWCC C	0.23	0.01	0.07	0.16	-0.60	0.04	0.42	2.79	2.93
Vol Cont	33.98	6.00	2.45	0.02	-0.42	26.79	41.84	4.02	4.40
Sat Vol Cont	34.86	6.26	2.50	0.07	-0.33	26.64	43.22	4.95	5.03
%S	94.923	37.488	6.12	-1.10	0.35	68.48	100.00	2.17	0.42
Sopt	84.957	6.0	2.46	-0.12	-0.32	76.84	92.23	4.63	4.14
Fenv	0.632	0.074	0.27	2.21	5.99	0.30	2.55	1.09	6.39
CBR	9.729	8.488	2.91	0.65	-2.00	4.32	19.52	1.87	3.38
Mropt	19501	9.4E+06	3065.61	0.28	-2.00	12564	27965	2.36	2.88
Mreq	4.05	0.034	0.18	0.30	-0.48	3.61	4.65	2.90	3.88
Soil Name	(GB)5								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0.00	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.50	0.67	0.82	N/A	N/A	6.90	10.10	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	17.73	12	4.00	0.09	-1.08	11.22	25.74	1.44	1.78
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.00	0.01	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.00	0.05	N/A	N/A	0.70	0.88	1.42	1.42
Vol Cont	18.61	4.97	2.23	-0.30	-0.17	10.97	24.70	4.66	3.71
Sat Vol Cont	25	2.82	1.68	-0.03	-0.68	20.61	29.19	2.82	2.69
%S	74.74	105.88	10.29	0.06	-0.37	41.85	100.00	3.87	2.97
Sopt	67.55	0.9	0.96	0.06	-1.02	65.72	69.48	1.39	1.47
Fenv	0.92	0.016	0.13	0.57	-0.09	0.65	1.46	2.74	5.55
Mropt	31443	7.6E+05	873.00	N/A	N/A	29732	33154	1.42	1.42
Mreq	4.458	0.00354	0.06	0.13	-0.48	4.30	4.64	3.37	3.82

Soil Name	(GB)35								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0.00	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.50	0.67	0.82	N/A	N/A	6.90	10.10	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	17.76	12	3.00	0.08	-1.07	11.23	25.78	1.47	1.81
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.00	0.01	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.00	0.05	N/A	N/A	0.70	0.88	1.42	1.42
Vol Cont	18.62	4.90	2.21	-0.30	-0.16	10.95	25.14	4.96	4.22
Sat Vol Cont	25.02	2.83	1.68	-0.04	-0.67	20.58	29.28	2.90	2.78
%S	74.76	103.86	10.19	0.07	-0.38	43.55	100.00	3.64	2.94
Sopt	67.54	0.9	0.96	0.05	-1.01	65.72	69.49	1.39	1.49
Fenv	0.92	0.015	0.12	0.55	-0.10	0.65	1.42	2.74	5.07
Mropt	37260	1.1E+06	1035.00	N/A	N/A	35232	39288	1.42	1.42
Mreq	4.531	0.00343	0.06	0.08	-0.54	4.38	4.72	3.41	4.18

Soil Name	(GB)50								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0.00	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.50	0.67	0.82	N/A	N/A	6.90	10.10	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	17.73	12	4.00	0.09	-1.08	11.21	25.71	1.44	1.77
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.00	0.01	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.00	0.05	N/A	N/A	0.70	0.88	1.42	1.42
Vol Cont	18.62	4.83	2.20	-0.29	-0.15	10.93	25.01	5.00	4.15
Sat Vol Cont	25	2.8	1.67	-0.02	-0.69	20.70	29.25	2.78	2.74
%S	74.82	103.36	10.17	0.09	-0.36	43.95	100.00	3.59	2.93
Sopt	67.55	0.9	0.96	0.05	-1.02	65.72	69.48	1.39	1.47
Fenv	0.92	0.015	0.12	0.54	-0.15	0.65	1.41	2.69	4.87
Mropt	37262	1.1E+06	1035.00	N/A	N/A	35234	39290	1.42	1.42
Mreq	4.531	0.00346	0.06	0.08	-0.55	4.37	4.73	3.60	4.36

Soil Name (GB)75

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0.00	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.50	0.67	0.82	N/A	N/A	6.90	10.10	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	17.76	12	4.00	0.07	-1.08	11.23	25.71	1.44	1.76
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.00	0.01	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.00	0.05	N/A	N/A	0.70	0.88	1.42	1.42
Vol Cont	18.64	4.91	2.22	-0.30	-0.13	11.03	25.04	4.84	4.08
Sat Vol Cont	25	2.81	1.68	-0.04	-0.67	20.62	29.31	2.88	2.83
%S	74.84	104.68	10.23	0.08	-0.37	44.37	100.00	3.46	2.86
Sopt	67.55	0.9	0.96	0.06	-1.02	65.72	69.48	1.41	1.48
Fenv	0.92	0.015	0.12	0.53	-0.15	0.65	1.41	2.73	5.01
Mropt	39880	1.2E+06	1107.00	N/A	N/A	37709	42051	1.42	1.42
Mreq	4.562	0.00345	0.06	0.06	-0.54	4.40	4.74	3.43	3.85

Soil Name (GB)95

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	12.97	3.36	1.83	N/A	N/A	9.38	16.57	1.42	1.42
PI	1.16	0.09	0.29	N/A	N/A	0.58	1.74	1.42	1.42
wPI	0.21	0.00	0.04	N/A	N/A	0.12	0.29	1.42	1.42
Wopt	8.50	0.67	0.82	N/A	N/A	6.90	10.10	1.42	1.42
Gamma	124	6.15	2.48	N/A	N/A	119.14	128.86	1.42	1.42
Suction	17.75	12	4.00	0.08	-1.08	11.21	25.55	1.43	1.71
SWCC A	12.96	31.01	5.57	N/A	N/A	2.04	23.87	1.42	1.42
SWCC B	1.05	0.00	0.01	N/A	N/A	1.03	1.07	1.42	1.42
SWCC C	0.79	0.00	0.05	N/A	N/A	0.70	0.88	1.42	1.42
Vol Cont	18.61	4.85	2.20	-0.31	-0.15	10.84	24.66	4.89	3.80
Sat Vol Cont	25	2.78	1.67	-0.03	-0.66	20.63	29.15	2.83	2.69
%S	74.81	103.1	10.15	0.05	-0.36	42.37	100.00	3.90	3.03
Sopt	67.54	0.9	0.96	0.07	-1.01	65.72	69.49	1.39	1.49
Fenv	0.92	0.015	0.12	0.58	-0.04	0.65	1.44	2.93	5.55
Mropt	40036	1.2E+06	1112.00	N/A	N/A	37857	42215	1.42	1.42
Mreq	4.562	0.00341	0.06	0.10	-0.51	4.40	4.75	3.71	4.26

Soil Name (GSM)5

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24.00	11.50	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.10	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.50	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	8.25	1	1.00	2.22	5.94	7.16	14.68	0.92	5.40
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.00	0.01	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.00	0.03	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	25.91	2.59	1.61	-0.02	-0.64	21.06	30.13	3.69	3.21
Sat Vol Cont	26.59	2.65	1.63	-0.02	-0.68	22.31	30.73	2.89	2.80
%S	95.35	30.53	5.53	-1.06	0.21	72.19	100.00	2.10	0.42
Sopt	70.39	0.2	0.46	-0.25	-1.00	69.39	71.17	1.49	1.15
Fenv	0.49	0.01	0.10	1.10	1.44	0.33	0.95	1.70	4.71
Mropt	21095	3.4E+05	586.00	N/A	N/A	19947	22243	1.42	1.42
Mreq	4.007	0.00755	0.09	0.25	-0.63	3.82	4.28	2.35	3.35

Soil Name (GSM)35

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24.00	11.50	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.10	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.50	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	8.25	1	1.00	2.24	5.96	7.16	14.61	0.89	5.22
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.00	0.01	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.00	0.03	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	25.91	2.63	1.62	-0.02	-0.67	21.32	30.09	3.30	3.00
Sat Vol Cont	26.58	2.68	1.64	-0.02	-0.70	22.40	30.70	2.73	2.70
%S	95.32	30.49	5.52	-1.05	0.19	72.25	100.00	2.11	0.43
Sopt	70.4	0.2	0.46	-0.26	-0.99	69.39	71.17	1.51	1.16
Fenv	0.49	0.01	0.10	1.08	1.42	0.33	0.94	1.68	4.66
Mropt	32449	8.1E+05	901.00	N/A	N/A	30683	34215	1.42	1.42
Mreq	4.193	0.00742	0.09	0.27	-0.61	4.01	4.47	2.32	3.56

Soil Name (GSM)50

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24.00	11.50	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.10	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.50	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	8.25	1	1.00	2.17	5.61	7.16	14.25	0.90	4.96
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.00	0.01	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.00	0.03	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	25.90	2.61	1.62	-0.01	-0.66	21.19	30.06	3.45	3.04
Sat Vol Cont	26.56	2.67	1.63	0.00	-0.70	22.28	30.73	2.89	2.81
%S	95.37	30.04	5.48	-1.05	0.20	73.53	100.00	1.95	0.41
Sopt	70.39	0.2	0.46	-0.23	-1.01	69.39	71.17	1.49	1.17
Fenv	0.49	0.01	0.10	1.05	1.24	0.33	0.93	1.68	4.50
Mropt	33653	8.7E+05	935.00	N/A	N/A	31821	35485	1.42	1.42
Mreq	4.211	0.00748	0.09	0.26	-0.61	4.02	4.49	2.41	3.52

Soil Name (GSM)75

Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24.00	11.50	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.10	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.50	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	8.25	1	1.00	2.20	5.89	7.16	14.83	0.94	5.69
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.00	0.01	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.00	0.03	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	25.92	2.68	1.64	-0.03	-0.68	21.19	30.04	3.36	2.93
Sat Vol Cont	26.58	2.7	1.64	-0.03	-0.71	22.24	30.64	2.86	2.67
%S	95.32	31.03	5.57	-1.07	0.24	73.23	100.00	1.93	0.41
Sopt	70.4	0.2	0.46	-0.25	-0.99	69.39	71.17	1.50	1.15
Fenv	0.49	0.01	0.10	1.06	1.15	0.33	0.93	1.65	4.40
Mropt	38901	1.2E+06	1080.00	N/A	N/A	36784	41018	1.42	1.42
Mreq	4.273	0.00769	0.09	0.28	-0.62	4.08	4.54	2.32	3.32

Soil Name	(GSM)95								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	24.00	11.50	3.39	N/A	N/A	17.36	30.65	1.42	1.42
PI	4.63	1.39	1.18	N/A	N/A	2.32	6.94	1.42	1.42
wPI	1.27	0.10	0.32	N/A	N/A	0.64	1.91	1.42	1.42
Wopt	9.50	0.84	0.91	N/A	N/A	7.71	11.29	1.42	1.42
Gamma	123	6.05	2.46	N/A	N/A	118.18	127.82	1.42	1.42
Suction	8.26	1	1.00	2.19	5.67	7.16	14.54	0.90	5.13
SWCC A	74.31	1020.09	31.94	N/A	N/A	11.71	136.91	1.42	1.42
SWCC B	0.95	0.00	0.01	N/A	N/A	0.93	0.97	1.42	1.42
SWCC C	0.44	0.00	0.03	N/A	N/A	0.39	0.49	1.42	1.42
Vol Cont	25.91	2.63	1.62	-0.02	-0.64	20.89	30.07	3.78	3.14
Sat Vol Cont	26.57	2.7	1.64	-0.01	-0.70	22.26	30.73	2.87	2.77
%S	95.29	30.9	5.56	-1.05	0.20	72.38	100.00	2.07	0.43
Sopt	70.4	0.2	0.46	-0.25	-0.99	69.39	71.17	1.53	1.18
Fenv	0.49	0.01	0.10	1.05	1.21	0.33	0.94	1.76	4.71
Mropt	39984	1.2E+06	1110.00	N/A	N/A	37808	42160	1.42	1.42
Mreq	4.287	0.00761	0.09	0.25	-0.62	4.10	4.56	2.38	3.38
Soil Name	(FGM)5								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.80	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.50	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.30	1.42	1.42
Suction	17.45	24	5.00	2.06	7.14	10.55	56.19	1.51	8.48
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.02	0.14	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.00	0.06	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	32.27	2.20	1.48	-0.02	-0.64	28.17	36.23	3.24	3.13
Sat Vol Cont	33.17	2.2	1.48	-0.03	-0.69	29.20	36.95	2.97	2.83
%S	96.03	18.93	4.35	-0.93	-0.06	79.60	100.00	1.97	0.48
Sopt	83.62	1.8	1.36	-0.43	-0.80	80.37	85.74	1.66	1.09
Fenv	0.53	0.023	0.15	1.67	2.78	0.34	1.31	1.09	4.42
Mropt	9227	6.6E+04	256.00	N/A	N/A	8725	9729	1.42	1.42
Mreq	3.675	0.01327	0.12	0.49	-0.53	3.48	4.05	1.54	2.95

Soil Name	(FGM)35								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.80	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.50	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.30	1.42	1.42
Suction	17.49	26	5.00	2.12	7.35	10.53	59.33	1.49	8.93
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.02	0.14	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.00	0.06	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	32.26	2.21	1.49	-0.02	-0.64	28.14	36.20	3.24	3.10
Sat Vol Cont	33.17	2.21	1.49	-0.02	-0.68	29.33	36.85	2.75	2.64
%S	95.97	19.22	4.38	-0.90	-0.13	79.24	100.00	2.02	0.49
Sopt	83.62	1.8	1.36	-0.43	-0.82	80.37	85.74	1.67	1.09
Fenv	0.53	0.023	0.15	1.71	3.01	0.34	1.30	1.07	4.29
Mropt	18357	2.6E+05	510.00	N/A	N/A	17358	19356	1.42	1.42
Mreq	3.976	0.01337	0.12	0.50	-0.52	3.78	4.36	1.63	3.16
Soil Name	(FGM)50								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.80	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.50	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.30	1.42	1.42
Suction	17.49	25	5.00	2.12	7.47	10.53	57.91	1.48	8.60
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.02	0.14	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.00	0.06	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	32.27	2.22	1.49	-0.01	-0.62	28.00	36.22	3.42	3.16
Sat Vol Cont	33.18	2.21	1.49	-0.04	-0.72	29.34	36.93	2.79	2.71
%S	95.97	19.23	4.38	-0.92	-0.03	78.59	100.00	2.14	0.50
Sopt	83.62	1.8	1.35	-0.42	-0.83	80.37	85.74	1.67	1.09
Fenv	0.54	0.024	0.15	1.75	3.24	0.34	1.40	1.12	4.97
Mropt	22927	4.1E+05	637.00	N/A	N/A	21679	24175	1.42	1.42
Mreq	4.073	0.01356	0.12	0.51	-0.47	3.87	4.47	1.64	3.29

Soil Name (FGM)75

Analysis L1

Properties	μ	σ²	σ	E[X³]	E[X⁴]	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.80	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.50	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.30	1.42	1.42
Suction	17.46	24	5.00	2.09	7.45	10.52	61.18	1.58	9.97
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.02	0.14	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.00	0.06	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	32.24	2.23	1.49	0.01	-0.64	28.11	36.18	3.23	3.08
Sat Vol Cont	33.18	2.23	1.49	-0.02	-0.70	29.33	36.93	2.77	2.70
%S	95.93	19.65	4.43	-0.90	-0.13	78.68	100.00	2.08	0.49
Sopt	83.61	1.9	1.36	-0.42	-0.85	80.37	85.74	1.64	1.08
Fenv	0.54	0.025	0.16	1.72	3.03	0.35	1.40	1.05	4.71
Mropt	30347	7.1E+05	843.00	N/A	N/A	28695	31999	1.42	1.42
Mreq	4.196	0.014	0.12	0.55	-0.45	4.00	4.60	1.55	3.15

