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Saltstone Disposal Cells No. 3 and 5

Geotechnical Investigation Report

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Table of Contents

List of Tables

List of Figures

1. Introduction

The Saltstone Production Facility (SPF) immobilizes salt solution by blending it with a dry material mixture containing cement and flyash to form a grout. The grout is pumped to the Saltstone Disposal Facility (SDF), which contains large storage disposal cells, where it is allowed to harden into a concrete-like solid waste form called saltstone.

A new set of disposal cells, Disposal Cells No. 3 and 5, will be constructed to store saltstone. The new disposal cells are located approximately 1,000 feet northeast of Vault 2, currently under construction, see Figure 1. The Disposal Cells No. 3 and 5 basic design consists of a cylindrical type disposal cell. The cylindrical disposal cells will be constructed of pre-cast concrete panels that will be erected on a poured in place concrete base slab (Ref. 1). The concrete disposal cell will be encased in a High Density Polyethylene (HDPE) and Geosynthetic Clay Liner (GCL) system.

An excavation of approximately 400 feet by 450 feet, 2 to 14 feet deep, will be excavated during the construction process. After the construction of the tanks is complete, soil will be backfilled around the tanks. A final cover system will be installed after the operational life of the disposal cells. The final cover system will include a soil cover ranging from 10 to 23.5 feet high.

The subsurface conditions in Z-Area were previously investigated and presented in reports prepared by WSRC and geotechnical engineering consultants. A comprehensive geotechnical investigation was conducted for the Disposal Cells No. 3 and 5 project site and the results are summarized in this report. The scope of this investigation included performing subsurface explorations to collect site-specific data, characterization of the subsurface conditions, laboratory testing, and calculations to determine: recommended soil properties, bearing capacity, liquefaction potential, liquefaction settlement, settlement due to the compression of soft zones, and slope stability.

This report is organized into six sections. Section 1 is the introduction, Section 2 describes the subsurface exploration, Section 3 describes the subsurface conditions, Section 4 discusses the engineering properties, Section 5 discusses engineering evaluations, and Section 6 provides the summary and conclusions. The following appendices are included with this report.

- Appendix A – Stratigraphy
- Appendix B – Test Data / Soil Properties
- Appendix C – Bearing Capacity and Static Settlement
- Appendix D – Liquefaction Analysis
- Appendix E – Soft Zone Analysis
- Appendix F – Slope Stability Analysis

2. Subsurface Exploration

Prior to performing subsurface investigations at SRS, the location is hand augered to a depth of 6 feet to check for underground interferences. Bag samples may be collected from these hand auger cuttings, or from the auger used to advance the boreholes. In the case of cone penetration tests (CPTs), no data is collected in the first 6 feet due to the hand augered hole.

2.1 Cone Penetration Tests (CPTs)

Seventeen (17) CPT soundings were performed for the Disposal Cells No. 3 and 5 subsurface investigation. Of the 17 CPTs, nine (9) were seismic cone penetration tests (SCPTs). The coordinates and elevations of the test locations are found in Table 1. Figure 2 provides a plan view of the locations. CPT logs, including shear wave velocity profiles, are included in Appendix B.

2.2 Geotechnical Boreholes

Four (4) geotechnical boreholes were drilled at the project site. Disturbed Standard Penetration Test (SPT) samples were taken in two boreholes, while undisturbed samples were collected in the other two boreholes. Boring logs are found in Appendix A. Bag samples were collected from the hand auger process and auger cuttings between 0 to 5 feet and 5 to 10 feet below ground surface from 2 of the boreholes.

2.2.1 Standard Penetration Test

SPT testing was performed in boreholes Z-V3V5-B01 and Z-V3V5-B04. SPT samples were taken continuously between 10 and 35 feet and at 5-foot intervals thereafter. The boreholes were terminated at a depth of 150 feet.

Standard Penetration Tests were performed in accordance with ASTM D1586. SPT N-values were determined by adding the number of blows required to drive the split-spoon sampler the middle 12 inches of the standard 24-inch drive. The SPT energy measurements were taken for the same equipment and the average energy transferred was about 81 percent (Appendix B).

2.2.2 Undisturbed Soil Samples

Undisturbed soil samples were taken in Z-V3V5-B02 and Z-V3V5-B03 with Shelby tubes in accordance with ASTM D 1587.

2.3 Laboratory Tests

Laboratory tests were performed on the disturbed and undisturbed samples taken during this investigation. Lab tests include index tests, triaxial tests, and consolidation tests. Modified proctor tests were performed on the bag samples. Laboratory results are included in Appendix B.

3. Subsurface Conditions

The subsurface conditions were determined based upon the previous and current investigations, as well as, knowledge of the general and specific subsurface conditions in the General Separations Area (GSA) of the SRS. The GSA includes F-Area, H-Area, S-Area, and Z-Area, where Saltstone Disposal Cells No. 3 and 5 will be located.

Subsurface conditions at the project site are described using an adaptation of the nomenclature developed by Mueser Rutledge Consulting Engineers (MRCE) and SRS geologic layers (Ref. 2, 3). Appendix A defines engineering layers based on boreholes and CPT soundings. Table 2 provides the stratigraphy in terms of geologic and engineering layers.

The subsurface conditions at the project site are similar to the general subsurface conditions in the GSA. Cross sections of the subsurface at Disposal Cells No. 3 and 5 are illustrated in Figures 3, 4, 5, and 6.

Table 1 provides the elevation of each engineering layer at each CPT and SPT borehole location. Table 3 provides the statistics of CPT tip resistance, friction ratio, pore pressure, and SCPT wave velocities for each engineering layers. Table 4 provides the statistics of SPT N-value for each engineering layers. The site stratigraphy (engineering layers) is described in the following sections in descending order from the ground surface.

3.1.1 Top Soil

Top soil at the site is approximately 1 foot thick and will be removed during excavation.

3.1.2 Fill

No fill materials were encountered at the project site.

3.1.3 S1/2 Layer

The S1/2 layer consists of the Upland, the Tobacco Road, and the upper Dry Branch formations (geologic units). The contact between the Tobacco Road and Upper Dry Branch formations is generally difficult to distinguish. However, the engineering properties for these formations are similar,

The Upland formation (S1) generally consists of red-brown and gray medium dense to dense medium to fine sand, with some clay and occasional interbedding of fine sandy clay layers. It generally classifies as a SC in the Unified Soil Classification System (USCS).

The Tobacco Road formation (S2 layer) consists of medium dense to very dense yellow-brown to red, fine to medium sand, with a trace of clay or silt. It generally classifies as a SM or SP-SM in the USCS.

The S2 layer also consists of the upper portion of the Dry Branch Formation (geologic unit). The Dry Branch Formation is present across the S2, C2, and S3 engineering layers, as described later.

3.1.4 C2 Layer

The Tan Clay (C2) layer is part of the Dry Branch Formation. The C2 consists of medium dense yellow-brown and light green clayey fine sand interlayered with stiff yellow-brown silty clay. The material C2 classifies as a borderline CH soil in the USCS.

3.1.5 S3 Layer

From a geologic perspective, the S3 layer (lower Dry Branch Formation) can be subdivided into S3a and S3b as described below. Since engineering properties for the subdivided layers are similar, a single S3 layer was used for engineering purposes.

The S3a and S3b layers consist of medium dense to dense light brown to gray fine to medium sand with some clay and sandy clay layers and pockets. The material generally classifies as a SC in the USCS. The S3b layer consists of dense to very dense light brown and yellow-brown fine to medium sand with a trace of clay and silt. The material generally classifies as a SP, SP-SM, or SP-SC in the USCS.

3.1.6 S4 Layer

The S4 layer (Santee/Tinker formation) extends from the bottom of the S3 formation to the top of the M1 layer (Warley Hill formation). The material consists of dense to very dense light gray-green calcareous fine to medium sand with some clay, silt, and occasional limestone and shell fragments. The material generally classifies as a SC or SM in the USCS. The formation is characterized by alternating low and high penetration resistances indicating the presence of limestone layers within the calcareous sands.

3.1.7 M1 Layer

The M1 layer (Warley Hill formation) consists of a hard dark gray-green clayey silt to a very dense dark gray fine to medium sand with some clay or silt. The material generally classifies as a MH in the USCS. A pick for the M1 layer was not determined during this evaluation.

3.1.8 Congaree Formation

The Congaree Formation generally consists of poorly graded coarse sands with silts. The material generally classified as SP-SM.

3.2 Groundwater

The average groundwater elevation in the vicinity of the project site is estimated at to be between 215 and 220 feet, MSL. A seasonal fluctuation of 5 feet was used for analysis.

3.3 Soft Zones

Across the SRS, the soil from approximately 100 to 250 feet below the ground surface is a marine deposit laid down during the Middle Eocene epoch, which occurred about 35 to 50 million years

ago. At the location of Saltstone Vault No. 2, these sediments occur within the Lower Dry Branch and Santee/Tinker Formations. Often found within these sediments are weak zones interspersed in stronger matrix materials. These weak zones, which vary in thickness and lateral extent, have been termed “soft zones”. These soft zones typically occur in the carbonate-bearing sediments of the Santee Limestone, the Utley Limestone, and the Griffins Landing Member of the lower Dry Branch Formation.

The prevailing assumption about the origin of soft zones involves dissolution of carbonate-rich, clastic sediments, resulting in vugular porosity (open pore space). When drilling into these zones, the drill rod meets little resistance and drops. Occasional rod drops have been described in numerous drilling reports for monitoring wells and geotechnical boreholes located in the central part of the SRS. Early subsurface investigations performed by the United States Army Corps of Engineers frequently described these zones as soft zones, or voids, and numerous subsequent subsurface investigations have described these same conditions at the SRS. However, much of the time, recovery of soil in the sampler precludes the zone from being characterized as a void.

For this project site, soft zones are indicated from SPT N-values less than 5 or CPT tip resistances (qt) less than 15 tons per square foot (tsf) within the S4 layer. The S3 layer contains a few lenses of less than 15 tsf material, but these occur higher in the soil column and are not considered soft zones associated with the dissolution of carbonate rich sediments.

4. Engineering Properties

The engineering properties of the subsurface materials encountered were assessed based on the results of the field exploration, laboratory testing, theoretical relationships, empirical formulas, and historical information.

As presented in Section 2, field explorations included CPTs and geotechnical boreholes with SPTs and undisturbed samples. CPTs were conducted to acquire tip resistance, sleeve friction, shear and compression wave velocities, and pore pressure. SPTs were conducted to acquire blow counts and soil samples for classification purposes. Undisturbed soil samples were obtained from geotechnical boreholes for strength and consolidation testing. Laboratory tests were performed on selected soil samples obtained from undisturbed sampling and from SPT sampling. Laboratory tests include sieve analysis, determination of Atterberg Limits, unit weight, strength tests, and consolidation tests.

Appendix C provides the details of evaluating data from field exploration and laboratory testing. In addition, theoretical relationships were used to compute Poisson's ratio (Appendix B) and empirical formulas and historical data were used to estimate subgrade modulus (Appendix C). Engineering properties are summarized in Appendix B.

5. Engineering Evaluations

Engineering evaluations were performed to determine bearing capacities, liquefaction potential, and slope stability. Appendix C provides the evaluation of bearing capacity and settlement, Appendix D provides the evaluation of liquefaction potential, Appendix E estimates subsidence associated with the compression of soft zones, and Appendix F provides an evaluation of slope stability.

5.1 Bearing Capacity

Ultimate bearing capacity and allowable bearing capacity were computed using site specific soil strength parameters. The design bearing capacity was computed using site specific soil strength parameters factored by the appropriate strength reduction factors. The allowable bearing capacity is used for design of foundations when the allowable stress design method is utilized. The design bearing capacity is used for the design of foundations when the strength method is utilized.

A more detailed analysis of bearing capacity is found in Appendix C.

5.1.1 Ultimate Bearing Capacity

For $\phi > 0°$, the ultimate bearing capacity q_u is computed using the equations originated by Terzaghi and later modified by others. Hansen's correction factors will be used for this calculation, as they result in lower values of bearing capacity (Ref. 4).

$$q_u = cN_c S_c D_c I_c G_c B_c + q_q N_q S_q D_q I_q G_q B_q + \frac{\gamma_z B}{2} N_\gamma S_\gamma D_\gamma I_\gamma G_\gamma B_\gamma r \quad \text{(Terzaghi)}$$

where c = cohesion,

q_q = overburden or surcharge pressure at the foundation base,

γ_z = effective unit weight of soil below the foundation base,

B = foundation width,

r_γ = foundation width reduction factor.

N_c, N_q, and N_γ are bearing capacity factors; S_c, S_q, and S_γ are foundation shape factors; D_c, D_q, and D_γ are depth factors; I_c, I_q, and I_γ are load inclination factors; B_c, B_q, and B_γ are foundation base inclination factors; and G_c, G_q, and G_γ are ground inclination factors. Further details on the computation of ultimate bearing capacity are found in Appendix C.

The equations above were used to compute the bearing capacities for an individual tank (150 ft diameter) and for the excavation limit (400 ft by 450 ft), which represents the area loaded by the fill soils associated with the disposal cells. The bearing capacities of an individual tank controlled, relative to the larger excavation limits, and are presented herein.

Using the equations listed above, the ultimate bearing capacity, or pressure required to cause a bearing failure of an individual tank (150 ft diameter) is:

q_u = 41,000 psf.

5.1.2 Allowable Bearing Capacity

The allowable static bearing capacity q_a is calculated by dividing the ultimate bearing capacity by a factor of safety. Considering a factor of safety of 3,

$$q_a = \frac{q_u}{FS} = 13{,}900 \text{ psf}$$

The allowable dynamic bearing capacity (temporary dynamic loading, non-seismic) is calculated by a ⅓ increase in allowable static bearing capacity

$$q_{dyn} = 1\tfrac{1}{3}\, q_a = 18{,}500 \text{ psf}$$

5.1.3 Design Bearing Capacity

The design bearing capacity q_Φ, used for Load and Resistance Factored Design (LRFD), was computed with the same equations as the ultimate bearing capacity, using reduced soil strength parameters. A strength reduction factor (f_c) of 0.5 was applied to the cohesion and a strength reduction factor (f_ϕ) of 0.8 was applied to the tangent of ϕ such that (Ref. 5).

$$c_{red} = f_c c$$

$$\phi_{red} = \tan^{-1}\left(f_\phi \tan\phi\right)$$

$$q_u = c_{red} N_c S_c D_c I_c G_c B_c + q_q N_q S_q D_q I_q G_q B_q + \frac{\gamma_z B}{2} N_\gamma S_\gamma D_\gamma I_\gamma G_\gamma B_\gamma r \quad \text{(Terzaghi)}$$

Considering an effective cohesion of 200 psf and an effective friction angle of 30°, the reduced cohesion, c_{red}, is 100 psf and the reduced friction angle, ϕ_{red}, is 24.8 degrees.

The bearing capacity factors, shape factors, and depth factors are calculated using the reduced cohesion and reduced friction angle, resulting in a design bearing capacity of 30,200 psf.

The strength reduction factor, Φ, is the ratio of the design bearing capacity to the ultimate bearing capacity:

$$\Phi = 16{,}900 \text{ psf} / 41{,}000 \text{ psf} = 0.41$$

5.2 Settlement and Heave

The excavation needed to support the construction of Disposal Cells No. 3 and 5 will range from 2 feet to 14 feet below ground surface. The removal of this overburden material represents a reduction in overburden stress ranging from approximately 250, to 1,700 psf. After operation of the Saltstone facility is complete (backfill and tank filling) approximately 3,000 psf will have been added at elevation 261 ft, msl. After installation of the closure cap (10 to 23.5 feet thick) is completed, a total of 4,300 to 6,000 psf will have been added at elevation 261 ft, msl.

Settlement and heave of the soil column are summarized in the following sections. Appendix C contains more details of the computations.

5.2.1 Heave

The Vault 2 disposal facility is located approximately 1000 feet southeast of the Disposal Cells No. 3 and 5 facility. The Vault 2 facility, which had 7 to 19 feet of overburden (900 to 2300 psf) removed during excavation, experienced approximately ¼ inch to 1 inch of heave. Similar heave movements are expected during the Disposal Cells No. 3 and 5 excavation. As a check, heave was also estimated from laboratory test results.

5.2.2 Burland and Burbidge

The Burland and Burbidge method estimates the immediate settlement of cohesionless soils, S_0, based on SPT data. The soil is assumed to be consolidated to the overburden pressure prior to excavation (Ref. 6).

$$S_0 = f_s \times f_1 \times q' \times B^{0.7} \times I_c \qquad \text{for a normally consolidated sand}$$

$$S_0 = f_s \times f_1 \times \left(q' - \tfrac{2}{3}\sigma'_{vo}\right) \times B^{0.7} \times I_c \qquad \text{for } q' > \sigma'_{vo}$$

$$S_0 = f_s \times f_1 \times q' \times B^{0.7} \times \frac{I_c}{3} \qquad \text{for } q' < \sigma'_{vo}$$

where f_s = shape factor, $f_s = \left(\dfrac{1.25 \times L/B}{(L/B) + 0.25}\right)^2$

f_i = layer correction factor, $f_1 = H/Z_1 \left(2 - H/Z_1\right)$

q' = average effective bearing pressure

σ'_{vo} = effective overburden

H = thickness of the layer

Z_1 = depth of influence of loaded area

= $1.35B^{0.75}$ for constant or increasing N_{ave} with depth

= 2B for decreasing N_{ave} with depth

N_{ave} = average SPT blow count over depth of influence

I_c =compressibility influence factor, $0.23/N_{ave}^{1.4}$

Upper and lower settlements may be determined by modification of I_c (Ref. 7):

Lower bound settlement is computed using $I_{cmin} = 0.08/N_{ave}^{1.3}$

Upper bound settlement is computed using $I_{cmax} = 1.34/N_{ave}^{1.67}$

Settlement after time *t,* at least 3 years following construction, may be estimated by:

$S_t = f_t S_0$

where $f_t = 1 + R_3 + R_c \log (t/3)$

R_i and R_c are the time–dependent settlement ratios, for t = 30 years

R_3 = 0.3 for static loads or 0.7 fluctuating loads

R_c = 0.2 for static loads or 0.8 fluctuating loads

Assuming static loads,

$f_t = 1 + 0.3 + 0.2 \log (30/3) = 1.5$

Therefore, total settlement at t = 30 years is:

$S_t = 1.5\ S_0$

The depth of influence for the excavation is approximately 120 feet using the Burland and Burbidge method. The immediate settlement calculated immediately prior to cap installation (pre-closure) is based on original excavation depths of 2 and 14 feet. Settlements after the completion of the cap (and 30 years after) are based on the original excavation depths (2 and 14 feet) and two cap thicknesses (10 and 23.5 feet).

The lower bound, upper bound, and average settlements were computed using I_{cmin}, I_{cmax}, and I_c as described earlier. For phases after closure cap completed, lower bound settlements are computed by averaging the 4 lower bound settlements using minimum and maximum excavation depths and minimum and maximum cap thicknesses, while upper bound settlements were computed by averaging the 4 upper bound settlements. The average settlement is the average of four settlements computed using I_c.

The average, lower, and upper bound settlements are given in the table below for the different phases of construction and operation. Due to the cohesive nature of the soil, settlements associated with the C2 layer were not included. The following table presents the settlement values using the Burland and Burbidge method.

	Lower Bound Settlement (inches)	**Upper Bound Settlement (inches)**	**Average Settlement (inches)**
Immediate After Operation is Complete	0.9	4.6	1.9
Immediate After Closure Cap is Complete	1.8	8.8	3.7
30 Years After Closure Cap is Complete	2.7	13.1	5.5

5.2.3 Schmertmann Method

The Schmertmann method estimates the immediate settlement of cohesionless soils, S_0, based on CPT data (Ref. 7):

$$S_0 = C_1 \times C_t \times \Delta P \times \sum_{i=1}^{n} \frac{\Delta z_i}{E_{si}} \times I_{zi}$$

where C_1 = strain relief from embedment correction factor, $C_1 = 1 - 0.5\ \sigma'_{vo} / \Delta p \geq 0.5$,

C_t = correction for time-dependent increase in settlement and $C_t = 1 + 0.2 \log (t/0.1)$

t = in years,

for t = 30 years, $C_t = 1 + 0.2 \log(30/0.1) = 1.5$

ΔP = net applied footing pressure

Δz_i = depth increment i,

σ'_{od} = effective overburden at base of foundation

I_{zp} = peak influence factor

$$= 0.5 + 0.1\left(\frac{\Delta P}{\sigma'_{Izp}}\right)^{0.5}$$

I_{zi} = influence factor of soil layer i

E_{si} = elastic modulus of soil layer i

$= 2.5\ q_c$ for L/B = 1

$= 3.5\ q_c$ for L/B $\geq$ 10

where q_c is the average tip stress of soil layer i in tsf. For this evaluation, thickness of each soil layer (depth increment) is 1 foot. The depth was determined relative to the foundation elevation, 261 ft, msl. The influence factor of a soil layer can be calculated based on the geometry of the foundation (Ref. 8). See Appendix C for further calculation details.

Previous analyses performed for the Vitrification Building, 221-S, found that the estimated Schmertmann settlements were more than double the measured settlements, likely due to the methodology underestimating the elastic modulus for the cohesionless soils present at SRS (Ref. 9). Realistic results may be obtained by dividing the Schmertmann result by a conservative adjustment factor of 2. The results are summarized in the table below.

Energy corrected SPT blow counts in the Congaree range from 70 to refusal and CPTs refused on the top of the Congaree (approximately 700 tsf, Z-V3V5-C10). A value of 350 tsf tip stress was used in this analysis for Congaree soils.

The Schmertmann settlement analysis was performed for all 17 CPTs and SCPTs. Average tip stresses were computed on 1-foot intervals, relative to the depth below the bottom of the foundation (i.e. 261 ft, msl). CPTs which refused at shallow depths were supplemented with the average tip stress values from the remaining CPTs for the corresponding 1-foot intervals. Due to the cohesive nature of the soil, settlements associated with the C2 layer were excluded by setting I_{zi} equal to 0 for each C2 1-foot interval.

	Lower Bound Settlement (inches)	**Upper Bound Settlement (inches)**	**Average Settlement (inches)**
Immediate After Operation is Complete	2.9	3.7	3.2
Immediate After Closure Cap is Complete	4.2	7.7	5.7
30 Years After Closure Cap is Complete	6.3	11.5	8.5

5.2.4 Settlement of Cohesive Layer

Settlement of the cohesive layer C2 was computed using one dimensional consolidation theory.

For normally consolidated soils:

$$S = \frac{C_c H}{1+e_o}\log\left(\frac{\sigma_o' + \Delta\sigma'}{\sigma_o'}\right)$$

For over consolidated soils

where $\sigma_o' + \Delta\sigma' < \sigma_p'$

$$S = \frac{C_r H}{1+e_o}\log\left(\frac{\sigma_o' + \Delta\sigma'}{\sigma_o'}\right)$$

where $\sigma_o' + \Delta\sigma' > \sigma_p'$

$$S = \frac{C_r H}{1+e_o}\log\left(\frac{\sigma_p'}{\sigma_o'}\right) + \frac{C_c H}{1+e_o}\log\left(\frac{\sigma_o' + \Delta\sigma'}{\sigma_p'}\right)$$

where

- H = thickness of cohesive layer
- C_c = virgin compression index
- C_r = recompression index
- σ_o' = initial effective overburden pressure
- σ_p' = preconsolidation pressure
- $\Delta\sigma'$ = change in effective pressure
- e_o = initial void ratio

Beneath the southeastern tanks (Tanks #3B and #5B) the C2 layer is approximately 11 feet thick and 33 feet below the bottom of the excavation. Beneath the northwestern tanks (Tank #3A and #5A) the C2 layer is approximately 5 feet thick and 39 feet below the bottom of the excavation. Beneath the northern tank (Tank #3A), the C2 layer ranges from 0 to 4 feet under half of the tank.

Maximum consolidation settlement within the C2 layer occurs where the C2 layer has the greatest thickness (southeast corner of the site, Tank #5B). The C2 layer "pinches out" towards the northwestern corner (Tank #3A) of the site. Thus the minimum consolidation settlement of the C2 layer is zero. Average C_c and C_r values for the C2 layer used in this calculation are 0.50 and 0.11, respectively. These values were interpreted from two consolidation tests within the site, as well as testing from the Vault 2 subsurface exploration. Overconsolidation ratios (OCR) for the C2 layer indicated the layer is normally consolidated. Estimated consolidation settlements of the C2 layer are summarized in the table below.

	Minimum Settlement (inches)	Maximum Settlement (inches)	Average Settlement (inches)
Heave After Excavation	0	-0.6	-0.4
Immediate Settlement After Operation is Complete	0	1.8	1.8
Immediate Settlement After Closure Cap is Complete	0	5.1	3.8

Site experience in other areas on site also indicates that the rate of secondary consolidation for the site is small, on the order of ¼ inch over 30 years, for structural loading ranging from 3 to 6 ksf (Ref. 9).

5.2.5 Summary of Settlement and Heave

Heave within the excavation for Disposal Cells No. 3 and 5 is expected to range from ¼ inch to approximately 1 inch. Settlements were computed for the soil column above the Congaree formation (considered to be incompressible) with the Burland and Burbidge method. For the Schmertmann method a tip stress of 350 tsf was assigned to the Congaree Formation and soil layers beneath the Congaree Formation. Due to the cohesive nature of the C2 layer soils, the settlement of the C2 layer was excluded from the Burland and Burbidge method and Schmertmann method as described in Appendix C. Therefore, the consolidation settlement of the C2 layer was calculated separately and added to the settlements determined by the Burland and Burbidge method and the Schmertmann method. Total static settlements are summarized in the Table 5.

5.3 Dynamic Settlement

Dynamic settlement includes the settlement due to liquefaction and/or partial liquefaction and the settlement due to the compression of soft zones. The following sections contain a summary of the liquefaction potential and the resulting settlements. Also contained in the following sections is an assessment of soft zone settlement potential. Appendix D and Appendix E contain the liquefaction and the soft zone calculations, respectively.

5.3.1 Liquefaction Potential

The liquefaction potential for the Saltstone Disposal Cells No. 3 and 5 is evaluated using a modified version of the "Simplified Procedure for Evaluating Soil Liquefaction Potential" (Ref. 10, 11, 12). The simplified procedure calculates the liquefaction factor of safety as the ratio of Cyclic Resistance Ratio (CRR) to the Cyclic Stress Ratio (CSR) generated by the earthquake.

$$\text{Factor of Safety} = = \frac{CRR_{7.5} \cdot K_{\sigma} \cdot K_{age} \cdot K_{\alpha} \cdot MSF}{CSR}$$

Where

K_{σ} = overburden correction factor
K_{age} = aging correction factor
K_{α} = static shear stress correction factor
$CRR_{7.5}$ = cyclic resistance ratio for magnitude 7.5 earthquake (soil capacity)
CSR = cyclic stress ratio generated by earthquake (earthquake demand)

Appendix D contains further details on the computation of the factor of safety.

Full liquefaction has been defined previously at SRS as occurring at factors of safety less than 1.15. Partial liquefaction occurs for factors of safety less than 2.2, but greater than 1.15. Once the factor of safety is determined, dynamic settlements are then calculated based on correlations between factor of safety and SRS site-specific volumetric strain curves.

Liquefaction potential was computed using shear wave velocity data and CPT tip resistances to determine CRR values. Both methods considered the Design Basis Earthquake (DBE) with a peak ground acceleration (PGA) of 0.20g. The fines contents were determined using CPT correlations that were corroborated with laboratory testing.

Liquefaction potential based on shear wave velocities indicates that the site is only slightly susceptible to liquefaction. CPT determination of liquefaction potential were computed using two sets of CRR curves, the previous SRS site-specific curves and the current SRS site-specific curves. Both sets of curve produced similar results.

5.3.2 Settlement due to Liquefaction and Partial Liquefaction

Settlements were calculated using the SRS site-specific volumetric strain curves for each of the 17 CPTs at Disposal Cells No. 3 and 5. Figure 7 illustrates the relationship between factor of safety and volumetric strain. Settlements were computed for each of the magnitudes in the USGS seismic hazard for SRS. Figure 8 illustrates the liquefaction induced settlement for CPT Z-V3V5-C06. Illustrations of the liquefaction induced settlements for all other CPTs may be found in Appendix E.

Settlements were not computed for the methodology that uses shear wave velocity to determine factor of safety, as the SRS specific correlations relate strain and CPT tip stress and not shear wave velocity. Also, the factors of safety determined by shear wave velocity methodologies are generally higher than the CPT tip stress method.

Settlement due to liquefaction, based on the new SRS CRR curves, ranges from ¼ inch to 2 inches with an average of less than 1 inch for the magnitude 7.5 earthquake, see Table 6. The magnitude weighted average using the USGS PGA hazard dissagregation is less than ½ inch for the 2,500 year earthquake.

5.3.3 Settlement due to the Compression of Soft Zones

No significant soft zones were identified beneath Disposal Cells No. 3 and 5 during the subsurface investigation. To provide a conservative estimate of surface settlement due to any soft zones that may exist between investigation locations, the soft zone configuration from Saltstone Vault No. 2 was employed. Surface settlements at a point x were computed as

$$s_S = H \{C_c/(1 + e_o)\} \log \{(P_o + \Delta P)/P_o\}$$

$$s(x) = R_{S/L}\ s_S\ W_{SZ} /W\ \mathrm{Exp}[-x^2/(2i^2)]$$

where $R_{S/L}$ is the ratio of the volume of the settlement to the volume lost at-depth

s_S is the compression of the soft zone at depth

W_{SZ} is the width of the soft zone

$i = W/(2\pi)^{1/2}$ is the distance from center of the probability curve to the point of inflection

W is the half width of the normal probability curve and estimated as

$W = z \tan \beta + W_{SZ}/2$

where z is the soft zone depth

$\beta = \tan^{-1}\{(W - W_{SZ}/2)/Z\}$ based on soil type

Surface settlements for wide soft zones are calculated by superimposing settlement profiles for multiple narrow soft zones to simulate the desired width. For Disposal Cells No. 3 and 5, a series of 5-foot wide soft zones were utilized to represent soft zones ranging in width from 25 feet to 150 feet.

The results of the soft zone analysis indicate that the maximum soft zone induced settlement is ½ inch and the maximum differential settlement is ½ inch. Maximum slope and curvature are 0.0010 ft/ft and 0.00005 per foot, respectively. Appendix E contains further details on the Disposal Cells No. 3 and 5 soft zone analysis.

5.4 Subgrade Modulus

The subgrade modulus is a foundation specific value and is not a specific soil property. The subgrade modulus correlates foundation pressure and settlement by

$$k_s = \frac{p}{\Delta}$$

where p = foundation contact pressure (pounds per square inch, psi)

Δ = foundation settlement (inches)

The subscript s refers to the foundation size. For example, k_1 refers to the subgrade modulus for a 1-foot square foundation. When no subscript is used, the value refers to the subgrade modulus for the entire foundation.

The subgrade modulus depends on the size and shape of the loaded area. The k_1 subgrade modulus estimated for for Disposal Units 3 and 5, based on SRS settlement data for large structures, ranges from 55 to 100 pci.

5.5 Lateral Earth Pressure

Lateral earth pressures within the fill material resulting from compaction were calculated using the method presented by Duncan et al. (Ref. 13). The method calculations σ_h' graphically and considers compaction effort and the method of compaction. The compaction induced lateral earth pressures are summarized in Table 7 and presented in Figure 6. See Appendix C for further details on the computation of lateral earth pressures.

5.6 Post Closure Slope Stability

The post-closure geometry at the Saltstone Disposal Cells No. 3 and 5 is assumed to be similar to the proposed post-closure geometry at Vault No. 4. However, final design of the closure system will determine slope geometry. It is anticipated that further slope stability analysis will be performed during final design and that final slopes will be designed to remain stable for the DBE. Post-closure slope stability evaluation of Vault No. 4 was performed using the Spencer method. This method was chosen because it satisfies both force and moment equilibrium of a sliding mass of soil.

Two independent computer software programs, SLOPE/W and PCSTABL, were used to compute the results. Appendix F provides the details of the analysis.

The post-closure geometry used in the analysis assumes 20 feet of compacted fill will be placed with side slopes conservatively chosen to be 4 H to 1 V. For the analysis, it is assumed that the compacted fill will be taken from onsite borrow sources and will be placed and compacted to SRS standards, i.e., 95% of ASTM D-1557 in loose lifts not exceeding 12 inches.

Comparisons of subsurface conditions at Vault No. 4 (Appendix F, Figure 1) with those at Disposal Cells No. 3 and 5 show good correlation between Disposal Cells No. 3 and 5 and Vault No. 4 soils. The acceptable safety factors were chosen based on past experience at the SRS and recommendations from the literature. For the static and pseudostatic (seismic) cases, the minimum acceptable safety factor was chosen as 1.5 and 1.0, respectively.

The minimum required safety factor for static and dynamic conditions is 1.5 and 1.0, respectively. The results in Tables 1 and 2 of Appendix F show that the stability of the assumed post-closure condition (4 H to 1 V) meets these requirements and is therefore stable under the conditions and assumptions analyzed. However, final design will dictate final closure slopes.

6. Summary and Conclusions

The geotechnical subsurface investigation for Saltstone Disposal Cells No. 3 and 5 collected information via standard penetration tests (SPT), undisturbed borings, cone penetrometer tests, (CPTs), and laboratory testing. Subsurface conditions were characterized and soil properties were determined using site-specific data, as well as existing data from nearby areas. Engineering evaluations were performed for bearing capacity, liquefaction potential, and slope stability. Settlements due to static loading, liquefaction, and soft zone compression were also computed.

6.1 Bearing Capacity

Bearing capacity for the Saltstone Disposal Cells No. 3 and 5 were determined for both allowable stress design and Load and Resistance Factored Design (LRFD) methods. The values for an individual tank controls over the values for the overall excavation.

1. For allowable stress design
   - Ultimate Bearing Capacity 41,000 psf
   - Allowable Static Bearing Capacity 13,900 psf
   - Allowable Dynamic Bearing Capacity 18,500 psf
2. For LRFD design
   - Ultimate Bearing Capacity 41,000 psf
   - Design Bearing Capacity 16,900 psf
   - Strength Reduction Factor 0.41

The theoretical bearing capacity, in either design approach, is significantly higher than the expected loading, therefore the foundation will have sufficient margin of safety against bearing failure.

6.2 Settlement

Average settlement values are summarized below for static and dynamic evaluations.

6.2.1 Static Settlement

Static settlements due to static loading, see Table 5.

- Heave during excavation ½ inch
- Operations complete 4 inches
- Closure Cap Complete 9 inches
- 30 Years after Closure 11 inches

6.2.2 Dynamic Settlement

Dynamic settlement due to liquefaction and partial liquefaction and the compression of soft zones

- Liquefaction 1 inch
- Soft Zone Settlements ½ inch
- Total Dynamic Settlement 1 ½ inches

The dynamic settlement will only occur after the design basis earthquake, which has a low probability of occurrence, 0.0004/year (2,500 year event). The project site is slightly susceptible to liquefaction. Estimated liquefaction and partial liquefaction induced settlements range from ¼ inch to 2 inches. Compression of the soft zones is assumed to occur after the design basis earthquake, after which the compression will propagate to the ground surface causing surface settlement.

6.2.3 Differential Settlement

The differential static settlement is estimated to be the same magnitude as the average settlement. Liquefaction settlements are expected to occur rather uniformly and thus not contribute significantly to differential settlement.

Maximum settlement and differential settlement of the soft zones are ½ inch.

6.3 Subgrade Modulus

The recommended subgrade modulus, k_1, is 100 pci.

6.4 Lateral Earth Pressures

Compaction induced lateral earth pressures are summarized in Table 7.

6.5 Slope Stability

Both static and pseudo-static slope stability analyses show that the assumed post-closure condition is stable with minimum computed safety factors well in excess of the required safety factors. In addition, the computed safety factors conservatively account for the soil strength and the application of the horizontal and vertical DBE seismic loads. However, additional stability analyses will be required once the final closure system configuration is determined. The analyses should take into account any geosynthetics and the interface shear resistance between the geosynthetic materials and the compacted fill. Based on the slopes being considered, it is not expected that neither static nor dynamic slope stability will be an issue.

6.6 Monitoring and Inspection

Heave markers shall be installed prior to the beginning of excavation and settlement monitoring points shall be installed on the foundation. Settlement surveying shall be conducted as soon as the monitoring points are installed. Surveying results shall be evaluated to verify the estimated settlement.

A detailed footing inspection is highly recommended prior to forming or placing concrete for a mud mat or the mat foundation. This is particularly important where the excavated depth to the bottom of the foundation is less than 6 feet. In addition, a proof roll of the excavation should be conducted prior to the placement of a mud mat or form work for the mat foundation.

7. References

1. M-TC-Z-00007, Rev. 0, Saltstone Facility Disposal Units #3 and #5 Project (U), November 2008.
2. Mueser Rutledge Consulting Engineers, 1985, Defense Waste Processing Facility, Savannah River Plant, 200 S-Area, October 14, 1986.
3. K-ESR-Z-00001, Rev. 0, Saltstone Vault No. 2 Geotechnical Investigation Report (U), April 2006.
4. Bowles, Joseph E., *Foundation Analysis and Design*, 4th Edition, McGraw-Hill Publishing Co., 1988.
5. Fang, Foundation Engineering Handbook, 2nd Edition, 1991.
6. "Settlement of Foundations on Sand and Gravel," *Proc. Institution of Civil Engineers*, Part 1, 78, December 1985.
7. US Army Corps of Engineers, EM 1110-1-1904, Settlement Analysis, September 1990.
8. Coduto, Donald P., Foundation Design, Principles and Practices, 1994.
9. K-ESR-S-00006, Rev. 2, Glass Waste Storage Building #2 Geotechnical Baseline and Evaluation Report, December 2007.
10. Seed, H.B. and Idriss, I. M., 1971. Simplified Procedure for Evaluating Soil Liquefaction Potential, Journal of the Soil Mechanics and Foundation Division, ASCE, Vol. 97, SM9, New York, NY, 1971.
11. NCEER, 1997. Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils, National Center for Earthquake Engineering Research, Technical Report No. NCEER-97-0022, State University of New York at Buffalo, NY, December 31, 1997.
12. Youd, T. L., Idriss, I. M., Andrus, R. D., Arango, I., Castro, G., Christian, J. T., Dobry, R., Finn, W. D., Harder Jr., L. F., Hynes, M. E., Ishihara, K., Koester, J. P., Liao, S. C., Marcuson III, W. F., Martin, G. R., Mitchell, J. K., Moriwaki, Y., Power, M. S., Robertson, P. K., Seed, R. B., and K. H. Stokoe II, 2001. Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils, Journal of Geotechnical and Environmental Engineering, Vol. 127, No. 10, October, 2001.
13. Duncan, Williams, Sehn, and Seed, Closure of "Estimation Earth Pressures Due to Compaction", Journal of Geotechnical Engineering, Vol. 119, No. 7 July 1993.

Tables

Table 1: Summary of CPT Tests and Stratigraphy

ID	CPT Type	SRS Northing	SRS Easting	Elevation ft, msl	Elevation Top Pick (ft, msl) C2 Layer	S3 Layer	S4 Layer	Congaree
ZV3V5C1	SCPT	78429	66907	264.9	NP	224	185	
ZV3V5C2	CPT	78267	66960	268.6	221	215	184	
ZV3V5C3	CPT	78477	66813	263.9	NP	219	190	
ZV3V5C4	SCPT	78405	66836	266.8	NP	221	186	
ZV3V5C5	CPT	78325	66863	268.8	226	221	186	
ZV3V5C6	SCPT	78244	66889	268.8	229	217	187	144
ZV3V5C7	SCPT	78173	66913	268.2	233	223	NDE	
ZV3V5C8	CPT	78374	66741	267.7	220	216	186	
ZV3V5C9	SCPT	78293	66768	270.4	225	216	173	
ZV3V5C10	CPT	78213	66794	270.7	227	211	178	144
ZV3V5C11	SCPT	78414	66623	264.7	218	215	185	
ZV3V5C12	SCPT	78343	66646	268.1	219	216	186	
ZV3V5C13	CPT	78262	66673	272.0	225	221	184	
ZV3V5C14	SCPT	78181	66699	273.0	228	216	186	
ZV3V5C15	CPT	78110	66723	271.6	231	220	178	
ZV3V5C16	CPT	78319	66575	268.7	NP	228	186	
ZV3V5C17	SCPT	78158	66628	274.6	228	219	186	
ZV3V5B01	Boring	78395	66839	266.9	No Stratigraphy – Undisturbed Sampling			
ZV3V5B02	Boring	78235	66894	269.9	228	218	188	145
ZV3V5B03	Boring	78333	66649	268.3	221	216	183	148
ZV3V5B04	Boring	78171	66702	272.8	No Stratigraphy – Undisturbed Sampling			

Table 2: Summary of Engineering and Geologic Layers

<table>
<tr><th>General Description</th><th>USCS</th><th>Engineering Layer</th><th>Geologic Layer</th></tr>
<tr><td>Medium dense to dense red-brown clayey fine sand</td><td>SC</td><td rowspan="3">S1/2</td><td>Upland</td></tr>
<tr><td>Medium dense to very dense fine to medium sand, some silt</td><td>SM, SP-SM</td><td>Tobacco Road</td></tr>
<tr><td>Medium dense to dense medium sand with some clay and sandy clay layers</td><td>SC</td><td rowspan="3">Dry Branch</td></tr>
<tr><td>Medium dense clayey fine sand interlayered with stiff silty clay</td><td>CH</td><td>C2</td></tr>
<tr><td>Medium dense to dense medium sand with some clay and sandy clay layers</td><td>SC, SP, SP-SM, SP-SC</td><td>S3</td></tr>
<tr><td>Dense to very dense calcareous fine to medium sand with some clay and silt</td><td>SM, SC</td><td>S4</td><td>Santee Tinker</td></tr>
<tr><td>Hard clayey silt to very dense fine to medium sand</td><td>MH</td><td>M1</td><td>Warley Hill</td></tr>
<tr><td>Dense poorly graded sands with silts</td><td>SP-SM</td><td>CG</td><td>Congaree</td></tr>
</table>

Table 3: Summary of CPT and SCPT Data

Layer	Description	Sleeve Friction (tsf)	Corrected Tip Resis-tance (tsf)	Friction Ratio (%)	Pore Pressure (tsf)	P Wave (fps)	S Wave (fps)	Poisson's Ratio
S1/2	Average	2.65	164.64	2.24	0.75	2500	1500	0.197
	Minimum	0.55	39.39	0.44	-0.05	1557	947	
	Maximum	8.36	345.74	11.85	9.32	4198	3981	
	Standard Deviation	1.81	69.36	2.21	1.21	791	883	
	No. of Data Points	468	468	468	468	14	10	
C2	Average	1.20	46.28	2.65	1.98	3490	1050	0.450
	Minimum	0.66	20.83	1.11	-0.01	2026	771	
	Maximum	2.37	118.24	5.20	5.25	6732	1404	
	Standard Deviation	0.45	26.73	0.90	1.41	1604	247	
	No. of Data Points	98	98	98	98	9	7	
S3	Average	2.06	143.86	1.95	1.52	3450	1230	0.427
	Minimum	0.44	16.32	0.41	-0.12	1875	799	
	Maximum	6.65	397.06	6.67	10.65	6095	2086	
	Standard Deviation	1.48	106.78	1.33	1.92	1609	318	
	No. of Data Points	370	371	370	371	9	14	
S4	Average	3.35	124.28	3.21	4.25	6095	1525	0.456
	Minimum	0.94	33.96	1.05	0.24	6095	1103	
	Maximum	9.06	518.16	7.30	12.89	6095	2756	
	Standard Deviation	1.93	90.90	1.33	3.13	0	620	
	No. of Data Points	151	156	151	156	1	11	
All	Average	2.31	119.76	2.51	2.12	3884	1326	
	No. of Data Points	1087	1093	1087	1093	34	42	

Table 4: Summary of SPT Statistics

Description	S1/2	C2	S3	S4
Average	24	9	17	55
Minimum	16	6	WH	11
Maximum	35	31	37	50 in 3 inches
Standard Deviation	5.1	6.9	11.0	35.7
No. of Data Points	28	4	17	55
Average Corrected N_{60}	32	12	23	74

WH: Weight of Hammer

Table 5: Summary of Static Settlements

	Minimum Settlement (inches)	Maximum Settlement (inches)	Average Settlement (inches)
Heave	¼	1	½
Operation Complete	2	6	4
Closure Cap Complete	3	13	9
Closure Cap Complete + 30 Yrs	5	18	11

Table 6: Summary of Liquefaction Induced Settlements – New SRS CRR Curves

	Settlement (inches)						
	M_w = 4.75	M_w = 5.25	M_w = 5.75	M_w = 6.25	M_w = 6.75	M_w = 7.5	2,500 Yr Weighting
Z-V3V5-C01	0.00	0.00	0.00	0.01	0.07	0.49	0.24
Z-V3V5-C02	0.00	0.00	0.04	0.16	0.47	1.93	0.95
Z-V3V5-C03	0.00	0.00	0.00	0.04	0.13	0.70	0.34
Z-V3V5-C04	0.00	0.00	0.00	0.00	0.02	0.24	0.12
Z-V3V5-C05	0.00	0.00	0.00	0.01	0.05	0.43	0.21
Z-V3V5-C06	0.00	0.00	0.02	0.08	0.29	1.30	0.64
Z-V3V5-C07	0.00	0.00	0.01	0.03	0.15	0.79	0.38
Z-V3V5-C08	0.00	0.00	0.01	0.07	0.24	1.16	0.57
Z-V3V5-C09	0.00	0.00	0.02	0.11	0.34	1.68	0.82
Z-V3V5-C10	0.00	0.00	0.00	0.01	0.10	0.78	0.38
Z-V3V5-C11	0.00	0.00	0.00	0.01	0.04	0.38	0.18
Z-V3V5-C12	0.00	0.00	0.01	0.05	0.19	1.00	0.49
Z-V3V5-C13	0.00	0.00	0.00	0.01	0.07	0.50	0.24
Z-V3V5-C14	0.00	0.00	0.00	0.03	0.13	0.88	0.43
Z-V3V5-C15	0.00	0.00	0.00	0.05	0.20	1.22	0.59
Z-V3V5-C16	0.00	0.00	0.02	0.10	0.32	1.48	0.73
Z-V3V5-C17	0.00	0.00	0.01	0.10	0.32	1.64	0.80
					Average	0.98	0.48

Table 7: Compaction Induced Lateral Earth Pressures

Depth (feet)	$\sigma_{H\ Design}$ (psf)
0	0
2	525
4	640
8	735
14	900

K_0 controls at 14 feet and below

Figures

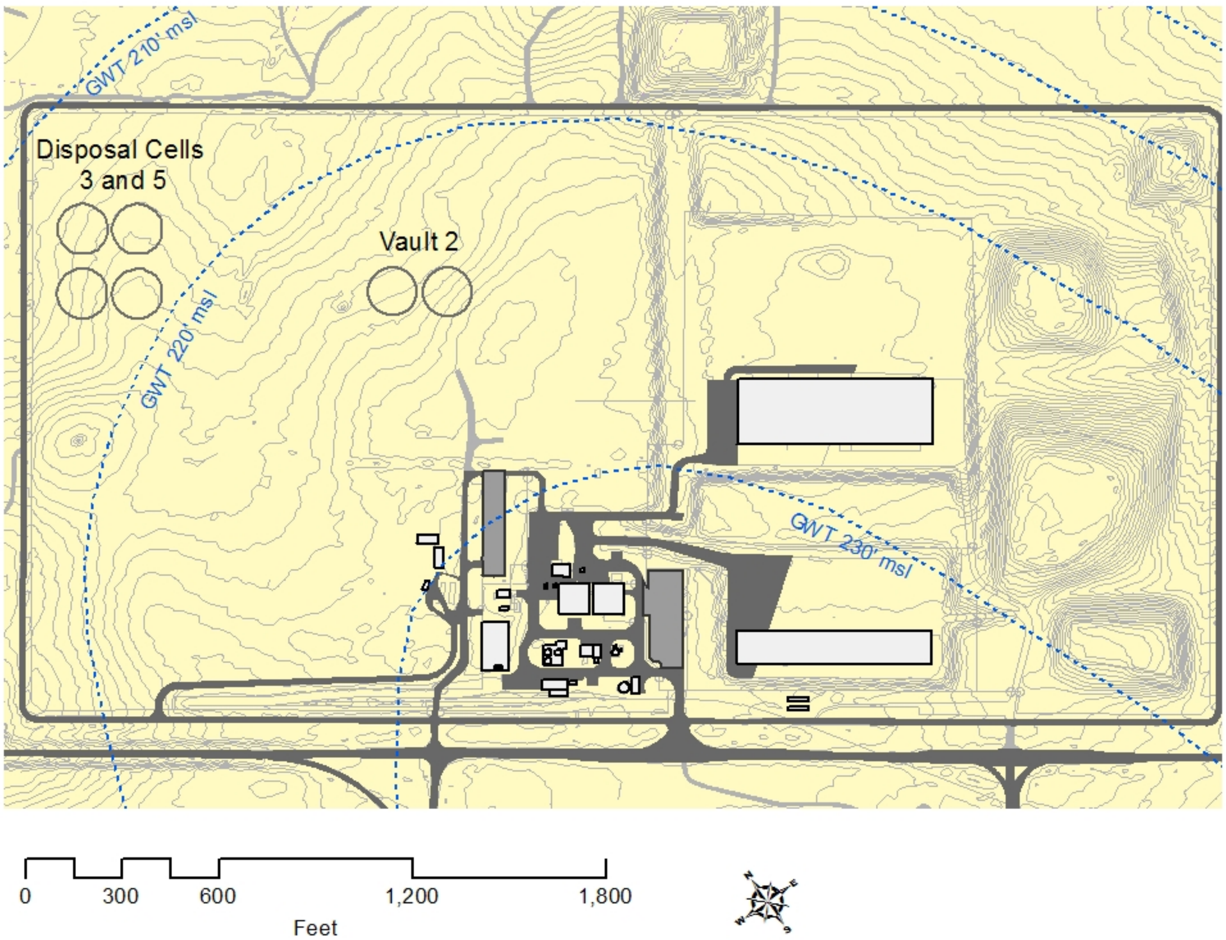


Figure 1: Z Area Location Map

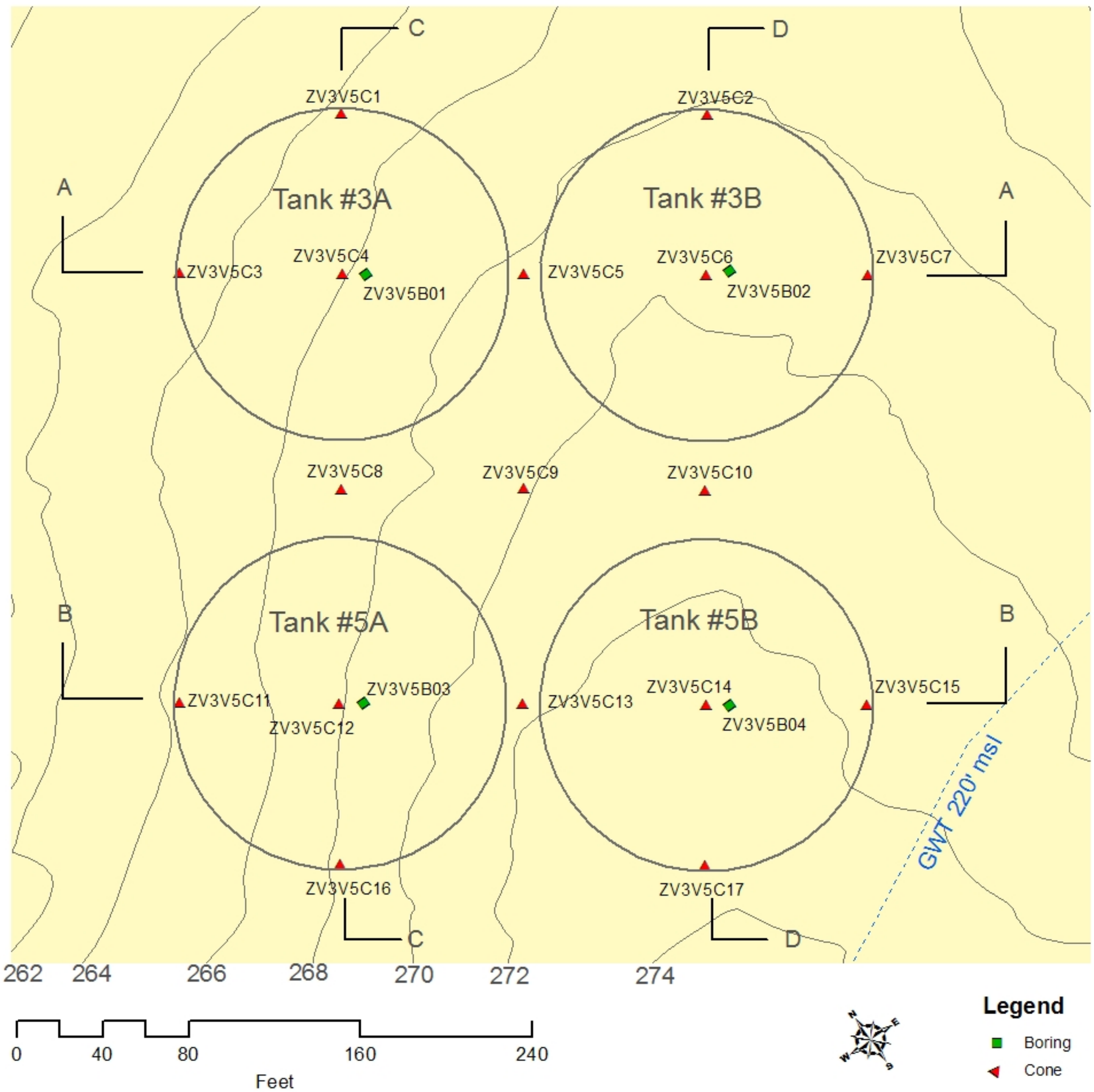


Figure 2: Disposal Cells No. 3 and 5 Location Map with Subsurface Investigation Locations

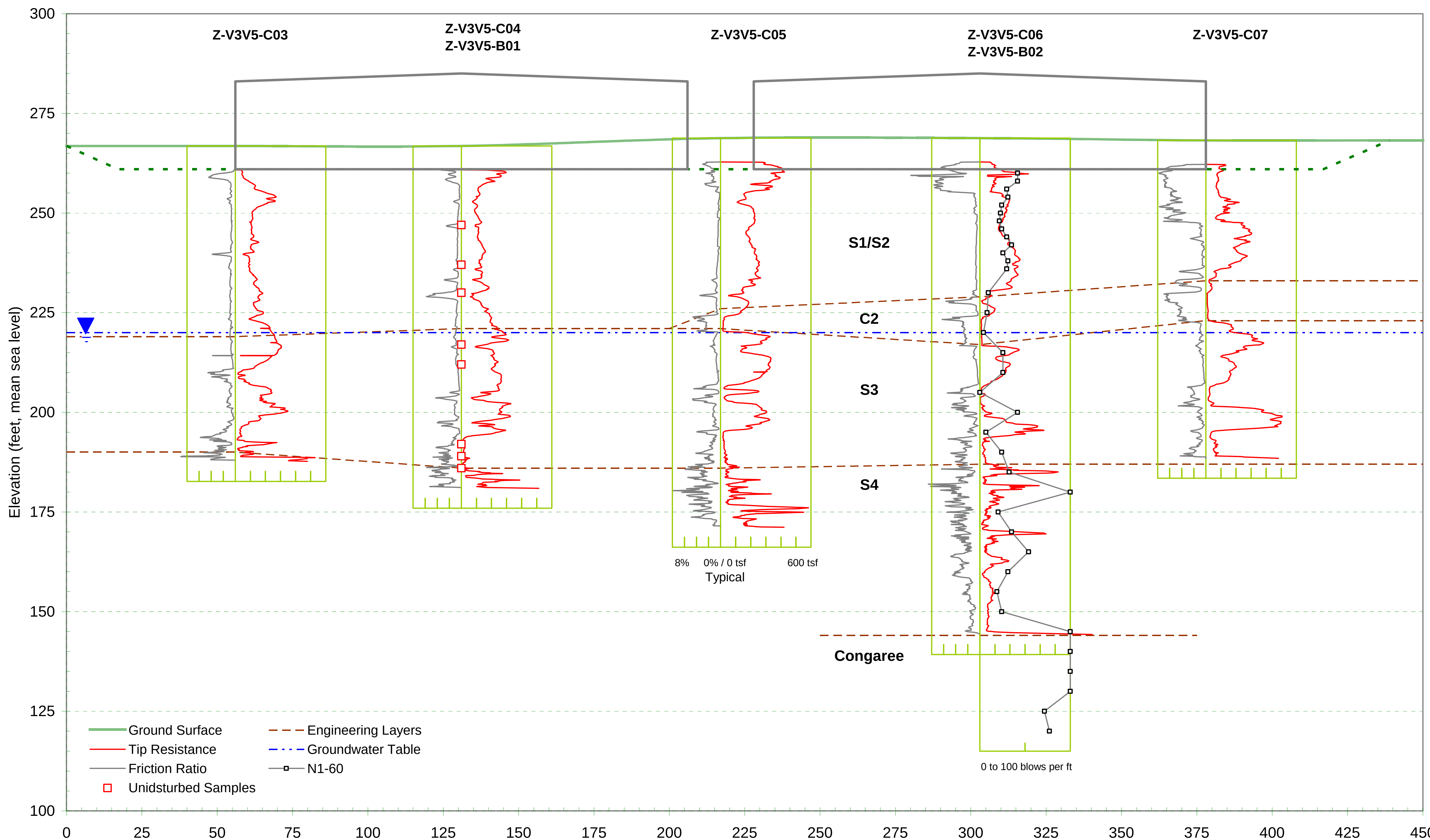


Figure 3: Cross Section AA

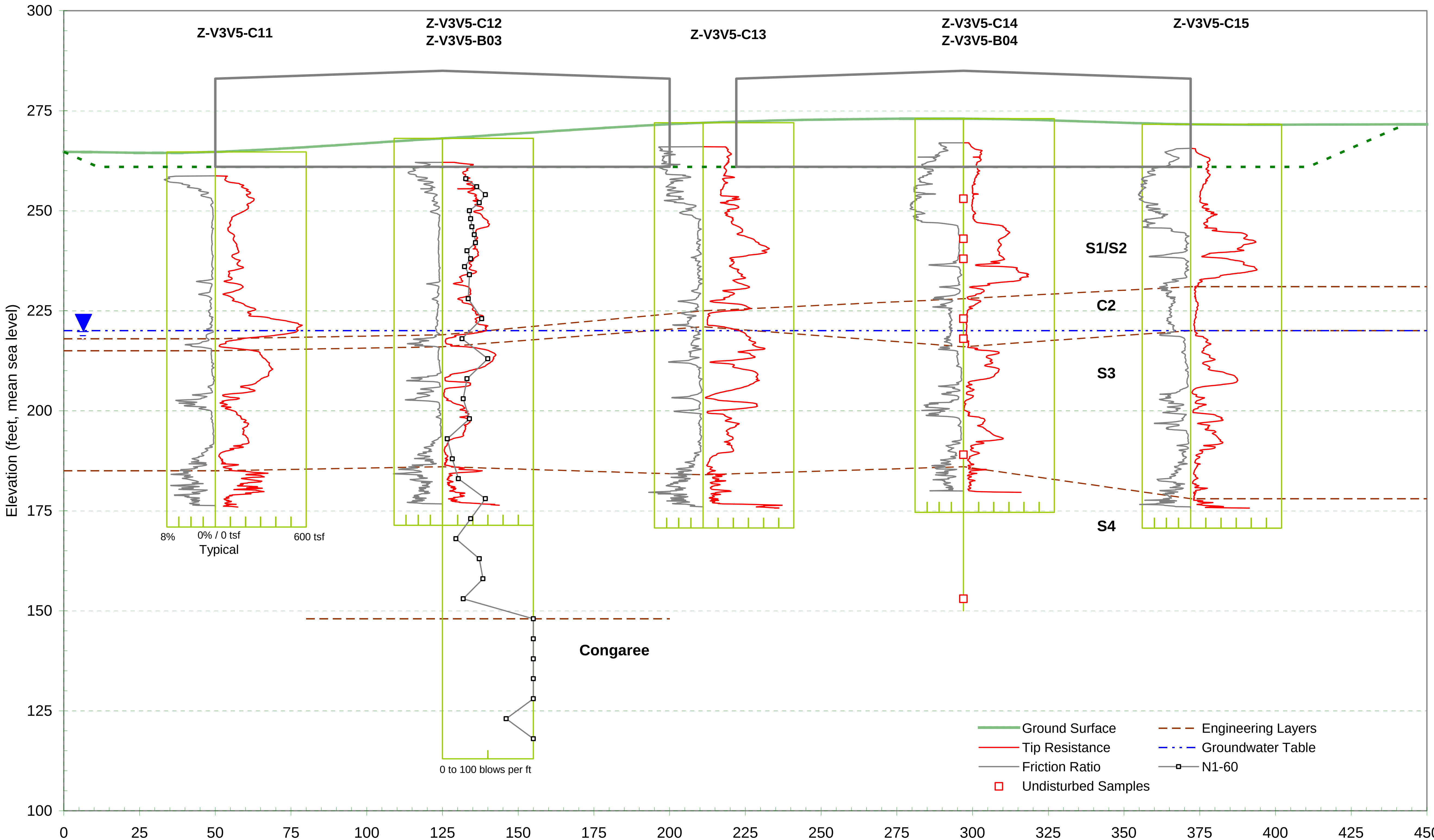


Figure 4: Cross Section BB

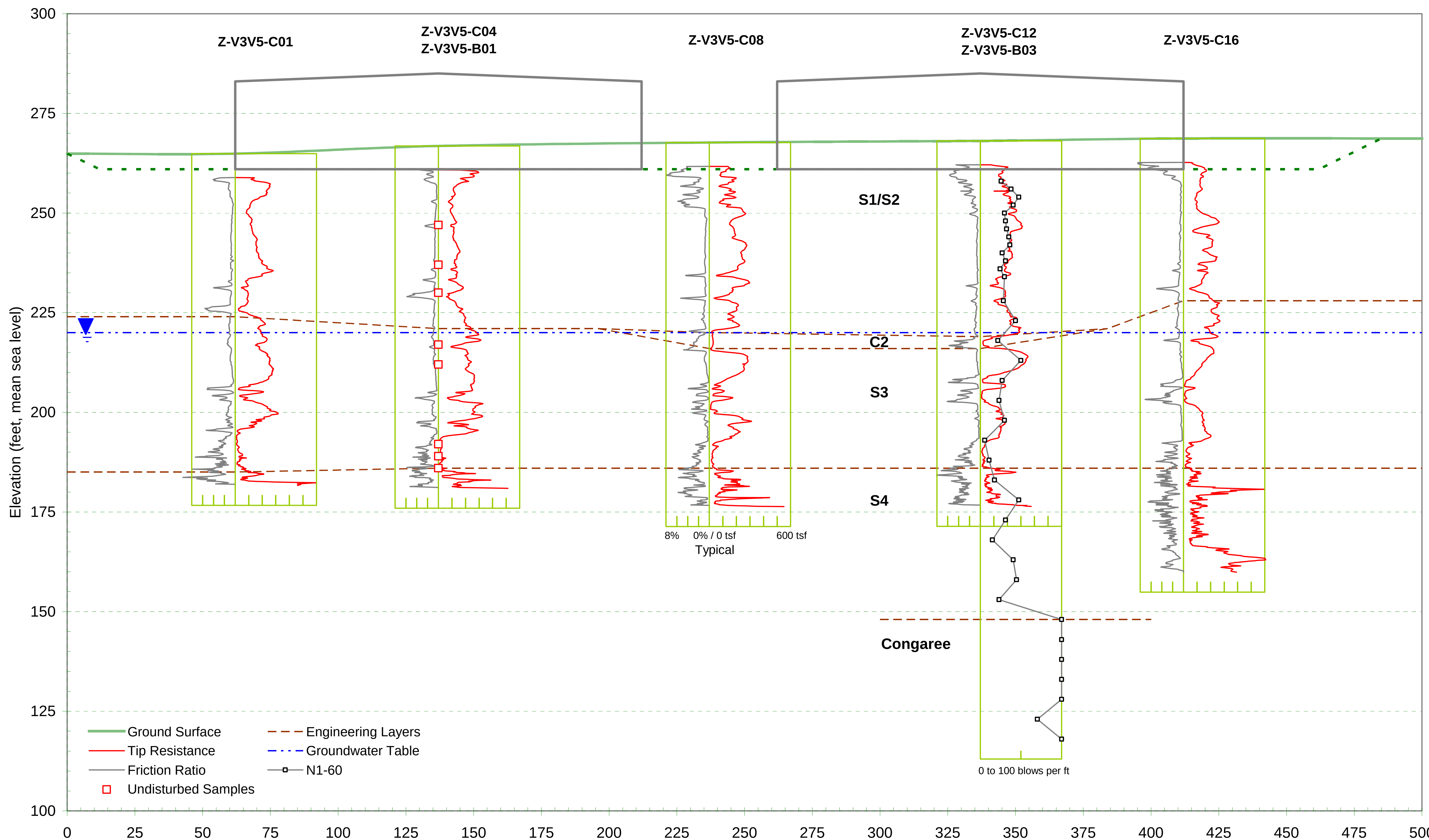


Figure 5: Cross Section CC

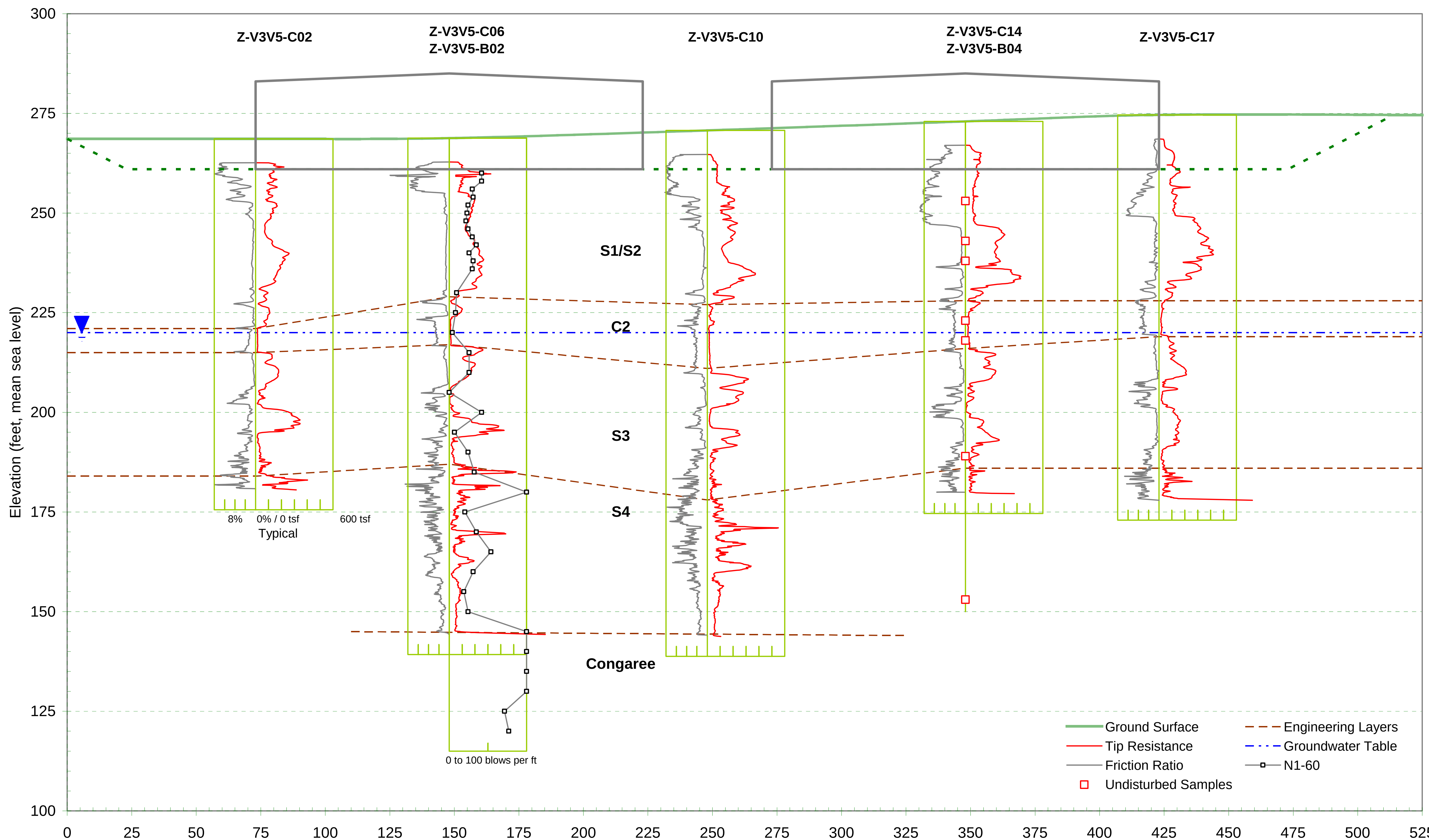


Figure 6: Cross Section DD

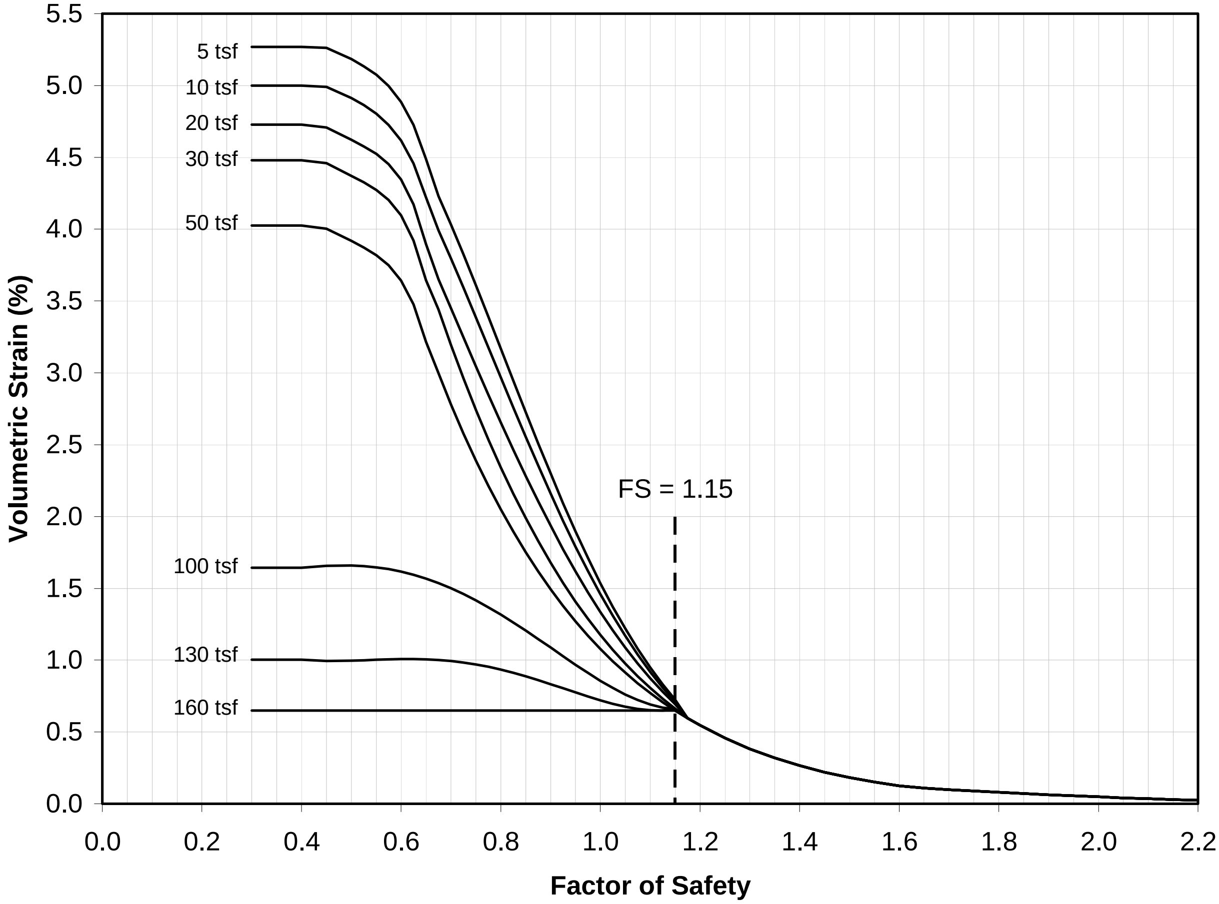


Figure 7: SRS Volumetric Strain Curves for Liquefaction Analysis

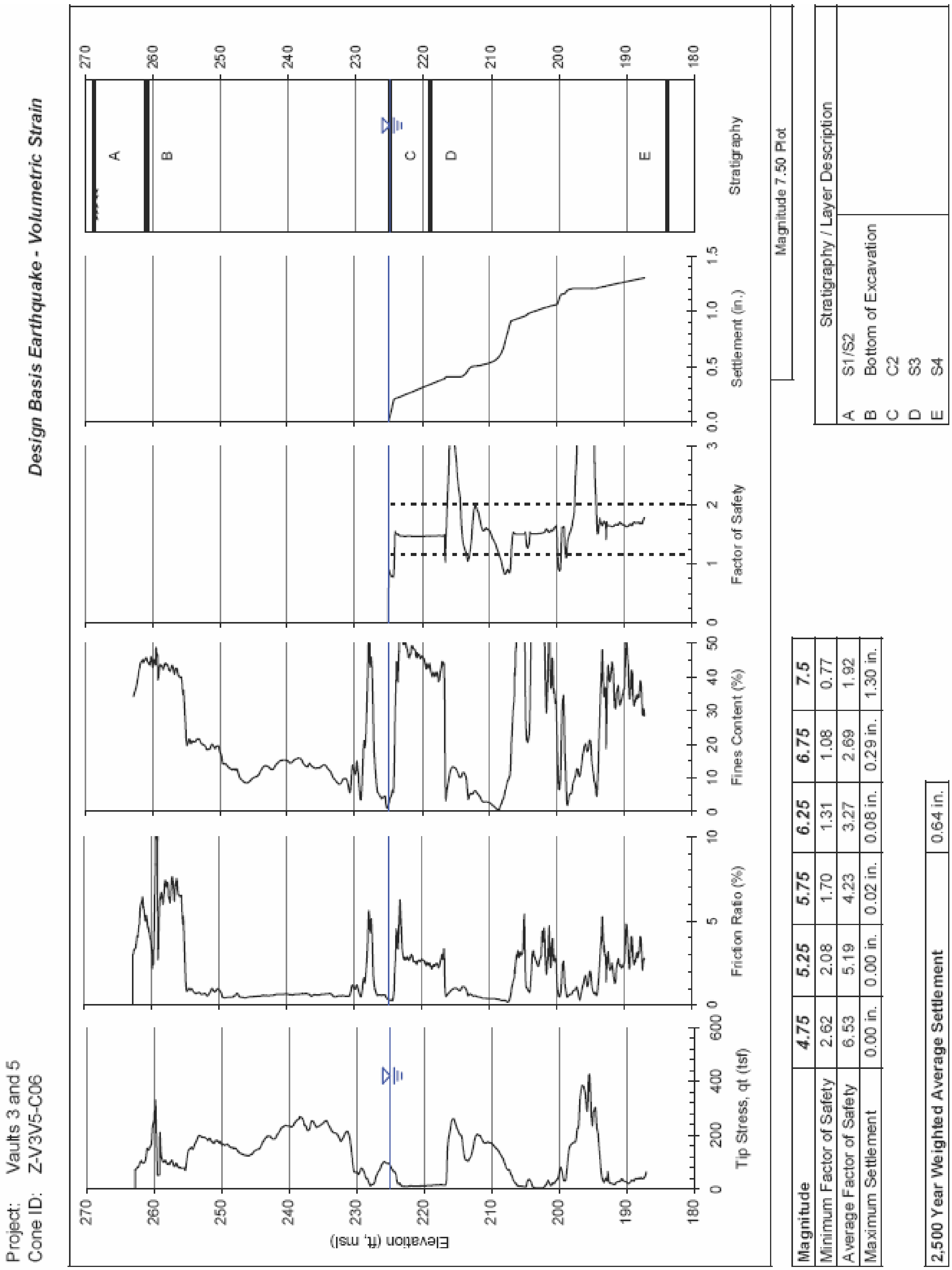


Figure 8: Liquefaction Induced Settlement of CPT Z-V3V5-C06

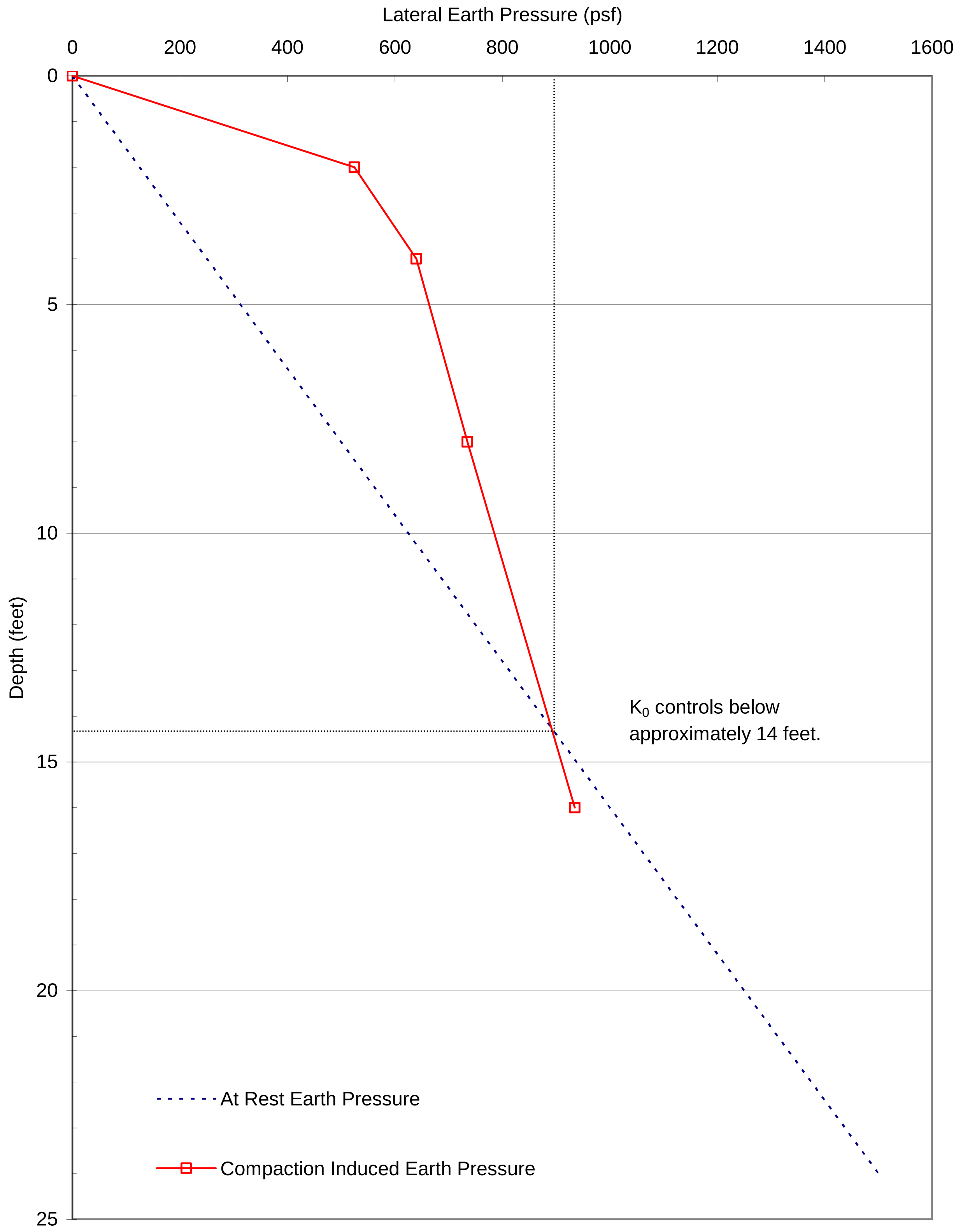


Figure 9: Compaction Induced Lateral Earth Pressures

Appendix A - Stratigraphy

K-CLC-Z-00012, Rev. 0

June 2009

Stratigraphy for Saltstone Vaults No. 3 and 5

(61 pages)

Calculation Cover Sheet

Project	Calculation No.	Project Number
Saltstone Vaults No. 3 and 5	K-CLC-Z-00012	~~N/A~~ 1546
Title Stratigraphy for Saltstone Vaults 3 and 5	**Functional Classification** PS **Discipline** Geotechnical	Sheet 1 of ~~22~~ 60
Calc Level ☒ Type 1 ☐ Type 2	**Type 1 Calc Status** ☐ Preliminary ☒ Confirmed	
Computer Program No. ☒ N/A	**Version / Release No.** N/A	
Purpose and Objective Develop engineering stratigraphy for the Saltstone Vaults 3 and 5 for use in engineering analysis.	**DC/RO** UNCLASSIFIED DOES NOT CONTAIN UNCLASSIFIED CONTROLLED NUCLEAR INFORMATION ADC & Reviewing Official (Name): A.A. Siddall Date: 7/23/2009	

Summary of Conclusion

See results and conclusions section.

Revision

Rev. No.	Revision Description
0	Original

Sign Off

Rev. No.	Originator (Print) Sign / Date	Verification / Checking Method	Verifier / Checker (Print) Sign / Date	Manager (Print) Sign / Date
0	Patti L. Bennett Patti Bennett 4/21/09	Document Review	Laura Bagwell 23APR09	William T. Li William T. Li 4/23/09
0		Document Review	Rucker J. Williams 7-1-09	

Additional Reviewer (Print)	Signature	Date
N/A		
Design Authority (Print)	**Signature**	**Date**
N/A		
Release to Outside Agency (Print)	**Signature**	**Date**
N/A		

Security Classification of the Calculation
Unclassified

1. INTRODUCTION

This calculation identifies engineering stratigraphic layers for CPTU soundings performed for the Saltstone Vaults No. 3 and 5. Engineering stratigraphic layers and nomenclature were based on previous subsurface investigations performed within Z Area by Mueser Rutledge Consulting Engineers (MRCE) and SRS. Figure 1 depicts the location of Vaults 3 and 5 within Z Area.

2. INPUT DATA

Subsurface data acquired for the Saltstone Vaults No. 3 and 5 investigation included nine (9) seismic piezocone penetration test (SCPTU) soundings and eight (8) piezocone penetration test soundings (CPTU). In addition four (4) borings were performed, including two (2) undisturbed and 2 standard penetration test (SPT) borings. These locations are depicted in Figure 2.

3. METHOD FOR DETERMINATION OF ENGINEERING LAYERS

Engineering layers developed for the Saltstone Vaults No. 3 and 5 area followed a scheme previously used by other investigations in Z Area. Utilization of this same layering provided a means to compare subsurface conditions between investigation sites. An S or C designation was used to divide layers into predominantly sand and clay units, respectively. The upper layer S1/2 exists from the surface to the C2 layer. The C2 layer corresponds to what has commonly been termed the "Tan Clay" layer. The S3 layer exists between the C2 layer and the S4 layer. The S4 layer corresponds to the Santee/Tinker Formation. This layering system was extended to the Saltstone Vaults No. 3 and 5 area by correlating CPT curve signatures to the CPT curve signatures interpreted for Vault No. 2 (Ref 1).

Table 2 summarizes the contacts between stratigraphic layers based on the SPT boring logs for ZV3V5B02 and ZV3V5B03. The contact elevations are approximate as SPT sampling was performed on 5-foot intervals below a depth of 35 feet.

The Congaree Formation, which consists of coarse, dense sands, was identified in the borings and on a few CPT signatures. This formation appears to be relatively flat across the site and exists at an elevation of approximately 145 ft, msl. CPTs ZV3V5C06 and ZV3V5C10 refused on (did not penetrate) the top of the Congaree Formation.

4. RESULTS AND CONCLUSIONS

Engineering stratigraphy for Saltstone Vaults No. 3 and 5 CPT soundings is summarized in Table 1.

Of interest in the Vaults 3 and 5 area is that the C2 layer 'pinches out' in the northern section of the site (Figure 3). Cones ZV3V5C1, ZV3V5C3, ZV3V5C4, and ZV3V5C16 do not appear to contain the C2 layer at all.

5. REFERENCES

1. K-CLC-Z-00005, Stratigraphy for the Saltstone Vault No. 2, Rev 0.

2. K-ESR-Z-00001, Saltstone Vault No. 2 Geotechnical Investigation Report, Rev 0.

3. AC39054N, Table 1 Summary of Seismic (SCPT) and Piezocone (PCPT) Soundings Conducted As Part of the Task 32 Field Investigation, Document Control Package No. 27253, April 2009.

4. Subcontract No. C002332N, Rev. 0, SOW FP-301-0R5724, Rev. 0, For Geotechnical Drilling and Technical Oversight Services for the Saltstone Vaults 3 and 5 Geotechnical Investigation, April 2009.