Soil Name (FGM)95

Analysis L1

Properties	μ	σ²	σ	E[X³]	E[X⁴]	Min	Max	α	β
P#200	67.45	90.84	9.53	N/A	N/A	48.77	86.13	1.42	1.42
PI	13.80	12.31	3.51	N/A	N/A	6.93	20.68	1.42	1.42
wPI	10.18	7.33	2.71	N/A	N/A	4.87	15.49	1.42	1.42
Wopt	15.50	2.22	1.49	N/A	N/A	12.58	18.42	1.42	1.42
Gamma	111.92	5.01	2.24	N/A	N/A	107.53	116.30	1.42	1.42
Suction	17.5	25	5.00	2.12	7.60	10.53	61.95	1.51	9.67
SWCC A	105.75	130.52	11.42	N/A	N/A	83.36	128.14	1.42	1.42
SWCC B	0.72	0.02	0.14	N/A	N/A	0.45	0.99	1.42	1.42
SWCC C	0.24	0.00	0.06	N/A	N/A	0.12	0.36	1.42	1.42
Vol Cont	32.26	2.23	1.49	0.00	-0.62	27.53	36.29	4.08	3.47
Sat Vol Cont	33.17	2.22	1.49	-0.03	-0.71	29.25	36.96	2.89	2.80
%S	95.97	19.42	4.41	-0.95	0.05	78.00	100.00	2.23	0.50
Sopt	83.61	1.9	1.36	-0.42	-0.85	80.37	85.74	1.63	1.07
Fenv	0.54	0.024	0.16	1.82	3.60	0.34	1.46	1.10	5.29
Mropt	37431	1.1E+06	1039.00	N/A	N/A	35394	39468	1.42	1.42
Mreq	4.285	0.01349	0.12	0.54	-0.43	4.09	4.69	1.60	3.26

Soil Name	(SFGM)5								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.40	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.80	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.30	N/A	N/A	110.49	119.51	1.42	1.42
Suction	10.44	3	2.00	1.91	5.67	7.91	22.62	1.52	7.30
SWCC A	80.27	122.50	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.90	0.00	0.00	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.40	0.00	0.04	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	30.20	2.32	1.52	-0.03	-0.71	26.17	33.94	2.85	2.65
Sat Vol Cont	30.96	2.43	1.56	-0.01	-0.73	26.99	34.81	2.68	2.60
%S	95.93	21.55	4.64	-1.00	0.09	78.15	100.00	1.92	0.44
Sopt	78.68	0.6	0.77	-0.56	-0.70	76.74	79.76	1.64	0.92
Fenv	0.46	0.015	0.12	1.60	2.53	0.30	1.06	1.07	4.14
Mropt	19408	2.9E+05	539.00	N/A	N/A	18352	20464	1.42	1.42
Mreq	3.934	0.01206	0.11	0.51	-0.49	3.75	4.31	1.61	3.17

Soil Name	(SFGM)35								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.40	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.80	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.30	N/A	N/A	110.49	119.51	1.42	1.42
Suction	10.45	3	2.00	1.86	5.41	7.92	24.21	1.54	8.40
SWCC A	80.27	122.50	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.90	0.00	0.00	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.40	0.00	0.04	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	30.22	2.29	1.51	-0.04	-0.67	26.14	33.98	2.97	2.74
Sat Vol Cont	30.98	2.39	1.55	-0.03	-0.68	26.87	34.88	2.93	2.79
%S	95.92	21.46	4.63	-0.98	0.02	77.51	100.00	2.04	0.45
Sopt	78.69	0.6	0.76	-0.56	-0.69	76.76	79.76	1.66	0.93
Fenv	0.46	0.015	0.12	1.68	2.93	0.30	1.08	1.06	4.30
Mropt	27760	5.9E+05	771.00	N/A	N/A	26249	29271	1.42	1.42
Mreq	4.091	0.0121	0.11	0.51	-0.50	3.91	4.46	1.56	3.07

Soil Name	(SFGM)50								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.40	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.80	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.30	N/A	N/A	110.49	119.51	1.42	1.42
Suction	10.45	3	2.00	1.93	5.78	7.91	24.31	1.53	8.39
SWCC A	80.27	122.50	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.90	0.00	0.00	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.40	0.00	0.04	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	30.21	2.28	1.51	-0.02	-0.66	26.13	34.05	3.03	2.85
Sat Vol Cont	30.96	2.38	1.54	-0.03	-0.70	26.90	34.92	2.91	2.84
%S	95.94	21.57	4.64	-1.00	0.10	77.78	100.00	1.98	0.44
Sopt	78.68	0.6	0.77	-0.56	-0.70	76.75	79.76	1.63	0.92
Fenv	0.46	0.015	0.12	1.67	2.86	0.30	1.06	1.05	4.14
Mropt	29725	6.8E+05	825.00	N/A	N/A	28107	31343	1.42	1.42
Mreq	4.117	0.01186	0.11	0.53	-0.47	3.93	4.47	1.57	2.93

Soil Name	(SFGM)75								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	60.02	71.93	8.48	N/A	N/A	43.40	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.80	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.30	N/A	N/A	110.49	119.51	1.42	1.42
Suction	10.45	3	2.00	1.94	5.72	7.92	22.64	1.46	7.05
SWCC A	80.27	122.50	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.90	0.00	0.00	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.40	0.00	0.04	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	30.19	2.29	1.51	-0.01	-0.68	26.34	33.98	2.70	2.65
Sat Vol Cont	30.96	2.41	1.55	-0.01	-0.70	26.92	34.85	2.82	2.71
%S	95.88	21.52	4.64	-0.95	-0.03	77.97	100.00	1.98	0.45
Sopt	78.68	0.6	0.77	-0.57	-0.70	76.75	79.76	1.63	0.91
Fenv	0.46	0.015	0.12	1.59	2.50	0.30	1.04	1.06	4.03
Mropt	34157	9.0E+05	949.00	N/A	N/A	32298	36016	1.42	1.42
Mreq	4.18	0.01183	0.11	0.50	-0.55	4.00	4.54	1.58	3.08

Soil Name	(SFGM)95								
Analysis	L1								
Properties	Mean	Var	Std Dev	Skew	Kurt	Min	Max	Alpha	Beta
P#200	60.02	71.93	8.48	N/A	N/A	43.40	76.65	1.42	1.42
PI	5.87	2.23	1.49	N/A	N/A	2.95	8.80	1.42	1.42
wPI	3.63	1.05	1.03	N/A	N/A	1.62	5.64	1.42	1.42
Wopt	13.25	1.62	1.27	N/A	N/A	10.75	15.75	1.42	1.42
Gamma	115	5.29	2.30	N/A	N/A	110.49	119.51	1.42	1.42
Suction	10.45	3	2.00	1.99	6.04	7.91	24.24	1.50	8.16
SWCC A	80.27	122.50	11.07	N/A	N/A	58.57	101.96	1.42	1.42
SWCC B	0.90	0.00	0.00	N/A	N/A	0.89	0.91	1.42	1.42
SWCC C	0.40	0.00	0.04	N/A	N/A	0.33	0.47	1.42	1.42
Vol Cont	30.21	2.28	1.51	-0.02	-0.70	26.28	34.06	2.85	2.80
Sat Vol Cont	30.97	2.38	1.54	-0.02	-0.70	27.03	34.88	2.75	2.73
%S	95.91	21.26	4.61	-0.97	0.01	77.09	100.00	2.15	0.47
Sopt	78.68	0.6	0.77	-0.58	-0.68	76.74	79.76	1.65	0.92
Fenv	0.46	0.015	0.12	1.69	3.06	0.30	1.08	1.09	4.39
Mropt	37849	1.1E+06	1051.00	N/A	N/A	35789	39909	1.42	1.42
Mreq	4.225	0.01181	0.11	0.51	-0.48	4.04	4.60	1.65	3.25
Soil Name	(CFGM)5								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21.00	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19.00	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	24.46	81	9.00	2.46	9.85	12.56	110.09	1.40	10.10
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.06	0.24	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.00	0.07	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	36.51	2.13	1.46	-0.03	-0.52	31.71	40.58	4.42	3.74
Sat Vol Cont	37.54	1.96	1.40	-0.02	-0.72	33.93	41.04	2.77	2.68
%S	96.29	15.15	3.89	-0.89	-0.04	79.71	100.00	2.50	0.56
Sopt	85.72	5.4	2.32	-0.30	-0.93	80.47	89.61	1.60	1.19
Fenv	0.58	0.026	0.16	1.52	2.84	0.34	1.58	1.62	6.64
Mropt	9476	6.9E+04	263.00	N/A	N/A	8960	9992	1.42	1.42
Mreq	3.724	0.01344	0.12	0.32	-0.53	3.49	4.12	2.25	3.73

Soil Name (CFGM)35
Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21.00	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19.00	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	24.43	81	9.00	2.44	9.34	12.60	100.76	1.36	8.75
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.06	0.24	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.00	0.07	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	36.48	2.18	1.48	-0.03	-0.53	32.19	40.64	3.65	3.55
Sat Vol Cont	37.53	1.94	1.39	-0.02	-0.69	33.93	40.98	2.77	2.64
%S	96.23	15.12	3.89	-0.83	-0.20	81.13	100.00	2.21	0.55
Sopt	85.73	5.4	2.31	-0.30	-0.92	80.48	89.61	1.61	1.19
Fenv	0.58	0.026	0.16	1.45	2.53	0.34	1.46	1.59	5.75
Mropt	14357	1.6E+05	399.00	N/A	N/A	13576	15138	1.42	1.42
Mreq	3.904	0.01325	0.12	0.30	-0.56	3.67	4.30	2.25	3.76

Soil Name (CFGM)50
Analysis L1

Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21.00	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19.00	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	24.42	79	9.00	2.42	9.43	12.56	100.89	1.40	9.04
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.06	0.24	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.00	0.07	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	36.49	2.15	1.47	-0.03	-0.51	31.86	40.68	4.22	3.82
Sat Vol Cont	37.54	1.9	1.38	-0.02	-0.70	33.93	41.04	2.86	2.78
%S	96.27	15.23	3.90	-0.88	-0.08	79.53	100.00	2.54	0.57
Sopt	85.73	5.4	2.32	-0.31	-0.93	80.47	89.61	1.60	1.18
Fenv	0.58	0.026	0.16	1.54	3.01	0.34	1.58	1.64	6.61
Mropt	16656	2.1E+05	463.00	N/A	N/A	15750	17563	1.42	1.42
Mreq	3.97	0.01344	0.12	0.30	-0.54	3.73	4.37	2.28	3.86

Soil Name	(CFGM)75								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21.00	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19.00	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	24.36	79	9.00	2.43	9.77	12.54	109.39	1.43	10.26
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.06	0.24	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.00	0.07	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	36.48	2.15	1.47	-0.02	-0.53	31.80	40.57	4.20	3.67
Sat Vol Cont	37.54	1.94	1.39	-0.02	-0.72	33.90	41.01	2.82	2.69
%S	96.2	15.28	3.91	-0.84	-0.16	80.68	100.00	2.30	0.56
Sopt	85.73	5.4	2.33	-0.32	-0.93	80.47	89.61	1.58	1.17
Fenv	0.58	0.026	0.16	1.47	2.58	0.34	1.50	1.61	5.98
Mropt	20166	3.1E+05	560.00	N/A	N/A	19068	21264	1.42	1.42
Mreq	4.054	0.01362	0.12	0.28	-0.61	3.81	4.46	2.28	3.82

Soil Name	(CFGM)95								
Analysis	L1								
Properties	μ	σ^2	σ	$E[X^3]$	$E[X^4]$	Min	Max	α	β
P#200	74.21	109.95	10.49	N/A	N/A	53.66	94.76	1.42	1.42
PI	21.00	28.49	5.34	N/A	N/A	10.54	31.46	1.42	1.42
wPI	16.12	20.54	4.53	N/A	N/A	7.24	25.01	1.42	1.42
Wopt	19.00	3.34	1.83	N/A	N/A	15.42	22.58	1.42	1.42
Gamma	106	4.49	2.12	N/A	N/A	101.85	110.16	1.42	1.42
Suction	24.5	83	9.00	2.50	10.09	12.56	110.35	1.38	9.92
SWCC A	118.48	85.79	9.26	N/A	N/A	100.32	136.63	1.42	1.42
SWCC B	0.63	0.06	0.24	N/A	N/A	0.16	1.09	1.42	1.42
SWCC C	0.16	0.00	0.07	N/A	N/A	0.03	0.29	1.42	1.42
Vol Cont	36.48	2.23	1.49	-0.04	-0.54	31.94	40.58	3.86	3.49
Sat Vol Cont	37.54	1.98	1.41	-0.04	-0.72	33.92	40.98	2.72	2.58
%S	96.21	15.61	3.95	-0.85	-0.16	80.44	100.00	2.28	0.55
Sopt	85.73	5.4	2.33	-0.30	-0.94	80.47	89.61	1.59	1.17
Fenv	0.58	0.027	0.16	1.51	2.79	0.34	1.53	1.57	6.07
Mropt	24558	4.7E+05	682.00	N/A	N/A	23221	25895	1.42	1.42
Mreq	4.138	0.0138	0.12	0.32	-0.56	3.90	4.52	2.19	3.48

APPENDIX C

STRUCTURAL NUMBERS FOR AC DEFICIENCIES FOR LEVEL 1 AND LEVEL 3B

Phoenix, AZ L1 (GB) Lowest MR					**Phoenix, AZ L1 (GB) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN1	0.880	1.412	2.117	3.107	SN1	0.802	1.311	1.980	2.910
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN1	0.907	1.446	2.164	3.174	SN1	0.829	1.345	2.026	2.976
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN1	0.932	1.479	2.208	3.238	SN1	0.855	1.378	2.071	3.041
Phoenix, AZ L1 (GSB) Lowest MR					**Phoenix, AZ L1 (GSB) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN1	1.397	2.096	3.076	4.449	SN1	1.150	1.765	2.605	3.806
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN1	1.489	2.221	3.257	4.684	SN1	1.232	1.875	2.759	4.022
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN1	1.579	2.345	3.435	4.911	SN1	1.313	1.984	2.915	4.234
Phoenix, AZ L1 (FGM) Lowest MR					**Phoenix, AZ L1 (FGM) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.377	2.070	3.039	4.400	SN_1	0.995	1.562	2.321	3.401
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.506	2.245	3.292	4.729	SN_1	1.101	1.701	2.515	3.679
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.637	2.425	3.551	5.054	SN_1	1.209	1.844	2.716	3.962
Phoenix, AZ L1 (SFGM) Lowest MR					**Phoenix, AZ L1 (SFGM) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.158	1.776	2.620	3.827	SN_1	0.971	1.530	2.278	3.339
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.253	1.903	2.800	4.077	SN_1	1.055	1.640	2.430	3.557
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.349	2.032	2.984	4.327	SN_1	1.137	1.749	2.582	3.773
Phoenix, AZ L1 (CFGM) Lowest MR					**Phoenix, AZ L1 (CFGM) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.213	1.850	2.724	3.972	SN_1	0.993	1.559	2.318	3.396
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.352	2.036	2.990	4.335	SN_1	1.116	1.721	2.542	3.717
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.505	2.244	3.290	4.726	SN_1	1.247	1.895	2.788	4.062

Phoenix, AZ L1 (GB) Medium MR					Phoenix, AZ L1 (GB) High MR				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.801	1.309	1.978	2.907	SN_1	0.774	1.274	1.930	2.839
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.827	1.343	2.023	2.971	SN_1	0.800	1.307	1.975	2.903
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.852	1.375	2.067	3.034	SN_1	0.824	1.339	2.019	2.965
Phoenix, AZ L1 (GSB) Medium MR					**Phoenix, AZ L1 (GSB) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.129	1.739	2.567	3.754	SN_1	1.052	1.636	2.424	3.550
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.210	1.845	2.717	3.963	SN_1	1.127	1.735	2.563	3.747
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.288	1.949	2.865	4.167	SN_1	1.199	1.831	2.698	3.937
Phoenix, AZ L1 (FGM) Medium MR					**Phoenix, AZ L1 (FGM) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.890	1.425	2.134	3.131	SN_1	0.765	1.262	1.915	2.817
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.993	1.560	2.319	3.398	SN_1	0.861	1.387	2.083	3.058
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.100	1.699	2.512	3.675	SN_1	0.958	1.513	2.255	3.306
Phoenix, AZ L1 (SFGM) Medium MR					**Phoenix, AZ L1 (SFGM) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.940	1.489	2.222	3.258	SN_1	0.878	1.408	2.112	3.099
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.026	1.602	2.377	3.481	SN_1	0.961	1.517	2.260	3.313
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.112	1.716	2.535	3.708	SN_1	1.044	1.626	2.410	3.528
Phoenix, AZ L1 (CFGM) Medium MR					**Phoenix, AZ L1 (CFGM) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.920	1.464	2.187	3.207	SN_1	0.831	1.347	2.030	2.981
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.034	1.612	2.391	3.502	SN_1	0.939	1.489	2.221	3.257
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.153	1.770	2.611	3.815	SN_1	1.052	1.637	2.425	3.551

Phoenix, AZ L1 (GB) Highest MR					**Phoenix, AZ - GB**				
Reliability = 85%					**Reliability = 85%, Mreq = 32893.72**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.770	1.269	1.924	2.830	SN_3	0.990	1.555	2.312	3.388
Reliability = 95%					**Reliability = 95%, Mreq = 25786.69**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.795	1.302	1.968	2.892	SN_3	1.115	1.719	2.540	3.715
Reliability = 99%					**Reliability = 99%, Mreq = 20270.1**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.819	1.333	2.010	2.953	SN_3	1.246	1.894	2.787	4.060
Phoenix, AZ L1 (GSB) Highest MR					**Phoenix, AZ - GSB**				
Reliability = 85%					**Reliability = 85%, Mreq = 20591.18**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.038	1.619	2.400	3.515	SN_3	1.238	1.882	2.770	4.037
Reliability = 95%					**Reliability = 95%, Mreq = 14443.32**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.113	1.717	2.537	3.711	SN_3	1.447	2.165	3.175	4.579
Reliability = 99%					**Reliability = 99%, Mreq = 10162.25**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.186	1.813	2.672	3.900	SN_3	1.677	2.481	3.630	5.153
Phoenix, AZ L1 (FGM) Highest MR					**Phoenix, AZ - FGM**				
Reliability = 85%					**Reliability = 85%, Mreq = 8550.92**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.675	1.145	1.760	2.597	SN_3	1.799	2.651	3.872	5.448
Reliability = 95%					**Reliability = 95%, Mreq = 4716.96**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.768	1.266	1.921	2.825	SN_3	2.274	3.333	4.781	6.543
Reliability = 99%					**Reliability = 99%, Mreq = 2893.67**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.866	1.393	2.092	3.070	SN_3	2.746	4.004	5.608	7.548
Phoenix, AZ L1 (SFGM) Highest MR					**Phoenix, AZ - SFGM**				
Reliability = 85%					**Reliability = 85%, Mreq = 12708.7**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.828	1.343	2.024	2.973	SN_3	1.528	2.275	3.335	4.784
Reliability = 95%					**Reliability = 95%, Mreq = 8040.84**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.909	1.450	2.168	3.181	SN_3	1.844	2.715	3.961	5.555
Reliability = 99%					**Reliability = 99%, Mreq = 5469.96**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.991	1.557	2.314	3.391	SN_3	2.146	3.149	4.545	6.258
Phoenix, AZ L1 (CFGM) Highest MR					**Phoenix, AZ - CFGM**				
Reliability = 85%					**Reliability = 85%, Mreq = 18189.9**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.756	1.251	1.900	2.795	SN_3	1.309	1.977	2.906	4.222
Reliability = 95%					**Reliability = 95%, Mreq = 11012.63**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.863	1.390	2.087	3.063	SN_3	1.622	2.405	3.522	5.018
Reliability = 99%, Mreq = 20270.1					**Reliability = 99%, Mreq = 6806.64**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.976	1.537	2.287	3.351	SN_3	1.970	2.895	4.207	5.853

Amarillo,TX L1 (GB) Lowest MR					**Amarillo,TX L1 (GB) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.070	1.660	2.457	3.596	SN1	0.984	1.547	2.302	3.373
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.114	1.719	2.539	3.714	SN1	1.028	1.605	2.381	3.488
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.155	1.772	2.615	3.820	SN1	1.067	1.657	2.453	3.591
Amarillo,TX L1 (GSB) Lowest MR					**Amarillo,TX L1 (GSB) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.784	2.630	3.842	5.412	SN_1	1.498	2.234	3.276	4.708
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.864	2.744	4.001	5.604	SN_1	1.566	2.327	3.410	4.878
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.926	2.832	4.122	5.750	SN_1	1.616	2.397	3.510	5.004
Amarillo,TX L1 (FGM) Lowest MR					**Amarillo,TX L1 (FGM) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.348	3.440	4.917	6.707	SN_1	1.792	2.642	3.859	5.433
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.502	3.661	5.191	7.039	SN_1	1.914	2.815	4.098	5.721
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.607	3.809	5.371	7.259	SN_1	1.995	2.931	4.256	5.911
Amarillo,TX L1 (SFGM) Lowest MR					**Amarillo,TX L1 (SFGM) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.889	2.779	4.049	5.662	SN_1	1.633	2.420	3.543	5.045
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.997	2.934	4.260	5.917	SN_1	1.727	2.550	3.729	5.274
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.073	3.043	4.406	6.092	SN_1	1.790	2.640	3.856	5.428
Amarillo,TX L1 (CFGM) Lowest MR					**Amarillo,TX L1 (CFGM) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.228	3.267	4.697	6.442	SN_1	1.892	2.784	4.056	5.671
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.407	3.525	5.022	6.834	SN_1	2.048	3.007	4.358	6.034
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.543	3.719	5.262	7.126	SN_1	2.166	3.178	4.582	6.303

Amarillo,TX L1 (GB) Medium MR					**Amarillo,TX L1 (GB) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN1	0.892	1.427	2.137	3.135	SN1	0.948	1.500	2.237	3.279
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN1	0.950	1.502	2.240	3.284	SN1	0.989	1.554	2.311	3.386
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN1	1.009	1.580	2.346	3.437	SN1	1.025	1.602	2.377	3.481
Amarillo,TX L1 (GSB) Medium MR					**Amarillo,TX L1 (GSB) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.123	1.730	2.555	3.736	SN1	1.380	2.073	3.043	4.406
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.310	1.979	2.908	4.225	SN_1	1.445	2.161	3.171	4.572
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.491	2.225	3.262	4.691	SN_1	1.494	2.229	3.268	4.699
Amarillo,TX L1 (FGM) Medium MR					**Amarillo,TX L1 (FGM) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.734	2.560	3.743	5.292	SN_1	1.449	2.168	3.180	4.584
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.814	2.673	3.902	5.485	SN_1	1.554	2.311	3.387	4.849
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.855	2.731	3.983	5.582	SN_1	1.627	2.411	3.531	5.029
Amarillo,TX L1 (SFGM) Medium MR					**Amarillo,TX L1 (SFGM) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.575	2.339	3.427	4.900	SN_1	1.494	2.228	3.267	4.697
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.667	2.467	3.611	5.129	SN_1	1.580	2.346	3.437	4.913
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.732	2.558	3.740	5.287	SN_1	1.639	2.428	3.555	5.059
Amarillo,TX L1 (CFGM) Medium MR					**Amarillo,TX L1 (CFGM) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.839	2.709	3.952	5.546	SN_1	1.644	2.435	3.564	5.071
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.974	2.901	4.216	5.863	SN_1	1.783	2.630	3.841	5.411
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.066	3.034	4.393	6.076	SN_1	1.891	2.783	4.054	5.668

Amarillo,TX L1 (GB) Highest MR					**Amarillo,TX - GB**				
Reliability = 85%					**Reliability = 85%, Mreq = 31463.35**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN1	0.947	1.499	2.236	3.278	SN_3	1.012	1.584	2.352	3.446
Reliability = 95%					**Reliability = 95%, Mreq = 24926.71**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN1	0.990	1.556	2.313	3.390	SN_3	1.133	1.743	2.573	3.762
Reliability = 99%					**Reliability = 99%, Mreq = 19845.61**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN1	1.030	1.607	2.384	3.492	SN_3	1.258	1.910	2.810	4.091
Amarillo,TX L1 (GSB) Highest MR					**Amarillo,TX - GSB**				
Reliability = 85%					**Reliability = 85%, Mreq = 16199.64**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN1	1.365	2.053	3.014	4.367	SN_3	1.377	2.070	3.038	4.399
Reliability = 95%					**Reliability = 95%, Mreq = 11142.57**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.431	2.143	3.144	4.538	SN_3	1.614	2.394	3.506	4.999
Reliability = 99%					**Reliability = 99%, Mreq = 7768.27**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.482	2.212	3.244	4.668	SN_3	1.869	2.751	4.011	5.616
Amarillo,TX L1 (FGM) Highest MR					**Amarillo,TX - FGM**				
Reliability = 85%					**Reliability = 85%, Mreq = 5549.37**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.329	2.005	2.945	4.275	SN_3	2.134	3.132	4.522	6.231
Reliability = 95%					**Reliability = 95%, Mreq = 3684.31**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.426	2.135	3.133	4.524	SN_3	2.502	3.660	5.190	7.038
Reliability = 99%					**Reliability = 99%, Mreq = 2711.1**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.491	2.224	3.261	4.690	SN_3	2.816	4.100	5.724	7.691
Amarillo,TX L1 (SFGM) Highest MR					**Amarillo,TX - SFGM**				
Reliability = 85%					**Reliability = 85%, Mreq = 9013.22**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.433	2.145	3.147	4.542	SN_3	1.761	2.598	3.797	5.357
Reliability = 95%					**Reliability = 95%, Mreq = 6674.78**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.517	2.260	3.312	4.755	SN_3	1.985	2.917	4.237	5.889
Reliability = 99%					**Reliability = 99%, Mreq = 5199.14**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.572	2.336	3.422	4.894	SN_3	2.189	3.211	4.625	6.355
Amarillo,TX L1 (CFGM) Highest MR					**Amarillo,TX - CFGM**				
Reliability = 85%					**Reliability = 85%, Mreq = 5477.68**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.521	2.265	3.320	4.765	SN_3	2.145	3.147	4.542	6.256
Reliability = 95%					**Reliability = 95%, Mreq = 3713.41**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.651	2.444	3.578	5.088	SN_3	2.494	3.650	5.177	7.022
Reliability = 99%, Mreq = 20270.1					**Reliability = 99%, Mreq = 2761**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.750	2.583	3.775	5.330	SN_3	2.796	4.073	5.691	7.651

McAlester, OK L1 (GB) Lowest MR					**McAlester, OK L1 (GB) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.101	1.702	2.515	3.679	SN_1	1.014	1.586	2.355	3.450
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.143	1.756	2.592	3.788	SN_1	1.054	1.640	2.429	3.556
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.180	1.805	2.661	3.885	SN_1	1.090	1.687	2.495	3.651
McAlester, OK L1 (GSB) Lowest MR					**McAlester, OK L1 (GSB) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.809	2.666	3.892	5.472	SN_1	1.514	2.256	3.308	4.749
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.881	2.768	4.033	5.644	SN_1	1.577	2.343	3.432	4.907
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.935	2.846	4.140	5.772	SN_1	1.625	2.409	3.528	5.026
McAlester, OK L1 (FGM) Lowest MR					**McAlester, OK L1 (FGM) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.429	3.556	5.062	6.882	SN_1	1.854	2.730	3.982	5.581
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.553	3.733	5.279	7.147	SN_1	1.949	2.865	4.166	5.804
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.634	3.848	5.419	7.317	SN_1	2.010	2.953	4.285	5.946
McAlester, OK L1 (SFGM) Lowest MR					**McAlester, OK L1 (SFGM) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.940	2.853	4.150	5.784	SN_1	1.682	2.488	3.640	5.165
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.028	2.979	4.320	5.988	SN_1	1.757	2.593	3.790	5.349
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.086	3.062	4.431	6.122	SN_1	1.806	2.661	3.886	5.465
McAlester, OK L1 (CFGM) Lowest MR					**McAlester, OK L1 (CFGM) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.310	3.385	4.846	6.622	SN_1	1.951	2.868	4.170	5.808
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.455	3.594	5.108	6.938	SN_1	2.074	3.044	4.407	6.092
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.570	3.757	5.308	7.181	SN_1	2.170	3.183	4.588	6.310

McAlester, OK L1 (GB) Medium MR					**McAlester, OK L1 (GB) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.893	1.429	2.140	3.140	SN_1	0.979	1.540	2.292	3.359
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.954	1.508	2.247	3.294	SN_1	1.016	1.590	2.360	3.458
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.016	1.590	2.360	3.458	SN_1	1.050	1.634	2.421	3.545
McAlester, OK L1 (GSB) Medium MR					**McAlester, OK L1 (GSB) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.154	1.771	2.613	3.817	SN_1	1.401	2.102	3.084	4.460
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.302	1.969	2.894	4.206	SN_1	1.462	2.184	3.204	4.616
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.458	2.179	3.197	4.606	SN_1	1.509	2.248	3.296	4.734
McAlester, OK L1 (FGM) Medium MR					**McAlester, OK L1 (FGM) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.704	2.518	3.684	5.219	SN_1	1.515	2.256	3.308	4.749
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.792	2.642	3.858	5.431	SN_1	1.601	2.375	3.479	4.965
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.848	2.722	3.970	5.567	SN_1	1.658	2.454	3.593	5.106
McAlester, OK L1 (SFGM) Medium MR					**McAlester, OK L1 (SFGM) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.589	2.358	3.455	4.935	SN_1	1.543	2.295	3.363	4.820
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.674	2.477	3.625	5.146	SN_1	1.612	2.391	3.501	4.993
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.735	2.562	3.746	5.295	SN_1	1.656	2.452	3.589	5.102
McAlester, OK L1 (CFGM) Medium MR					**McAlester, OK L1 (CFGM) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.859	2.736	3.990	5.591	SN_1	1.704	2.518	3.683	5.218
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.974	2.901	4.216	5.863	SN_1	1.810	2.668	3.895	5.476
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.060	3.024	4.380	6.060	SN_1	1.894	2.787	4.060	5.676