6. LIST OF FIGURES

7. LIST OF TABLES

9. ATTACHMENTS

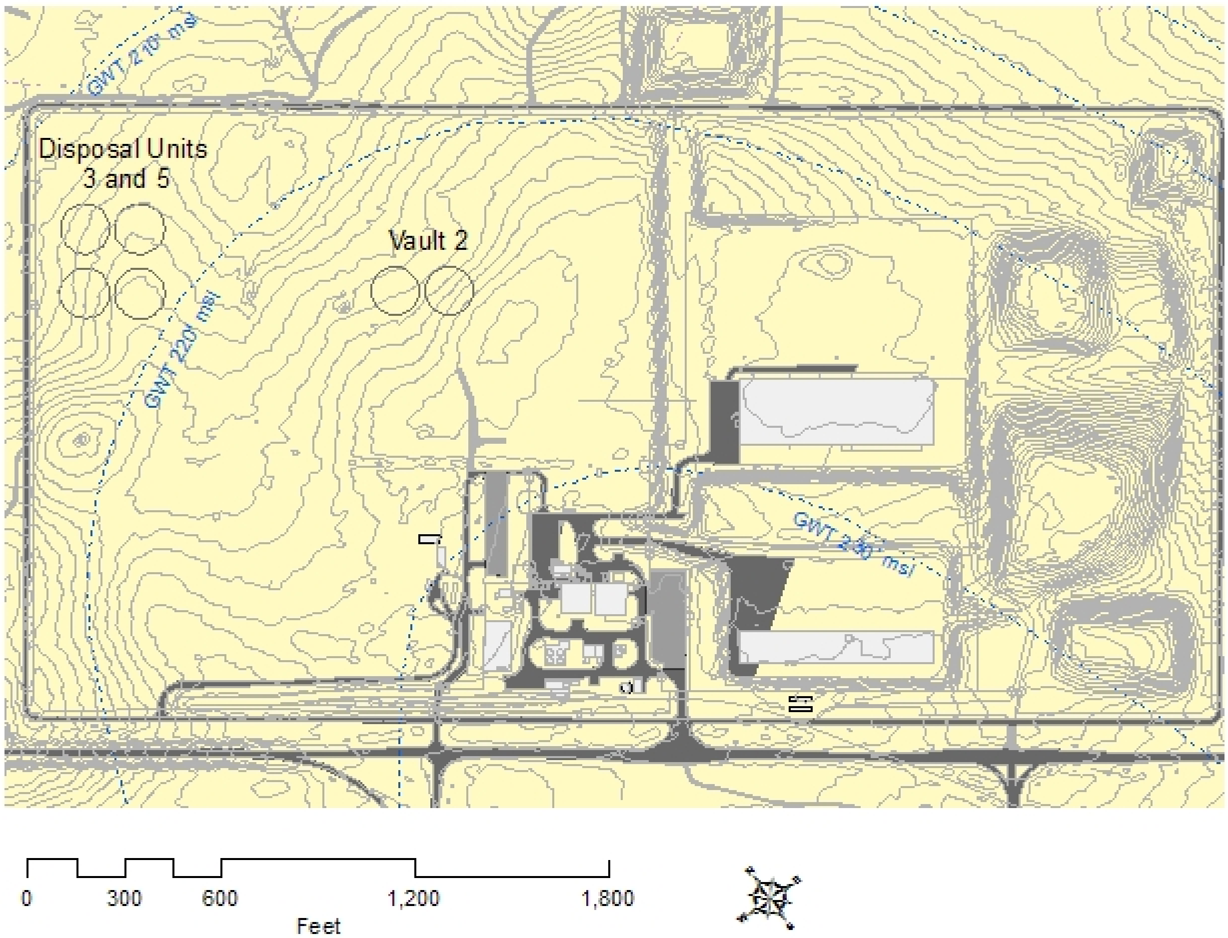


Figure 1: Vaults 3 and 5 Location Map

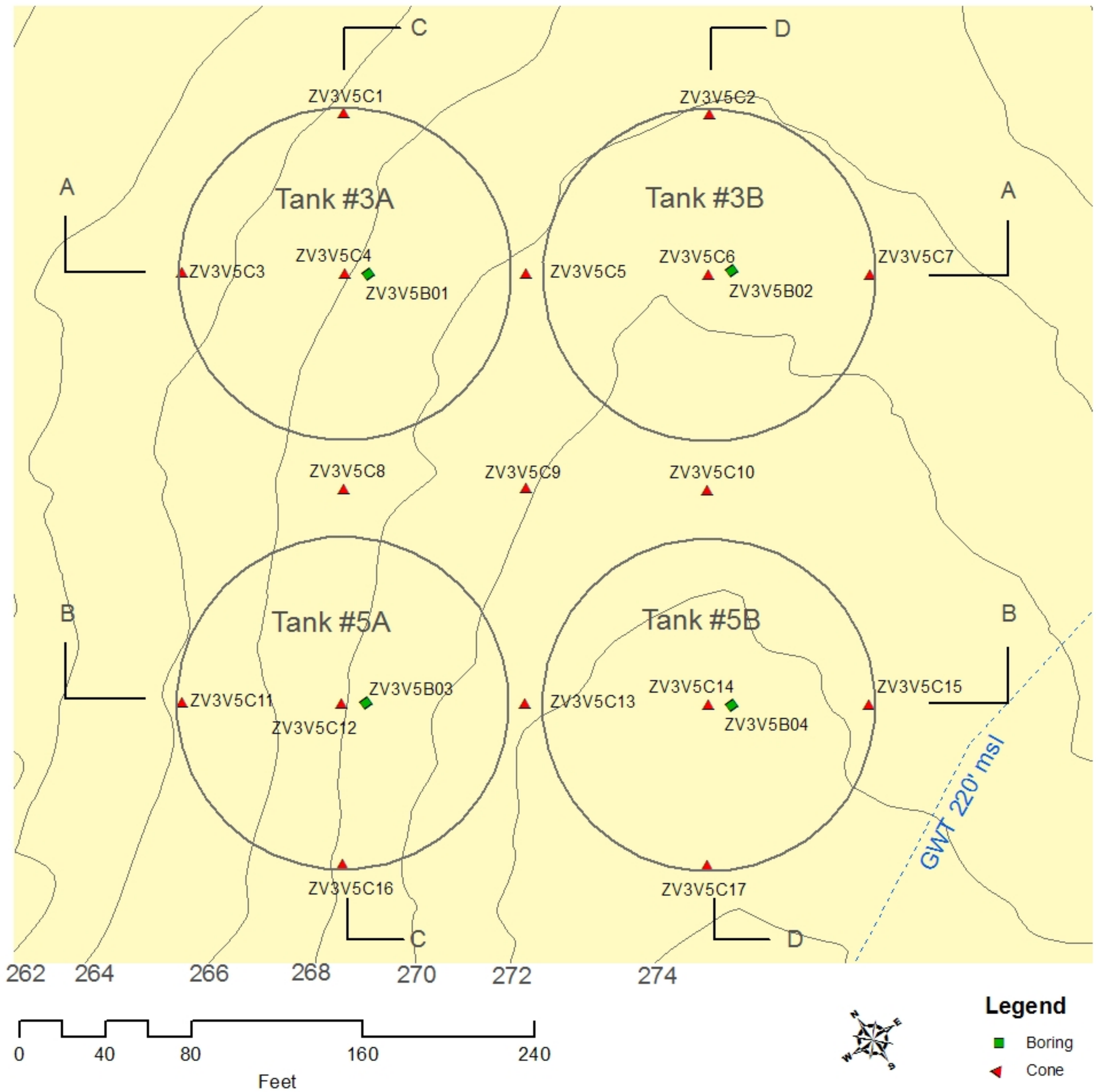


Figure 2: Geotechnical Investigation Locations

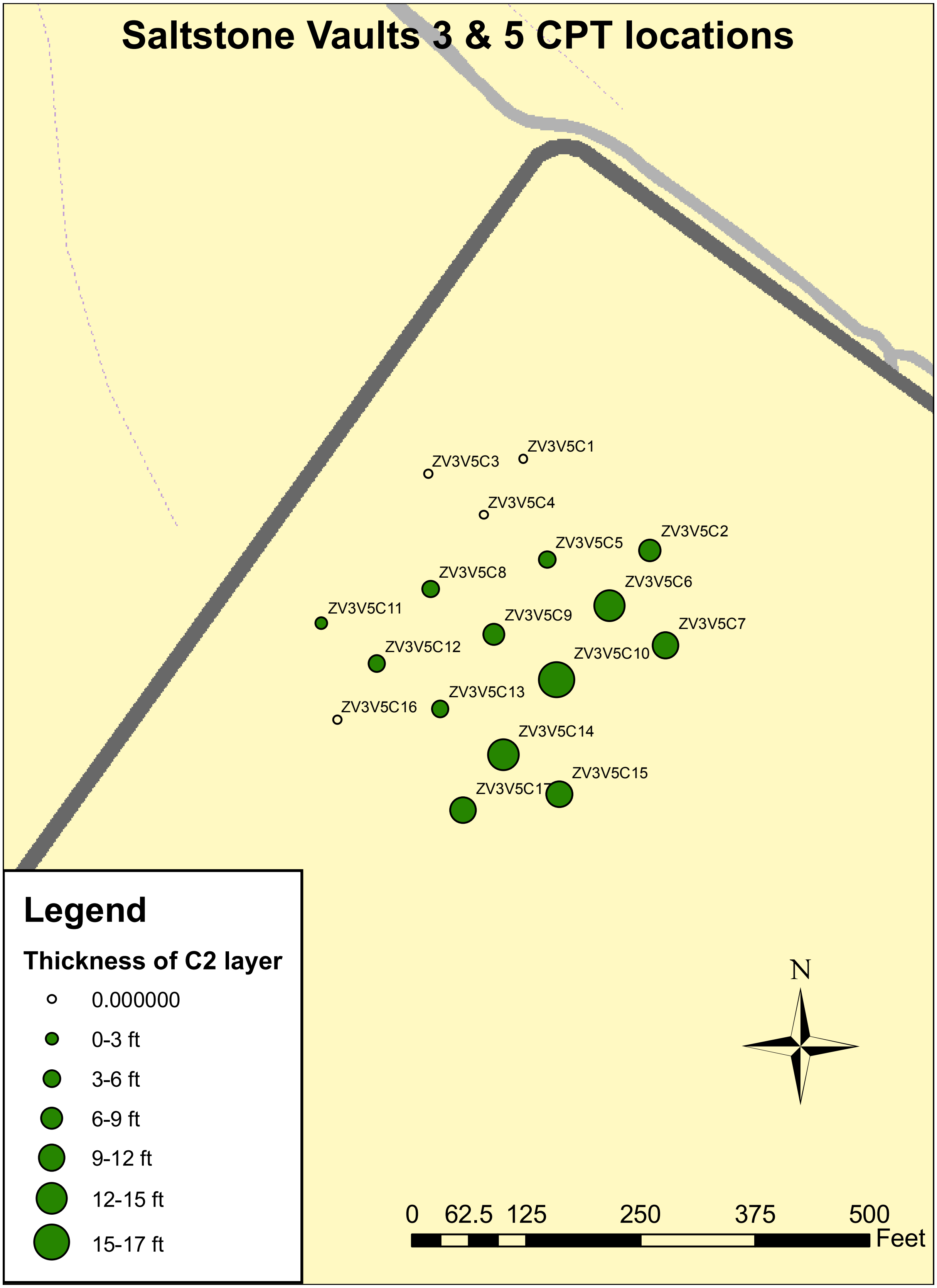


Figure 3: C2 Layer Thickness

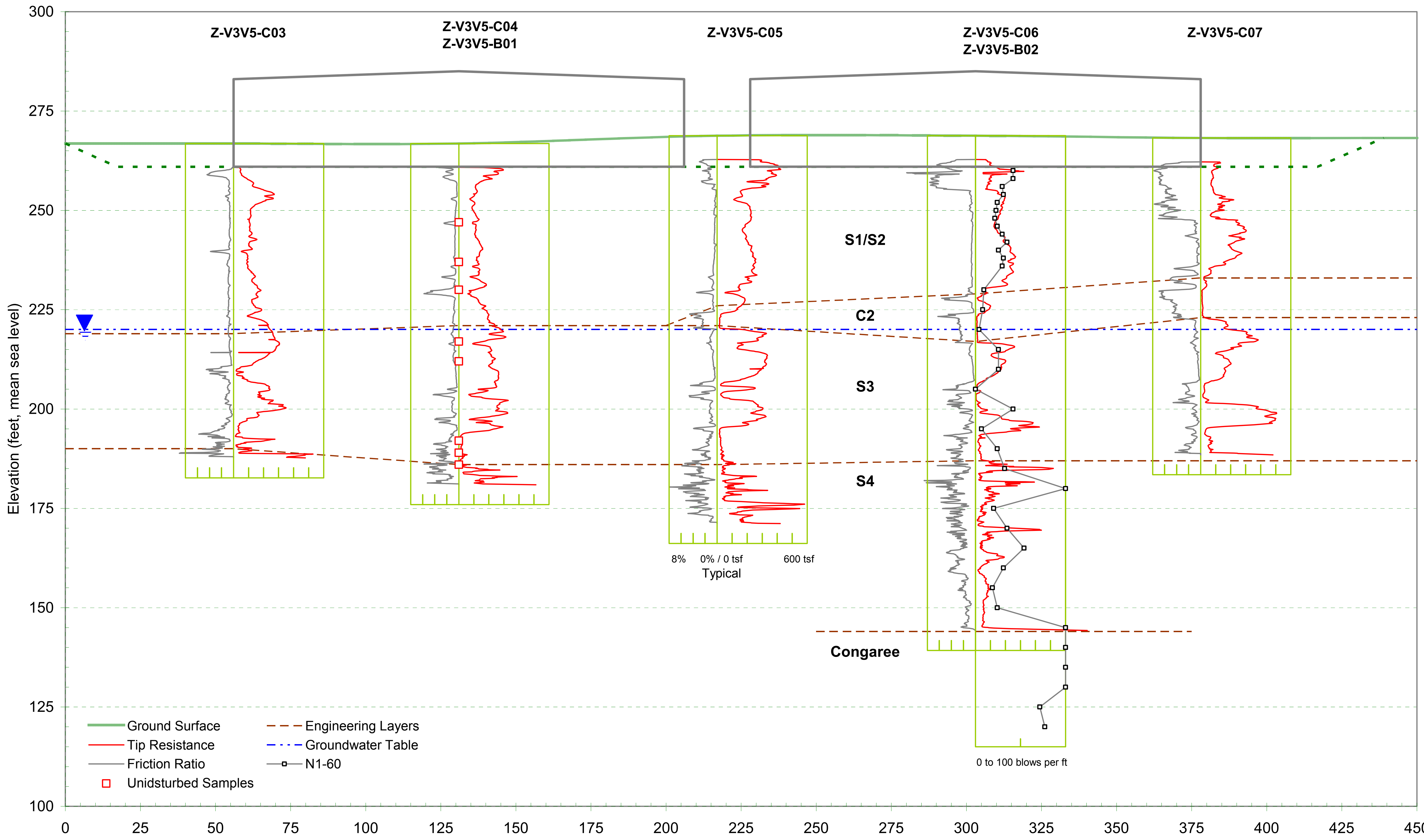


Figure 4: Cross Section AA

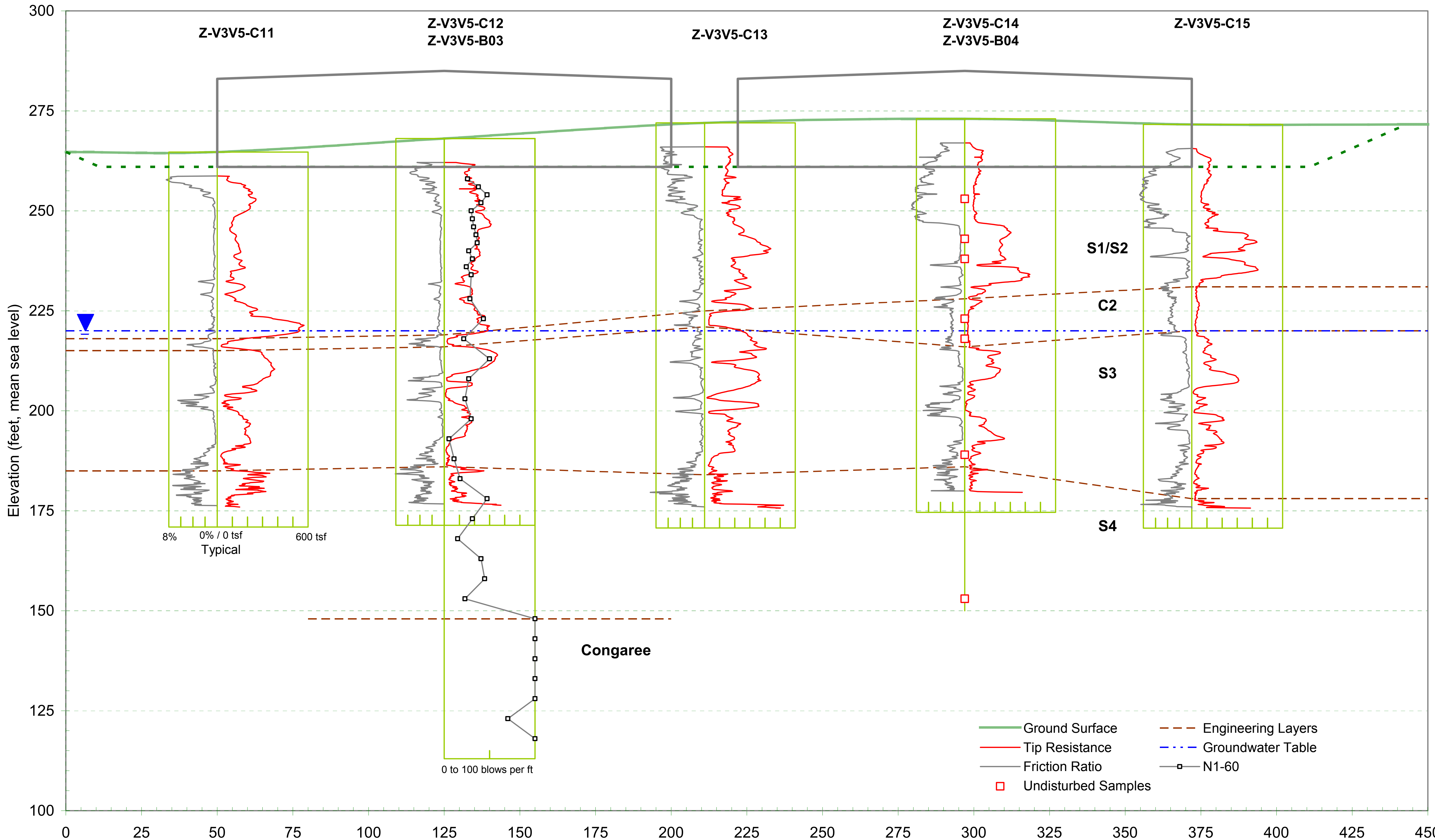


Figure 5: Cross Section BB

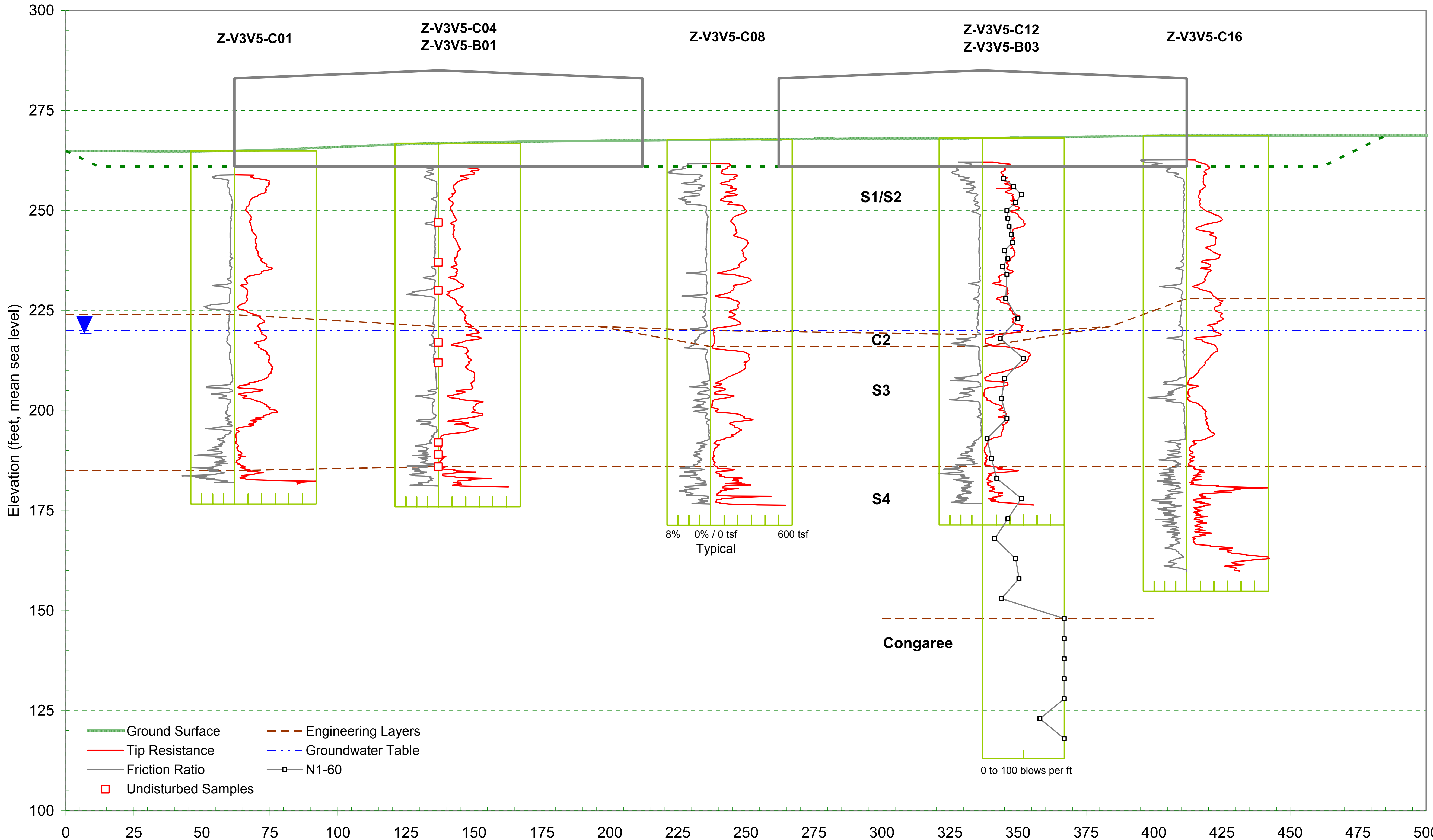


Figure 6: Cross Section CC

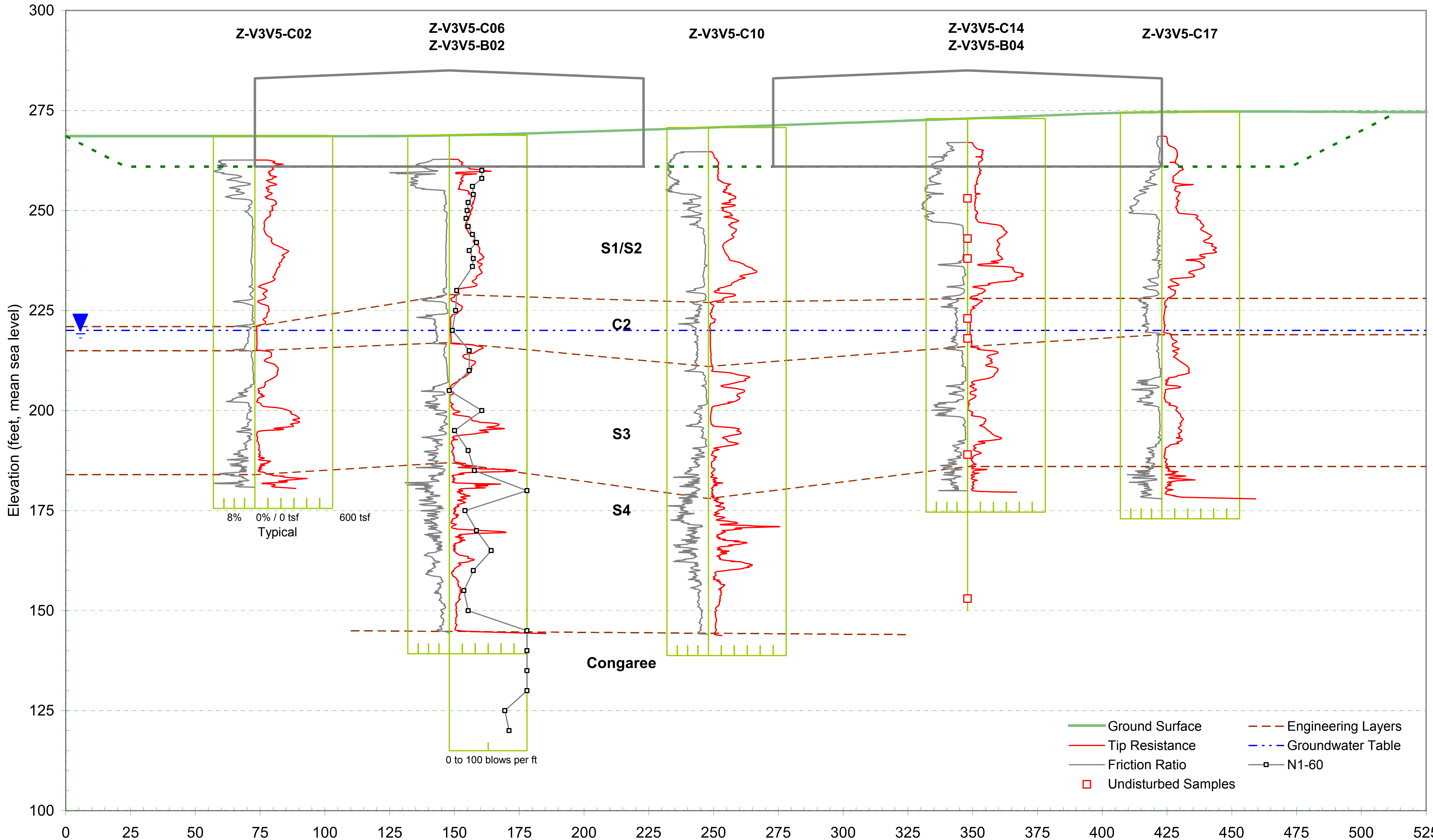


Figure 7: Cross Section DD

Table 1 – Engineering Stratigraphy Based on CPTs -Tops of Stratigraphic Layers in feet msl.

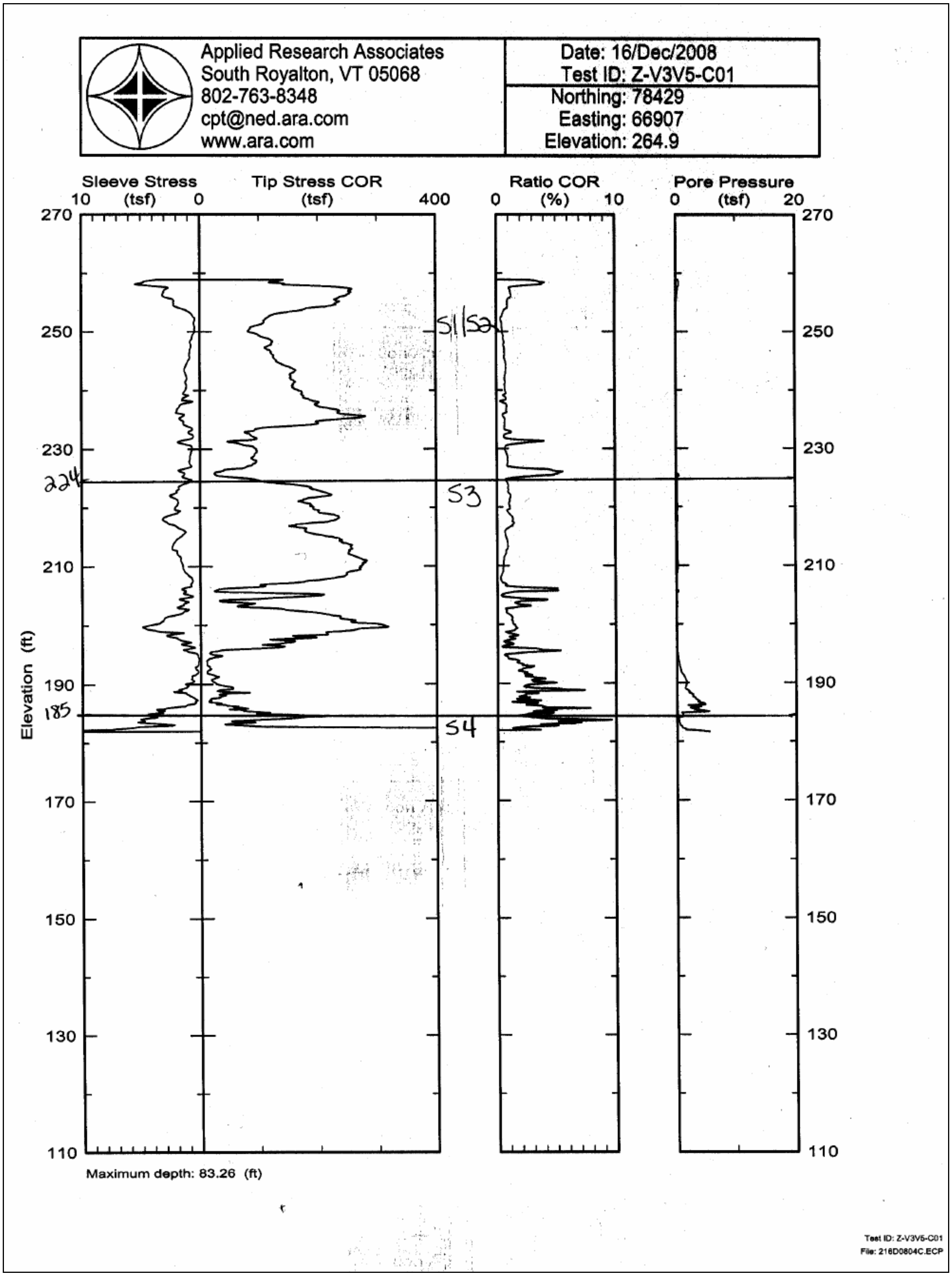
CPT ID	Ground Elevation	C2	S3	S4	Congaree	SRS_E	SRS_N
ZV3V5C1	264.9	NP	224	185		66,907	78,429
ZV3V5C2	268.6	221	215	184		66,960	78,267
ZV3V5C3	263.9	NP	219	190		66,813	78,477
ZV3V5C4	266.8	NP	221	186		66,836	78,405
ZV3V5C5	268.8	226	221	186		66,863	78,325
ZV3V5C6	268.8	229	217	187	144	66,889	78,244
ZV3V5C7	268.2	233	223	NDE		66,913	78,173
ZV3V5C8	267.7	220	216	186		66,741	78,374
ZV3V5C9	270.4	225	216	173		66,768	78,293
ZV3V5C10	270.7	227	211	178	144	66,794	78,213
ZV3V5C11	264.7	218	215	185		66,623	78,414
ZV3V5C12	268.1	219	216	186		66,646	78,343
ZV3V5C13	272	225	221	184		66,673	78,262
ZV3V5C14	273	228	216	186		66,699	78,181
ZV3V5C15	271.6	231	220	178		66,723	78,110
ZV3V5C16	268.7	NP	228	186		66,575	78,319
ZV3V5C17	274.6	228	219	186		66,628	78,158

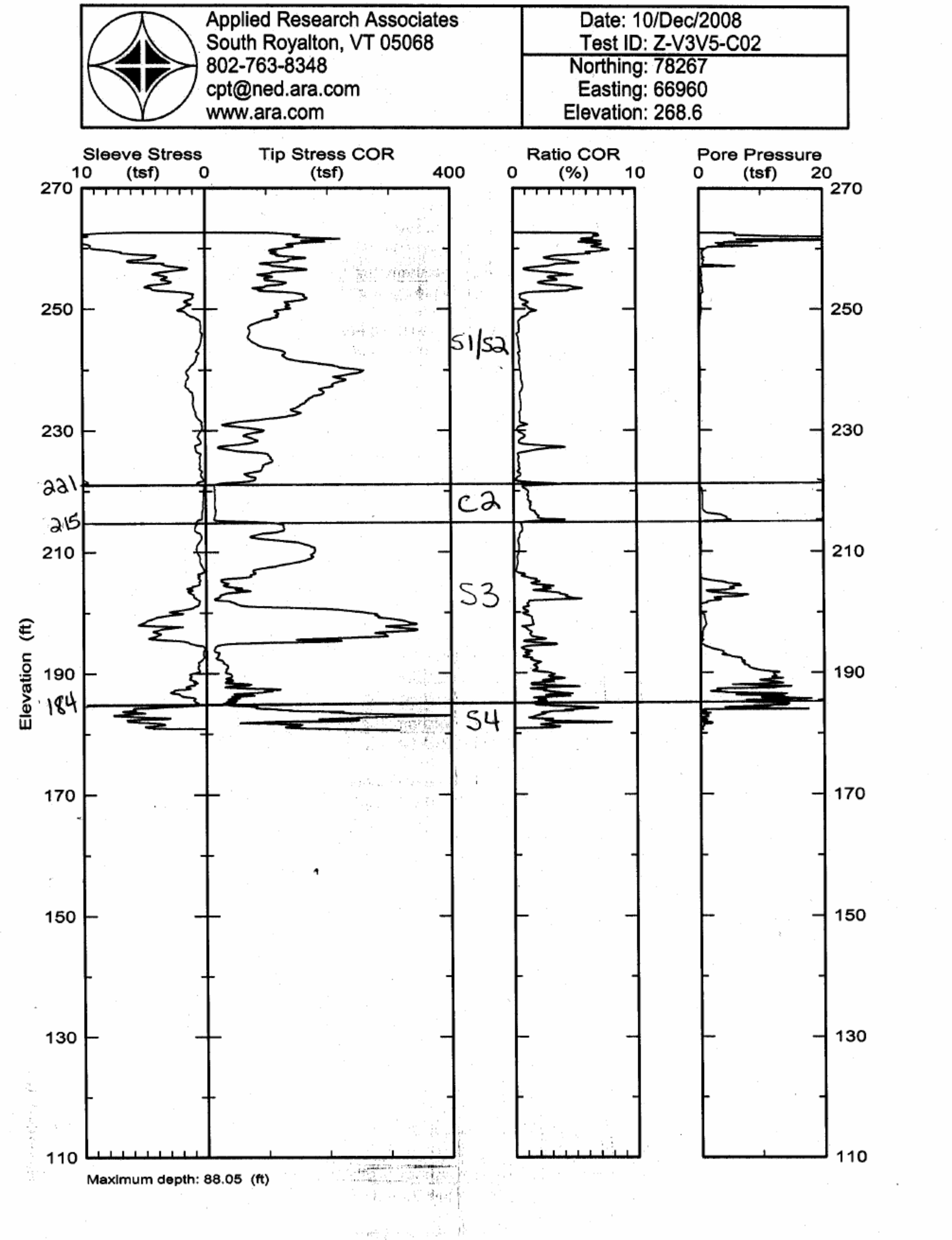
NDE – Not Deep Enough
NP – Not Present

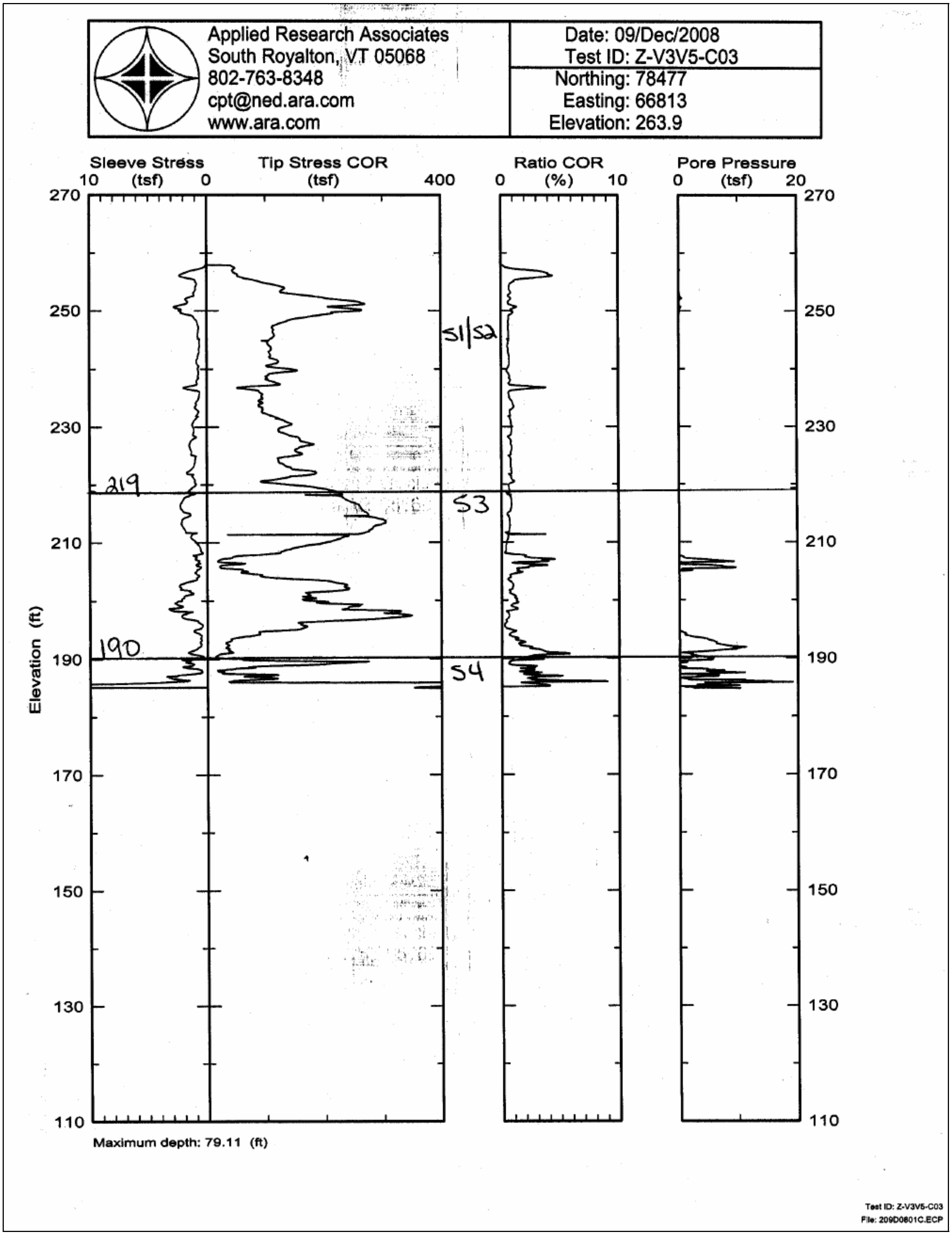
Table 2 – Engineering Stratigraphy Based on SPT Borings-Tops of Stratigraphic Layers in feet msl.

Boring ID	Ground Elevation	C2	S3	S4	Congaree	SRS_E	SRS_N
ZV3V5B02	269.9	228	218	188	145	66,894	78,235
ZV3V5B03	268.3	221	216	183	148	66,649	78,333

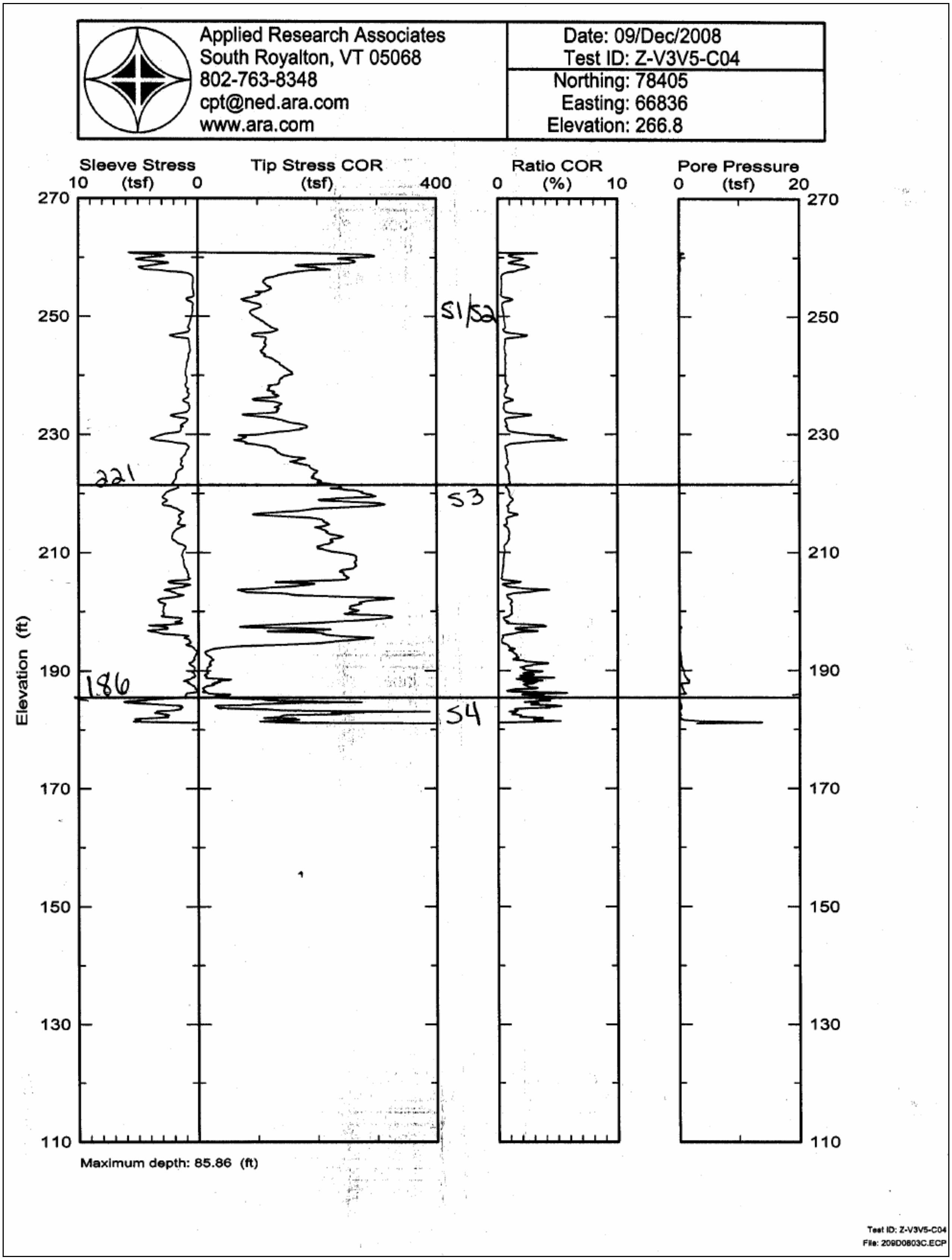
Attachment 1

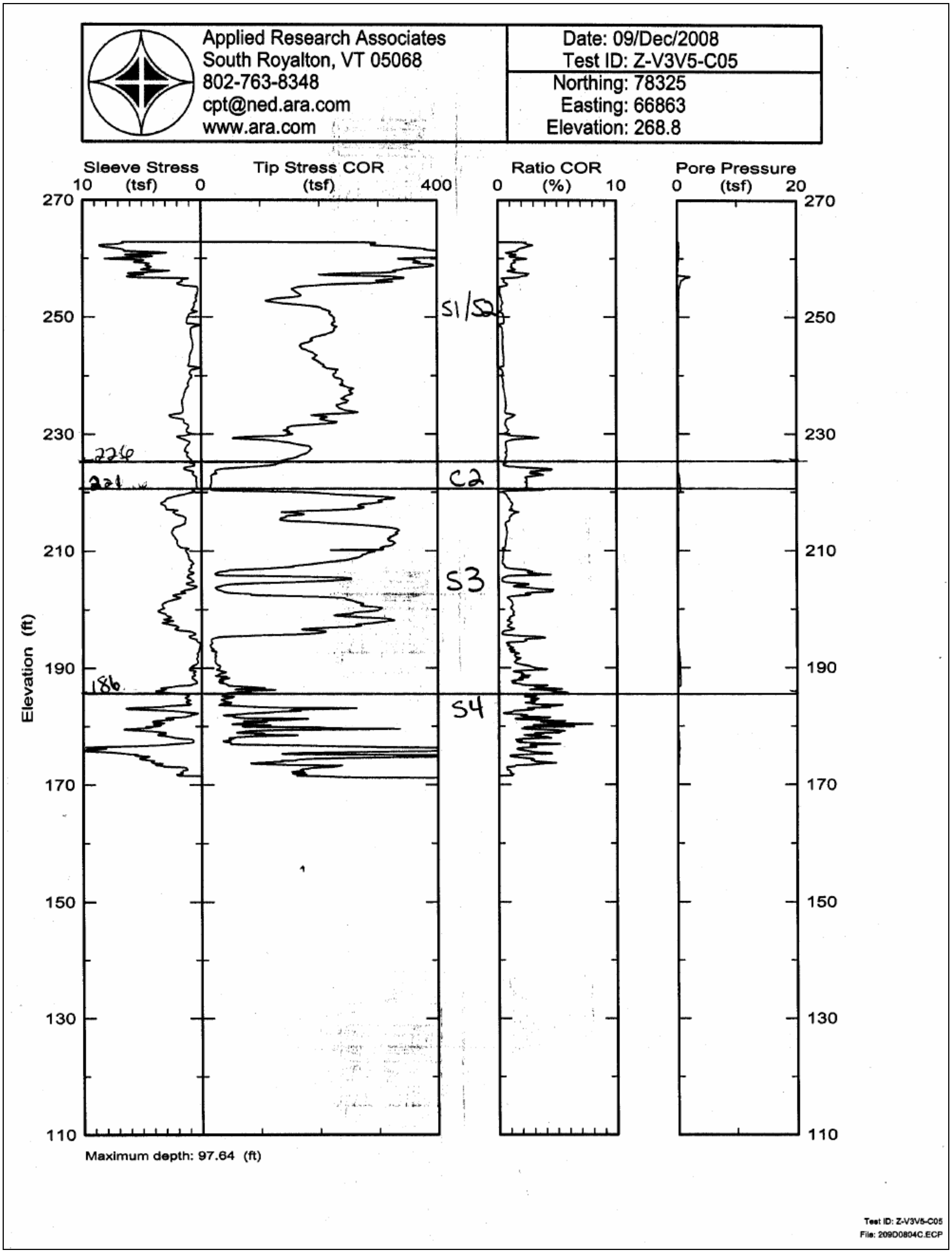



Applied Research Associates
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com
Date: 10/Dec/2008
Test ID: Z-V3V5-C02
Northing: 78267
Easting: 66960
Elevation: 268.6
Sleeve Stress (tsf)
Tip Stress COR (tsf)
Ratio COR (%)
Pore Pressure (tsf)
Elevation (ft)
S1/S2
C2
S3
S4
221
215
184
Maximum depth: 88.05 (ft)

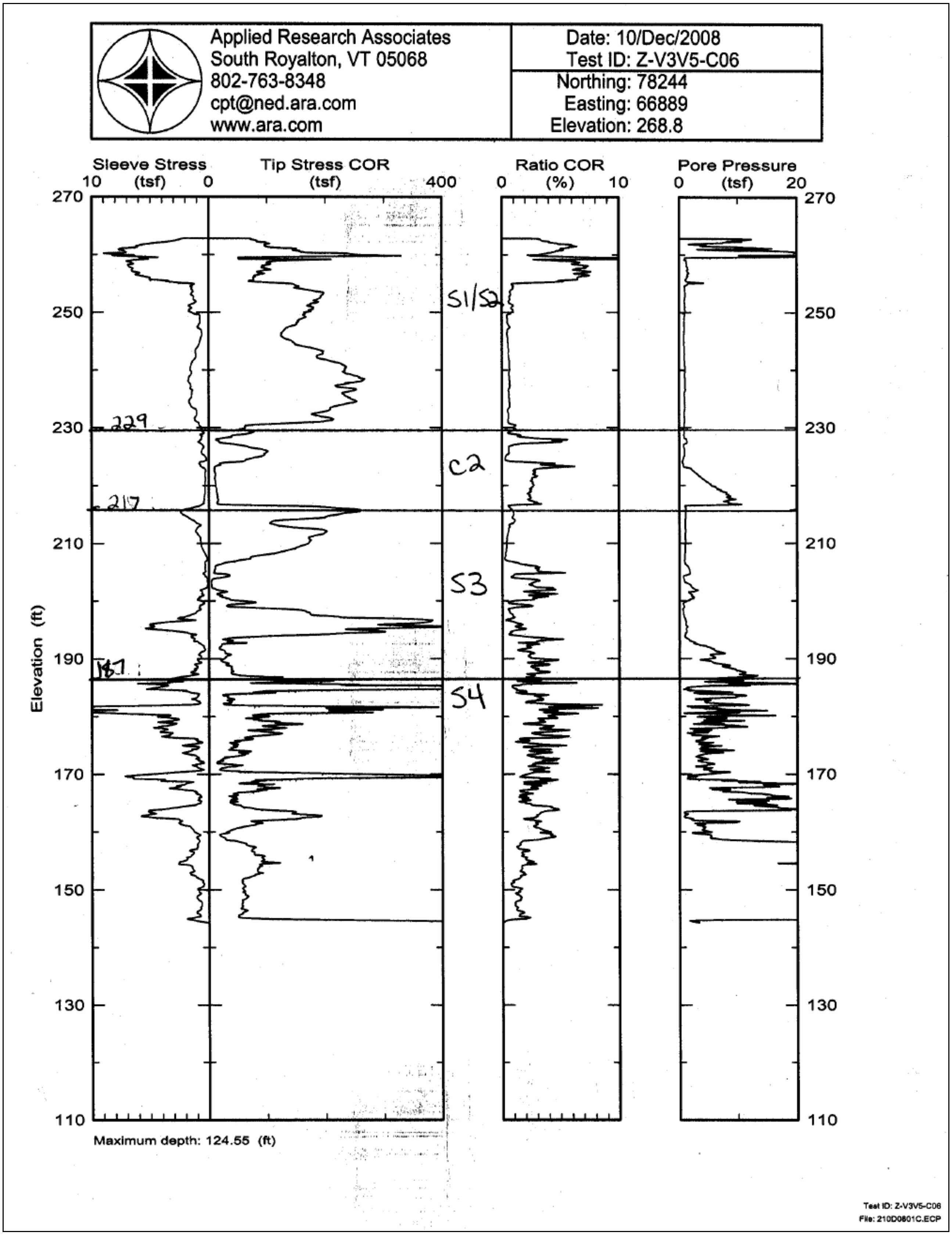


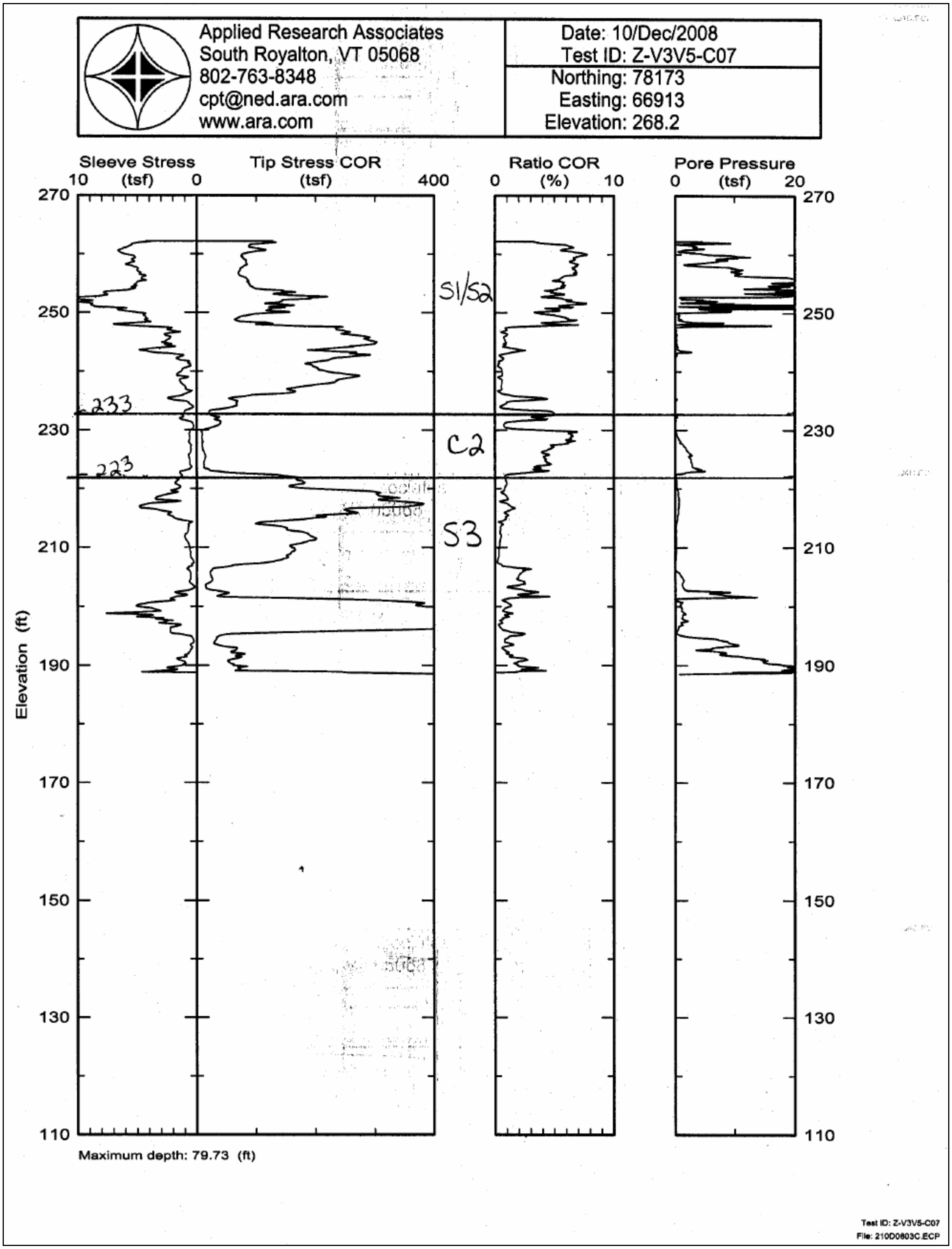
Applied Research Associates
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com
Date: 09/Dec/2008
Test ID: Z-V3V5-C03
Northing: 78477
Easting: 66813
Elevation: 263.9
Sleeve Stress 10 (tsf) 0
Tip Stress COR (tsf) 400
Ratio COR 0 (%) 10
Pore Pressure 0 (tsf) 20
Elevation (ft)
270
250
230
210
190
170
150
130
110
S1|S2
219
S3
190
S4
Maximum depth: 79.11 (ft)
Test ID: Z-V3V5-C03
File: 209D0801C.ECP

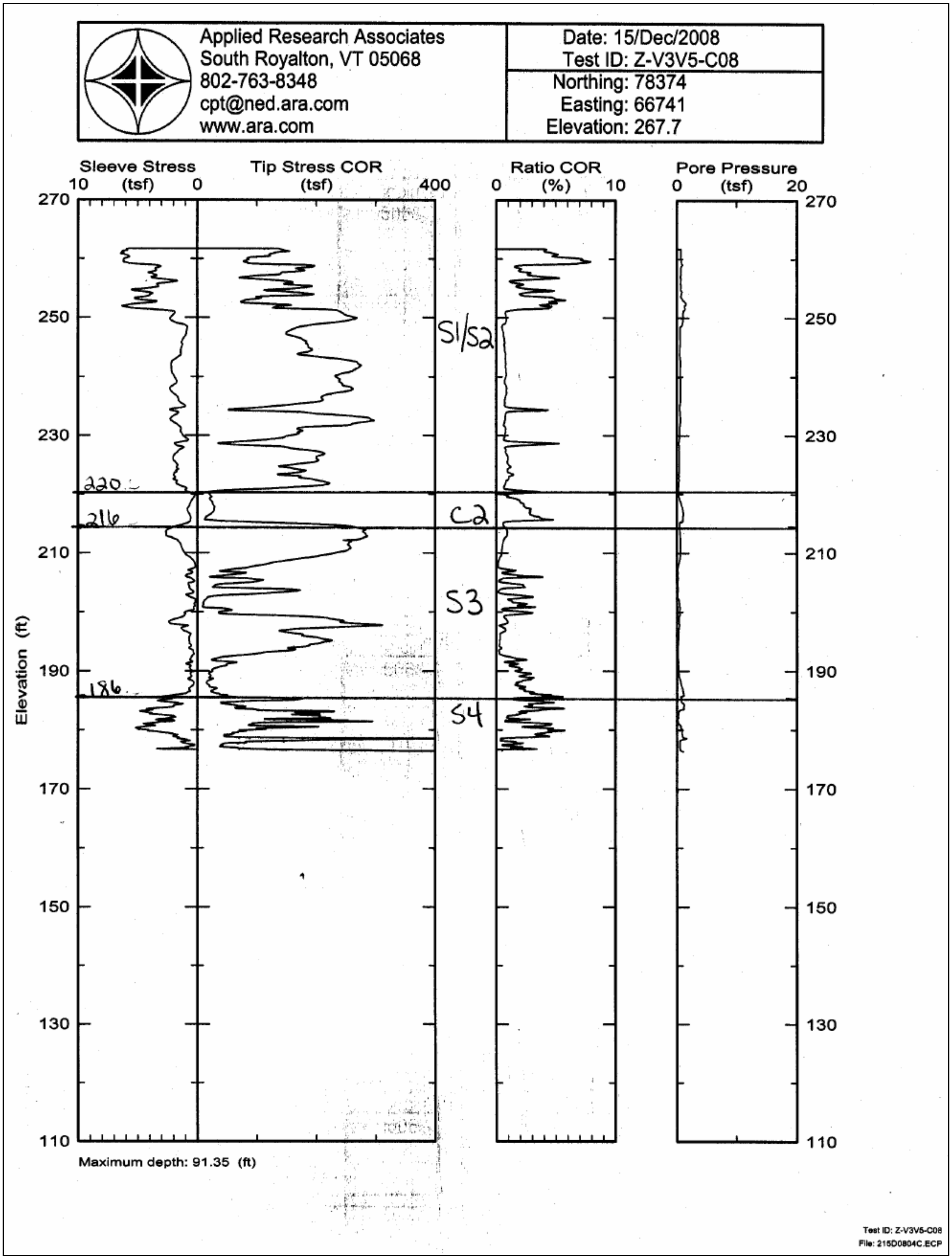

Applied Research Associates
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com
Date: 09/Dec/2008
Test ID: Z-V3V5-C04
Northing: 78405
Easting: 66836
Elevation: 266.8
Sleeve Stress (tsf)
Tip Stress COR (tsf)
Ratio COR (%)
Pore Pressure (tsf)
Elevation (ft)
S1/S2
221
S3
186
S4
Maximum depth: 85.86 (ft)
Test ID: Z-V3V5-C04
File: 209D0803C.ECP

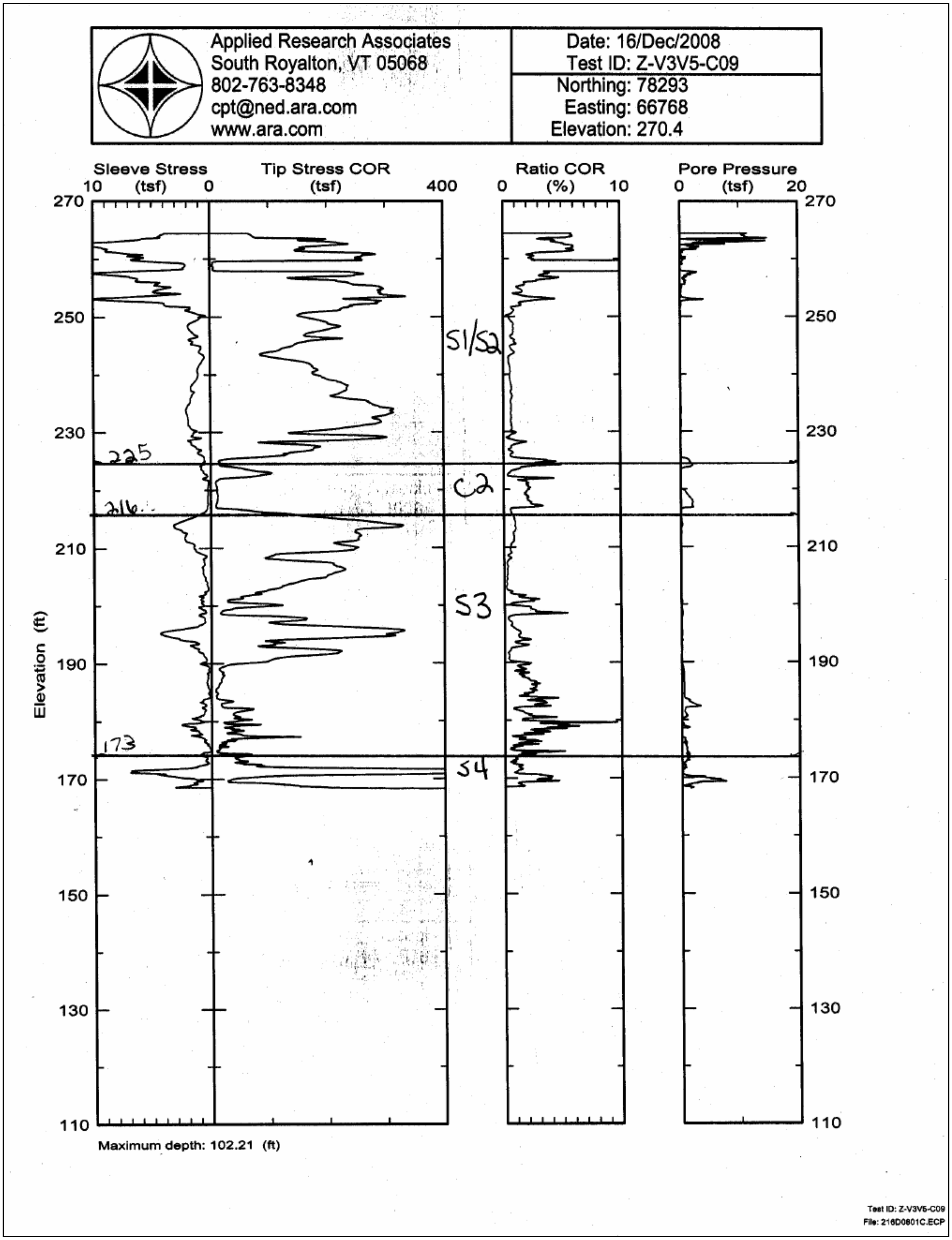


Applied Research Associates
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com
Date: 09/Dec/2008
Test ID: Z-V3V5-C05
Northing: 78325
Easting: 66863
Elevation: 268.8
Sleeve Stress (tsf)
Tip Stress COR (tsf)
Ratio COR (%)
Pore Pressure (tsf)
Elevation (ft)
S1/S2
C2
S3
S4
226
221
186
Maximum depth: 97.64 (ft)
Test ID: Z-V3V5-C05
File: 209D0804C.ECP

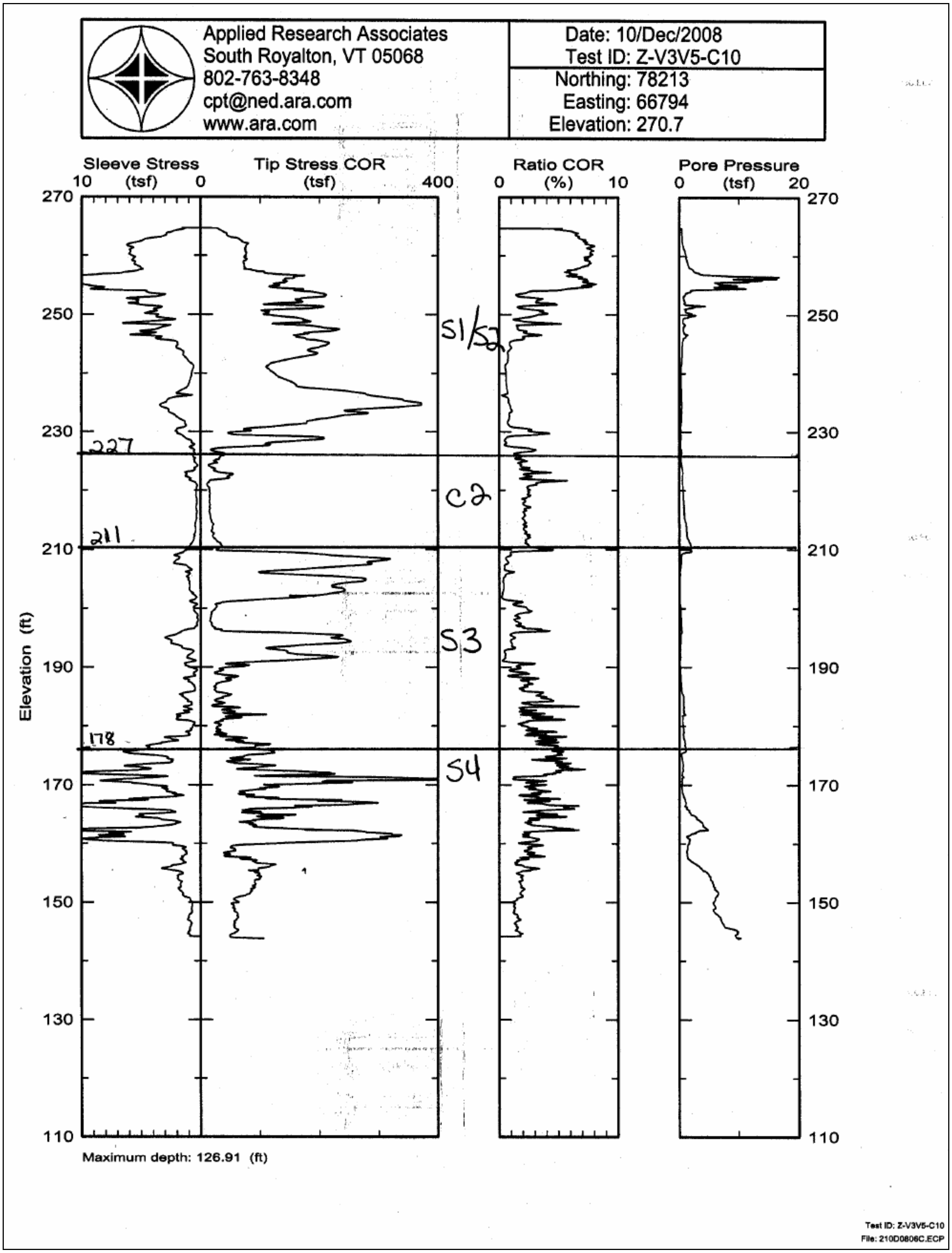

Applied Research Associates
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com
Date: 10/Dec/2008
Test ID: Z-V3V5-C06
Northing: 78244
Easting: 66889
Elevation: 268.8
Sleeve Stress (tsf)
Tip Stress COR (tsf)
Ratio COR (%)
Pore Pressure (tsf)
Elevation (ft)
S1/S2
229
C2
217
S3
187
S4
Maximum depth: 124.55 (ft)
Test ID: Z-V3V5-C06
File: 210D0801C.ECP

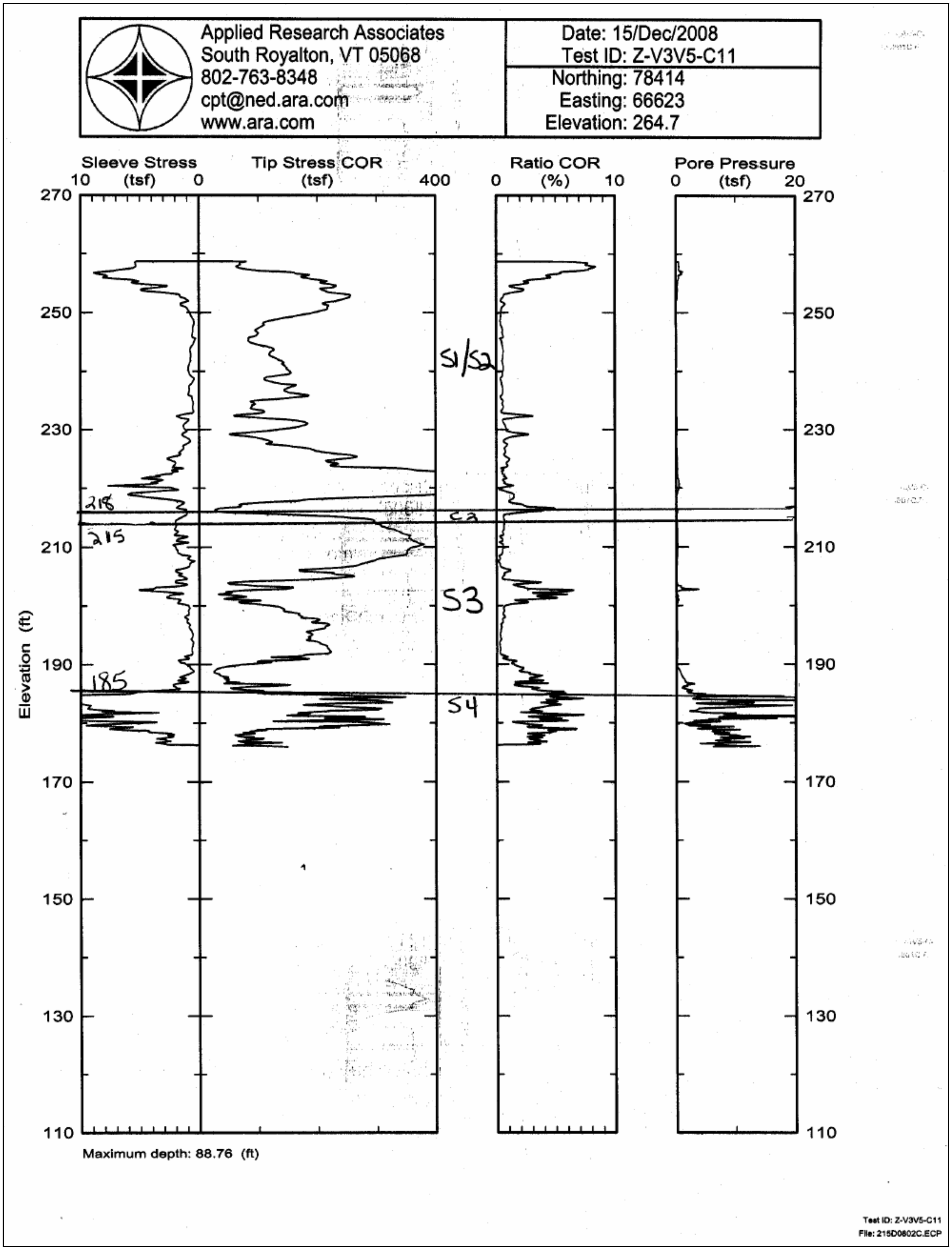

Applied Research Associates
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com
Date: 10/Dec/2008
Test ID: Z-V3V5-C07
Northing: 78173
Easting: 66913
Elevation: 268.2
Sleeve Stress
10 (tsf) 0
Tip Stress COR
(tsf) 400
Ratio COR
0 (%) 10
Pore Pressure
0 (tsf) 20
Elevation (ft)
270
250
230
210
190
170
150
130
110
S1/S2
233
C2
223
S3
Maximum depth: 79.73 (ft)
Test ID: Z-V3V5-C07
File: 210D0803C.ECP

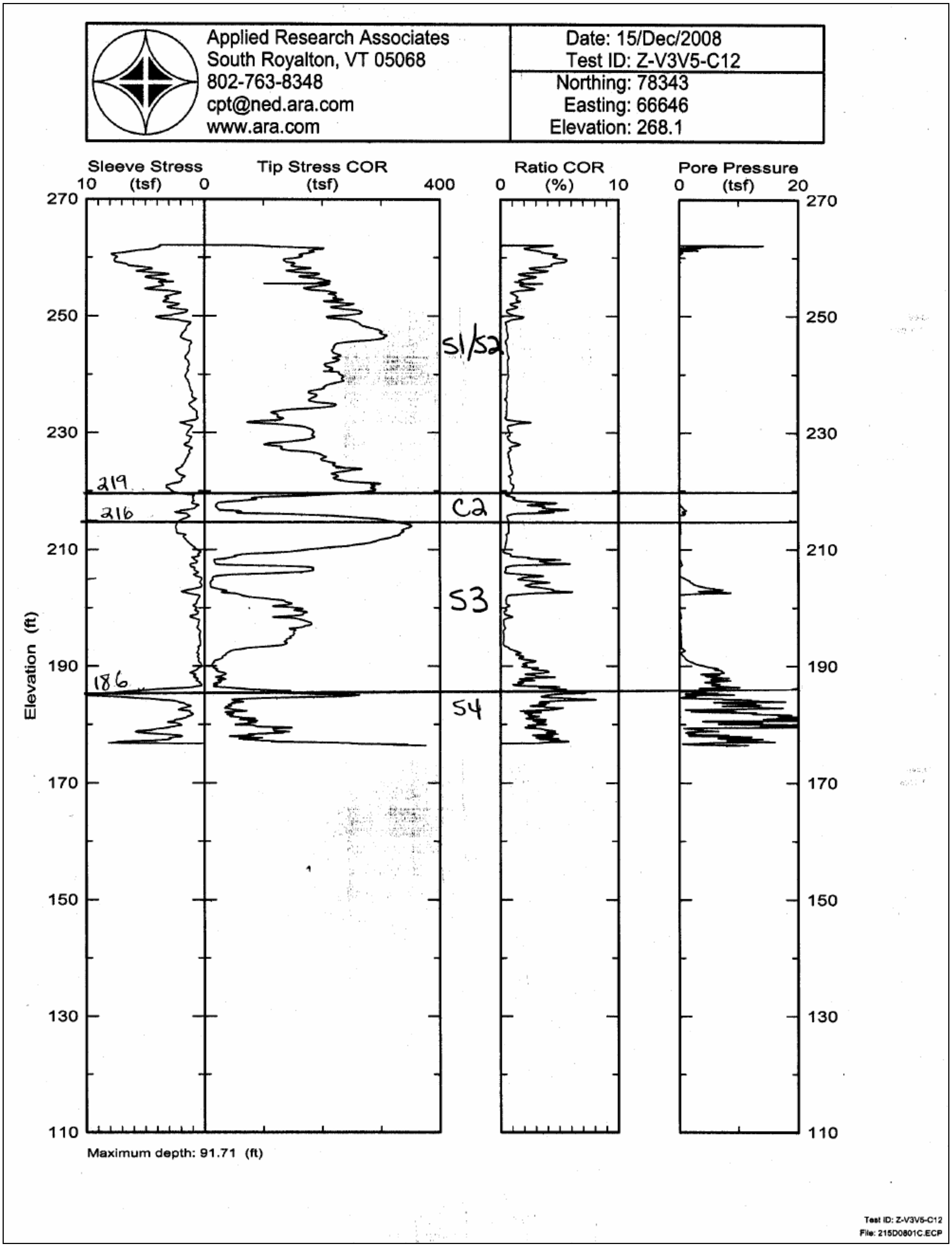

Applied Research Associates
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com
Date: 15/Dec/2008
Test ID: Z-V3V5-C08
Northing: 78374
Easting: 66741
Elevation: 267.7
Sleeve Stress (tsf)
Tip Stress COR (tsf)
Ratio COR (%)
Pore Pressure (tsf)
Elevation (ft)
S1/S2
C2
S3
S4
220
216
186
Maximum depth: 91.35 (ft)
Test ID: Z-V3V5-C08
File: 215D0804C.ECP



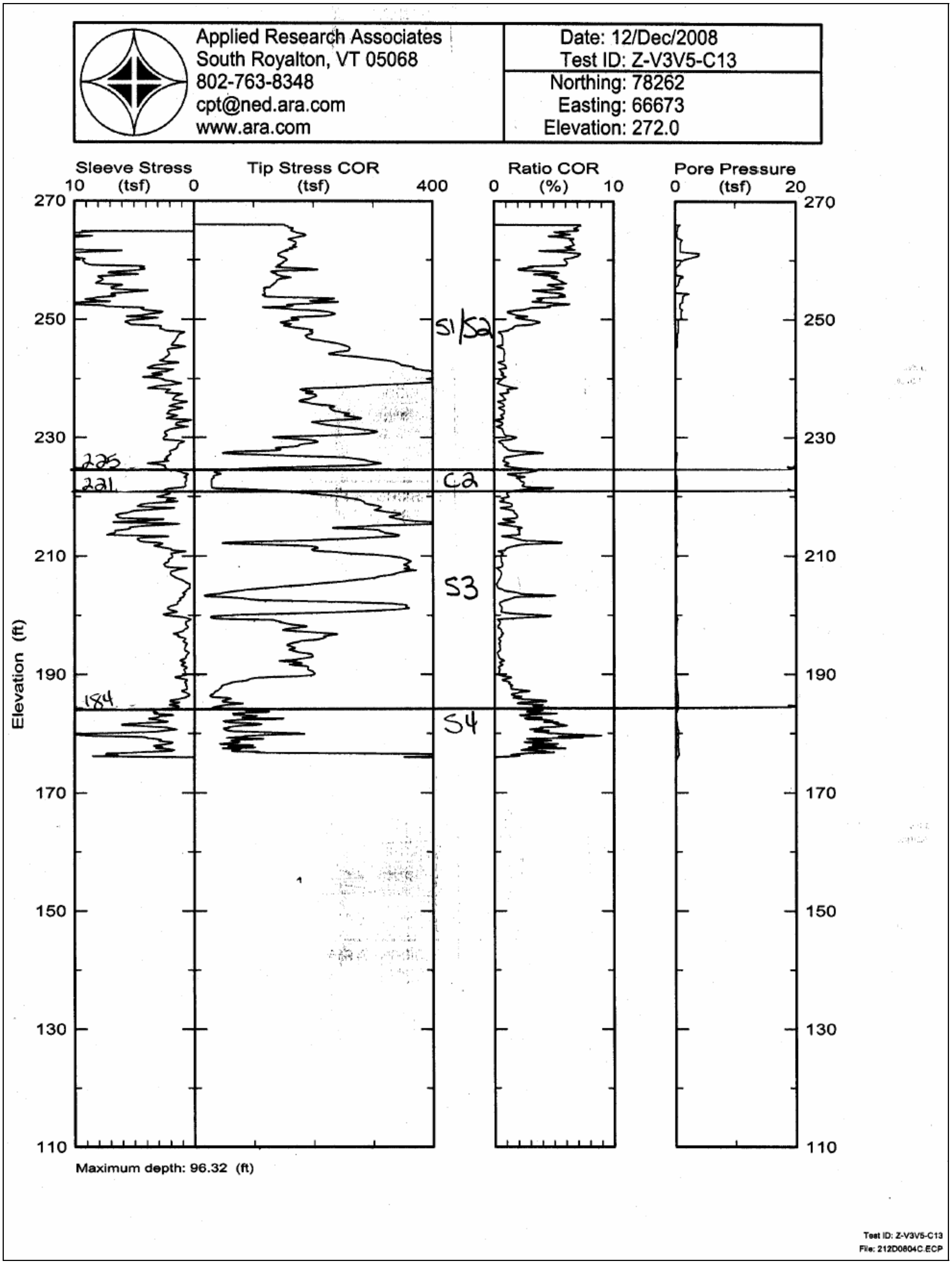
Applied Research Associates
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com
Date: 16/Dec/2008
Test ID: Z-V3V5-C09
Northing: 78293
Easting: 66768
Elevation: 270.4
Sleeve Stress (tsf)
Tip Stress COR (tsf)
Ratio COR (%)
Pore Pressure (tsf)
Elevation (ft)
S1/S2
C2
S3
S4
225
216
173
Maximum depth: 102.21 (ft)
Test ID: Z-V3V5-C09
File: 216D0801C.ECP


Applied Research Associates
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com
Date: 10/Dec/2008
Test ID: Z-V3V5-C10
Northing: 78213
Easting: 66794
Elevation: 270.7
Sleeve Stress
10 (tsf) 0
Tip Stress COR
(tsf) 400
Ratio COR
0 (%) 10
Pore Pressure
0 (tsf) 20
Elevation (ft)
270
250
230
210
190
170
150
130
110
227
211
178
S1/S2
C2
S3
S4
Maximum depth: 126.91 (ft)
Test ID: Z-V3V5-C10
File: 210D0806C.ECP

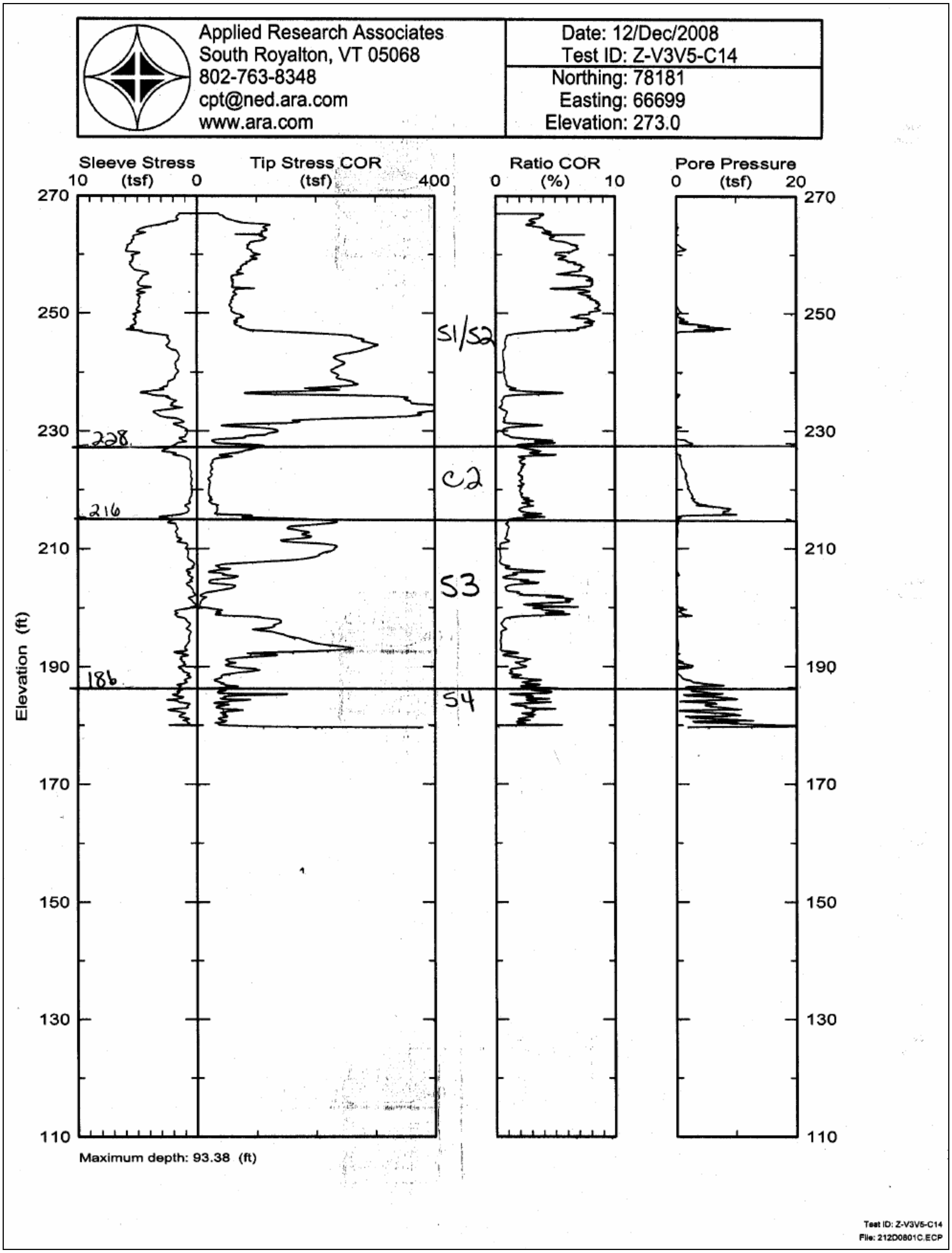

Applied Research Associates
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com
Date: 15/Dec/2008
Test ID: Z-V3V5-C11
Northing: 78414
Easting: 66623
Elevation: 264.7
Sleeve Stress (tsf)
Tip Stress COR (tsf)
Ratio COR (%)
Pore Pressure (tsf)
Elevation (ft)
218
215
185
S1/S2
S2
S3
S4
Maximum depth: 88.76 (ft)
Test ID: Z-V3V5-C11
File: 215D0802C.ECP

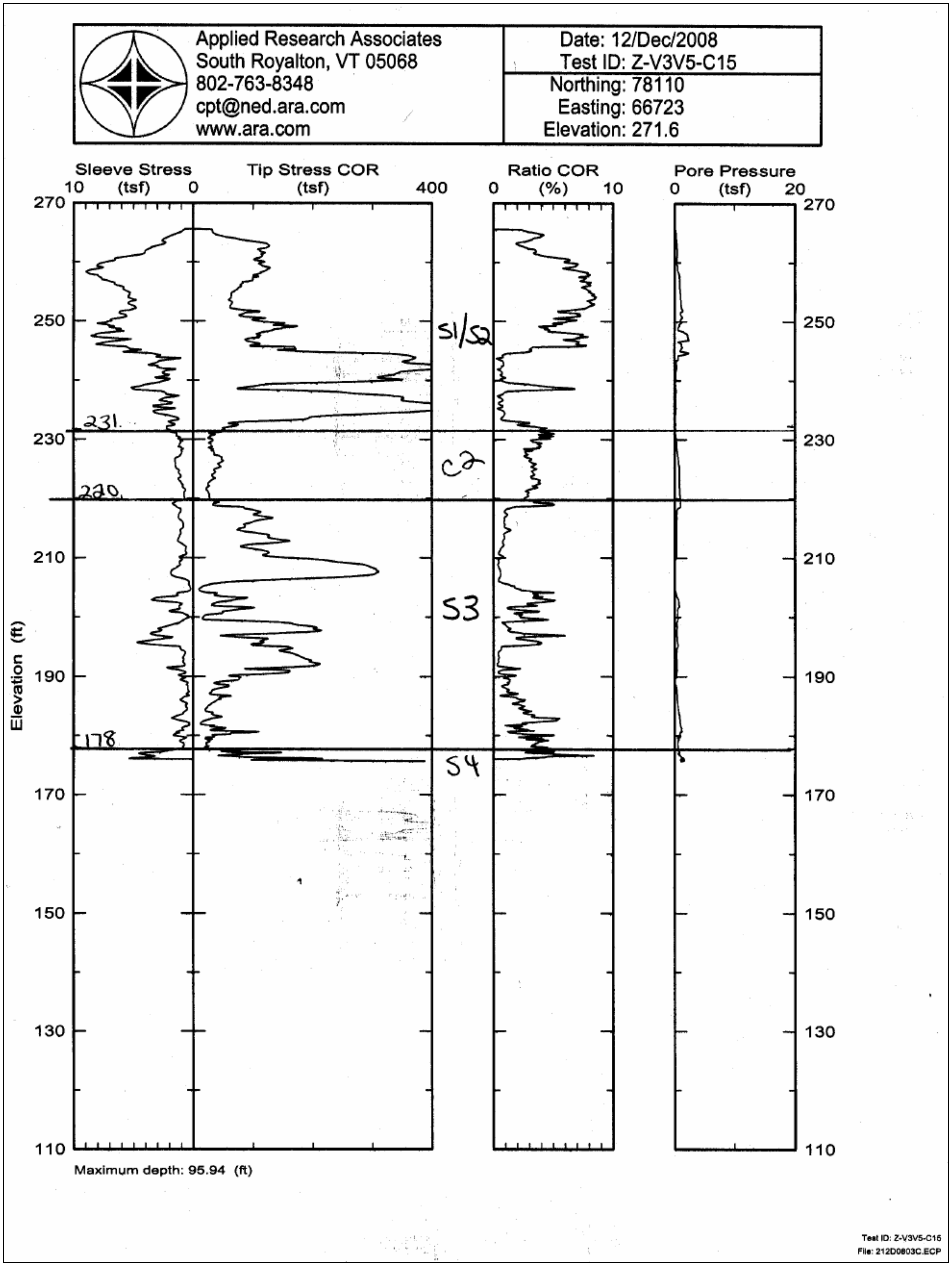


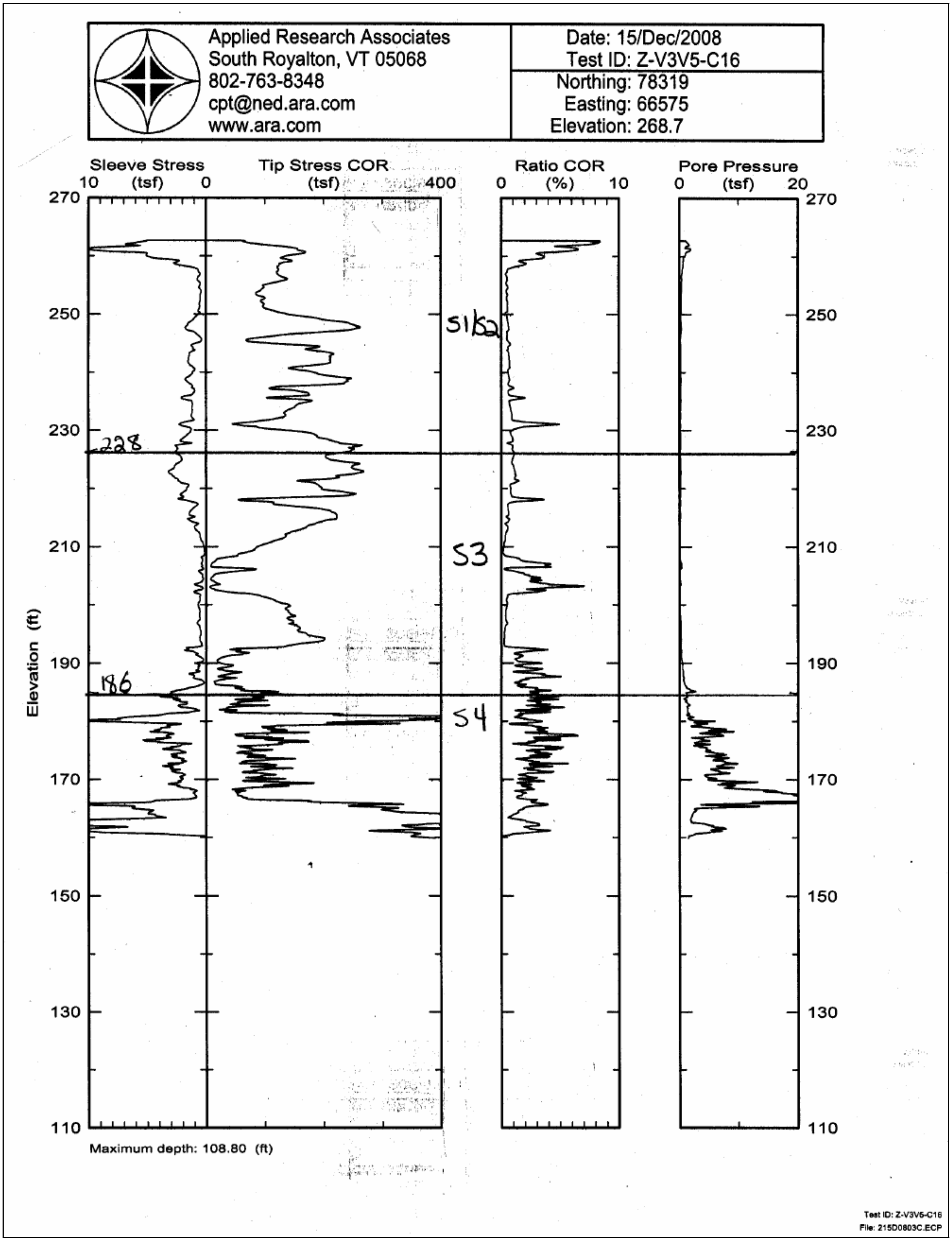
Applied Research Associates
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com
Date: 15/Dec/2008
Test ID: Z-V3V5-C12
Northing: 78343
Easting: 66646
Elevation: 268.1
Sleeve Stress
10 (tsf) 0
Tip Stress COR
(tsf) 400
Ratio COR
0 (%) 10
Pore Pressure
0 (tsf) 20
Elevation (ft)
270
250
230
210
190
170
150
130
110
219
216
186
S1/S2
C2
S3
S4
Maximum depth: 91.71 (ft)
Test ID: Z-V3V5-C12
File: 215D0801C.ECP

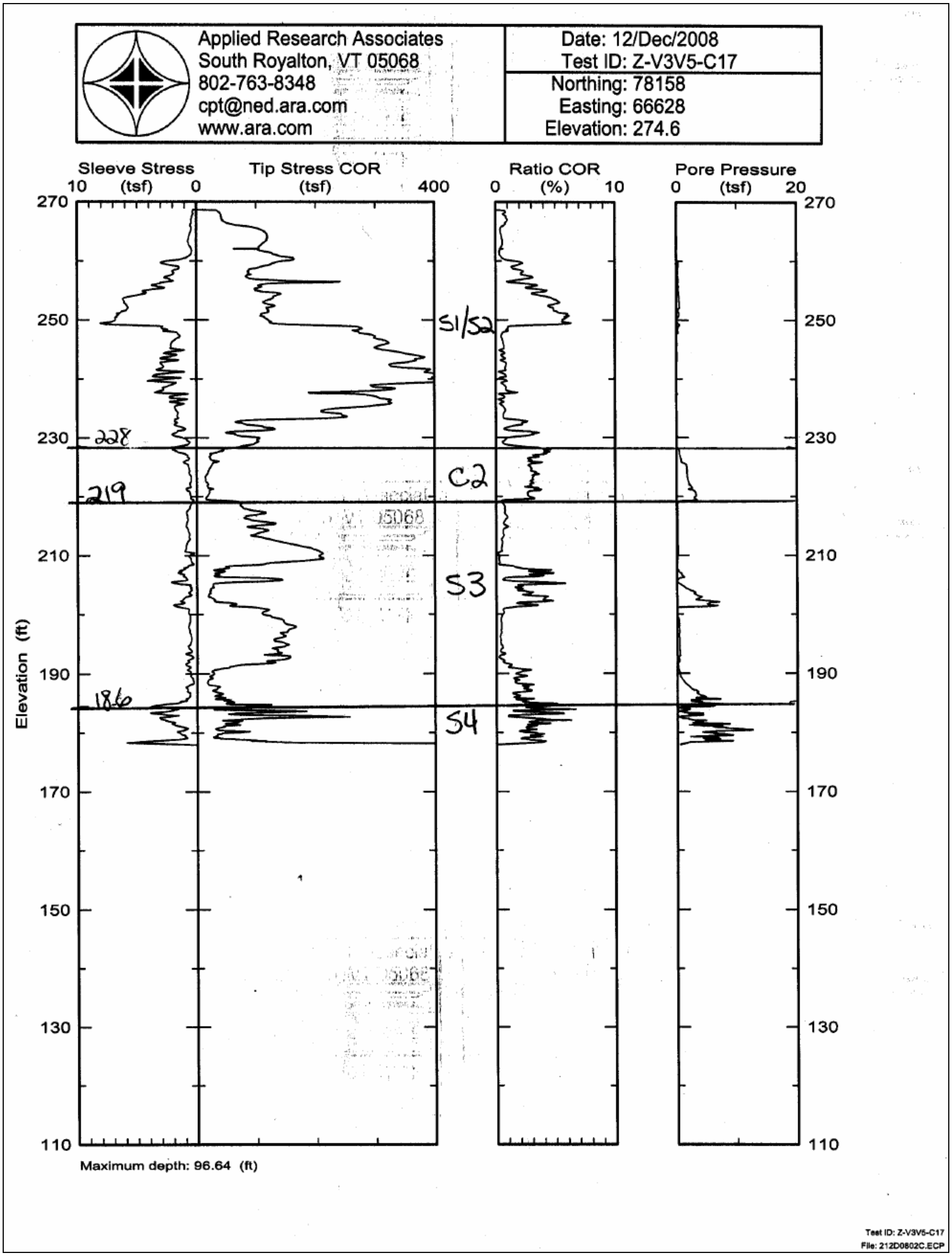


Applied Research Associates
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com
Date: 12/Dec/2008
Test ID: Z-V3V5-C13
Northing: 78262
Easting: 66673
Elevation: 272.0
Sleeve Stress
10 (tsf) 0
Tip Stress COR
(tsf) 400
Ratio COR
0 (%) 10
Pore Pressure
0 (tsf) 20
Elevation (ft)
270
250
230
210
190
170
150
130
110
225
221
184
S1/S2
C2
S3
S4
Maximum depth: 96.32 (ft)
Test ID: Z-V3V5-C13
File: 212D0804C.ECP


Applied Research Associates
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com
Date: 12/Dec/2008
Test ID: Z-V3V5-C14
Northing: 78181
Easting: 66699
Elevation: 273.0
Sleeve Stress (tsf)
Tip Stress COR (tsf)
Ratio COR (%)
Pore Pressure (tsf)
Elevation (ft)
228
216
186
S1/S2
C2
S3
S4
Maximum depth: 93.38 (ft)
Test ID: Z-V3V5-C14
File: 212D0801C.ECP


Applied Research Associates
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com
Date: 12/Dec/2008
Test ID: Z-V3V5-C15
Northing: 78110
Easting: 66723
Elevation: 271.6
Sleeve Stress (tsf)
Tip Stress COR (tsf)
Ratio COR (%)
Pore Pressure (tsf)
Elevation (ft)
231.
220.
178
S1/S2
C2
S3
S4
Maximum depth: 95.94 (ft)
Test ID: Z-V3V5-C15
File: 212D0803C.ECP


Applied Research Associates
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com
Date: 15/Dec/2008
Test ID: Z-V3V5-C16
Northing: 78319
Easting: 66575
Elevation: 268.7
Sleeve Stress
10 (tsf) 0
Tip Stress COR
(tsf) 400
Ratio COR
0 (%) 10
Pore Pressure
0 (tsf) 20
Elevation (ft)
270
250
230
210
190
170
150
130
110
228
186
S1/S2
S3
S4
Maximum depth: 108.80 (ft)
Test ID: Z-V3V5-C16
File: 215D0803C.ECP


Applied Research Associates
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com
Date: 12/Dec/2008
Test ID: Z-V3V5-C17
Northing: 78158
Easting: 66628
Elevation: 274.6
Sleeve Stress (tsf)
Tip Stress COR (tsf)
Ratio COR (%)
Pore Pressure (tsf)
Elevation (ft)
S1/S2
C2
S3
S4
228
219
186
Maximum depth: 96.64 (ft)
Test ID: Z-V3V5-C17
File: 212D0802C.ECP

Attachment B

OSR 30-25# (2-13-97)

Soil Boring Log

Page 1 of 8

Project: Saltstone Vaults 3 and 5		Date: 3/05/09	Area: Z-Area
Boring No.: Z-V3V5-B01	SRS Coordinates: N 78395.0 E 66839.0		Reference Elevation: 266.9' msl
Driller: Steve Butrej	Drilling Subcontractor: Fugro		Total Hole Depth: 150.0' bgs
Technical Oversight: Bill Joyce / Oversight Company: SAIC	Groundwater Depths: Date N/A RLG 3/31/09 Time / Depth		Drilling Methods and Depths: Auger-10' Mud Rotary

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		0					Hand Auger 0'-6', Auger 6'-10'
							mod yel brn SAND (SW), well graded dry, med dense, fn grn
							lt brn SAND (SW), well graded, dry, med dense
							lt brn SANDY SILT (SM) poorly sorted, fn grn, dry
		5					rd brn CLAYEY SAND (SC) poorly sorted fn-vfn grn sl moist
							SAA
		10					↑
							Consistent Drilling Response
		15					↓
		20					

Samples Submitted for Laboratory Tests

Bulk Sample	0.0'-5.0'	
Bulk Sample	5.0'-10.0'	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 2 of 8

Project Siltstone Vaults 3 and 5							Boring No. Z-V3V5-B01	Date 3/05/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
ST-1		20		24" / 21½"	90		rd brn SAND (SP) poorly sorted med-fn grn, moist, sbrnd
		25					Consistent Moderate Drilling
ST-2		30		24" / 16"	68		rd brn SAND (SP) little fines occ crse grn, med-fn grn, moist, sbrnd
		35					Slightly Harder Drilling at 35.5'
ST-3				24" / 20"	83		RLG 3.31.09 rd brn-lt brn Silty SAND (SM) to clayey sand ~~CLAY~~ (SC) fn grn w/ thin Clay laminae (soft) sl moist, sbang, fe oxide
		40					

Samples Submitted for Laboratory Tests

Shelby Tube	20.0' - 22.0'	
Shelby Tube	30.0' - 32.0'	
Shelby Tube	37.0' - 39.0'	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 3 of 8

Project	Silt stone Vault 3 and 5	Boring No. Z-V3V5-B01	Date 3/05/09

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		40					↑ Consistent Drilling Response ↓
		45					Drilling Response Slows A Little ↓
							RLG 3-31-09
ST-4		50		15" / 12"	80		yel orange SAND (SP) poorly ~~sorted~~ Graded fn gvn, sl moist, trace oxide
							Drilling Softer At 54'
							RLG 3-31-09
ST-5		55		24" / 14½"	60		yel orange SAND (SP) poorly ~~sorted~~ Graded fn-med grn, moist, oxide pockets, Sbml
		60					

3/05 ... End of ... 3/06/...