McAlester, OK L1 (GB) Highest MR					**McAlester, OK - GB**				
Reliability = 85%					**Reliability = 85%, Mreq = 30804.22**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.977	1.538	2.288	3.354	SN_3	1.023	1.598	2.371	3.474
Reliability = 95%					**Reliability = 95%, Mreq = 24198.91**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.016	1.589	2.359	3.455	SN_3	1.149	1.764	2.603	3.804
Reliability = 99%					**Reliability = 99%, Mreq = 18918.55**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.050	1.635	2.422	3.546	SN_3	1.286	1.947	2.862	4.163
McAlester, OK L1 (GSB) Highest MR					**McAlester, OK - GSB**				
Reliability = 85%					**Reliability = 85%, Mreq = 15376.06**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.383	2.077	3.049	4.414	SN_3	1.409	2.112	3.100	4.481
Reliability = 95%					**Reliability = 95%, Mreq = 10701.35**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.442	2.158	3.165	4.566	SN_3	1.642	2.432	3.560	5.066
Reliability = 99%					**Reliability = 99%, Mreq = 7588.53**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.488	2.220	3.255	4.681	SN_3	1.887	2.776	4.045	5.658
McAlester, OK L1 (FGM) Highest MR					**McAlester, OK - FGM**				
Reliability = 85%					**Reliability = 85%, Mreq = 5259.32**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.381	2.074	3.045	4.408	SN_3	2.180	3.197	4.607	6.333
Reliability = 95%					**Reliability = 95%, Mreq = 3399.31**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.458	2.179	3.196	4.606	SN_3	2.581	3.772	5.327	7.205
Reliability = 99%					**Reliability = 99%, Mreq = 2427.85**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN1	1.510	2.250	3.299	4.737	SN_3	2.938	4.266	5.923	7.937
McAlester, OK L1 (SFGM) Highest MR					**McAlester, OK - SFGM**				
Reliability = 85%					**Reliability = 85%, Mreq = 8849.52**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.475	2.202	3.229	4.648	SN_3	1.774	2.617	3.823	5.389
Reliability = 95%					**Reliability = 95%, Mreq = 6621.84**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.546	2.300	3.371	4.829	SN_3	1.991	2.926	4.249	5.903
Reliability = 99%					**Reliability = 99%, Mreq = 5148.63**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.593	2.364	3.463	4.945	SN_3	2.198	3.223	4.641	6.374
McAlester, OK L1 (CFGM) Highest MR					**McAlester, OK - CFGM**				
Reliability = 85%					**Reliability = 85%, Mreq = 5274.58**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.578	2.344	3.434	4.909	SN_3	2.177	3.193	4.602	6.327
Reliability = 95%					**Reliability = 95%, Mreq = 3706.21**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.684	2.490	3.644	5.169	SN_3	2.496	3.652	5.180	7.026
Reliability = 99%, Mreq = 20270.1					**Reliability = 99%, Mreq = 2811.57**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.762	2.600	3.799	5.359	SN_3	2.777	4.046	5.659	7.611

Salem, OR L1 (GB) Lowest MR					**Salem, OR L1 (GB) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN$_1$	1.134	1.745	2.577	3.766	SN$_1$	1.044	1.626	2.410	3.529
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN$_1$	1.172	1.795	2.647	3.866	SN$_1$	1.080	1.673	2.475	3.623
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN$_1$	1.205	1.839	2.708	3.951	SN$_1$	1.111	1.714	2.533	3.704
Salem, OR L1 (GSB) Lowest MR					**Salem, OR L1 (GSB) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN$_1$	1.830	2.695	3.933	5.522	SN$_1$	1.534	2.283	3.346	4.798
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN$_1$	1.894	2.787	4.060	5.676	SN$_1$	1.592	2.363	3.461	4.943
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN$_1$	1.942	2.856	4.154	5.789	SN$_1$	1.636	2.423	3.548	5.051
Salem, OR L1 (FGM) Lowest MR					**Salem, OR L1 (FGM) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN$_1$	2.524	3.692	5.229	7.086	SN$_1$	1.930	2.838	4.130	5.760
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN$_1$	2.615	3.821	5.386	7.278	SN$_1$	2.001	2.939	4.267	5.925
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN$_1$	2.670	3.898	5.480	7.391	SN$_1$	2.042	2.999	4.346	6.020
Salem, OR L1 (SFGM) Lowest MR					**Salem, OR L1 (SFGM) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN$_1$	1.994	2.929	4.254	5.908	SN$_1$	1.729	2.554	3.735	5.281
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN$_1$	2.062	3.027	4.384	6.065	SN$_1$	1.791	2.641	3.857	5.430
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN$_1$	2.102	3.085	4.461	6.158	SN$_1$	1.827	2.692	3.929	5.517
Salem, OR L1 (CFGM) Lowest MR					**Salem, OR L1 (CFGM) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN$_1$	2.416	3.537	5.038	6.853	SN$_1$	2.060	3.025	4.381	6.062
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN$_1$	2.527	3.696	5.233	7.091	SN$_1$	2.157	3.165	4.565	6.282
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN$_1$	2.609	3.812	5.375	7.263	SN$_1$	2.230	3.269	4.700	6.445

Salem, OR L1 (GB) Medium MR					**Salem, OR L1 (GB) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.936	1.485	2.216	3.250	SN_1	1.011	1.584	2.352	3.445
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.989	1.554	2.311	3.386	SN_1	1.046	1.628	2.413	3.534
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.044	1.626	2.410	3.529	SN_1	1.074	1.666	2.466	3.609
Salem, OR L1 (GSB) Medium MR					**Salem, OR L1 (GSB) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.172	1.794	2.646	3.864	SN_1	1.417	2.123	3.116	4.501
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.366	2.054	3.016	4.370	SN_1	1.472	2.198	3.224	4.641
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.546	2.299	3.370	4.827	SN_1	1.514	2.256	3.308	4.749
Salem, OR L1 (FGM) Medium MR					**Salem, OR L1 (FGM) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.733	2.559	3.742	5.290	SN_1	1.573	2.336	3.423	4.895
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.811	2.668	3.895	5.477	SN_1	1.634	2.421	3.545	5.048
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.863	2.742	3.998	5.601	SN_1	1.671	2.473	3.619	5.139
Salem, OR L1 (SFGM) Medium MR					**Salem, OR L1 (SFGM) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.603	2.378	3.483	4.970	SN_1	1.584	2.353	3.447	4.924
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.684	2.490	3.644	5.170	SN_1	1.641	2.431	3.559	5.065
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.744	2.574	3.763	5.316	SN_1	1.676	2.480	3.629	5.151
Salem, OR L1 (CFGM) Medium MR					**Salem, OR L1 (CFGM) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.922	2.827	4.115	5.742	SN1	1.792	2.643	3.859	5.433
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.017	2.963	4.298	5.962	SN_1	1.879	2.765	4.030	5.640
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.091	3.069	4.439	6.131	SN_1	1.945	2.860	4.160	5.796

Salem, OR L1 (GB) Highest MR					**Salem, OR - GB**				
Reliability = 85%					**Reliability = 85%, Mreq = 28512.83**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.008	1.580	2.346	3.437	SN_3	1.062	1.650	2.444	3.577
Reliability = 95%					**Reliability = 95%, Mreq = 22953.07**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.045	1.627	2.412	3.532	SN_3	1.177	1.802	2.657	3.879
Reliability = 99%					**Reliability = 99%, Mreq = 18603.37**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.076	1.669	2.470	3.615	SN_3	1.295	1.960	2.881	4.188
Salem, OR L1 (GSB) Highest MR					**Salem, OR - GSB**				
Reliability = 85%					**Reliability = 85%, Mreq = 14871.08**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.400	2.101	3.083	4.458	SN_3	1.429	2.140	3.140	4.533
Reliability = 95%					**Reliability = 95%, Mreq = 10722.27**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.455	2.175	3.191	4.599	SN_3	1.640	2.430	3.557	5.063
Reliability = 99%					**Reliability = 99%, Mreq = 7837.81**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.497	2.232	3.272	4.704	SN_3	1.863	2.742	3.998	5.601
Salem, OR L1 (FGM) Highest MR					**Salem, OR - FGM**				
Reliability = 85%					**Reliability = 85%, Mreq = 5285.26**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.439	2.154	3.159	4.558	SN_3	2.175	3.191	4.599	6.323
Reliability = 95%					**Reliability = 95%, Mreq = 3600.29**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.497	2.233	3.273	4.705	SN_3	2.524	3.692	5.229	7.086
Reliability = 99%					**Reliability = 99%, Mreq = 2685.37**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.531	2.279	3.341	4.791	SN_3	2.826	4.114	5.740	7.712
Salem, OR L1 (SFGM) Highest MR					**Salem, OR - SFGM**				
Reliability = 85%					**Reliability = 85%, Mreq = 8604.54**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.519	2.263	3.318	4.761	SN_3	1.794	2.645	3.863	5.437
Reliability = 95%					**Reliability = 95%, Mreq = 6477.46**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.573	2.337	3.424	4.896	SN_3	2.009	2.951	4.283	5.943
Reliability = 99%					**Reliability = 99%, Mreq = 5022.37**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.604	2.380	3.485	4.973	SN_3	2.219	3.254	4.680	6.421
Salem, OR L1 (CFGM) Highest MR					**Salem, OR - CFGM**				
Reliability = 85%					**Reliability = 85%, Mreq = 4774.54**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.663	2.461	3.602	5.118	SN_3	2.263	3.318	4.762	6.519
Reliability = 95%					**Reliability = 95%, Mreq = 3453.96**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.743	2.574	3.762	5.315	SN_3	2.565	3.750	5.300	7.172
Reliability = 99%, Mreq = 20270.1					**Reliability = 99%, Mreq = 2668.81**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.802	2.656	3.879	5.456	SN_3	2.833	4.123	5.752	7.726

Eureka, CA L1 (GB) Lowest MR					**Eureka, CA L1 (GB) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.137	1.749	2.582	3.774	SN_1	1.048	1.631	2.417	3.539
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.176	1.800	2.654	3.875	SN_1	1.083	1.678	2.482	3.632
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.209	1.845	2.717	3.963	SN_1	1.114	1.718	2.538	3.712
Eureka, CA L1 (GSB) Lowest MR					**Eureka, CA L1 (GSB) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.833	2.701	3.941	5.531	SN_1	1.536	2.286	3.351	4.803
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.899	2.794	4.070	5.687	SN_1	1.592	2.362	3.461	4.942
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.949	2.865	4.167	5.804	SN_1	1.633	2.420	3.543	5.045
Eureka, CA L1 (FGM) Lowest MR					**Eureka, CA L1 (FGM) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.539	3.713	5.254	7.116	SN_1	1.939	2.850	4.147	5.780
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.625	3.834	5.402	7.297	SN_1	2.008	2.950	4.281	5.941
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.675	3.905	5.488	7.402	SN_1	2.050	3.010	4.361	6.038
Eureka, CA L1 (SFGM) Lowest MR					**Eureka, CA L1 (SFGM) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.002	2.941	4.269	5.927	SN_1	1.733	2.559	3.741	5.289
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.068	3.037	4.397	6.081	SN_1	1.791	2.641	3.857	5.430
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.109	3.095	4.473	6.173	SN_1	1.825	2.689	3.925	5.512
Eureka, CA L1 (CFGM) Lowest MR					**Eureka, CA L1 (CFGM) Low MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.433	3.562	5.068	6.890	SN_1	2.069	3.038	4.398	6.082
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.538	3.712	5.253	7.115	SN_1	2.159	3.168	4.568	6.287
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.616	3.822	5.388	7.279	SN_1	2.226	3.263	4.692	6.436

Eureka, CA L1 (GB) Medium MR					**Eureka, CA L1 (GB) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	0.954	1.509	2.249	3.296	SN_1	1.012	1.584	2.353	3.446
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.003	1.572	2.335	3.422	SN_1	1.048	1.631	2.418	3.540
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.052	1.637	2.425	3.551	SN_1	1.079	1.673	2.475	3.622
Eureka, CA L1 (GSB) Medium MR					**Eureka, CA L1 (GSB) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.224	1.865	2.745	4.002	SN_1	1.423	2.132	3.128	4.517
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.358	2.043	3.001	4.349	SN_1	1.478	2.207	3.236	4.657
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.493	2.227	3.266	4.696	SN_1	1.519	2.263	3.318	4.761
Eureka, CA L1 (FGM) Medium MR					**Eureka, CA L1 (FGM) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.518	2.261	3.315	4.758	SN_1	1.582	2.349	3.441	4.918
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.631	2.417	3.539	5.040	SN_1	1.640	2.429	3.556	5.061
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.737	2.565	3.750	5.300	SN_1	1.673	2.476	3.623	5.144
Eureka, CA L1 (SFGM) Medium MR					**Eureka, CA L1 (SFGM) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.624	2.408	3.526	5.023	SN_1	1.591	2.361	3.459	4.940
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.700	2.513	3.676	5.209	SN_1	1.646	2.438	3.569	5.077
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.755	2.590	3.785	5.343	SN_1	1.679	2.483	3.634	5.157
Eureka, CA L1 (CFGM) Medium MR					**Eureka, CA L1 (CFGM) High MR**				
Reliability = 85%					**Reliability = 85%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.927	2.834	4.125	5.754	SN_1	1.807	2.663	3.888	5.468
Reliability = 95%					**Reliability = 95%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.018	2.964	4.300	5.965	SN_1	1.889	2.779	4.049	5.662
Reliability = 99%					**Reliability = 99%**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	2.088	3.065	4.434	6.125	SN_1	1.949	2.866	4.167	5.805

Eureka, CA L1 (GB) Highest MR					**Eureka, CA - GB**				
Reliability = 85%					**Reliability = 85%, Mreq = 27745.12**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.012	1.584	2.352	3.445	SN_3	1.076	1.669	2.469	3.614
Reliability = 95%					**Reliability = 95%, Mreq = 22375.92**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.048	1.631	2.417	3.539	SN_3	1.191	1.821	2.683	3.916
Reliability = 99%					**Reliability = 99%, Mreq = 18076.97**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.080	1.673	2.475	3.623	SN_3	1.312	1.982	2.913	4.231
Eureka, CA L1 (GSB) Highest MR					**Eureka, CA - GSB**				
Reliability = 85%					**Reliability = 85%, Mreq = 14229.48**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.403	2.105	3.089	4.467	SN_3	1.456	2.177	3.194	4.602
Reliability = 95%					**Reliability = 95%, Mreq = 10294.81**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.458	2.179	3.197	4.606	SN_3	1.668	2.468	3.612	5.131
Reliability = 99%					**Reliability = 99%, Mreq = 7554.27**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.500	2.236	3.278	4.712	SN_3	1.890	2.781	4.052	5.666
Eureka, CA L1 (FGM) Highest MR					**Eureka, CA - FGM**				
Reliability = 85%					**Reliability = 85%, Mreq = 6588.34**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.446	2.163	3.173	4.576	SN_3	1.995	2.932	4.257	5.913
Reliability = 95%					**Reliability = 95%, Mreq = 4064.53**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.501	2.238	3.281	4.715	SN_3	2.409	3.527	5.025	6.838
Reliability = 99%					**Reliability = 99%, Mreq = 2678.66**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.533	2.282	3.345	4.797	SN_3	2.829	4.118	5.745	7.718
Eureka, CA L1 (SFGM) Highest MR					**Eureka, CA - SFGM**				
Reliability = 85%					**Reliability = 85%, Mreq = 8120.63**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.523	2.268	3.325	4.771	SN_3	1.836	2.705	3.946	5.538
Reliability = 95%					**Reliability = 95%, Mreq = 6083.52**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.578	2.343	3.433	4.908	SN_3	2.059	3.023	4.379	6.059
Reliability = 99%					**Reliability = 99%, Mreq = 4699.55**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.611	2.389	3.499	4.991	SN_3	2.277	3.338	4.787	6.550
Eureka, CA L1 (CFGM) Highest MR					**Eureka, CA - CFGM**				
Reliability = 85%					**Reliability = 85%, Mreq = 4914.08**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.673	2.475	3.622	5.142	SN_3	2.238	3.281	4.715	6.463
Reliability = 95%					**Reliability = 95%, Mreq = 3609.46**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.751	2.584	3.777	5.333	SN_3	2.522	3.689	5.225	7.080
Reliability = 99%, Mreq = 20270.1					**Reliability = 99%, Mreq = 2804.86**				
Traffic	10^5	10^6	10^7	10^8	Traffic	10^5	10^6	10^7	10^8
SN_1	1.808	2.665	3.890	5.470	SN_3	2.779	4.049	5.663	7.616

APPENDIX D

ASPHALT DEFICIENCIES FOR THE 1,500 DATA POINTS

RATIO	SN_3	SN_1	AC	RATIO	SN_3	SN_1	AC
0.80	0.99	0.88	-0.25	0.67	0.99	0.80	-0.43
0.80	1.55	1.41	-0.32	0.67	1.55	1.31	-0.56
0.80	2.31	2.12	-0.44	0.67	2.31	1.98	-0.75
0.80	3.39	3.11	-0.64	0.67	3.39	2.91	-1.09
0.66	1.11	0.91	-0.47	0.56	1.11	0.83	-0.65
0.66	1.72	1.45	-0.62	0.56	1.72	1.34	-0.85
0.66	2.54	2.16	-0.86	0.56	2.54	2.03	-1.17
0.66	3.71	3.17	-1.23	0.56	3.71	2.98	-1.68
0.55	1.25	0.93	-0.72	0.46	1.25	0.85	-0.89
0.55	1.89	1.48	-0.94	0.46	1.89	1.38	-1.17
0.55	2.79	2.21	-1.32	0.46	2.79	2.07	-1.63
0.55	4.06	3.24	-1.87	0.46	4.06	3.04	-2.32
1.31	1.24	1.40	0.36	0.85	1.24	1.15	-0.20
1.31	1.88	2.10	0.49	0.85	1.88	1.77	-0.27
1.31	2.77	3.08	0.70	0.85	2.77	2.60	-0.38
1.31	4.04	4.45	0.94	0.85	4.04	3.81	-0.52
1.07	1.45	1.49	0.09	0.69	1.45	1.23	-0.49
1.07	2.16	2.22	0.13	0.69	2.16	1.87	-0.66
1.07	3.18	3.26	0.19	0.69	3.18	2.76	-0.95
1.07	4.58	4.68	0.24	0.69	4.58	4.02	-1.27
0.86	1.68	1.58	-0.22	0.56	1.68	1.31	-0.83
0.86	2.48	2.34	-0.31	0.56	2.48	1.98	-1.13
0.86	3.63	3.44	-0.44	0.56	3.63	2.91	-1.63
0.86	5.15	4.91	-0.55	0.56	5.15	4.23	-2.09
0.53	1.80	1.38	-0.96	0.26	1.80	0.99	-1.83
0.53	2.65	2.07	-1.32	0.26	2.65	1.56	-2.48
0.53	3.87	3.04	-1.89	0.26	3.87	2.32	-3.52
0.53	5.45	4.40	-2.38	0.26	5.45	3.40	-4.65
0.36	2.27	1.51	-1.74	0.18	2.27	1.10	-2.66
0.36	3.33	2.25	-2.47	0.18	3.33	1.70	-3.71
0.36	4.78	3.29	-3.39	0.18	4.78	2.52	-5.15
0.36	6.54	4.73	-4.12	0.18	6.54	3.68	-6.51
0.27	2.75	1.64	-2.52	0.13	2.75	1.21	-3.49
0.27	4.00	2.43	-3.59	0.13	4.00	1.84	-4.91
0.27	5.61	3.55	-4.67	0.13	5.61	2.72	-6.57
0.27	7.55	5.05	-5.67	0.13	7.55	3.96	-8.15
0.53	1.53	1.16	-0.84	0.37	1.53	0.97	-1.27
0.53	2.28	1.78	-1.13	0.37	2.28	1.53	-1.69
0.53	3.33	2.62	-1.63	0.37	3.33	2.28	-2.40
0.53	4.78	3.83	-2.17	0.37	4.78	3.34	-3.28
0.40	1.84	1.25	-1.34	0.28	1.84	1.05	-1.79
0.40	2.72	1.90	-1.85	0.28	2.72	1.64	-2.44
0.40	3.96	2.80	-2.64	0.28	3.96	2.43	-3.48
0.40	5.56	4.08	-3.36	0.28	5.56	3.56	-4.54
0.32	2.15	1.35	-1.81	0.22	2.15	1.14	-2.29
0.32	3.15	2.03	-2.54	0.22	3.15	1.75	-3.18
0.32	4.54	2.98	-3.55	0.22	4.54	2.58	-4.46
0.32	6.26	4.33	-4.39	0.22	6.26	3.77	-5.65

RATIO	SN_3	SN_1	AC	RATIO	SN_3	SN_1	AC
0.67	0.99	0.80	-0.43	0.63	0.99	0.77	-0.49
0.67	1.55	1.31	-0.56	0.63	1.55	1.27	-0.64
0.67	2.31	1.98	-0.76	0.63	2.31	1.93	-0.87
0.67	3.39	2.91	-1.09	0.63	3.39	2.84	-1.25
0.56	1.11	0.83	-0.65	0.52	1.11	0.80	-0.72
0.56	1.72	1.34	-0.86	0.52	1.72	1.31	-0.94
0.56	2.54	2.02	-1.18	0.52	2.54	1.98	-1.28
0.56	3.71	2.97	-1.69	0.52	3.71	2.90	-1.84
0.46	1.25	0.85	-0.90	0.44	1.25	0.82	-0.96
0.46	1.89	1.38	-1.18	0.44	1.89	1.34	-1.26
0.46	2.79	2.07	-1.64	0.44	2.79	2.02	-1.75
0.46	4.06	3.03	-2.33	0.44	4.06	2.96	-2.49
0.82	1.24	1.13	-0.25	0.71	1.24	1.05	-0.42
0.82	1.88	1.74	-0.33	0.71	1.88	1.64	-0.56
0.82	2.77	2.57	-0.46	0.71	2.77	2.42	-0.79
0.82	4.04	3.75	-0.64	0.71	4.04	3.55	-1.11
0.67	1.45	1.21	-0.54	0.57	1.45	1.13	-0.73
0.67	2.16	1.84	-0.73	0.57	2.16	1.74	-0.98
0.67	3.18	2.72	-1.04	0.57	3.18	2.56	-1.39
0.67	4.58	3.96	-1.40	0.57	4.58	3.75	-1.89
0.54	1.68	1.29	-0.88	0.46	1.68	1.20	-1.09
0.54	2.48	1.95	-1.21	0.46	2.48	1.83	-1.48
0.54	3.63	2.87	-1.74	0.46	3.63	2.70	-2.12
0.54	5.15	4.17	-2.24	0.46	5.15	3.94	-2.76
0.21	1.80	0.89	-2.07	0.16	1.80	0.76	-2.35
0.21	2.65	1.42	-2.79	0.16	2.65	1.26	-3.16
0.21	3.87	2.13	-3.95	0.16	3.87	1.91	-4.45
0.21	5.45	3.13	-5.27	0.16	5.45	2.82	-5.98
0.14	2.27	0.99	-2.91	0.11	2.27	0.86	-3.21
0.14	3.33	1.56	-4.03	0.11	3.33	1.39	-4.42
0.14	4.78	2.32	-5.60	0.11	4.78	2.08	-6.13
0.14	6.54	3.40	-7.15	0.11	6.54	3.06	-7.92
0.11	2.75	1.10	-3.74	0.08	2.75	0.96	-4.06
0.11	4.00	1.70	-5.24	0.08	4.00	1.51	-5.66
0.11	5.61	2.51	-7.03	0.08	5.61	2.26	-7.62
0.11	7.55	3.68	-8.80	0.08	7.55	3.31	-9.64
0.35	1.53	0.94	-1.34	0.31	1.53	0.88	-1.48
0.35	2.28	1.49	-1.79	0.31	2.28	1.41	-1.97
0.35	3.33	2.22	-2.53	0.31	3.33	2.11	-2.78
0.35	4.78	3.26	-3.47	0.31	4.78	3.10	-3.83
0.26	1.84	1.03	-1.86	0.23	1.84	0.96	-2.01
0.26	2.72	1.60	-2.53	0.23	2.72	1.52	-2.72
0.26	3.96	2.38	-3.60	0.23	3.96	2.26	-3.87
0.26	5.56	3.48	-4.71	0.23	5.56	3.31	-5.10
0.21	2.15	1.11	-2.35	0.19	2.15	1.04	-2.51
0.21	3.15	1.72	-3.26	0.19	3.15	1.63	-3.46
0.21	4.54	2.54	-4.57	0.19	4.54	2.41	-4.85
0.21	6.26	3.71	-5.80	0.19	6.26	3.53	-6.20

RATIO	SN_3	SN_1	AC	RATIO	SN_3	SN_1	AC
0.63	0.99	0.77	-0.50	0.85	1.31	1.21	-0.22
0.63	1.55	1.27	-0.65	0.85	1.98	1.85	-0.29
0.63	2.31	1.92	-0.88	0.85	2.91	2.72	-0.41
0.63	3.39	2.83	-1.27	0.85	4.22	3.97	-0.57
0.52	1.11	0.80	-0.73	0.65	1.62	1.35	-0.61
0.52	1.72	1.30	-0.95	0.65	2.40	2.04	-0.84
0.52	2.54	1.97	-1.30	0.65	3.52	2.99	-1.21
0.52	3.71	2.89	-1.87	0.65	5.02	4.33	-1.55
0.43	1.25	0.82	-0.97	0.52	1.97	1.51	-1.06
0.43	1.89	1.33	-1.28	0.52	2.90	2.24	-1.48
0.43	2.79	2.01	-1.77	0.52	4.21	3.29	-2.09
0.43	4.06	2.95	-2.52	0.52	5.85	4.73	-2.56
0.69	1.24	1.04	-0.45	0.56	1.31	0.99	-0.72
0.69	1.88	1.62	-0.60	0.56	1.98	1.56	-0.95
0.69	2.77	2.40	-0.84	0.56	2.91	2.32	-1.34
0.69	4.04	3.51	-1.19	0.56	4.22	3.40	-1.88
0.56	1.45	1.11	-0.76	0.43	1.62	1.12	-1.15
0.56	2.16	1.72	-1.02	0.43	2.40	1.72	-1.55
0.56	3.18	2.54	-1.45	0.43	3.52	2.54	-2.23
0.56	4.58	3.71	-1.97	0.43	5.02	3.72	-2.96
0.45	1.68	1.19	-1.12	0.34	1.97	1.25	-1.64
0.45	2.48	1.81	-1.52	0.34	2.90	1.90	-2.27
0.45	3.63	2.67	-2.18	0.34	4.21	2.79	-3.23
0.45	5.15	3.90	-2.85	0.34	5.85	4.06	-4.07
0.13	1.80	0.67	-2.55	0.48	1.31	0.92	-0.88
0.13	2.65	1.15	-3.42	0.48	1.98	1.46	-1.17
0.13	3.87	1.76	-4.80	0.48	2.91	2.19	-1.63
0.13	5.45	2.60	-6.48	0.48	4.22	3.21	-2.31
0.09	2.27	0.77	-3.42	0.37	1.62	1.03	-1.34
0.09	3.33	1.27	-4.70	0.37	2.40	1.61	-1.80
0.09	4.78	1.92	-6.50	0.37	3.52	2.39	-2.57
0.09	6.54	2.82	-8.45	0.37	5.02	3.50	-3.45
0.07	2.75	0.87	-4.27	0.28	1.97	1.15	-1.86
0.07	4.00	1.39	-5.93	0.28	2.90	1.77	-2.56
0.07	5.61	2.09	-7.99	0.28	4.21	2.61	-3.63
0.07	7.55	3.07	-10.18	0.28	5.85	3.82	-4.63
0.27	1.53	0.83	-1.59	0.40	1.31	0.83	-1.09
0.27	2.28	1.34	-2.12	0.40	1.98	1.35	-1.43
0.27	3.33	2.02	-2.98	0.40	2.91	2.03	-1.99
0.27	4.78	2.97	-4.11	0.40	4.22	2.98	-2.82
0.21	1.84	0.91	-2.12	0.30	1.62	0.94	-1.55
0.21	2.72	1.45	-2.88	0.30	2.40	1.49	-2.08
0.21	3.96	2.17	-4.07	0.30	3.52	2.22	-2.96
0.21	5.56	3.18	-5.40	0.30	5.02	3.26	-4.00
0.17	2.15	0.99	-2.63	0.23	1.97	1.05	-2.09
0.17	3.15	1.56	-3.62	0.23	2.90	1.64	-2.86
0.17	4.54	2.31	-5.07	0.23	4.21	2.43	-4.05
0.17	6.26	3.39	-6.52	0.23	5.85	3.55	-5.23

RATIO	SN_3	SN_1	AC	RATIO	SN_3	SN_1	AC
0.34	1.31	0.76	-1.26	1.19	1.76	1.89	0.29
0.34	1.98	1.25	-1.65	1.19	2.60	2.78	0.41
0.34	2.91	1.90	-2.29	1.19	3.80	4.05	0.57
0.34	4.22	2.79	-3.24	1.19	5.36	5.66	0.69
0.26	1.62	0.86	-1.72	1.02	1.99	2.00	0.03
0.26	2.40	1.39	-2.31	1.02	2.92	2.93	0.04
0.26	3.52	2.09	-3.26	1.02	4.24	4.26	0.05
0.26	5.02	3.06	-4.44	1.02	5.89	5.92	0.06
0.20	1.97	0.98	-2.26	0.87	2.19	2.07	-0.26
0.20	2.90	1.54	-3.09	0.87	3.21	3.04	-0.38
0.20	4.21	2.29	-4.37	0.87	4.63	4.41	-0.50
0.20	5.85	3.35	-5.69	0.87	6.35	6.09	-0.60
1.12	1.01	1.07	0.13	1.10	2.15	2.23	0.19
1.12	1.58	1.66	0.17	1.10	3.15	3.27	0.27
1.12	2.35	2.46	0.24	1.10	4.54	4.70	0.35
1.12	3.45	3.60	0.34	1.10	6.26	6.44	0.42
0.97	1.13	1.11	-0.04	0.91	2.49	2.41	-0.20
0.97	1.74	1.72	-0.06	0.91	3.65	3.52	-0.28
0.97	2.57	2.54	-0.08	0.91	5.18	5.02	-0.35
0.97	3.76	3.71	-0.11	0.91	7.02	6.83	-0.43
0.83	1.26	1.15	-0.24	0.78	2.80	2.54	-0.57
0.83	1.91	1.77	-0.31	0.78	4.07	3.72	-0.80
0.83	2.81	2.61	-0.44	0.78	5.69	5.26	-0.97
0.83	4.09	3.82	-0.62	0.78	7.65	7.13	-1.19
1.86	1.38	1.78	0.92	0.95	1.01	0.98	-0.06
1.86	2.07	2.63	1.27	0.95	1.58	1.55	-0.08
1.86	3.04	3.84	1.83	0.95	2.35	2.30	-0.11
1.86	4.40	5.41	2.30	0.95	3.45	3.37	-0.17
1.42	1.61	1.86	0.57	0.82	1.13	1.03	-0.24
1.42	2.39	2.74	0.80	0.82	1.74	1.61	-0.31
1.42	3.51	4.00	1.12	0.82	2.57	2.38	-0.44
1.42	5.00	5.60	1.38	0.82	3.76	3.49	-0.62
1.08	1.87	1.93	0.13	0.70	1.26	1.07	-0.43
1.08	2.75	2.83	0.18	0.70	1.91	1.66	-0.58
1.08	4.01	4.12	0.25	0.70	2.81	2.45	-0.81
1.08	5.62	5.75	0.30	0.70	4.09	3.59	-1.14
1.28	2.13	2.35	0.49	1.22	1.38	1.50	0.28
1.28	3.13	3.44	0.70	1.22	2.07	2.23	0.37
1.28	4.52	4.92	0.90	1.22	3.04	3.28	0.54
1.28	6.23	6.71	1.08	1.22	4.40	4.71	0.70
1.00	2.50	2.50	0.00	0.93	1.61	1.57	-0.11
1.00	3.66	3.66	0.00	0.93	2.39	2.33	-0.15
1.00	5.19	5.19	0.00	0.93	3.51	3.41	-0.22
1.00	7.04	7.04	0.00	0.93	5.00	4.88	-0.27
0.82	2.82	2.61	-0.48	0.70	1.87	1.62	-0.57
0.82	4.10	3.81	-0.66	0.70	2.75	2.40	-0.81
0.82	5.72	5.37	-0.80	0.70	4.01	3.51	-1.14
0.82	7.69	7.26	-0.98	0.70	5.62	5.00	-1.39