Samples Submitted for Laboratory Tests

Shelby Tube	50.0'-52.25'	
Shelby Tube	55.0-57.0'	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 4 of 8

Project Saltstone Vaults 3 and 5	Boring No. Z-V3V5-B01	Date 3/06/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		60					↑
		65					Consistent Drilling Response ↓
		70					Slightly Harder Drilling Response 72'-73 ↓
ST-6		75		24" / 0"	0		No Recovery
ST-7				24" / 18"	75	∴	Shelby Tube was damaged. Bottom 1.0' of tube was crumpled. Pieces of well cemented sandstone on bottom
		80					

Samples Submitted for Laboratory Tests Not submitted

Shelby Tube	75.0'-77.0'	No recovery
Shelby Tube	78.0'-80.0'	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 5 of 8

Project Saltstone Vaults 3 and 5							Boring No. Z-V3V5-B01	Date 3/06/09
Sampling			6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description	
No.	Type	Depth						
		80						
ST-8				24" / 14"	58	/·/·	RLG 3.31.09 gr n ak Clayey SAND (SC) poorly Graded, vfn grn, sl moist includes well cemented sandstone, weathered shell, and oxides	
		85					↓	
		90					↓	
							Consistent Drilling Response	
		95					↓	
		100					↓	

Samples Submitted for Laboratory Tests

Shelby Tube	81.0'-83.0	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 6 of 8

Project	Saltstone Vaults 3 and 5	Boring No. Z-V3V5-B01	Date 3/06/09

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		100					↓ Consistent Drilling Response Some Harder Sections
		105					↓ Appear To Be Out of the Santee.
		110					↓
		115					↓ Very Hard At 118'. Determined Later Bit Was Wearing Out
		120					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 2 of 8

Project	Boring No.	Date
Saltstone Vaults 3 and 5	Z-V3V5-B01	3/06/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		120					↓
							Slow Hard Drilling
							↓
		125					Change Bits. Wing Bit Is Worn Down. Run In With 3 7/8" Roller Cone Bit
							Easier Consistent Drilling
		130					↓
		135					↓
		140					↓

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 8 of 8

Project	Boring No.	Date
Saltstone Vaults 3 and 5	Z-V3V5-BØ1	3/Ø6/Ø9

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		140					
							Consistent Drilling Response
		145					
		150					Total Depth of Boring-15Ø.Ø'
		5					
		0					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log

Page 1 of 8

Project: Saltstone Vaults 3 and 5		Date: 3/10/09	Area: Z-Area
Boring No.: Z-V3V5-B02	SRS Coordinates: N 78235.0 E 66894.0		Reference Elevation: 269.9' msl
Driller: Steven Butrej	Drilling Subcontractor: Fugro		Total Hole Depth: 150.0' bgs
Technical Oversight: Bill Joyce	Oversight Company: SAIC	Groundwater Depths Date: N/A Time: RLG 3.31.09 Depth	Drilling Methods and Depths: Auger-10' Mud Rotary

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		0					3-10-09 Tuesday Sunny 85°
							0'-10' is drilled out
		5					↓
		10					
SS-1			8, 14, 17, 25	24" / 22"	92		rd brn mottled Sandy Lean Clay (CL) sl moist, very stiff low plasticity; rd brn Silty Sand (SM), fn-med grn, sl moist dense, ssrnd poorly graded
SS-2			8, 15, 16, 18	24" / 22"	92		yel-rd brn Silty Sand (SM) fn-med grn, sl moist dense, ssrnd, trace fine gravel poorly graded; Clay content increases with depth
SS-3		15	7, 10, 12, 14	24" / 24"	100		yel-red brn Clayey Sand (SC) with pockets of Silty Sand (SM) fn-med grn, sl moist, medium dense, ssrnd, poorly graded
SS-4			8, 11, 12, 12	24" / 23"	96		yel-rd brn Silty Sand (SM) upper part of spoon Clayey sand, fn-med grn, sl moist, medium dense, ssrnd, poorly graded
SS-5			8, 8, 10, 10	24" / 22"	92		rd brn Clayey Sand (SC) with sections of SM, fn-med grn sl moist, medium dense, ssrnd, poorly graded
		20					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 2 of 8

Project: Saltstone Vaults 3 and 5							Boring No. Z-V3VS-B02	Date 3/10/09
Sampling			6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description	
No.	Type	Depth						
SS-6		20	6, 8, 9, 10	24" / 21"	88		red brn Silty Sand (SM) med-fn grn, sl moist, medium dense, sbrnd, poorly graded	
SS-7			6, 8, 8, 9	24" / 20"	83		SAA with occ. clayey stringers	
SS-8		25	6, 9, 9, 10	24" / 18"	75		lt brn-red brn poorly graded Sand with silt (SP-SM) med-fn grn, moist, medium dense, sbrnd	
SS-9			8, 10, 12, 14	24" / 17"	71		lt brn-yel poorly graded Sand with silt (SP-SM) med-fn grn, moist, medium dense, sbrnd-sbang, oxide pocket	
SS-10			9, 12, 14, 15	24" / 16"	67		yel poorly graded Sand (SP) little silt, moist, fn-med grn, medium dense, sbrnd-sbang	
SS-11		30	9, 9, 10, 13	24" / 16"	67		yel brn poorly graded Sand with silt (SP-SM) fn-med grn, moist, medium dense, sbrnd-sbang	
SS-12			7, 11, 12, 14	24" / 16"	67		SAA	
SS-13		35	9, 10, 12, 12	24" / 18"	75		yel brn poorly graded Sand with silt (SP-SM) med-fn grn, moist, medium dense, sbang	
		40						

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 3 of 8

Project: Saltstone Vaults 3 and 5 | Boring No. Z-V3V5-B02 | Date 3/10/09 - 3/11/09

No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		40	3				lt brn - red brn Clayey Sand (SC) fn-med grn, moist loose sand, includes mang. oxide
SS-14			3	24"	83		
			4	20"			
			5				
							RLG 3.31.09
		45	WH				tn - lt brn Lean ~~Less~~ Clay with Sand (CL) medium stiff moist, malleable, with mang. oxide stringers, laminated
SS-15			3	24"	100		
			3	24"			
			5				
							RLG 3.31.09
		50	WH				tn - lt brn Lean ~~Less~~ Clay with Sand (CL), soft moist, malleable with mang. oxide, sand pockets/thin laminae
SS-16			WH	24"	100		
			3	24"			
			4				
		55	6				rd brn Silty Sand (SM) fn-med grn moist medium dense, s/brnd, poorly graded
SS-17			11	24"	67		
			8	16"			
			10				
		60					

3/10/09 End of. 3/11/09

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 4 of 8

Project: Saltstone Vaults 3 and 5
Boring No.: Z-V3V5-B02
Date: 3/11/09

No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		60					
SS-18			6, 9, 10, 14	24" / 16"	67		lt brn-red brn poorly graded Sand with Silt (SP-SM) med-fn grn, wet, medium dense, sbang
							RLG 3·31·09 Lean
		65					
SS-19			WH, WH, WH, WH	24" / 24"	100		Yel brn-tn ~~Loess~~ Lean Clay with Sand (CL) sand pockets, very soft, moist-wet, malleable, abndt mang. oxide
		70					
SS-20			8, 14, 17, 19	24" / 20"	83		lt red brn poorly graded Sand with Silt (SP-SM) fn grn, wet, dense sand, sbang
							RLG 3·31·09
		75					
SS-21			2, 2, 3, 3	24" / 24"	100		lt brn-red brn ~~Loess~~ Lean Clay with sand (CL) soft, wet, malleable, with mang oxide
							rd grn Silty Sand (SM) med grn w/ occ crse grn, loose sand, wet, sbang, poorly graded
		80					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 5 of 8

Project	Boring No.	Date
Saltstone Vaults 3 and 5	Z-V3V5-B02	3/11/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
SS-22		80	1, 6, 12, 15	24" / 24"	100		grn gry Clayey Sand (SC) fn grn, moist-wet medium dense, poorly graded, with kaolin pockets and well cemented sandstone, some weathered shell fragments
SS-23		85	5, 14, 10, 13	24" / 24"	100		grn wh Clayey Sand (SC) fn grn, moist wet, medium dense poorly graded with kaolin (clay) and well cemented sandstone some mang. oxide
SS-24		90	3.31.09 RLG 100/2" Refusal	3.31.09 RLG 2"/0"	3.31.09 RLG 0% Refusal		Refusal - 2" with 100 blows
SS-25		95	11, 9, 6, 10	24" / 24"	100		grn wh Clayey Sand (SC) fn grn, wet-moist medium dense poorly graded, includes well cemented sandstone, mang. oxide, and weathered shell fragments.
		100					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 6 of 8

Project	Saltstone Vaults 3 and 5	Boring No. Z-V3V5-B02	Date 3/11/09-3/12/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
SS-26		100	10, 13, 13, 10	24" / 24"	100		grn wh Clayey Sand (SC) fn grn, moist, medium dense, poorly graded, abndt weathered shell fragments, some sandstone
SS-27		105	9, 18, 22, 23	24" / 24"	100	Shell Hash	Shell Hash with white-gry Clayey Sand (SC) fn grn moist-dry, dense, poorly graded, weathered shell fragments trace mang. oxide
SS-28		110	7, 11, 12, 23	24" / 24"	100		dk grn gry Silty Sand (SM) med-fn grn sl moist medium dense, poorly graded, thin clay laminae in bottom of run, stained-stang, trace oxide
SS-29		115	4, 7, 7, 13	24" / 24"	100		dk grn gry Silty Sand (SM) fn-med grn sl moist, medium dense, poorly graded, stand-stang, trace oxides
		120					

End of 3/12/09

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

Soil Boring Log (Contd)

Project: Saltstone Vaults 3 and 5 | Boring No. Z-V3V5-B02 | Date 3/12/09

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description (RLG 3.31.09)
SS-30		120	5 / 8 / 10 / 15	24" / 24"	100	SC	dk grn gry Clayey Sand (SC), Lean Clay (CL) from 120.5'-121.1' med-fn grn, sl moist, medium dense, poorly graded, sbrnd-sbang
SS-31		125	50/3" Refusal (RLG 3.31.09)	3" / 0" (3.31.09 RLG)	0% Refusal (3.31.09 RLG)		Refusal - 3" with 50 blows
SS-32		130	40 / 50-4" Refusal	Refusal	NOT RECORDED Refusal (RLG 3.31.09)		6"-40 blows, 4"-50 blows Recovered soil: lt gry poorly graded sand with silt (SP-SM) fn grn, sl moist sbang, trace mica, not enough to jar sample
SS-33		135	43 / 50-4"	Refusal	NOT RECORDED Refusal (RLG 3.31.09)		6"-43 blows, 4"-50 blows Jarred recovered soil: lt gry poorly graded sand with silt (SP-SM) fn grn, sl moist, sbang, trace mica
		140					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 8 of 8

Project: Saltstone Vaults 3 and 5	Boring No. Z-V3V5-B02	Date 3/12/09

No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
SS-34		140	50, 42, 45, 50-5"	23" / 19"	83		lt gry-gry poorly graded Sand with Silt (SP-SM) fn-med grn, moist-wet, very dense, sbang.
		145					RLG 3.31.09
SS-35			32, 24, 29, 39	24" / 23"	96		lt gry Silty Sand (SM) with LEAN Clay (CL) thin laminae included fn-med grn, wet, very dense, sbang-sbrnd
		150			3.31.09 RLG		
SS-36			21, 25, 32, 39	24" / 24"	100%		lt gry poorly graded Sand with Silt (SP-SM) fn-med grn, wet, very dense, sbang-sbrnd
							Total drill depth - 150'
							Total split-spoon depth - 152'
		155					
		160					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log

Page 1 of 8

Project: Saltstone Vaults 3 and 5		Date: 3/13/09	Area: Z-Area
Boring No.: Z-V3V5-B03	SRS Coordinates: N 78333.0 E 66649.4		Reference Elevation: 268.3' msl
Driller: Steven Butrej	Drilling Subcontractor: Fugro		Total Hole Depth: 150.0' bgs
Technical Oversight: Bill Joyce	Oversight Company: JAIC	Groundwater Depths: 3.31.09 Date: N/A RLH Time: Depth:	Drilling Methods and Depths: Auger-10' Mud Rotary

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		0					3-13-09 Friday Cloudy C0°
							0'-10' is drilled out
		5					
SS-1		10	6, 8, 11, 15	24" / 20"	83		rd brn Silty Sand (SM), fn-med grn, sl moist, medium dense, 5Grnd, poorly graded
SS-2			7, 13, 15, 21	24" / 22"	92		rd brn Clayey Sand (SC) fn-med grn, sl moist medium dense, 5Grnd, poorly graded
SS-3		15	12, 16, 19, 20	24" / 24"	100		yel-rd brn Silty Sand (SM) fn-med grn, sl moist, dense sand, 5Grnd, poorly graded, occ mng. oxide pockets
SS-4			11, 15, 15, 14	24" / 22"	92		yel-rd brn poorly graded Sand with Silt (SP-SM) med-fn grn, sl moist medium dense-dense sand, 5Grnd-5Gray
SS-5		20	8, 11, 11, 12	24" / 23"	96		yel-rd brn poorly graded Sand with Silt (SP-SM) med grn, moist, medium dense, 5Gray

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 2 of 8

Project: SaltStone Vaults 3 and 5	Boring No. Z-V3V5-B03	Date 3/13/09

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
SS-6		20	9, 11, 12, 15	24" / 19"	79		yel lt brn poorly graded Sand with Silt (SP-SM) med-fn grn with occ crse grn moist, medium dense, sbang
SS-7			9, 11, 13, 14	24" / 19"	79		SAA
SS-8		25	9, 13, 13, 16	24" / 19"	79		Yel lt brn poorly graded Sand with Silt (SP-SM) med-fn grn, moist medium dense, sbang-sbrnd, occ kaolin
SS-9			9, 13, 14, 15	24" / 18"	75		SAA
SS-10			9, 11, 9, 11	24" / 19"	79		lt brn poorly graded Sand with Silt (SP-SM) med-fn grn w/ occ crse grn, moist, medium dense, sbang, abndt iron oxide in sand bottom of run
SS-11		30	9, 11, 12, 16	24" / 21"	88		lt brn poorly graded Sand with Silt (SP-SM) med-fn grn w/ occ crse grn moist, medium dense, sbang, includes iron oxide section (top of run) kaolin stringers
SS-12			8, 9, 9, 13	24" / 24"	100		lt brn-rd brn Silty Sand (SM) med-fn grn moist, medium dense sbang-sbrnd, trace oxides, occ kaolin stringer
SS-13		35	7, 10, 12, 15	24" / 22"	92		upper 0.6' Lean Clay with Sand (CL) rd brn; lt brn Silty Sand (SM) med-fn grn, moist, medium dense, sbang-sbrnd, trace oxides
		40					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 3 of 8

Project: Saltstone Vaults 3 and 5 | Boring No.: Z-V3V5-B03 | Date: 3/13/09

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
SS-14		40	5, 9, 12, 14	24" / 24"	100		rd-lt brn Silty Sand (SM) with thin clay (CL) laminae, fn-med grn, moist, medium dense, sbrnd-sbang, trace oxides
SS-15		45	9, 14, 18, 23	24" / 18"	75		yel-lt brn poorly graded Sand with silt (SP-SM) fn grn moist dense sand, sbang, trace oxides, kaolin
							RLG 3.31.09
SS-16		50	2, 6, 10, 13	24" / 24"	100		fn ~~loess~~ Lean Clay with Sand (CL) sandier at bottom of run, very stiff, moist, malleable, abndt mang. oxide
SS-17		55	14, 18, 19, 21	24" / 24"	100		lt brn poorly graded Sand with Silt (SP-SM) med-fn grn, moist, dense sand, sbrnd-sbang, trace oxide
		60					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 4 of 8

Project	Saltstone Vaults 3 and 5	Boring No. Z-V3V5-B03	Date 3/13/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		60					RLG 3.31.09 LEAN
SS-18			4, 8, 12, 13	24" / 24"	100		upper 0.6' ~~Lest~~ LEAN Clay (CL) tn, malleable; tn-lt brn Silty Sand (SM) med-fn grn wet, medium dense, sbang-sbrnd, poorly graded, trace oxides
		65					
SS-19			4, 7, 10, 17	24" / 23"	96		yel grn-lt brn Silty Sand (SM), dry kaolin section upper part of run, fn-med grn moist, medium dense, sbang-sbrnd, poorly graded, trace oxides
		70					
SS-20			7, 11, 11, 11	24" / 16"	67		lt brn poorly graded Sand with Silt (SP-SM) med-fn grn, wet-moist, medium dense, sbang-sbrnd, abdnt mang. oxide
		75					RLG 3.31.09 LEAN
SS-21			1, 2, 2, 1	24" / 24"	100		yel grn-lt brn ~~Lest~~ LEAN Clay with Sand (CL) sand is fn grn, wet, soft, malleable, good plasticity, with mang. oxide
		80					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 5 of 8

Project	Saltstone Vaults 3 and 5	Boring No. Z-V3V5-B03	Date 3/13/09 + 3/17/09

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description (RLG 3.31.09, LEAN)
SS-22		80	3, 4, 4, 7	24" / 24"	100		yel grn-wh ~~Lean~~ Clay with Sand (CL) with sandstone sections, wet, medium stiff, malleable, good plasticity, with many oxide weathered shell fragments
SS-23		85	5, 6, 7, 10	24" / 24"	100		grn wh Clayey Sand (SC) fn grn, moist-wet medium dense, poorly graded, with well cemented sandstone, some mang. oxide.
SS-24		90	6, 10, 25, 34	24" / 24"	100		grn wh Clayey Sand (SC) fn grn, moist-wet dense sand poorly graded with well cemented sandstone, some mang. oxide, trace weathered shell fragments
SS-25		95	7, 9, 14, 13	24" / 24"	100		Matrix is grn wh Clayey Sand (SC), fn grn, moist-wet medium dense, poorly graded includes about well cemented sandstone with shell hash (weathered shell fragments) trace mang oxide
		100					

3/13/09 End of day 3/17/09

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 6 of 8

Project	Boring No.	Date
Saltstone Vaults 3 and 5	Z-V3V5-B03	3/17/09

No. (Sampling)	Type (Sampling)	Depth (Sampling)	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
SS-26		100	5, 5, 6, 10	24" / 24"	100	Shell Hash	matrix is grn wh Clayey Sand (SC) fn grn, moist-wet, medium dense, poorly graded mostly shell hash (weathered shell fragments)
SS-27		105	9, 13, 17, 19	24" / 24"	100		Clayey Silt with ~~Sand~~ some sand grn gry ~~Silt with Sand~~ (ML) v fn-fn grn, wet, medium dense, poorly graded includes weathered shell fragments, trace mang. oxide
SS-28		110	8, 15, 18, 30	24" / 24"	100		grn gry poorly graded Sand with Silt (SP-SM) fn-med grn, dense, thin clay laminae on bottom, some sandst trace m; grn gry lean Clay with sand (CL) dry, low plasticity, some clean laminae, hard
SS-29		115	5, 8, 9, 19	24" / 24"	100		dk grn gry Silty Sand (SM) fn-med grn, sl moist, medium dense, poorly graded, orange-stained, trace oxides, ~~Clay~~ Clay (CL) bottom 0.4'. LEAN RLG 3.31.09
		120					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 7 of 8

Project: Saltstone Vaults 3 and 5 | Boring No.: Z-V3V5-B03 | Date: 3/17/09

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
SS-30		120	5 / 38 / 50-5" / Refusal	17" / 17"	100		Refusal at 120'5" Lt-med gry poorly graded sand with silt (SP-SM) med-fn w/ occ crse grn, 3 ang-sbrnd wet
SS-31		125	50-3" Refusal	RLG 3.31.09 3"/0" Refusal	RLG 0%		Refusal - 50 blows went 3" SAA - Not enough to jar.
SS-32		130	50-3" Refusal	3.31.09 RLG 3"/0" Refusal	RLG 0%		Refusal - 50 blows went 3" SAA - Not enough to jar
SS-33		135	50-5" Refusal	RLG 3.31.09 NOT RECORDED Refusal			Refusal - 50 blows went 5" Lt-med gry poorly graded Sand (SP) med-fn grn, wet, 3 ang-sbrnd trace ox
		140					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 8 of 8

Project: Saltstone Vaults 3 and 5							Boring No. 2-V3V5-B03	Date 3/17/09
Sampling			**6-Inch Blow Counts**	**Inches Driven / Inches Recovered**	**% Rec**	**Lithology**	**Description**	
No.	**Type**	**Depth**						
SS-34		140	50-5" Refusal	Refusal (NOT RECORDED RLG 3.31.09)			Refusal - 50 blows went 5" lt-med gry poorly graded Sand (SP) fn-med grn, wet, sbang-sbrnd, trace oxides	
SS-35		145	12 21 31 48	24" / 20"	83		RLG 3.31.09 med-dk gry Silty Sand (SM) some thin LEAN clay (CL) laminae top of run, med-fn grn wet very dense sand, sbrnd-ssang, poorly graded	
SS-36		150	26 30 50 56	24" / 19"	79		med-dk gry poorly graded Sand with silt (SP-SM) med-fn grn w/ occ crse grn, wet-saturated, very dense sand, Brnd-sbang	
							Total drill depth - 156'	
							Total split-spoon depth - 152'	
		5						
		0						

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log

Page 1 of 8

Project: Saltstone Vaults 3 and 5		Date: 3/09/09	Area: Z-Area
Boring No.: Z-V3V5-B04	SRS Coordinates: N 78171.0 E 66702.0		Reference Elevation: 272.8' msl
Driller: Steve Butrey	Drilling Subcontractor: Fugro		Total Hole Depth: 150.0' bgs
Technical Oversight: Bill Joyce / Oversight Company: SAIC	Groundwater Depths: Date N/A RLG 3.31.09 Time / Depth		Drilling Methods and Depths: Auger-10', Mud Rotary

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		0					Hand Auger 0'-6', Auger 6'-10'
							Top Soil 0.0'-1.0' w/ roots
							mod yel brn SAND (SW), well graded dry, med dense, med-fn grn
							red brn SANDY SILT (SM) poorly sorted fn grn dry
		5					red brn CLAYEY SAND (SC) poorly sorted, fn-vfn grn, sl moist, med dense
							SAA
		10					
							Consistent Drilling Response (↑ 10'–20' ↓)
		15					
		20					

Samples Submitted for Laboratory Tests

Bulk Sample	1.0'-5.0'	
Bulk Sample	5.0'-10.0'	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 2 of 8

Project	Saltstone Vaults 3 and 5						Boring No. Z-V3V5-B04	Date 3/09/09
Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		20					RLG 3.31.09 Graded
ST-1				24" / 21½"	90		red brn SAND (SP), poorly ~~sorted~~, little fines, fn-med grn, moist, stand.
		25					Consistent Moderate Drilling
		30					Poorly GRADED RLG 3.31.09
ST-2				24" / 23"	95		lt brn SAND (SP) little fines, med grn, occ crse grn, moist, stand
							Drilling Softer at 32.5'
		35					Only able to push 20" (1.66')
ST-3				20" / 13½"	68		CLAYEY SAND RLG 3.31.09 lt brn ~~SAND-CLAY~~ mixture (SC) med-fn grn w/ thin clay laminae (soft) kaolin, sl moist, stong, trace oxide
		40					

Samples Submitted for Laboratory Tests

Shelby Tube	20.0'-22.0'	
Shelby Tube	30.0'-32.0'	
Shelby Tube	35.0' - ~~37.0'~~ 36.66'	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 3 of 8

Project	Saltstone Vaults 3 and 5					Boring No. Z-VSV5-B04	Date 3/09/09
Sampling			6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
No.	Type	Depth					
		40					Consistent Drilling Response
		45					Drilling Softer at 47'
		50					
ST-4				24" / 23"	95		grn white SANDY CLAY (CL) vfn grn sand, soft low-medium plasticity, abndt many oxide pockets, sl moist
		55					
ST-5				24" / 23"	95		red brn SANDY CLAY (CL) fn grn sand pockets soft low-medium plasticity, sl moist, many oxide pockets
		60					

Samples Submitted for Laboratory Tests

Shelby Tube	50.0'-52.0'	
Shelby Tube	55.0'-57.0'	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 4 of 8

Project Saltstone Vaults 3 and 5	Boring No. Z-V3V5-B04	Date 3/09/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		60					↑
							Consistent Drilling Response
		65					↓
							Drilling Response Harder at 69'
		70					↑
							Consistent Drilling Response
		75					↓
		80					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 5 of 8

Project: Saltstone Vaults 3 and 5 | Boring No. Z-V3V5-B94 | Date 3/09/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		80					Consistent Drilling Response
ST-6		85		24" / 26"	100		gray white SILTY SAND (SM), poorly ~~sorted~~ GRADED, vfn-fn grn, sl moist, medium dense, consolidated, abndt oxides (ALG 3.31.09)
							Drilling Response Harder at 87'
		90					
							Inconsistent Hard and Slightly Softer Drilling Response
		95					
		100					

Samples Submitted for Laboratory Tests

Shelby Tube	84.0'-86.0'	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 6 of 8

Project Saltstone Vaults 3 and 5	Boring No. Z-V3V5-B04	Date 3/09/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		100					↑
		105					
							Inconsistent Hard and Slightly Softer Drilling Response
		110					↓
		115					
		120					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 7 of 8

Project: Saltstone Vaults 3 and 5

Boring No.: Z-V3V5-B04

Date: 3/09/09-3/10/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		120					Change bits - run in with 3 7/8" roller cone bit.
ST-7				24" / 14"	58		grn gry SANDY LEAN CLAY (CL) vfn grn sand, firm-hard, low plasticity, sl moist, micaceous RLG 3.31.09
		125					
		130					Consistent Drilling Response
		135					
		140					

3/09/09 End of 3/10/09

Samples Submitted for Laboratory Tests

Shelby Tube	120.0'-122.0'	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 8 of 8

Project Saltstone Vaults 3 and 5 | Boring No. Z-V3V5-BP4 | Date 3/14/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		140					↑ Consistent Drilling Response ↓
		145					
		150					Total Depth Of Boring - 150.0'
		5					
		0					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

Appendix B – Test Data / Soil Properties

K-CLC-Z-00013, Rev. 0

June 2009

Test Data Evaluation for Saltstone Disposal Cells 3 and 5

(240 pages)

Calculation Cover Sheet

Project	Calculation No.	Project Number
Saltstone Disposal Cells No. 3 and 5	K-CLC-Z-00013	~~N/A~~ Y546
Title Test Data Evaluation for Saltstone Disposal Cells 3 and 5	**Functional Classification** PS **Discipline** Geotechnical	Sheet 1 of 239
Calc Level ☒ Type 1 ☐ Type 2	**Type 1 Calc Status** ☐ Preliminary ☒ Confirmed	
Computer Program No. ☒ N/A	**Version / Release No.** N/A	
Purpose and Objective Engineering evaluation of test data and determination of engineering properties for the Saltstone Disposal Cells 3 and 5.	**DC/RO** UNCLASSIFIED DOES NOT CONTAIN UNCLASSIFIED CONTROLLED NUCLEAR INFORMATION ADC & Reviewing Official: [signature] A.A. Siddall (Name) Date: 7/23/2009	

Summary of Conclusion

See results and conclusions section.

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Revision

Rev. No.	Revision Description
0	Original

Sign Off

Rev. No.	Originator (Print) Sign / Date	Verification / Checking Method	Verifier / Checker (Print) Sign / Date	Manager (Print) Sign / Date
0	D. Bruce Nothdurft, PE, PG [signature] 6/24/09	Document Review	Rucker J. Williams [signature] 6-24-09	William T. Li [signature] 6-25-09

Additional Reviewer (Print)	Signature	Date
N/A		
Design Authority (Print)	**Signature**	**Date**
N/A		
Release to Outside Agency (Print)	**Signature**	**Date**
N/A		

Security Classification of the Calculation

Unclassified

TABLE OF CONTENTS

1. INTRODUCTION

This calculation provides an evaluation of the available geotechnical test data for the project site. The results of the evaluation will be used to provide recommended soil properties.

2. INPUT DATA

Input data includes the field exploration and the laboratory test data as described in the following sections.

2.1 Field Exploration

The field exploration includes Cone Penetrometer Tests (CPTs), seismic Cone Penetrometer Tests (SCPTs), and geotechnical boreholes. Tables 1, 2, and 3 show the field exploration performed at the project site. Figures 1 illustrates the location of Disposal Cells 3 and 5. Figure 2 shows the geotechnical exploratory map. Subsurface cross sections are illustrated in K-CLC-Z-00012 (Ref.1). Appendix A provides the CPT and SCPT logs (Ref. 2). Appendix B provides the geotechnical Borehole Logs (Ref. 3).

2.2 Laboratory Testing

Laboratory tests were performed on samples retrieved from four geotechnical boreholes. These boreholes are listed in Tables 2 and 3, respectively. Table 3 shows the elevations of the engineering layers at these geotechnical boreholes where the soil samples were taken.

Table 4 shows the undisturbed soil samples used for the evaluation. Table 5 shows the disturbed soil samples used for the evaluation. Appendix C provides the laboratory test reports (Ref. 4). The Engineering Layer for each sample is shown in Tables 3, 4 and 5. These layers were identified in Reference 1.

3. DATA ANALYSIS COMPUTATIONS

3.1 CPT and SCPT Data

Statistics of CPT and SCPT data, including tip resistances, sleeve frictions, friction ratios, pore pressures, compressive wave velocities, and shear wave velocities are shown in Table 6.

Average compression and shear wave velocity for each engineering layer was computed using the following equation:

$$V_{ave} = \Sigma\, d_i / (\Sigma\, (d_i / V_i)$$

where d_i is the distance between two points at Location i where the wave velocity is measured and V_i is the measured wave velocity at Location i.

Poisson's ratio is computed using the following equation:

$$\nu = (2V_s^2 - V_p^2) / (2V_s^2 - 2V_p^2)$$

where ν is the Poisson's ratio and V_s and V_p are the shear and compression wave velocities at each data point.

Poisson's ratio data points from all the wave velocity data points, regardless of the values, were used to compute the averages.

The average Poisson's ratios are 0.197 for Layer S1/2 and 0.444 for the other layers. Assuming the phreatic surface to be at a depth of 55 feet based on data from past hydrogeologic studies, the average Poisson's ratios are 0.304 and 0.445 respectively, above and below the groundwater table. For comparison, the average Poisson's ratios for Vault 2 above and below the water table were 0.236 and 0.368, respectively. The recommended Poisson's ratios are 0.30 and 0.44, respectively, above and below the groundwater table.

3.2 SPT Data

Table 7 shows the SPT blow-count statistics for the various Engineering Layers. Also shown are energy-corrected blow counts N_{60}, corresponding to 60% of input energy using:

$$N_{60} = (ER/60)\, N_{MEASURED}$$

where $N_{MEASURED}$ is the measured blow counts

ER, the average energy ratio measured was 81% (Appendix B).

The recommended N_{60} value is the arithmetic average, exclusive of SPT samples that met refusal, for soils above the Congaree formation, approximately 120 feet below the surface (Ref. 1). The recommended N_{60} is 28 blows per foot.

3.3 Laboratory Data

Laboratory test data are evaluated in the following sections.

3.3.1 Grain size Distribution and Atterberg Limits

Results of particle size analyses and Atterberg Limits testing performed on selected samples are included in Tables 8 and 9, respectively.

3.3.2 Unit Weight and Moisture Contents

Unit weight and moisture contents tests were determined on selected undisturbed soil samples, some of the results were part of the strength testing. The results are provided in Table 10.

3.3.3 Strength

Strength tests were performed on selected samples. Test results are summarized in Table 11. The results from sample Z-V3V5-B04 ST3 appeared to be in question and were excluded when determining the design value. Strength test results are consistent with the results obtained from corresponding engineering layers elsewhere at the SRS.

3.3.4 Consolidation

Consolidation tests were performed on selected soil samples. Pre-consolidation pressures were determined using the Casagrande method (Ref. 6). Table 12 summarizes the initial pressures, pre-consolidation pressures, over-consolidation ratios, compression Indices, re-compression indices, and ratio of compression to re-compression indices. These test results are consistent with the results obtained from corresponding engineering layers elsewhere at the SRS.

3.4 Groundwater Elevation

Ground water elevation was obtained from Figure 1. The groundwater elevation at the project site is estimated to range from 215 to 220 ft, msl (Ref 5). A seasonal groundwater fluctuation is estimated to be ± 5 feet.

3.5 Unit Weight of Fills

Soils excavated above 261 feet, MSL may be used for backfill material around the tanks. Based on the proctor test results on remolded samples and the evaluation of the density test results on undisturbed samples, wet density of the compacted fill is estimated to be 120 pcf.

4. RESULTS AND CONCLUSIONS

The results are summarized below. Recommended soil values are also given.

- Table 6 provides statistics of CPT and SCPT data.
- Table 7 provides statistics of SPT data.
  - The recommended N_{60} for the soil column is 28 blows per foot.
- Tables 8 and 9 provide particle size analyses and Atterberg Limits, respectively.
- Table 10 provides the statistics of moisture contents and unit weight.
  - Recommended total unit weight for in situ soils is 120 pcf.
- Table 11 provides effective and total strength parameters.
  - Recommended total stress parameters are a friction angle of 9° and a total cohesion of 2400 psf.
  - Recommended effective stress parameters are an effective friction angle of 30° and an effective cohesion of 200 psf.
- Table 12 provides the consolidation parameters including OCR, C_c, C_r, and C_c/C_r.
- Table 13 provides the results of the modified Proctor tests.
  - Recommended total unit weight for fill soils is 120 pcf.
- Table 14 provides the results of the hydraulic conductivity tests.
- The recommended Poisson’s ratios are 0.25 and 0.40, respectively, above and below the groundwater table.
- Average groundwater table elevation 215 to 220 feet mean sea level with seasonal fluctuation of ± 5 feet. Areas of perched water may be expected to occur above the groundwater table elevations.

6. REFERENCES

1. K-CLC-Z-000012, Stratigraphy for Saltstone Disposal Cells 3 and 5, Rev. 0, April 2009.
2. Subcontract No. AC39054N, Task 32, Applied Research Associates, Inc., Cone Penetrometer Data Report, April 2009.
3. Subcontract No. C002332N Task 301, Science Applications International Corporation, Geotechnical Drilling and Technical Oversight Services for Saltstone Vaults 3 & 5 Geotechnical Investigation, Standard Penetration Data Report, April 2009.
4. Subcontract No. AC54317N, Test Report – Saltstone Vaults 3 and 5, May 2009.
5. WSRC-TR-98-0045, The Regional Water Table of the Savannah River Site and Related Coverages, September 1998.
6. ASTM D 2435-04, Standard Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading.

Table 1 Piezocone Penetrometer Tests at the Project Site

CPT or SCPT I.D.	Type of CPT or SCPT	SRS North (feet)	SRS East (feet)	Ground Elevation (feet MSL)	Total Depth (feet)
Z-V3V5-C1	Seismic	78,429	66,907	264.9	83.3
Z-V3V5-C2	Non-seismic	78,267	66,960	268.6	88.1
Z-V3V5-C3	Non-seismic	78,477	66,813	263.9	79.1
Z-V3V5-C4	Seismic	78,405	66,836	266.8	85.9
Z-V3V5-C5	Non-seismic	78,325	66,863	268.8	97.6
Z-V3V5-C6	Seismic	78,244	66,889	268.8	124.6
Z-V3V5-C7	Seismic	78,173	66,913	268.2	79.7
Z-V3V5-C8	Non-seismic	78,374	66,741	267.7	91.4
Z-V3V5-C9	Seismic	78,293	66,768	270.4	102.2
Z-V3V5-C10	Non-seismic	78,213	66,794	270.7	126.9
Z-V3V5-C11	Seismic	78,414	66,623	264.7	88.8
Z-V3V5-C12	Seismic	78,343	66,646	268.1	91.7
Z-V3V5-C13	Non-seismic	78,262	66,673	272.0	96.3
Z-V3V5-C14	Seismic	78,181	66,699	273.0	93.4
Z-V3V5-C15	Non-seismic	78,110	66,723	271.6	95.9
Z-V3V5-C16	Non-seismic	78,319	66,575	268.7	108.8
Z-V3V5-C17	Seismic	78,158	66,628	274.6	96.6

Table 2 Geotechnical Boreholes at the Project Site

Borehole I.D.	Type of Borehole	SRS North (feet)	SRS East (feet)	Ground Elevation (feet MSL)	Total Depth (feet)
Z-V3V5-B1	UD	78,395	66,839	266.9	150.0
Z-V3V5-B2	SPT	78,235	66,894	269.9	150.0
Z-V3V5-B3	SPT	78,333	66,649	268.3	150.0
Z-V3V5-B4	UD	78,171	66,702	272.8	150.0

Table 3 Engineering Layers at Geotechnical Borehole Locations

Exploratory I.D.	Nearest CPT or SCPYu	Ground Elevation (feet MSL)	Contact Between S1/2 and C2 (ft, MSL)	Contact Between C2 and S3 (ft, MSL)	Contact Between S3 and S4 (ft, MSL)
Z-V3V5-B1	Z-V3V5-C04	266.9	224 (No C2)	224 (No C2)	186.0
Z-V3V5-B2	Z-V3V5- C06	269.9	229	217	189.0
Z-V3V5-B3	Z-V3V5- C12	268.3	219.0	216.0	186.0
Z-V3V5-B4	Z-V3V5- C14	272.8	237	216.0	186.0

Table 4 Undisturbed Soil Samples

Sample No.	Layer	SRS North (feet)	SRS East (feet)	Ground Elev. (ft, msl)	Depth from (feet)	Depth to (feet)	Elev. from (ft, msl)	Elev. to (ft, msl)
Z-V3V5-B1-ST1	S1/2	78,395	66,839	266.9	20.0	22.0	246.9	244.9
Z-V3V5-B1-ST2	S1/2	-	-	-	30.0	32.0	236.9	234.9
Z-V3V5-B1-ST3	S1/2	-	-	-	37.0	39.0	229.9	227.9
Z-V3V5-B1-ST4	S3	-	-	-	50.0	51.25	216.9	215.65
Z-V3V5-B1-ST5	S3	-	-	-	55.0	57.0	211.9	209.9
Z-V3V5-B1-ST6	S3	-	-	-	75.0	77.0	191.9	189.9
Z-V3V5-B1-ST7	S3	-	-	-	78.0	80.0	188.9	186.9
Z-V3V5-B1-ST8	S4	-	-	-	81.0	83.0	185.9	183.9
Z-V3V5-B4-ST1	S1/2	78,171	66,702	272.8	20.0	22.0	252.8	250.8
Z-V3V5-B4-ST2	S1/2	-	-	-	30.0	32.0	242.8	240.8
Z-V3V5-B4-ST3	S1/2	-	-	-	35.0	36.66	237.8	236.14
Z-V3V5-B4-ST4	C2	-	-	-	50.0	52.0	222.8	220.8
Z-V3V5-B4-ST5	C2	-	-	-	55.0	57.0	217.8	215.8
Z-V3V5-B4-ST6	S3	-	-	-	84.0	86.0	188.8	186.8
Z-V3V5-B4-ST7	S4	-	-	-	120.0	122.0	152.8	150.8

*No recovery

Table 5 Disturbed Soil Samples

Sample No.	Layer	Depth from (feet)	Depth to (feet)	Elev. from (ft, msl)	Elev. to (ft, msl)
Z-V3V5-B2-SS1	S1/2	10.0	12.0	259.9	257.9
Z-V3V5-B2-SS2	S1/2	12.0	14.0	257.9	255.9
Z-V3V5-B2-SS3	S1/2	14.0	16.0	255.9	253.9
Z-V3V5-B2-SS4	S1/2	16.0	18.0	253.9	251.9
Z-V3V5-B2-SS5	S1/2	18.0	20.0	251.9	249.9
Z-V3V5-B2-SS6	S1/2	20.0	22.0	249.9	247.9
Z-V3V5-B2-SS7	S1/2	22.0	24.0	247.9	245.9
Z-V3V5-B2-SS8	S1/2	24.0	26.0	245.9	243.9
Z-V3V5-B2-SS9	S1/2	26.0	28.0	243.9	241.9
Z-V3V5-B2-SS10	S1/2	28.0	30.0	241.9	239.9
Z-V3V5-B2-SS11	S1/2	30.0	32.0	239.9	237.9
Z-V3V5-B2-SS12	S1/2	32.0	34.0	237.9	235.9
Z-V3V5-B2-SS13	S1/2	34.0	36.0	235.9	233.9
Z-V3V5-B2-SS14	C2	40.0	42.0	229.9	227.9
Z-V3V5-B2-SS15	C2	45.0	47.0	224.9	222.9
Z-V3V5-B2-SS16	C2/S3	50.0	52.0	219.9	217.9
Z-V3V5-B2-SS17	S3	55.0	57.0	214.9	212.9
Z-V3V5-B2-SS18	S3	60.0	62.0	209.9	207.9
Z-V3V5-B2-SS19	S3	65.0	67.0	204.9	202.9
Z-V3V5-B2-SS20	S3	70.0	72.0	199.9	197.9
Z-V3V5-B2-SS21	S3	75.0	77.0	194.9	192.9
Z-V3V5-B2-SS22	S3/S4	80.0	82.0	189.9	187.9
Z-V3V5-B2-SS23	S4	85.0	87.0	184.9	182.9
Z-V3V5-B2-SS24	S4	90.0	92.0	179.9	177.9
Z-V3V5-B2-SS25	S4	95.0	97.0	174.9	172.9
Z-V3V5-B2-SS26	S4	100.0	102.0	169.9	167.9
Z-V3V5-B2-SS27	S4	105.0	107.0	164.9	162.9
Z-V3V5-B2-SS28	S4	110.0	112.0	159.9	157.9
Z-V3V5-B2-SS29	S4	115.0	117.0	154.9	152.9
Z-V3V5-B2-SS30	S4	120.0	122.0	149.9	147.9
Z-V3V5-B2-SS31	S4	125.0	125.25	144.9	144.65
Z-V3V5-B2-SS32	S4	130.0	130.83	139.9	139.07
Z-V3V5-B2-SS33	S4	135.0	135. 83	134.9	134.07
Z-V3V5-B2-SS34	S4	140.0	141.92	129.9	127.98
Z-V3V5-B2-SS35	S4	145.0	147.0	124.9	122.9
Z-V3V5-B2-SS36	S4	150.0	152.0	119.9	117.9

Table 5 Disturbed Soil Samples, continued

Sample No.	Layer	Depth from (feet)	Depth to (feet)	Elev. from (ft, msl)	Elev. to (ft, msl)
Z-V3V5-B3-SS1	S1/2	10.0	12.0	258.3	256.3
Z-V3V5-B3-SS2	S1/2	12.0	14.0	256.3	254.3
Z-V3V5-B3-SS3	S1/2	14.0	16.0	254.3	252.3
Z-V3V5-B3-SS4	C2	16.0	18.0	252.3	250.3
Z-V3V5-B3-SS5	S3	18.0	20.0	250.3	248.3
Z-V3V5-B3-SS6	S3	20.0	22.0	248.3	246.3
Z-V3V5-B3-SS7	S3	22.0	24.0	246.3	244.3
Z-V3V5-B3-SS8	S3	24.0	26.0	244.3	242.3
Z-V3V5-B3-SS9	S3	26.0	28.0	242.3	240.3
Z-V3V5-B3-SS10	S3 & S4	28.0	30.0	240.3	238.3
Z-V3V5-B3-SS11	S4	30.0	32.0	238.3	236.3
Z-V3V5-B3-SS12	S4	32.0	34.0	236.3	234.3
Z-V3V5-B3-SS13	S4	34.0	36.0	234.3	232.3
Z-V3V5-B3-SS14	S4	40.0	42.0	228.3	226.3
Z-V3V5-B3-SS15	S4	45.0	47.0	223.3	221.3
Z-V3V5-B3-SS16	S4	50.0	52.0	218.3	216.3
Z-V3V5-B3-SS17	S4	55.0	57.0	213.3	211.3
Z-V3V5-B3-SS18	S4	60.0	62.0	208.3	206.3
Z-V3V5-B3-SS19	S4	65.0	67.0	203.3	201.3
Z-V3V5-B3-SS20	S4	70.0	72.0	198.3	196.3
Z-V3V5-B3-SS21	S4	75.0	77.0	193.3	191.3
Z-V3V5-B3-SS22	S4	80.0	82.0	188.3	186.3
Z-V3V5-B3-SS23	S4	85.0	87.0	183.3	181.3
Z-V3V5-B3-SS24	S4	90.0	92.0	178.3	176.3
Z-V3V5-B3-SS25	S4	95.0	97.0	173.3	171.3
Z-V3V5-B3-SS26	S4	100.0	102.0	168.3	166.3
Z-V3V5-B3-SS27	S4	105.0	107.0	163.3	161.3
Z-V3V5-B3-SS28	S4	110.0	112.0	158.3	156.3
Z-V3V5-B3-SS29	S4	115.0	117.0	153.3	151.3
Z-V3V5-B3-SS30	S4	120.0	121.42	148.3	146.88
Z-V3V5-B3-SS31	S4	125.0	125.25	143.3	143.05
Z-V3V5-B3-SS32	S4	130.0	130.25	138.3	138.05
Z-V3V5-B3-SS33	S4	135.0	135.42	133.3	132.88
Z-V3V5-B3-SS34	S4	140.0	140.42	128.3	127.88
Z-V3V5-B3-SS35	S4	145.0	147.0	123.3	121.3
Z-V3V5-B3-SS36	S4	150.0	152.0	118.3	116.3

Table 6 CPT and SCPT Data

Layer	Description	Sleeve Friction (tsf)	Tip Resis-tance (tsf)	Friction Ratio (%)	Pore Pressure (tsf)	P Wave (fps)	S Wave (fps)	Poisson's Ratio
S1/2	Average	2.65	164.64	2.24	0.75	2500	1500	0.197
	Minimum	0.55	39.39	0.44	-0.05	1557	947	
	Maximum	8.36	345.74	11.85	9.32	4198	3981	
	Standard Deviation	1.81	69.36	2.21	1.21	791	883	
	No. of Data Points	468	468	468	468	14	10	
C2	Average	1.20	46.28	2.65	1.98	3490	1050	0.450
	Minimum	0.66	20.83	1.11	-0.01	2026	771	
	Maximum	2.37	118.24	5.20	5.25	6732	1404	
	Standard Deviation	0.45	26.73	0.90	1.41	1604	247	
	No. of Data Points	98	98	98	98	9	7	
S3	Average	2.06	143.86	1.95	1.52	3450	1230	0.427
	Minimum	0.44	16.32	0.41	-.12	1875	799	
	Maximum	6.65	397.06	6.67	10.65	6095	2086	
	Standard Deviation	1.48	106.78	1.33	1.92	1609	318	
	No. of Data Points	370	371	370	371	9	14	
S4	Average	3.35	124.28	3.21	4.25	6095	1525	0.456
	Minimum	0.94	33.96	1.05	0.24	6095	1103	
	Maximum	9.06	518.16	7.30	12.89	6095	2756	
	Standard Deviation	1.93	90.90	1.33	3.13	0	620	
	No. of Data Points	151	156	151	156	1	11	
All	Average	2.31	119.76	2.51	2.12	3884	1326	
	No. of Data Points	1087	1093	1087	1093	34	42	

Table 7 SPT Blow Count Data

Description	S1/2	C2	S3	S4
Average	24	9	17	55
Minimum	16	6	WH	11
Maximum	35	31	37	50 in 3 inches
Standard Deviation	5.1	6.9	11.0	35.7
No. of Data Points	28	4	17	55
Average Corrected N_{60}	32	12	23	74

Table 8 Distribution of Particle Sizes

Sample No.	Layer	% passing U.S. standard sieve sizes / (opening in mm)								
		3/8 (9.50)	4 (4.75)	10 (2.00)	20 (0.85)	40 (0.425)	60 (0.250)	100 (0.150)	140 (0.106)	200 (0.075)
Z-V3V5-B1 0-5 ft	S1/2	-	100.0	99.7	97.0	87.6	63.0	26.0	17.0	13.4
Z-V3V5-B1 5-10 ft	S1/2	-	100.0	99.0	96.5	86.0	68.0	41.0	35.0	34.4
Z-V3V5-B1/B4-0-10 ft	S1/2	-	100.0	99.9	96.0	82.0	63.0	37.0	38.5	24.9
Z-V3V5-B1-ST1	S1/2	-	100.0	98.0	81.0	47.5	29.0	17.5	12.0	10.1
Z-V3V5-B1-ST2	S1/2	-	100.0	93.9	76.0	36.7	18.0	12.0	10.5	9.5
Z-V3V5-B1-ST3	S1/2	-	100.0	98.6	92.0	84.1	74.0	53.0	44.0	39.9
Z-V3V5-B1-ST4	S3	-	100.0	99.5	94.0	76.7	51.0	11.0	6.0	4.9
Z-V3V5-B1-ST5	S3	-	100.0	99.3	82.0	46.5	31.0	10.7	6.5	5.8
Z-V3V5-B4 0-5 ft	S1/2	-	100.0	99.8	95.0	77.2	58.0	35.0	25.0	20.4
Z-V3V5-B4 5-10 ft	S1/2	-	100.0	99.5	93.5	77.5	62.0	43.5	36.5	32.9
Z-V3V5-B4-ST1	S1/2	-	100.0	99.9	95.0	84.0	67.0	44.0	37.5	36.5
Z-V3V5-B4-ST2	S1/2	100.0	100.0	99.3	78.0	34.7	21.0	12.0	9.0	8.1
Z-V3V5-B4-ST3	S1/2	100.0	100.0	99.8	90.0	46.3	18.0	11.0	9.0	8.2
Z-V3V5-B4-ST4	S1/2	-	100.0	100.0	100.0	99.7	97.0	70.0	48.0	42.2
Z-V3V5-B4-ST5	C2	-	100.0	99.9	99.0	98.2	93.0	87.0	82.0	80.1
Z-V3V5-B4-ST6	S1/2	-	100.0	99.9	98.0	94.5	88.0	63.0	38.0	24.6
Z-V3V5-B2-SS9,10,11	S1/2	100.0	100.0	99.6	77.5	36.0	18.0	11.5	8.5	7.3
Z-V3V5-B2-SS26,27	S4	85.0	81.7	77.6	70.5	62.2	53.0	37.5	29.5	23.7
Z-V3V5-B2-SS29,30	S4	-	100.0	98.8	91.0	66.1	48.5	34.5	28.0	22.8
Z-V3V5-B3-SS1,2,3	S1/2	-	100.0	99.7	91.0	76.8	60.5	37.0	32.0	31.4
Z-V3V5-B3-SS7,8,9	S1/2	100.0	99.8	98.2	86.0	45.7	20.0	12.0	8.5	7.4
Z-V3V5-B3-SS22,23,24	S4	84.0	78.0	76.2	74.5	73.5	72.1	58.5	39.0	29.9

Table 9 Atterberg Limits and USCS

Sample No.	Layer	LL (%)	PL (%)	PI (%)	USCS
Z-V3V5-B2-SS1A	S1/2	68	34	34	MH
Z-V3V5-B2-SS1B	S1/2	42	21	21	CL
Z-V3V5-B2-SS5	S1/2	40	22	18	SC
Z-V3V5-B2-SS9/10/11	S1/2	33	18	15	SP-SW
Z-V3V5-B2-SS12	S1/2	NP	NP	NP	SC
Z-V3V5-B2-SS15	C2	87	32	55	CH
Z-V3V5-B2-SS18	S3	NP	NP	NP	SP-SM
Z-V3V5-B2-SS21A	S3	63	20	43	CH
Z-V3V5-B2-SS21B	S3	38	25	13	SM
Z-V3V5-B2-SS25	S4	NP	NP	NP	SM
Z-V3V5-B2-SS26/27	S4	45	28	17	SM
Z-V3V5-B2-SS29/30	S4	48	21	27	SC
Z-V3V5-B2-SS33	Congaree	NP	NP	NP	SM
Z-V3V5-B3-SS2	S1/2	54	22	32	CH
Z-V3V5-B3-SS1/2/3	S1/2	53	26	27	SC
Z-V3V5-B3-SS5	S3	37	22	15	SC
Z-V3V5-B3-SS7/8/9	S3	28	20	8	SP
Z-V3V5-B3-SS11/12	S4	37	18	19	SC
Z-V3V5-B3-SS13A	S4	51	20	31	CH
Z-V3V5-B3-SS13B	S4	33	20	13	SC
Z-V3V5-B3-SS16	S4	83	38	45	MH
Z-V3V5-B3-SS18A	S4	104	45	59	MH
Z-V3V5-B3-SS18B	S4	44	25	19	SC
Z-V3V5-B3-SS21	S4	33	28	5	SM
Z-V3V5-B3-SS22/23/24	S4	39	26	13	SM
Z-V3V5-B3-SS28A	S4	51	32	19	MH
Z-V3V5-B3-SS34	Congaree	NP	NP	NP	SM
Z-V3V5-B4-ST1	S1/2	42	23	19	SC
Z-V3V5-B4-ST2	S1/2	39	22	17	SW
Z-V3V5-B4-ST3	S1/2	NP	NP	NP	SW
Z-V3V5-B4-ST4	C2	74	40	34	SM
Z-V3V5-B4-ST6	S3	49	33	16	SM

Table 10 Unit Weights and Water Contents

Sample No.	Layer	Type of Test	Wet Unit Weight (pcf)	Moisture Content (%)	Dry Unit Weight (pcf)
Z-V3V5-B4-ST5	C2	Unit Weight	93.6	69.1	55.4
Z-V3V5-B4-ST6	S3	Unit Weight	115.3	33.2	86.5
Z-V3V5-B1-ST2	S1/2	Hyd. Conductivity	110.0	14.0	96.6
Z-V3V5-B4-ST2	S1/2	Hyd. Conductivity	120.8	13.9	106.1
Z-V3V5-B1-ST1	S1/2	Triaxial 1 of 3	117.2	11.7	104.9
Z-V3V5-B1-ST1	S1/2	Triaxial 2 of 3	117.2	14.2	102.6
Z-V3V5-B1-ST1	S1/2	Triaxial 3 of 3	119.6	12.4	106.4
Z-V3V5-B4-ST1	S1/2	Triaxial 1 of 3	129.1	19.1	108.4
Z-V3V5-B4-ST1	S1/2	Triaxial 2 of 3	130.1	19.1	109.2
Z-V3V5-B4-ST1	S1/2	Triaxial 3 of 3	128.7	19.8	107.4
Z-V3V5-B4-ST6	S3	Consolidation	118.6	29.8	91.4
Z-V3V5-B1-ST4	S3	Consolidation	106.9	13.3	94.4
Z-V3V5-B4-ST2	S1/2	Consolidation	123.2	15.8	106.4
Z-V3V5-B1-ST5	C2	Consolidation	122.0	17.9	103.5
Z-V3V5-B4-ST4	C2	Consolidation	103.8	50.3	69.1
Z-V3V5-B4-ST5	C2	Consolidation	92.8	64.3	56.5
Average	S1/2	9 tests	121.8	15.6	105.3
Average	C2	4 tests	103.1	50.4	71.1
Average	S3	3 tests	113.6	25.4	90.8
Average	S4	0 tests	-	-	-
Average	All	16 tests	115.6	26.1	94.1

Table 11 Consolidated Undrained Triaxial Test with Pore Pressure Measurements

Sample No.	Layer	Total (Stress) Friction Angle ϕ (degrees)	Total (Stress) Cohesion C (psf)	Effective Friction Angle ϕ' (degrees)	Effective Cohesion c' (psf)
Z-V3V5-B1-ST1	S1/2	31.1	2,606	33.4	137
Z-V3V5-B1-ST3	S1/2	8.0	2,808	29.6	299
Z-V3V5-B4-ST1	S1/2	10.8	2,462	34.8	322
Z-V3V5-B4-ST3	S1/2	-	-	33.1	357
Z-V3V5-B4-ST4	C2	9.5	1,041	25.7	376
Design Values	**-**	**9**	**2400**	**30**	**200**

Table 12 Consolidation Tests

Sample No.	Layer	P'_O (ksf)	P'_C (ksf)	Initial Void Ratio	OCR	C_c	C_r	C_c/C_r
Z-V3V5-B1-ST4	S3	6.0	3.4	0.60	0.6	0.051	0.0083	6.1
Z-V3V5-B1-ST5	S3	6.3	8.0	0.75	1.3	0.030	0.0083	3.6
Z-V3V5-B4-ST2	S1/2	3.8	7.0	0.57	1.8	0.036	0.0050	7.3
Z-V3V5-B4-ST4	C2	6.1	6.1	1.44	1.0	0.48	0.075	6.4
Z-V3V5-B4-ST5	C2	6.2	4.3	1.98	0.7	0.51	0.136	3.8
Z-V3V5-B4-ST6	S3	7.8	5.0	0.81	0.6	0.725	0.083	8.7

Table 13 Modified Proctor Tests

Source	Sample	Ground Elev. (ft, MSL)	Depth From (feet)	Depth To (feet)	Elev. From (ft, MSL)	Elev. to (ft, MSL)	Max. Dry Density (pcf)	Optimal Water Content (%)
Z-V3V5-B1 Bag 1	Composite	266.9	0.0	5.0	266.9	261.9	116.5	8.2
Z-V3V5-B1 Bag 2	Composite	266.9	5.0	10.0	261.9	256.9	122.9	12.2
Z-V3V5-B1/B4	Composite	-	0.0	10.0	272.8	256.9	126.8	8.9
Z-V3V5-B4 Bag 1	Composite	272.8	0.0	5.0	272.8	267.8	128.1	7.6
Z-V3V5-B4 Bag 2	Composite	272.8	5.0	10.0	267.8	262.8	128.0	9.7

Table 14 Hydraulic Conductivity Tests

Sample No.	Layer	Wet Unit Wt. (pcf)	Dry Unit Wt. (pcf)	Initial Water Content, %	Hydraulic Conductivity (cm/sec)
Z-V3V5-B1-ST2	S1/2	110.0	96.6	14.0	4.3E-04
Z-V3V5-B4-ST2	S1/2	120.8	106.1	13.9	9.9E-04

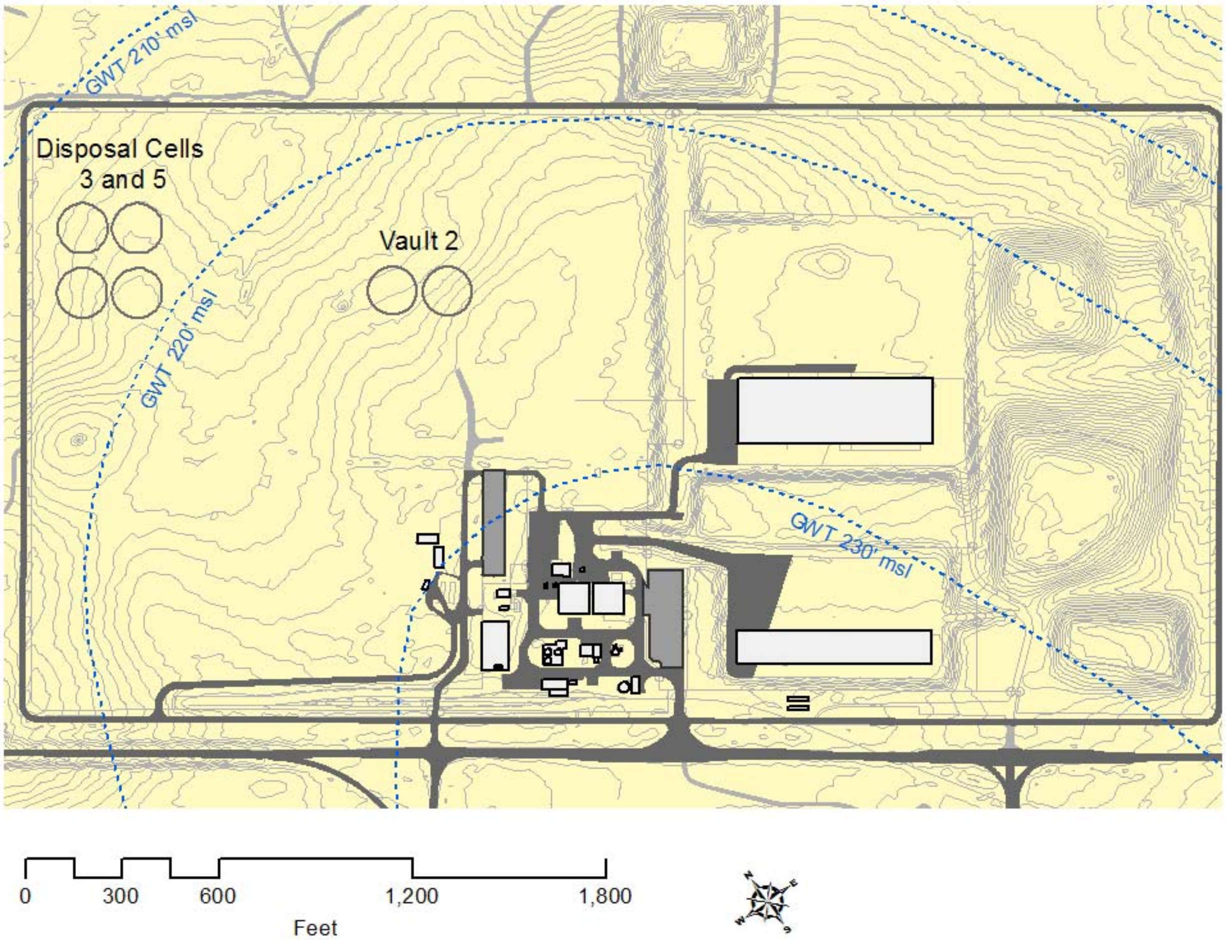


Figure 1 Location of Disposal Cells 3 and 5

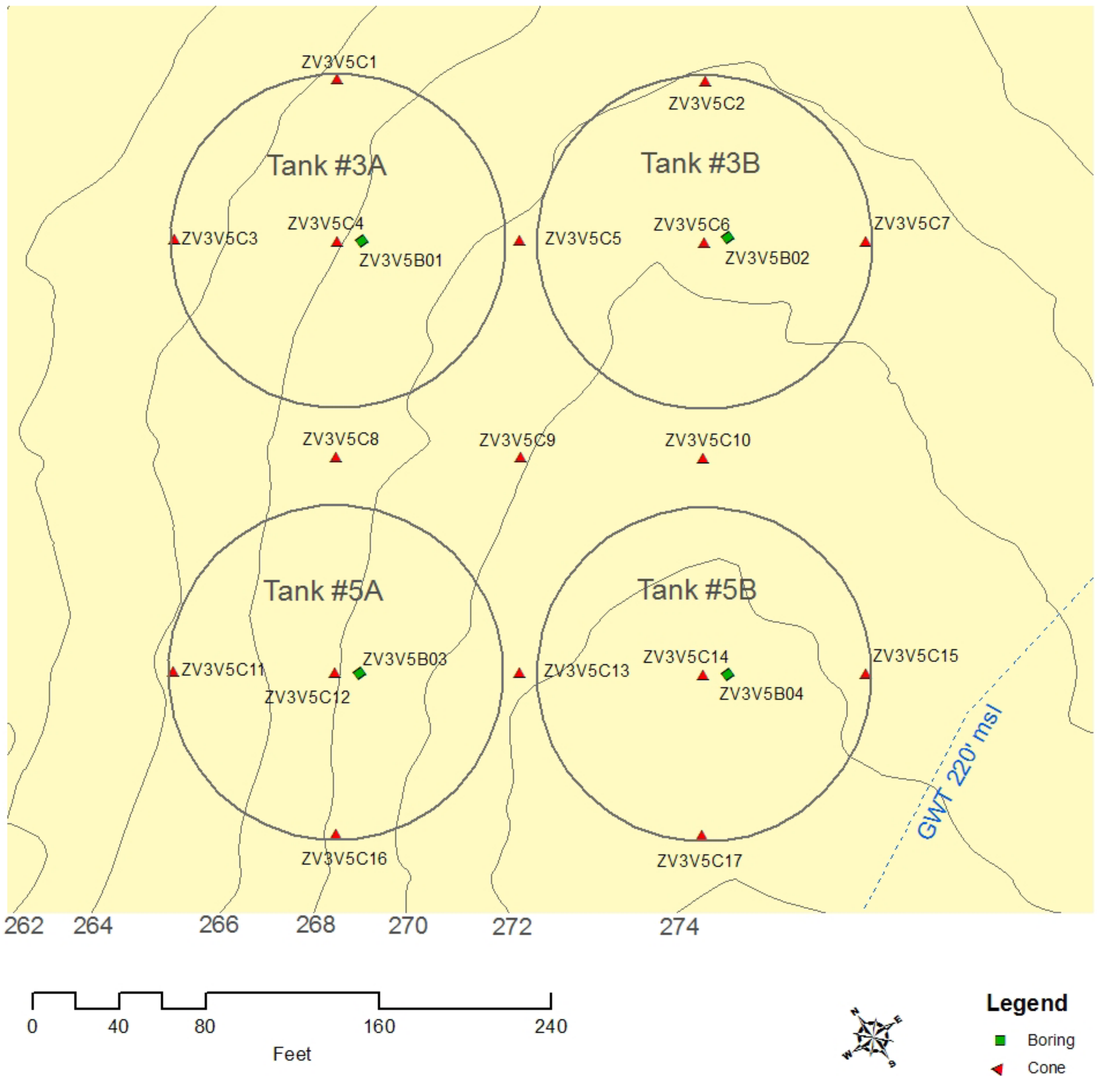
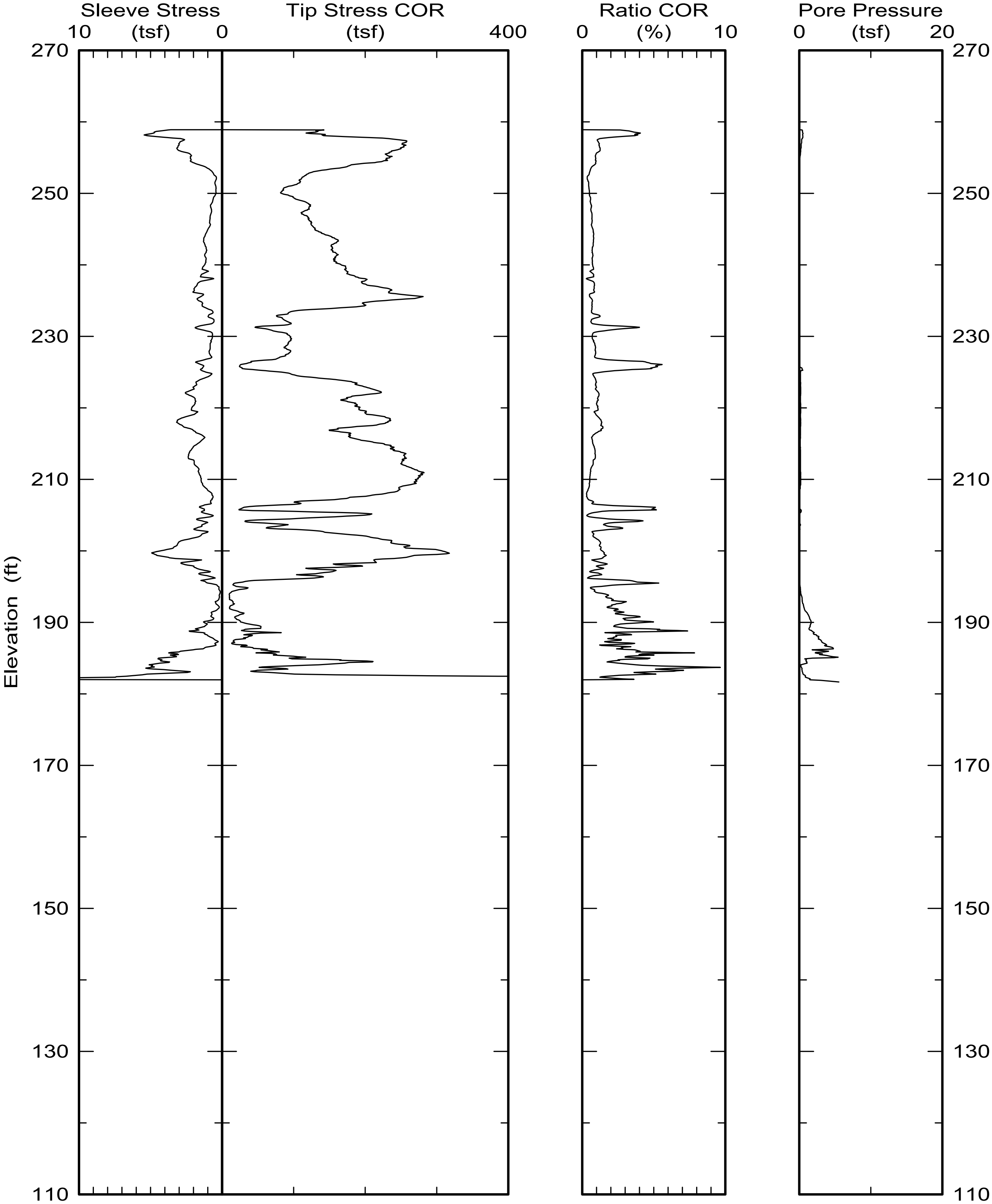


Figure 2 Disposal Cells 3 and 5 Geotechnical Exploration Locations

Appendix A CPT and SCPT Data

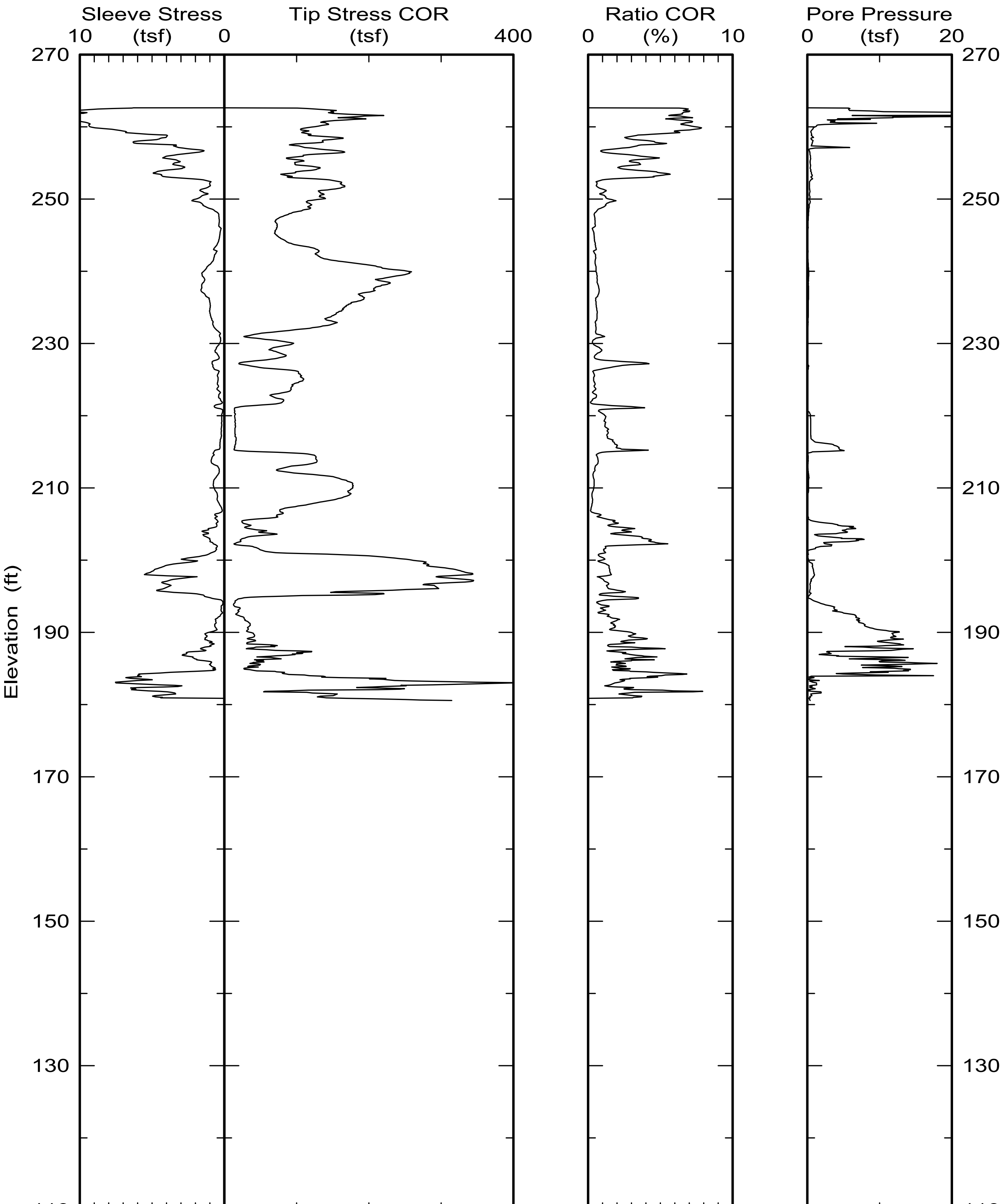
Applied Research Associates South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Date: 16/Dec/2008 Test ID: Z-V3V5-C01 Northing: 78429 Easting: 66907 Elevation: 264.9



Maximum depth: 83.26 (ft)

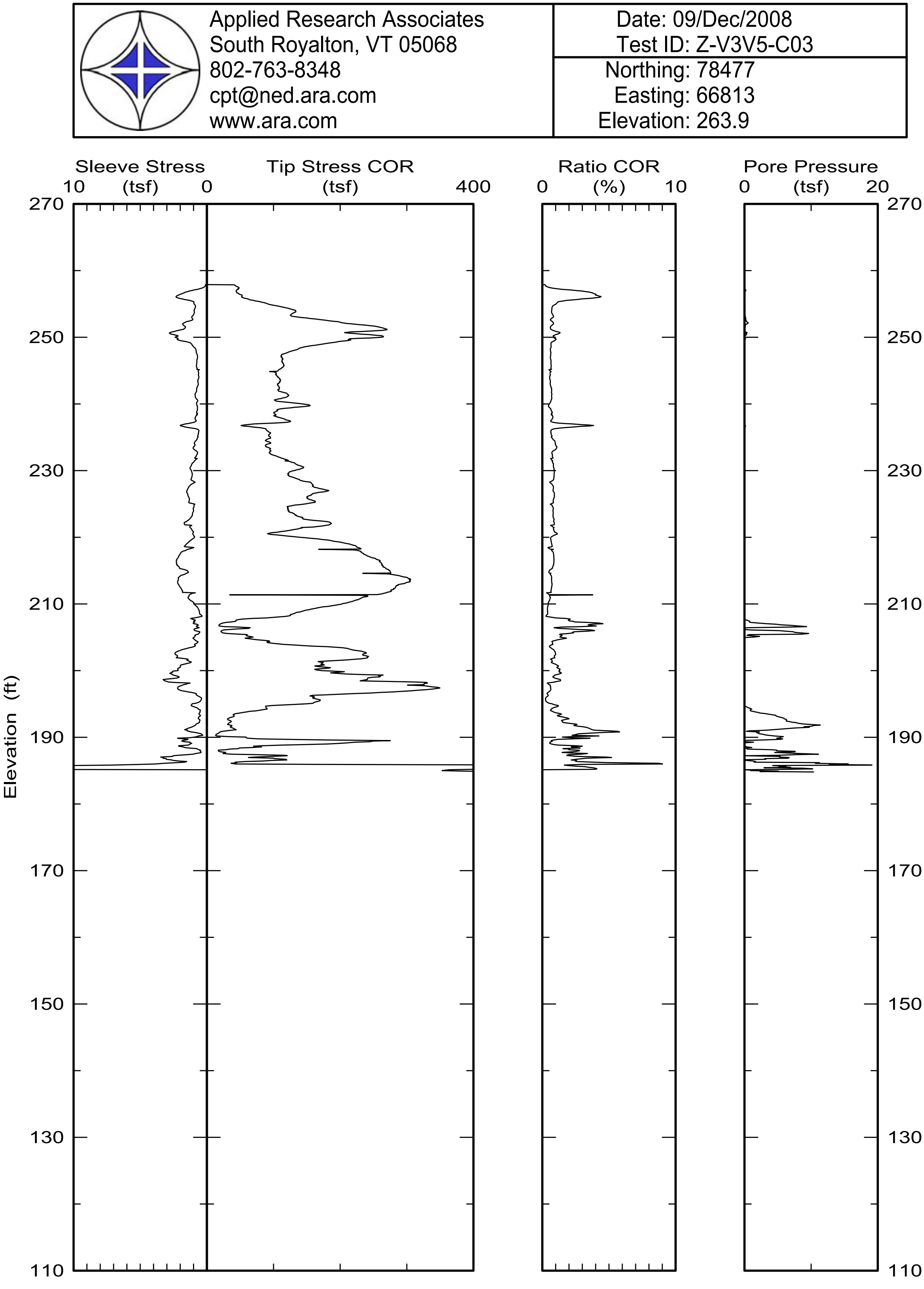
Test ID: Z-V3V5-C01
File: 216D0804C.ECP

Applied Research Associates South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Date: 10/Dec/2008 Test ID: Z-V3V5-C02 Northing: 78267 Easting: 66960 Elevation: 268.6



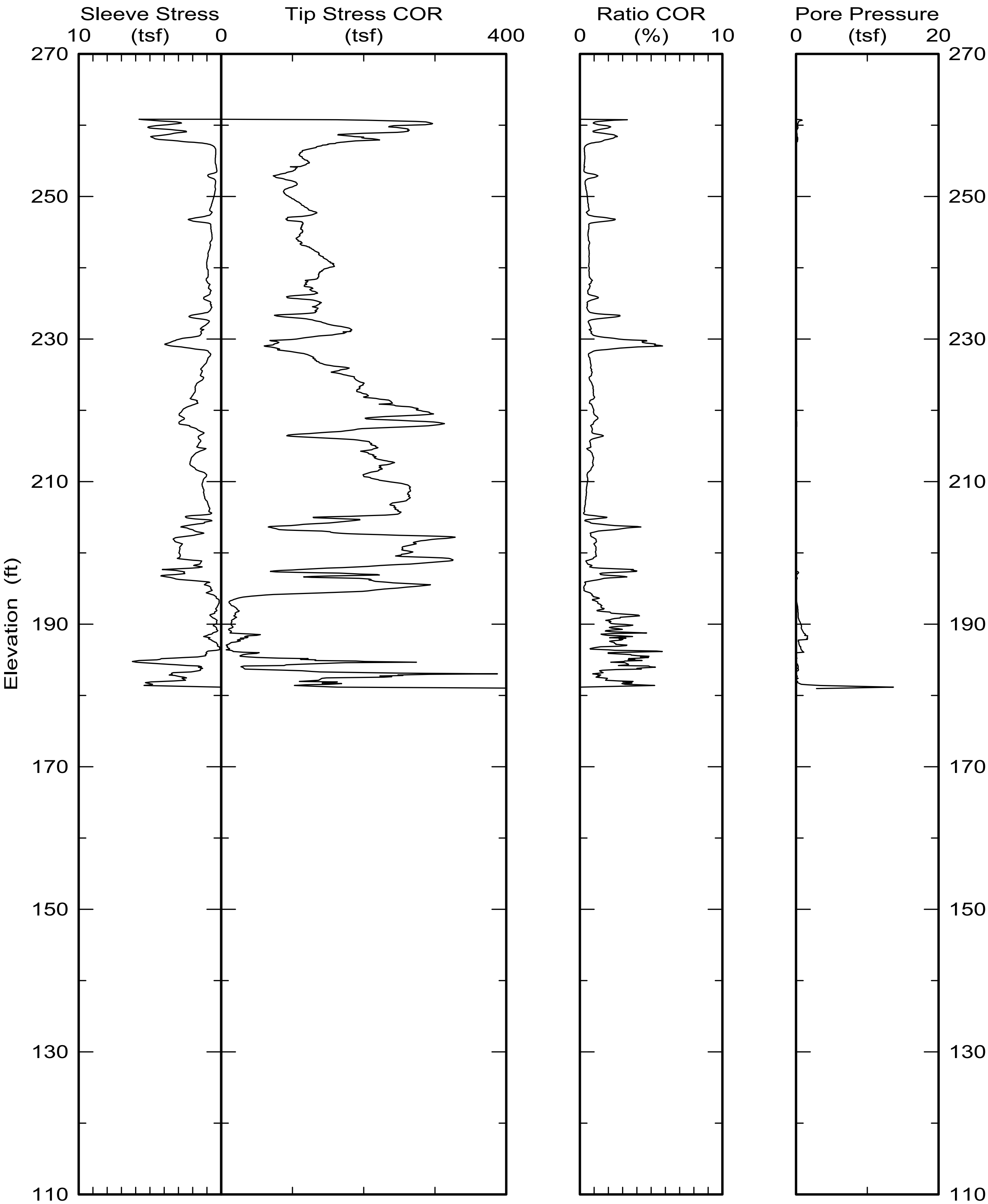
Maximum depth: 88.05 (ft)

Test ID: Z-V3V5-C02
File: 210D0804C.ECP



Test ID: Z-V3V5-C03
File: 209D0801C.ECP

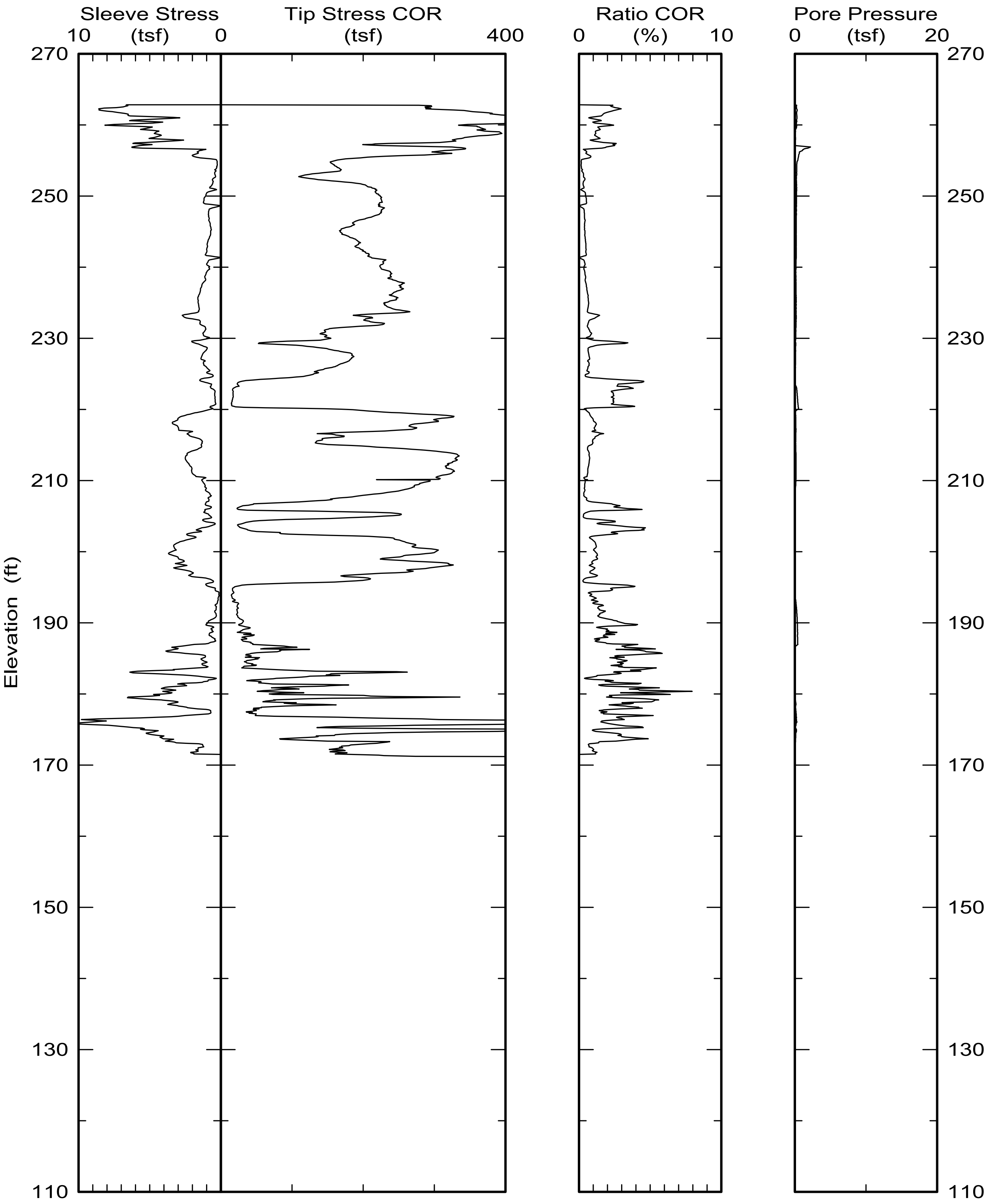
Applied Research Associates South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Date: 09/Dec/2008 Test ID: Z-V3V5-C04 Northing: 78405 Easting: 66836 Elevation: 266.8



Maximum depth: 85.86 (ft)