RATIO	SN_3	SN_1	AC	RATIO	SN_3	SN_1	AC
0.64	2.13	1.79	-0.78	0.64	1.38	1.12	-0.58
0.64	3.13	2.64	-1.11	0.64	2.07	1.73	-0.77
0.64	4.52	3.86	-1.51	0.64	3.04	2.56	-1.10
0.64	6.23	5.43	-1.81	0.64	4.40	3.74	-1.51
0.50	2.50	1.91	-1.34	0.61	1.61	1.31	-0.69
0.50	3.66	2.81	-1.92	0.61	2.39	1.98	-0.94
0.50	5.19	4.10	-2.48	0.61	3.51	2.91	-1.36
0.50	7.04	5.72	-2.99	0.61	5.00	4.22	-1.76
0.41	2.82	1.99	-1.87	0.58	1.87	1.49	-0.86
0.41	4.10	2.93	-2.66	0.58	2.75	2.22	-1.20
0.41	5.72	4.26	-3.34	0.58	4.01	3.26	-1.70
0.41	7.69	5.91	-4.04	0.58	5.62	4.69	-2.10
0.83	1.76	1.63	-0.29	0.59	2.13	1.73	-0.91
0.83	2.60	2.42	-0.41	0.59	3.13	2.56	-1.30
0.83	3.80	3.54	-0.58	0.59	4.52	3.74	-1.77
0.83	5.36	5.05	-0.71	0.59	6.23	5.29	-2.14
0.71	1.99	1.73	-0.59	0.44	2.50	1.81	-1.56
0.71	2.92	2.55	-0.83	0.44	3.66	2.67	-2.24
0.71	4.24	3.73	-1.15	0.44	5.19	3.90	-2.93
0.71	5.89	5.27	-1.40	0.44	7.04	5.48	-3.53
0.60	2.19	1.79	-0.91	0.34	2.82	1.85	-2.18
0.60	3.21	2.64	-1.30	0.34	4.10	2.73	-3.11
0.60	4.63	3.86	-1.75	0.34	5.72	3.98	-3.96
0.60	6.35	5.43	-2.11	0.34	7.69	5.58	-4.79
0.73	2.15	1.89	-0.58	0.76	1.76	1.57	-0.42
0.73	3.15	2.78	-0.83	0.76	2.60	2.34	-0.59
0.73	4.54	4.06	-1.11	0.76	3.80	3.43	-0.84
0.73	6.26	5.67	-1.33	0.76	5.36	4.90	-1.04
0.60	2.49	2.05	-1.01	0.65	1.99	1.67	-0.72
0.60	3.65	3.01	-1.46	0.65	2.92	2.47	-1.02
0.60	5.18	4.36	-1.86	0.65	4.24	3.61	-1.42
0.60	7.02	6.03	-2.25	0.65	5.89	5.13	-1.73
0.52	2.80	2.17	-1.43	0.55	2.19	1.73	-1.04
0.52	4.07	3.18	-2.03	0.55	3.21	2.56	-1.49
0.52	5.69	4.58	-2.52	0.55	4.63	3.74	-2.01
0.52	7.65	6.30	-3.06	0.55	6.35	5.29	-2.43
0.78	1.01	0.89	-0.27	0.68	2.15	1.84	-0.70
0.78	1.58	1.43	-0.36	0.68	3.15	2.71	-1.00
0.78	2.35	2.14	-0.49	0.68	4.54	3.95	-1.34
0.78	3.45	3.14	-0.71	0.68	6.26	5.55	-1.61
0.70	1.13	0.95	-0.42	0.55	2.49	1.97	-1.18
0.70	1.74	1.50	-0.55	0.55	3.65	2.90	-1.70
0.70	2.57	2.24	-0.76	0.55	5.18	4.22	-2.18
0.70	3.76	3.28	-1.09	0.55	7.02	5.86	-2.63
0.63	1.26	1.01	-0.57	0.46	2.80	2.07	-1.66
0.63	1.91	1.58	-0.75	0.46	4.07	3.03	-2.36
0.63	2.81	2.35	-1.05	0.46	5.69	4.39	-2.95
0.63	4.09	3.44	-1.49	0.46	7.65	6.08	-3.58

RATIO	SN_3	SN_1	AC	RATIO	SN_3	SN_1	AC
0.88	1.01	0.95	-0.15	0.51	2.15	1.64	-1.14
0.88	1.58	1.50	-0.19	0.51	3.15	2.43	-1.62
0.88	2.35	2.24	-0.26	0.51	4.54	3.56	-2.22
0.88	3.45	3.28	-0.38	0.51	6.26	5.07	-2.69
0.76	1.13	0.99	-0.33	0.43	2.49	1.78	-1.62
0.76	1.74	1.55	-0.43	0.43	3.65	2.63	-2.32
0.76	2.57	2.31	-0.60	0.43	5.18	3.84	-3.03
0.76	3.76	3.39	-0.85	0.43	7.02	5.41	-3.66
0.65	1.26	1.03	-0.53	0.37	2.80	1.89	-2.06
0.65	1.91	1.60	-0.70	0.37	4.07	2.78	-2.93
0.65	2.81	2.38	-0.98	0.37	5.69	4.05	-3.72
0.65	4.09	3.48	-1.39	0.37	7.65	5.67	-4.51
1.00	1.38	1.38	0.01	0.88	1.01	0.95	-0.15
1.00	2.07	2.07	0.01	0.88	1.58	1.50	-0.19
1.00	3.04	3.04	0.01	0.88	2.35	2.24	-0.26
1.00	4.40	4.41	0.01	0.88	3.45	3.28	-0.38
0.77	1.61	1.44	-0.39	0.76	1.13	0.99	-0.32
0.77	2.39	2.16	-0.53	0.76	1.74	1.56	-0.43
0.77	3.51	3.17	-0.76	0.76	2.57	2.31	-0.59
0.77	5.00	4.57	-0.97	0.76	3.76	3.39	-0.85
0.58	1.87	1.49	-0.85	0.65	1.26	1.03	-0.52
0.58	2.75	2.23	-1.19	0.65	1.91	1.61	-0.69
0.58	4.01	3.27	-1.69	0.65	2.81	2.38	-0.97
0.58	5.62	4.70	-2.09	0.65	4.09	3.49	-1.36
0.39	2.13	1.45	-1.56	0.98	1.38	1.36	-0.03
0.39	3.13	2.17	-2.19	0.98	2.07	2.05	-0.04
0.39	4.52	3.18	-3.05	0.98	3.04	3.01	-0.05
0.39	6.23	4.58	-3.74	0.98	4.40	4.37	-0.07
0.30	2.50	1.55	-2.15	0.75	1.61	1.43	-0.42
0.30	3.66	2.31	-3.07	0.75	2.39	2.14	-0.57
0.30	5.19	3.39	-4.10	0.75	3.51	3.14	-0.82
0.30	7.04	4.85	-4.98	0.75	5.00	4.54	-1.05
0.25	2.82	1.63	-2.70	0.57	1.87	1.48	-0.88
0.25	4.10	2.41	-3.84	0.57	2.75	2.21	-1.23
0.25	5.72	3.53	-4.98	0.57	4.01	3.24	-1.74
0.25	7.69	5.03	-6.05	0.57	5.62	4.67	-2.16
0.67	1.76	1.49	-0.61	0.32	2.13	1.33	-1.83
0.67	2.60	2.23	-0.84	0.32	3.13	2.00	-2.56
0.67	3.80	3.27	-1.21	0.32	4.52	2.95	-3.58
0.67	5.36	4.70	-1.50	0.32	6.23	4.28	-4.45
0.57	1.99	1.58	-0.92	0.25	2.50	1.43	-2.45
0.57	2.92	2.35	-1.30	0.25	3.66	2.14	-3.47
0.57	4.24	3.44	-1.82	0.25	5.19	3.13	-4.67
0.57	5.89	4.91	-2.22	0.25	7.04	4.52	-5.71
0.48	2.19	1.64	-1.25	0.20	2.82	1.49	-3.01
0.48	3.21	2.43	-1.78	0.20	4.10	2.22	-4.26
0.48	4.63	3.55	-2.43	0.20	5.72	3.26	-5.60
0.48	6.35	5.06	-2.94	0.20	7.69	4.69	-6.82

RATIO	SN$_3$	SN$_1$	AC	RATIO	SN$_3$	SN$_1$	AC
0.61	1.76	1.43	-0.75	1.32	2.18	2.43	0.57
0.61	2.60	2.14	-1.03	1.32	3.20	3.56	0.82
0.61	3.80	3.15	-1.48	1.32	4.61	5.06	1.03
0.61	5.36	4.54	-1.85	1.32	6.33	6.88	1.25
0.52	1.99	1.52	-1.06	0.97	2.58	2.55	-0.06
0.52	2.92	2.26	-1.49	0.97	3.77	3.73	-0.09
0.52	4.24	3.31	-2.10	0.97	5.33	5.28	-0.11
0.52	5.89	4.75	-2.58	0.97	7.21	7.15	-0.13
0.44	2.19	1.57	-1.40	0.75	2.94	2.63	-0.69
0.44	3.21	2.34	-1.99	0.75	4.27	3.85	-0.95
0.44	4.63	3.42	-2.73	0.75	5.92	5.42	-1.15
0.44	6.35	4.89	-3.32	0.75	7.94	7.32	-1.41
0.43	2.15	1.52	-1.42	1.25	1.77	1.94	0.38
0.43	3.15	2.26	-2.01	1.25	2.62	2.85	0.54
0.43	4.54	3.32	-2.78	1.25	3.82	4.15	0.74
0.43	6.26	4.76	-3.39	1.25	5.39	5.78	0.90
0.35	2.49	1.65	-1.92	1.05	1.99	2.03	0.08
0.35	3.65	2.44	-2.74	1.05	2.93	2.98	0.12
0.35	5.18	3.58	-3.63	1.05	4.25	4.32	0.16
0.35	7.02	5.09	-4.40	1.05	5.90	5.99	0.19
0.30	2.80	1.75	-2.38	0.88	2.20	2.09	-0.25
0.30	4.07	2.58	-3.39	0.88	3.22	3.06	-0.37
0.30	5.69	3.78	-4.35	0.88	4.64	4.43	-0.48
0.30	7.65	5.33	-5.27	0.88	6.37	6.12	-0.57
1.16	1.02	1.10	0.18	1.16	2.18	2.31	0.30
1.16	1.60	1.70	0.23	1.16	3.19	3.38	0.43
1.16	2.37	2.52	0.33	1.16	4.60	4.85	0.56
1.16	3.47	3.68	0.47	1.16	6.33	6.62	0.67
0.99	1.15	1.14	-0.01	0.96	2.50	2.46	-0.09
0.99	1.76	1.76	-0.02	0.96	3.65	3.59	-0.13
0.99	2.60	2.59	-0.03	0.96	5.18	5.11	-0.16
0.99	3.80	3.79	-0.04	0.96	7.03	6.94	-0.20
0.83	1.29	1.18	-0.24	0.82	2.78	2.57	-0.47
0.83	1.95	1.81	-0.32	0.82	4.05	3.76	-0.66
0.83	2.86	2.66	-0.46	0.82	5.66	5.31	-0.80
0.83	4.16	3.88	-0.63	0.82	7.61	7.18	-0.98
1.82	1.41	1.81	0.91	0.98	1.02	1.01	-0.02
1.82	2.11	2.67	1.26	0.98	1.60	1.59	-0.03
1.82	3.10	3.89	1.80	0.98	2.37	2.36	-0.04
1.82	4.48	5.47	2.25	0.98	3.47	3.45	-0.05
1.40	1.64	1.88	0.54	0.84	1.15	1.05	-0.21
1.40	2.43	2.77	0.76	0.84	1.76	1.64	-0.28
1.40	3.56	4.03	1.08	0.84	2.60	2.43	-0.40
1.40	5.07	5.64	1.31	0.84	3.80	3.56	-0.56
1.07	1.89	1.94	0.11	0.70	1.29	1.09	-0.44
1.07	2.78	2.85	0.16	0.70	1.95	1.69	-0.59
1.07	4.05	4.14	0.22	0.70	2.86	2.50	-0.83
1.07	5.66	5.77	0.26	0.70	4.16	3.65	-1.16

RATIO	SN_3	SN_1	AC	RATIO	SN_3	SN_1	AC
1.18	1.41	1.51	0.24	0.77	1.02	0.89	-0.29
1.18	2.11	2.26	0.33	0.77	1.60	1.43	-0.38
1.18	3.10	3.31	0.47	0.77	2.37	2.14	-0.53
1.18	4.48	4.75	0.61	0.77	3.47	3.14	-0.76
0.91	1.64	1.58	-0.15	0.68	1.15	0.95	-0.44
0.91	2.43	2.34	-0.20	0.68	1.76	1.51	-0.58
0.91	3.56	3.43	-0.29	0.68	2.60	2.25	-0.81
0.91	5.07	4.91	-0.36	0.68	3.80	3.29	-1.16
0.69	1.89	1.63	-0.59	0.61	1.29	1.02	-0.61
0.69	2.78	2.41	-0.84	0.61	1.95	1.59	-0.81
0.69	4.05	3.53	-1.18	0.61	2.86	2.36	-1.14
0.69	5.66	5.03	-1.44	0.61	4.16	3.46	-1.60
0.66	2.18	1.85	-0.74	0.64	1.41	1.15	-0.58
0.66	3.20	2.73	-1.06	0.64	2.11	1.77	-0.78
0.66	4.61	3.98	-1.42	0.64	3.10	2.61	-1.11
0.66	6.33	5.58	-1.71	0.64	4.48	3.82	-1.51
0.49	2.58	1.95	-1.44	0.58	1.64	1.30	-0.77
0.49	3.77	2.86	-2.06	0.58	2.43	1.97	-1.05
0.49	5.33	4.17	-2.64	0.58	3.56	2.89	-1.51
0.49	7.21	5.80	-3.19	0.58	5.07	4.21	-1.96
0.38	2.94	2.01	-2.11	0.53	1.89	1.46	-0.97
0.38	4.27	2.95	-2.98	0.53	2.78	2.18	-1.36
0.38	5.92	4.28	-3.72	0.53	4.05	3.20	-1.93
0.38	7.94	5.95	-4.52	0.53	5.66	4.61	-2.39
0.88	1.77	1.68	-0.21	0.54	2.18	1.70	-1.08
0.88	2.62	2.49	-0.29	0.54	3.20	2.52	-1.54
0.88	3.82	3.64	-0.42	0.54	4.61	3.68	-2.10
0.88	5.39	5.16	-0.51	0.54	6.33	5.22	-2.53
0.73	1.99	1.76	-0.53	0.39	2.58	1.79	-1.79
0.73	2.93	2.59	-0.76	0.39	3.77	2.64	-2.57
0.73	4.25	3.79	-1.04	0.39	5.33	3.86	-3.34
0.73	5.90	5.35	-1.26	0.39	7.21	5.43	-4.03
0.61	2.20	1.81	-0.89	0.30	2.94	1.85	-2.48
0.61	3.22	2.66	-1.28	0.30	4.27	2.72	-3.51
0.61	4.64	3.89	-1.72	0.30	5.92	3.97	-4.44
0.61	6.37	5.46	-2.07	0.30	7.94	5.57	-5.39
0.76	2.18	1.95	-0.51	0.76	1.77	1.59	-0.42
0.76	3.19	2.87	-0.74	0.76	2.62	2.36	-0.59
0.76	4.60	4.17	-0.98	0.76	3.82	3.45	-0.84
0.76	6.33	5.81	-1.18	0.76	5.39	4.93	-1.03
0.62	2.50	2.07	-0.96	0.65	1.99	1.67	-0.72
0.62	3.65	3.04	-1.38	0.65	2.93	2.48	-1.02
0.62	5.18	4.41	-1.76	0.65	4.25	3.62	-1.42
0.62	7.03	6.09	-2.12	0.65	5.90	5.15	-1.72
0.53	2.78	2.17	-1.38	0.55	2.20	1.74	-1.05
0.53	4.05	3.18	-1.96	0.55	3.22	2.56	-1.50
0.53	5.66	4.59	-2.43	0.55	4.64	3.75	-2.03
0.53	7.61	6.31	-2.96	0.55	6.37	5.29	-2.45