Test ID: Z-V3V5-C04
File: 209D0803C.ECP

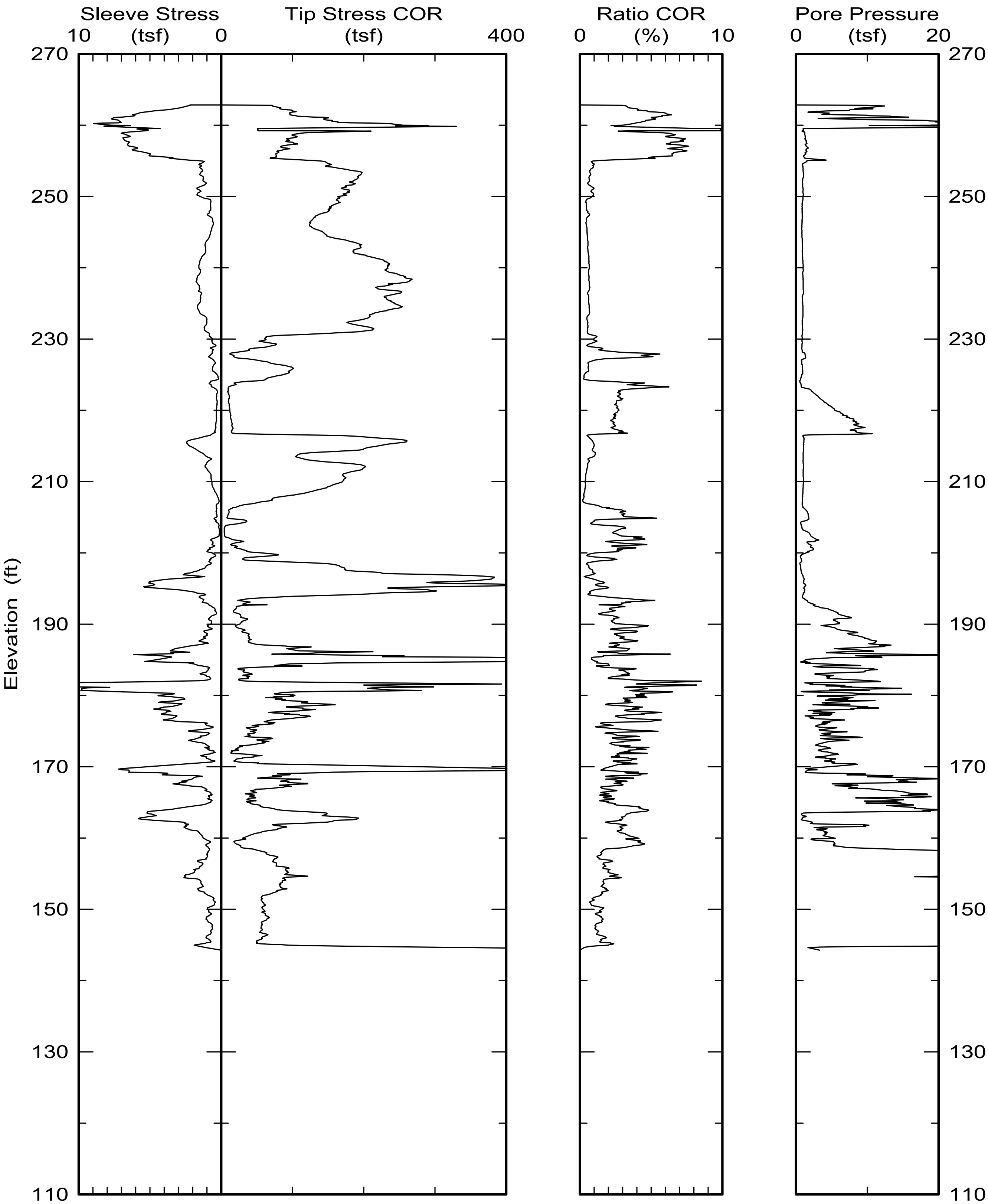
Applied Research Associates South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Date: 09/Dec/2008 Test ID: Z-V3V5-C05 Northing: 78325 Easting: 66863 Elevation: 268.8



Maximum depth: 97.64 (ft)

Test ID: Z-V3V5-C05
File: 209D0804C.ECP

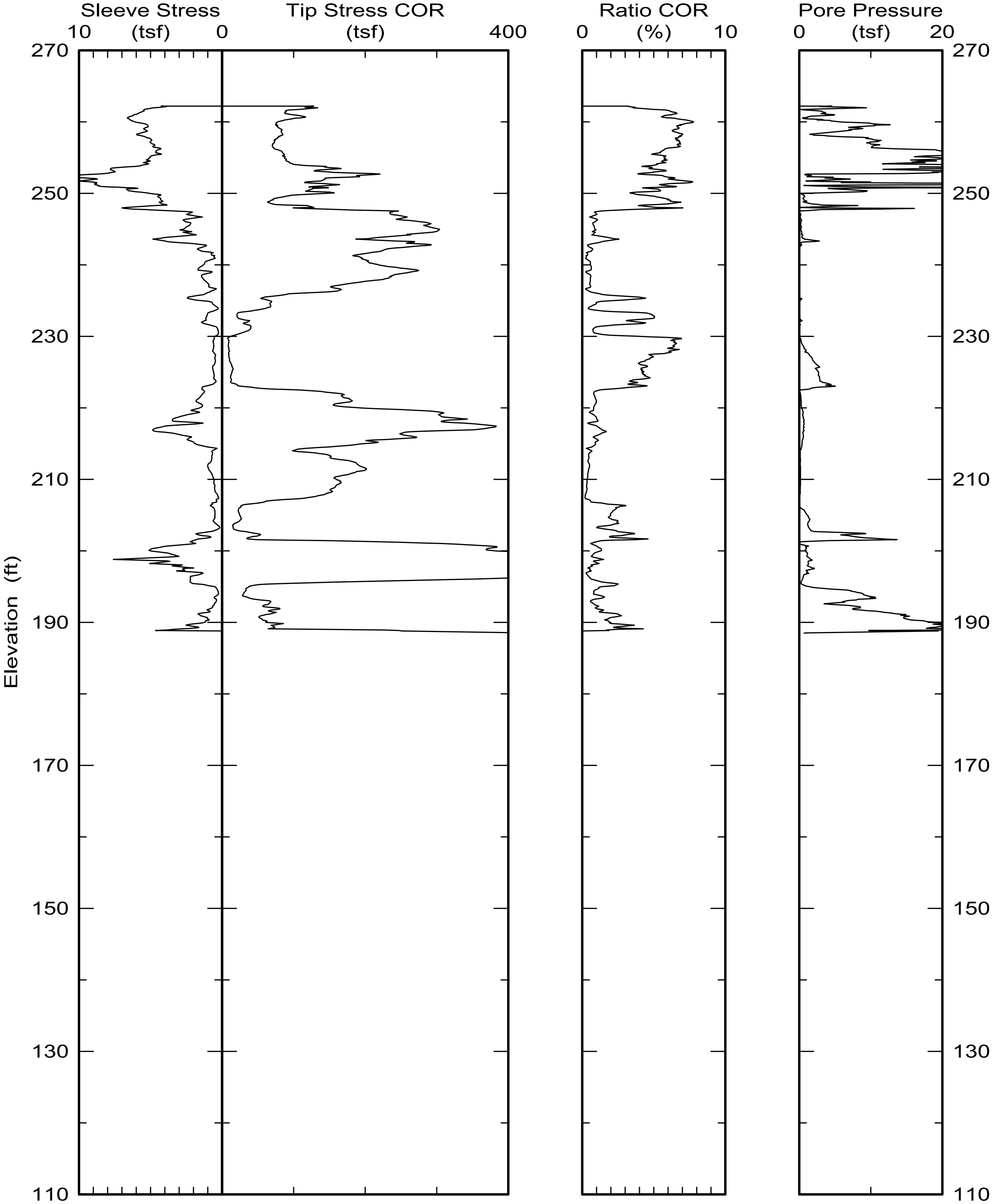
Applied Research Associates South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Date: 10/Dec/2008 Test ID: Z-V3V5-C06
	Northing: 78244 Easting: 66889 Elevation: 268.8



Maximum depth: 124.55 (ft)

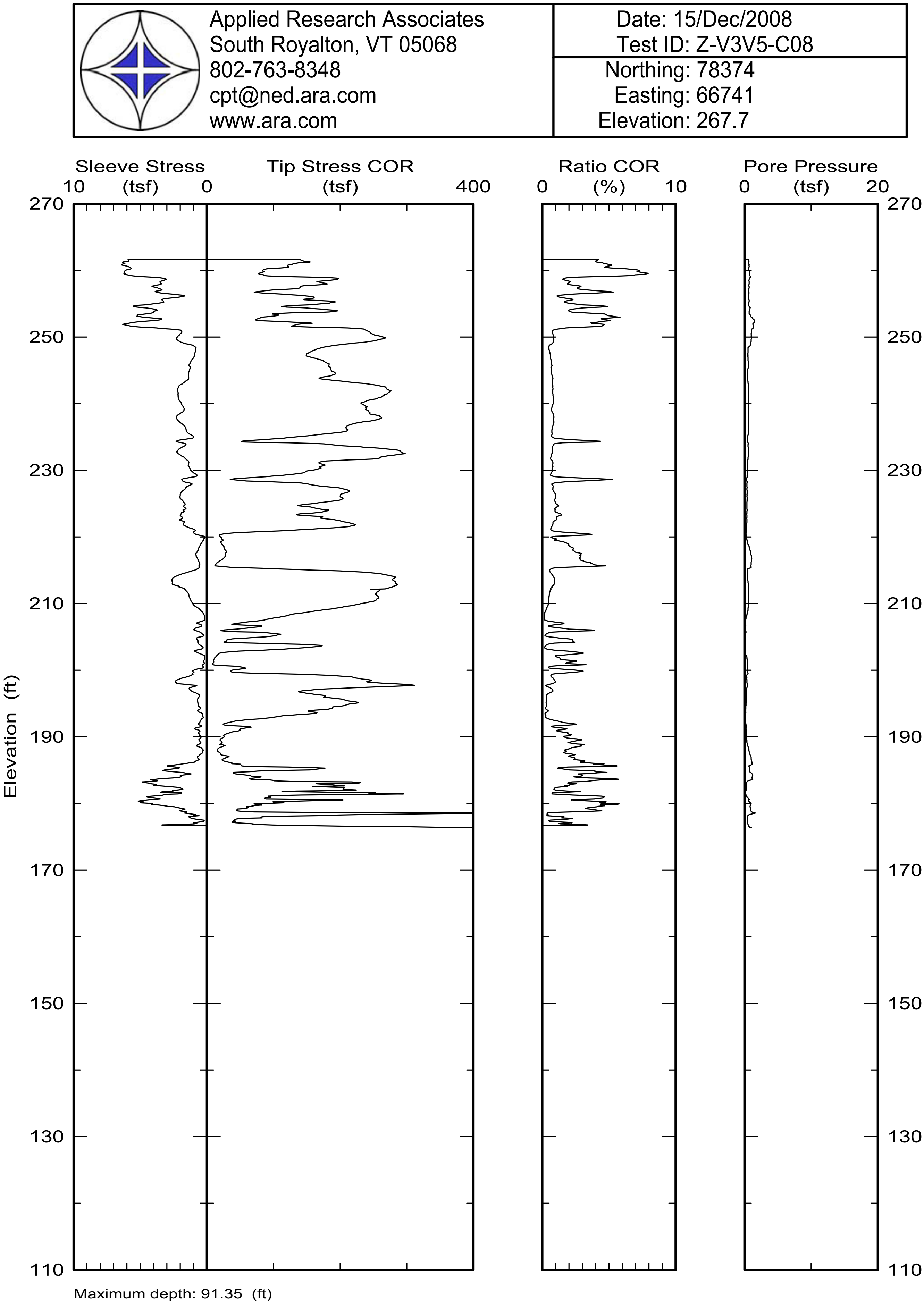
Test ID: Z-V3V5-C06
File: 210D0801C.ECP

Applied Research Associates South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Date: 10/Dec/2008 Test ID: Z-V3V5-C07 Northing: 78173 Easting: 66913 Elevation: 268.2



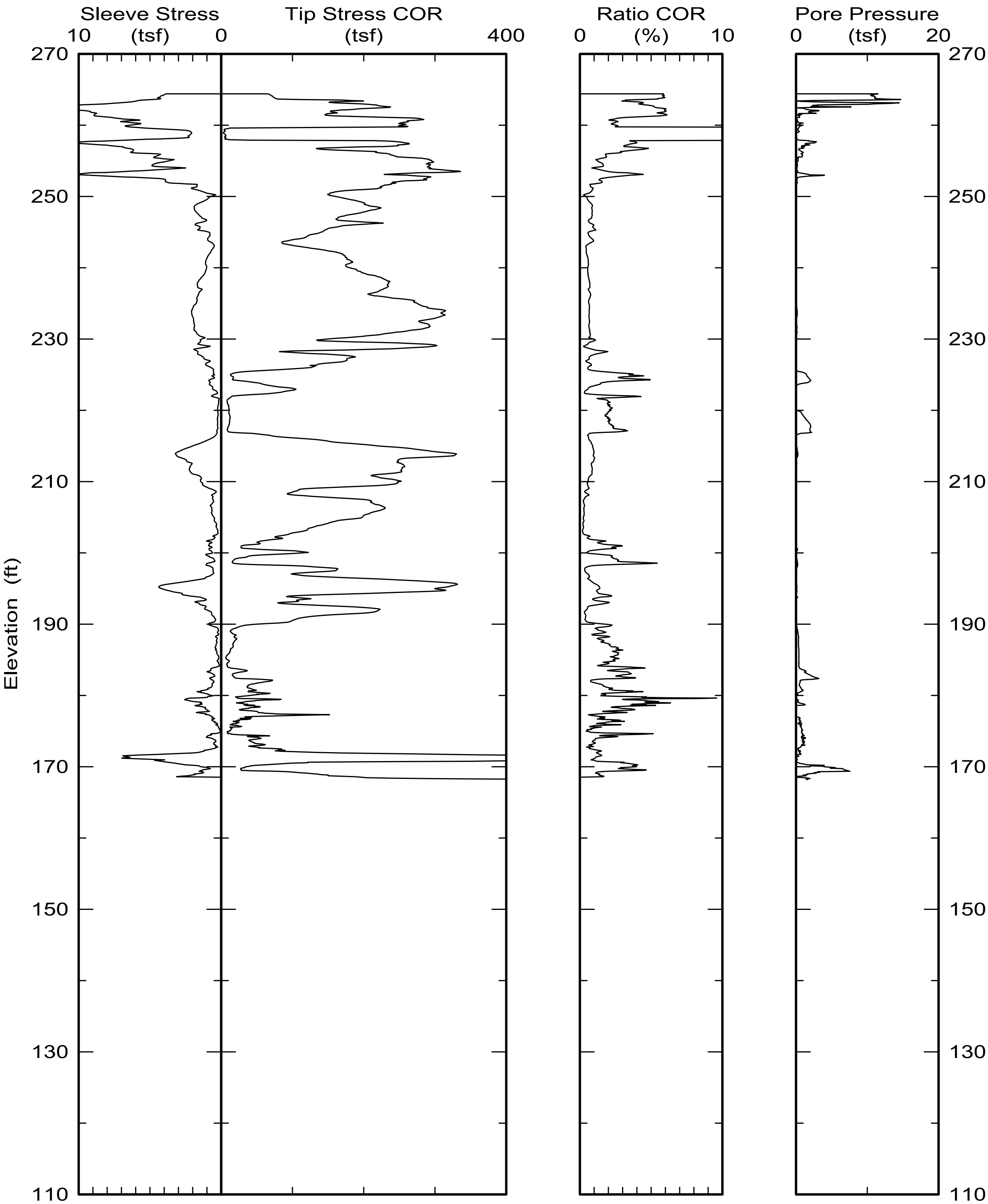
Maximum depth: 79.73 (ft)

Test ID: Z-V3V5-C07
File: 210D0803C.ECP



Test ID: Z-V3V5-C08
File: 215D0804C.ECP

Applied Research Associates South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Date: 16/Dec/2008 Test ID: Z-V3V5-C09 Northing: 78293 Easting: 66768 Elevation: 270.4

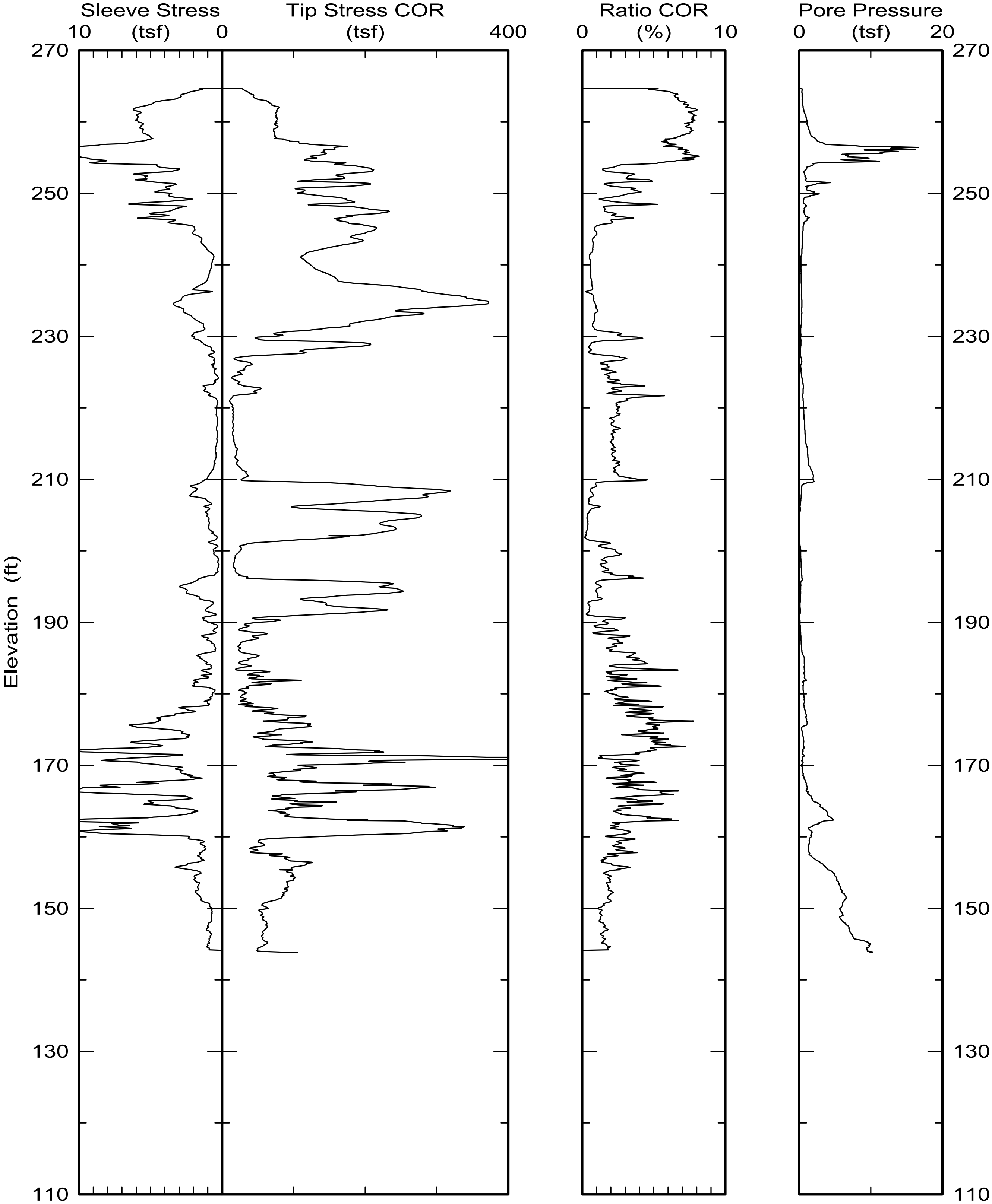


Maximum depth: 102.21 (ft)

Test ID: Z-V3V5-C09
File: 216D0801C.ECP

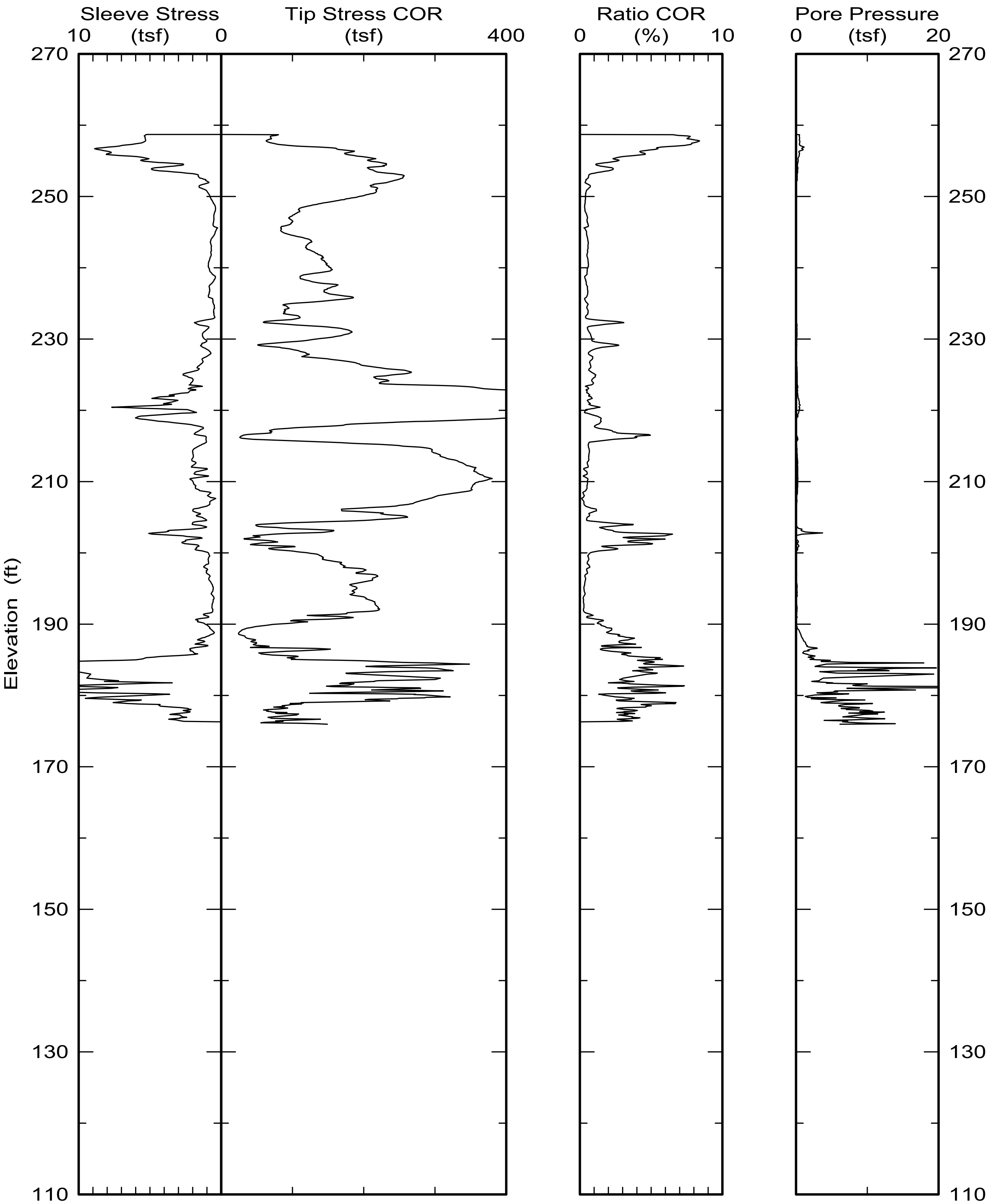
Applied Research Associates
South Royalton, VT 05068
802-763-8348
cpt@ned.ara.com
www.ara.com

Date: 10/Dec/2008
Test ID: Z-V3V5-C10
Northing: 78213
Easting: 66794
Elevation: 270.7



Maximum depth: 126.91 (ft)

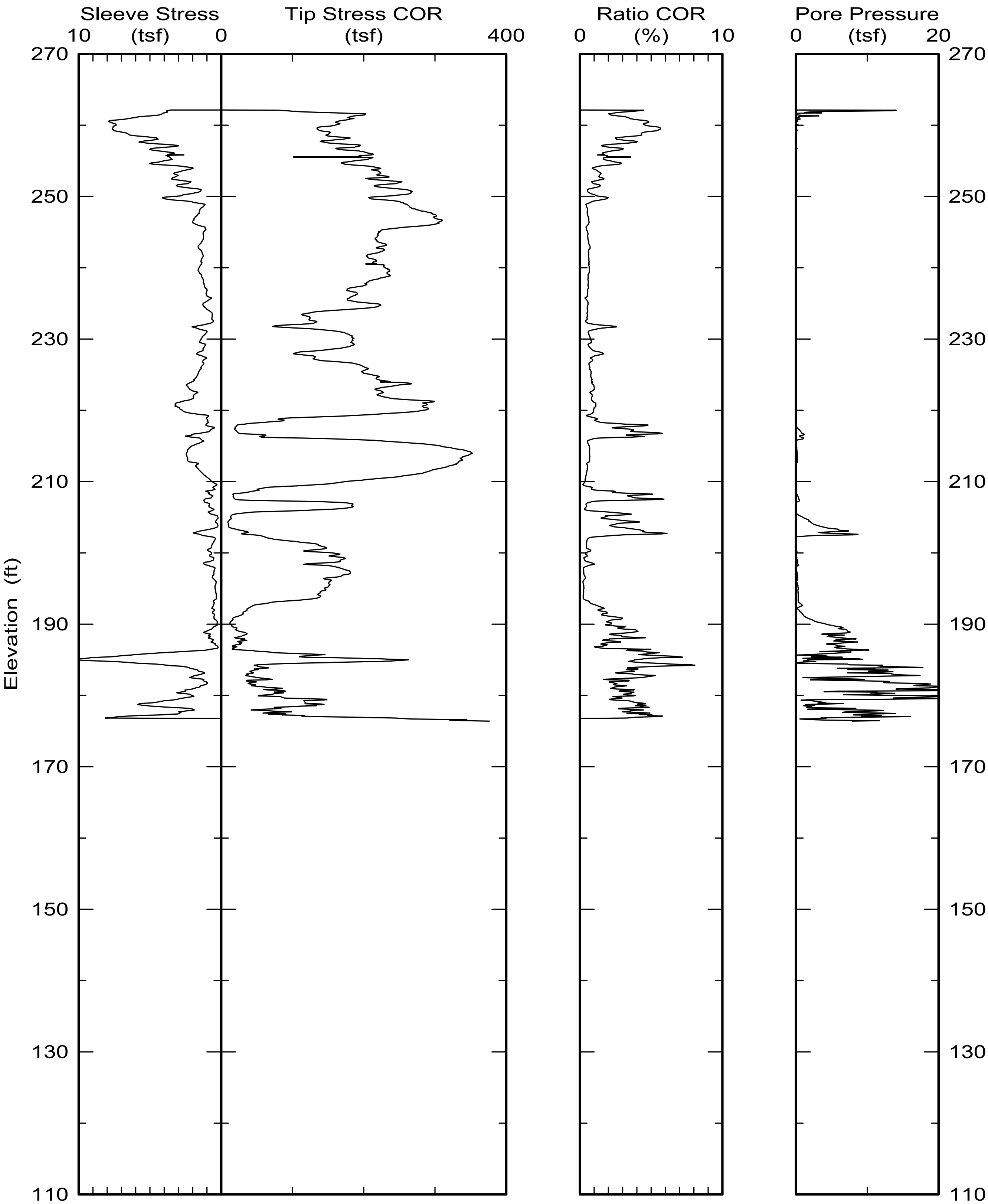
Applied Research Associates South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Date: 15/Dec/2008 Test ID: Z-V3V5-C11
	Northing: 78414 Easting: 66623 Elevation: 264.7



Maximum depth: 88.76 (ft)

Test ID: Z-V3V5-C11
File: 215D0802C.ECP

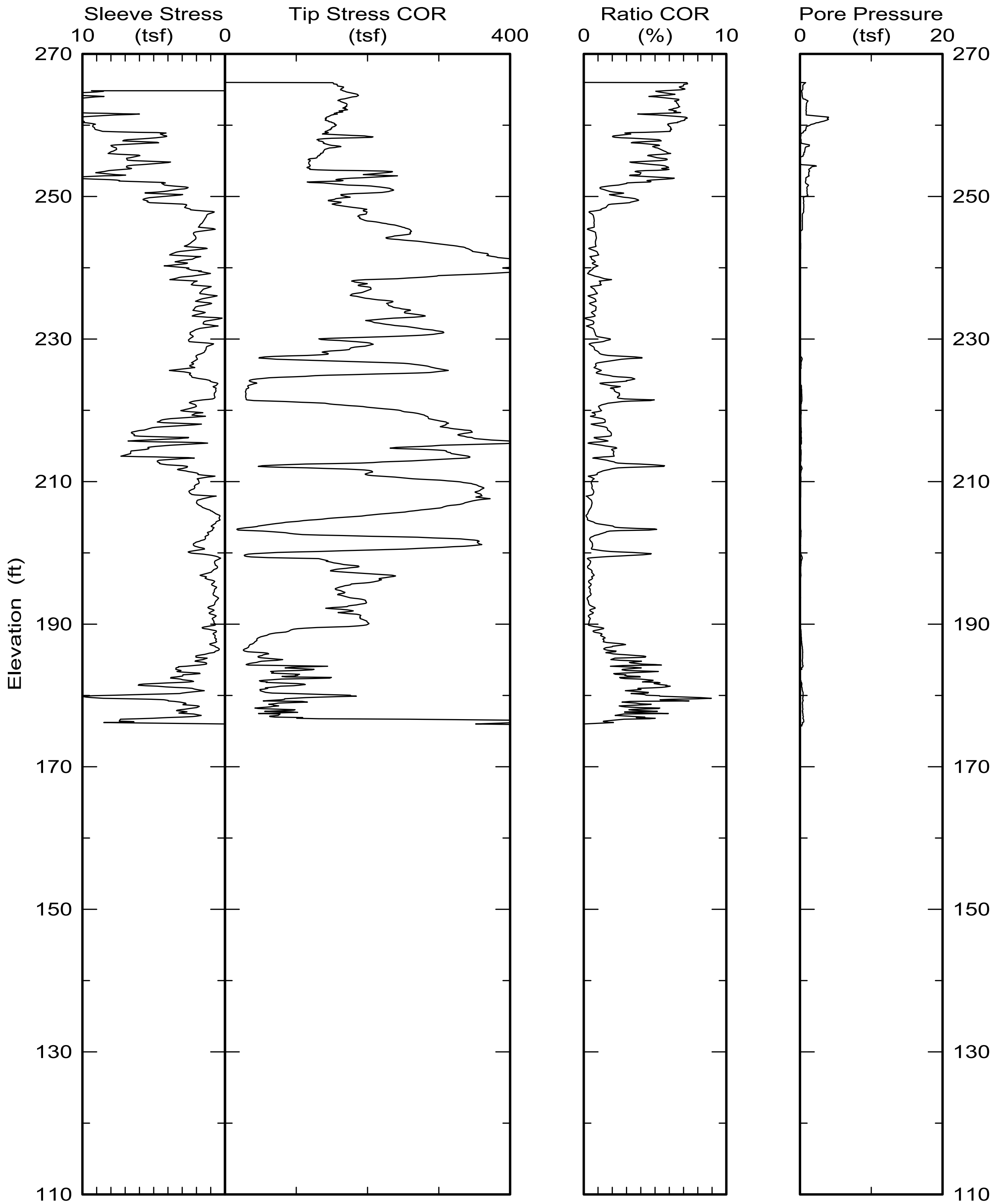
Applied Research Associates South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Date: 15/Dec/2008 Test ID: Z-V3V5-C12 Northing: 78343 Easting: 66646 Elevation: 268.1



Maximum depth: 91.71 (ft)

Test ID: Z-V3V5-C12
File: 215D0801C.ECP

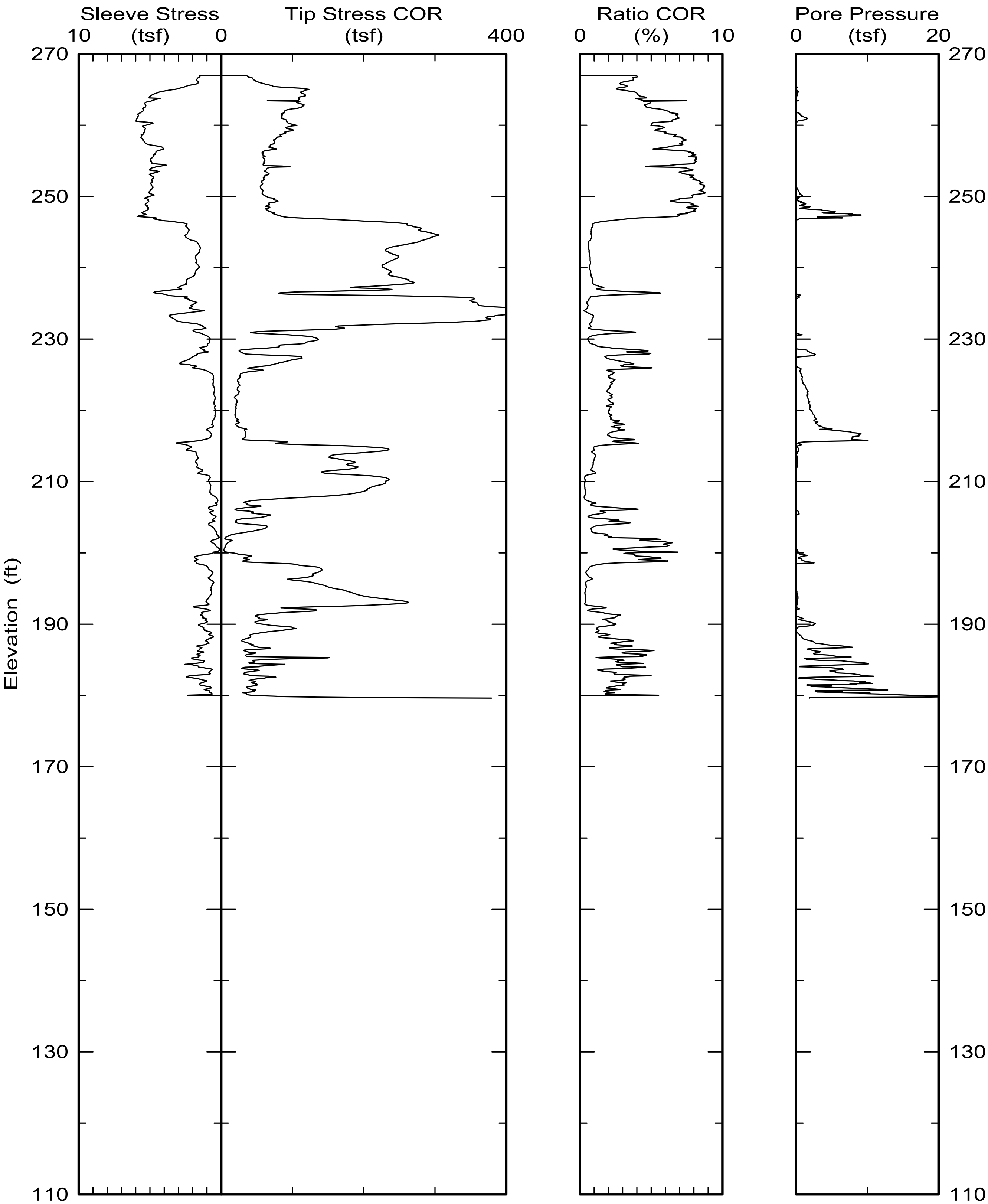
Applied Research Associates South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Date: 12/Dec/2008 Test ID: Z-V3V5-C13 Northing: 78262 Easting: 66673 Elevation: 272.0



Maximum depth: 96.32 (ft)

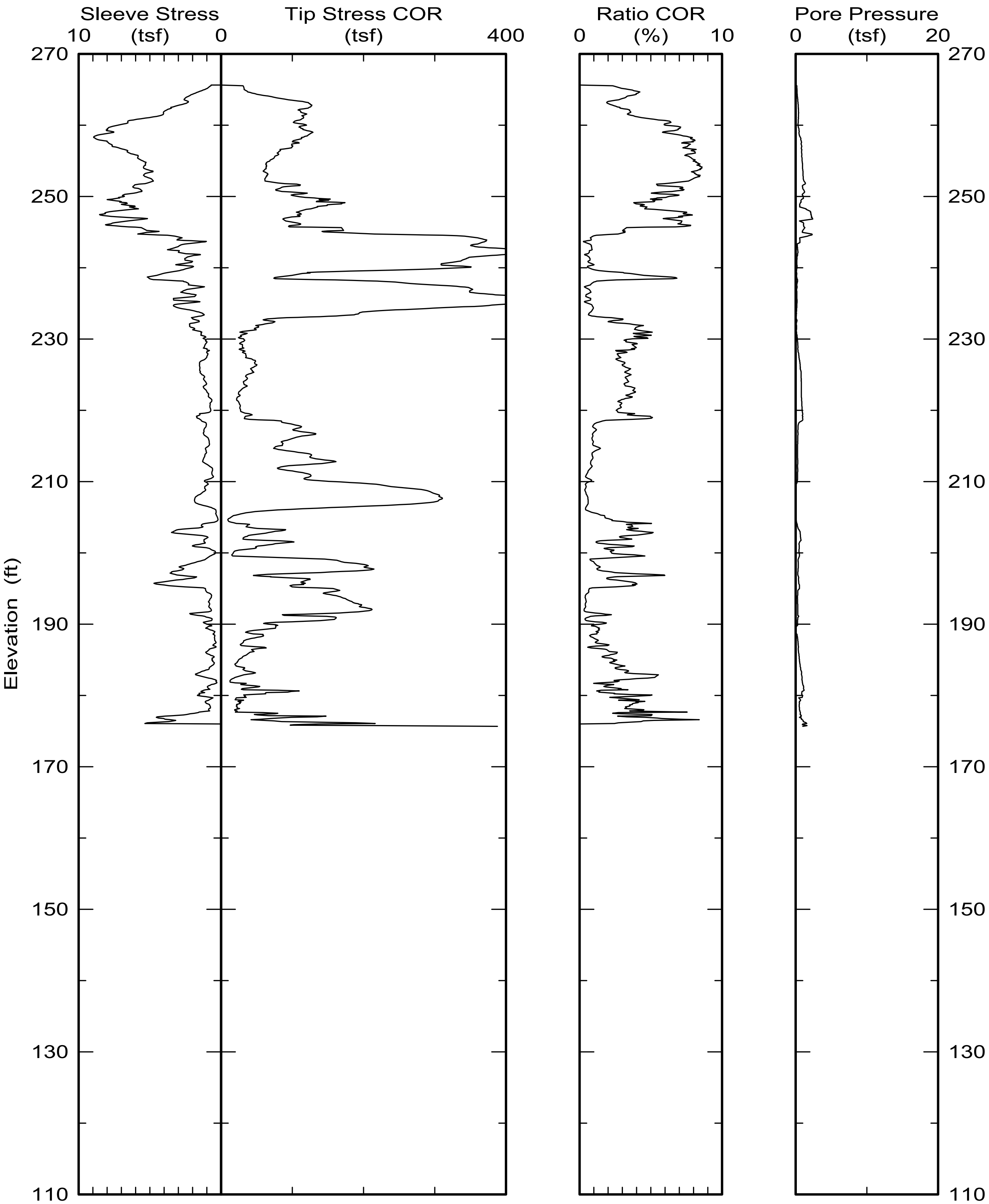
Test ID: Z-V3V5-C13
File: 212D0804C.ECP

Applied Research Associates South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Date: 12/Dec/2008 Test ID: Z-V3V5-C14 Northing: 78181 Easting: 66699 Elevation: 273.0



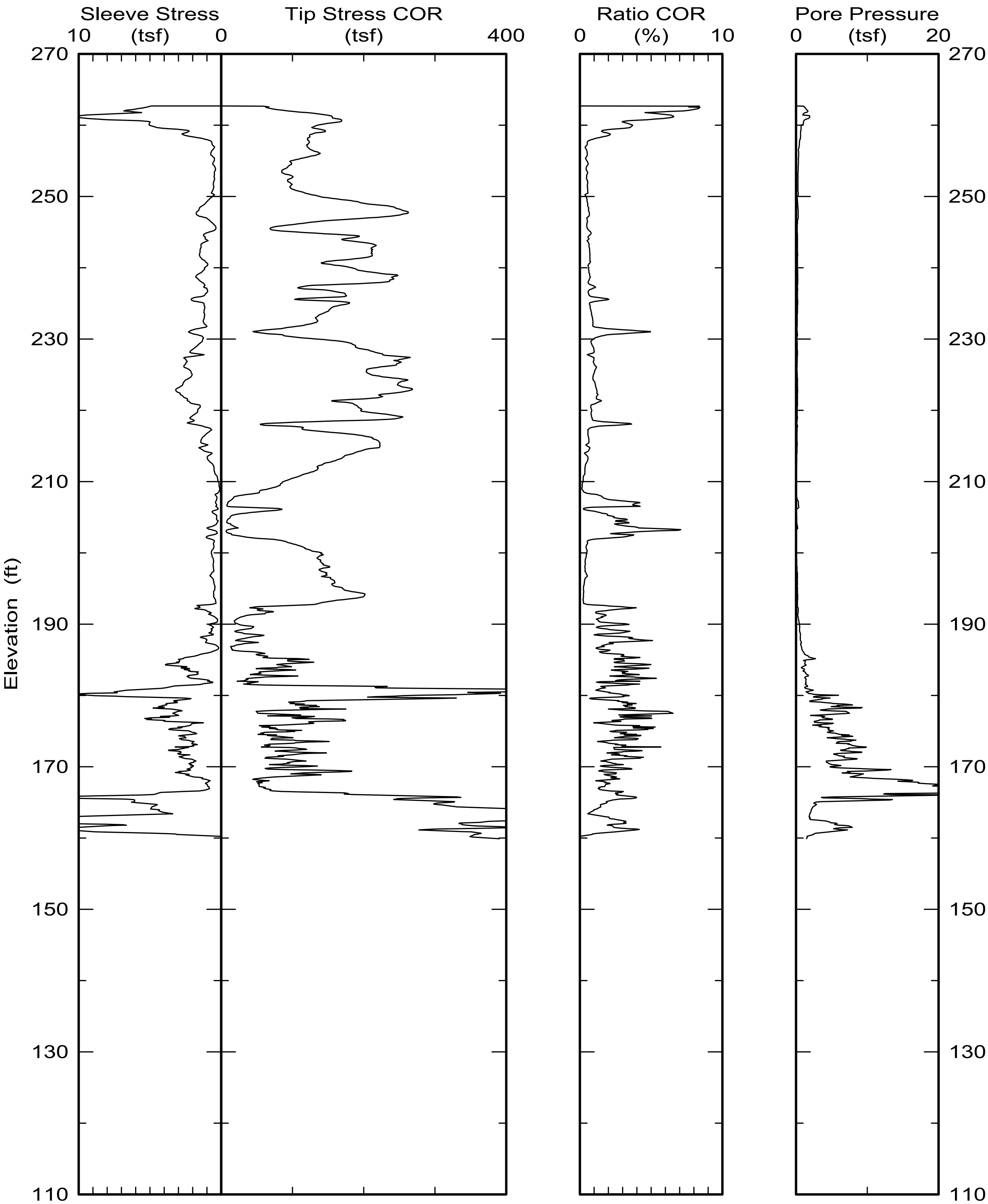
Maximum depth: 93.38 (ft)

Applied Research Associates South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Date: 12/Dec/2008 Test ID: Z-V3V5-C15 Northing: 78110 Easting: 66723 Elevation: 271.6



Maximum depth: 95.94 (ft)

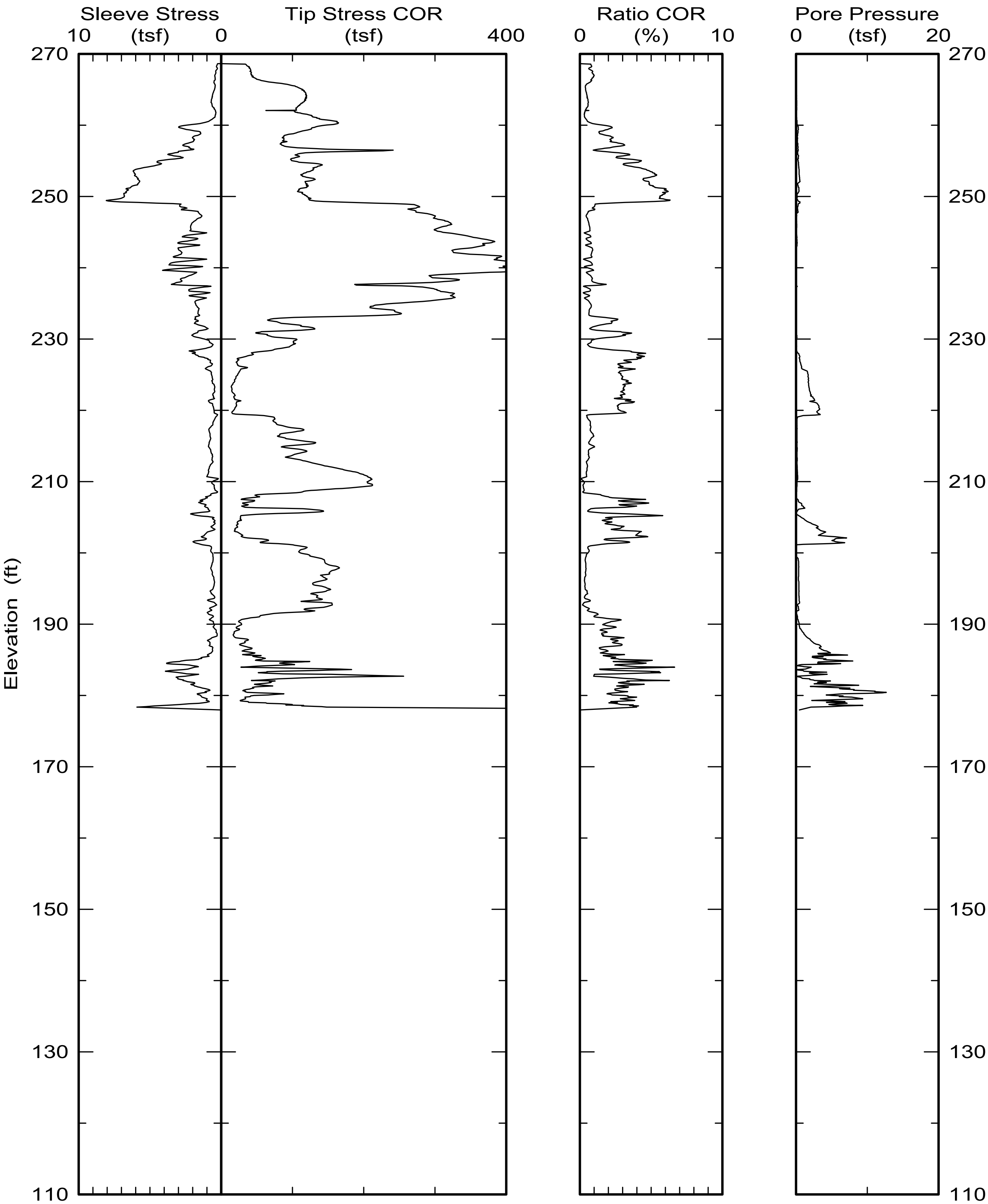
Applied Research Associates South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Date: 15/Dec/2008 Test ID: Z-V3V5-C16 Northing: 78319 Easting: 66575 Elevation: 268.7



Maximum depth: 108.80 (ft)

Test ID: Z-V3V5-C16
File: 215D0803C.ECP

Applied Research Associates South Royalton, VT 05068 802-763-8348 cpt@ned.ara.com www.ara.com	Date: 12/Dec/2008 Test ID: Z-V3V5-C17 Northing: 78158 Easting: 66628 Elevation: 274.6



Maximum depth: 96.64 (ft)

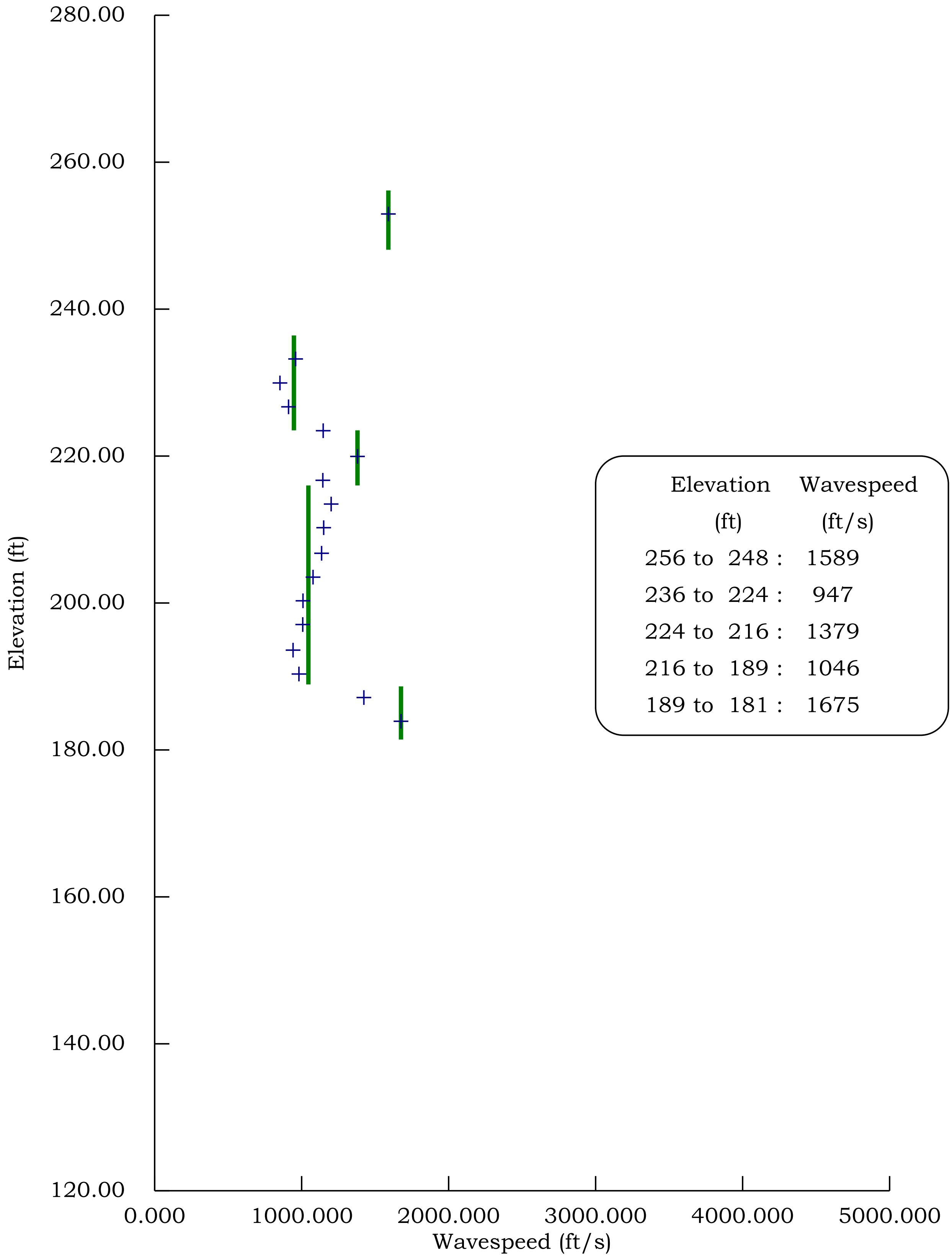
Test ID: Z-V3V5-C17
File: 212D0802C.ECP

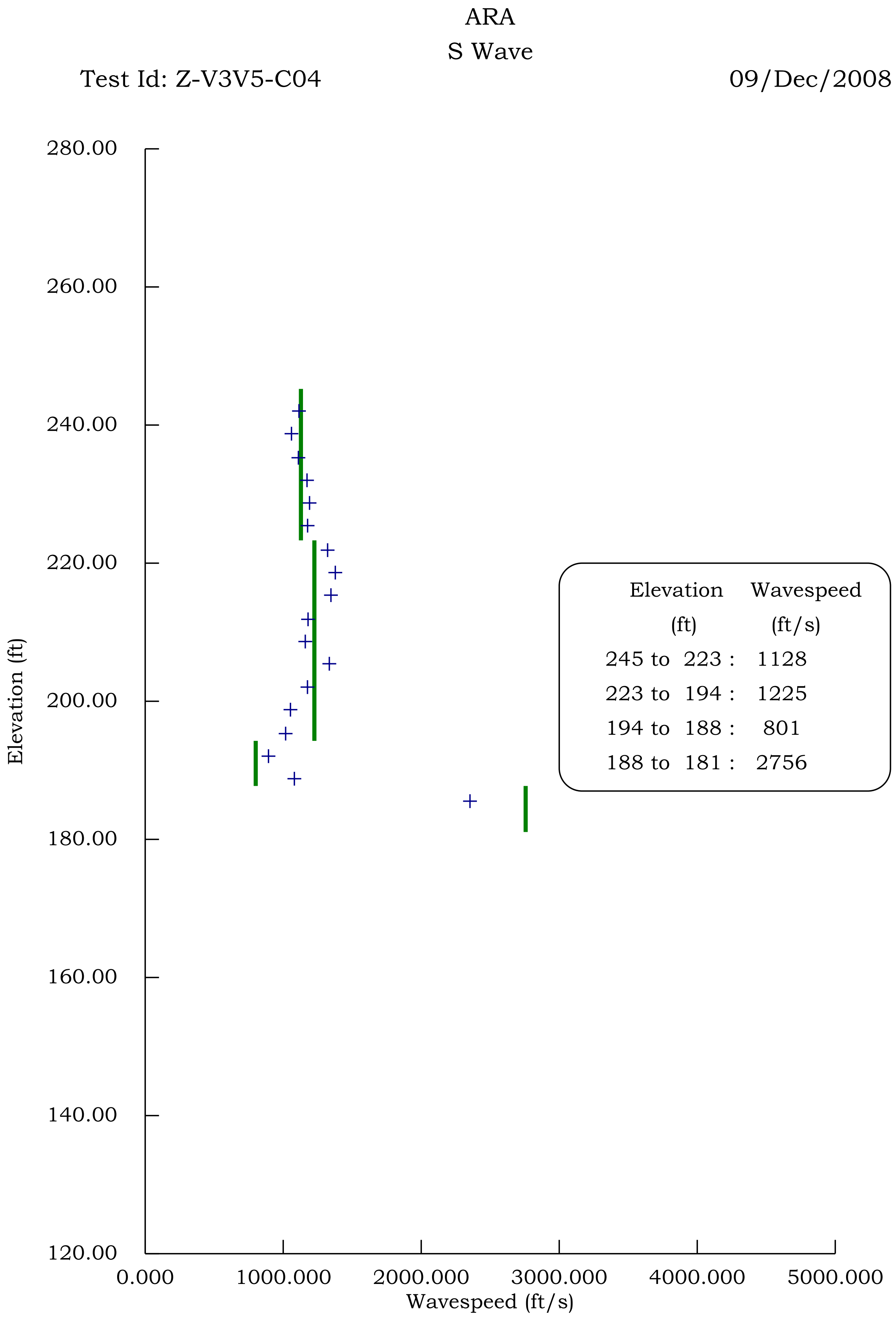
ARA

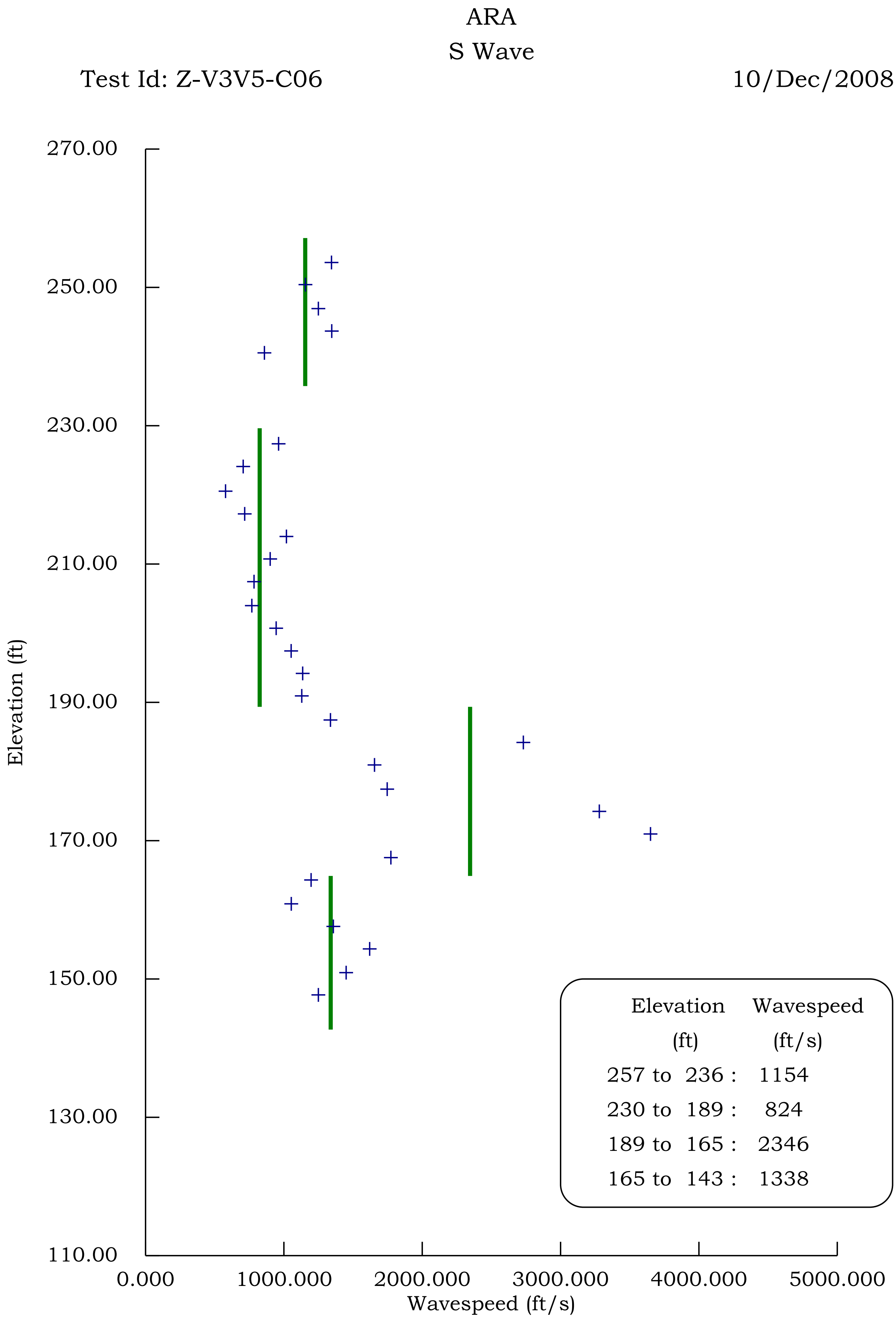
S Wave

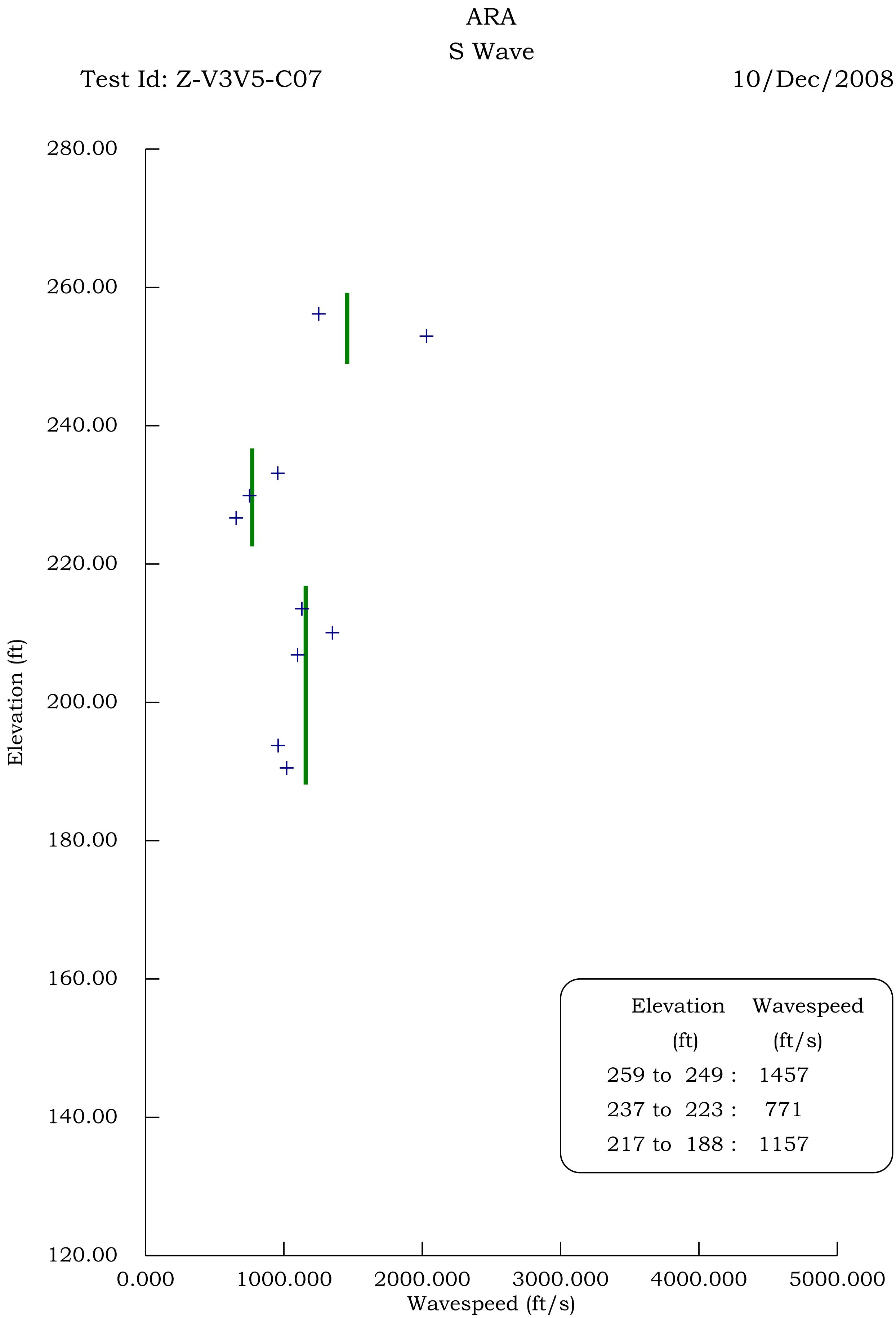
Test Id: Z-V3V5-C01

16/Dec/2008

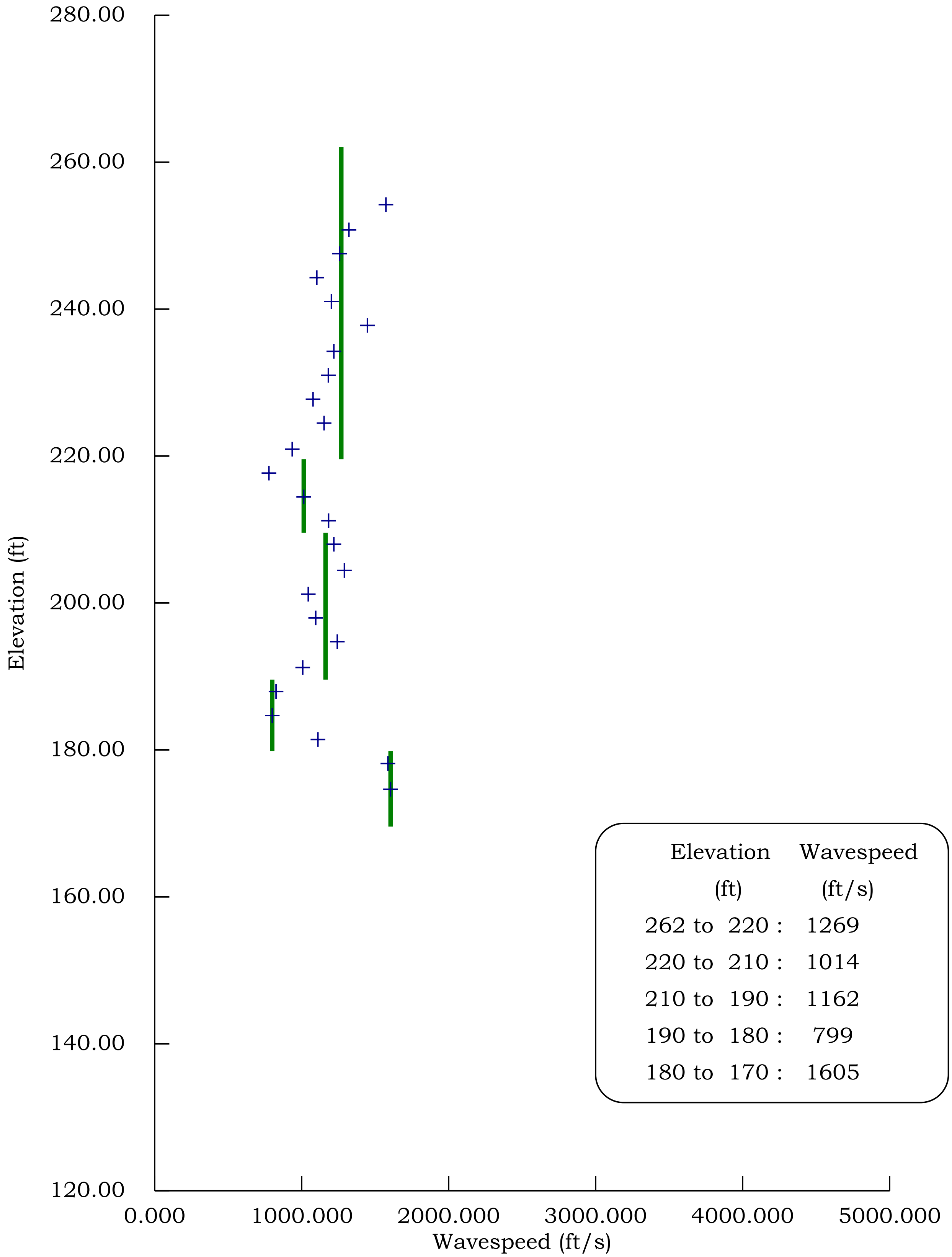



ARA
S Wave
Test Id: Z-V3V5-C04
09/Dec/2008
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
Elevation (ft)
0.000
1000.000
2000.000
3000.000
4000.000
5000.000
Wavespeed (ft/s)
Elevation (ft) Wavespeed (ft/s)
245 to 223 : 1128
223 to 194 : 1225
194 to 188 : 801
188 to 181 : 2756


ARA
S Wave
Test Id: Z-V3V5-C06
10/Dec/2008
Elevation (ft)
270.00
250.00
230.00
210.00
190.00
170.00
150.00
130.00
110.00
0.000
1000.000
2000.000
3000.000
4000.000
5000.000
Wavespeed (ft/s)
Elevation (ft) Wavespeed (ft/s)
257 to 236 : 1154
230 to 189 : 824
189 to 165 : 2346
165 to 143 : 1338

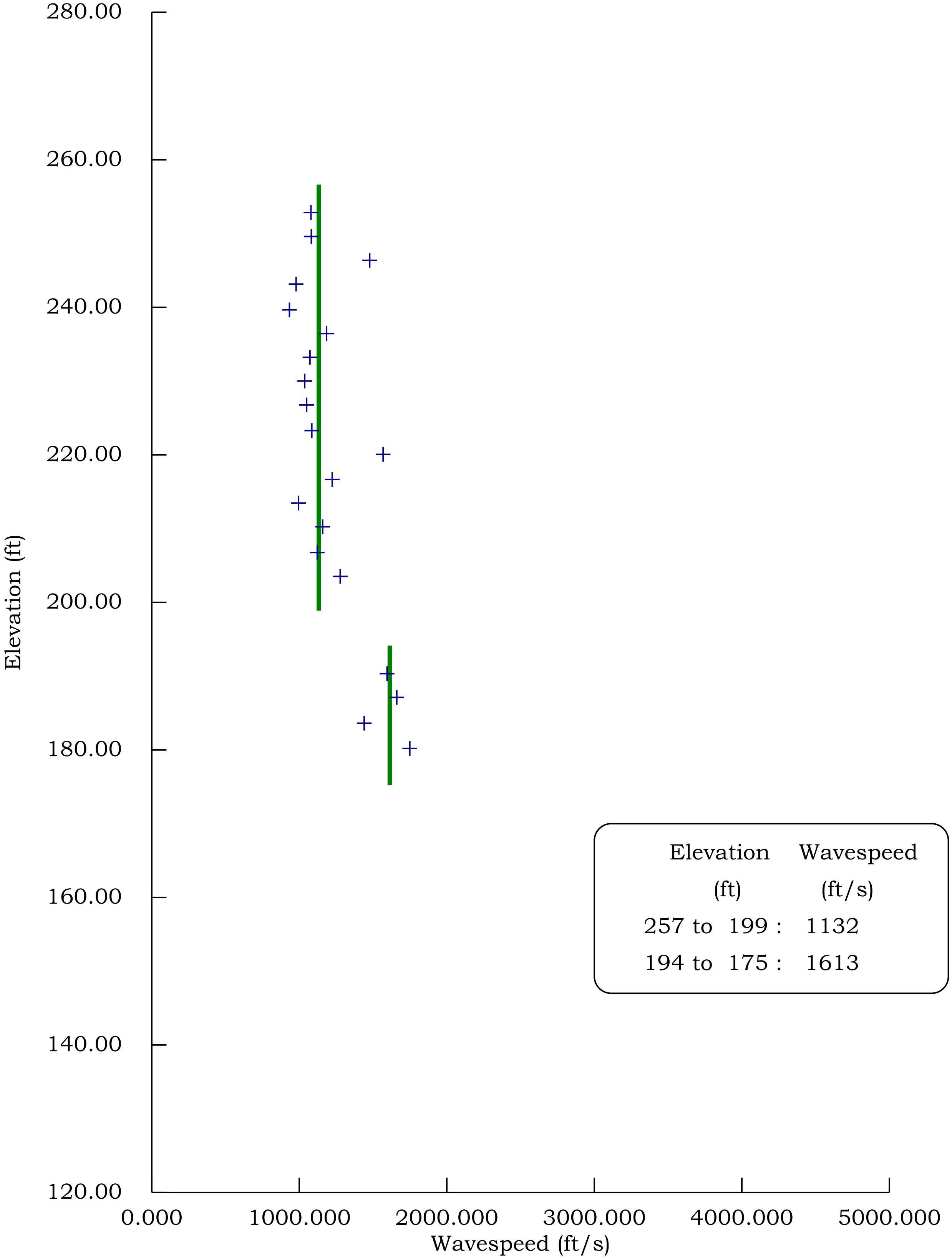

ARA
S Wave
Test Id: Z-V3V5-C07
10/Dec/2008
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
Elevation (ft)
0.000
1000.000
2000.000
3000.000
4000.000
5000.000
Wavespeed (ft/s)
Elevation (ft)
Wavespeed (ft/s)
259 to 249 : 1457
237 to 223 : 771
217 to 188 : 1157

ARA
S Wave
Test Id: Z-V3V5-C09 16/Dec/2008

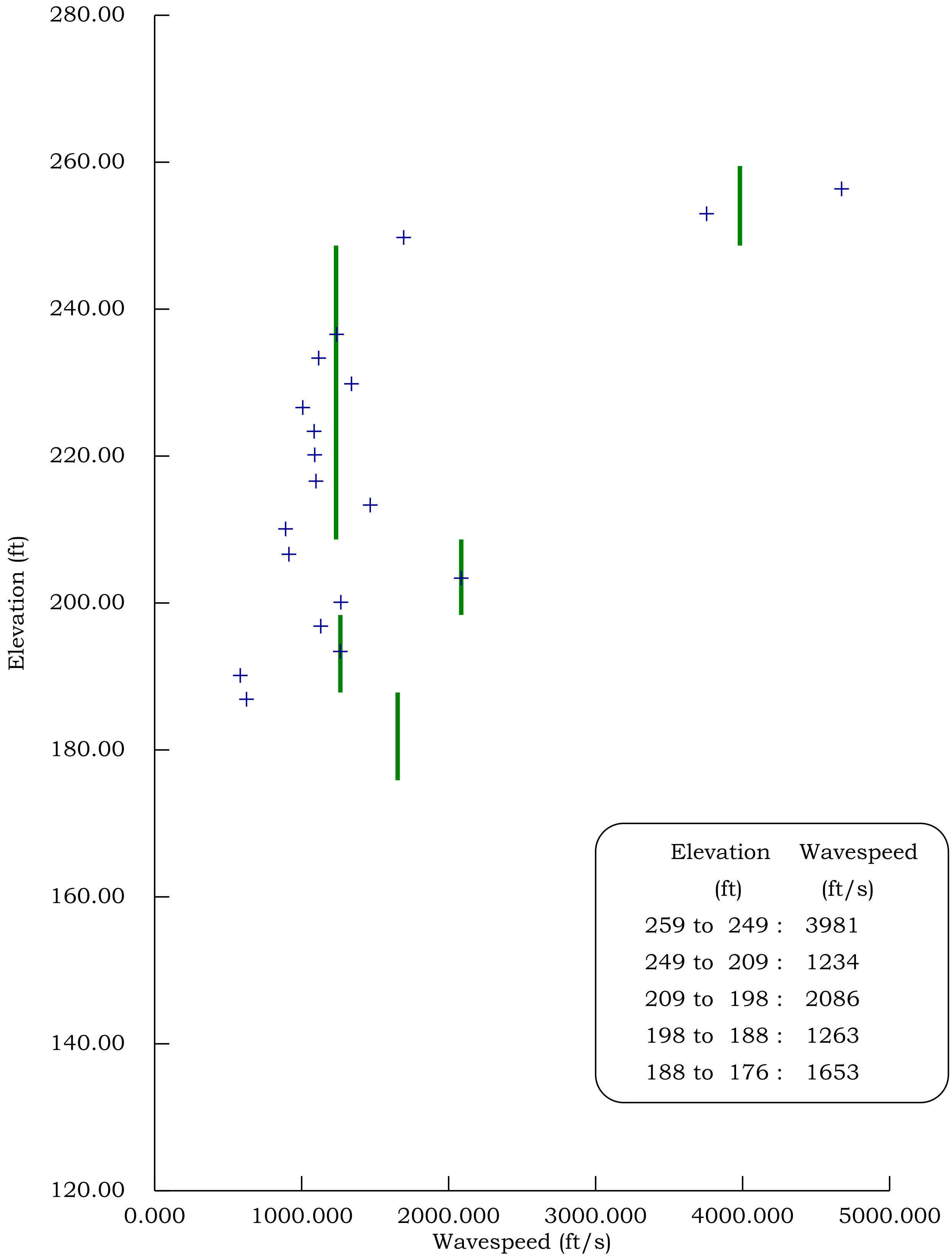


Elevation (ft)	Wavespeed (ft/s)
262 to 220 :	1269
220 to 210 :	1014
210 to 190 :	1162
190 to 180 :	799
180 to 170 :	1605

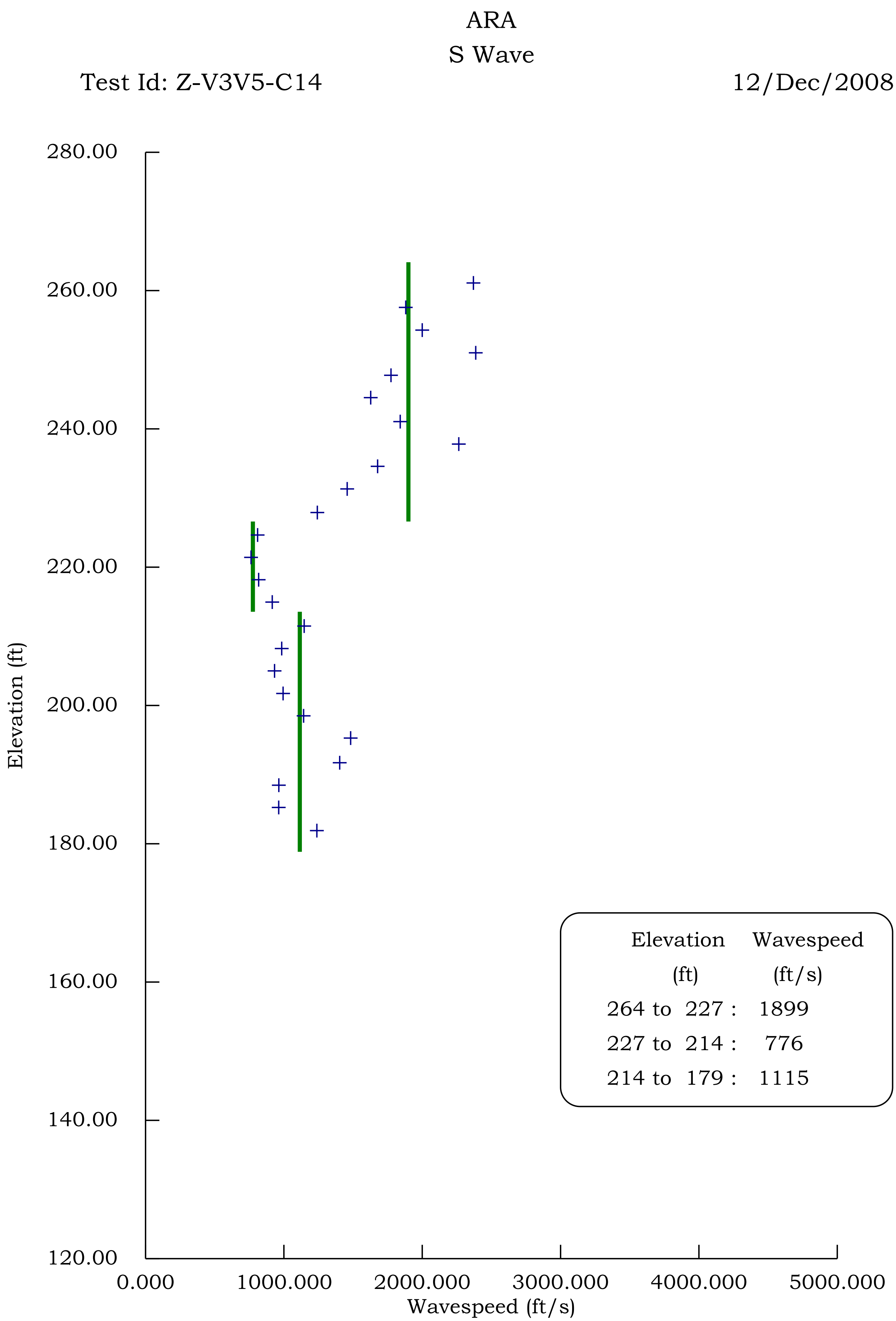
ARA
S Wave
Test Id: Z-V3V5-C11 15/Dec/2008

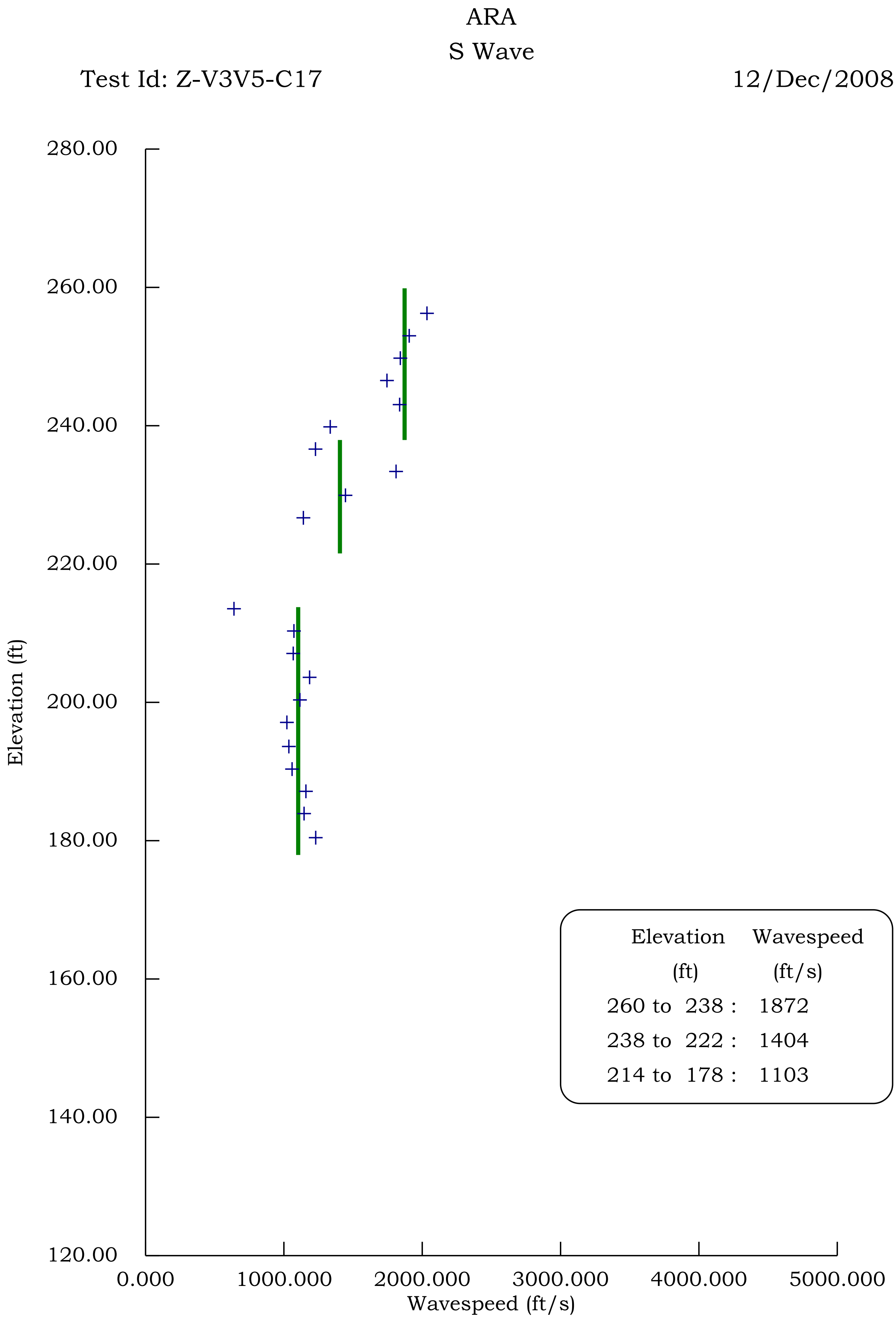


ARA
S Wave
Test Id: Z-V3V5-C12 15/Dec/2008

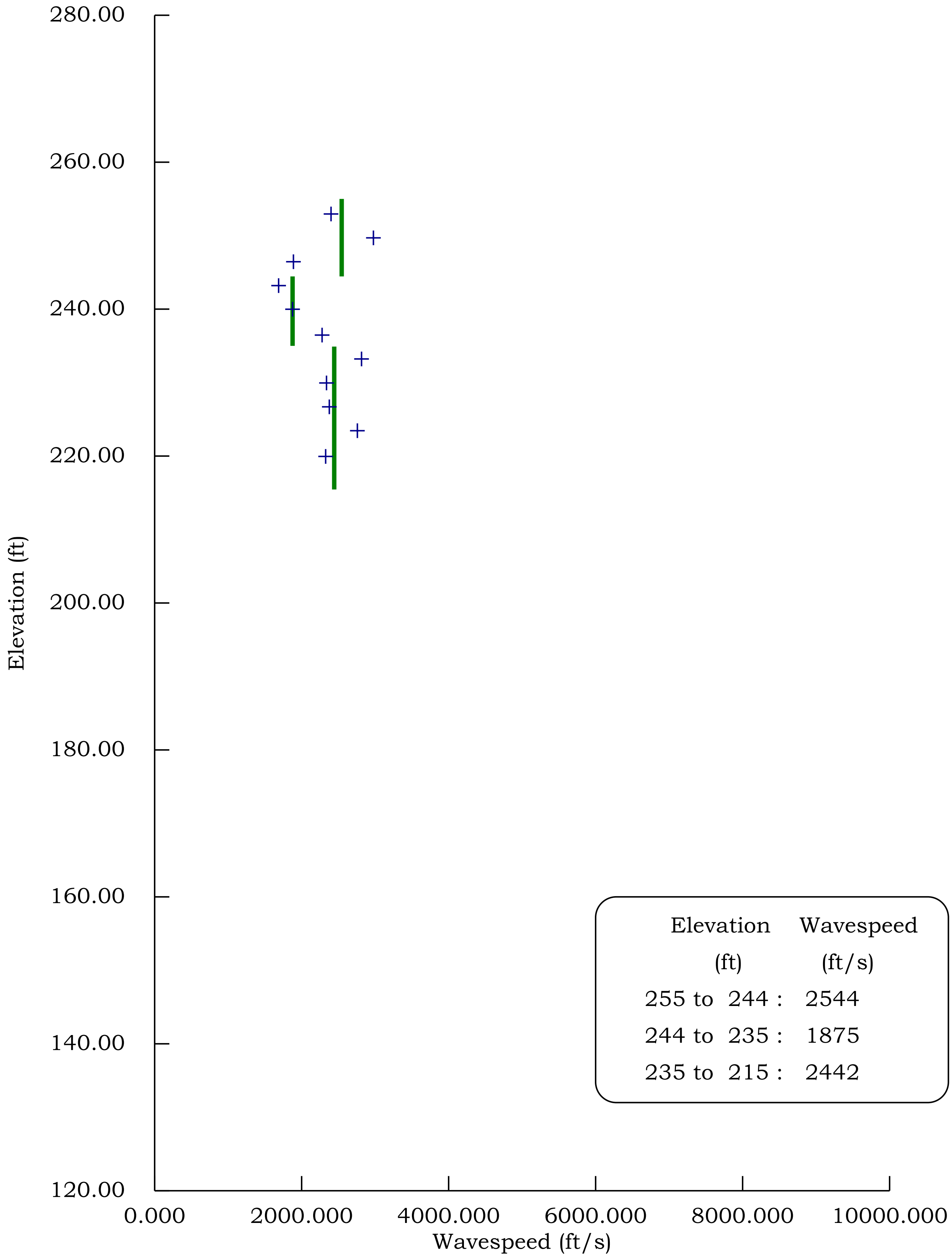


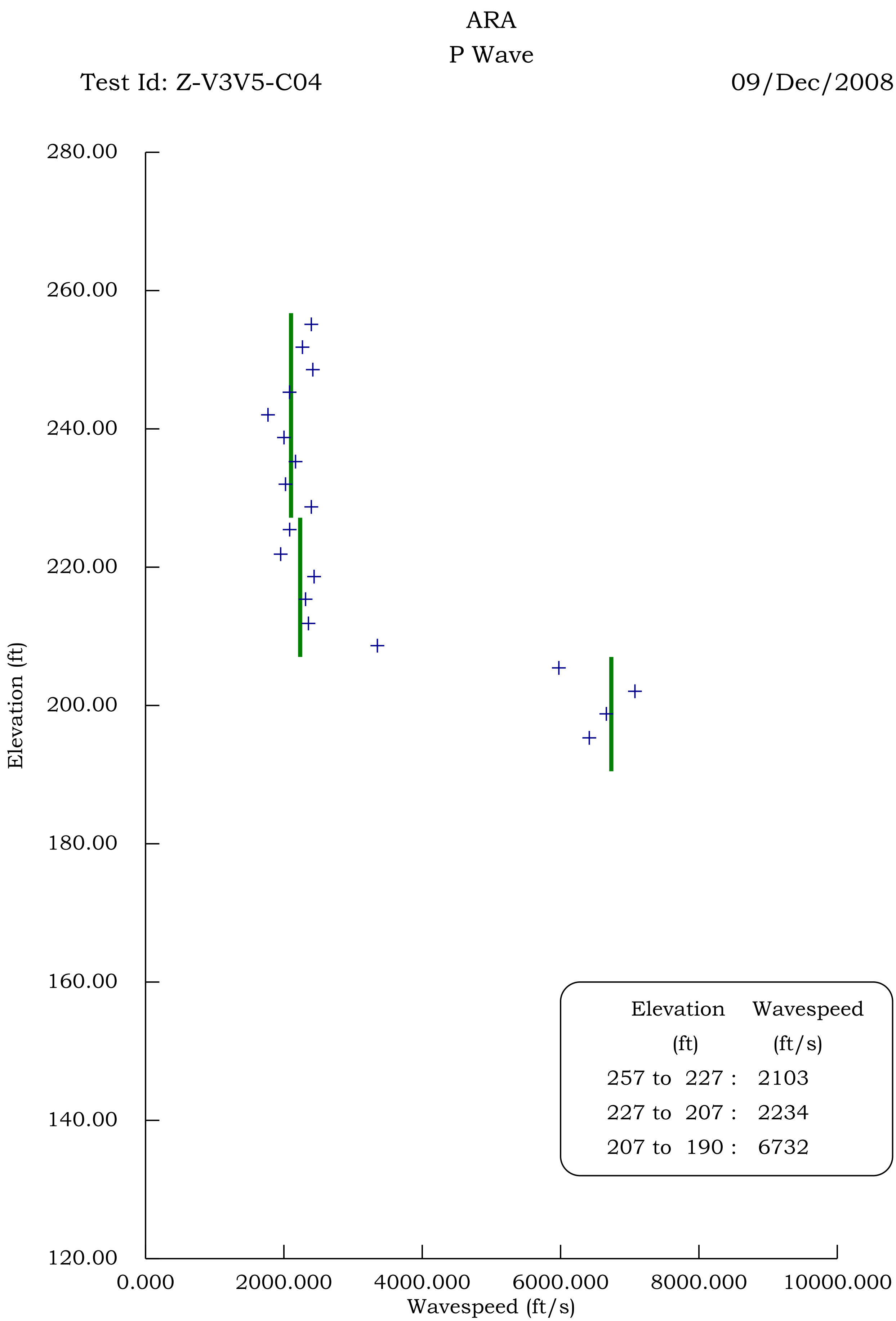
Elevation (ft)	Wavespeed (ft/s)
259 to 249 :	3981
249 to 209 :	1234
209 to 198 :	2086
198 to 188 :	1263
188 to 176 :	1653