RATIO	SN_3	SN_1	AC	RATIO	SN_3	SN_1	AC
0.67	2.18	1.86	-0.72	0.71	1.77	1.54	-0.53
0.67	3.19	2.74	-1.04	0.71	2.62	2.29	-0.73
0.67	4.60	3.99	-1.39	0.71	3.82	3.36	-1.04
0.67	6.33	5.59	-1.67	0.71	5.39	4.82	-1.29
0.55	2.50	1.97	-1.19	0.59	1.99	1.61	-0.86
0.55	3.65	2.90	-1.71	0.59	2.93	2.39	-1.22
0.55	5.18	4.22	-2.19	0.59	4.25	3.50	-1.70
0.55	7.03	5.86	-2.64	0.59	5.90	4.99	-2.07
0.46	2.78	2.06	-1.63	0.49	2.20	1.66	-1.23
0.46	4.05	3.02	-2.32	0.49	3.22	2.45	-1.75
0.46	5.66	4.38	-2.91	0.49	4.64	3.59	-2.39
0.46	7.61	6.06	-3.52	0.49	6.37	5.10	-2.89
0.92	1.02	0.98	-0.10	0.54	2.18	1.70	-1.08
0.92	1.60	1.54	-0.13	0.54	3.19	2.52	-1.54
0.92	2.37	2.29	-0.18	0.54	4.60	3.68	-2.09
0.92	3.47	3.36	-0.26	0.54	6.33	5.22	-2.52
0.78	1.15	1.02	-0.30	0.44	2.50	1.81	-1.56
0.78	1.76	1.59	-0.40	0.44	3.65	2.67	-2.24
0.78	2.60	2.36	-0.55	0.44	5.18	3.90	-2.92
0.78	3.80	3.46	-0.79	0.44	7.03	5.48	-3.52
0.65	1.29	1.05	-0.54	0.37	2.78	1.89	-2.01
0.65	1.95	1.63	-0.71	0.37	4.05	2.79	-2.86
0.65	2.86	2.42	-1.00	0.37	5.66	4.06	-3.63
0.65	4.16	3.55	-1.40	0.37	7.61	5.68	-4.40
0.99	1.41	1.40	-0.02	0.91	1.02	0.98	-0.10
0.99	2.11	2.10	-0.02	0.91	1.60	1.54	-0.14
0.99	3.10	3.08	-0.04	0.91	2.37	2.29	-0.19
0.99	4.48	4.46	-0.05	0.91	3.47	3.35	-0.27
0.76	1.64	1.46	-0.41	0.77	1.15	1.02	-0.30
0.76	2.43	2.18	-0.56	0.77	1.76	1.59	-0.40
0.76	3.56	3.20	-0.81	0.77	2.60	2.36	-0.56
0.76	5.07	4.62	-1.02	0.77	3.80	3.46	-0.79
0.58	1.89	1.51	-0.86	0.65	1.29	1.05	-0.53
0.58	2.78	2.25	-1.20	0.65	1.95	1.63	-0.71
0.58	4.05	3.30	-1.70	0.65	2.86	2.42	-1.00
0.58	5.66	4.73	-2.10	0.65	4.16	3.55	-1.40
0.41	2.18	1.51	-1.51	0.96	1.41	1.38	-0.06
0.41	3.20	2.26	-2.14	0.96	2.11	2.08	-0.08
0.41	4.61	3.31	-2.95	0.96	3.10	3.05	-0.11
0.41	6.33	4.75	-3.60	0.96	4.48	4.41	-0.15
0.30	2.58	1.60	-2.23	0.73	1.64	1.44	-0.45
0.30	3.77	2.37	-3.18	0.73	2.43	2.16	-0.62
0.30	5.33	3.48	-4.20	0.73	3.56	3.17	-0.90
0.30	7.21	4.96	-5.09	0.73	5.07	4.57	-1.14
0.23	2.94	1.66	-2.91	0.56	1.89	1.49	-0.91
0.23	4.27	2.45	-4.12	0.56	2.78	2.22	-1.27
0.23	5.92	3.59	-5.30	0.56	4.05	3.25	-1.80
0.23	7.94	5.11	-6.43	0.56	5.66	4.68	-2.22

RATIO	SN$_3$	SN$_1$	AC	RATIO	SN$_3$	SN$_1$	AC
0.33	2.18	1.38	-1.82	1.81	1.43	1.83	0.91
0.33	3.20	2.07	-2.55	1.81	2.14	2.70	1.26
0.33	4.61	3.05	-3.55	1.81	3.14	3.93	1.80
0.33	6.33	4.41	-4.37	1.81	4.53	5.52	2.25
0.24	2.58	1.46	-2.55	1.43	1.64	1.89	0.58
0.24	3.77	2.18	-3.62	1.43	2.43	2.79	0.81
0.24	5.33	3.20	-4.84	1.43	3.56	4.06	1.14
0.24	7.21	4.61	-5.91	1.43	5.06	5.68	1.39
0.19	2.94	1.51	-3.25	1.11	1.86	1.94	0.18
0.19	4.27	2.25	-4.58	1.11	2.74	2.86	0.26
0.19	5.92	3.30	-5.96	1.11	4.00	4.15	0.35
0.19	7.94	4.74	-7.27	1.11	5.60	5.79	0.43
0.64	1.77	1.47	-0.68	1.47	2.18	2.52	0.79
0.64	2.62	2.20	-0.94	1.47	3.19	3.69	1.14
0.64	3.82	3.23	-1.35	1.47	4.60	5.23	1.43
0.64	5.39	4.65	-1.68	1.47	6.32	7.09	1.73
0.54	1.99	1.55	-1.01	1.10	2.52	2.62	0.21
0.54	2.93	2.30	-1.42	1.10	3.69	3.82	0.29
0.54	4.25	3.37	-2.00	1.10	5.23	5.39	0.36
0.54	5.90	4.83	-2.44	1.10	7.09	7.28	0.44
0.45	2.20	1.59	-1.37	0.86	2.83	2.67	-0.36
0.45	3.22	2.36	-1.95	0.86	4.11	3.90	-0.49
0.45	4.64	3.46	-2.68	0.86	5.74	5.48	-0.59
0.45	6.37	4.95	-3.25	0.86	7.71	7.39	-0.73
0.45	2.18	1.58	-1.36	1.30	1.79	1.99	0.45
0.45	3.19	2.34	-1.93	1.30	2.65	2.93	0.65
0.45	4.60	3.43	-2.65	1.30	3.86	4.25	0.89
0.45	6.33	4.91	-3.22	1.30	5.44	5.91	1.07
0.37	2.50	1.68	-1.85	1.07	2.01	2.06	0.12
0.37	3.65	2.49	-2.64	1.07	2.95	3.03	0.17
0.37	5.18	3.64	-3.49	1.07	4.28	4.38	0.23
0.37	7.03	5.17	-4.22	1.07	5.94	6.06	0.28
0.31	2.78	1.76	-2.31	0.87	2.22	2.10	-0.27
0.31	4.05	2.60	-3.29	0.87	3.25	3.09	-0.38
0.31	5.66	3.80	-4.23	0.87	4.68	4.46	-0.50
0.31	7.61	5.36	-5.12	0.87	6.42	6.16	-0.60
1.15	1.06	1.13	0.16	1.18	2.26	2.42	0.35
1.15	1.65	1.75	0.22	1.18	3.32	3.54	0.50
1.15	2.44	2.58	0.30	1.18	4.76	5.04	0.63
1.15	3.58	3.77	0.43	1.18	6.52	6.85	0.76
0.99	1.18	1.17	-0.01	0.96	2.56	2.53	-0.09
0.99	1.80	1.80	-0.02	0.96	3.75	3.70	-0.12
0.99	2.66	2.65	-0.02	0.96	5.30	5.23	-0.15
0.99	3.88	3.87	-0.03	0.96	7.17	7.09	-0.18
0.85	1.30	1.20	-0.21	0.81	2.83	2.61	-0.51
0.85	1.96	1.84	-0.28	0.81	4.12	3.81	-0.71
0.85	2.88	2.71	-0.39	0.81	5.75	5.37	-0.86
0.85	4.19	3.95	-0.54	0.81	7.73	7.26	-1.05

RATIO	SN$_3$	SN$_1$	AC	RATIO	SN$_3$	SN$_1$	AC
0.96	1.06	1.04	-0.04	0.79	2.26	2.06	-0.46
0.96	1.65	1.63	-0.05	0.79	3.32	3.02	-0.67
0.96	2.44	2.41	-0.08	0.79	4.76	4.38	-0.86
0.96	3.58	3.53	-0.11	0.79	6.52	6.06	-1.04
0.83	1.18	1.08	-0.22	0.64	2.56	2.16	-0.93
0.83	1.80	1.67	-0.29	0.64	3.75	3.16	-1.33
0.83	2.66	2.48	-0.41	0.64	5.30	4.56	-1.67
0.83	3.88	3.62	-0.58	0.64	7.17	6.28	-2.02
0.72	1.30	1.11	-0.42	0.54	2.83	2.23	-1.37
0.72	1.96	1.71	-0.56	0.54	4.12	3.27	-1.94
0.72	2.88	2.53	-0.79	0.54	5.75	4.70	-2.39
0.72	4.19	3.70	-1.10	0.54	7.73	6.44	-2.91
1.18	1.43	1.53	0.24	0.78	1.06	0.94	-0.29
1.18	2.14	2.28	0.32	0.78	1.65	1.49	-0.38
1.18	3.14	3.35	0.47	0.78	2.44	2.22	-0.52
1.18	4.53	4.80	0.60	0.78	3.58	3.25	-0.74
0.93	1.64	1.59	-0.11	0.70	1.18	0.99	-0.43
0.93	2.43	2.36	-0.15	0.70	1.80	1.55	-0.56
0.93	3.56	3.46	-0.22	0.70	2.66	2.31	-0.79
0.93	5.06	4.94	-0.27	0.70	3.88	3.39	-1.12
0.73	1.86	1.64	-0.52	0.63	1.30	1.04	-0.57
0.73	2.74	2.42	-0.72	0.63	1.96	1.63	-0.76
0.73	4.00	3.55	-1.02	0.63	2.88	2.41	-1.07
0.73	5.60	5.05	-1.25	0.63	4.19	3.53	-1.50
0.74	2.18	1.93	-0.56	0.64	1.43	1.17	-0.59
0.74	3.19	2.84	-0.80	0.64	2.14	1.79	-0.79
0.74	4.60	4.13	-1.07	0.64	3.14	2.65	-1.12
0.74	6.32	5.76	-1.28	0.64	4.53	3.86	-1.52
0.55	2.52	2.00	-1.19	0.65	1.64	1.37	-0.62
0.55	3.69	2.94	-1.71	0.65	2.43	2.05	-0.85
0.55	5.23	4.27	-2.19	0.65	3.56	3.02	-1.23
0.55	7.09	5.92	-2.64	0.65	5.06	4.37	-1.57
0.43	2.83	2.04	-1.78	0.63	1.86	1.55	-0.72
0.43	4.11	3.00	-2.53	0.63	2.74	2.30	-1.01
0.43	5.74	4.35	-3.17	0.63	4.00	3.37	-1.43
0.43	7.71	6.02	-3.85	0.63	5.60	4.83	-1.76
0.91	1.79	1.73	-0.15	0.56	2.18	1.73	-1.01
0.91	2.65	2.55	-0.21	0.56	3.19	2.56	-1.44
0.91	3.86	3.73	-0.29	0.56	4.60	3.74	-1.95
0.91	5.44	5.28	-0.36	0.56	6.32	5.29	-2.35
0.75	2.01	1.79	-0.50	0.43	2.52	1.81	-1.62
0.75	2.95	2.64	-0.70	0.43	3.69	2.67	-2.33
0.75	4.28	3.86	-0.97	0.43	5.23	3.90	-3.03
0.75	5.94	5.43	-1.17	0.43	7.09	5.48	-3.66
0.61	2.22	1.83	-0.89	0.34	2.83	1.86	-2.19
0.61	3.25	2.69	-1.28	0.34	4.11	2.74	-3.12
0.61	4.68	3.93	-1.71	0.34	5.74	4.00	-3.96
0.61	6.42	5.52	-2.06	0.34	7.71	5.60	-4.80

RATIO	SN_3	SN_1	AC	RATIO	SN_3	SN_1	AC
0.76	1.79	1.60	-0.43	0.45	2.18	1.57	-1.37
0.76	2.65	2.38	-0.61	0.45	3.19	2.34	-1.94
0.76	3.86	3.48	-0.86	0.45	4.60	3.42	-2.67
0.76	5.44	4.97	-1.06	0.45	6.32	4.90	-3.25
0.64	2.01	1.68	-0.74	0.33	2.52	1.63	-2.02
0.64	2.95	2.49	-1.05	0.33	3.69	2.42	-2.89
0.64	4.28	3.64	-1.45	0.33	5.23	3.55	-3.83
0.64	5.94	5.17	-1.76	0.33	7.09	5.05	-4.63
0.54	2.22	1.74	-1.08	0.26	2.83	1.67	-2.63
0.54	3.25	2.57	-1.54	0.26	4.11	2.47	-3.73
0.54	4.68	3.76	-2.08	0.26	5.74	3.62	-4.82
0.54	6.42	5.32	-2.51	0.26	7.71	5.14	-5.85
0.66	2.26	1.92	-0.77	0.74	1.79	1.58	-0.48
0.66	3.32	2.83	-1.12	0.74	2.65	2.35	-0.66
0.66	4.76	4.11	-1.47	0.74	3.86	3.45	-0.95
0.66	6.52	5.74	-1.77	0.74	5.44	4.92	-1.17
0.54	2.56	2.02	-1.25	0.61	2.01	1.64	-0.84
0.54	3.75	2.96	-1.79	0.61	2.95	2.43	-1.18
0.54	5.30	4.30	-2.28	0.61	4.28	3.56	-1.64
0.54	7.17	5.96	-2.75	0.61	5.94	5.07	-2.00
0.46	2.83	2.09	-1.69	0.49	2.22	1.68	-1.23
0.46	4.12	3.07	-2.40	0.49	3.25	2.48	-1.76
0.46	5.75	4.44	-2.98	0.49	4.68	3.63	-2.39
0.46	7.73	6.13	-3.62	0.49	6.42	5.15	-2.89
0.91	1.06	1.01	-0.12	0.55	2.26	1.79	-1.07
0.91	1.65	1.58	-0.15	0.55	3.32	2.64	-1.53
0.91	2.44	2.35	-0.21	0.55	4.76	3.86	-2.05
0.91	3.58	3.44	-0.30	0.55	6.52	5.43	-2.47
0.78	1.18	1.05	-0.30	0.45	2.56	1.88	-1.56
0.78	1.80	1.63	-0.40	0.45	3.75	2.77	-2.24
0.78	2.66	2.41	-0.55	0.45	5.30	4.03	-2.89
0.78	3.88	3.53	-0.79	0.45	7.17	5.64	-3.48
0.67	1.30	1.07	-0.50	0.38	2.83	1.95	-2.02
0.67	1.96	1.67	-0.67	0.38	4.12	2.86	-2.87
0.67	2.88	2.47	-0.94	0.38	5.75	4.16	-3.62
0.67	4.19	3.61	-1.32	0.38	7.73	5.80	-4.39
0.98	1.43	1.42	-0.03	0.90	1.06	1.01	-0.12
0.98	2.14	2.12	-0.04	0.90	1.65	1.58	-0.16
0.98	3.14	3.12	-0.06	0.90	2.44	2.35	-0.22
0.98	4.53	4.50	-0.07	0.90	3.58	3.44	-0.32
0.77	1.64	1.47	-0.38	0.78	1.18	1.04	-0.30
0.77	2.43	2.20	-0.53	0.78	1.80	1.63	-0.40
0.77	3.56	3.22	-0.76	0.78	2.66	2.41	-0.56
0.77	5.06	4.64	-0.96	0.78	3.88	3.53	-0.79
0.60	1.86	1.51	-0.79	0.67	1.30	1.08	-0.50
0.60	2.74	2.26	-1.10	0.67	1.96	1.67	-0.66
0.60	4.00	3.31	-1.57	0.67	2.88	2.47	-0.93
0.60	5.60	4.75	-1.94	0.67	4.19	3.61	-1.30