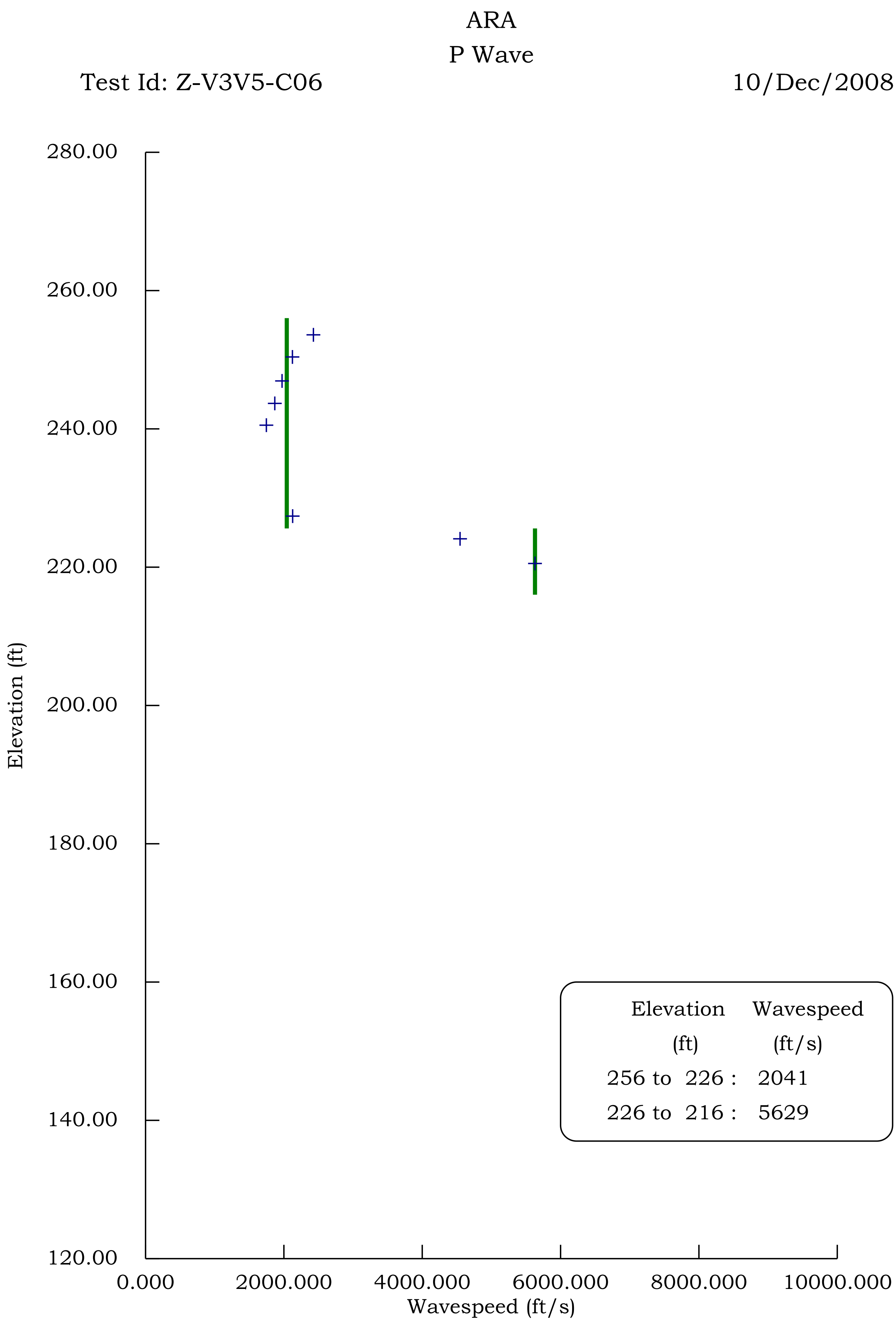

ARA
S Wave
Test Id: Z-V3V5-C14
12/Dec/2008
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
Elevation (ft)
0.000
1000.000
2000.000
3000.000
4000.000
5000.000
Wavespeed (ft/s)
Elevation (ft) Wavespeed (ft/s)
264 to 227 : 1899
227 to 214 : 776
214 to 179 : 1115

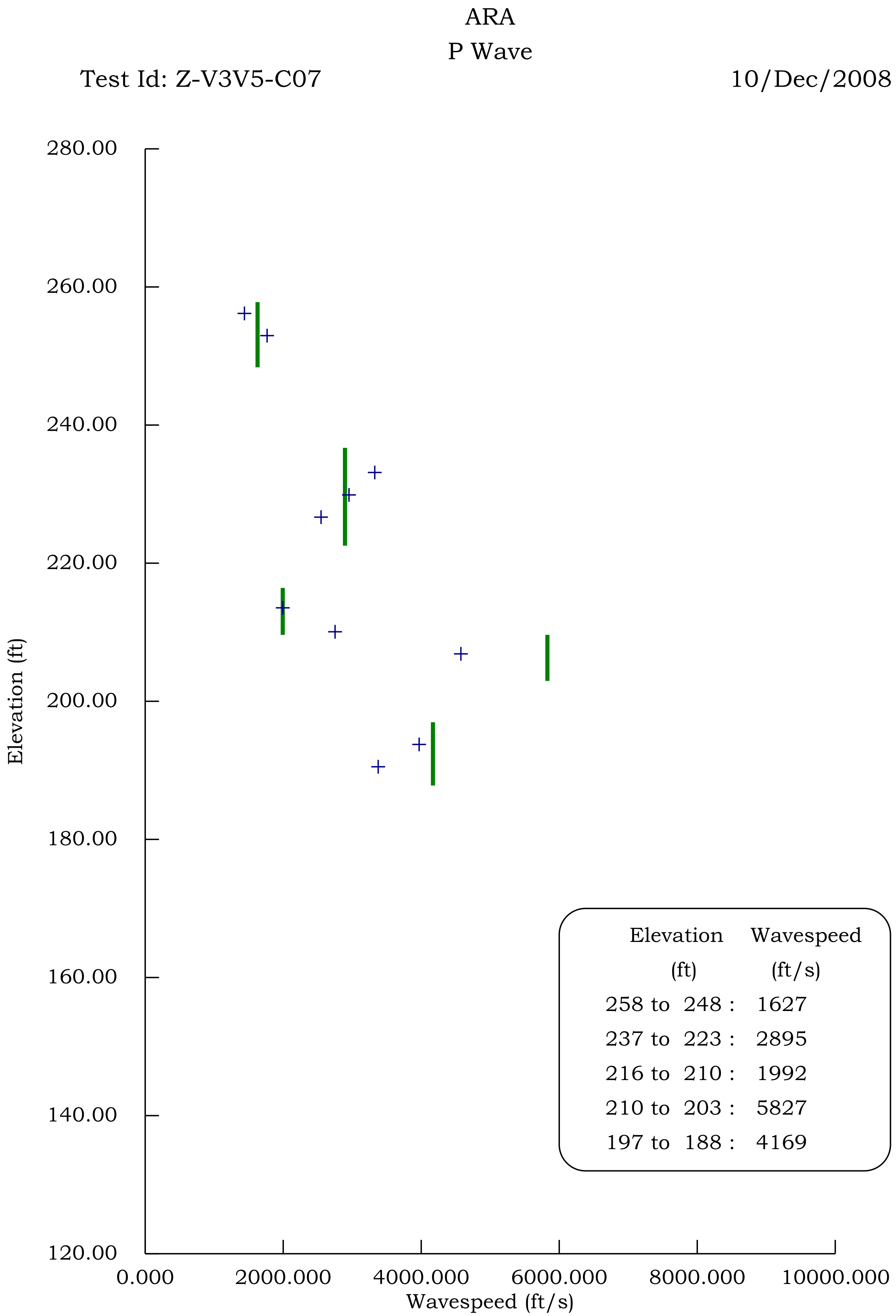

ARA
S Wave
Test Id: Z-V3V5-C17
12/Dec/2008
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
Elevation (ft)
0.000
1000.000
2000.000
3000.000
4000.000
5000.000
Wavespeed (ft/s)
Elevation (ft)
Wavespeed (ft/s)
260 to 238 : 1872
238 to 222 : 1404
214 to 178 : 1103

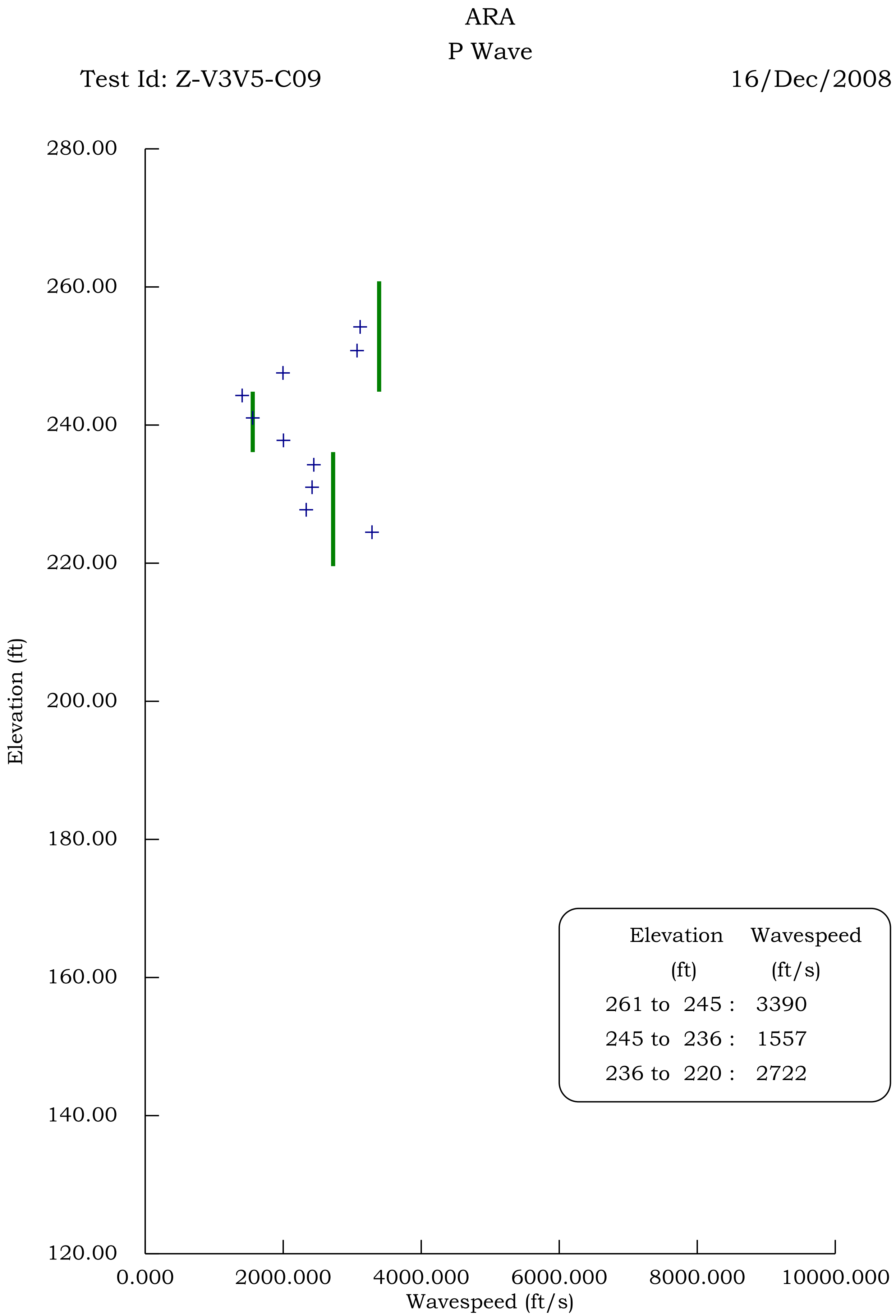
ARA
P Wave
Test Id: Z-V3V5-C01 16/Dec/2008

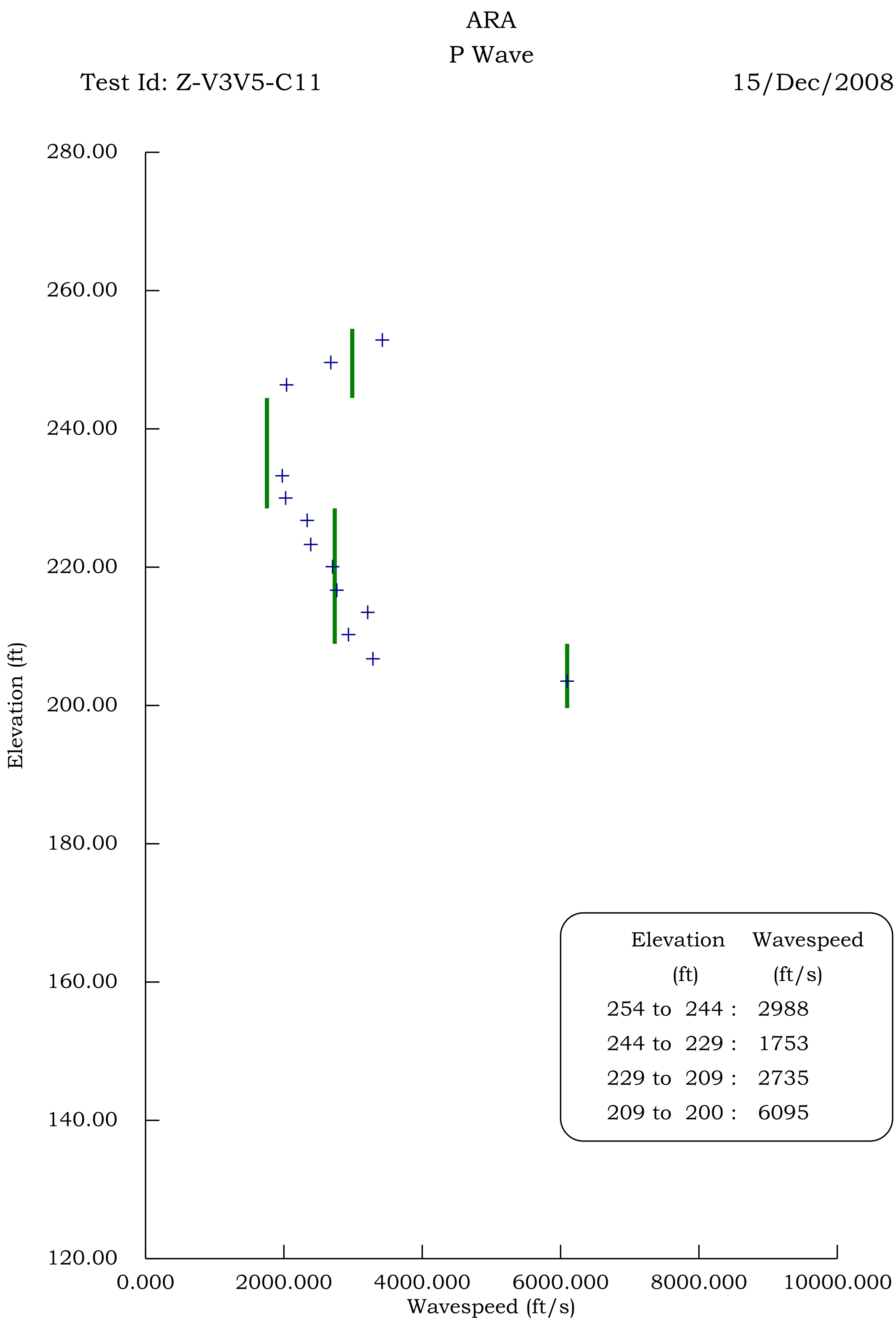


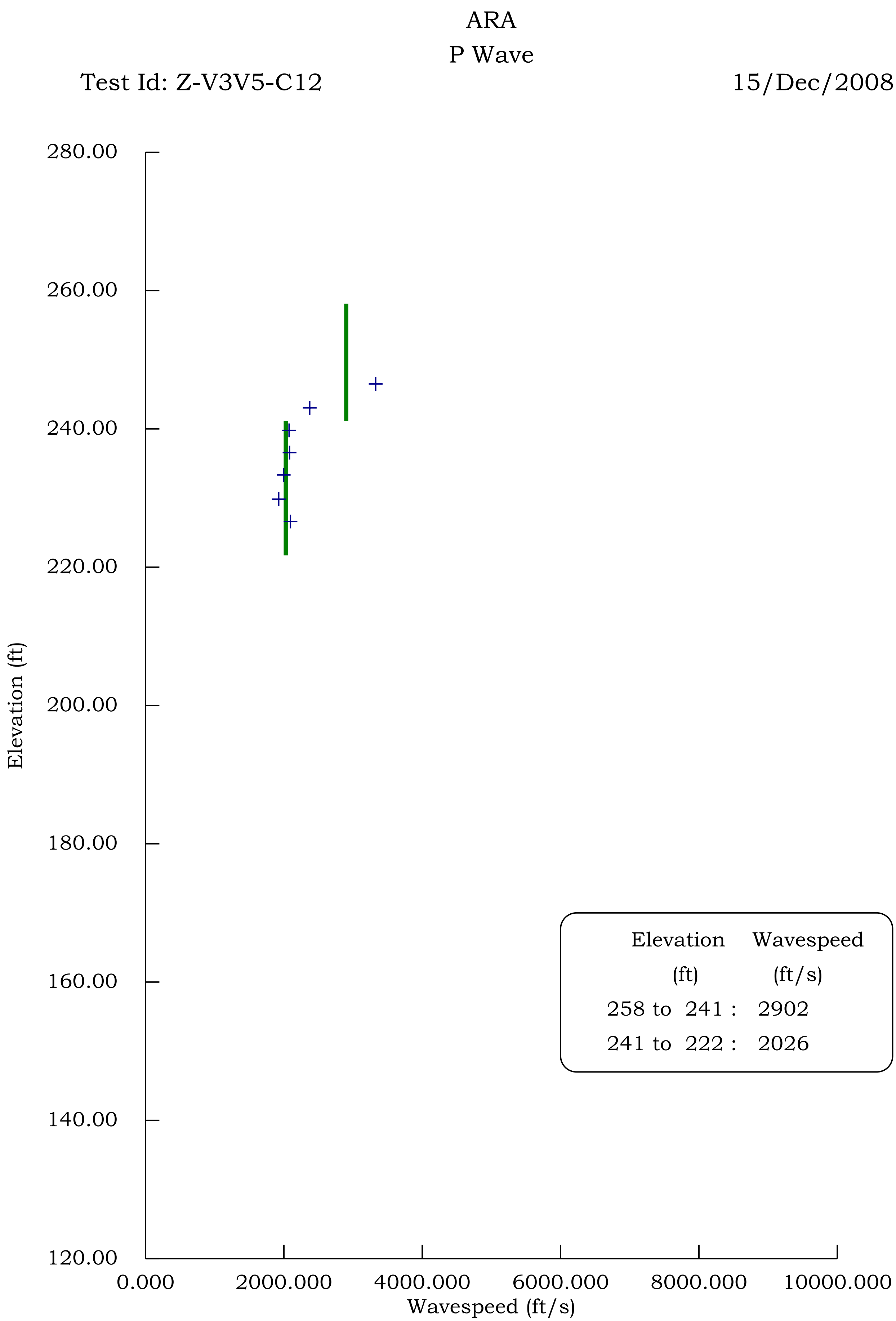

ARA
P Wave
Test Id: Z-V3V5-C04
09/Dec/2008
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
Elevation (ft)
0.000
2000.000
4000.000
6000.000
8000.000
10000.000
Wavespeed (ft/s)
Elevation (ft) Wavespeed (ft/s)
257 to 227 : 2103
227 to 207 : 2234
207 to 190 : 6732

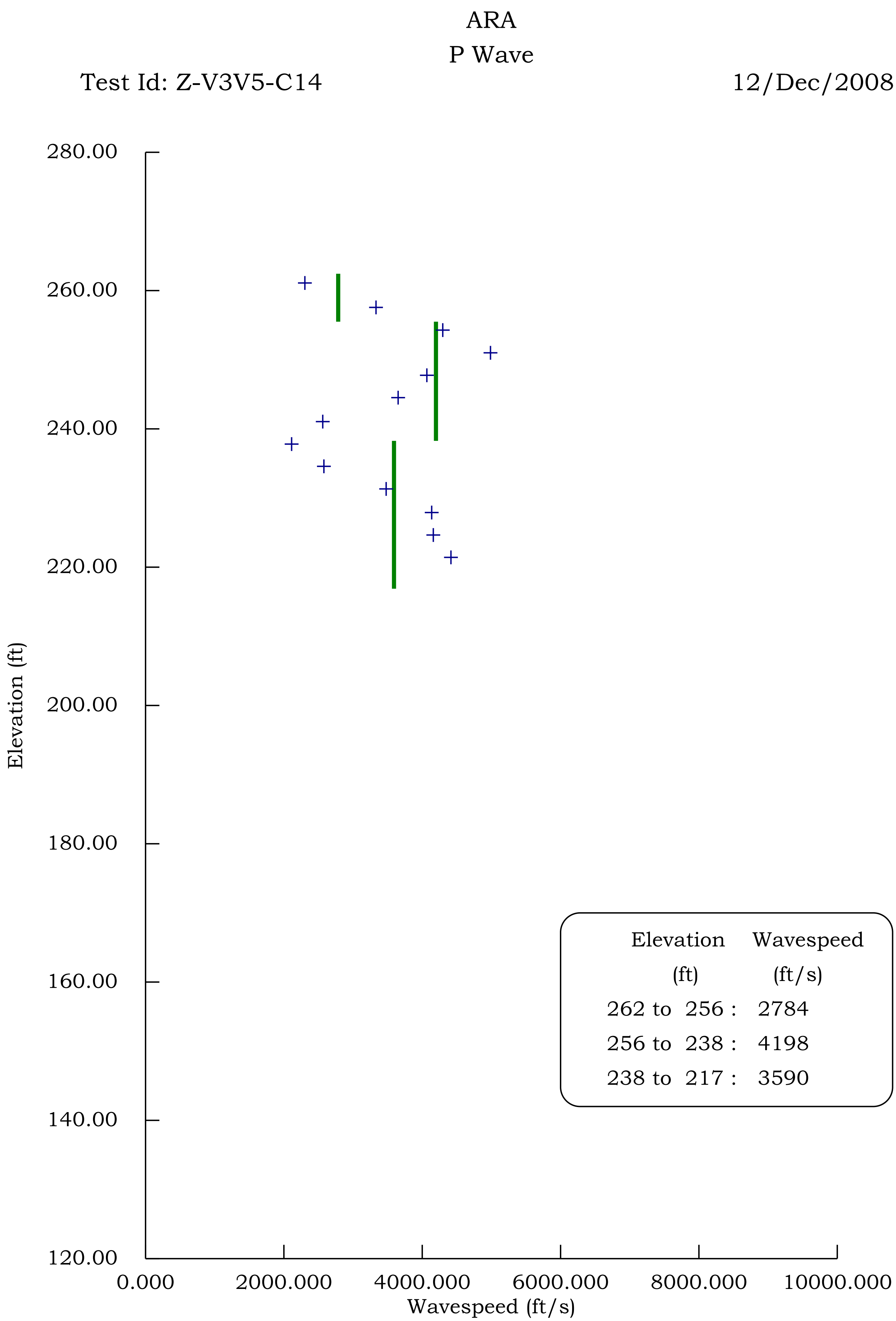

ARA
P Wave
Test Id: Z-V3V5-C06
10/Dec/2008
Elevation (ft)
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
0.000
2000.000
4000.000
6000.000
8000.000
10000.000
Wavespeed (ft/s)
Elevation (ft)
Wavespeed (ft/s)
256 to 226 : 2041
226 to 216 : 5629

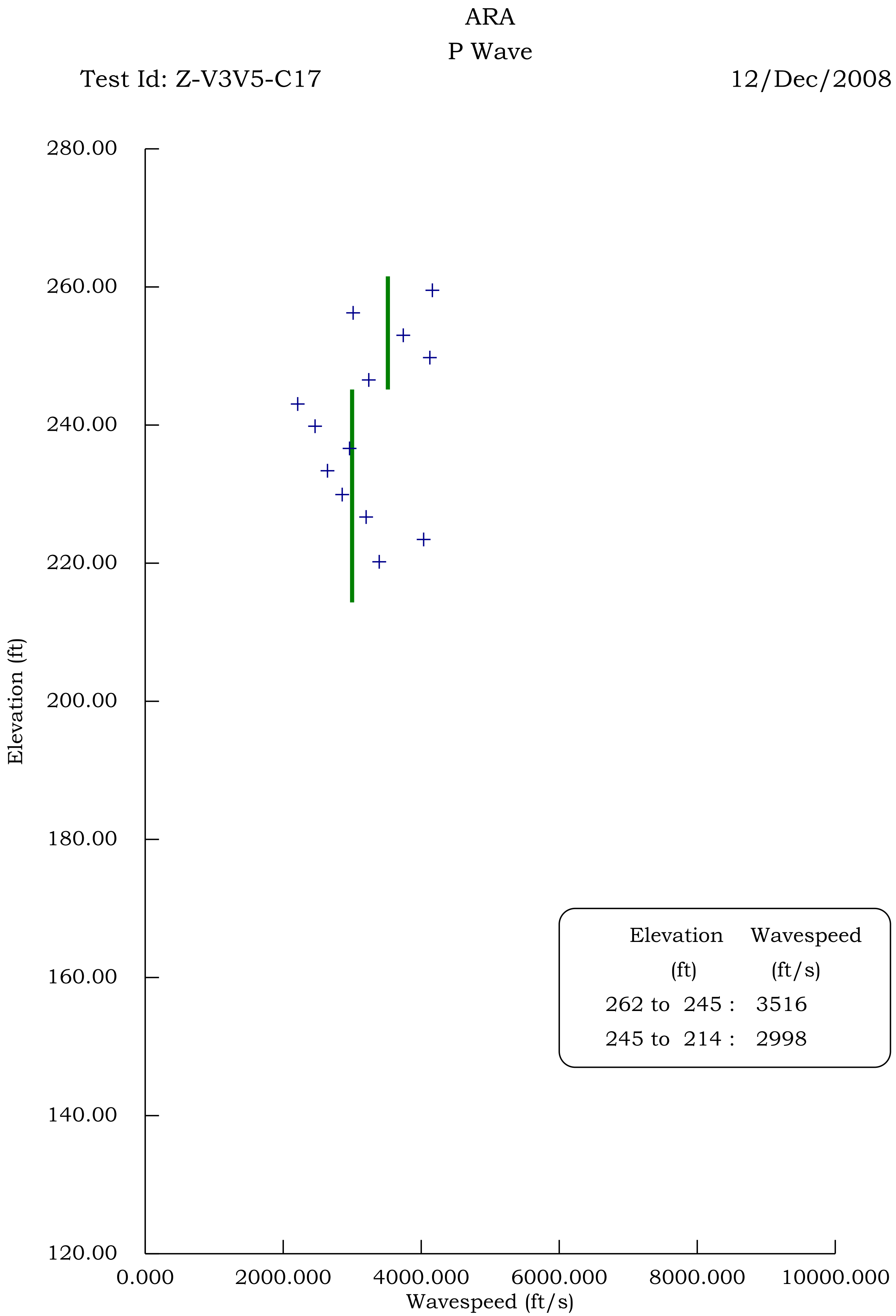

ARA
P Wave
Test Id: Z-V3V5-C07
10/Dec/2008
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
Elevation (ft)
0.000
2000.000
4000.000
6000.000
8000.000
10000.000
Wavespeed (ft/s)
Elevation (ft) Wavespeed (ft/s)
258 to 248 : 1627
237 to 223 : 2895
216 to 210 : 1992
210 to 203 : 5827
197 to 188 : 4169


ARA
P Wave
Test Id: Z-V3V5-C09
16/Dec/2008
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
Elevation (ft)
0.000
2000.000
4000.000
6000.000
8000.000
10000.000
Wavespeed (ft/s)
Elevation (ft) Wavespeed (ft/s)
261 to 245 : 3390
245 to 236 : 1557
236 to 220 : 2722


ARA
P Wave
Test Id: Z-V3V5-C11
15/Dec/2008
Elevation (ft)
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
0.000
2000.000
4000.000
6000.000
8000.000
10000.000
Wavespeed (ft/s)
Elevation (ft)
Wavespeed (ft/s)
254 to 244 : 2988
244 to 229 : 1753
229 to 209 : 2735
209 to 200 : 6095


ARA
P Wave
Test Id: Z-V3V5-C12
15/Dec/2008
Elevation (ft)
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
0.000
2000.000
4000.000
6000.000
8000.000
10000.000
Wavespeed (ft/s)
Elevation (ft) Wavespeed (ft/s)
258 to 241 : 2902
241 to 222 : 2026


ARA
P Wave
Test Id: Z-V3V5-C14
12/Dec/2008
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
Elevation (ft)
0.000
2000.000
4000.000
6000.000
8000.000
10000.000
Wavespeed (ft/s)
Elevation (ft)
Wavespeed (ft/s)
262 to 256 : 2784
256 to 238 : 4198
238 to 217 : 3590


ARA
P Wave
Test Id: Z-V3V5-C17
12/Dec/2008
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
Elevation (ft)
0.000
2000.000
4000.000
6000.000
8000.000
10000.000
Wavespeed (ft/s)
Elevation (ft)
Wavespeed (ft/s)
262 to 245 : 3516
245 to 214 : 2998

Appendix B Boring Logs

OSR 30-25# (2-13-97)

Soil Boring Log

Page 1 of 8

Project: Saltstone Vaults 3 and 5	Date: 3/05/09	Area: Z-Area
Boring No.: Z-V3V5-B01	SRS Coordinates: N 78395.0 E 66839.0	Reference Elevation: 266.9' msl
Driller: Steve Butrej	Drilling Subcontractor: Fugro	Total Hole Depth: 150.0' bgs
Technical Oversight: Bill Joyce / Oversight Company: SAIC	Groundwater Depths: Date N/A RLG 3/31/09 Time Depth	Drilling Methods and Depths: Auger-10' Mud Rotary

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		0					Hand Auger 0'-6', Auger 6'-10'
							mod yel brn SAND (SW), well graded, dry, med dense, fn grn
							lt brn SAND (SW), well graded, dry, med dense
							lt brn SANDY SILT (SM) poorly sorted, fn grn, dry
		5					rd brn CLAYEY SAND (SC) poorly sorted fn-vfn grn, sl moist
							SAA
		10					↑
							Consistent Drilling Response
		15					↓
		20					

Samples Submitted for Laboratory Tests

Bulk Sample	0.0'-5.0'	
Bulk Sample	5.0'-10.0'	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Project: Siltstone Vaults 3 and 5 | Boring No.: Z-V3V5-B01 | Date: 3/05/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		20					
ST-1				24" / 21½"	90		rd brn SAND (SP) poorly sorted med-fn grn, moist, sbrnd
		25					Consistent Moderate Drilling
		30					
ST-2				24" / 16"	68		rd brn SAND (SP) little fines occ crse grn, med-fn grn, moist, sbrnd
		35					Slightly Harder Drilling at 35.5'
ST-3				24" / 20"	83		rd brn - lt brn silty SAND ~~CLAY~~ (SC) [(SM) to clayey sand — RLG 3.31.09] fn grn w/ thin clay laminae (soft) sl moist, sbang, tr oxide
		40					

Samples Submitted for Laboratory Tests

Shelby Tube	20.0' - 22.0'	
Shelby Tube	30.0' - 32.0'	
Shelby Tube	37.0' - 39.0'	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 3 of 8

Project Siltstone Vault 3 and 5	Boring No. Z-V3V5-B01	Date 3/05/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		40					↑ Consistent Drilling Response ↓
		45					Drilling Response Shows A Little ↓
							RLG 3-31-09
ST-4		50		15" / 12"	80	(dotted)	yel orange SAND (SP) poorly ~~sorted~~ Graded fn grn, sl moist, trace oxide
							Drilling Softer At 54'
ST-5		55		24" / 14½"	60	(dotted)	RLG 3-31-09 yel orange SAND (SP) poorly ~~sorted~~ Graded fn-med grn, moist, oxide pockets, Sbml
		60					

3/05/\[illegible\] End of 3/06/\[illegible\]

Samples Submitted for Laboratory Tests

Shelby Tube	50.0'-51.25'	
Shelby Tube	55.0-57.0'	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Project: Saltstone Vaults 3 and 5 | Boring No.: Z-V3V5-BØ1 | Date: 3/Ø6/Ø9

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		60					↑
		65					Consistent Drilling Response
							↓
		70					Slightly Harder Drilling Response 72'-73 ↓
ST-6		75		24" / Ø"	Ø		No Recovery
ST-7				24" / 18"	75		Shelby Tube was damaged. Bottom 1.Ø' of tube was crumpled. Pieces of well cemented sandstone on bottom
		80					

Samples Submitted for Laboratory Tests Not submitted

Shelby Tube	75.Ø'-77.Ø'	No recovery
Shelby Tube	78.Ø'-8Ø.Ø'	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 5 of 8

Project	Boring No.	Date
Saltstone Vaults 3 and 5	Z-V3V5-B01	3/06/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		80					
ST-8				24" / 14"	58	/./.	RLG 3-31-09 grn wh Clayey SAND (SC) poorly Graded ~~sorted~~, vfn grn, sl moist includes well cemented sandstone, weathered shell, and oxides
		85					↓
		90					Consistent Drilling Response
		95					↓
		100					

Samples Submitted for Laboratory Tests

Shelby Tube	81.0'-83.0	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 6 of 8

Project	Saltstone Vaults 3 and 5	Boring No. Z-V3V5-B01	Date 3/06/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		100					↓
							Consistent Drilling Response Some Harder Sections
		105					↓
							Appear To Be Out of the Santee.
		110					↓
		115					
							Very Hard At 118'. Determined Later Bit Was Wearing Out
		120					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 7 of 8

Project	Boring No.	Date
Saltstone Vaults 3 and 5	Z-V3V5-B01	3/06/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		120					↓ Slow Hard Drilling ↓
		125					Change Bits. Wing Bit Is Worn Down. Run In With 3 7/8" Roller Cone Bit
							Easier Consistent Drilling ↓
		130					
		135					
		140					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 8 of 8

Project Saltstone Vaults 3 and 5							Boring No. Z-V3V5-B01	Date 3/06/09
Sampling			6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description	
No.	Type	Depth						
		140					↓	
							Consistent Drilling Response	
		145					↓	
		150					Total Depth Of Boring - 150.0'	
		5						
		0						

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log

Page 1 of 8

Project: Saltstone Vaults 3 and 5	Date: 3/10/09	Area: Z-Area
Boring No.: Z-V3V5-B02	SRS Coordinates: N 78235.0 E 66894.0	Reference Elevation: 269.9' msl
Driller: Steven Butrej	Drilling Subcontractor: Fugro	Total Hole Depth: 150.0' bgs
Technical Oversight: Bill Joyce; Oversight Company: SAIC	Groundwater Depths RLG 3.31.09 Date N/A Time Depth	Drilling Methods and Depths: Auger-10' Mud Rotary

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		0					3-10-09 Tuesday Sunny 85°
							0'-10' is drilled out
		5					↓
SS-1		10	8, 14, 17, 25	24" / 22"	92		rd brn mottled Sandy Lean Clay (CL) sl moist, very stiff low plasticity; rd brn Silty Sand (SM), fn-med grn, sl moist, dense, ssrnd, poorly graded
SS-2			8, 15, 16, 18	24" / 22"	92		yel-rd brn Silty Sand (SM) fn-med grn, sl moist, dense, ssrnd, trace fine gravel, poorly graded; Clay content increases with depth
SS-3		15	7, 10, 12, 14	24" / 24"	100		yel-red brn Clayey Sand (SC) with pockets of Silty Sand (SM) fn-med grn, sl moist, medium dense, ssrnd, poorly graded
SS-4			8, 11, 12, 12	24" / 23"	96		yel-rd brn Silty Sand (SM) upper part of spoon clayey sand, fn-med grn, sl moist, medium dense, ssrnd, poorly graded
SS-5		20	8, 8, 10, 10	24" / 22"	92		rd brn Clayey Sand (SC) with sections of SM, fn-med grn, sl moist, medium dense, ssrnd, poorly graded

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 2 of 8

Project	Boring No.	Date
Saltstone Vaults 3 and 5	Z-V3V5-BØ2	3/1Ø/Ø9

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
SS-6		20	6, 8, 9, 10	24" / 21"	88		rd brn Silty Sand (SM) med-fn grn, sl moist, medium dense, sbrnd, poorly graded
SS-7			6, 8, 8, 9	24" / 20"	83		SAA with occ. clayey stringers
SS-8		25	6, 9, 9, 1Ø	24" / 18"	75		lt brn-rd brn poorly graded Sand with silt (SP-SM) med-fn grn, moist, medium dense, sbrnd
SS-9			8, 10, 12, 14	24" / 17"	71		lt brn-yel poorly graded Sand with silt (SP-SM) med-fn grn, moist, medium dense, sbrnd-sbang, oxide peds
SS-1Ø			9, 12, 14, 15	24" / 16"	67		yel poorly graded Sand (SP) little silt, moist, fn-med grn, medium dense, sbrnd-sbang
SS-11		30	9, 9, 1Ø, 13	24" / 16"	67		yel brn poorly graded Sand with silt (SP-SM) fn-med grn, moist, medium dense, sbrnd-sbang
SS-12			7, 11, 12, 14	24" / 16"	67		SAA
SS-13		35	9, 10, 12, 12	24" / 18"	75		yel brn poorly graded Sand with silt (SP-SM) med-fn grn, moist, medium dense, sbang
		40					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 3 of 8

Project	Saltstone Vaults 3 and 5	Boring No. Z-V3V5-B02	Date 3/10/09 - 3/11/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
SS-14		40	3, 3, 4, 5	24" / 20"	83		lt brn-red brn Clayey Sand (SC) fn-med grn, moist loose sand, includes mang. oxide
SS-15		45	WH, 3, 3, 5	24" / 24"	100		RLG 3.31.09 Lean; tn-lt brn ~~Loss~~ Lean Clay with Sand (CL) medium stiff moist, malleable, with mang. oxide stringers, laminated
SS-16		50	WH, WH, 3, 4	24" / 24"	100		RLG 3.31.09 Lean; tn-lt brn ~~Loss~~ Lean Clay with Sand (CL), soft, moist, malleable with mang. oxide, sand pockets/thin laminae
SS-17		55	6, 11, 8, 10	24" / 16"	67		rd brn Silty Sand (SM) fn-med grn moist, medium dense, SSand, poorly graded
		60					

3/10/09 End of ... 3/11/09

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Project	Boring No.	Date
Saltstone Vaults 3 and 5	Z-V3V5-B02	3/11/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
SS-18		60	6, 9, 10, 14	24" / 16"	67		lt brn-rd brn poorly graded Sand with Silt (SP-SM) med-fn grn, wet, medium dense, sbang
							RLG 3.31.09 Lean
SS-19		65	WH, WH, WH, WH	24" / 24"	100		Yel brn-tn ~~Less~~ Clay with Sand (CL) sand pockets very soft, moist-wet, malleable, abndt mang. oxide
SS-20		70	8, 14, 17, 19	24" / 20"	83		lt red brn poorly graded Sand with Silt (SP-SM) fn grn, wet, dense sand, sbang
							RLG 3.31.09 Lean
SS-21		75	2, 2, 3, 3	24" / 24"	100		lt brn-rd brn ~~Less~~ Clay with sand (CL) soft, wet, malleable, with mang oxide
							rd grn Silty Sand (SM) med grn w/ occ crse grn, loose sand, wet, sbang, poorly graded
		80					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Project	Boring No.	Date
Saltstone Vaults 3 and 5	Z-V3V5-B02	3/11/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
SS-22		80	1, 6, 12, 15	24" / 24"	100		grn gry Clayey Sand (SC) fn grn, moist-wet medium dense, poorly graded, with kaolin pockets and well cemented sandstone, some weathered shell fragments
SS-23		85	5, 14, 10, 13	24" / 24"	100		grn wh Clayey Sand (SC) fn grn, moist-wet, medium dense poorly graded, with kaolin (dry) and well cemented sandstone, some mang. oxide
SS-24		90	100/2" Refusal (3.31.09 RLG)	2"/0" (3.31.09 RLG)	0% Refusal (3.31.09 RLG)		Refusal - 2" with 100 blows
SS-25		95	11, 9, 6, 10	24" / 24"	100		grn wh Clayey Sand (SC) fn grn, wet-moist medium dense poorly graded, includes well cemented sandstone, mang. oxide, and weathered shell fragments.
		100					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 6 of 8

Project: Saltstone Vaults 3 and 5

Boring No.: Z-V3V5-BB2

Date: 3/11/09 - 3/12/09

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
SS-26		100	10, 13, 13, 10	24" / 24"	100		grn wh Clayey Sand (SC) fn grn, moist, medium dense, poorly graded, abundt weathered shell fragments, some sandstone
SS-27		105	9, 18, 22, 23	24" / 24"	100	Shell Hash	Shell Hash with white-gry Clayey Sand (SC) fn grn moist-dry, dense, poorly graded, weathered shell fragments trace mang. oxide
SS-28		110	7, 11, 12, 23	24" / 24"	100		dk grn gry Silty Sand (SM) med-fn grn sl moist, medium dense, poorly graded, thin clay laminae in bottom of run, sbrnd-sbang, trace oxide
SS-29		115	4, 7, 7, 13	24" / 24"	100		dk grn gry Silty Sand (SM) fn-med grn sl moist, medium dense, poorly graded, sbrnd-sbang, trace oxides
		120					

End of ☐ 3/12/09

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Project: Saltstone Vaults 3 and 5 | Boring No. Z-V3V5-B02 | Date 3/12/09

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description (RLG 3.31.09)
SS-30		120	5, 8, 10, 15	24" / 24"	100		dk grn gry Clayey Sand (SC), ~~Less Clay~~ Lean Clay (CL) from 120.5'-121.1', med-fn grn, sl moist, medium dense, poorly graded, sbrnd-sbang
			RLG	3.31.09 RLG	3.31.09 RLG		
SS-31		125	50/3" Refusal	3" / 0" Refusal	0% Refusal		Refusal - 3" with 50 blows
					RLG 3.31.09		
SS-32		130	40, 50-4" Refusal	Refusal	NOT RECORDED Refusal		6"-40 blows, 4"-50 blows Recovered soil: lt gry poorly graded sand with silt (SP-SM) fn grn, sl moist sbang, trace mica, not enough to jar sample
					RLG 3.31.09		
SS-33		135	43, 50-4"	Refusal	NOT RECORDED Refusal		6"-43 blows, 4"-50 blows Jarred recovered soil: lt gry poorly graded sand with silt (SP-SM) fn grn, sl moist, sbang, trace mica
		140					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 8 of 8

Project	Boring No.	Date
Saltstone Vaults 3 and 5	Z-V3V5-B02	3/12/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
SS-34		140	50 42 45 50-5"	23" / 19"	83		lt gry-gry poorly graded Sand with Silt (SP-SM) fn-med grn, moist-wet, very dense, sbang.
							RLG 3.31.09
SS-35		145	32 24 29 39	24" / 23"	96		lt gry Silty Sand (SM) with LEAN Clay (CL) thin laminae included fn-med grn, wet, very dense, sbang-sbrnd
					3.31.09 RLG		
SS-36		150	21 25 32 39	24" / 24"	100%		lt gry poorly graded Sand with Silt (SP-SM) fn-med grn, wet, very dense, sbang-sbrnd
							Total drill depth - 150'
							Total split-spoon depth - 152'
		155					
		160					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log

Project: Saltstone Vaults 3 and 5		Date: 3/13/09	Area: Z-Area
Boring No.: Z-V3V5--B03	SRS Coordinates: N 78333.0 E 66649.0		Reference Elevation: 268.3' msl
Driller: Steven Butrej	Drilling Subcontractor: Fugro		Total Hole Depth: 150.0' bgs
Technical Oversight: Bill Joyce / Oversight Company: SAIC	Groundwater Depths: Date N/A Time Depth (3.31.09 RL4)		Drilling Methods and Depths: Auger-10' Mud Rotary

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		0					3-13-09 Friday Cloudy 60°
							0'-10' is drilled out
		5					
SS-1		10	6, 8, 11, 15	24" / 20"	83		rd brn Silty Sand (SM), fn-med grn, sl moist, medium dense, 5Yr4/, poorly graded
SS-2			7, 13, 15, 21	24" / 22"	92		rd brn Clayey Sand (SC) fn-med grn. sl moist, medium dense, 5Yr4/, poorly graded
SS-3		15	12, 16, 19, 24	24" / 24"	100		yel-rd brn Silty Sand (SM) fn-med grn, sl moist, dense sand, 5Yr4/, poorly graded, occ mang. oxide pockets
SS-4			11, 15, 15, 14	24" / 22"	92		yel-rd brn poorly graded Sand with Silt (SP-SM) med-fn grn, sl moist, medium dense-dense sand, 5Yr4/-5Yr6/.
SS-5		20	8, 11, 11, 12	24" / 23"	96		yel-rd brn poorly graded Sand with Silt (SP-SM) med grn, moist, medium dense, 5Yr6/

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 2 of 8

Project	Saltstone Vaults 3 and 5	Boring No. Z-V3V5-B03	Date 3/13/09

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
SS-6		20	9, 11, 12, 15	24" / 19"	79		yel lt brn poorly graded Sand with Silt (SP-SM) med-fn grn with occ crse grn moist, medium dense, sbang
SS-7			9, 11, 13, 14	24" / 19"	79		SAA
SS-8		25	9, 13, 13, 16	24" / 19"	79		Yel lt brn poorly graded Sand with Silt (SP-SM) med-fn grn, moist, medium dense, sbang-sbrnd, occ kaolin
SS-9			9, 13, 14, 15	24" / 18"	75		SAA
SS-10			9, 11, 9, 11	24" / 19"	79		lt brn poorly graded Sand with Silt (SP-SM) med-fn grn w/ occ crse grn, moist, medium dense, sbang, abndt iron oxide in sand bottom of run
SS-11		30	9, 11, 12, 16	24" / 21"	88		lt brn poorly graded Sand with Silt (SP-SM) med-fn grn w/ occ crse grn moist, medium dense, sbang, includes iron oxide section (top of run), kaolin stringers
SS-12			8, 9, 9, 13	24" / 24"	100		lt brn-red brn Silty Sand (SM) med-fn grn moist, medium dense sbang-sbrnd, trace oxides, occ kaolin stringer
SS-13		35	7, 10, 12, 15	24" / 22"	92		upper 0.6' Lean Clay with Sand (CL) red brn lt brn Silty Sand (SM) med-fn grn, moist, medium dense, sbang-sbrnd, trace oxides
		40					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 3 of 8

Project	Boring No.	Date
Saltstone Vaults 3 and 5	Z-V3V5-B03	3/13/09

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
SS-14		40	5, 9, 12, 14	24" / 24"	100		rd-lt brn Silty Sand (SM) with thin clay (CL) laminae, fn-med grn, moist, medium dense, sbrnd-sbang, trace oxides
SS-15		45	9, 14, 18, 23	24" / 18"	75		yel-lt brn poorly graded Sand with silt (SP-SM) fn grn moist dense sand, sbang, trace oxides, kaolin
							RLG 3.31.09
SS-16		50	2, 6, 10, 13	24" / 24"	100		fn ~~loess~~ Lean Clay with Sand (CL) sandier at bottom of run, very stiff, moist, malleable, abndt mang. oxide
SS-17		55	14, 18, 19, 21	24" / 24"	100		lt brn poorly graded Sand with Silt (SP-SM) med-fn grn, moist, dense sand, sbrnd-sbang, trace oxide
		60					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Project	Boring No.	Date
Saltstone Vaults 3 and 5	Z-V3V5-B03	3/13/09

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description (RLG 3.31.09 LEAN)
SS-18		60	4, 8, 12, 13	24" / 24"	100		upper 0.6' ~~Fat~~ LEAN Clay (CL) tn, malleable; tn-lt brn Silty Sand (SM) med-fn grn, wet, medium dense, sbang-sbrnd, poorly graded, trace oxides
SS-19		65	4, 7, 10, 17	24" / 23"	96		yel grn-lt brn Silty Sand (SM), dry kaolin section upper part of run, fn-med grn, moist, medium dense, sbang-sbrnd, poorly graded, trace oxides
SS-20		70	7, 11, 11, 11	24" / 16"	67		lt brn poorly graded Sand with Silt (SP-SM) med-fn grn, wet-moist, medium dense, sbang-sbrnd, abundant mang. oxide
SS-21		75	1, 2, 2, 1	24" / 24"	100		RLG 3.31.09 yel grn-lt brn ~~Fat~~ LEAN Clay with Sand (CL) sand is fn grn, wet, soft, malleable, good plasticity, with mang. oxide
		80					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Project	Saltstone Vaults 3 and 5	Boring No. Z-V3V5-B03	Date 3/13/09 + 3/17/09

RLG 3.31.09

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
SS-22		80	3, 4, 4, 7	24" / 24"	100		yel gry-wh Lean Clay with Sand (CL) with sandstone sections, wet, medium stiff, malleable, good plasticity, with many oxide weathered shell fragments
SS-23		85	5, 6, 7, 10	24" / 24"	100		gry wh Clayey Sand (SC) fn grn, moist-wet medium dense poorly graded, with well cemented sandstone, some mang. oxide.
SS-24		90	6, 10, 25, 34	24" / 24"	100		gry wh Clayey Sand (SC) fn grn, moist-wet dense sand poorly graded with well cemented sandstone, some mang. oxide, trace weathered shell fragments
SS-25		95	7, 9, 14, 13	24" / 24"	100		Matrix is gry wh Clayey Sand (SC), fn grn, moist-wet medium dense, poorly graded includes about well cemented sandstone with shell hash (weathered shell fragments) trace mang oxide
		100					

Right margin: 3/13/09 End of day 3/17/09

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 6 of 8

Project Saltstone Vaults 3 and 5	Boring No. Z-V3V5-B03	Date 3/17/09

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
SS-26		100	5, 5, 6, 10	24" / 24"	100	shell Hash	matrix is gry wh Clayey Sand (SC) fn grn, moist-wet medium dense, poorly graded mostly shell hash (weathered shell fragments)
SS-27		105	9, 13, 17, 19	24" / 24"	100		Clayey Silt with ~~Sand~~ some sand grn gry ~~Silt with Sand~~ (ML) vfn-fn grn, wet, medium dense, poorly graded includes weathered shell fragments, trace many oxides
SS-28		110	8, 15, 18, 30	24" / 24"	100		grn gry poorly graded Sand with silt (SP-SM) fn-med grn, dense thin clay laminae on bottom, some sand/silt trace mi grn gry lean Clay with sand (CL) dry, low plasticity, some clean laminae, hard
SS-29		115	5, 8, 9, 19	24" / 24"	100		dk grn gry Silty Sand (SM) fn-med grn, sl moist medium dense, poorly graded, orange-brown, trace oxides ~~Clamer~~ Clay (CL) bottom 0.4'. LEAN RLG 3.31.09
		120					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 7 of 8

Project	Boring No.	Date
Saltstone Vaults 3 and 5	Z-V3V5-B03	3/17/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		120	5				Refusal at 120.5"
SS-30			38	17" / 17"	100		H-med gry poorly graded Sand with silt
			50-5"				(SP-SM) med-fn w/ occ crse grn, sbang-sbrnd
			Refusal				wet
				RLG 3.31.09	RLG		
		125	50-3"	3"/0"	0%		Refusal - 50 blows went 3"
SS-31			Refusal	Refusal			SAA - Not enough to jar.
				RLG 3.31.09	RLG		
		130	50-3"	3"/0"	0%		Refusal - 50 blows went 3"
SS-32			Refusal	Refusal			SAA - Not enough to jar
				RLG 3.31.09			
		135	50-5"	NOT RECORDED			Refusal - 50 blows went 5"
SS-33			Refusal	Refusal			H-med gry poorly graded Sand (SP), med-fn grn, wet, sbang-sbrnd, trace oxide
		140					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 8 of 8

Project: Saltstone Vaults 3 and 5	Boring No. Z-V3V5-B03	Date 3/17/09

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
SS-34		140	50-5" Refusal	Refusal; NOT RECORDED RLG 3.31.09			Refusal - 50 blows went 5" lt-med gry poorly graded Sand (SP) fn-med grn, wet, sbang-sbrnd, trace oxides
SS-35		145	12, 21, 31, 48	24" / 20"	83		med-dk gry Silty Sand (SM) some thin lean clay (CL) laminae top of run, med-fn grn wet, very dense sand, sbrnd-sbang, poorly graded (RLG 3.31.09)
SS-36		150	26, 30, 50, 56	24" / 19"	79		med-dk gry poorly graded Sand with silt (SP-SM) med-fn grn w/ occ crse grn, wet-saturated, very dense sand, Brnd-sbang
							Total drill depth - 150'
							Total split-spoon depth - 152'
		5					
		0					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log

Project: Saltstone Vaults 3 and 5		Date: 3/09/09	Area: Z-Area
Boring No.: Z-V3V5-B04	SRS Coordinates: N 78171.0 E 66702.0		Reference Elevation: 272.8' msl
Driller: Steve Butrey	Drilling Subcontractor: Fugro		Total Hole Depth: 150.0' bgs
Technical Oversight: Bill Joyce	Oversight Company: SAIC	Groundwater Depths Date N/A RLG 3.31.09 Time Depth	Drilling Methods and Depths: Auger-10', Mud Rotary

Sampling No.	Type	Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		0					Hand Auger 0'-6', Auger 6'-10' Top Soil 0.0'-1.0' w/roots
							mod yel brn SAND (SW), well graded dry, med dense, med-fn grn
							red brn SANDY SILT (SM) poorly sorted fn grn, dry
		5					red brn CLAYEY SAND (SC) poorly sorted, fn-vfn grn, sl moist, med dense
							SAA
		10					Consistent Drilling Response (10'–20')
		15					
		20					

Samples Submitted for Laboratory Tests

Bulk Sample	1.0'-5.0'	
Bulk Sample	5.0'-10.0'	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 2 of 8

Project: Saltstone Vaults 3 and 5	Boring No. Z-V3V5-B04	Date 3/09/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
ST-1		20		24" / 21½"	90	(dots)	RLG 3.31.09 Graded; red brn SAND (SP), poorly ~~sorted~~ graded, little fines, fn-med grn, moist, sbrnd.
		25					Consistent Moderate Drilling
ST-2		30		24" / 23"	95	(dots)	Poorly GRADED RLG 3.31.09; lt brn SAND (SP) little fines, med grn, occ crse grn, moist sbrnd. Drilling softer at 32.5'
ST-3		35		20" / 13½"	68	(hatched)	Only able to push 20" (1.66'). RLG 3.31.09 CLAYEY SAND; lt brn ~~SAND CLAY~~ mixture (SC), med-fn grn w/ thin clay laminae (soft) kaolin, sl moist, sbang, trace oxide
		40					

Samples Submitted for Laboratory Tests

Shelby Tube	20.0'-22.0'	
Shelby Tube	30.0'-32.0'	
Shelby Tube	35.0' - ~~37.0'~~ 36.66'	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Project	Boring No.	Date
Saltstone Vaults 3 and 5	Z-V3V5-B04	3/09/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		40					↑ Consistent Drilling Response ↓
		45					Drilling Softer at 47'
		50					
ST-4				24" / 23"	95	(hatched)	gry white SANDY CLAY (CL) vfn grn sand, soft, low-medium plasticity, abndt mang. oxide pockets, sl moist
		55					
ST-5				24" / 23"	95	(hatched)	red brn SANDY CLAY (CL) fn grn sand pockets soft low-medium plasticity, sl moist, many oxide pockets
		60					

Samples Submitted for Laboratory Tests

Shelby Tube	50.0'-52.0'	
Shelby Tube	55.0'-57.0'	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 4 of 8

Project	Boring No.	Date
Saltstone Vaults 3 and 5	Z-V3V5-B04	3/09/09

Sampling			6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
No.	Type	Depth					
		60					
							Consistent Drilling Response
		65					
							Drilling Response Harder at 69'
		70					
							Consistent Drilling Response
		75					
		80					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 5 of 8

Project	Boring No.	Date
Saltstone Vaults 3 and 5	Z-V3V5-B94	3/09/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		80					↑ Consistent Drilling Response ↓
ST-6		85		24" / 26"	100	⁝	gry white SILTY SAND (SM), poorly ~~sorted~~ GRADED (RLG 3.31-09), vfn-fn grn, sl moist, medium dense, consolidated, abndt oxides
							Drilling Response Harder at 87' ↑ ↓
		90					
							Inconsistent Hard and Slightly Softer Drilling Response
		95					↓
		100					

Samples Submitted for Laboratory Tests

Shelby Tube	84.0'-86.0'	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Project	Saltstone Vaults 3 and 5	Boring No.	Z-V3V5-B04	Date	3/09/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		100					↑
		105					
							Inconsistent Hard and Slightly Softer Drilling Response
		110					
		115					
		120					↓

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 7 of 8

Project	Boring No.	Date
Saltstone Vaults 3 and 5	Z-V3V5-B04	3/09/09-3/10/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		120					Change bits - run in with 3 7/8" roller cone bit.
ST-7				24" / 14"	58	//////	grn gry SANDY LEAN CLAY (CL) vfn grn sand, firm-hard, ~~no~~ low plasticity, sl moist, micaceous RLG 3.31.09
		125					
		130					Consistent Drilling Response
		135					
		140					

3/09/09 End of 3/10/09

Samples Submitted for Laboratory Tests

Shelby Tube	120.0'-122.0'	

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

OSR 30-25# (2-13-97)

Soil Boring Log (Contd)

Page 8 of 8

Project	Boring No.	Date
Saltstone Vaults 3 and 5	Z-V3V5-B04	3/14/09

Sampling No.	Sampling Type	Sampling Depth	6-Inch Blow Counts	Inches Driven / Inches Recovered	% Rec	Lithology	Description
		140					↑ Consistent Drilling Response ↓
		145					
		150					Total Depth Of Boring - 150.0'
		5					
		0					

Samples Submitted for Laboratory Tests

Note—Standard Penetration Resistance is sum of blows for 2nd – 6" and 3rd – 6" to drive 1-3/8" I.D., 2" O.D. Split Barrel Sampler with 140 pound hammer falling 30 inches.

GRL engineers, inc.
Dynamic Measurements and Analyses

February 25, 2009

Mr. Ken Parton
Fugro Consultants, Inc.
6105 Rookin St.
Houston, TX 77074
(713) 346-4000

Re: SPT Hammer Calibration
Fugro Texas – CME 75 (S/N 362087)
GRL Job No. 081107

Dear Mr. Parton,

This report transmits results from SPT Energy Measurement Testing performed on February 24, 2009 at the above referenced site. The testing was conducted to calibrate an automatic hammer mounted to a CME 75 drill rig. A 140 lb drop weight was utilized for the testing. Appendix A describes our measurement and analysis methods while Appendix B gives a summary of the field data and results.

OBJECTIVES

The objectives of the current testing were to perform SPT Energy Measurements according to ASTM D4633-05. These objectives were met using our Pile Driving Analyzer®, Model PAK, which acquired the SPT hammer's transfer energies using an instrumented NWJ rod section and two piezoresistive accelerometers.

TESTING AND EQUIPMENT

Drilling and SPT Hammer Equipment

SPT energy measurements were collected for an automatic hammer mounted to a CME 75 drill rig. The anvil was 2.5 inches in diameter and had an overall length, including overlap, of 12 inches. The drill rig serial number was 362087. The drilling method appeared to be a solid stem continuous flight auger. The split spoon sampler was lowered into the open hole and energy measurements were collected at sampling penetrations ranging between 0.5 and 26 ft.

Instrumentation

A Model PAK Pile Driving Analyzer (PDA) data acquisition system was used to collect and process the dynamic measurements of force and velocity. A two foot long section of NWJ rod subsection was instrumented with two full bridge foil resistance strain gage and two piezoresistive accelerometers mounted at the midpoint location of the instrumented subsection.

Analog signals from the strain gages and accelerometers were conditioned, digitized, stored and processed with the PDA. The sampling frequency used during the SPT testing was 20 kHz. Selected output from the PDA for each recorded impact included the maximum average compressive stress (CSX), maximum tension stress (TSX), maximum energy transfer (EMX), hammer transfer efficiency (ETR), maximum rod top force (FMX), maximum rod top velocity (VMX), and the hammer operating rate (BPM).

MEASUREMENTS AND CALCULATIONS

FV Method (EMX)

The FV Method is currently recognized in ASTM D4633-05, and is the theoretically correct result. Energy transfer to the PDA gage location, EMX, was computed by the PDA using the force, F(t), and velocity, v(t), records as follows:

$$EMX = \int_a^b F(t) \cdot v(t) dt$$

The time "a" corresponds to the start of the record when the energy transfer begins, and "b" is the time at which energy transferred to the rod reaches a maximum value.

Any cross-sectional area difference between the GRL rod subsection and the drill rods, any loose connections or changes in area at section joints, or any cross-sectional area differences between the individual drill rod sections will result in stress wave reflections that can influence the stress wave transmission. The EMX transferred energy calculation method, utilizing both force and velocity records, is theoretically correct and gives energy transfer results that are not adversely affected by cross-sectional area changes or loose connectors. The EMX results are included in Appendix B for all records collected and accepted after checking them for consistency.

Corrected SPT number (N_{60})

While the primary purpose of SPT energy testing is to calculate the maximum transfer energy (EMX) of each hammer blow, the overall average EMX value can be used to calculate the corrected SPT number (N_{60}). To adjust the SPT N-Value for hammer performance, the following correction as suggested by Seed for N-Value adjustment to 60% transfer efficiency (e.g. 210 ft-pounds for the 140 lb hammer) was used:

$$N_{60} = \left(\frac{E_m}{210}\right) N_m$$

Where:

N_{60} = Corrected N-value
E_m = overall average measured energy transfer (EMX)
N_m =number of blows for last 12 inches of sampler penetration

A general introduction to dynamic SPT testing methods is included in this report as Appendix A. References for more detailed descriptions of our testing and analysis methods are available upon request.

RESULTS

Upon return to the office, the records collected by the PDA were checked for consistency and accuracy. For example, records from very weak startup or final impacts were not included in the results. Appendix B contains a representative plot of force and normalized velocity versus time and plots and tables of PDA results for all hammer blows at each dynamically monitored sampling depth. The PDA results include maximum average compressive stress (CSX), maximum tension stress (TSX), maximum energy transfer (EMX), hammer transfer efficiency (ETR), maximum rod top force (FMX), maximum rod top velocity (VMX), and the hammer operating rate (BPM). The plots show each calculated PDA result versus sampling spoon penetration while the tables show statistical summaries for each 6 inch increment. At the end of each table, on the next page, a statistical evaluation showing only results which correspond to the N-Value is presented.

Table 1 summarizes the average transfer energy values calculated by the EMX method. The records averaged consist only of the hammer blows at each dynamically monitored sampling depth that correspond to the N-Values. The "energy transfer ratio" (ETR) is defined as the ratio of maximum transferred energy EMX divided by the theoretical hammer potential energy of 350 ft-lbs for the 140 lb hammer. The average hammer operating rate is reported in blows per

minute (BPM). Calculated N_{60} values using the overall average EMX and the relationship described above are also shown in Table 1.

CONCLUSIONS

RIG: CME 75 (S/N: 362087) - 140 lb Hammer
The average maximum energy transfer to the NWJ SPT rod using a 140 lb drop weight was 81% for the CME 75 (s/n: 362087) drill rig. The standard deviation was 3%. The average blow rate of the automatic hammer during the time of testing was 55 blows/min with a standard deviation of 1 blow/min.

Please review ASTM D4633-05 prior to applying these test results.

We appreciate the opportunity to be of assistance to you on this project. Please contact our office should you have any questions regarding this submittal, require additional information, or if we may be of further service.

Sincerely,

GRL Engineers, Inc.

Matt Nagy
Project Engineer

Ryan C. Allin

MN:RCA:dms

Appendix C Laboratory Test Reports

MACTEC

engineering and constructing a better tomorrow

May 19, 2009

Savannah River Nuclear Solutions
Bldg. 730-2B Room 1086
Aiken, SC 29808

Attention: Mr. Jim Mason, Site Geotechnical Services
Subject: **Test Report – Saltstone Vaults 3 & 5**
Subcontract No. AC54317N, Delivery Order No. 6
MACTEC Project No. 6155-08-0031

Dear Mr. Mason:

MACTEC Engineering & Consulting, Inc. (MACTEC) has completed the assigned testing services for Delivery Order No. 6, Subcontract No. AB54317N. The test results are included in Attachment 1. An equipment list used in this Delivery Order is included in Attachment 2. The tests performed in this Delivery Order are listed below along with applicable ASTM or other procedures:

Permeability	ASTM D5084
Capillary/Moisture Relationship	ASTM D3152
Porosity	USCOE EM1110-2-1906
Consolidation	ASTM D2435
Atterburg Limits	ASTM D4318
Grainsize with Hydrometer	ASTM D422
Grainsize	ASTM D422
Modified Proctor	ASTM D1557
Unit Weight &Moisture Content	MACTEC TP-4
Specific Gravity	ASTM D854
CU Triaxial	ASTM D4767
Natural Moisture Content	ASTM D2216

These tests were performed in accordance with the above referenced contract order and MACTEC's Quality Assurance Manual (QAM) Revision 1.

MACTEC Engineering and Consulting, Inc.
396 Plasters Avenue, NE • Atlanta, GA 30324 • Phone: 404-873-4761 • Fax: 404-817-0221

www.mactec.com

We appreciate the opportunity of serving your geotechnical laboratory testing needs. If you have questions, please contact us.

Sincerely,

MACTEC Engineering and Consulting, Inc.

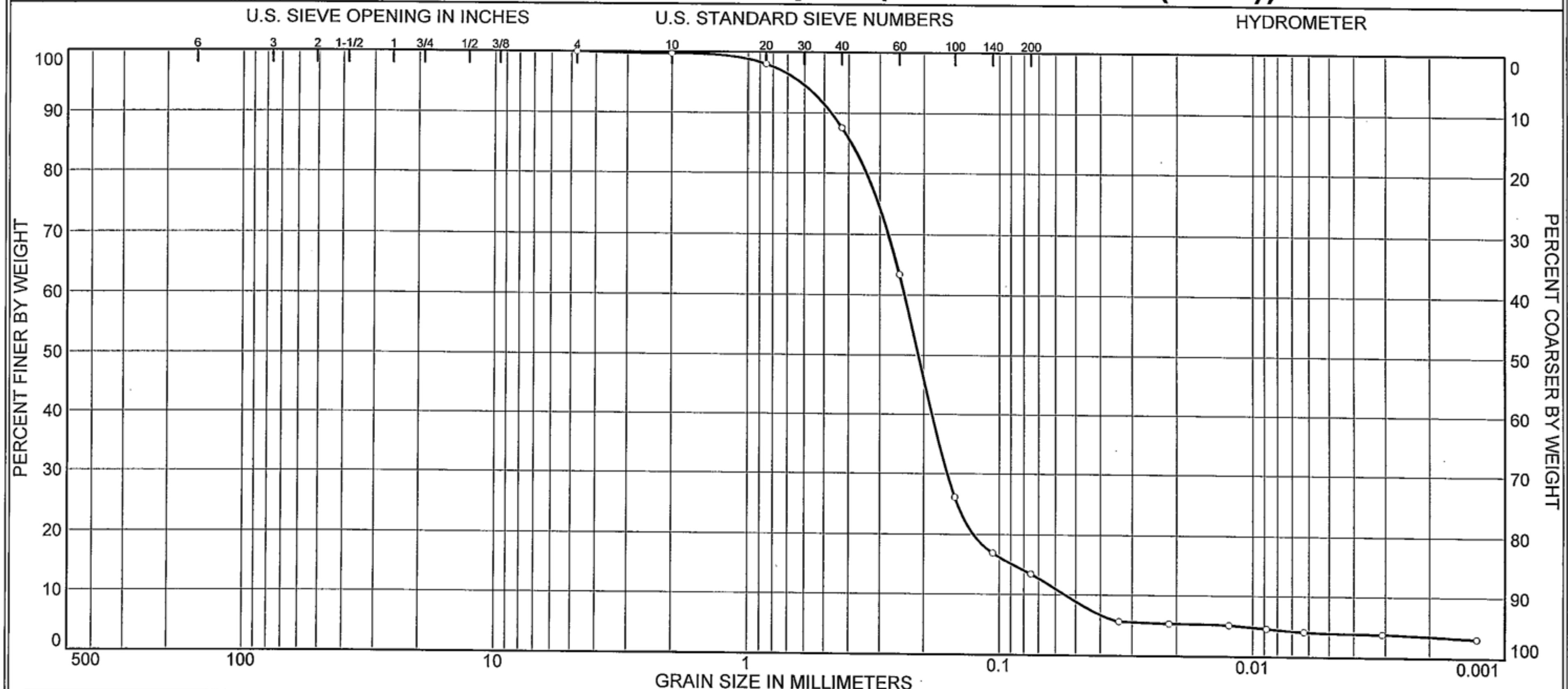
Jianren Wang
Principal

John E Lynch
John Lynch
Laboratory Manager

Cc: WSRC
Vendor Documents
Building 704-IN/Room 137
Aiken, SC 29808

ATTACHMENT 1

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	0.0	0.3	12.1	74.2	9.5	3.9

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B01	Bag 1	0-5 ft	3/18/09	SM	Brown Silty Sand	8.2	NV	NP

Client SRNS

Project Saltstone Vaults 3 & 5

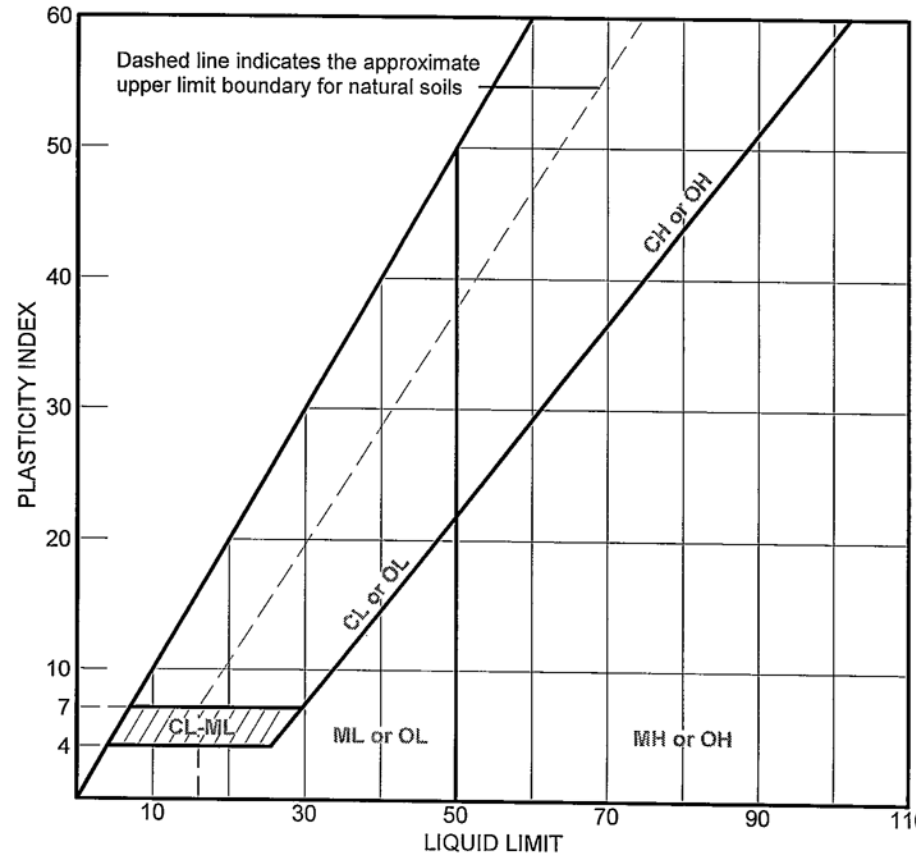
Project No. 6155-08-0031.06 | Lab No. 9465

MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewed By: JW

JW
5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)



	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B01	Bag 1	0-5 ft	3/18/09	SM	Brown Silty Sand	8.2	NV	NP

Client SRNS

Project Saltstone Vaults 3 & 5

Project No. 6155-08-0031.06 Lab No. 9465

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed BY: JW

JW 5/18/09

COMPACTION TEST REPORT

Project No.: 6155-08-0031.06 **Date:** 3/19/09
Project: Saltstone Vaults 3 & 5

Location: Z-V3V5-B01
Elev./Depth: 0-5 ft **Sample No.** Bag 1
Remarks: Tested By: EH Reviewed By: JW JW 5/18/09

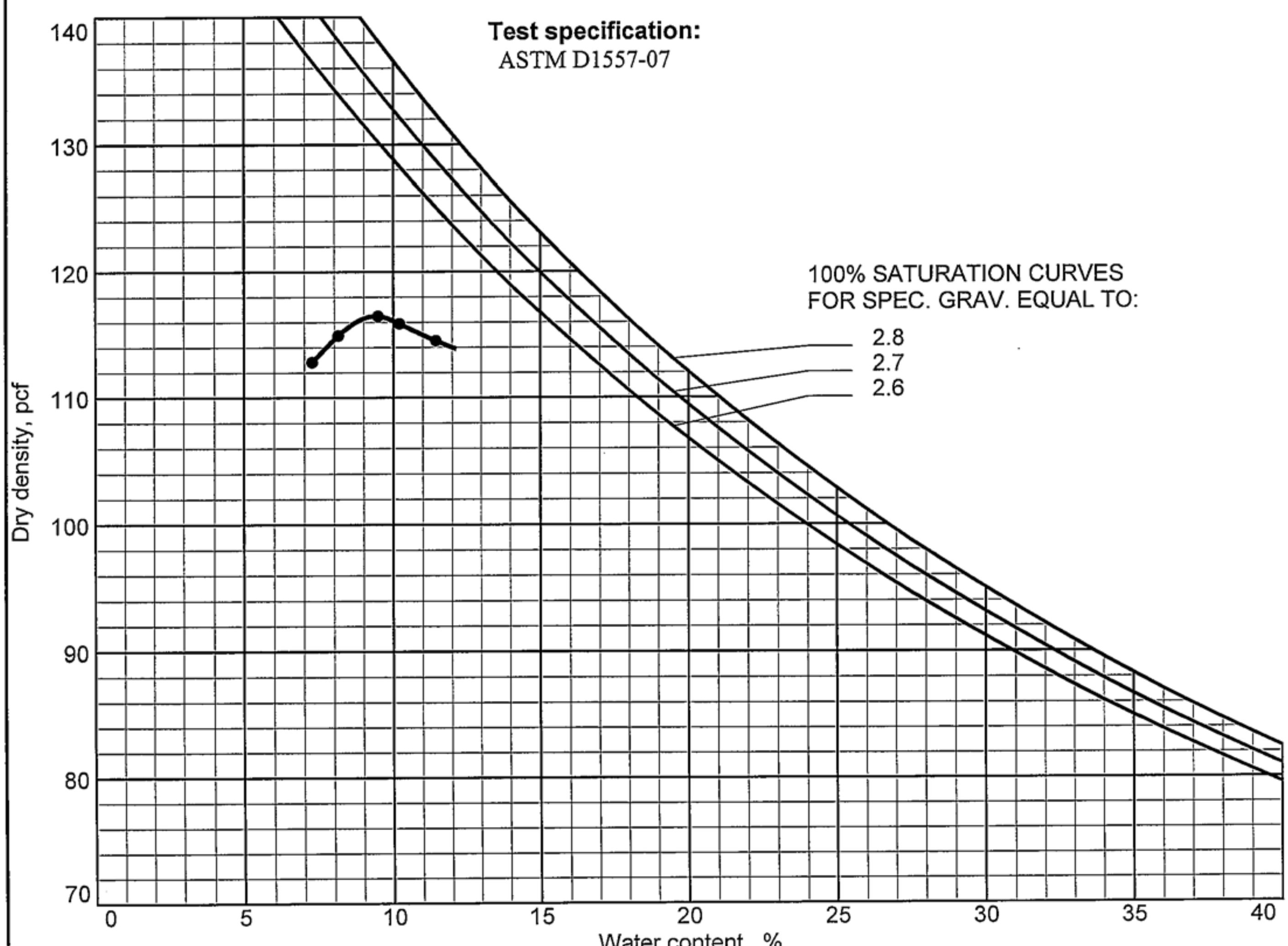
MATERIAL DESCRIPTION

Description: Brown Silty Sand

Classifications - **USCS:** SM **AASHTO:**
Nat. Moist. = 8.2 % **Sp.G. =**
Liquid Limit = NV **Plasticity Index =** NP
% > 3/4 in. = 0.0 % **% < No.200 =** 13.4 %

TEST RESULTS
Maximum dry density = 116.5 pcf
Optimum moisture = 9.4 %

Test specification:
ASTM D1557-07



Lab 9465

MACTEC Engineering and Consulting, Inc.

MOISTURE DENSITY TEST DATA

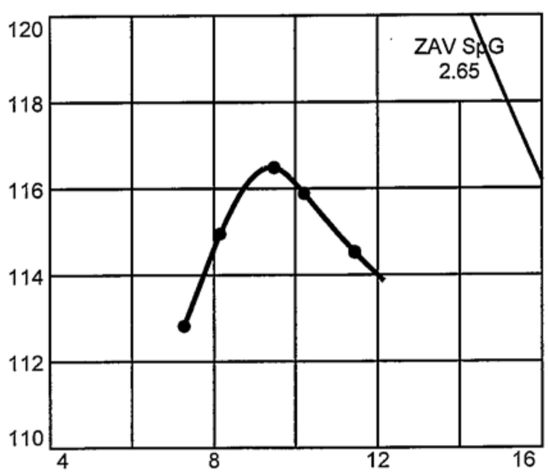
Client: SRNS
Project: Saltstone Vaults 3 & 5
Project Number: 6155-08-0031.06

Specimen Data

Source: Z-V3V5-B01
Sample No.: Bag 1
Elev. or Depth: 0-5 ft
Sample Length(in./cm.): 9465
Location: Z-V3V5-B01
Description: Brown Silty Sand
Liquid Limit: NV
Plasticity Index: NP
Natural Moisture: 8.2
Date: 3/19/09
USCS Classification: SM
AASHTO Classification:
Testing Remarks: Tested By: EH Reviewed By: JW
Percent retained on 3/4 in. sieve: 0.0
Percent passing No. 200 sieve: 13.4
Specific gravity:

Test Data And Results

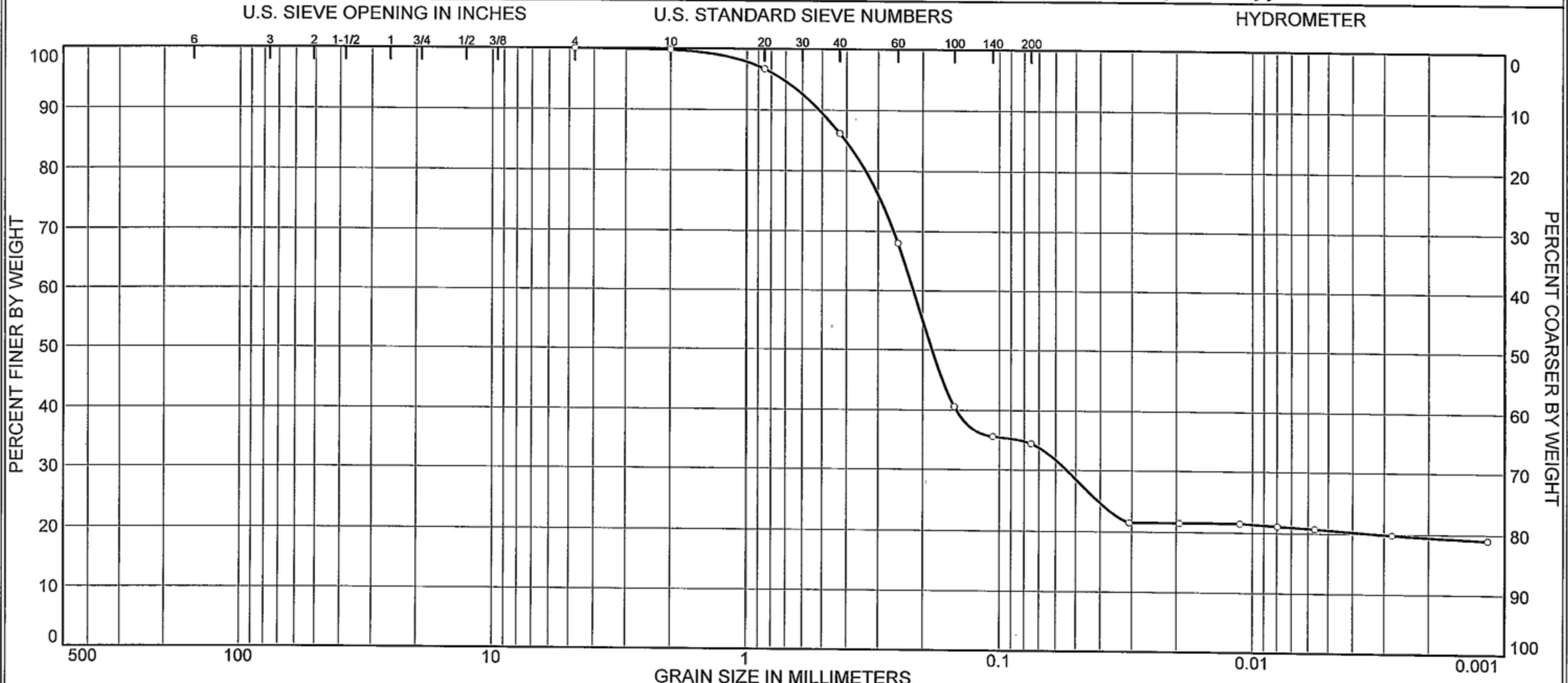
Type of test: ASTM D1557-07



POINT NO.	1	2	3	4	5
WM + WS	3928.6	3980.0	3977.1	3978.9	3878.9
WM	2053.2	2053.2	2053.2	2053.2	2053.2
WW+T	412.00	440.20	457.60	524.00	469.10
WD+T	381.60	400.20	418.70	471.00	437.90
TARE	8.40	8.30	8.30	8.30	8.40
MOIST	8.1	10.2	9.5	11.5	7.3
MOISTURE	8.1	10.2	9.5	11.5	7.3
DRY DEN	114.9	115.9	116.5	114.5	112.8

Max dry den= 116.5 pcf **Opt moisture=** 9.4 %

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	0.0	0.2	13.6	51.8	13.9	20.5

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B01	Bag 2	5-10 ft	3/18/09	SC	Brown Clayey Sand	15.6	43	20

Client SRNS

Project Saltstone Vaults 3 & 5

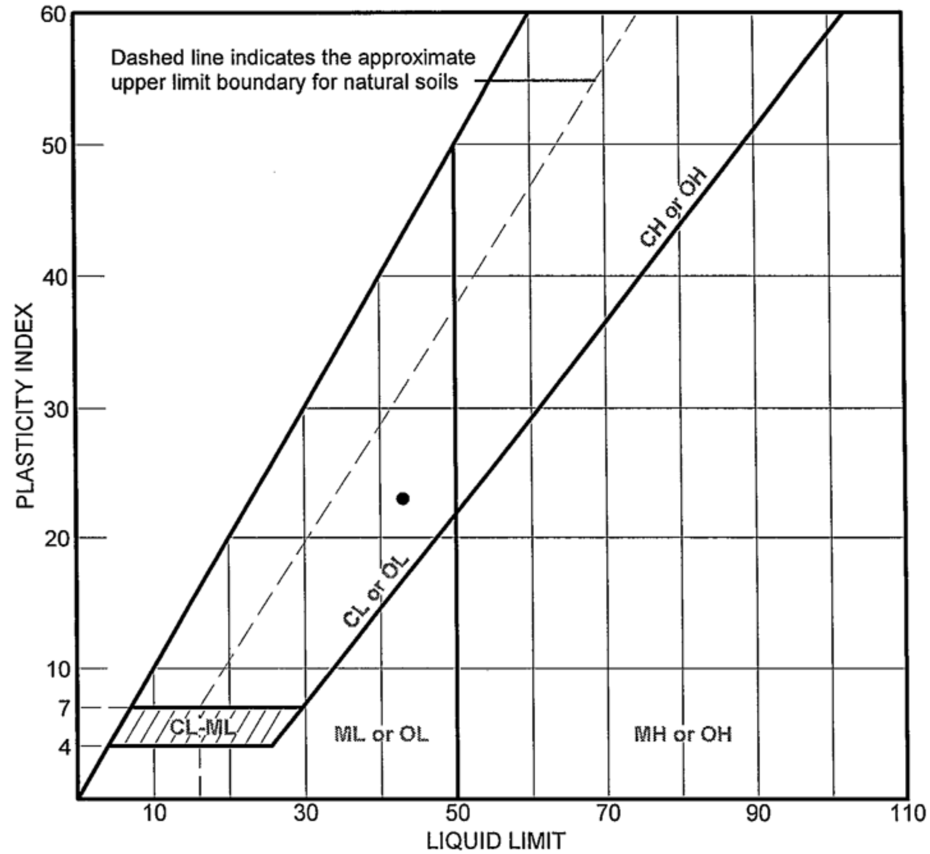
Project No. 6155-08-0031.06 Lab No. 9466

MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewed By: JW

JW 5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)



	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B01	Bag 2	5-10 ft	3/18/09	SC	Brown Clayey Sand	15.6	43	23

Client SRNS

Project Saltstone Vaults 3 & 5

Project No. 6155-08-0031.06 | Lab No. 9466

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW 5/18/09

COMPACTION TEST REPORT

Project No.: 6155-08-0031.06 **Date:** 3/19/09
Project: Saltstone Vaults 3 & 5

Location: Z-V3V5-B01
Elev./Depth: 5-10 ft **Sample No.** Bag 2
Remarks: Tested By: EH Reviewed By: JW JW 5/18/09

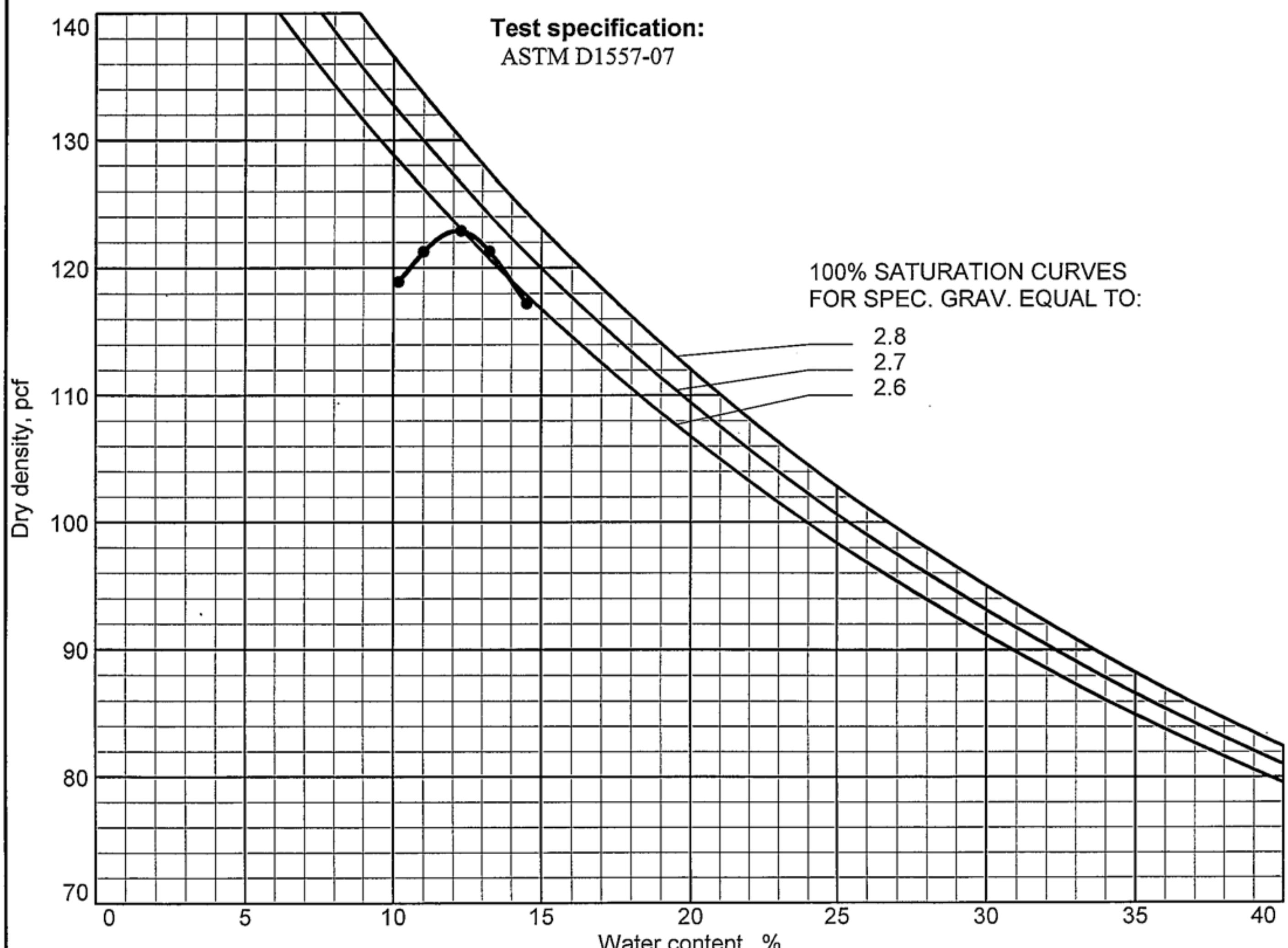
MATERIAL DESCRIPTION

Description: Brown Clayey Sand

Classifications - **USCS:** SC **AASHTO:**
Nat. Moist. = 15.6 % **Sp.G. =**
Liquid Limit = 43 **Plasticity Index =** 23
% > 3/4 in. = 0.0 % **% < No.200 =** 34.4 %

TEST RESULTS
Maximum dry density = 122.9 pcf
Optimum moisture = 12.2 %

Test specification:
ASTM D1557-07



Lab 9466

MACTEC Engineering and Consulting, Inc.

MOISTURE DENSITY TEST DATA

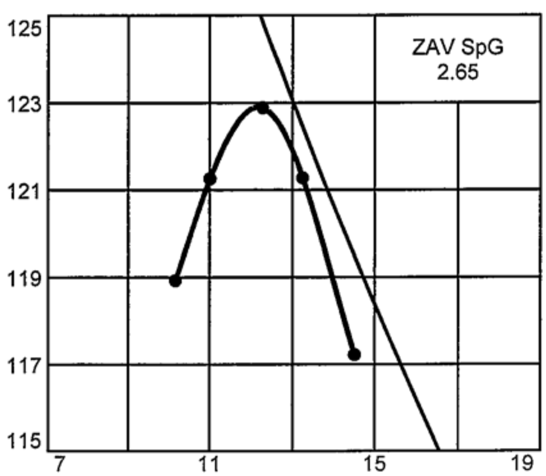
Client: SRNS
Project: Saltstone Vaults 3 & 5
Project Number: 6155-08-0031.06

Specimen Data

Source: Z-V3V5-B01
Sample No.: Bag 2
Elev. or Depth: 5-10 ft **Sample Length(in./cm.):** 9466
Location: Z-V3V5-B01
Description: Brown Clayey Sand
Liquid Limit: 43 **Plasticity Index:** 23 **Natural Moisture:** 15.6
Date: 3/19/09 **USCS Classification:** SC **AASHTO Classification:**
Testing Remarks: Tested By: EH Reviewed By: JW
Percent retained on 3/4 in. sieve: 0.0
Percent passing No. 200 sieve: 34.4 **Specific gravity:**

Test Data And Results

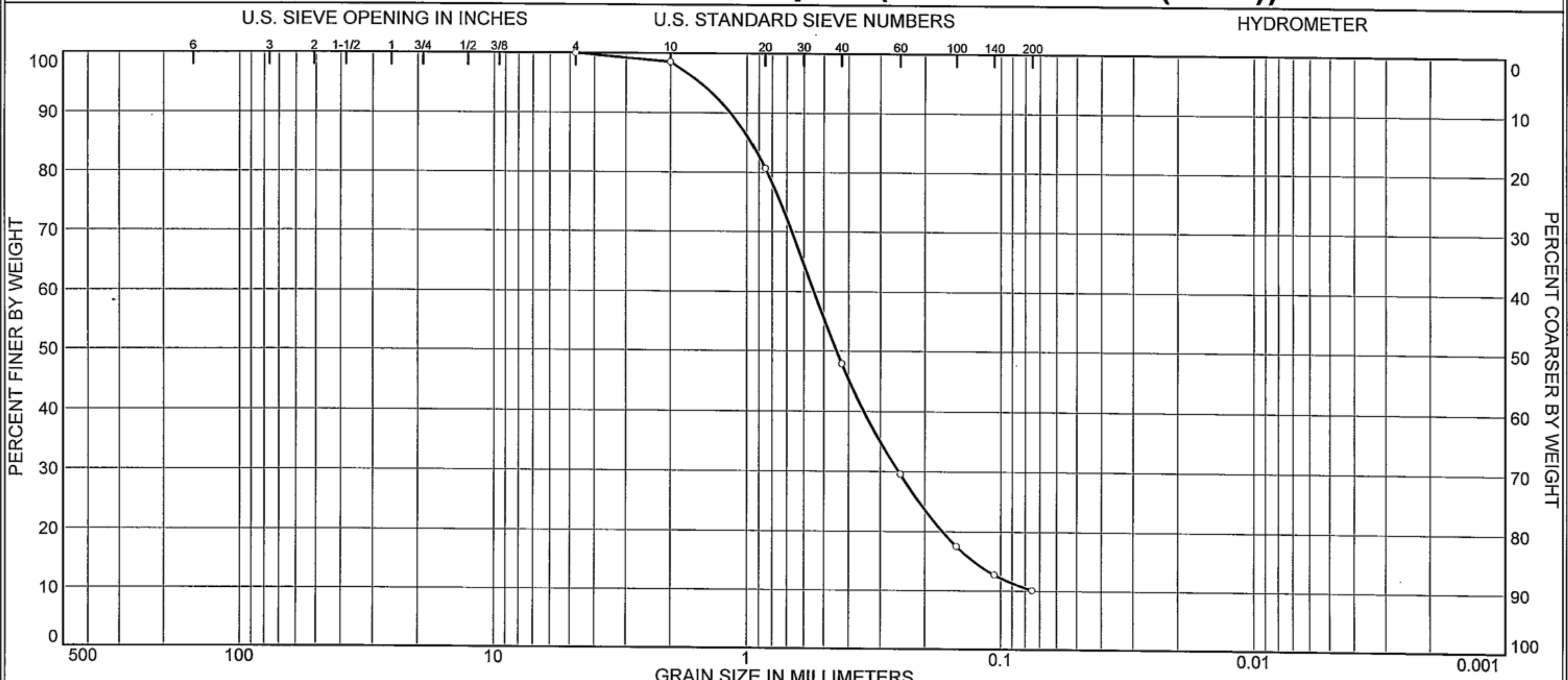
Type of test: ASTM D1557-07



POINT NO.	1	2	3	4	5
WM + WS	4029.8	4134.7	4078.2	4083.8	4125.3
WM	2053.2	2053.2	2053.2	2053.2	2053.2
WW+T	534.80	536.30	462.80	521.70	524.70
WD+T	486.20	478.60	405.20	470.80	464.30
TARE	8.20	8.40	8.30	8.20	8.40
MOIST	10.2	12.3	14.5	11.0	13.2
MOISTURE	10.2	12.3	14.5	11.0	13.2
DRY DEN	118.9	122.9	117.2	121.3	121.3

Max dry den= 122.9 pcf **Opt moisture=** 12.2 %

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL COARSE	% GRAVEL FINE	% SAND COARSE	% SAND MEDIUM	% SAND FINE	% FINES SILT	% FINES CLAY
○	0.0	0.0	0.0	1.4	50.7	37.8	10.1	

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B01	ST1	20-22 ft	4/7/09	SP-SC	Brown Poorly Graded Sand with Clay	11.1	31	20

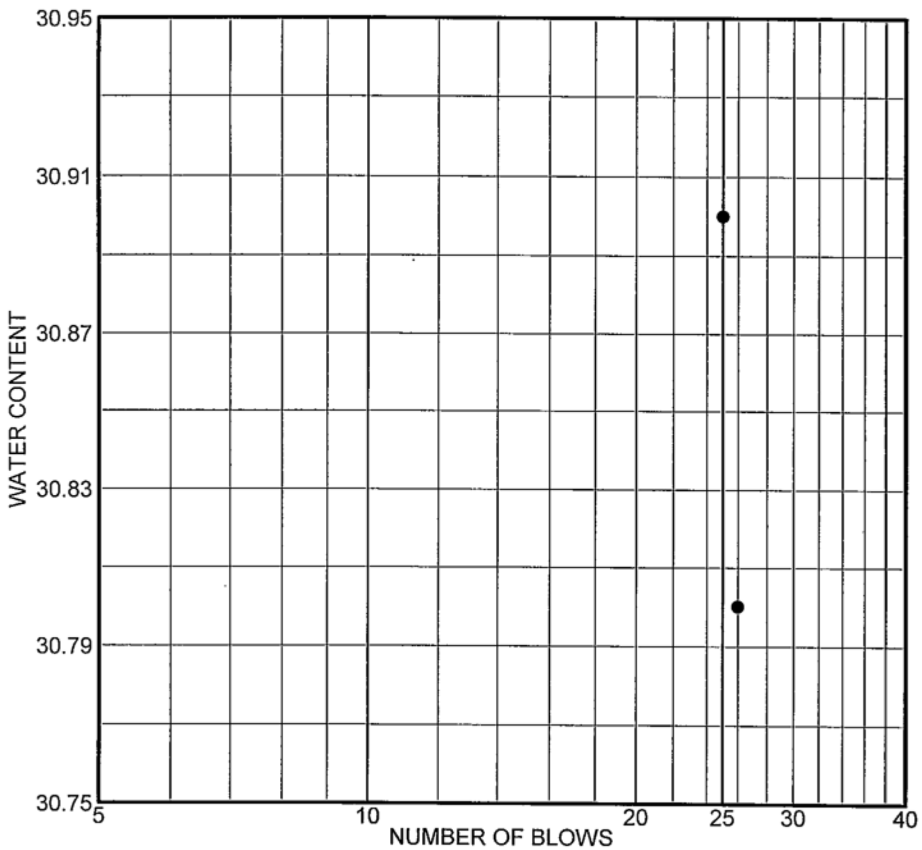
Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9476

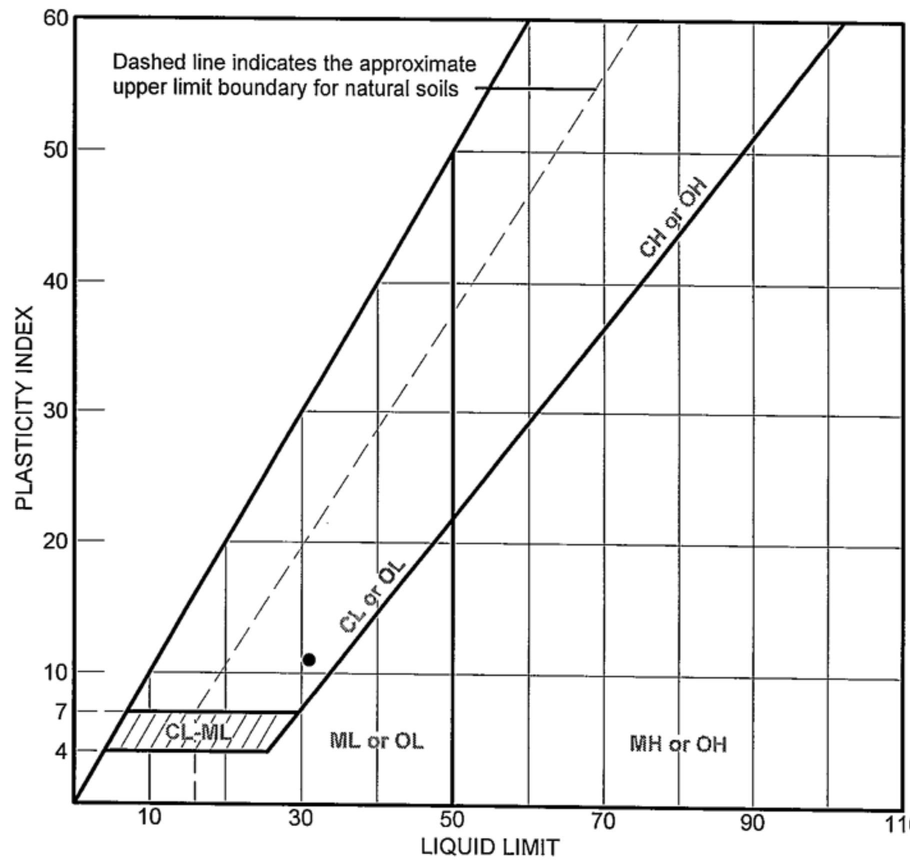
MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewed By: JW

JW
5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)





	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B01	ST1	20-22 ft	4/7/09	SP-SC	Brown Poorly Graded Sand with Clay	11.1	31	11

Client SRNS

Project Saltstone Vaults 3 & 5

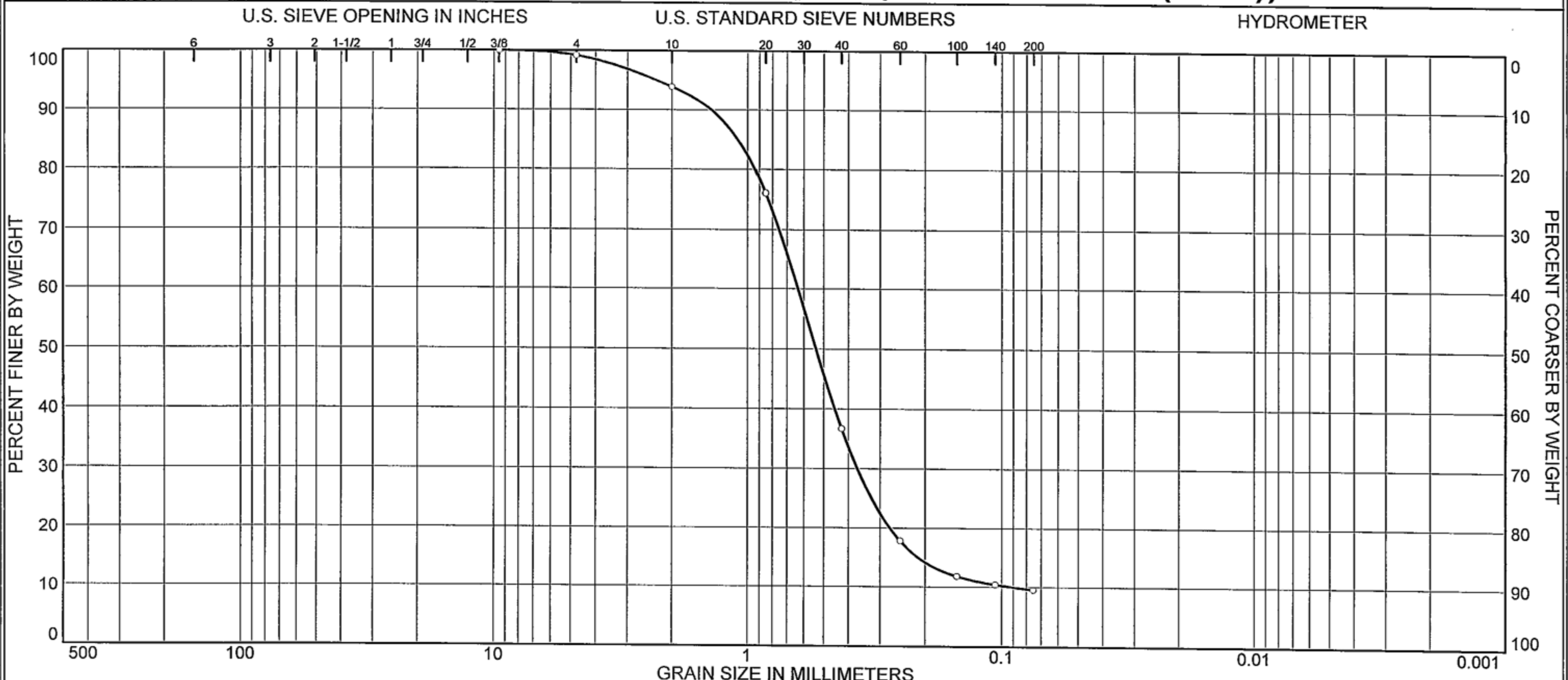
Project No. 6155-08-0031.06 Lab No. 9476

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW 5/18/09

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	0.8	5.3	57.2	27.2	9.5	

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B01	ST2	30-32 ft	4/7/09	SW-SC	Reddish Brown Well-graded Sand with Clay	11.9	38	20

Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9477

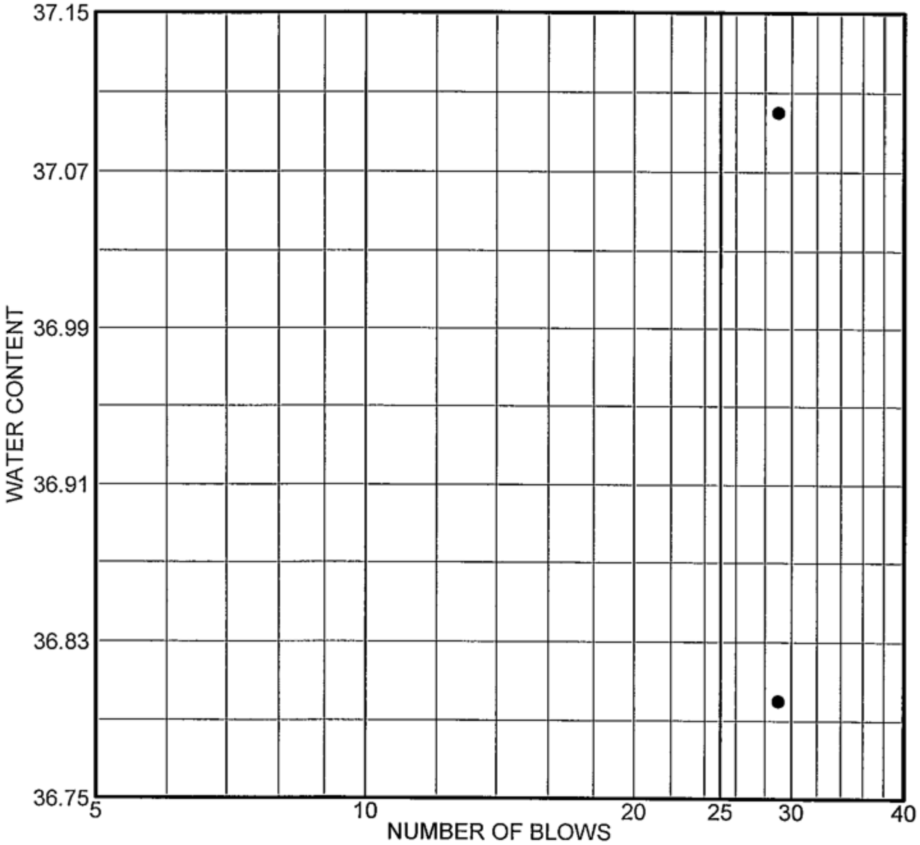
MACTEC ENGINEERING AND CONSULTING, INC.

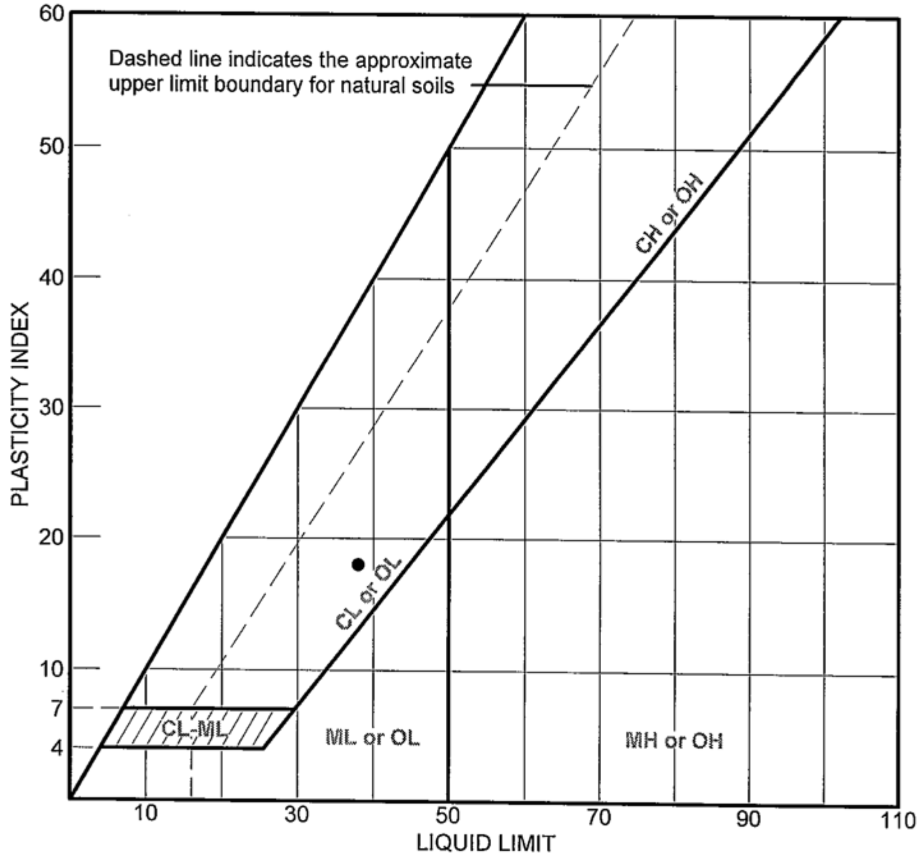
○ Tested By: EH Reviewed By: JW

Specific Gravity = 2.68

JW 5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)





	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B01	ST2	30-32 ft	4/7/09	SW-SC	Reddish Brown Well-graded Sand with Clay	11.9	38	18

Client SRNS

Project Saltstone Vaults 3 & 5

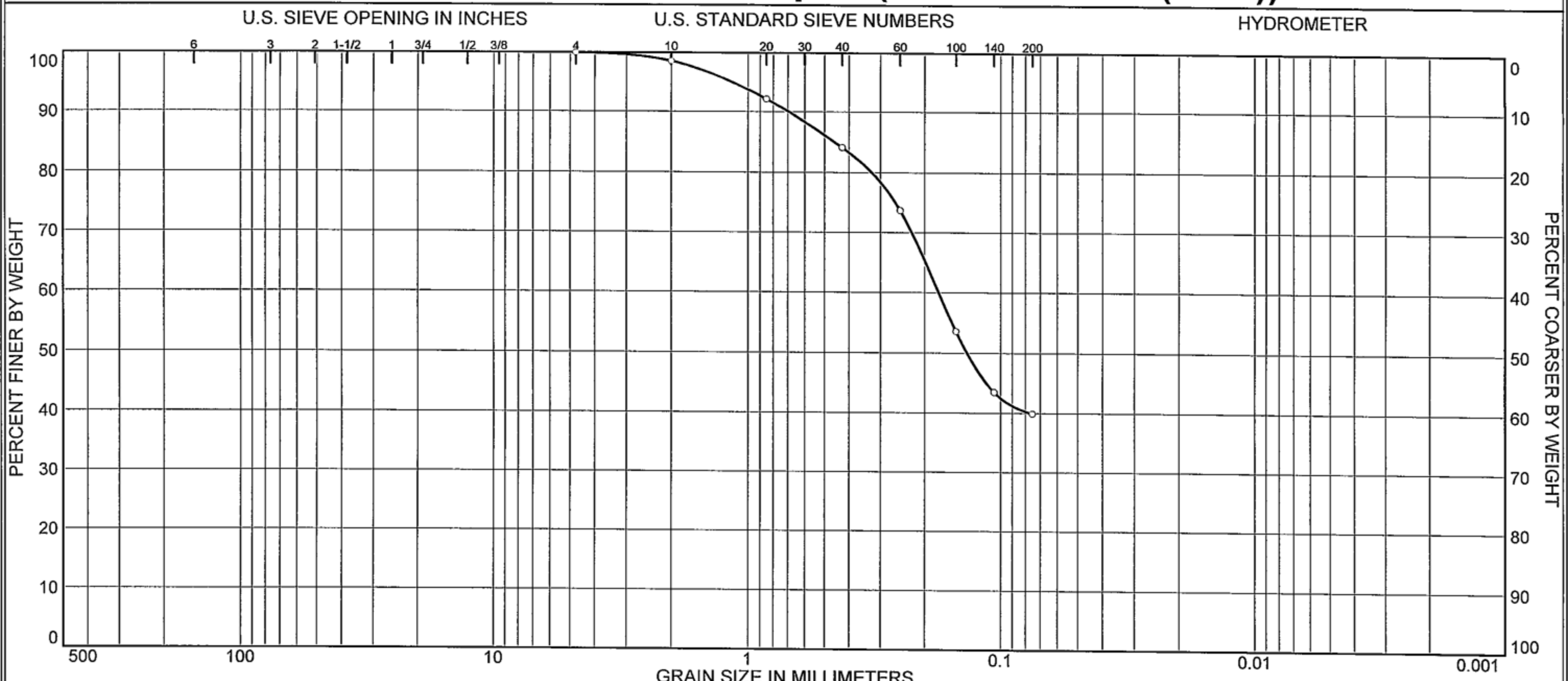
Project No. 6155-08-0031.06 Lab No. 9477

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: Eh Reviewed By: JW

JW 5/18/09

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL COARSE	% GRAVEL FINE	% SAND COARSE	% SAND MEDIUM	% SAND FINE	% FINES SILT	% FINES CLAY
○	0.0	0.0	0.0	1.4	14.5	44.2	39.9	

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B01	ST3	37-39 ft	4/8/09	SC	Brown Clayey Sand	22.1	53	21

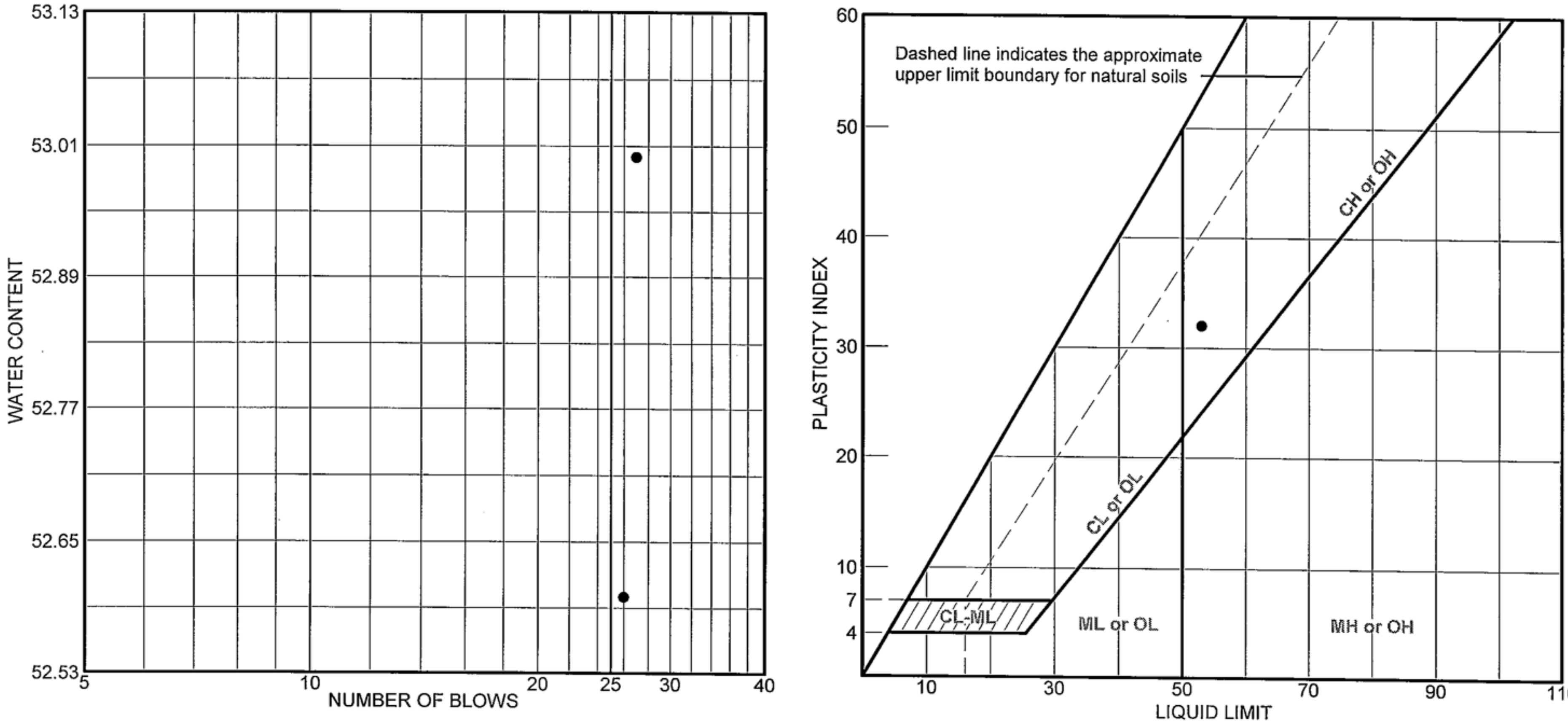
Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9478

MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewed By: JW

JW 5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)



	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B01	ST3	37-39 ft	4/8/09	SC	Brown Clayey Sand	22.1	53	32

Client SRNS

Project Saltstone Vaults 3 & 5

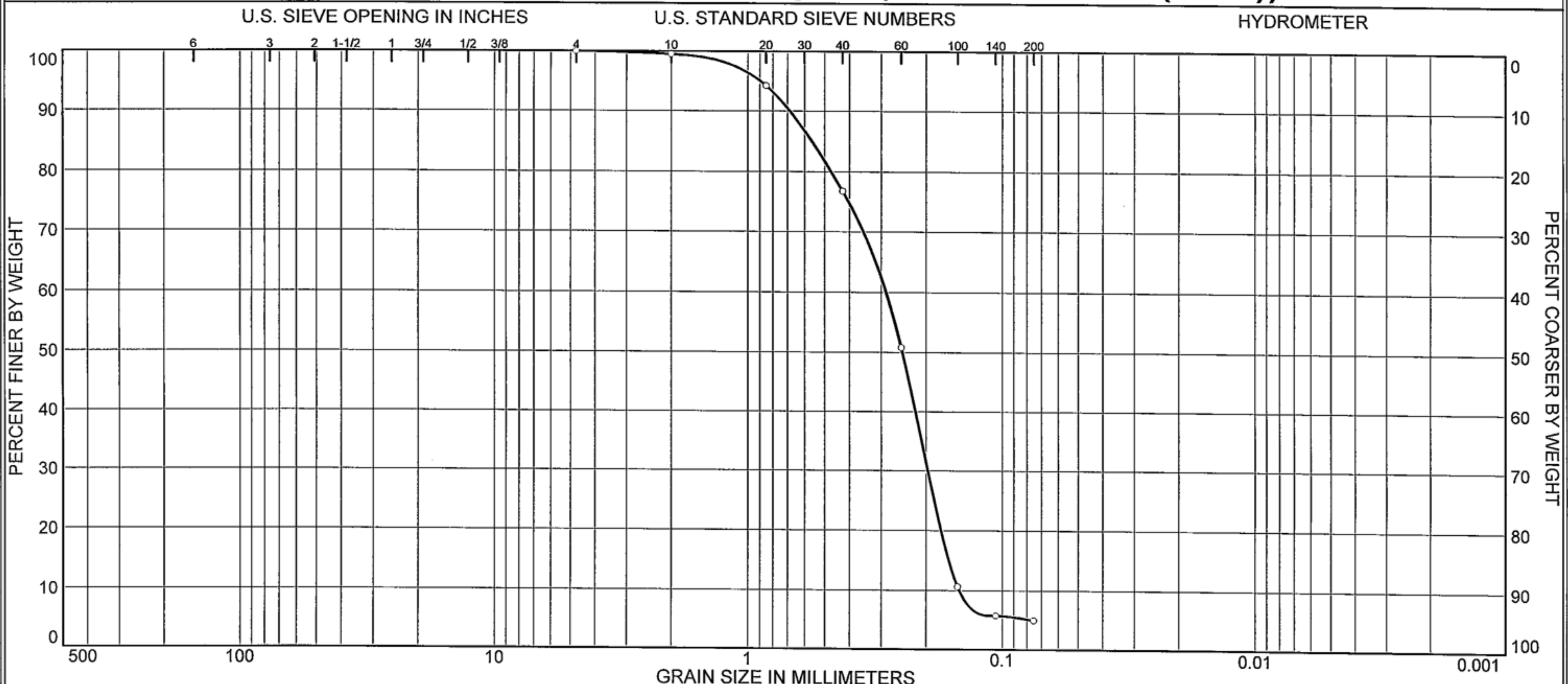
Project No. 6155-08-0031.06 Lab No. 9478

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW 5/18/09

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	0.0	0.5	22.8	71.8	4.9	

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B01	ST4	50-52 ft	4/3/09	SP	Brown Poorly Graded Sand	12.9	NV	NP

Client SRNS

Project Saltstone Vaults 3 & 5

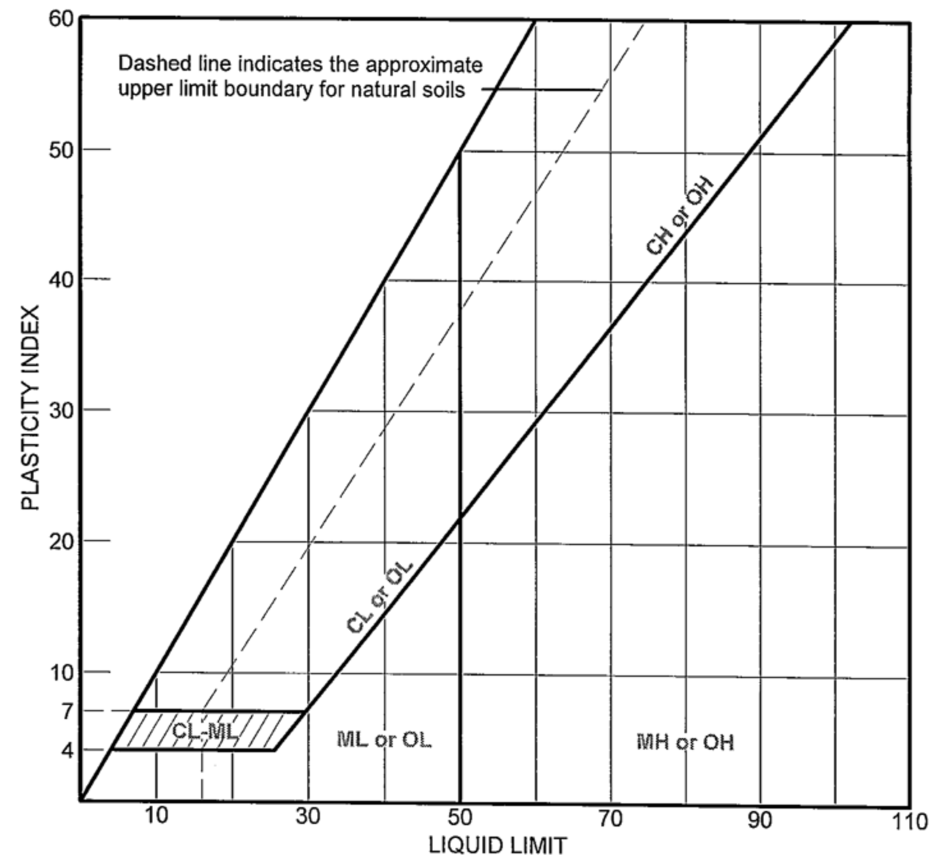
Project No. 6155-08-0031.06 Lab No. 9479

MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewed By: JW

JW 5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)



	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B01	ST4	50-52 ft	4/3/09	SP	Brown Poorly Graded Sand	12.9	NV	NP

Client SRNS

Project Saltstone Vaults 3 & 5

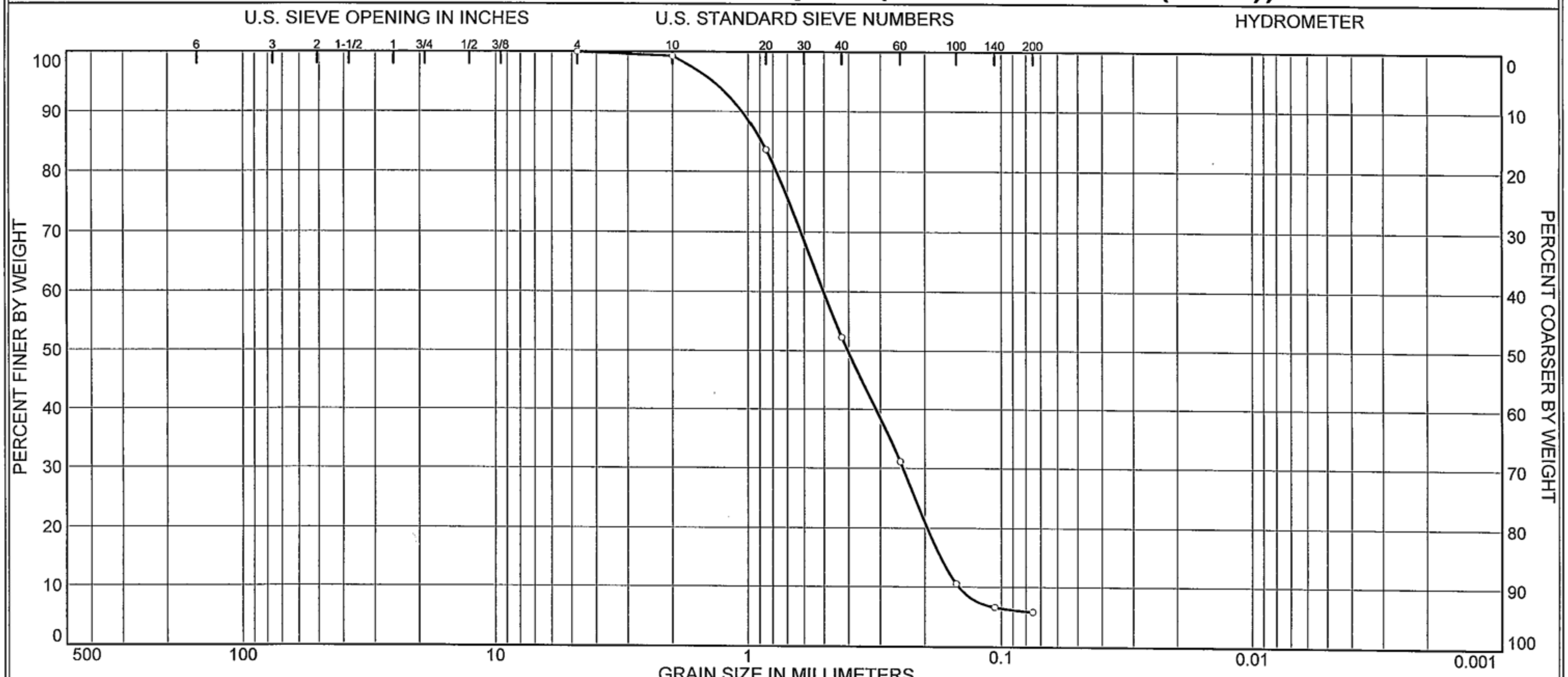
Project No. 6155-08-0031.06 Lab No. 9479

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW 5/18/09

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	0.0	0.7	47.0	46.5	5.8	

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B01	ST5	55-57 ft	4/3/09	SP-SM	Brown Poorly Graded Sand with Silt	16.0	NV	NP

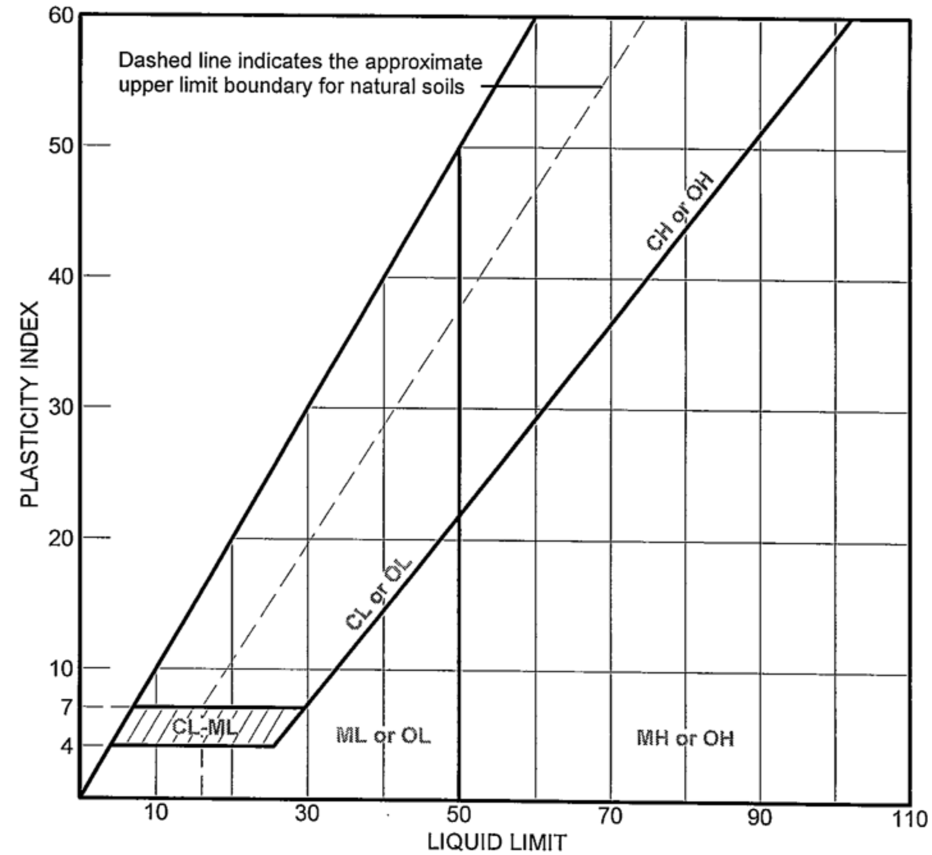
Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9480

MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewed By: JW

JW 5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)



	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B01	ST5	55-57 ft	4/3/09	SP-SM	Brown Poorly Graded Sand with Silt	16.0	NV	NP

Client SRNS

Project Saltstone Vaults 3 & 5

Project No. 6155-08-0031.06 Lab No. 7480

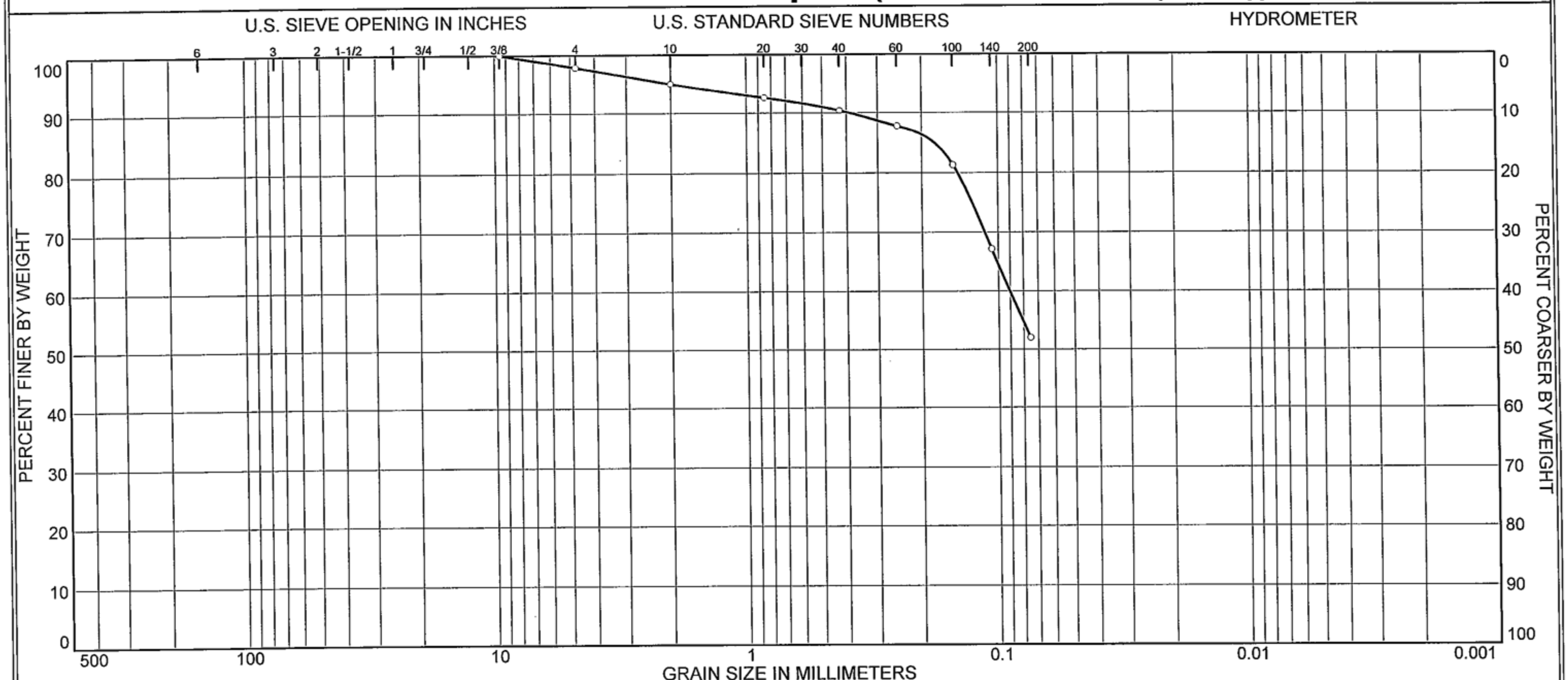
MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW 5/18/09

K-CLC-Z-00013, Rev. 0

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	2.1	2.9	4.6	38.4	52.0	

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B01	ST7	78-80 ft	4/22/09	CL	Tan Sandy Lean Clay	30.6	36	23

Client SRNS

Project Saltstone Vaults 3 & 5

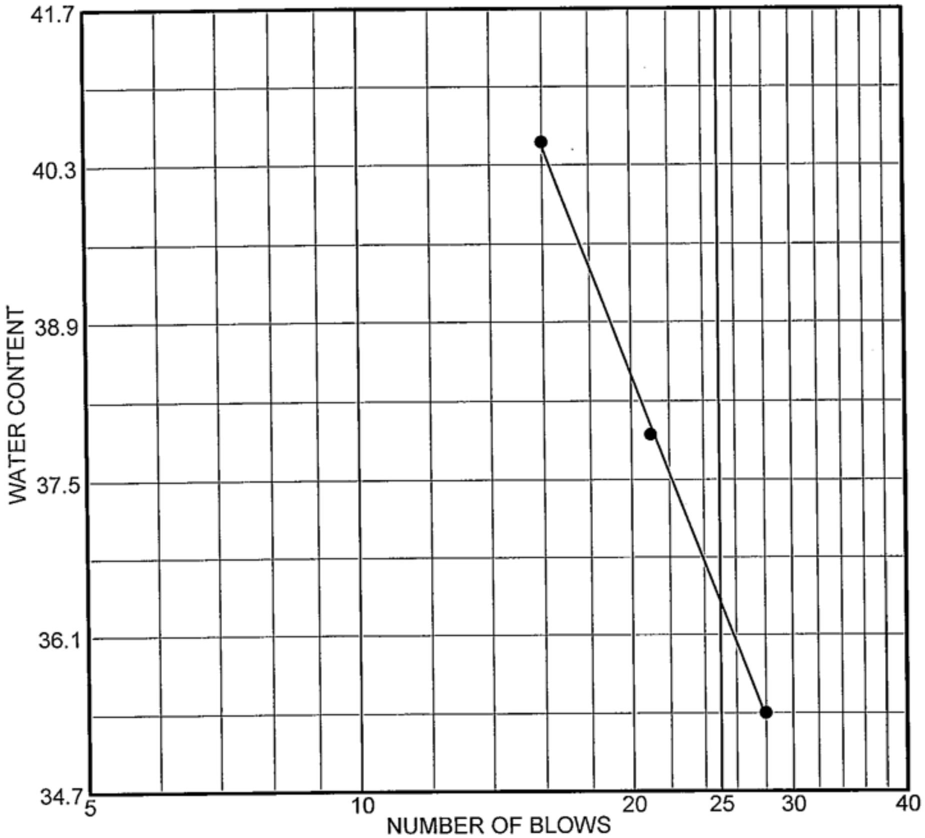
Project No. 6155-08-0031.06 Lab No. 9482

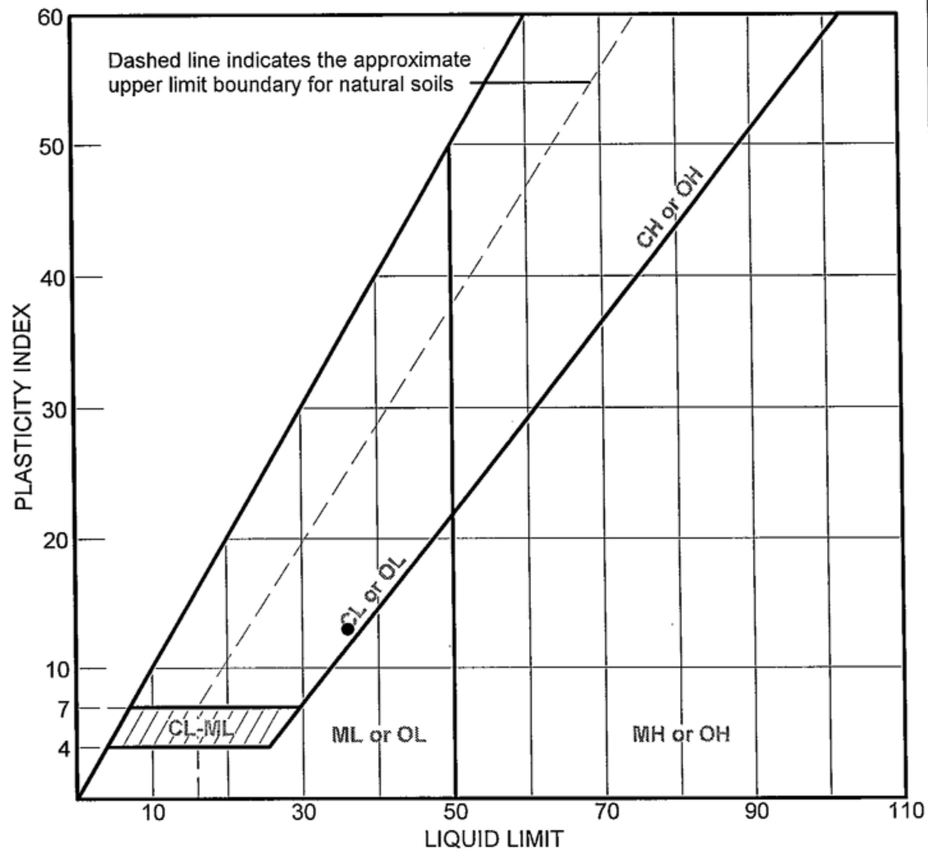
MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewed By: JW

JW 5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)





	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B01	ST7	78-80 ft	4/22/09	CL	Tan Sandy Lean Clay	30.6	36	13

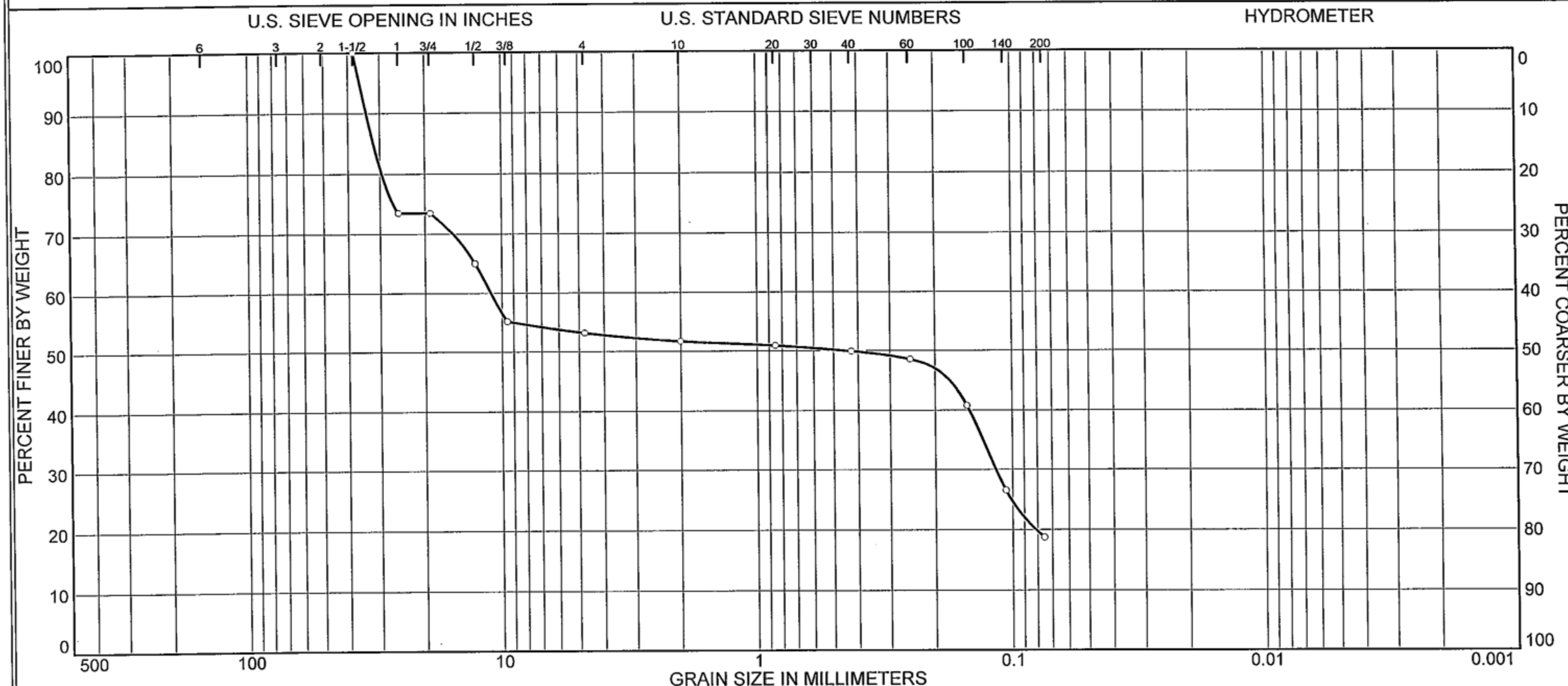
Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9482

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW 5/18/09

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	26.5	20.3	1.5	1.8	31.2	18.7	

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B01	ST8	81-83 ft	4/22/09	GM	Tan Silty Gravel with Sand	23.1	42	30

Client SRNS

Project Saltstone Vaults 3 & 5

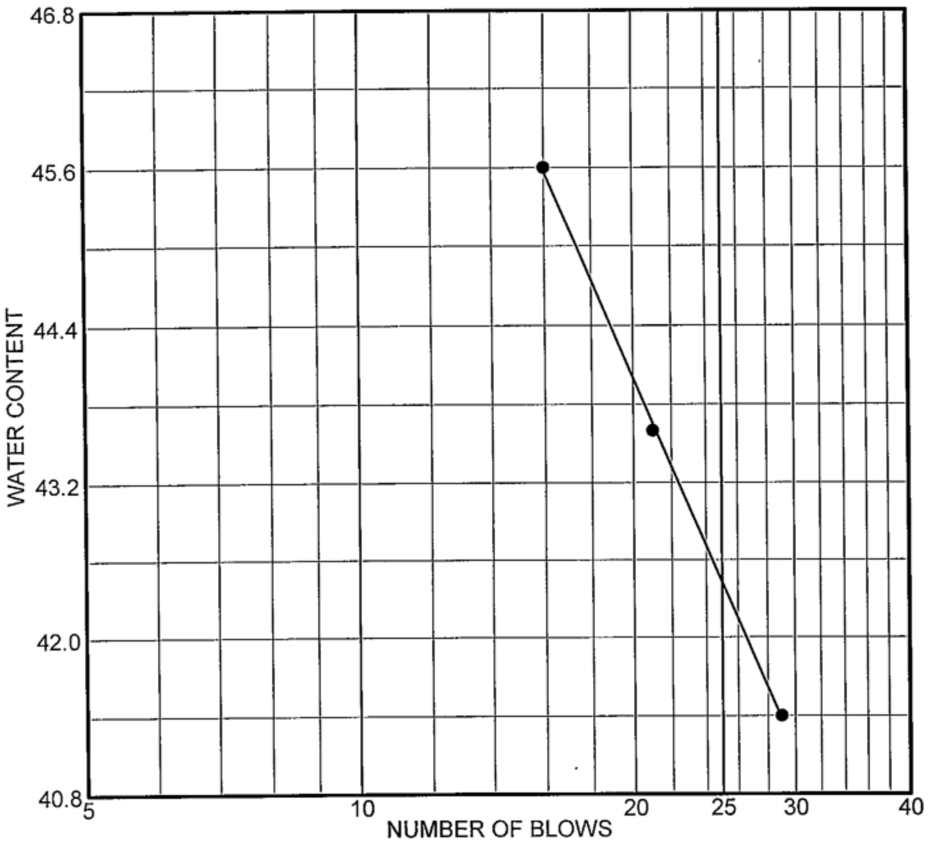
Project No. 6155-08-0031.06 Lab No. 9483

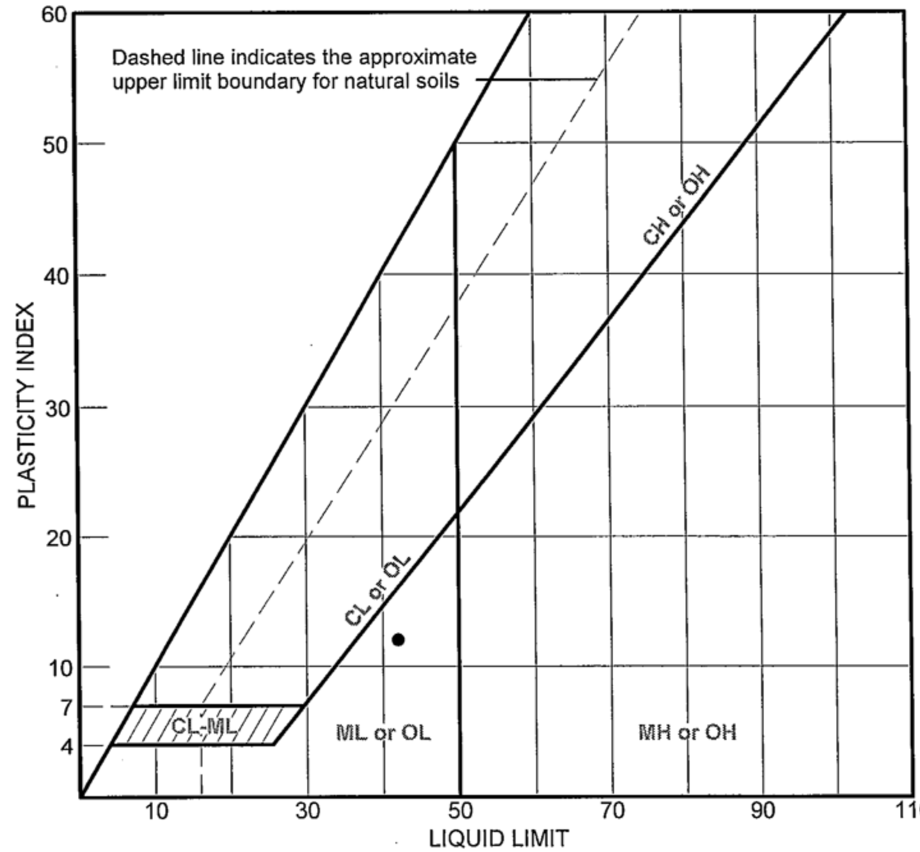
MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewed By: JW

JW 5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)





	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B01	ST8	81-83 ft	4/22/09	GM	Tan Silty Gravel with Sand	23.1	42	12

Client SRNS

Project Saltstone Vaults 3 & 5

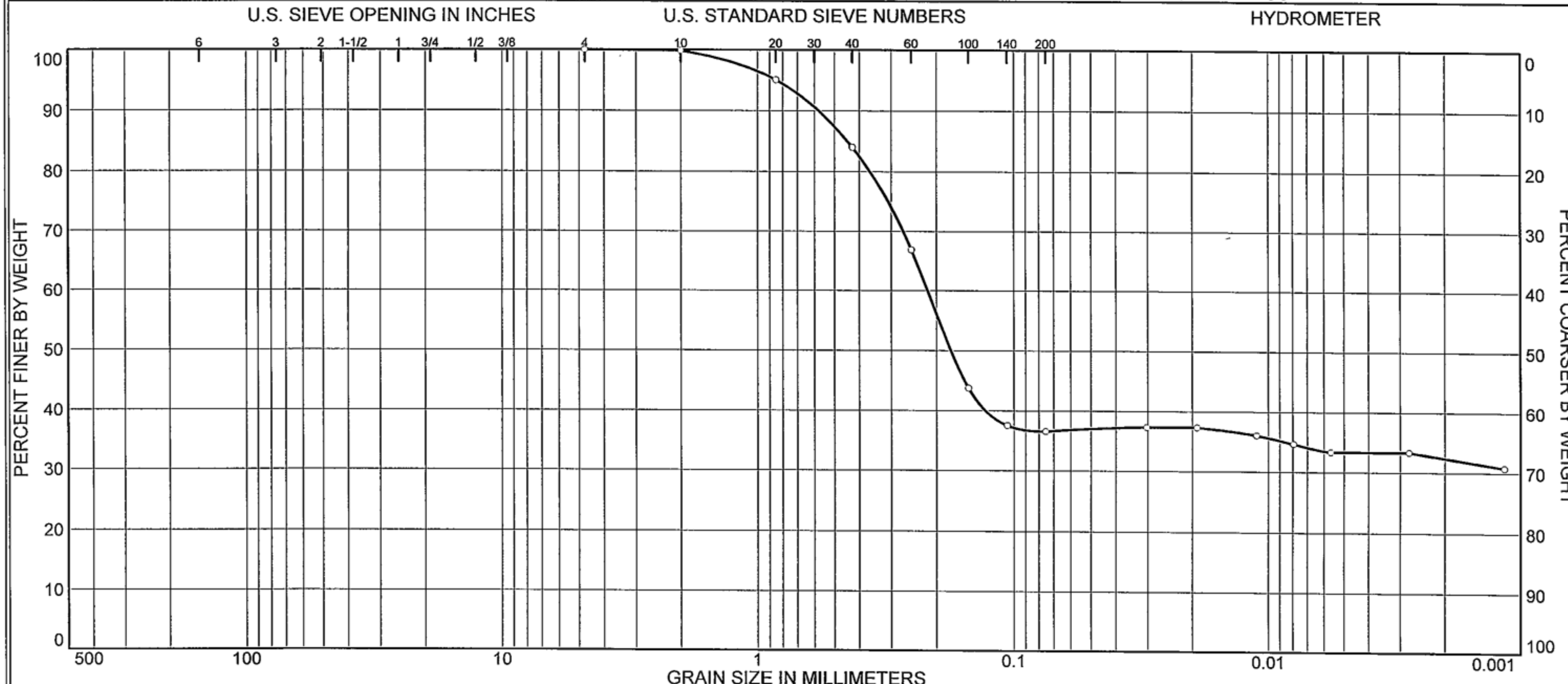
Project No. 6155-08-0031.06 Lab No. 9483

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW 5/18/09

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	0.0	0.1	15.9	47.5	3.2	33.3

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B04	ST1	20-22 ft	4/3/09	SC	Reddish Brown Clayey Sand	21.3	42	23

Client SRNS

Project Saltstone Vaults 3 & 5

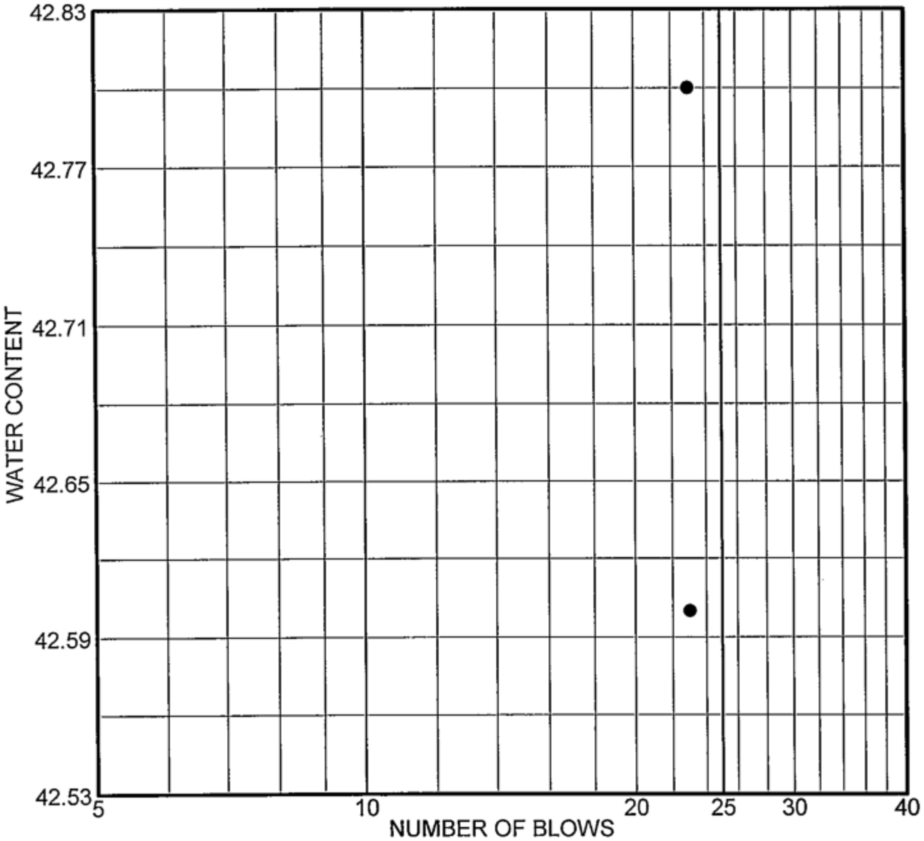
Project No. 6155-08-0031.06 Lab No. 9458

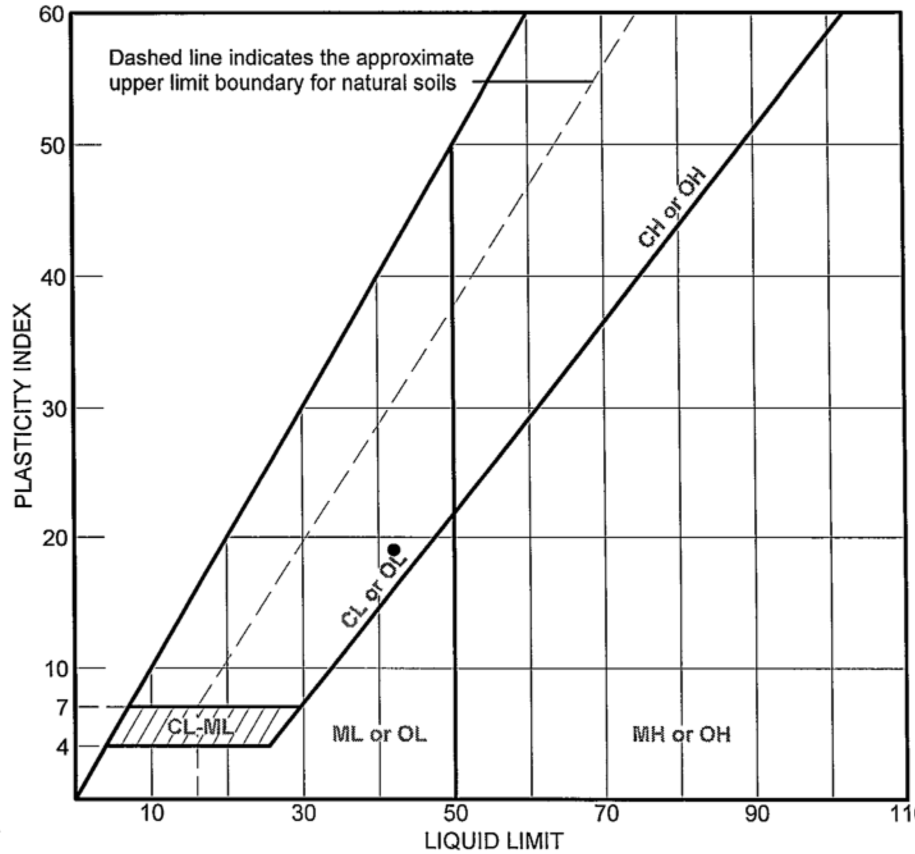
MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewed By: JW

JW 5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)

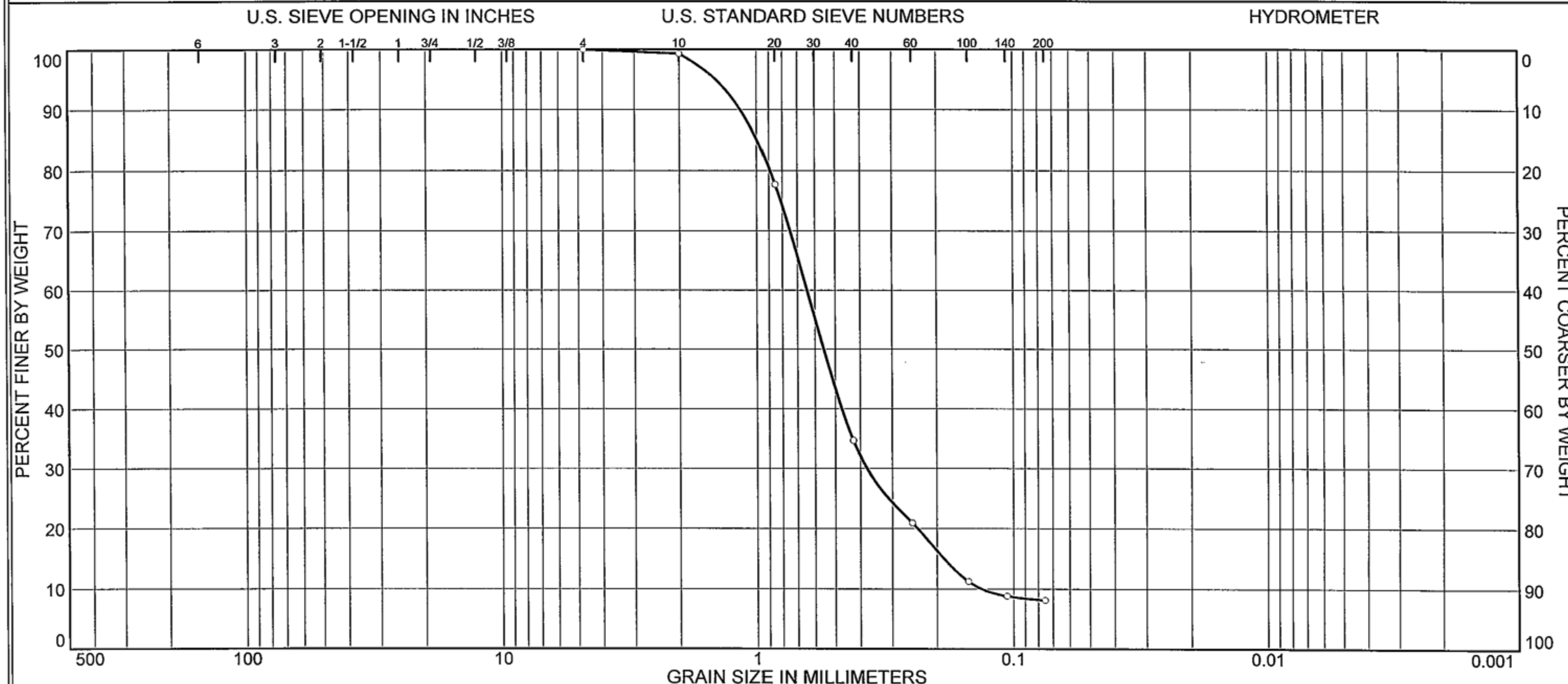




	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B04	ST1	20-22 ft	4/3/09	SC	Reddish Brown Clayey Sand	21.3	42	19

Client SRNS Project Saltstone Vaults 3 & 5 Project No. 6155-08-0031.06 — Lab No. 9458	**MACTEC ENGINEERING AND CONSULTING, INC.**	● Tested By: EH Reviewed By: JW JW 5/18/09

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	0.0	0.7	64.6	26.6	8.1	

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B04	ST2	30-32 ft	3/25/09	SP-SC	Brown Poorly Graded Sand with Clay	15.1	39	22

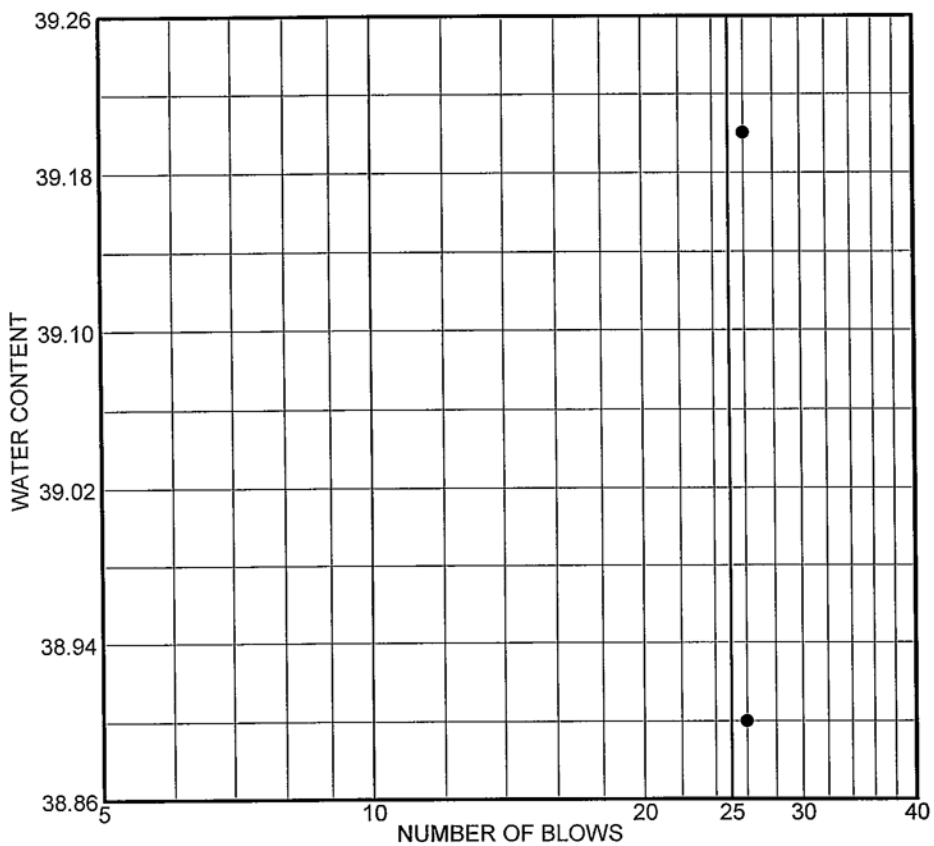
Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9459

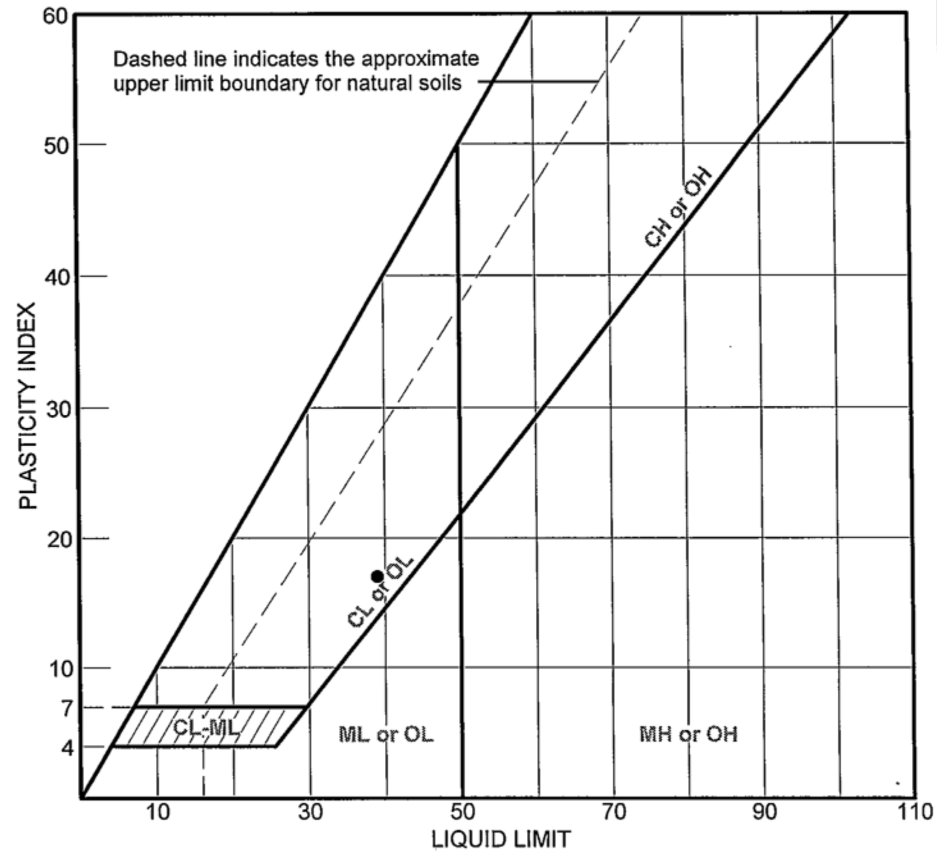
MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewed By: JW
Specific Gravity = 2.67

JW 5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)

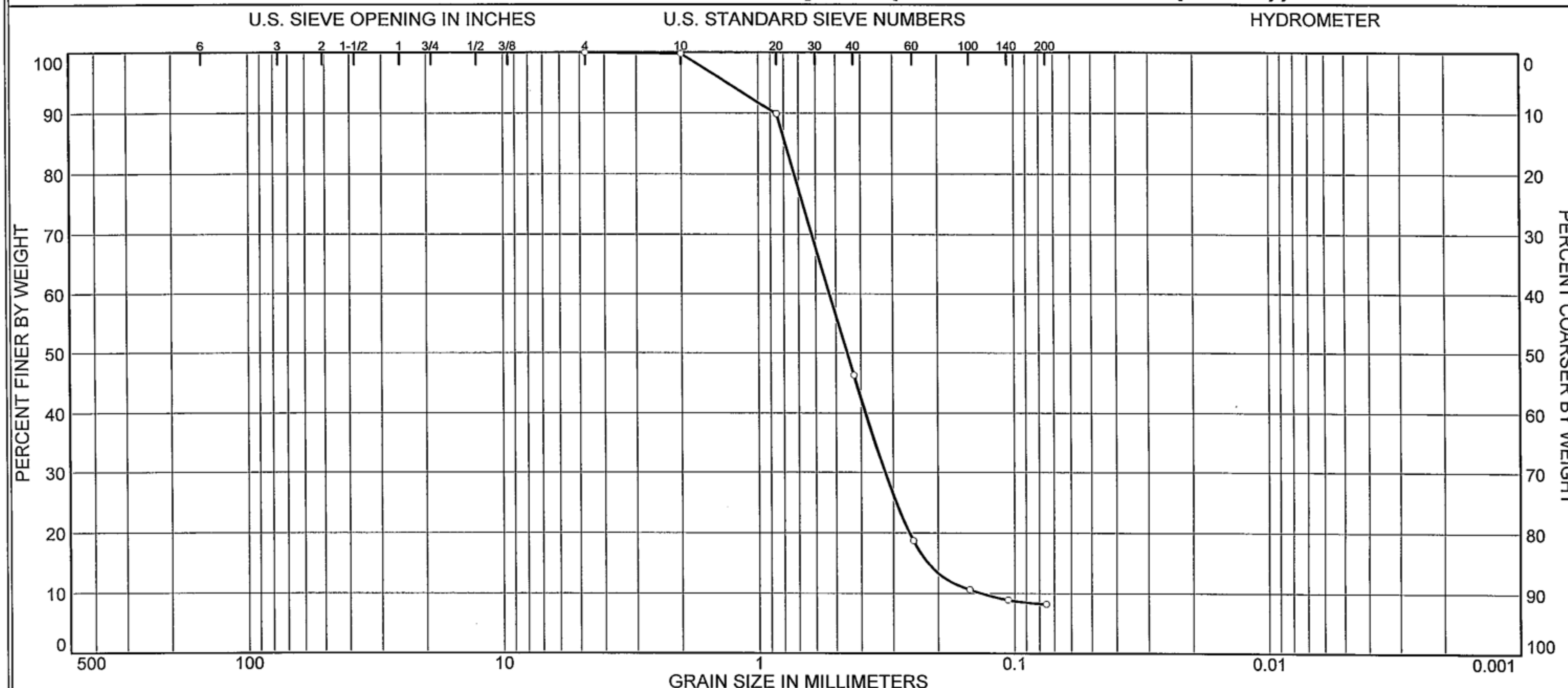




	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B04	ST2	30-32 ft	3/25/09	SP-SC	Brown Poorly Graded Sand with Clay	15.1	39	17

Client SRNS Project Saltstone Vaults 3 & 5 Project No. 6155-08-0031.06 — Lab No. 9459	**MACTEC ENGINEERING AND CONSULTING, INC.**	● Tested By: EH Reviewed By: JW JW 5/18/09

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	0.0	0.2	53.5	38.1	8.2	

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B04	ST3	35-37 ft	4/3/09	SP-SM	Brown Poorly Graded Sand with Silt	10.3	NV	NP

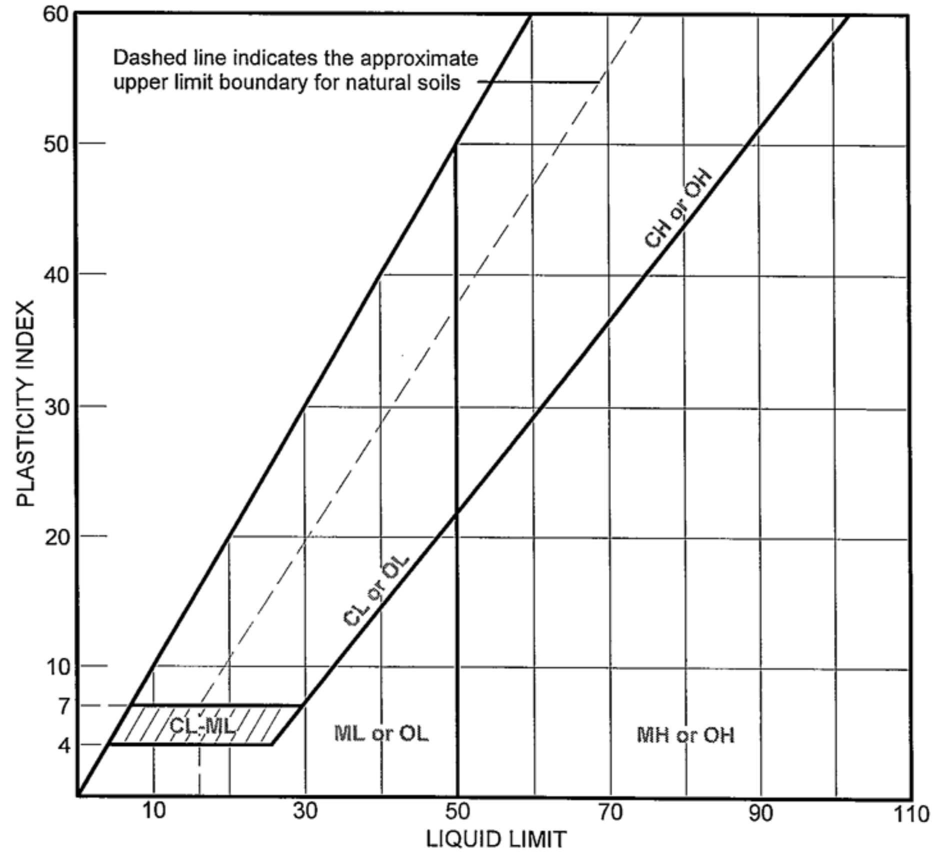
Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9460

MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewed By: JW

JW
5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)



	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B04	ST3	35-37 ft	4/3/09	SP-SM	Brown Poorly Graded Sand with Silt	10.3	NV	NP

Client SRNS

Project Saltstone Vaults 3 & 5

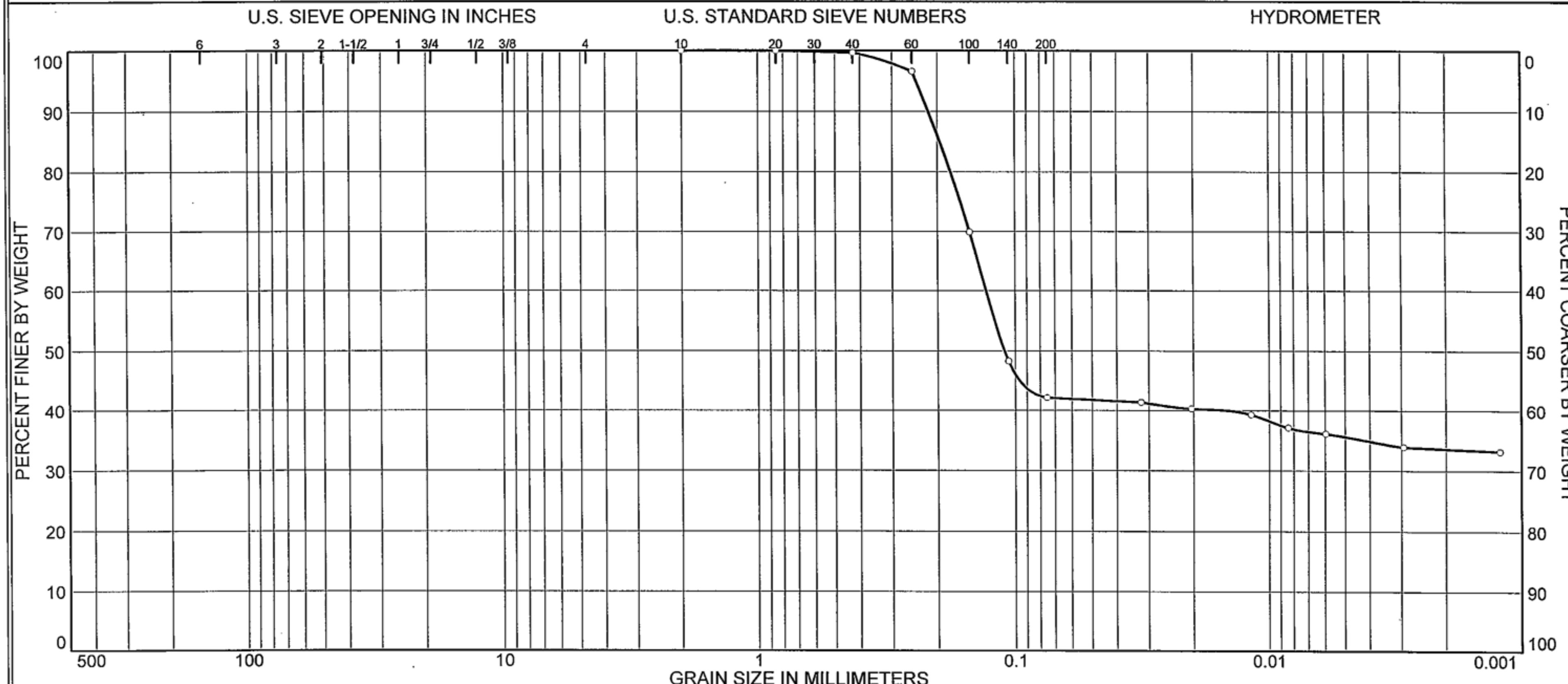
Project No. 6155-08-0031.06 Lab No. 9460

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW 5/18/09

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	0.0	0.0	0.3	57.5	6.6	35.6

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B04	ST4	50-52 ft	3/25/09	SM	Tan Silty Sand	51.0	74	40

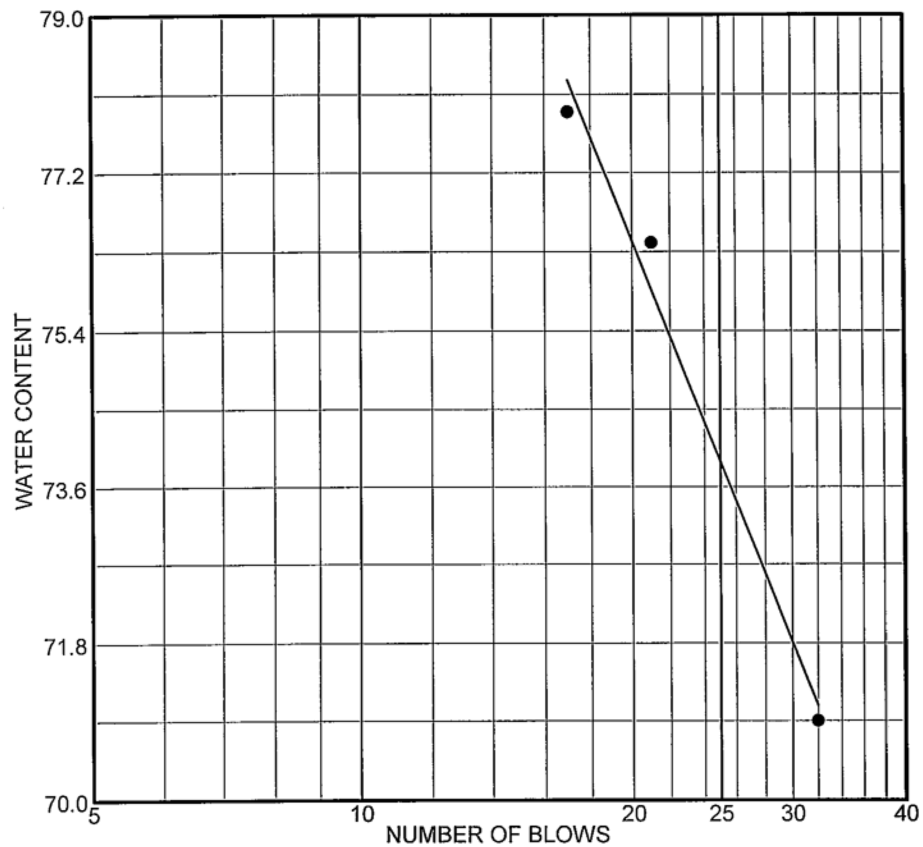
Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9461

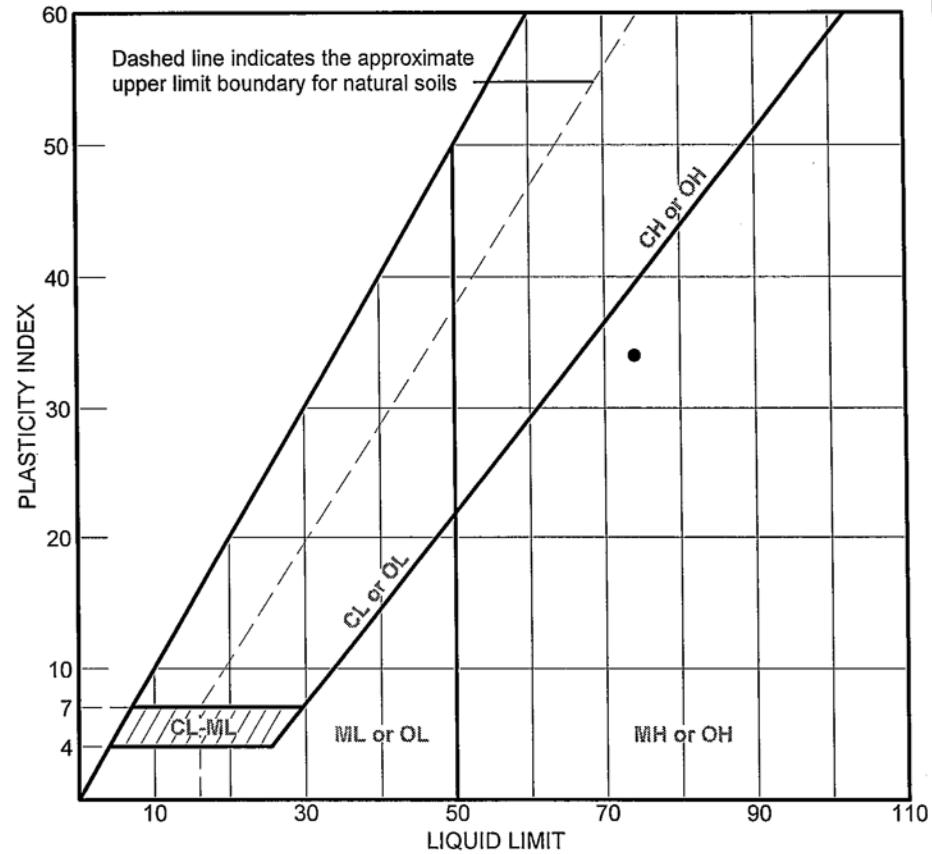
MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewed By: JW

JW 5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)





	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B04	ST4	50-52 ft	3/25/09	SM	Tan Silty Sand	51.0	74	34