RATIO	SN_3	SN_1	AC	RATIO	SN_3	SN_1	AC
0.95	1.43	1.40	-0.07	1.12	1.08	1.14	0.14
0.95	2.14	2.10	-0.09	1.12	1.67	1.75	0.18
0.95	3.14	3.08	-0.13	1.12	2.47	2.58	0.26
0.95	4.53	4.46	-0.17	1.12	3.61	3.77	0.36
0.75	1.64	1.46	-0.42	0.97	1.19	1.18	-0.04
0.75	2.43	2.18	-0.58	0.97	1.82	1.80	-0.05
0.75	3.56	3.19	-0.83	0.97	2.68	2.65	-0.07
0.75	5.06	4.60	-1.05	0.97	3.92	3.88	-0.09
0.59	1.86	1.50	-0.83	0.83	1.31	1.21	-0.23
0.59	2.74	2.23	-1.16	0.83	1.98	1.84	-0.31
0.59	4.00	3.27	-1.65	0.83	2.91	2.72	-0.45
0.59	5.60	4.70	-2.04	0.83	4.23	3.96	-0.61
0.36	2.18	1.44	-1.67	1.75	1.46	1.83	0.86
0.36	3.19	2.15	-2.36	1.75	2.18	2.70	1.19
0.36	4.60	3.16	-3.27	1.75	3.19	3.94	1.70
0.36	6.32	4.56	-4.01	1.75	4.60	5.53	2.11
0.27	2.52	1.50	-2.33	1.38	1.67	1.90	0.53
0.27	3.69	2.23	-3.32	1.38	2.47	2.79	0.74
0.27	5.23	3.27	-4.44	1.38	3.61	4.07	1.04
0.27	7.09	4.71	-5.41	1.38	5.13	5.69	1.26
0.21	2.83	1.53	-2.94	1.08	1.89	1.95	0.13
0.21	4.11	2.28	-4.17	1.08	2.78	2.87	0.19
0.21	5.74	3.34	-5.45	1.08	4.05	4.17	0.26
0.21	7.71	4.79	-6.64	1.08	5.67	5.80	0.31
0.67	1.79	1.52	-0.62	1.86	2.00	2.54	1.23
0.67	2.65	2.26	-0.87	1.86	2.93	3.71	1.77
0.67	3.86	3.32	-1.24	1.86	4.26	5.25	2.27
0.67	5.44	4.76	-1.54	1.86	5.91	7.12	2.74
0.55	2.01	1.57	-0.99	1.25	2.41	2.62	0.49
0.55	2.95	2.34	-1.40	1.25	3.53	3.83	0.70
0.55	4.28	3.42	-1.95	1.25	5.03	5.40	0.86
0.55	5.94	4.90	-2.38	1.25	6.84	7.30	1.04
0.44	2.22	1.60	-1.40	0.86	2.83	2.68	-0.35
0.44	3.25	2.38	-1.99	0.86	4.12	3.90	-0.48
0.44	4.68	3.49	-2.72	0.86	5.74	5.49	-0.58
0.44	6.42	4.97	-3.29	0.86	7.72	7.40	-0.72
0.46	2.26	1.66	-1.37	1.24	1.84	2.00	0.38
0.46	3.32	2.46	-1.95	1.24	2.70	2.94	0.54
0.46	4.76	3.60	-2.64	1.24	3.95	4.27	0.73
0.46	6.52	5.12	-3.19	1.24	5.54	5.93	0.88
0.37	2.56	1.74	-1.87	1.01	2.06	2.07	0.02
0.37	3.75	2.57	-2.67	1.01	3.02	3.04	0.03
0.37	5.30	3.76	-3.49	1.01	4.38	4.40	0.04
0.37	7.17	5.31	-4.22	1.01	6.06	6.08	0.05
0.31	2.83	1.80	-2.34	0.82	2.28	2.11	-0.38
0.31	4.12	2.66	-3.33	0.82	3.34	3.09	-0.55
0.31	5.75	3.88	-4.26	0.82	4.79	4.47	-0.71
0.31	7.73	5.46	-5.16	0.82	6.55	6.17	-0.86

RATIO	SN_3	SN_1	AC	RATIO	SN_3	SN_1	AC
1.24	2.24	2.43	0.44	0.87	1.84	1.73	-0.24
1.24	3.28	3.56	0.64	0.87	2.70	2.56	-0.33
1.24	4.71	5.07	0.80	0.87	3.95	3.74	-0.47
1.24	6.46	6.89	0.97	0.87	5.54	5.29	-0.57
1.02	2.52	2.54	0.04	0.70	2.06	1.79	-0.61
1.02	3.69	3.71	0.05	0.70	3.02	2.64	-0.87
1.02	5.22	5.25	0.06	0.70	4.38	3.86	-1.19
1.02	7.08	7.11	0.08	0.70	6.06	5.43	-1.43
0.85	2.78	2.62	-0.37	0.57	2.28	1.83	-1.03
0.85	4.05	3.82	-0.52	0.57	3.34	2.69	-1.47
0.85	5.66	5.39	-0.63	0.57	4.79	3.92	-1.96
0.85	7.62	7.28	-0.77	0.57	6.55	5.51	-2.36
0.95	1.08	1.05	-0.06	0.82	2.24	2.07	-0.38
0.95	1.67	1.63	-0.09	0.82	3.28	3.04	-0.55
0.95	2.47	2.42	-0.12	0.82	4.71	4.40	-0.72
0.95	3.61	3.54	-0.17	0.82	6.46	6.08	-0.87
0.82	1.19	1.08	-0.25	0.67	2.52	2.16	-0.82
0.82	1.82	1.68	-0.33	0.67	3.69	3.17	-1.18
0.82	2.68	2.48	-0.46	0.67	5.22	4.57	-1.49
0.82	3.92	3.63	-0.64	0.67	7.08	6.29	-1.80
0.70	1.31	1.11	-0.45	0.56	2.78	2.23	-1.26
0.70	1.98	1.72	-0.60	0.56	4.05	3.26	-1.79
0.70	2.91	2.54	-0.85	0.56	5.66	4.69	-2.21
0.70	4.23	3.71	-1.18	0.56	7.62	6.44	-2.68
1.13	1.46	1.54	0.18	0.79	1.08	0.95	-0.28
1.13	2.18	2.29	0.25	0.79	1.67	1.51	-0.36
1.13	3.19	3.35	0.36	0.79	2.47	2.25	-0.50
1.13	4.60	4.80	0.46	0.79	3.61	3.30	-0.72
0.89	1.67	1.59	-0.17	0.70	1.19	1.00	-0.43
0.89	2.47	2.36	-0.24	0.70	1.82	1.57	-0.57
0.89	3.61	3.46	-0.35	0.70	2.68	2.34	-0.79
0.89	5.13	4.94	-0.43	0.70	3.92	3.42	-1.12
0.70	1.89	1.63	-0.58	0.62	1.31	1.05	-0.59
0.70	2.78	2.42	-0.82	0.62	1.98	1.64	-0.79
0.70	4.05	3.54	-1.16	0.62	2.91	2.43	-1.11
0.70	5.67	5.04	-1.41	0.62	4.23	3.55	-1.55
0.93	2.00	1.94	-0.13	0.67	1.46	1.22	-0.53
0.93	2.93	2.85	-0.19	0.67	2.18	1.86	-0.71
0.93	4.26	4.15	-0.25	0.67	3.19	2.74	-1.02
0.93	5.91	5.78	-0.30	0.67	4.60	4.00	-1.36
0.63	2.41	2.01	-0.91	0.62	1.67	1.36	-0.71
0.63	3.53	2.95	-1.31	0.62	2.47	2.04	-0.97
0.63	5.03	4.28	-1.69	0.62	3.61	3.00	-1.39
0.63	6.84	5.94	-2.04	0.62	5.13	4.35	-1.78
0.44	2.83	2.05	-1.77	0.56	1.89	1.49	-0.90
0.44	4.12	3.01	-2.52	0.56	2.78	2.23	-1.26
0.44	5.74	4.36	-3.14	0.56	4.05	3.27	-1.79
0.44	7.72	6.04	-3.82	0.56	5.67	4.70	-2.20

RATIO	SN$_3$	SN$_1$	AC	RATIO	SN$_3$	SN$_1$	AC
0.51	2.00	1.52	-1.09	0.95	1.46	1.42	-0.08
0.51	2.93	2.26	-1.52	0.95	2.18	2.13	-0.10
0.51	4.26	3.31	-2.14	0.95	3.19	3.13	-0.15
0.51	5.91	4.76	-2.62	0.95	4.60	4.52	-0.19
0.37	2.41	1.63	-1.77	0.75	1.67	1.48	-0.43
0.37	3.53	2.42	-2.52	0.75	2.47	2.21	-0.59
0.37	5.03	3.54	-3.38	0.75	3.61	3.24	-0.86
0.37	6.84	5.04	-4.09	0.75	5.13	4.66	-1.08
0.29	2.83	1.74	-2.48	0.59	1.89	1.52	-0.84
0.29	4.12	2.56	-3.53	0.59	2.78	2.26	-1.18
0.29	5.74	3.75	-4.53	0.59	4.05	3.32	-1.67
0.29	7.72	5.30	-5.50	0.59	5.67	4.76	-2.06
0.74	1.84	1.62	-0.48	0.56	2.00	1.58	-0.94
0.74	2.70	2.41	-0.68	0.56	2.93	2.35	-1.32
0.74	3.95	3.53	-0.96	0.56	4.26	3.44	-1.85
0.74	5.54	5.02	-1.17	0.56	5.91	4.92	-2.26
0.62	2.06	1.70	-0.82	0.38	2.41	1.64	-1.75
0.62	3.02	2.51	-1.16	0.38	3.53	2.43	-2.50
0.62	4.38	3.68	-1.60	0.38	5.03	3.56	-3.34
0.62	6.06	5.21	-1.93	0.38	6.84	5.06	-4.04
0.52	2.28	1.75	-1.19	0.26	2.83	1.67	-2.63
0.52	3.34	2.59	-1.70	0.26	4.12	2.48	-3.73
0.52	4.79	3.79	-2.28	0.26	5.74	3.62	-4.82
0.52	6.55	5.34	-2.74	0.26	7.72	5.14	-5.85
0.68	2.24	1.93	-0.71	0.70	1.84	1.59	-0.56
0.68	3.28	2.83	-1.02	0.70	2.70	2.36	-0.78
0.68	4.71	4.12	-1.34	0.70	3.95	3.46	-1.11
0.68	6.46	5.75	-1.61	0.70	5.54	4.94	-1.36
0.56	2.52	2.02	-1.15	0.57	2.06	1.65	-0.94
0.56	3.69	2.96	-1.65	0.57	3.02	2.44	-1.33
0.56	5.22	4.30	-2.10	0.57	4.38	3.57	-1.84
0.56	7.08	5.96	-2.54	0.57	6.06	5.08	-2.23
0.48	2.78	2.09	-1.57	0.46	2.28	1.68	-1.36
0.48	4.05	3.06	-2.24	0.46	3.34	2.48	-1.94
0.48	5.66	4.43	-2.79	0.46	4.79	3.63	-2.62
0.48	7.62	6.13	-3.39	0.46	6.55	5.16	-3.17
0.88	1.08	1.01	-0.15	0.58	2.24	1.81	-0.98
0.88	1.67	1.58	-0.19	0.58	3.28	2.66	-1.40
0.88	2.47	2.35	-0.27	0.58	4.71	3.89	-1.88
0.88	3.61	3.45	-0.38	0.58	6.46	5.47	-2.26
0.76	1.19	1.05	-0.33	0.48	2.52	1.89	-1.44
0.76	1.82	1.63	-0.43	0.48	3.69	2.78	-2.07
0.76	2.68	2.42	-0.60	0.48	5.22	4.05	-2.67
0.76	3.92	3.54	-0.85	0.48	7.08	5.66	-3.22
0.66	1.31	1.08	-0.53	0.40	2.78	1.95	-1.89
0.66	1.98	1.67	-0.70	0.40	4.05	2.87	-2.69
0.66	2.91	2.48	-0.99	0.40	5.66	4.17	-3.40
0.66	4.23	3.62	-1.38	0.40	7.62	5.80	-4.12

RATIO	SN$_3$	SN$_1$	AC	RATIO	SN$_3$	SN$_1$	AC
0.88	1.08	1.01	-0.15	0.48	2.24	1.67	-1.28
0.88	1.67	1.58	-0.19	0.48	3.28	2.47	-1.83
0.88	2.47	2.35	-0.27	0.48	4.71	3.62	-2.48
0.88	3.61	3.45	-0.38	0.48	6.46	5.14	-3.00
0.76	1.19	1.05	-0.33	0.39	2.52	1.75	-1.75
0.76	1.82	1.63	-0.43	0.39	3.69	2.58	-2.51
0.76	2.68	2.42	-0.60	0.39	5.22	3.78	-3.29
0.76	3.92	3.54	-0.86	0.39	7.08	5.33	-3.97
0.66	1.31	1.08	-0.53	0.33	2.78	1.81	-2.21
0.66	1.98	1.67	-0.70	0.33	4.05	2.66	-3.15
0.66	2.91	2.48	-0.99	0.33	5.66	3.89	-4.03
0.66	4.23	3.62	-1.38	0.33	7.62	5.47	-4.88
0.92	1.46	1.40	-0.12	0.63	1.84	1.52	-0.71
0.92	2.18	2.11	-0.16	0.63	2.70	2.27	-0.99
0.92	3.19	3.09	-0.24	0.63	3.95	3.33	-1.41
0.92	4.60	4.47	-0.31	0.63	5.54	4.77	-1.74
0.73	1.67	1.46	-0.48	0.52	2.06	1.58	-1.09
0.73	2.47	2.18	-0.66	0.52	3.02	2.34	-1.54
0.73	3.61	3.20	-0.94	0.52	4.38	3.43	-2.15
0.73	5.13	4.61	-1.19	0.52	6.06	4.91	-2.62
0.57	1.89	1.50	-0.89	0.42	2.28	1.61	-1.51
0.57	2.78	2.24	-1.24	0.42	3.34	2.39	-2.16
0.57	4.05	3.28	-1.76	0.42	4.79	3.50	-2.93
0.57	5.67	4.71	-2.17	0.42	6.55	4.99	-3.54
0.46	2.00	1.45	-1.25				
0.46	2.93	2.16	-1.75				
0.46	4.26	3.17	-2.46				
0.46	5.91	4.58	-3.04				
0.31	2.41	1.50	-2.06				
0.31	3.53	2.24	-2.93				
0.31	5.03	3.28	-3.96				
0.31	6.84	4.71	-4.83				
0.21	2.83	1.53	-2.94				
0.21	4.12	2.28	-4.17				
0.21	5.74	3.35	-5.45				
0.21	7.72	4.80	-6.64				