Client SRNS

Project Saltstone Vaults 3 & 5

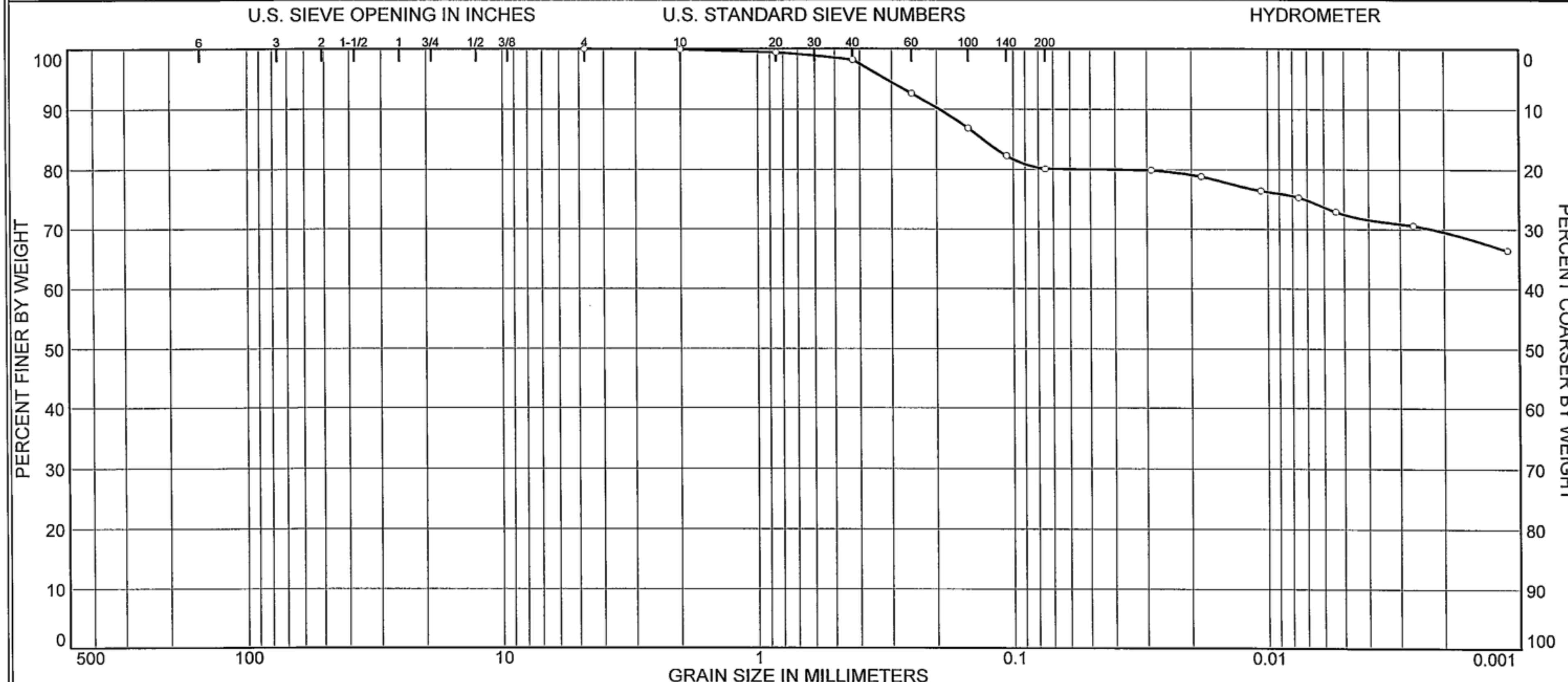
Project No. 6155-08-0031.06 | Lab No. 9461

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW 5/18/09

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL COARSE	% GRAVEL FINE	% SAND COARSE	% SAND MEDIUM	% SAND FINE	% FINES SILT	% FINES CLAY
○	0.0	0.0	0.0	0.1	1.7	18.1	7.6	72.5

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B04	ST5	55-57 ft	3/25/09	MH	Yellowish Brown Elastic Silt with Sand	64.6	128	54

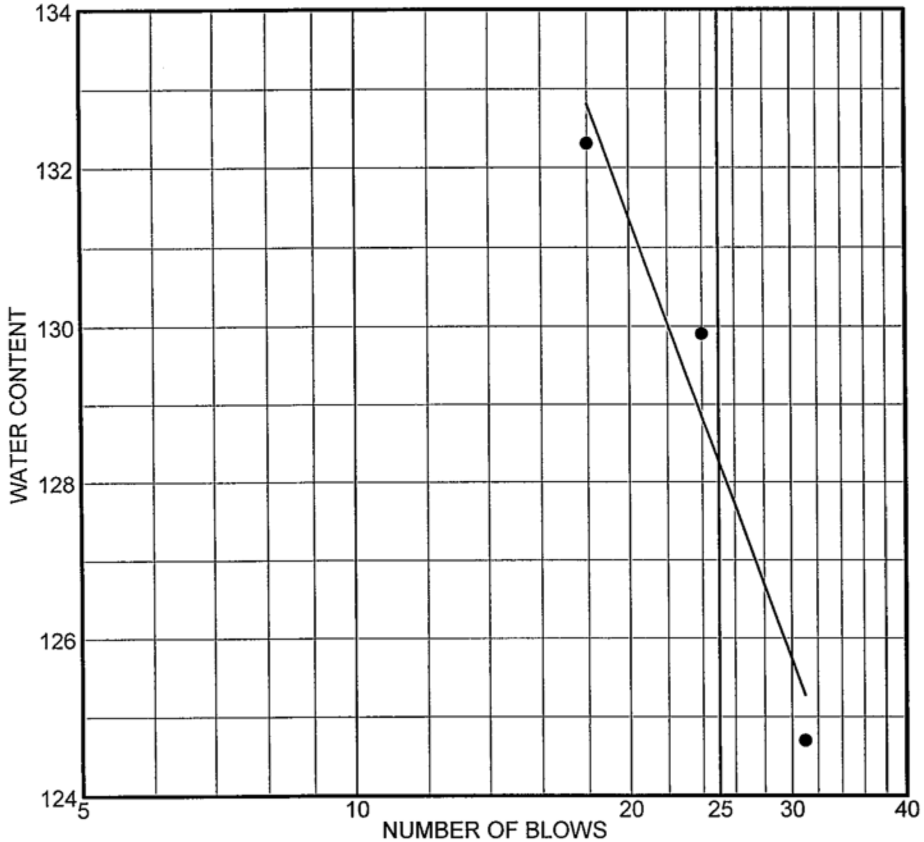
Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9462

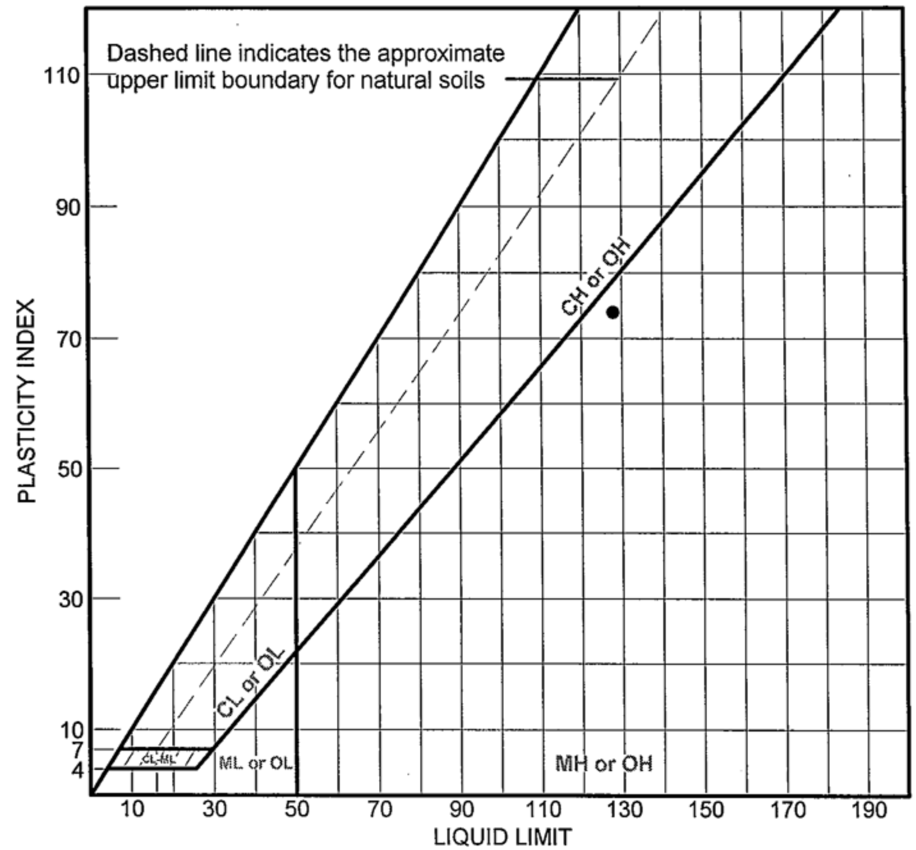
MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewed By: JW

JW 5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)





	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B04	ST5	55-57 ft	3/25/09	MH	Yellowish Brown Elastic Silt with Sand	64.6	128	74

Client SRNS

Project Saltstone Vaults 3 & 5

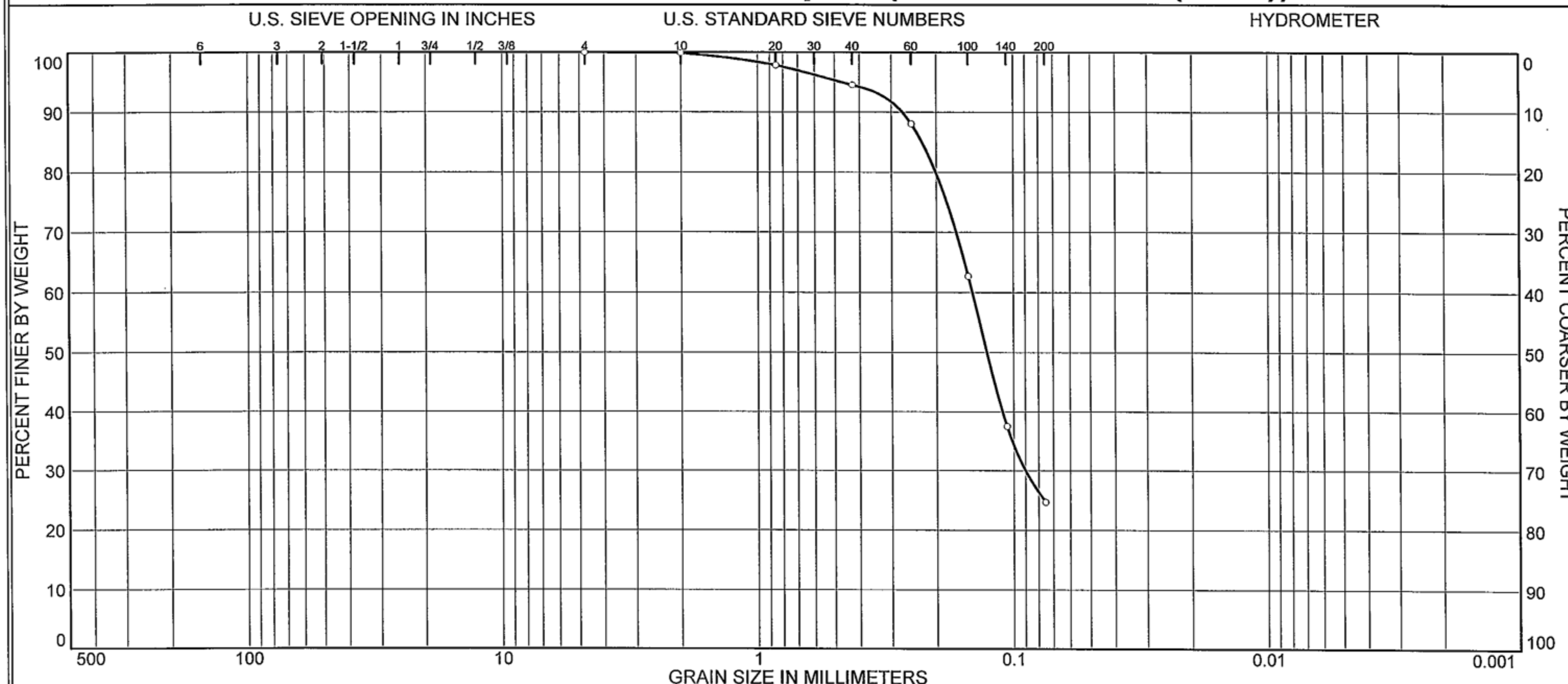
Project No. 6155-08-0031.06 | Lab No. 9462

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW 5/18/09

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	0.0	0.1	5.4	69.9	24.6	

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B04	ST6	84-86 ft	3/25/09	SM	Tan Silty Sand	29.9	49	33

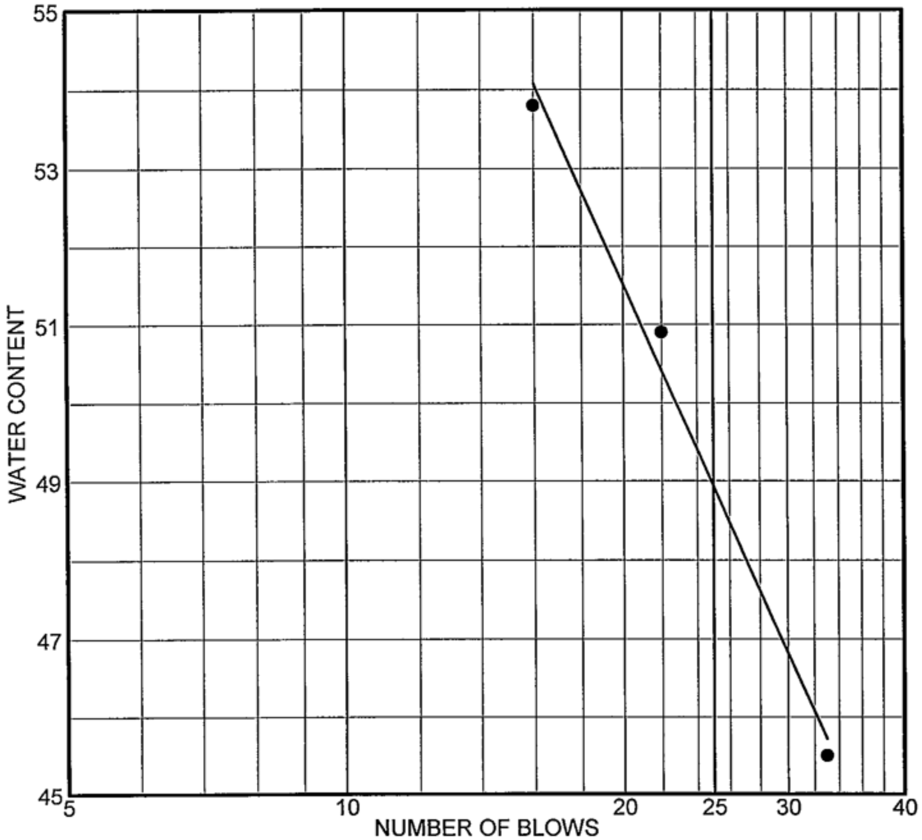
Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9463

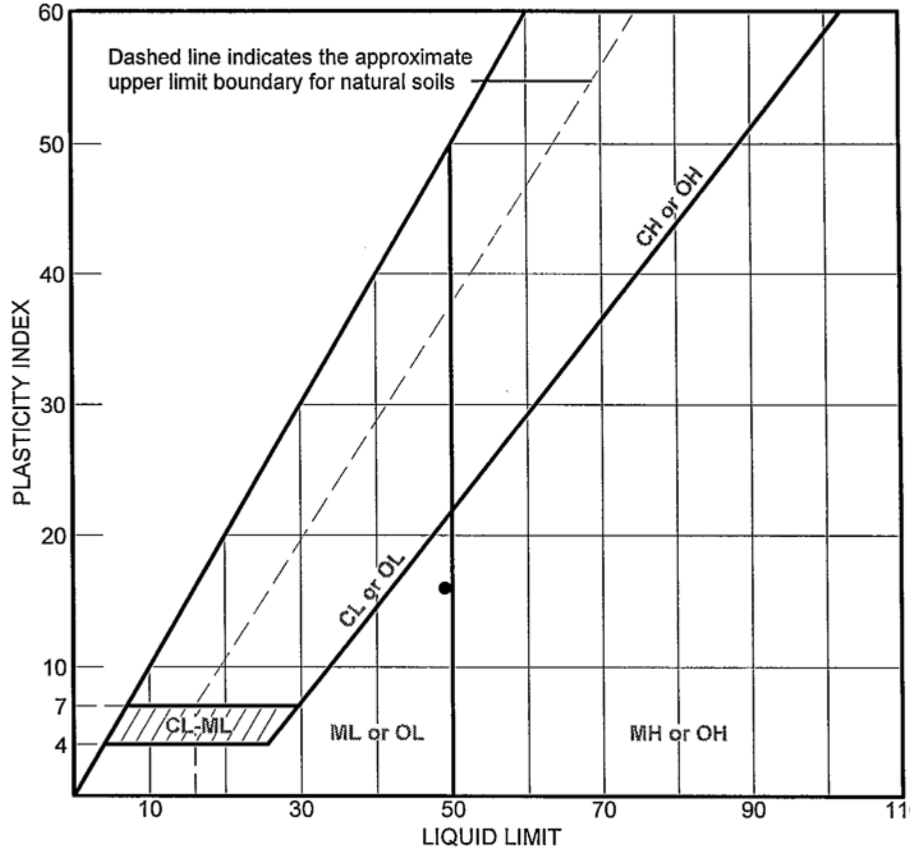
MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewed By: JW

JW 5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)





	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B04	ST6	84-86 ft	3/25/09	SM	Tan Silty Sand	29.9	49	16

Client SRNS

Project Saltstone Vaults 3 & 5

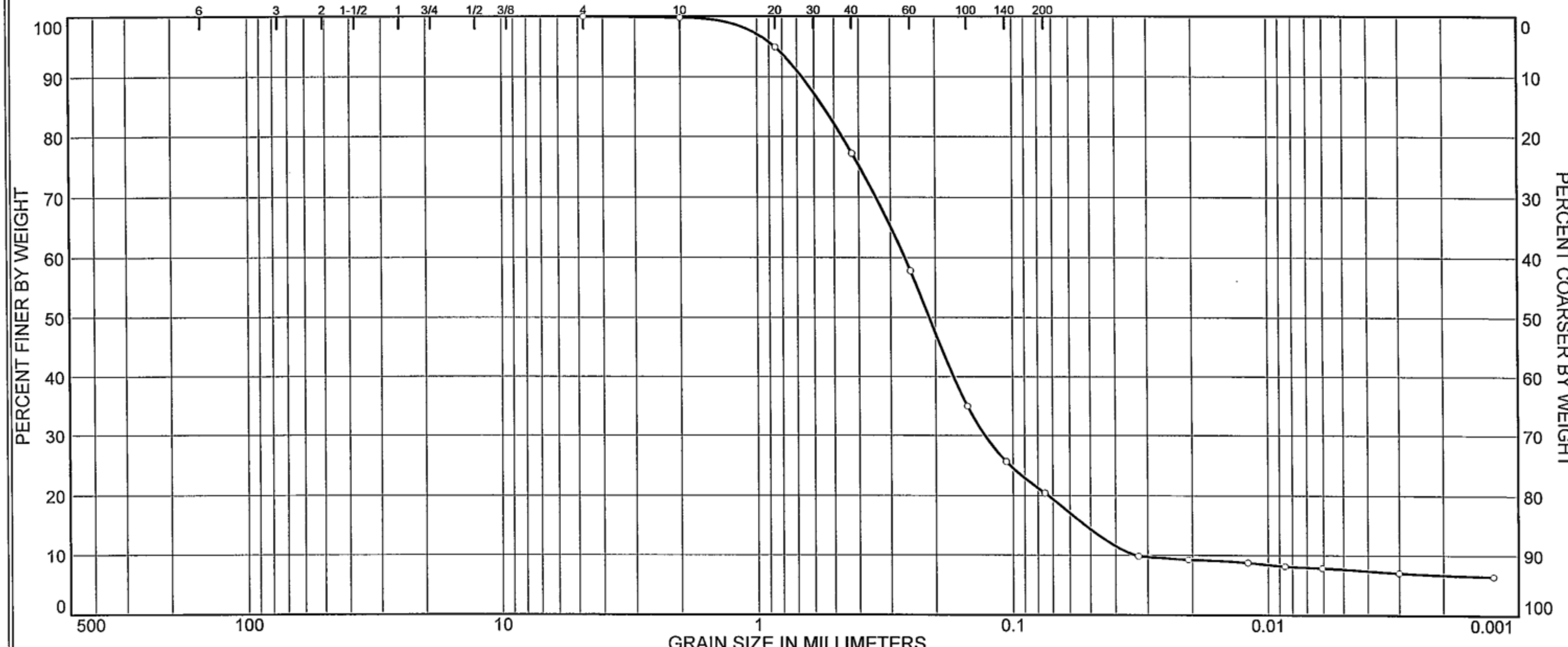
Project No. 6155-08-0031.06 Lab No. 9463

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW 5/18/09

Particle Size Distribution Report (ASTM D422-63 (2007))



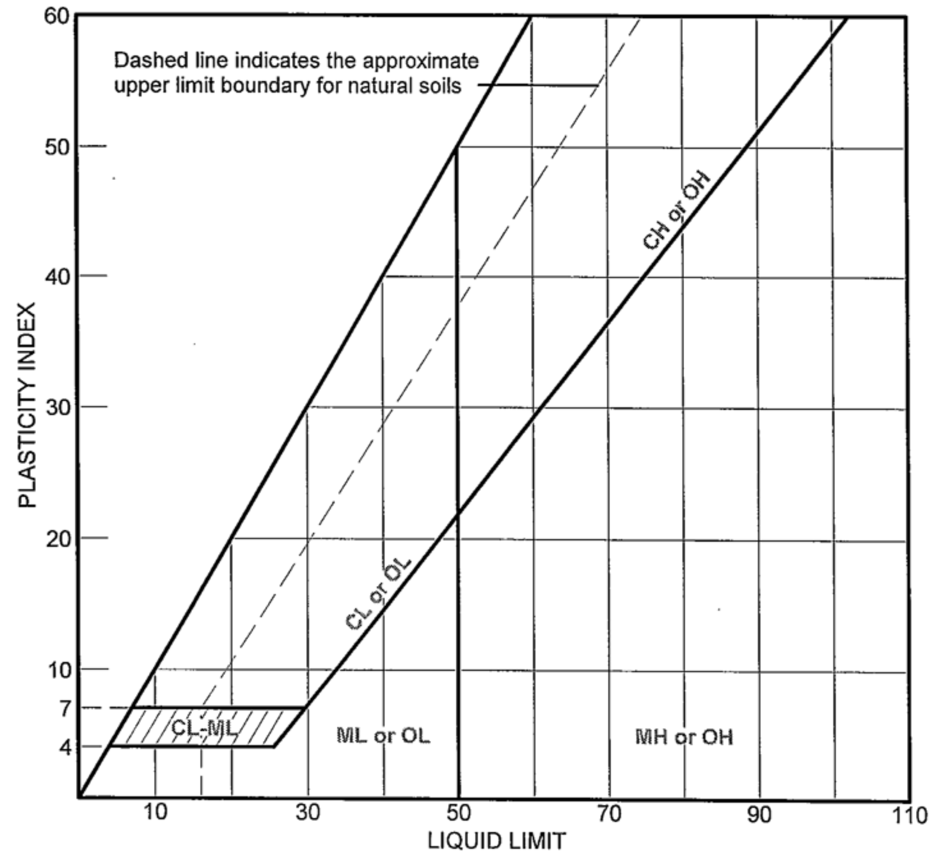
	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	0.0	0.2	22.6	56.8	12.8	7.6

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B04	Bag 1	0-5 ft	3/18/09	SM	Brown Silty Sand	8.6	NV	NP

Client SRNS Project Saltstone Vaults 3 & 5 Project No. 6155-08-0031.06 Lab No. 9467	**MACTEC ENGINEERING AND CONSULTING, INC.**	○ Tested By: EH Reviewed By: JW JW 5/18/09

B-130

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)



	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B04	Bag 1	0-5 ft	3/18/09	SM	Brown Silty Sand	8.6	NV	NP

Client SRNS Project Saltstone Vaults 3 & 5 Project No. 6155-08-0031.06 Lab No. 9467	MACTEC ENGINEERING AND CONSULTING, INC.	● Tested By: EH Reviewed By: JW JW 5/18/09

B-131

COMPACTION TEST REPORT

Project No.: 6155-08-0031.06 **Date:** 3/20/09
Project: Saltstone Vaults 3 & 5

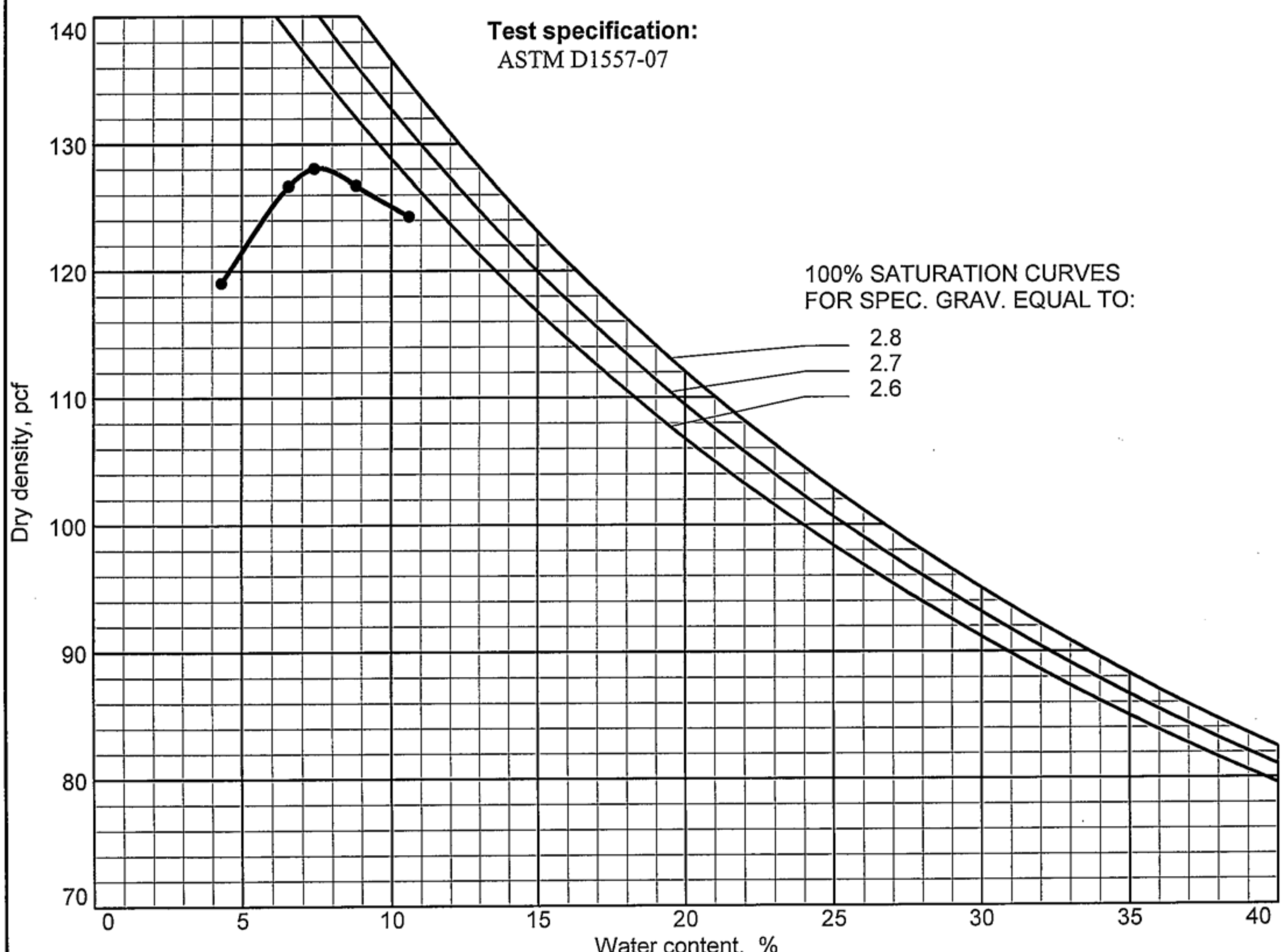
Location: Z-V3V5-B04
Elev./Depth: 0-5 ft **Sample No.** Bag 1
Remarks: Tested By: EH Reviewed By: JW JW 5/18/09

MATERIAL DESCRIPTION

Description: Brown Silty Sand

Classifications - **USCS:** SM **AASHTO:**
Nat. Moist. = 8.6 % **Sp.G. =**
Liquid Limit = NV **Plasticity Index =** NP
% > 3/4 in. = 0.0 % **% < No.200 =** 20.4 %

TEST RESULTS
Maximum dry density = 128.1 pcf
Optimum moisture = 7.6 %



Lab 9467

MACTEC Engineering and Consulting, Inc.

MOISTURE DENSITY TEST DATA

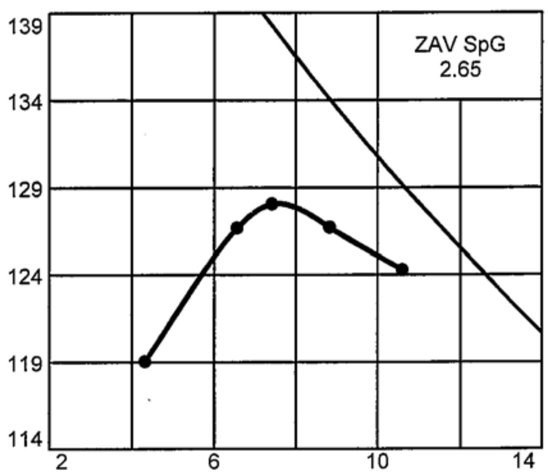
Client: SRNS
Project: Saltstone Vaults 3 & 5
Project Number: 6155-08-0031.06

Specimen Data

Source: Z-V3V5-B04
Sample No.: Bag 1
Elev. or Depth: 0-5 ft **Sample Length(in./cm.):** 9467
Location: Z-V3V5-B04
Description: Brown Silty Sand
Liquid Limit: NV **Plasticity Index:** NP **Natural Moisture:** 8.6
Date: 3/20/09 **USCS Classification:** SM **AASHTO Classification:**
Testing Remarks: Tested By: EH Reviewed By: JW
Percent retained on 3/4 in. sieve: 0.0
Percent passing No. 200 sieve: 20.4 **Specific gravity:**

Test Data And Results

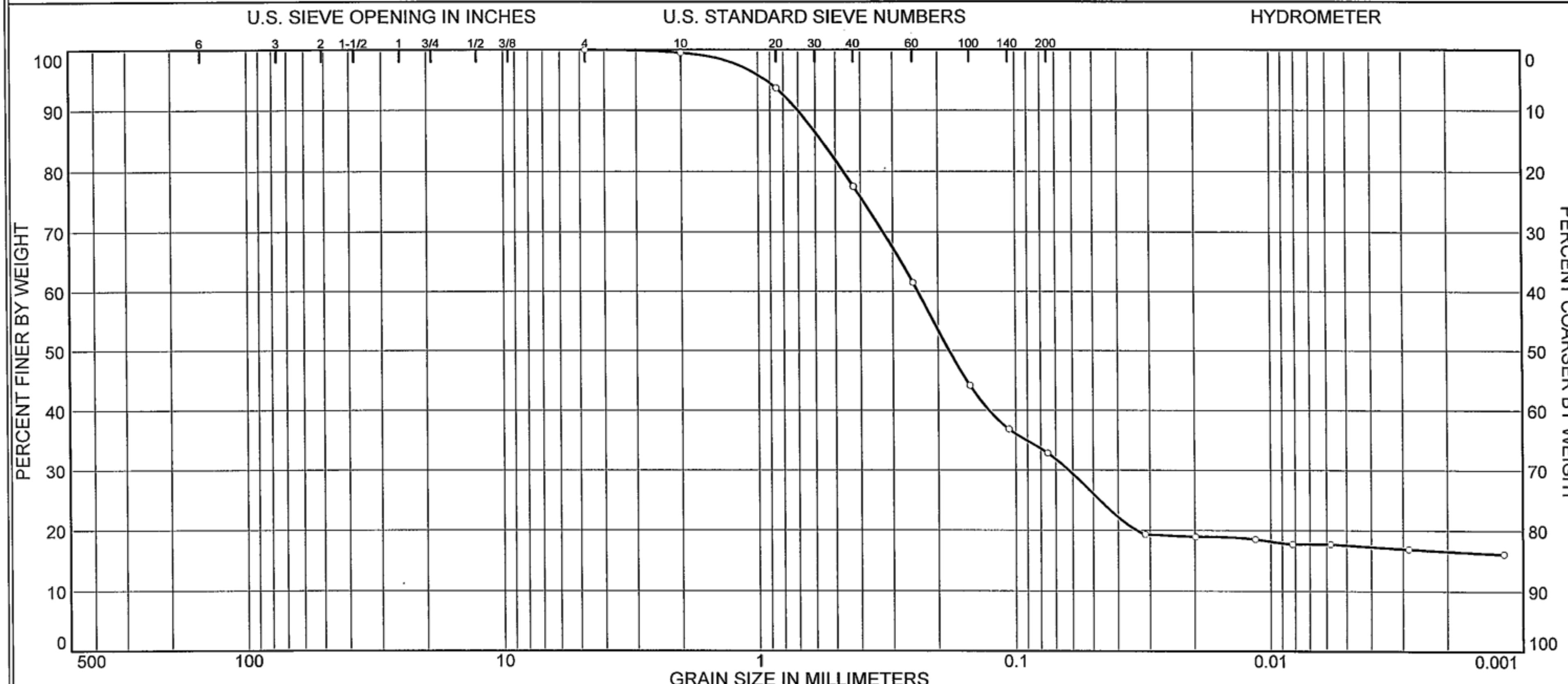
Type of test: ASTM D1557-07



POINT NO.	1	2	3	4	5
WM + WS	4133.6	4127.1	4089.6	3926.9	4128.3
WM	2053.3	2053.3	2053.3	2053.3	2053.3
WW+T	615.40	624.90	562.80	566.70	530.50
WD+T	566.20	565.80	528.70	543.60	494.50
TARE	8.30	8.30	8.20	8.20	8.20
MOIST	8.8	10.6	6.6	4.3	7.4
MOISTURE	8.8	10.6	6.6	4.3	7.4
DRY DEN	126.7	124.3	126.7	119.1	128.1

Max dry den= 128.1 pcf **Opt moisture=** 7.6 %

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	0.0	0.5	22.0	44.6	15.4	17.5

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B04	Bag 2	5-10 ft	3/18/09	SC	Reddish Brown Clayey Sand	13.9	38	19

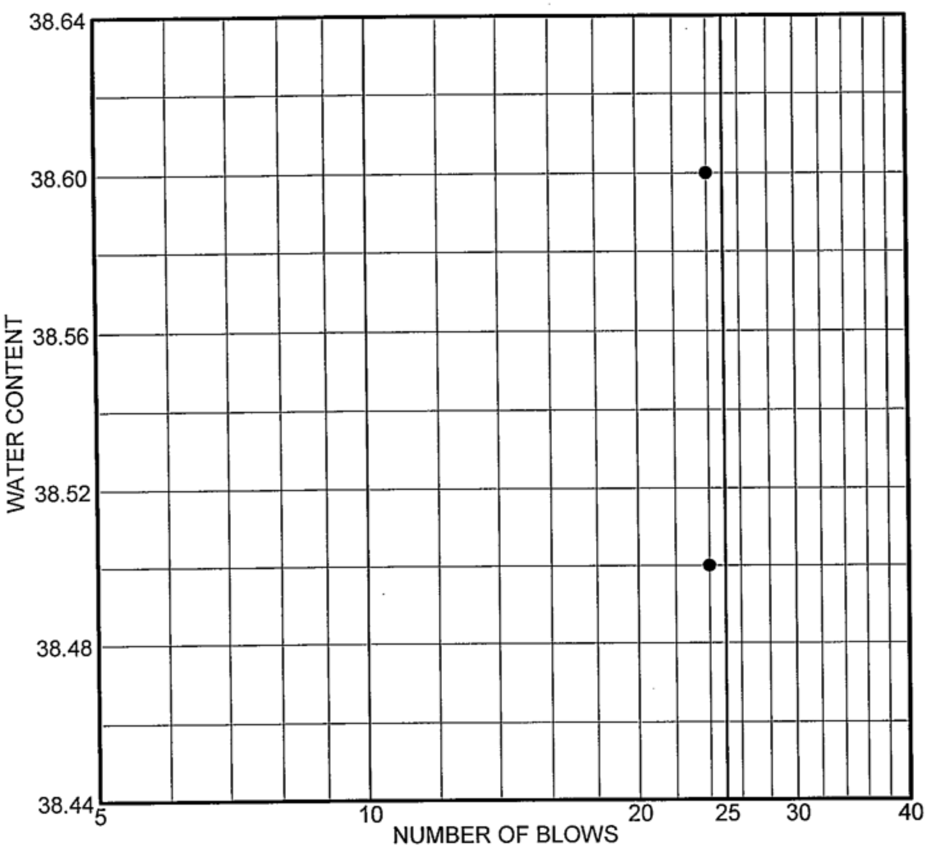
Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9468

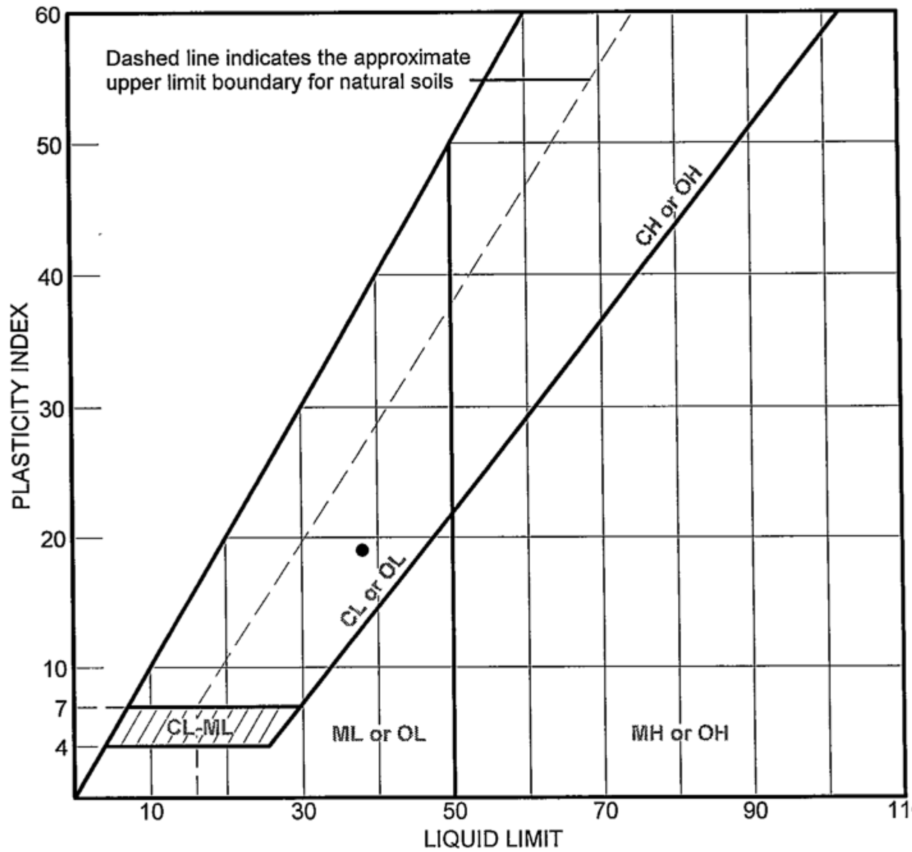
MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewd By: JW

JW
5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)





	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B04	Bag 2	5-10 ft	3/18/09	SC	Reddish Brown Clayey Sand	13.9	38	19

Client SRNS Project Saltstone Vaults 3 & 5 Project No. 6155-08-0031.06 / Lab No. 9468	**MACTEC ENGINEERING AND CONSULTING, INC.**	● Tested By: EH Reivewed By: JW JW 5/18/09

COMPACTION TEST REPORT

Project No.: 6155-08-0031.06 **Date:** 3/20/09
Project: Saltstone Vaults 3 & 5

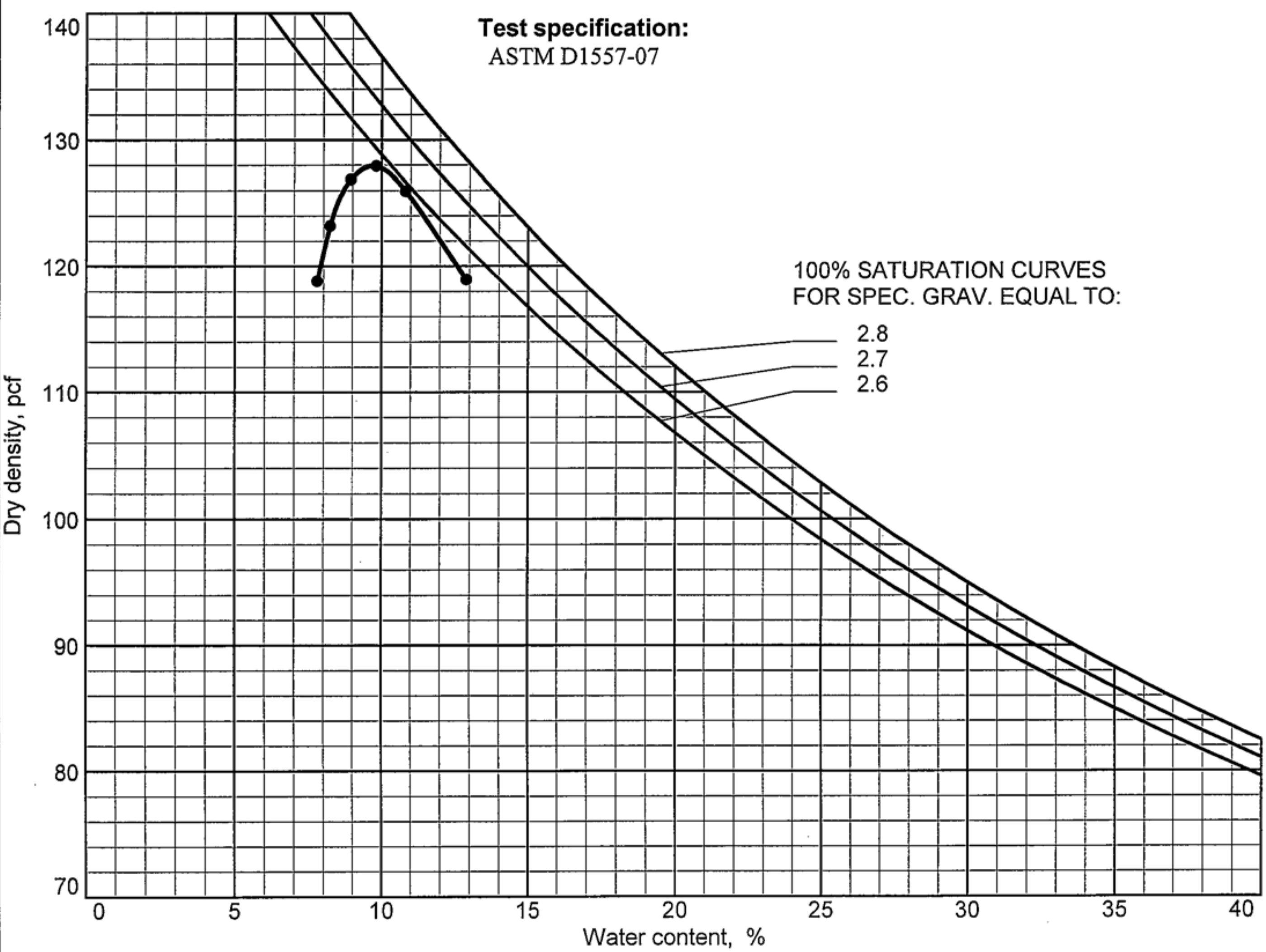
Location: Z-V3V5-B04
Elev./Depth: 5-10 ft **Sample No.** Bag 2
Remarks: Tested By: EH Reviewed By: JW JW 5/18/09

MATERIAL DESCRIPTION

Description: Reddish Brown Clayey Sand

Classifications - **USCS:** SC **AASHTO:**
Nat. Moist. = 13.9 % **Sp.G. =**
Liquid Limit = 38 **Plasticity Index =** 19
% > 3/4 in. = 0.0 % **% < No.200 =** 32.9 %

TEST RESULTS
Maximum dry density = 128.0 pcf
Optimum moisture = 9.7 %



Lab 9468

MACTEC Engineering and Consulting, Inc.

MOISTURE DENSITY TEST DATA

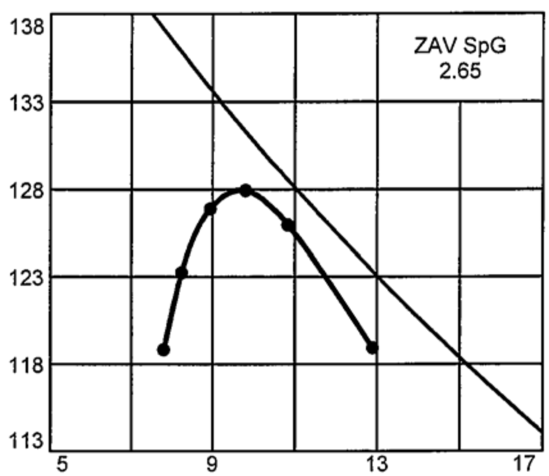
Client: SRNS
Project: Saltstone Vaults 3 & 5
Project Number: 6155-08-0031.06

Specimen Data

Source: Z-V3V5-B04
Sample No.: Bag 2
Elev. or Depth: 5-10 ft **Sample Length (in./cm.):** 9468
Location: Z-V3V5-B04
Description: Reddish Brown Clayey Sand
Liquid Limit: 38 **Plasticity Index:** 19 **Natural Moisture:** 13.9
Date: 3/20/09 **USCS Classification:** SC **AASHTO Classification:**
Testing Remarks: Tested By: EH Reviewed By: JW
Percent retained on 3/4 in. sieve: 0.0
Percent passing No. 200 sieve: 32.9 **Specific gravity:**

Test Data And Results

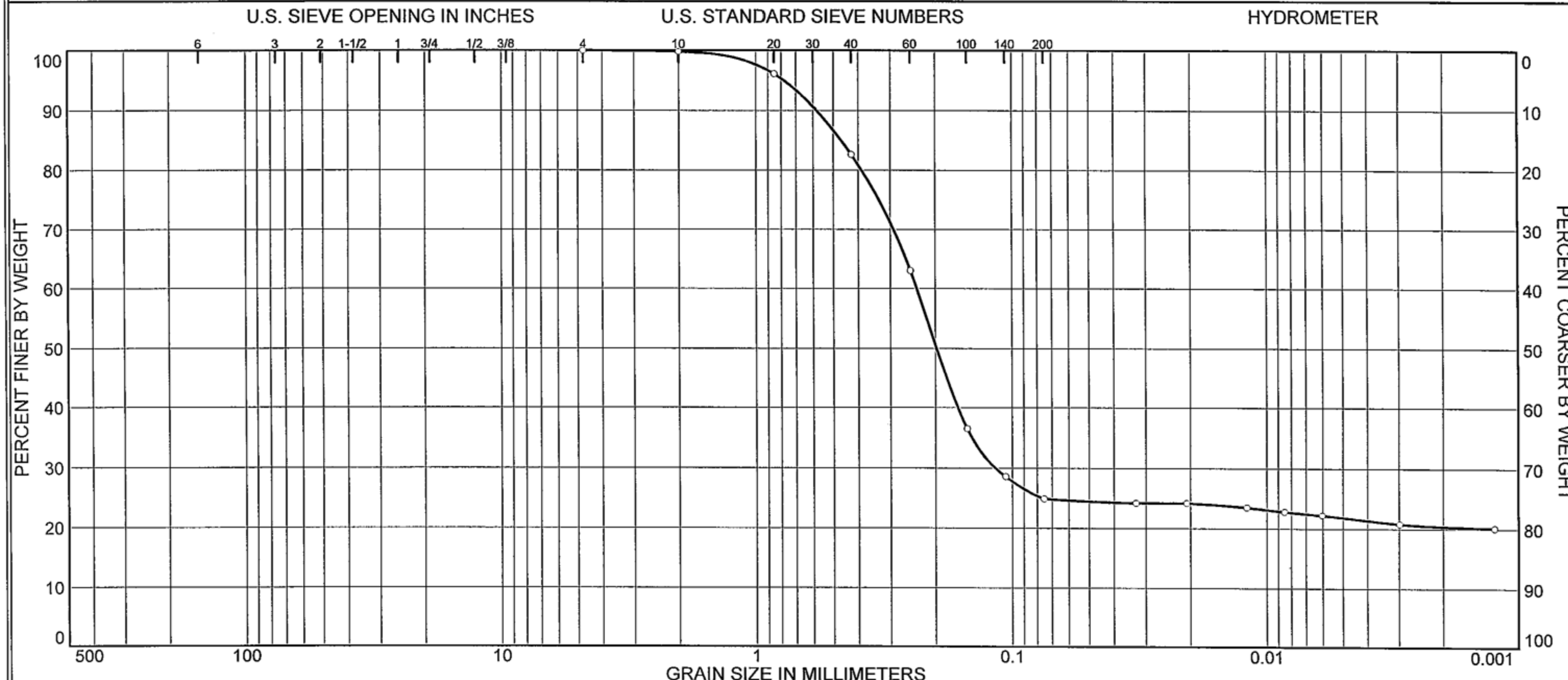
Type of test: ASTM D1557-07



POINT NO.	1	2	3	4	5	6
WM + WS	4065.3	4159.4	4078.8	4172.7	3985.4	4138.6
WM	2053.2	2053.2	2053.2	2053.2	2053.2	2053.2
WW+T	385.70	541.50	648.50	527.60	535.70	518.80
WD+T	357.00	489.40	575.40	481.20	497.60	476.90
TARE	8.30	8.30	8.10	8.30	8.30	8.20
MOIST	8.2	10.8	12.9	9.8	7.8	8.9
MOISTURE	8.2	10.8	12.9	9.8	7.8	8.9
DRY DEN	123.2	126.0	118.9	127.9	118.8	126.9

Max dry den= 128.0 pcf **Opt moisture=** 9.7 %

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	0.0	0.2	17.2	57.7	3.1	21.8

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B01/B04	Composite	0-10 ft	4/8/09	SC	Brown Clayey Sand		27	17

Client SRNS

Project Saltstone Vaults 3 & 5

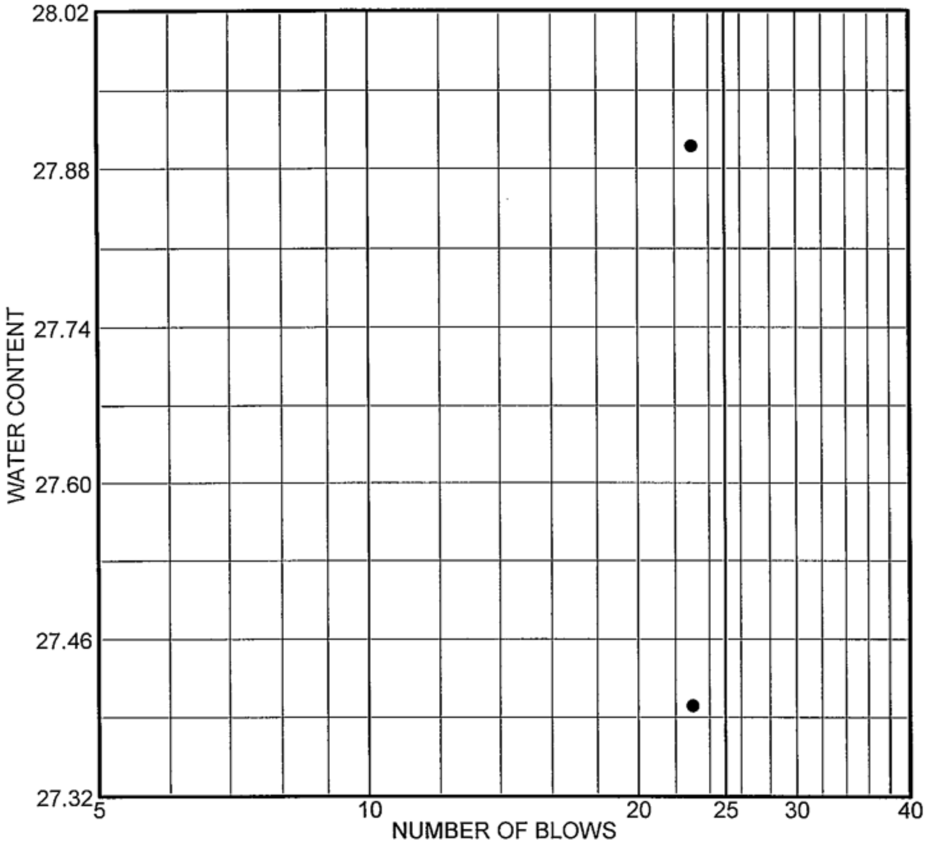
Project No. 6155-08-0031.06 | Lab No. Composite

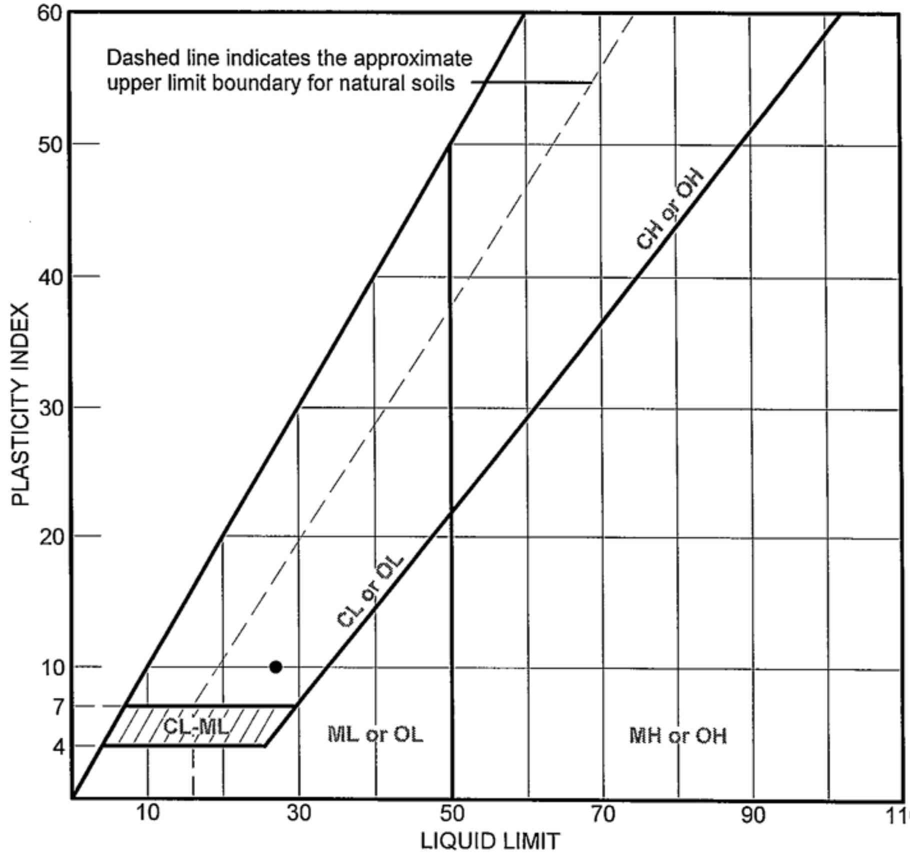
MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewed By: JW
Specific Gravity = 2.70

JW 5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)





	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B01/B04	Composite	0-10 ft	4/8/09	SC	Brown Clayey Sand		27	10

Client SRNS

Project Saltstone Vaults 3 & 5

Project No. 6155-08-0031.06 Lab No. Composite

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW 5/18/09

COMPACTION TEST REPORT

Project No.: 6155-08-0031.06 **Date:** 4/8/09
Project: Saltstone Vaults 3 & 5

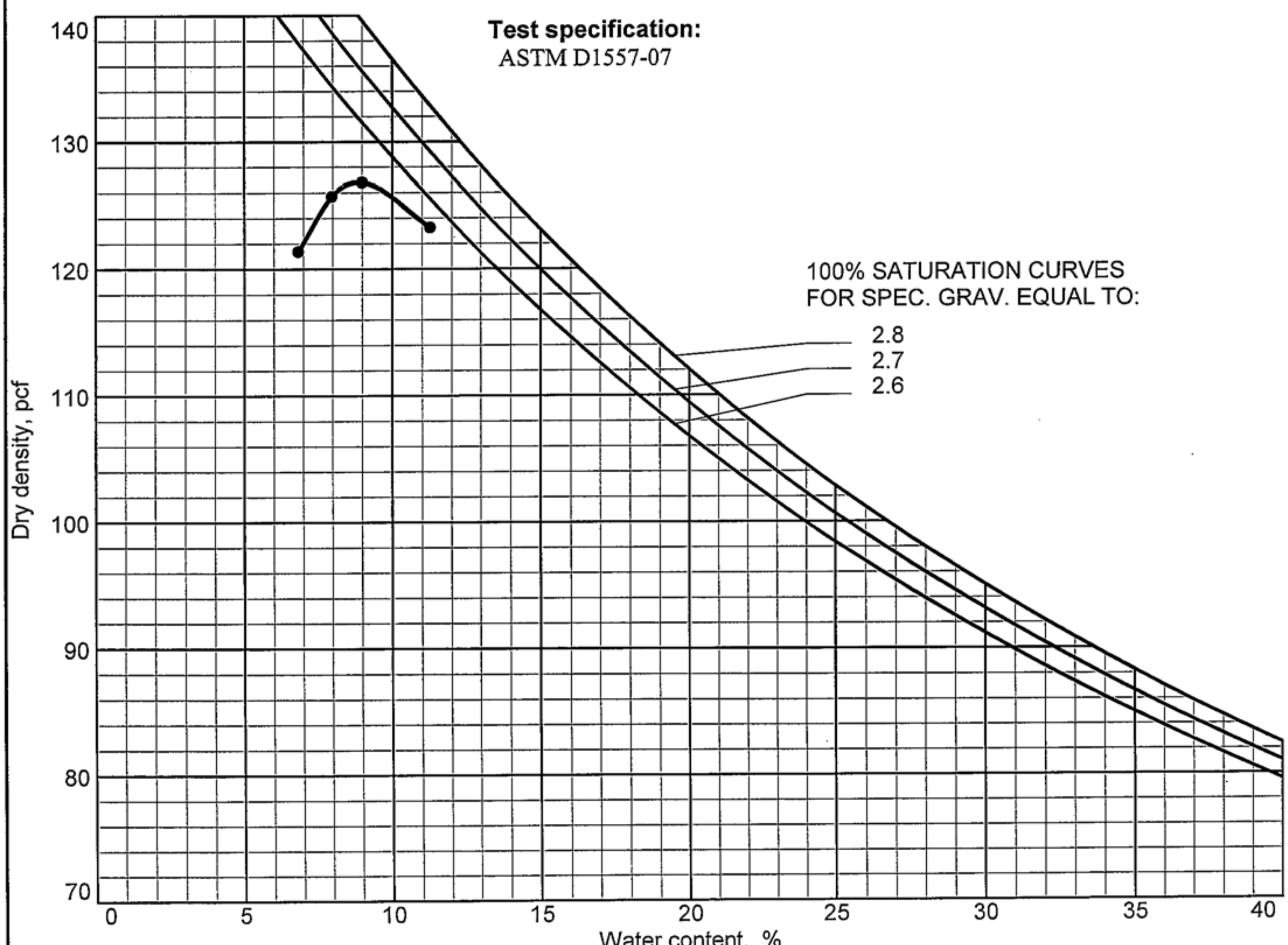
Location: Z-V3V5-B01/B04 (9465/9466/9467/9468)
Elev./Depth: 0-10 ft **Sample No.** Composite
Remarks: Tested By :CS Reviewed by: JW JW 5/18/09

MATERIAL DESCRIPTION

Description: Brown Clayey Sand

Classifications - **USCS:** SC **AASHTO:**
Nat. Moist. = **Sp.G. =**
Liquid Limit = 27 **Plasticity Index =** 10
% > 3/4 in. = 0.0 % **% < No.200 =** 24.9 %

TEST RESULTS
Maximum dry density = 126.8 pcf
Optimum moisture = 8.9 %



Lab Composite

MACTEC Engineering and Consulting, Inc.

MOISTURE DENSITY TEST DATA

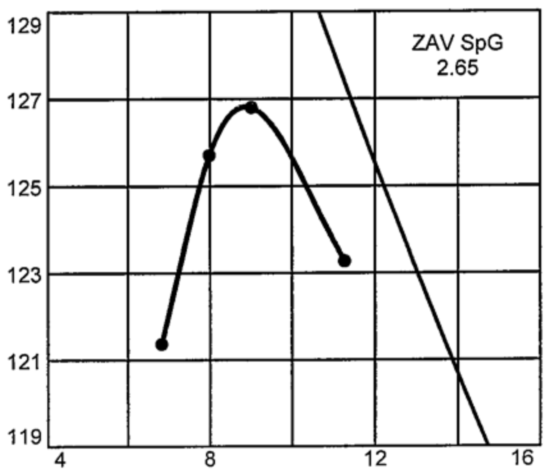
Client: SRNS
Project: Saltstone Vaults 3 & 5
Project Number: 6155-08-0031.06

Specimen Data

Source: Z-V3V5-B01/B04
Sample No.: Composite
Elev. or Depth: 0-10 ft **Sample Length(in./cm.):**
Location: Z-V3V5-B01/B04 (9465/9466/9467/9468)
Description: Brown Clayey Sand
Liquid Limit: 27 **Plasticity Index:** 10 **Natural Moisture:**
Date: 4/8/09 **USCS Classification:** SC **AASHTO Classification:**
Testing Remarks: Tested By :CS Reviewed by: JW
Percent retained on 3/4 in. sieve: 0.0
Percent passing No. 200 sieve: 24.9 **Specific gravity:**

Test Data And Results

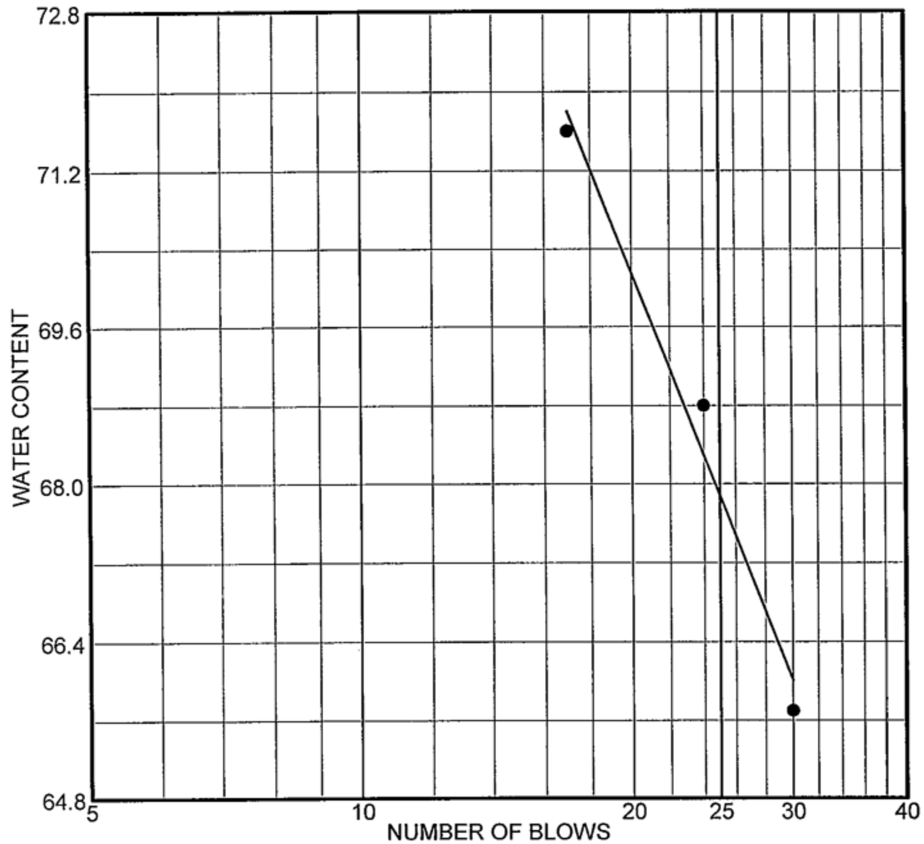
Type of test: ASTM D1557-07

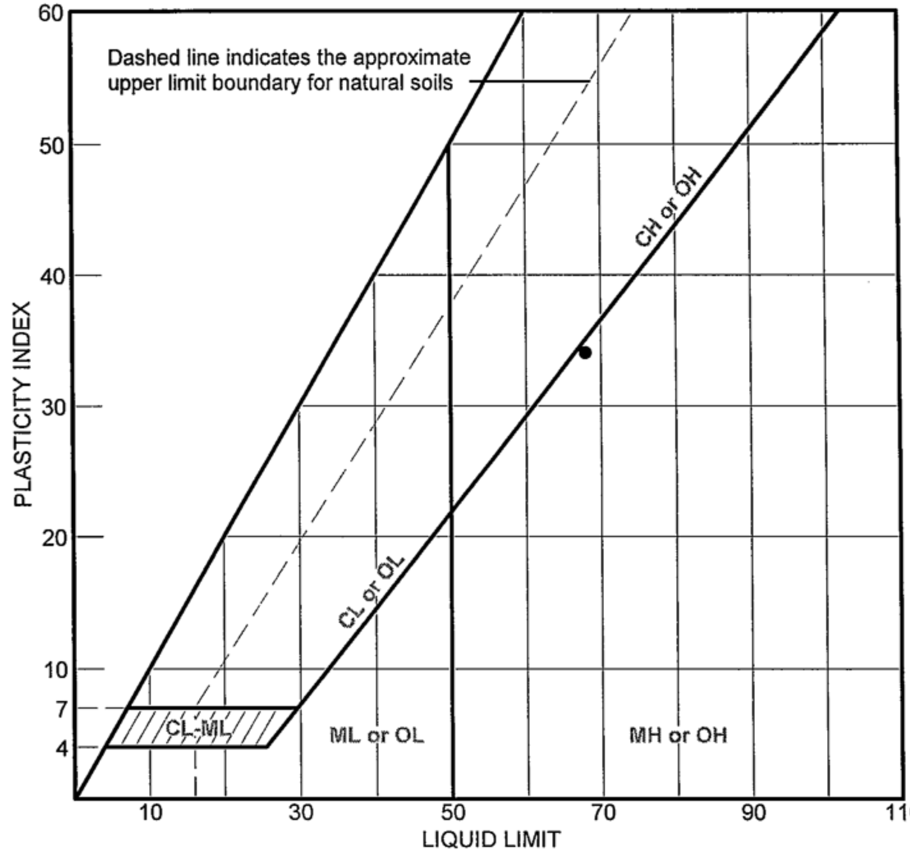


POINT NO.	1	2	3	4
WM + WS	4138.1	4122.3	4009.0	4100.7
WM	2052.9	2052.9	2052.9	2052.9
WW+T	653.80	649.20	580.80	564.60
WD+T	600.50	584.30	544.20	523.50
TARE	8.20	8.40	8.30	8.40
MOIST	9.0	11.3	6.8	8.0
MOISTURE	9.0	11.3	6.8	8.0
DRY DEN	126.8	123.3	121.4	125.7

Max dry den= 126.8 pcf **Opt moisture=** 8.9 %

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)





	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B02	SS1A	10-11 ft	4/8/09		Brown Silt (Visual)	30.8	68	34

Client SRNS

Project Saltstone Vaults 3 & 5

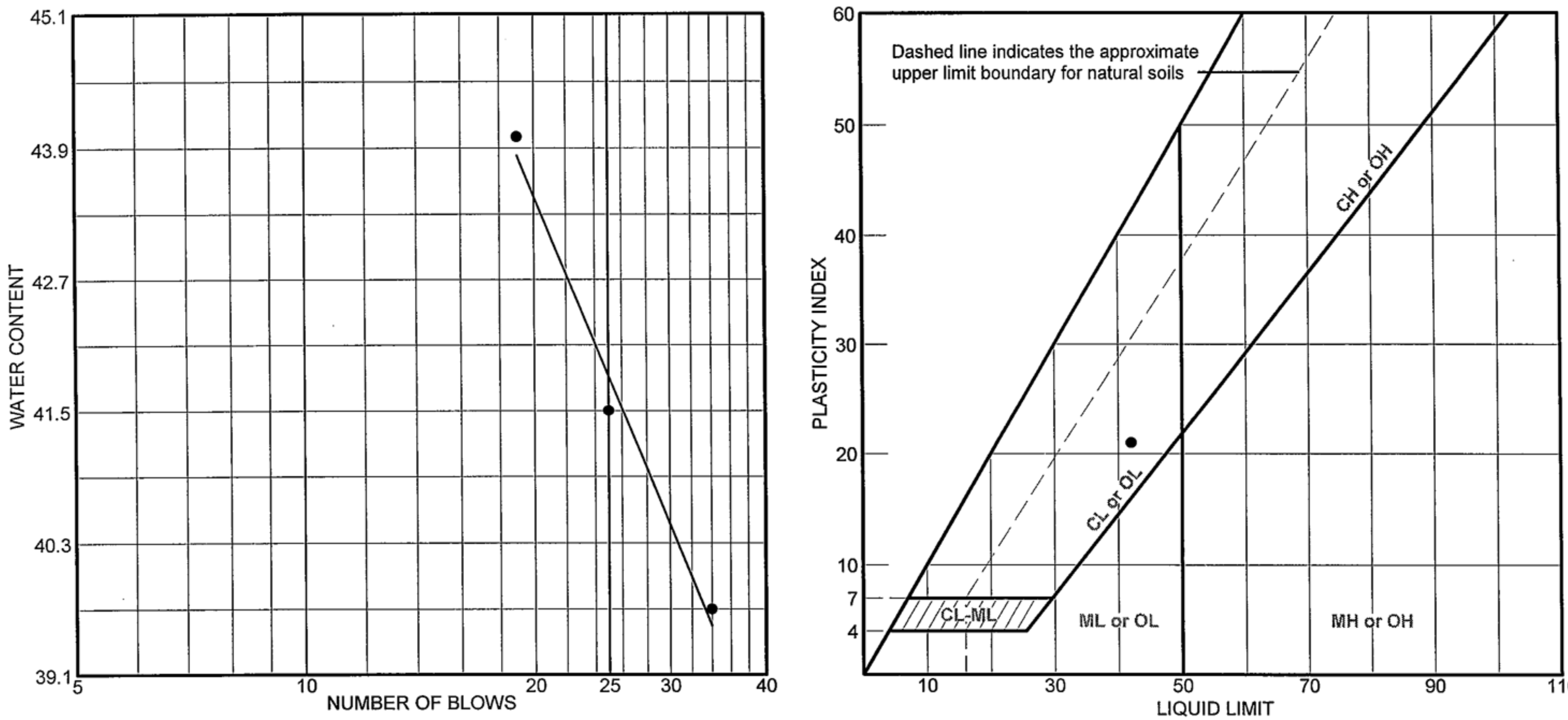
Project No. 6155-08-0031.06 Lab No. 9484

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW
5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)



	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B02	SS1B	11-12 ft	4/8/09		Reddish Brown Sandy Clay (Visual)	17.6	42	21

Client SRNS

Project Saltstone Vaults 3 & 5

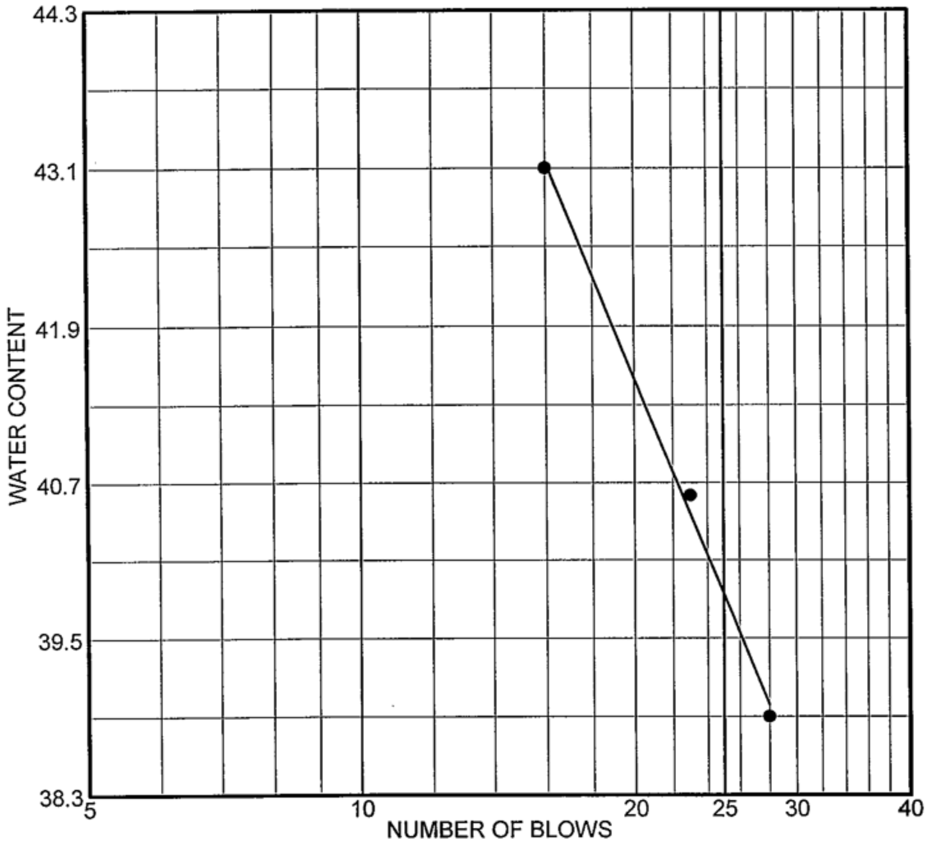
Project No. 6155-08-0031.06 | Lab No. 9485

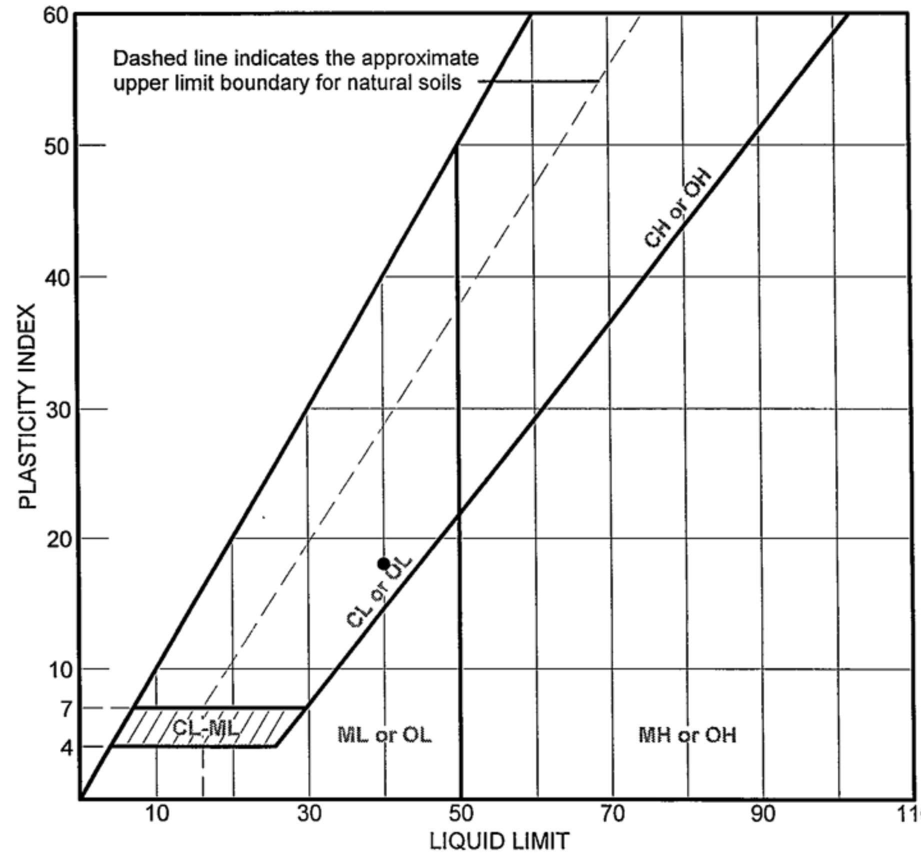
MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW
5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)





	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B02	SS5	18-20 ft	4/8/09		Reddish Brown CLayey Sand (Visual)	16.4	40	18

Client SRNS

Project Saltstone Vaults 3 & 5

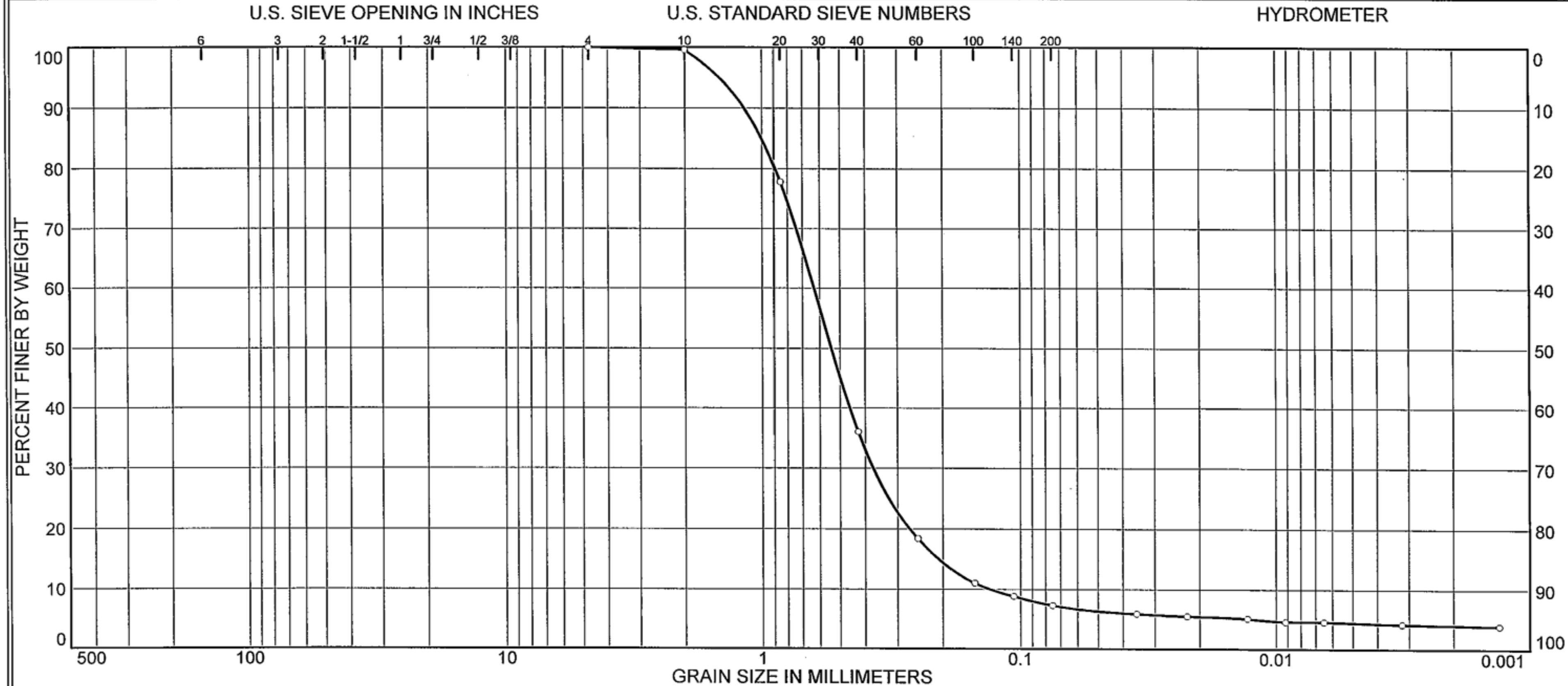
Project No. 6155-08-0031.06 | Lab No. 9489

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW 5/18/09

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	0.0	0.4	63.6	28.7	2.9	4.4

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B02	SS9/10/11	26-32 ft	4/3/09	SP-SC	Yellowish Brown Poorly Graded Sand with Clay	10.0	33	18

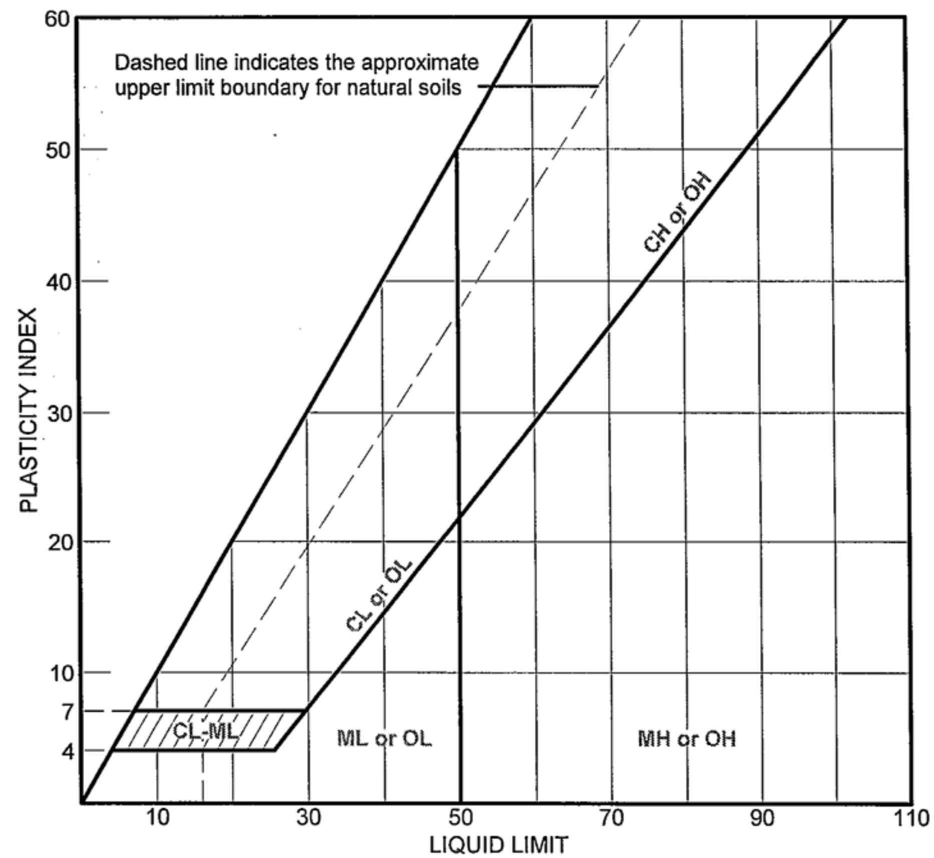
Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9493/94/95

MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewed By: JW
Composite, Lab No. 9493, 9494 and 9495

JW
5/18/09

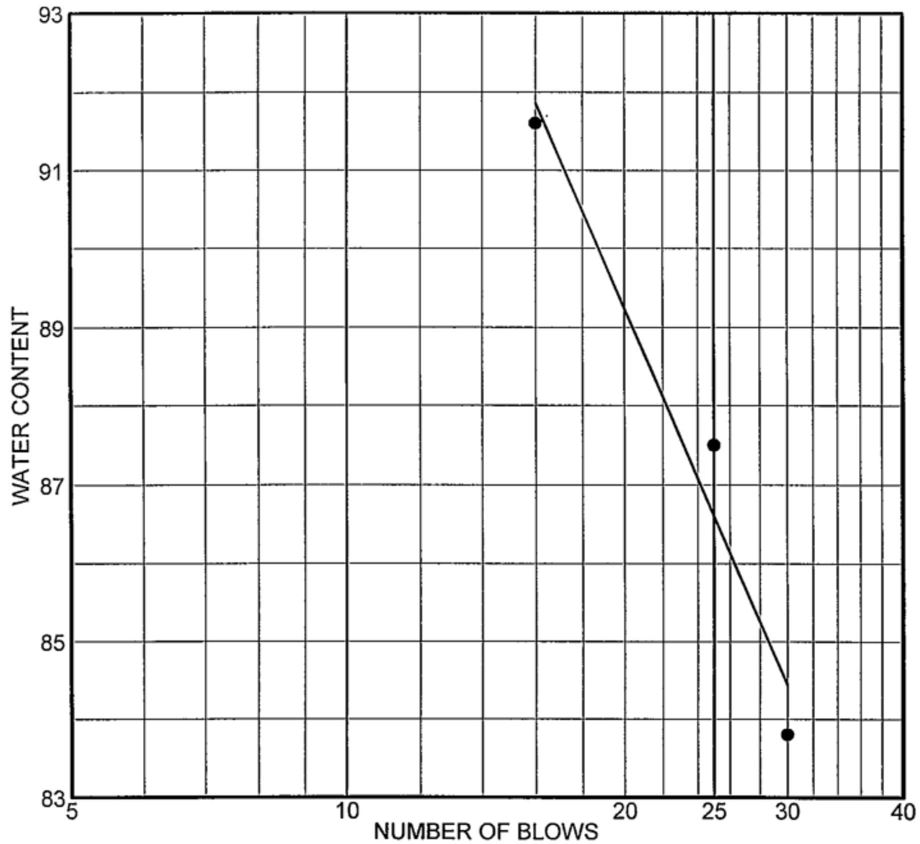
LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)

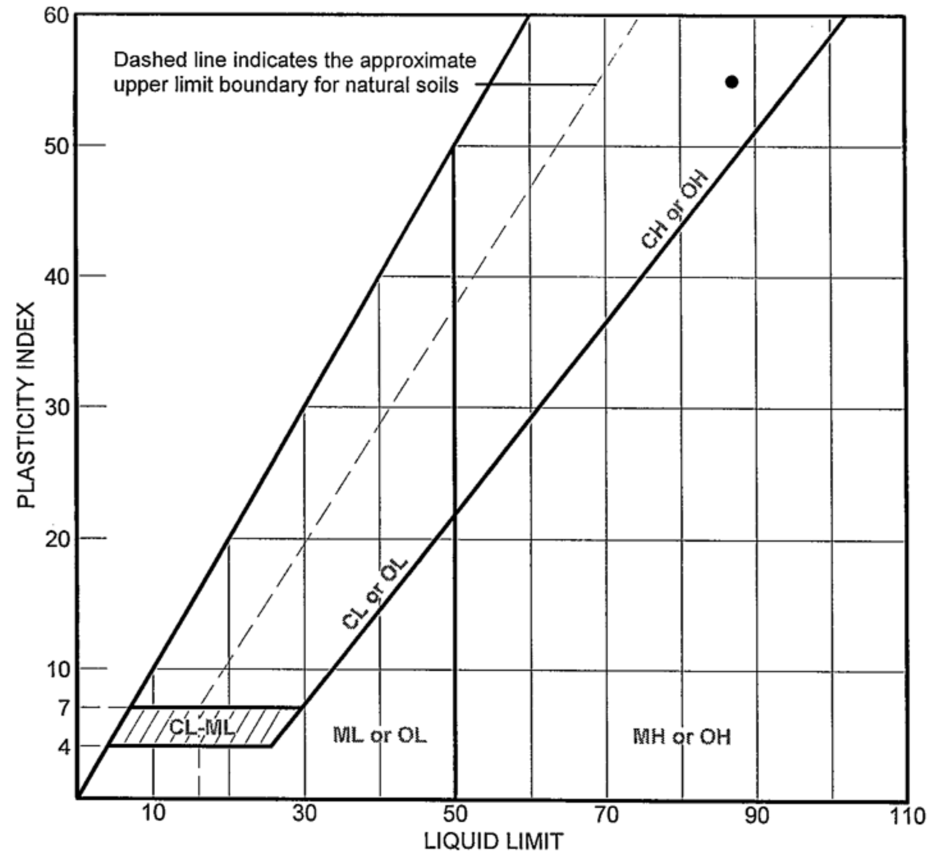


	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B02	SS12	32-34 ft	4/8/09		Yellowish Brown Sand (Visual)	12.0	NV	NP

Client SRNS Project Saltstone Vaults 3 & 5 Project No. 6155-08-0031.06 Lab No. 9496	**MACTEC ENGINEERING AND CONSULTING, INC.**	● Tested By :EH Reviewed By :JW JW 5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)

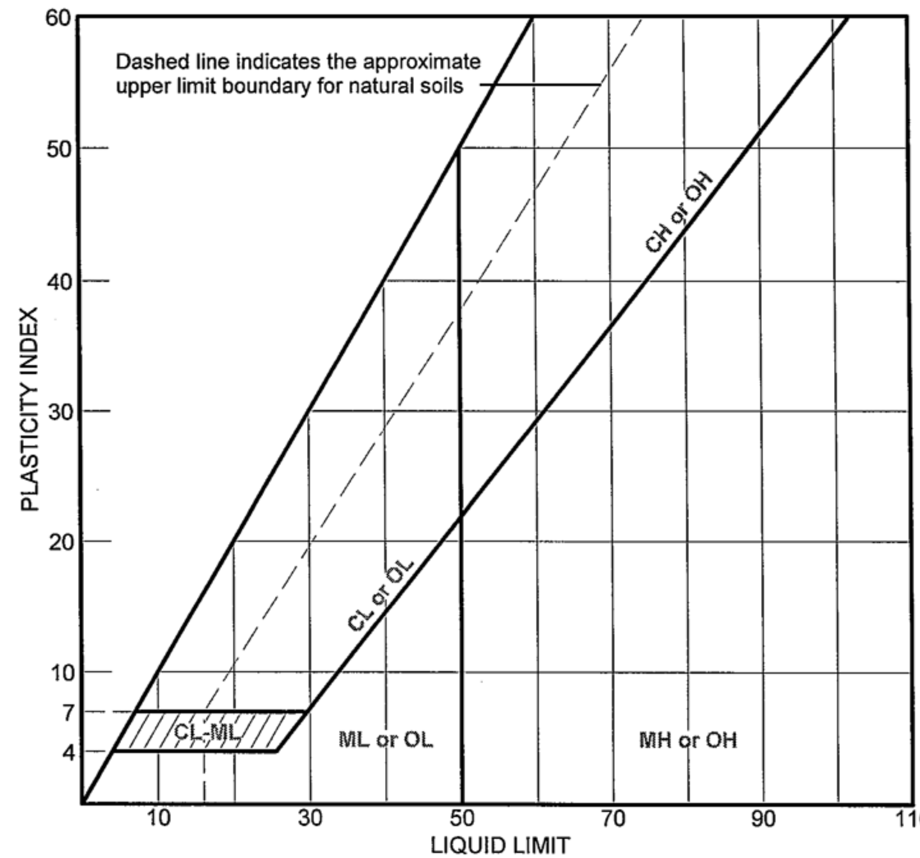




	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B02	SS15	45-47 ft	4/8/09		Yellowish Brown Clay (Visual)	46.3	87	55

Client SRNS Project Saltstone Vaults 3 & 5 Project No. 6155-08-0031.06 Lab No. 9499	**MACTEC ENGINEERING AND CONSULTING, INC.**	● Tested By: EH Reviewed By: JW JW 5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)



	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B02	SS18	60-62 ft	4/8/09		Brown Sand (Visual)	20.7	NV	NP

Client SRNS

Project Saltstone Vaults 3 & 5

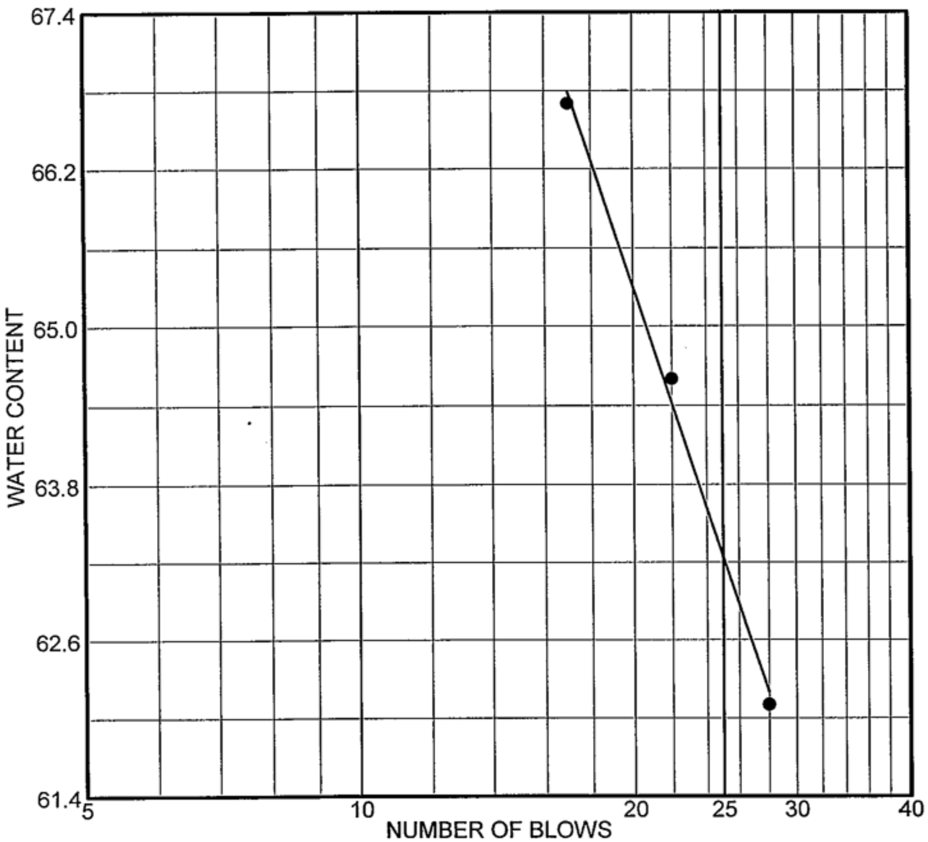
Project No. 6155-08-0031.06 Lab No. 9502

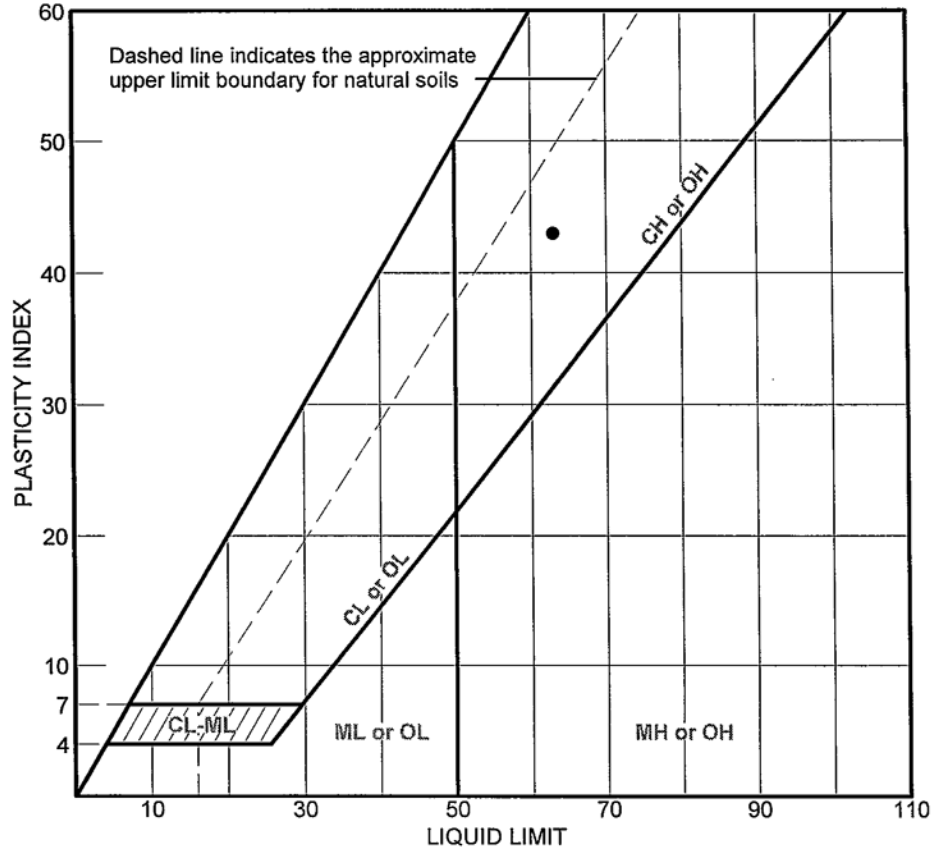
MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW
5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)

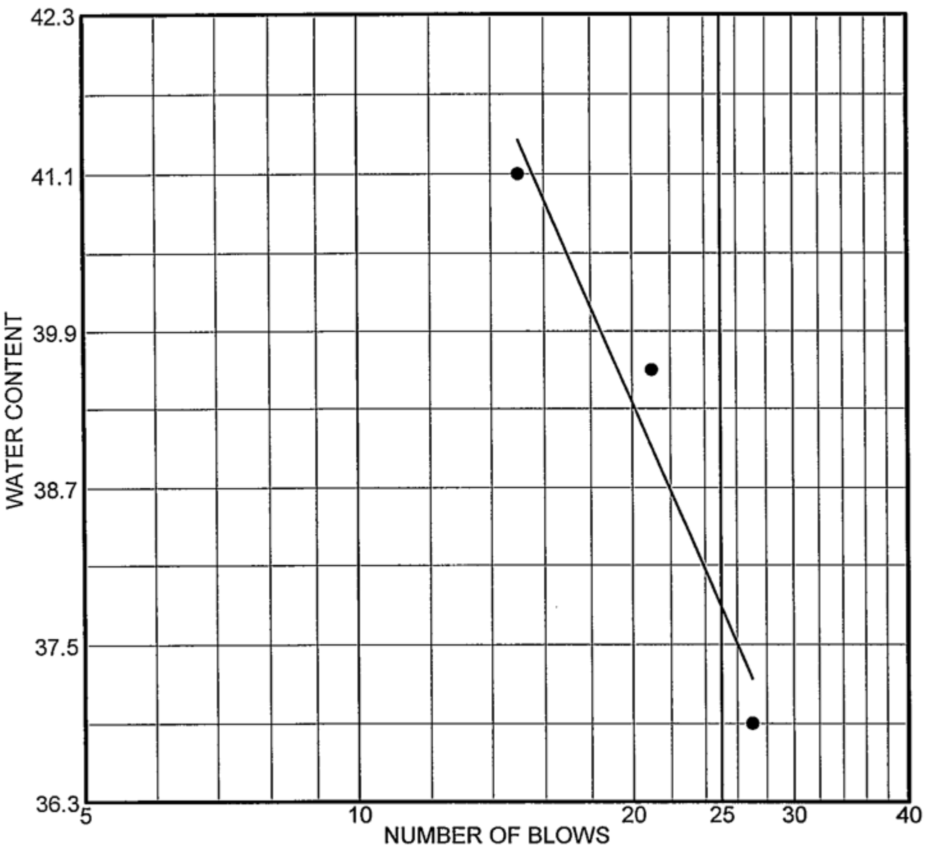


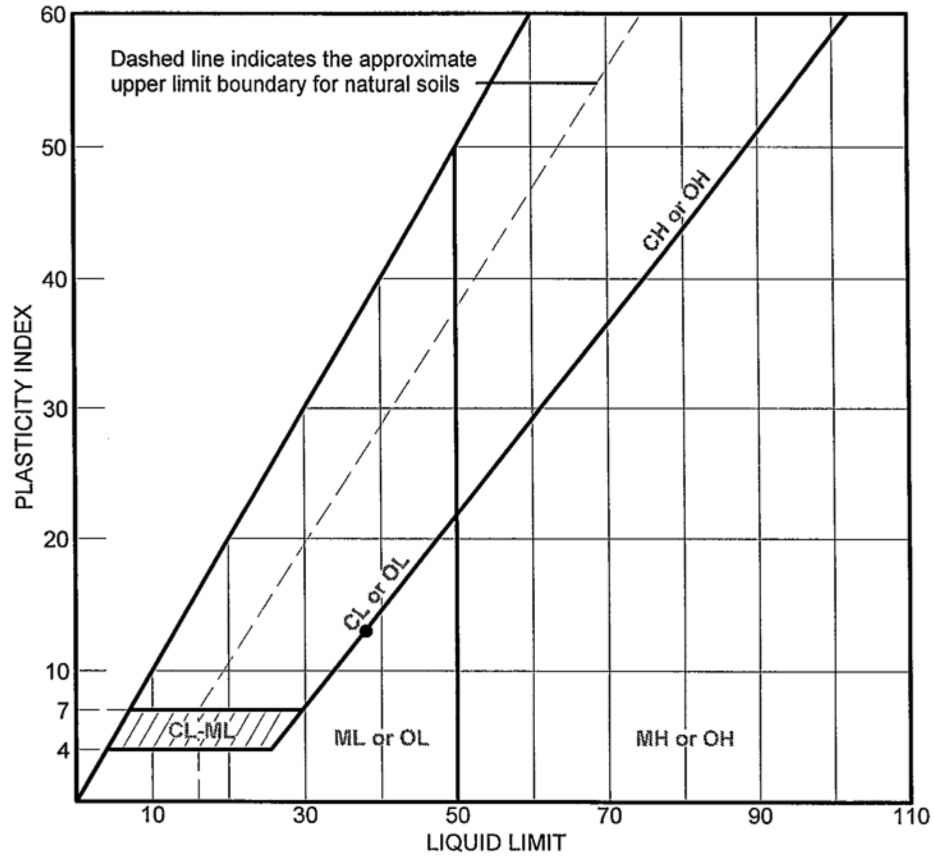


	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B02	SS21A	75-76 ft	4/8/09		Brown Sandy Clay (Visual)	33.7	63	43

Client SRNS	**MACTEC ENGINEERING AND CONSULTING, INC.**	● Tested By: EH Reviewed By: JW
Project Saltstone Vaults 3 & 5		JW 5/18/09
Project No. 6155-08-0031.06 Lab No. 9505		

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)

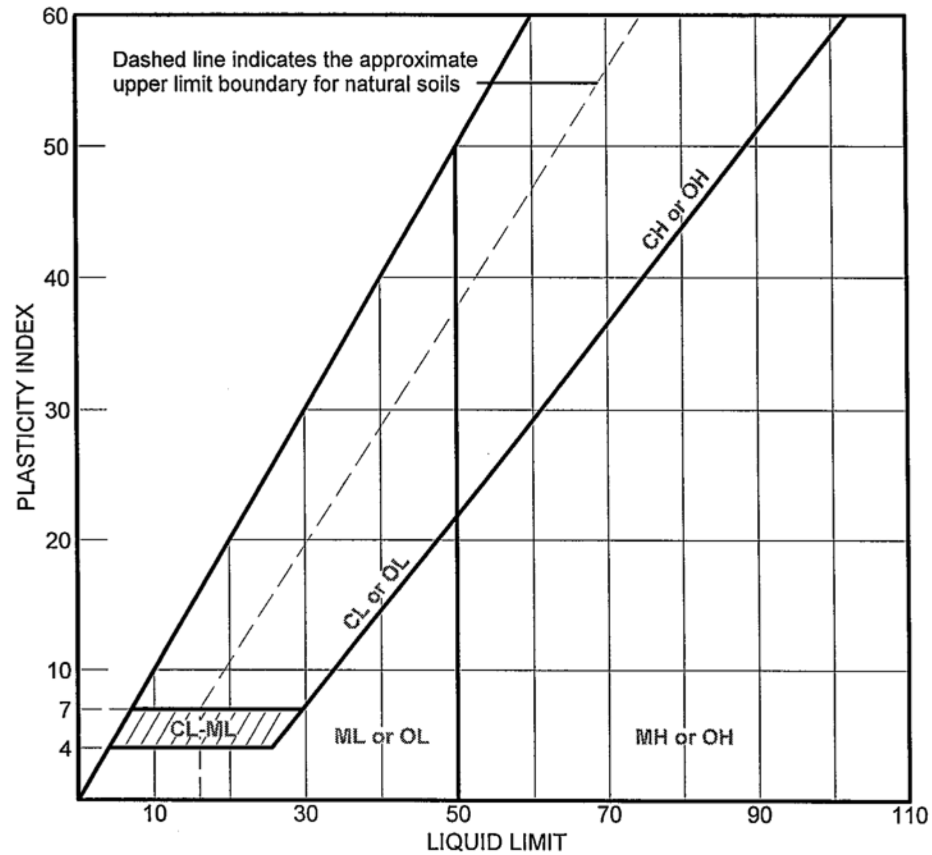




	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B02	SS21B	76-77 ft	4/8/09		Greyish Brown Silty Sand (Visual)	31.1	38	13

Client SRNS	**MACTEC ENGINEERING AND CONSULTING, INC.**	● Tested By: EH Reviewed By: JW
Project Saltstone Vaults 3 & 5		JW 5/18/09
Project No. 6155-08-0031.06 Lab No. 9506		

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)



	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B02	SS25	95-97 ft	4/8/09		Tan Silty Sand with Gravel (Visual)	33.0	NV	NP

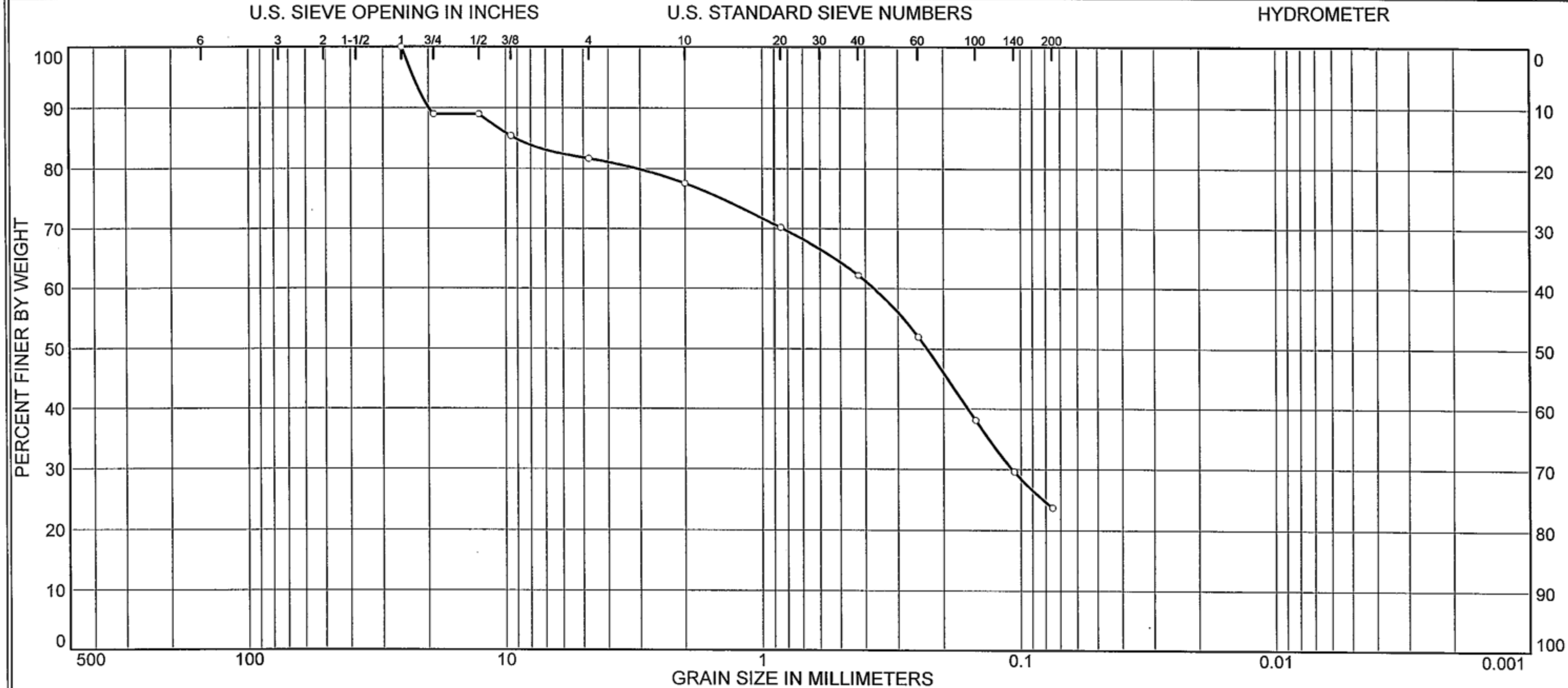
Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9510

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW
5/18/09

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	11.0	7.3	4.1	15.4	38.5	23.7	

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B02	SS26/27	100-107 ft	4/3/09	SM	Tan Silty Sand with Gravel	25.9	45	28

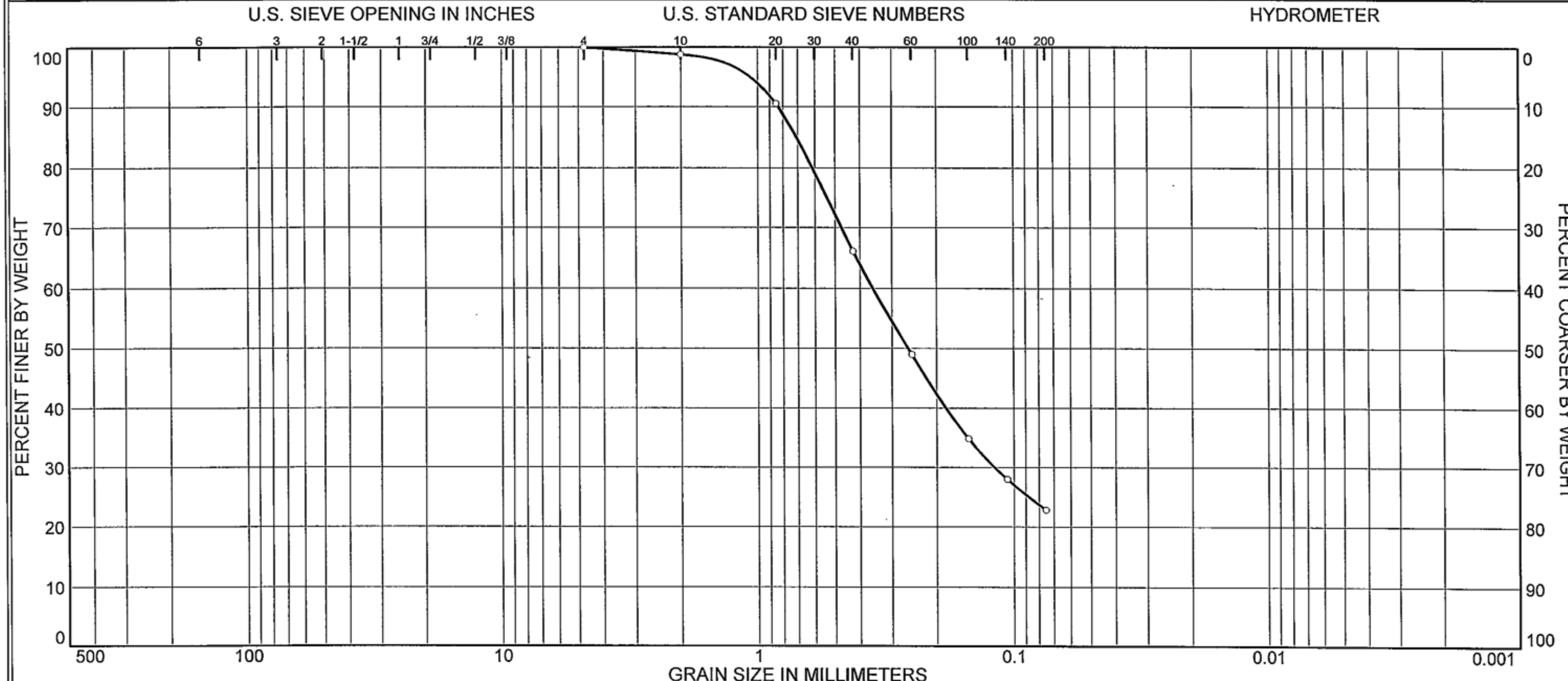
Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9511/9512

MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewed By: JW

JW
5/18/09

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	0.0	1.2	32.7	43.3	22.8	

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B02	SS29/30	115-122 ft	4/3/09	SC	Dark Grey Clayey Sand	22.0	48	21

Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9514/9415

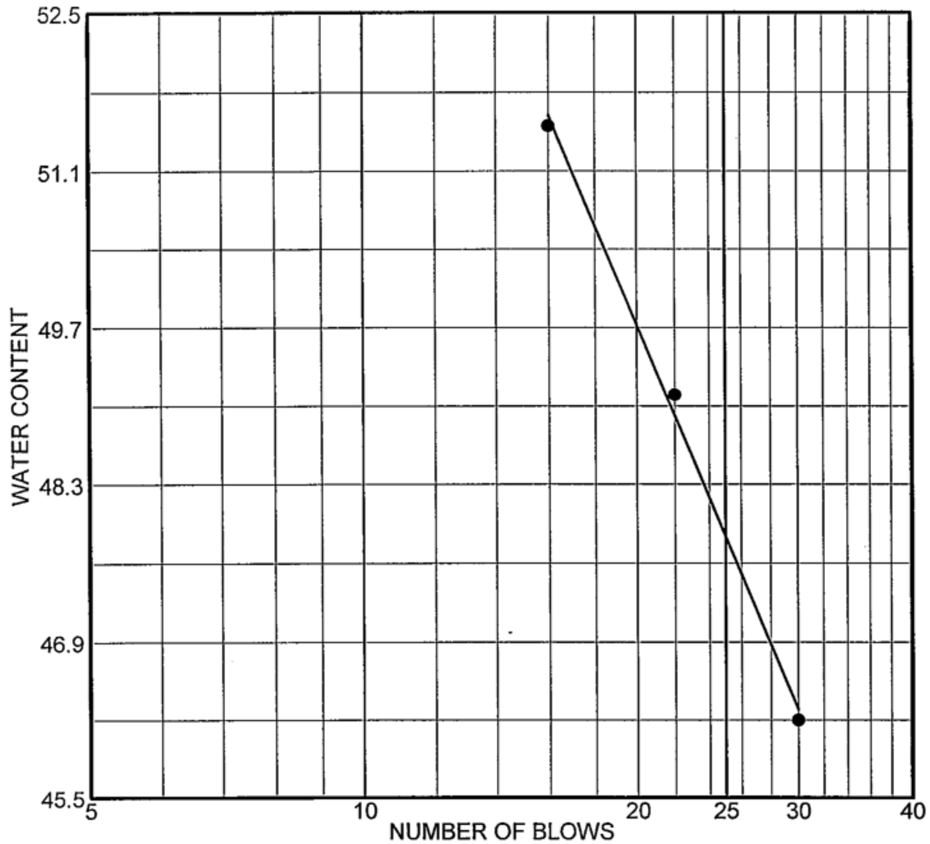
MACTEC ENGINEERING AND CONSULTING, INC.

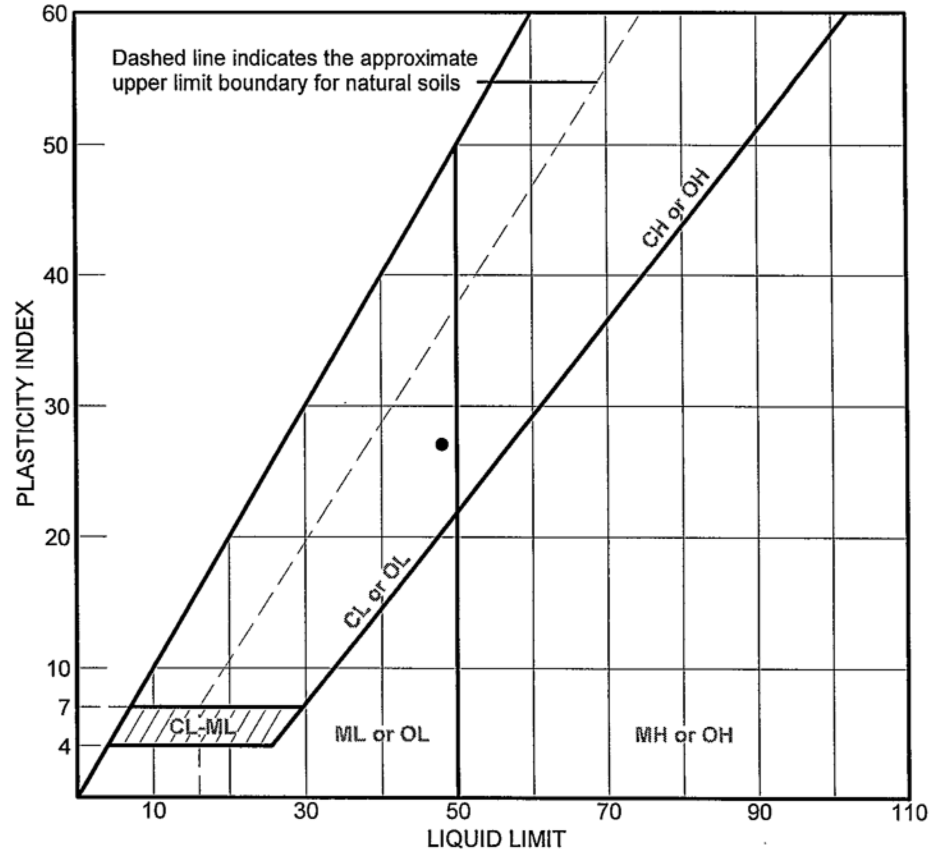
○ Tested By: EH Reviewed By: JW

JO 5/18/09

B-153

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)

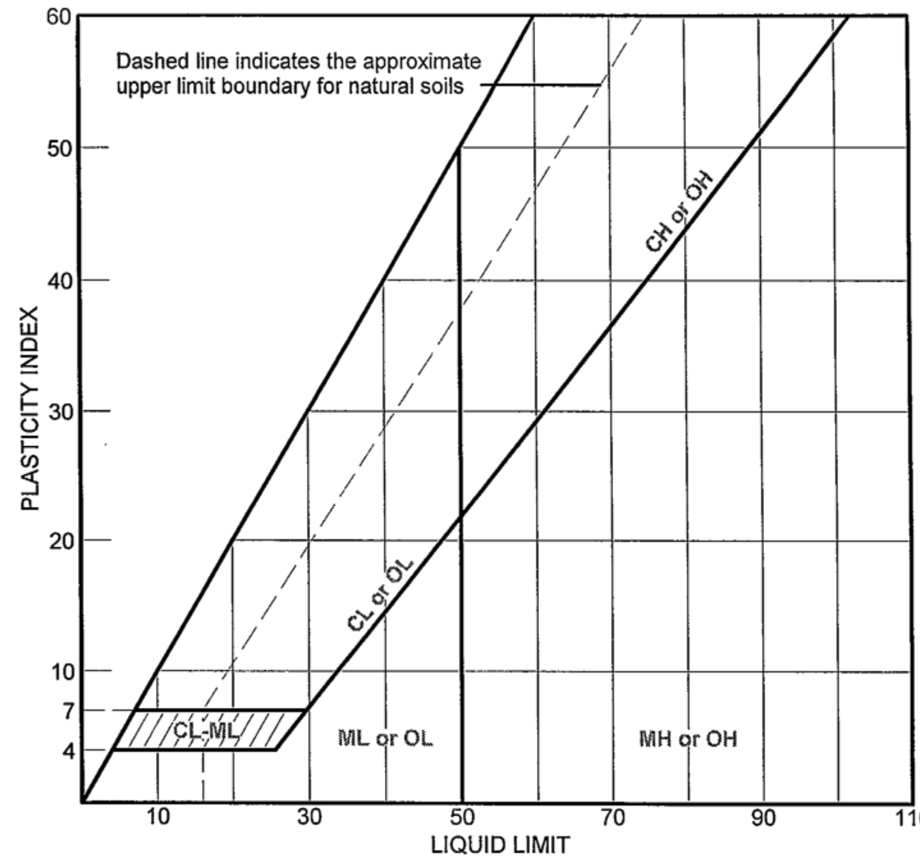




	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B02	SS29/30	115-122 ft	4/3/09	SC	Dark Grey Clayey Sand	22.0	48	27

Client SRNS	**MACTEC ENGINEERING AND CONSULTING, INC.**	● Tested By: EH Reviewed By: JW
Project Saltstone Vaults 3 & 5		JW 5/18/09
Project No. 6155-08-0031.06 Lab No. 9414/9415		

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)



	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B02	SS33	135-137 ft	4/8/09		Grey Silty Sand (Visual)	21.3	NV	NP

Client SRNS

Project Saltstone Vaults 3 & 5

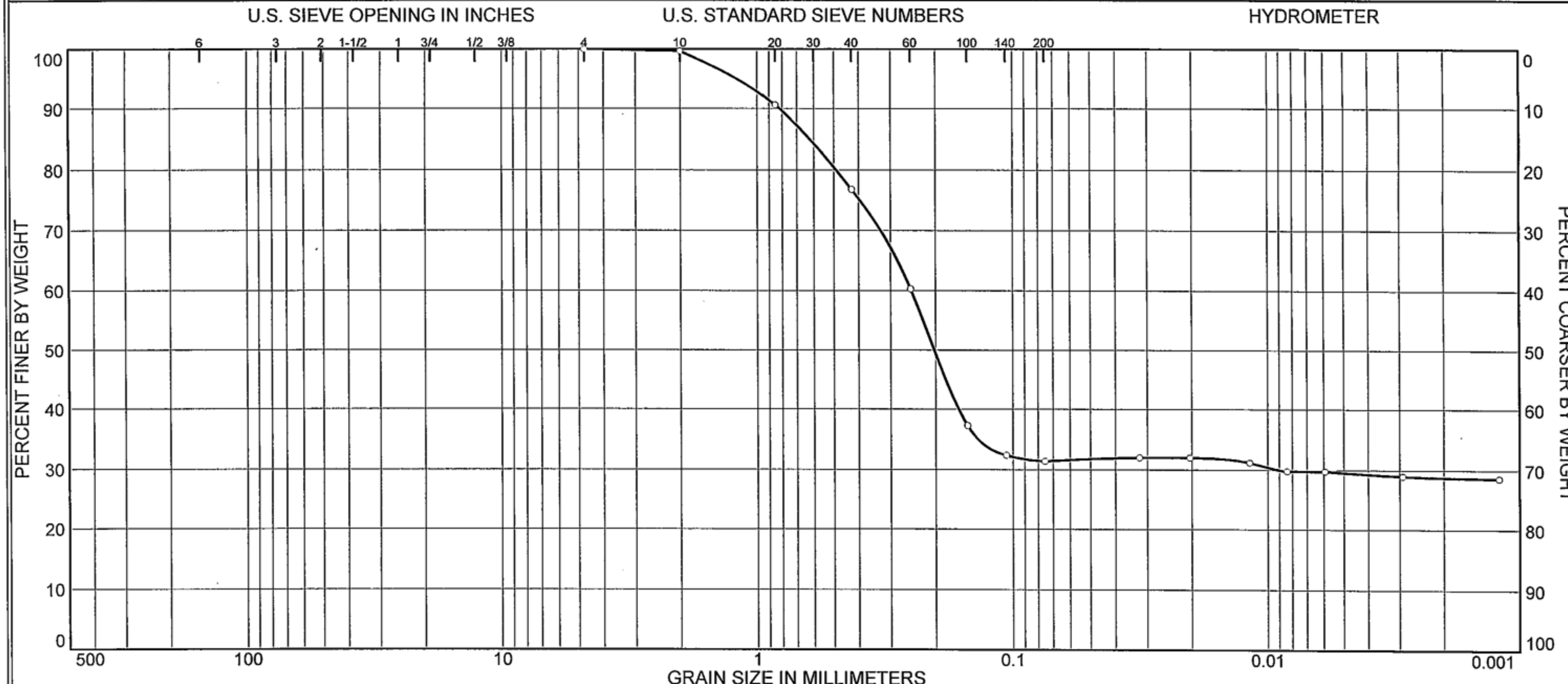
Project No. 6155-08-0031.06 Lab No. 9518

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW
5/18/09

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	0.0	0.3	22.9	45.4	1.8	29.6

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B03	SS1/2/3	10-16 ft	4/3/09	SC	Red Clayey Sand	19.3	53	26

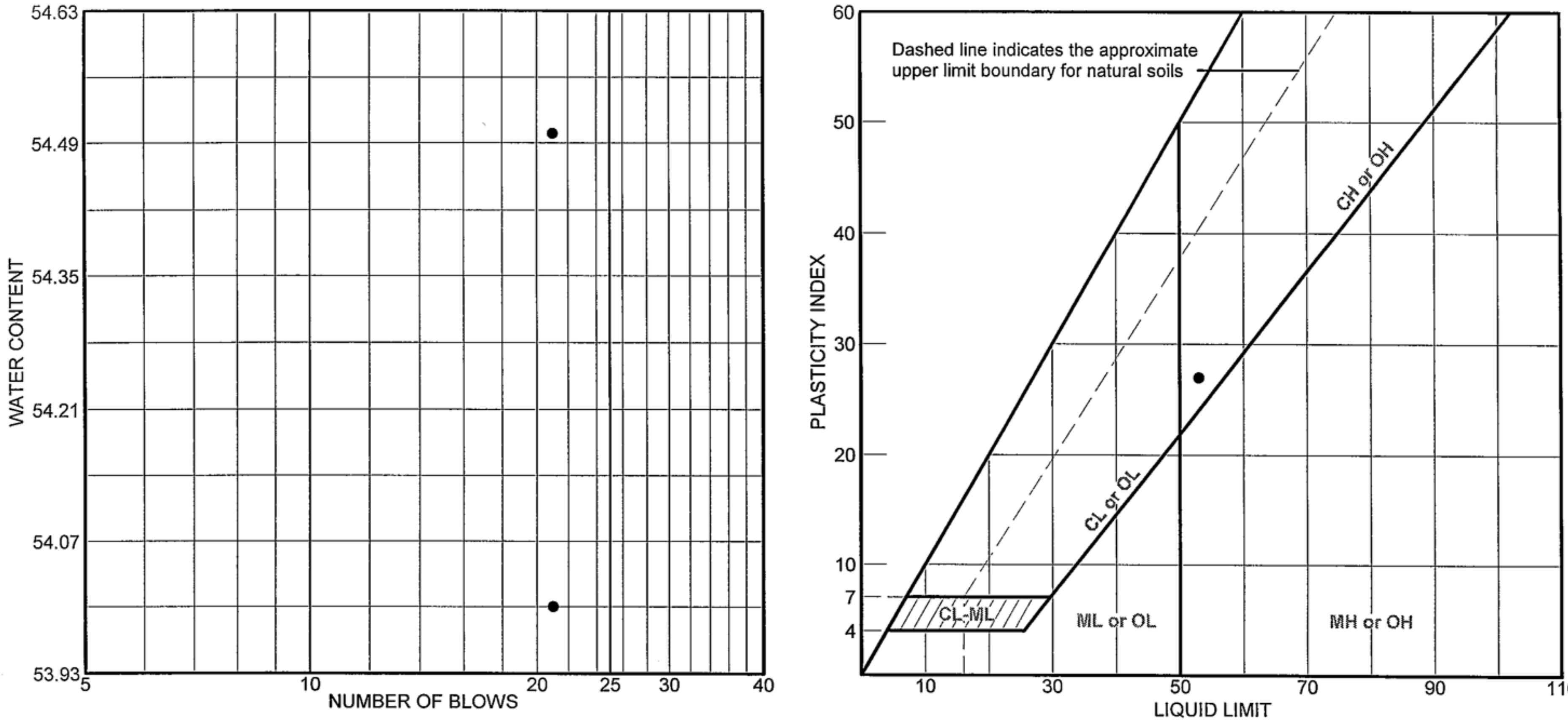
Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9522/23/24

MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested by: EH Reviewed By: JW

JW
5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)



	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B03	SS1/2/3	10-16 ft	4/3/09	SC	Red Clayey Sand	19.3	53	27

Client SRNS

Project Saltstone Vaults 3 & 5

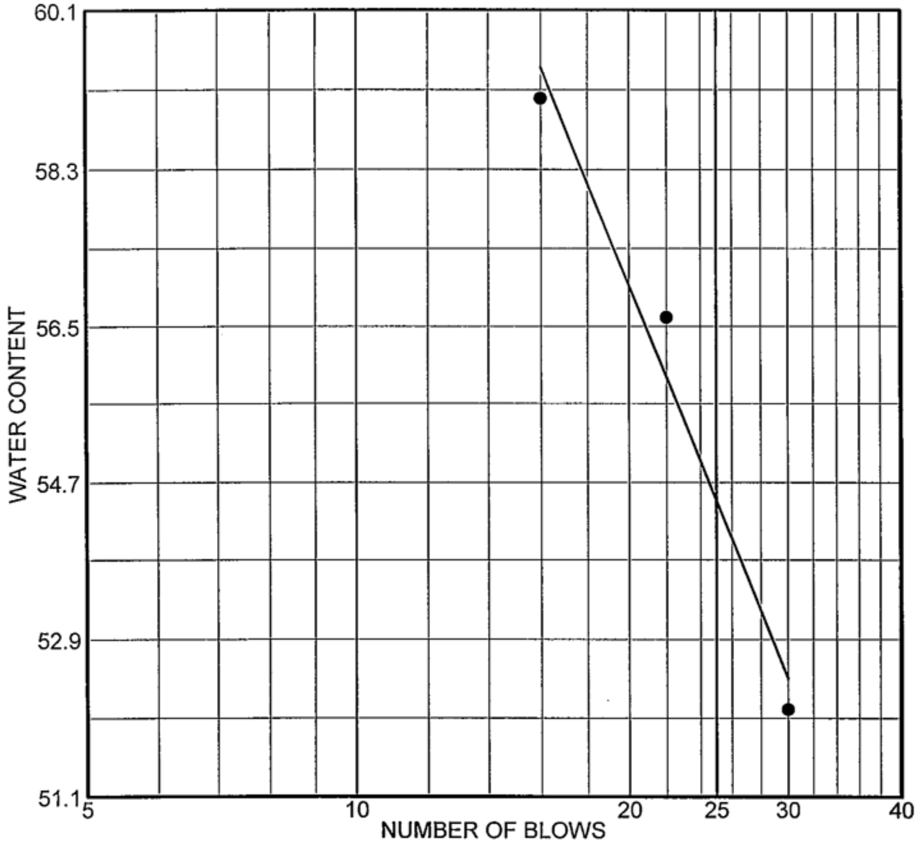
Project No. 6155-08-0031.06 Lab No. 9522/23/24

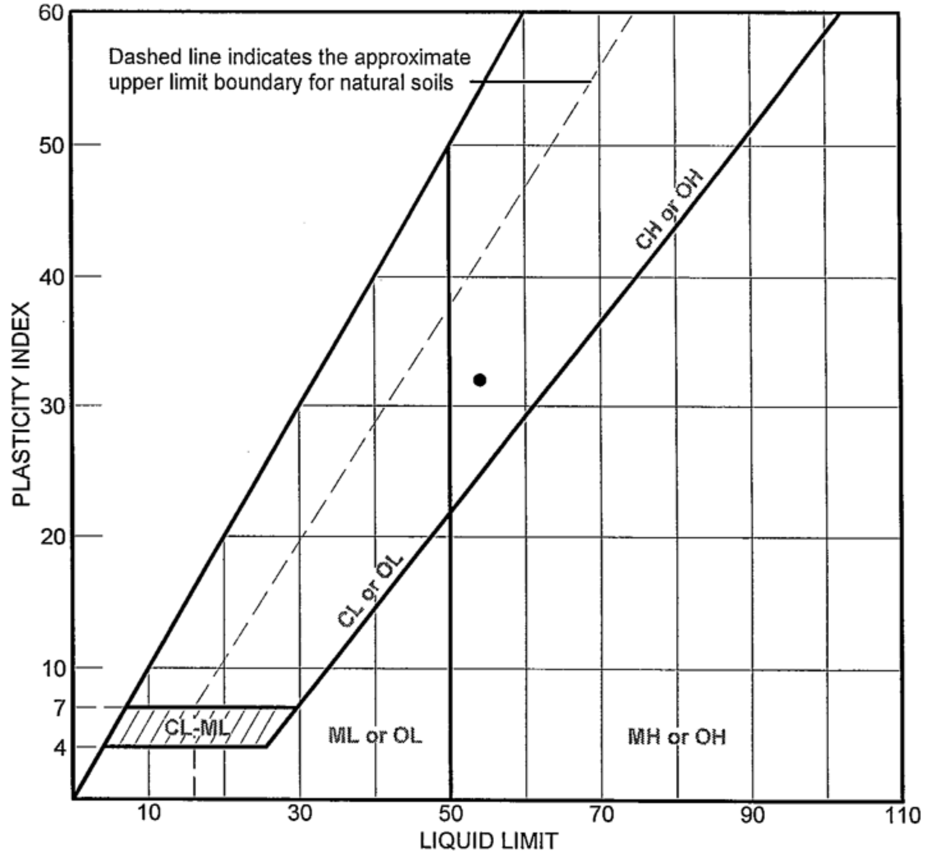
MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By :EH Reviewed By: JW

JW 5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)

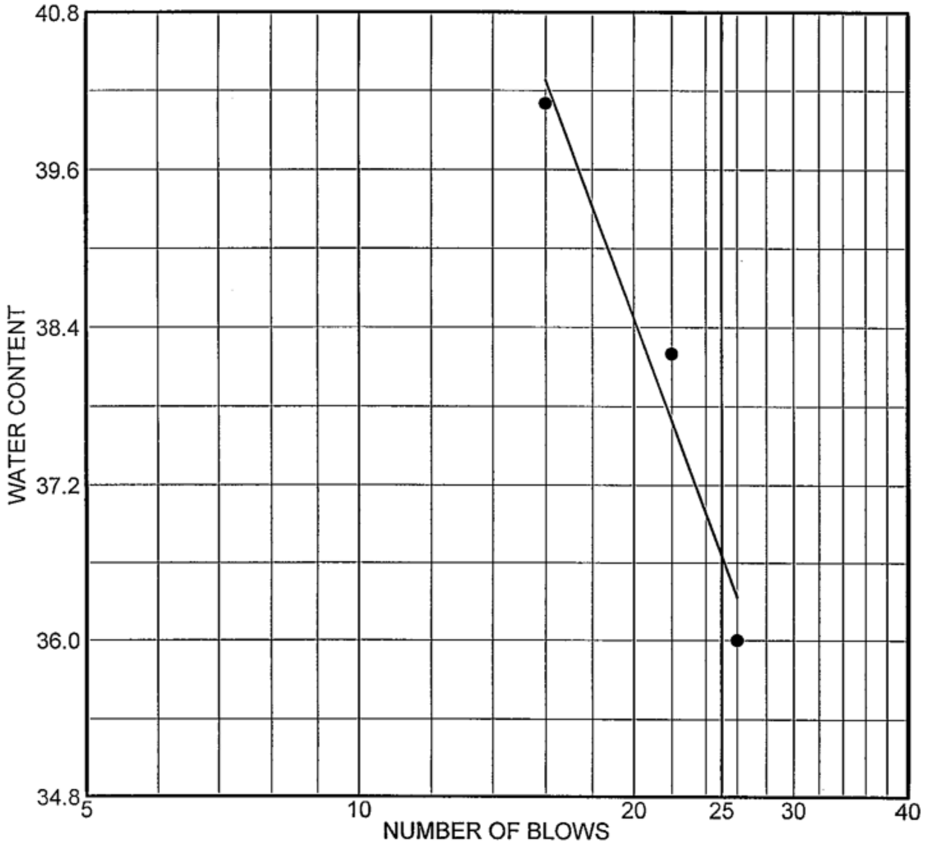


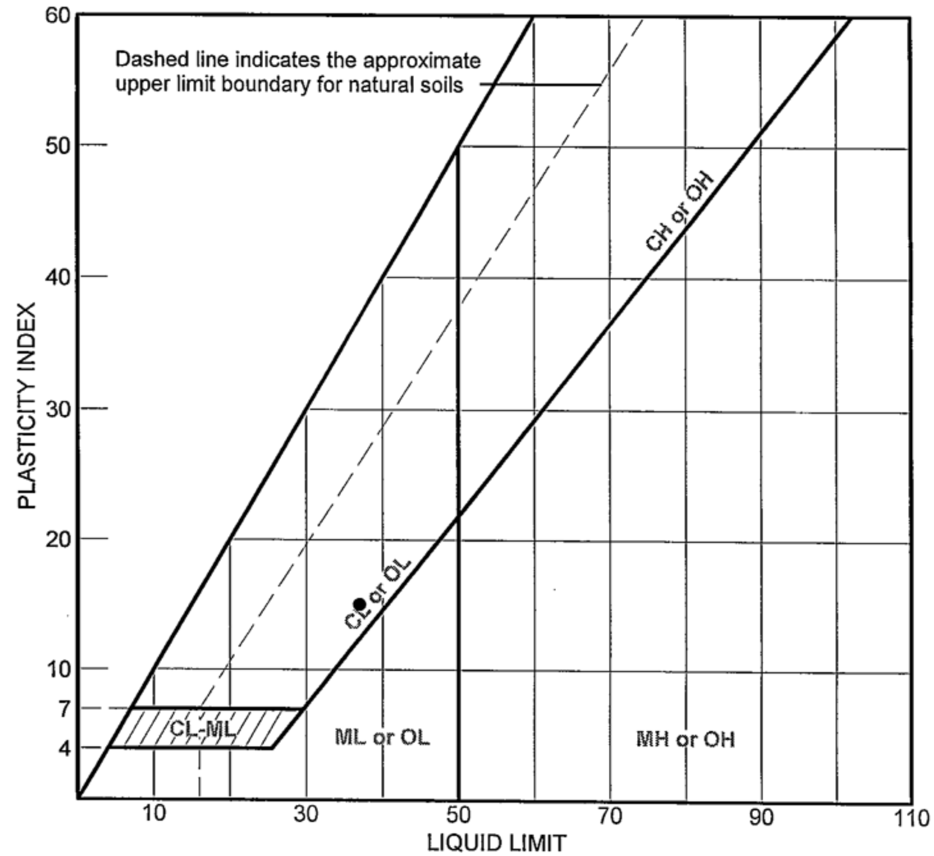


	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B03	SS2	12-14 ft	4/3/09		Red Sandy Clay (Visual)	20.7	54	32

Client SRNS	**MACTEC ENGINEERING AND CONSULTING, INC.**	● Tested By: EH Reviewed By: JW
Project Saltstone Vaults 3 & 5		JW 5/18/09
Project No. 6155-08-0031.06 Lab No. 9523		

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)





	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B03	SS5	18-20 ft	4/10/09		Yellowish Brown Clayey Sand (Visual)	19.1	37	15

Client SRNS

Project Saltstone Vaults 3 & 5

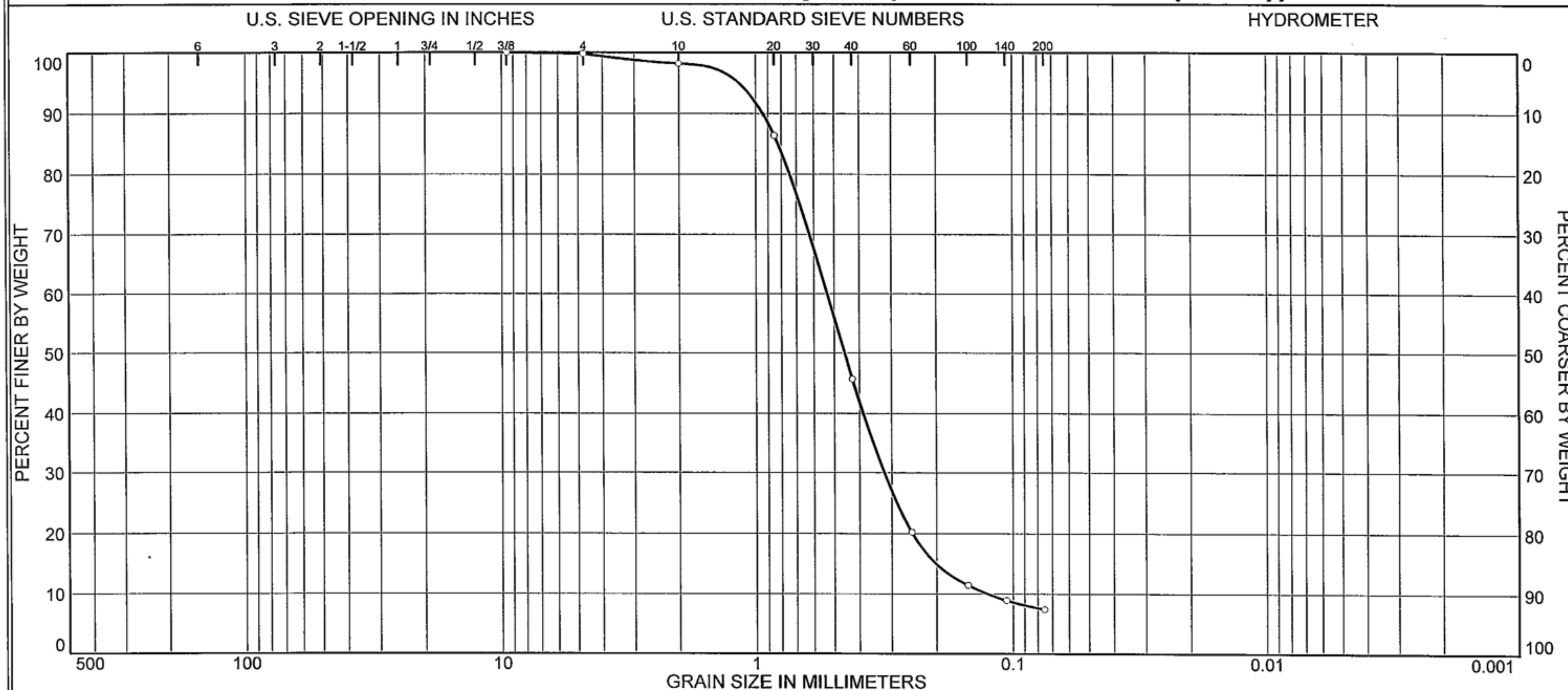
Project No. 6155-08-0031.06 Lab No. 9526

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW
5/19/09

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	0.2	1.6	52.5	38.3	7.4	

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B03	SS7/8/9	22-28 ft	4/3/09	SP-SC	Brown Poorly Graded Sand with Clay	11.2	28	20

Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9528/29/30

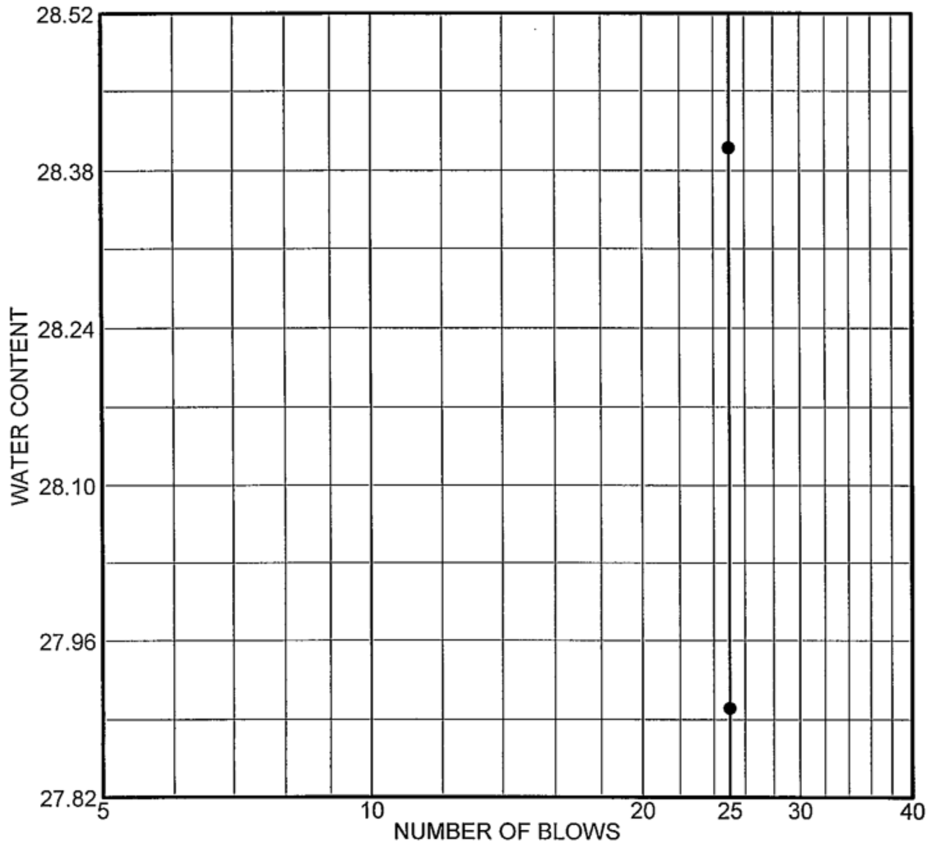
MACTEC ENGINEERING AND CONSULTING, INC.

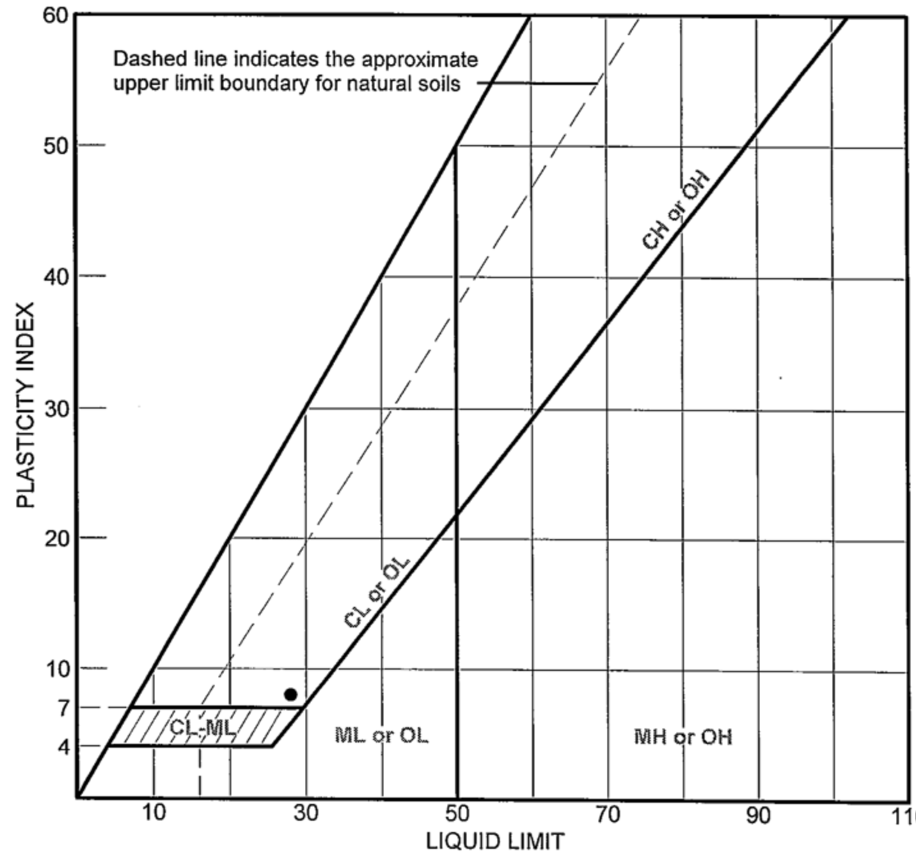
○ Tested By: EH Reviewed By: JW

Composite, Lab No. 9528, 9529 and 9530

JW 5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)





	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B03	SS7/8/9	22-28 ft	4/3/09	SP-SC	Brown Poorly Graded Sand with Clay	11.2	28	8

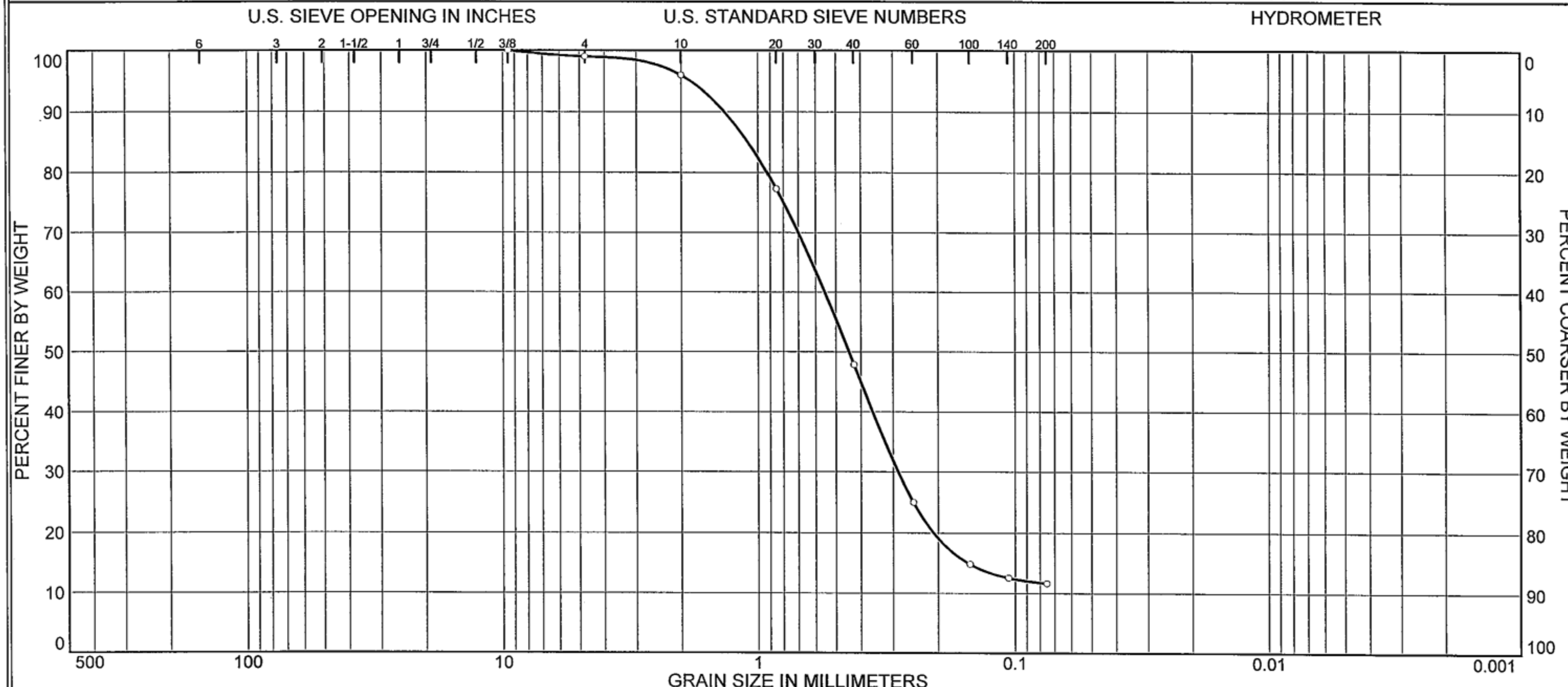
Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9528/29/30

MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW 5/18/09

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	1.0	3.0	48.1	36.3	11.6	

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B03	SS11/12	30-34 ft	4/7/09	SP-SC	Brown Poorly Graded Sand with Clay	16.0	37	18

Client SRNS

Project Saltstone Vaults 3 & 5

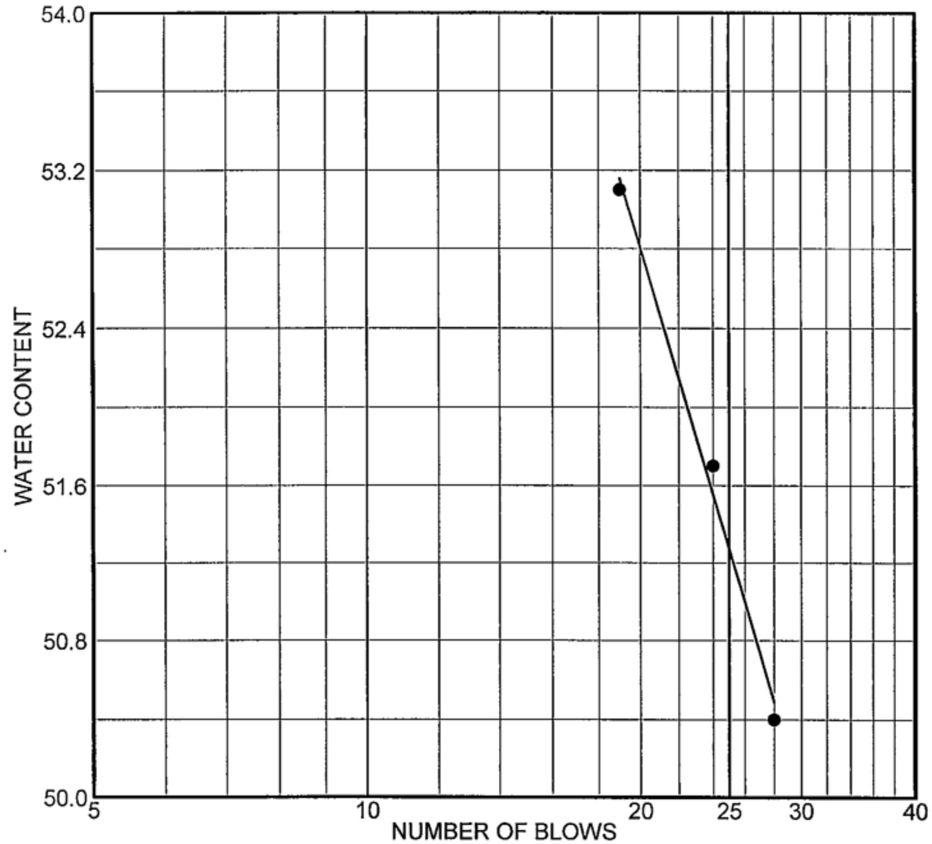
Project No. 6155-08-0031.06 Lab No. 9532/9533

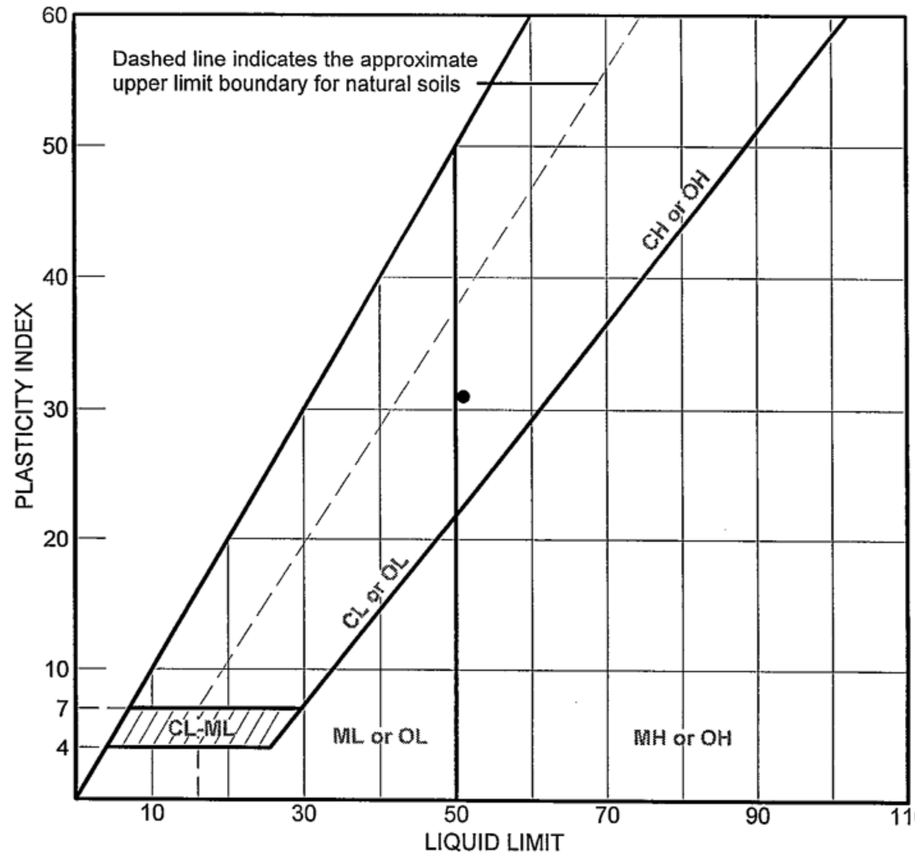
MACTEC ENGINEERING AND CONSULTING, INC.

○ Tested By: EH Reviewed By: JW

JW
5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)





	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B03	SS13A	34-34.6 ft	4/10/09		Brown Sandy Clay (Visual)	21.2	51	31

Client SRNS

Project Saltstone Vaults 3 & 5

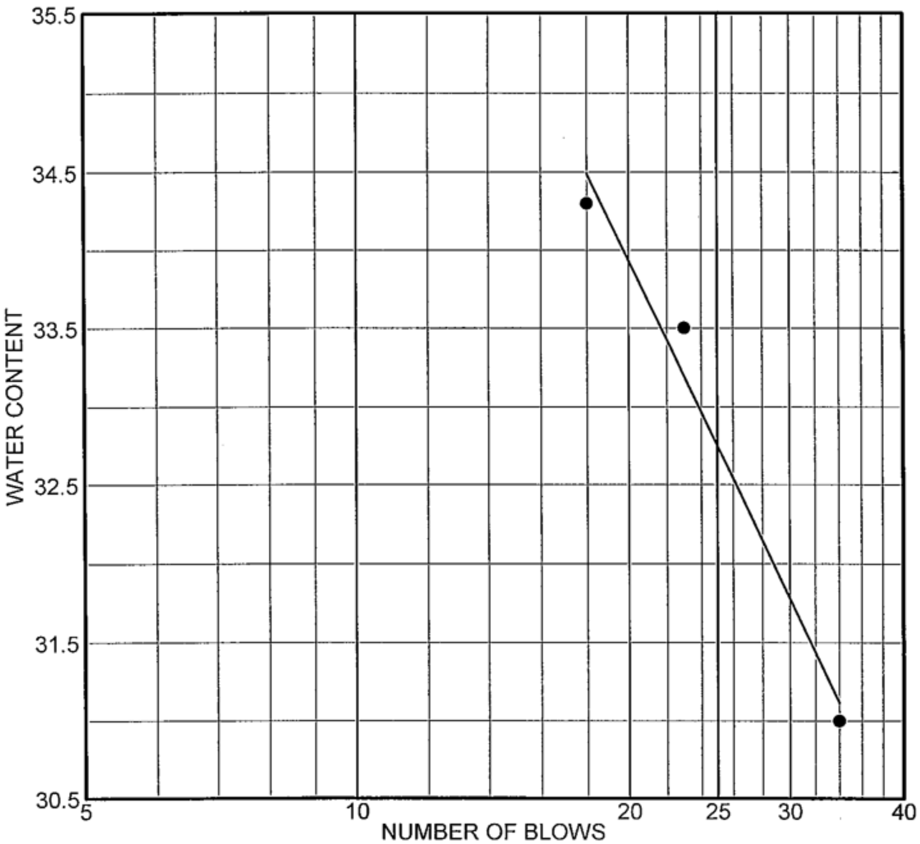
Project No. 6155-08-0031.06 Lab No. 9534

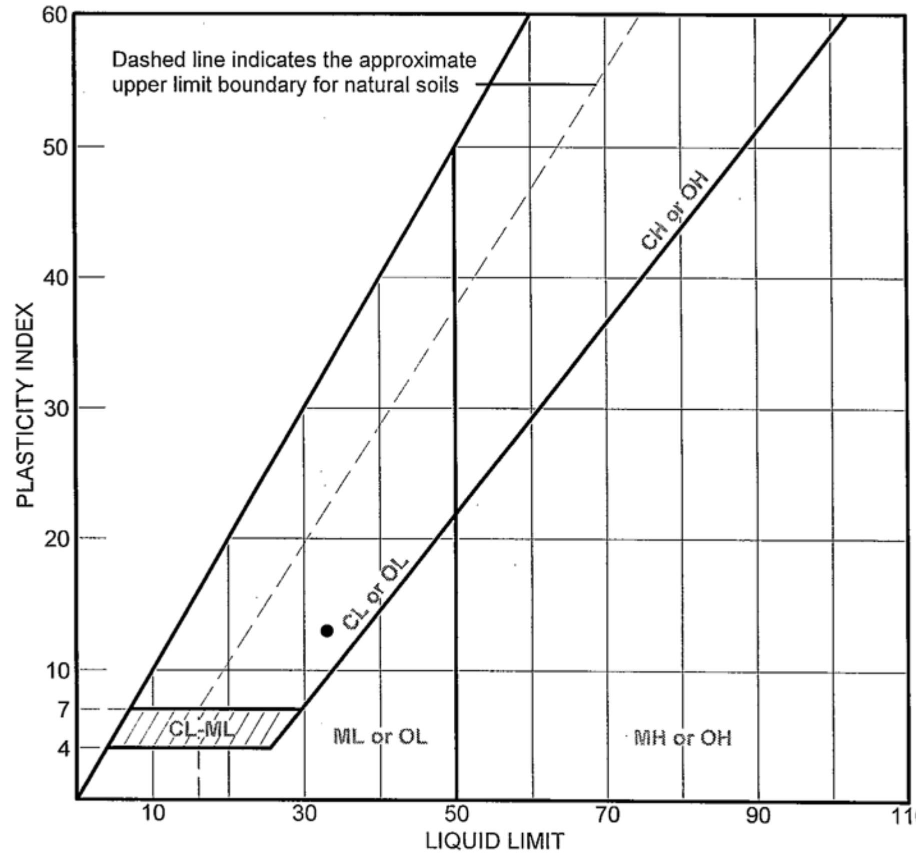
MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW
5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)

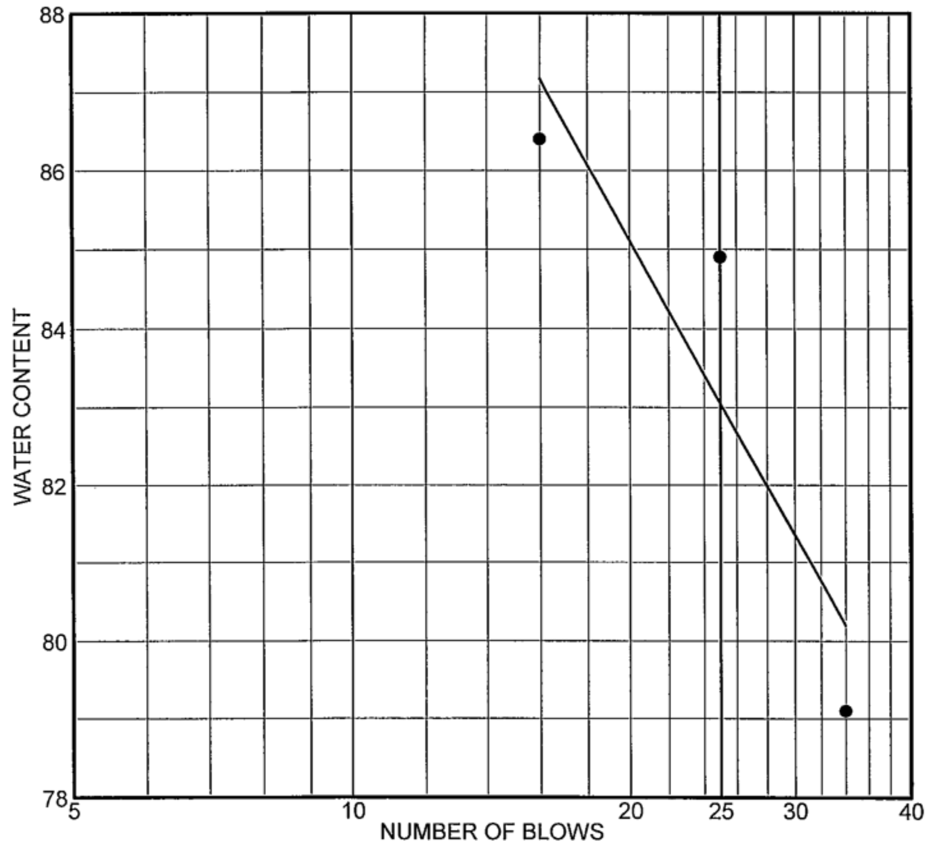


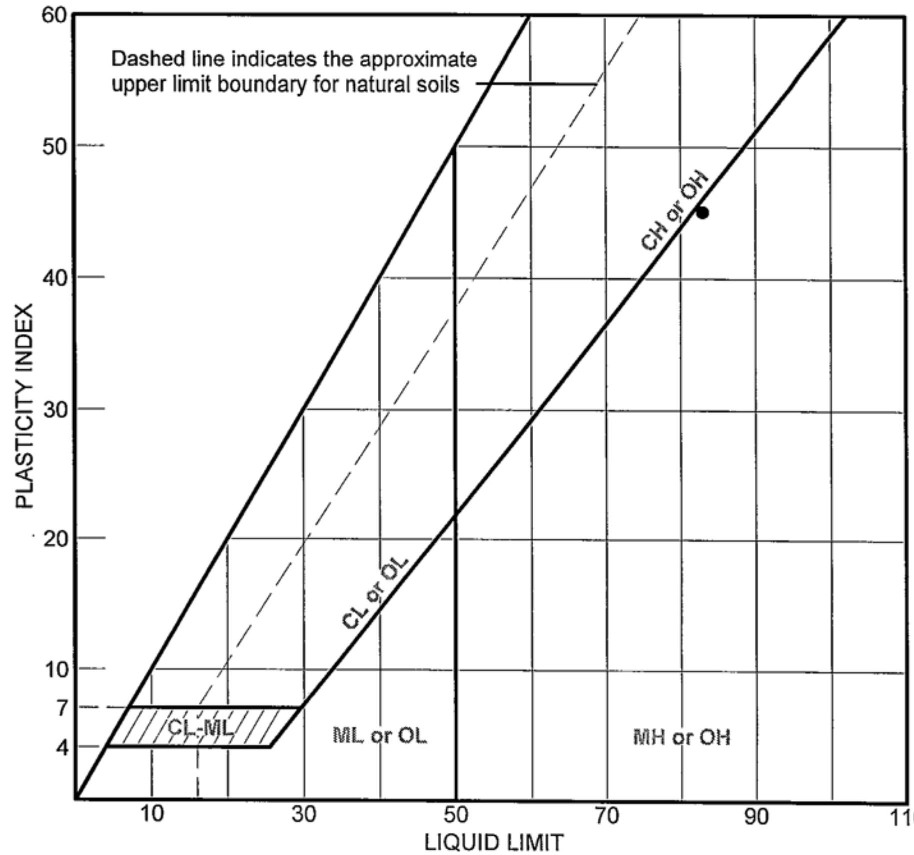


	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B03	SS13B	34.6-36 ft	4/10/09		Yellowish Brown Clayey Sand (Visual)	14.2	33	13

Client SRNS	**MACTEC ENGINEERING AND CONSULTING, INC.**	● Tested By: EH Reviewed By: JW
Project Saltstone Vaults 3 & 5		JW 5/18/09
Project No. 6155-08-0031.06 Lab No. 9535		

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)

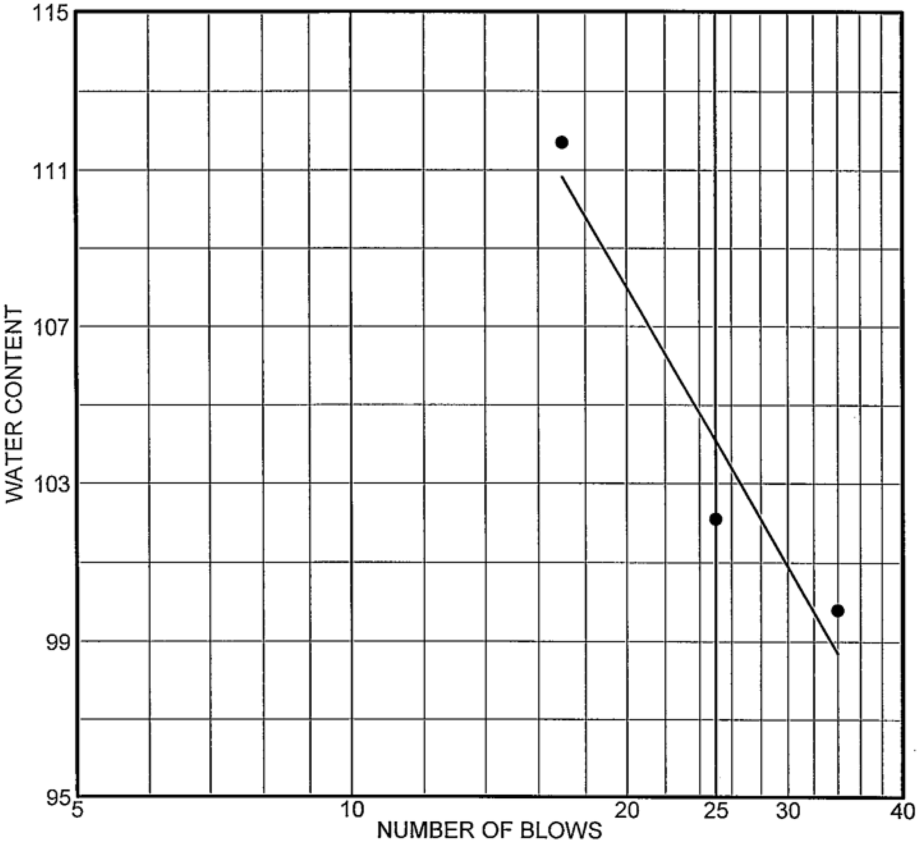


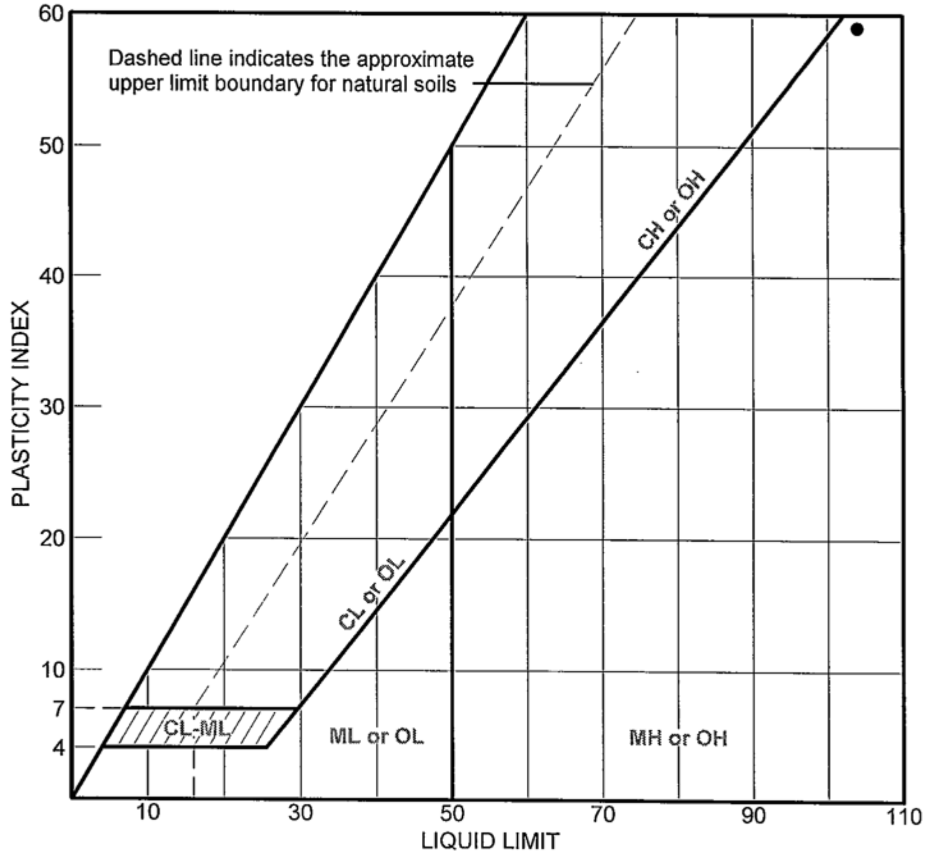


	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B03	SS16	50-52 ft	4/10/09		Yellowish Silt (Visual)	37.8	83	45

Client SRNS	**MACTEC ENGINEERING AND CONSULTING, INC.**	● Tested By: EH Reviewed By: JW
Project Saltstone Vaults 3 & 5		JW 5/18/09
Project No. 6155-08-0031.06 Lab No. 9538		

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)





	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B03	SS18A	60-60.6 ft	4/10/09		Yellowish Silt (Visual)	48.0	104	59

Client SRNS

Project Saltstone Vaults 3 & 5

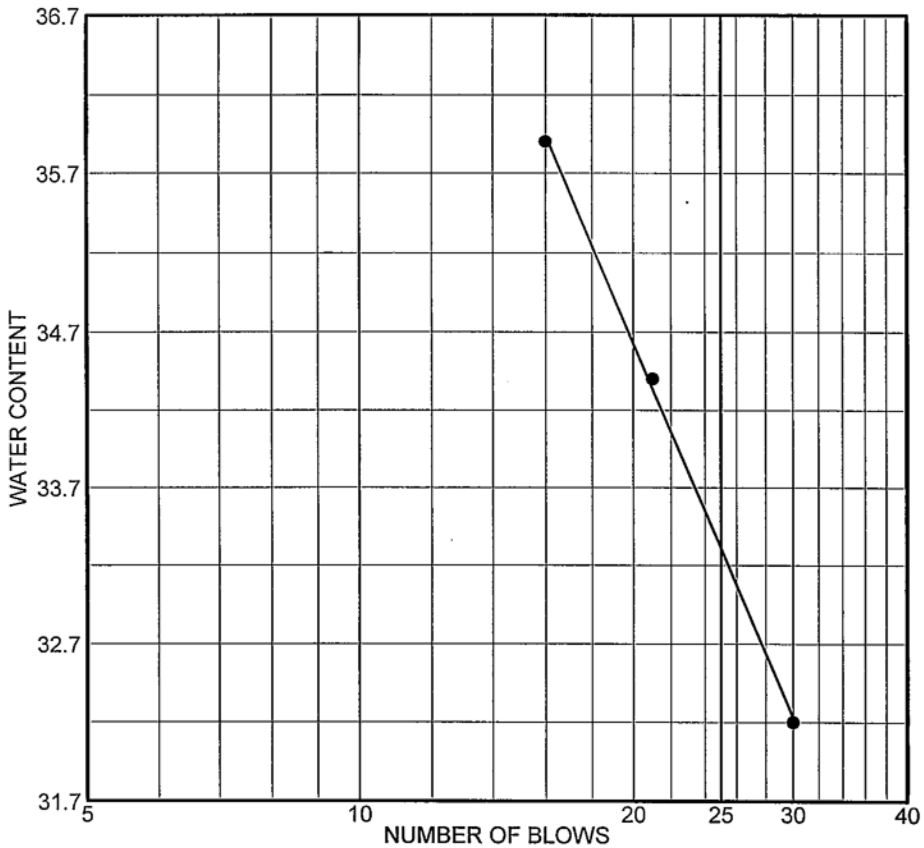
Project No. 6155-08-0031.06 Lab No. 9540

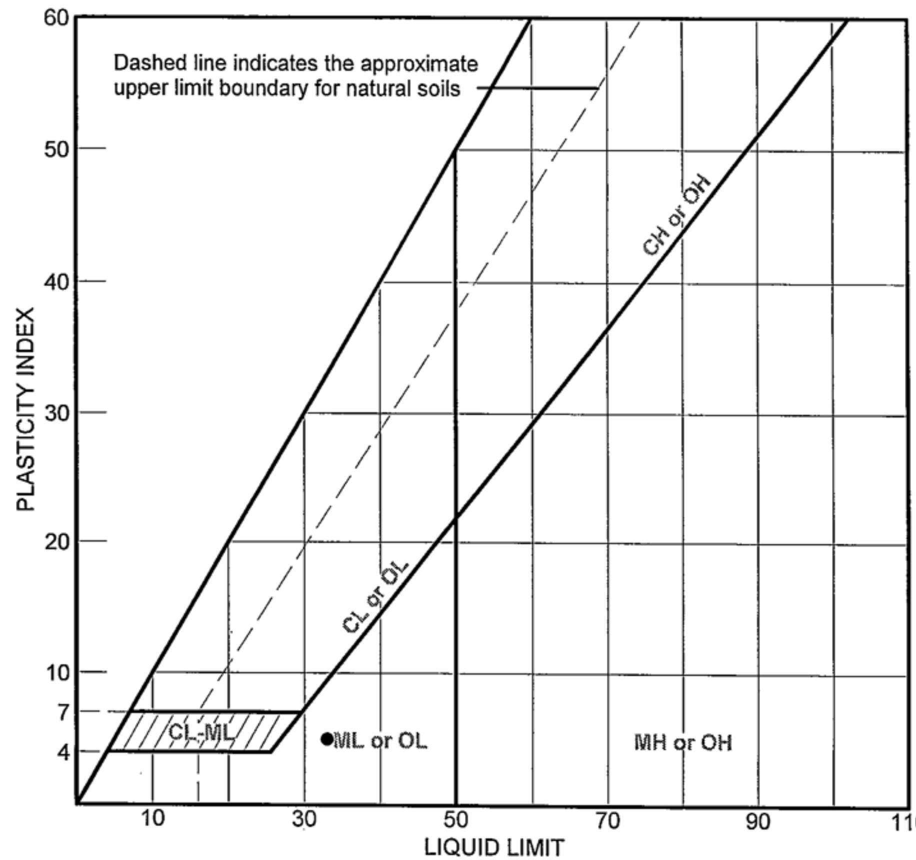
MACTEC ENGINEERING AND CONSULTING, INC.

● Tested By: EH Reviewed By: JW

JW 5/18/09

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)

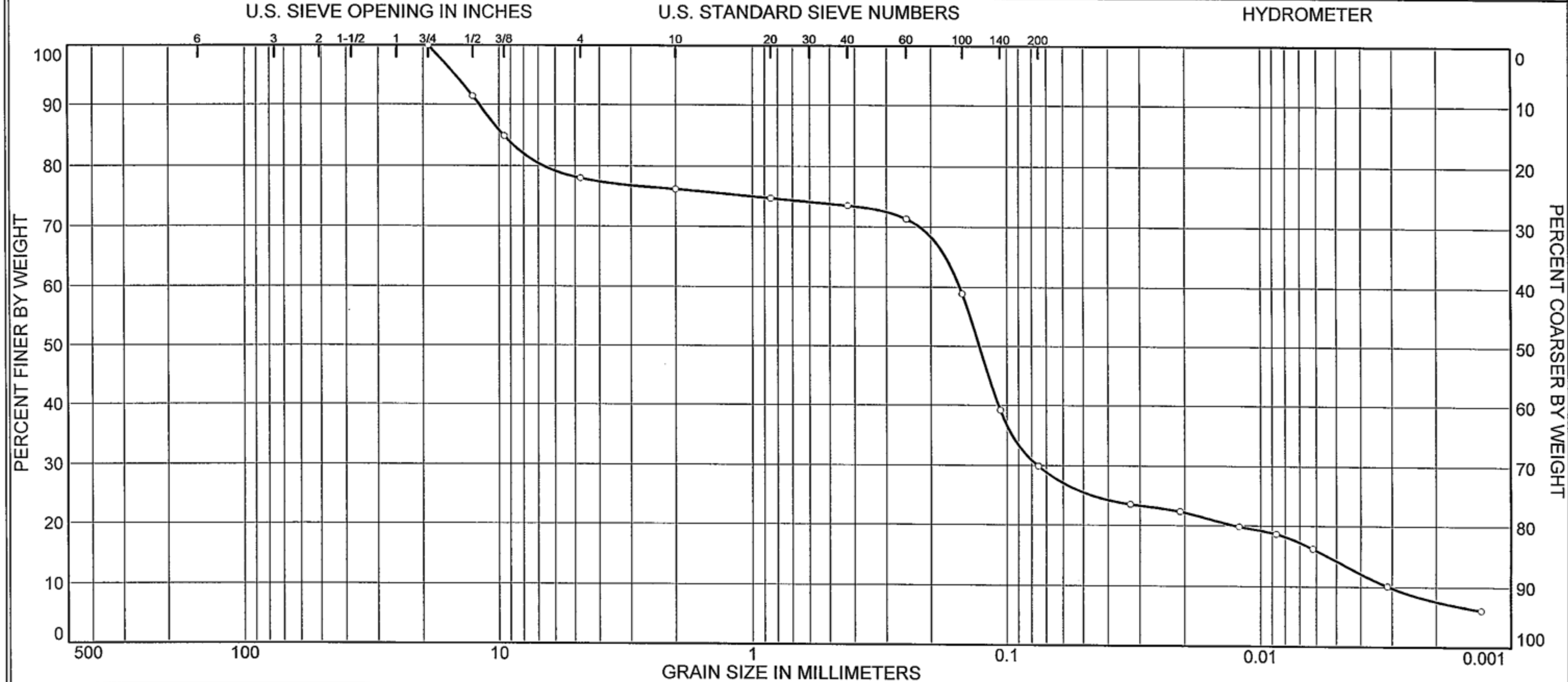




	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B03	SS21	75-77 ft	4/10/09		Tan Silty Sand (Visual)	32.8	33	5

Client SRNS Project Saltstone Vaults 3 & 5 Project No. 6155-08-0031.06 Lab No. 9544	**MACTEC ENGINEERING AND CONSULTING, INC.**	● Tested By: EH Reviewed By :JW JW 5/18/09

Particle Size Distribution Report (ASTM D422-63 (2007))



	% COBBLES	% GRAVEL		% SAND			% FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	22.0	1.8	2.7	43.6	15.7	14.2

	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PL
○	Z-V3V5-B03	SS22/23/24	80-92 ft	4/3/09	SM	Tan Silty Sand with Gravel	33.2	39	26

Client SRNS
Project Saltstone Vaults 3 & 5
Project No. 6155-08-0031.06 Lab No. 9545/46/47

MACTEC ENGINEERING AND CONSULTING, INC.

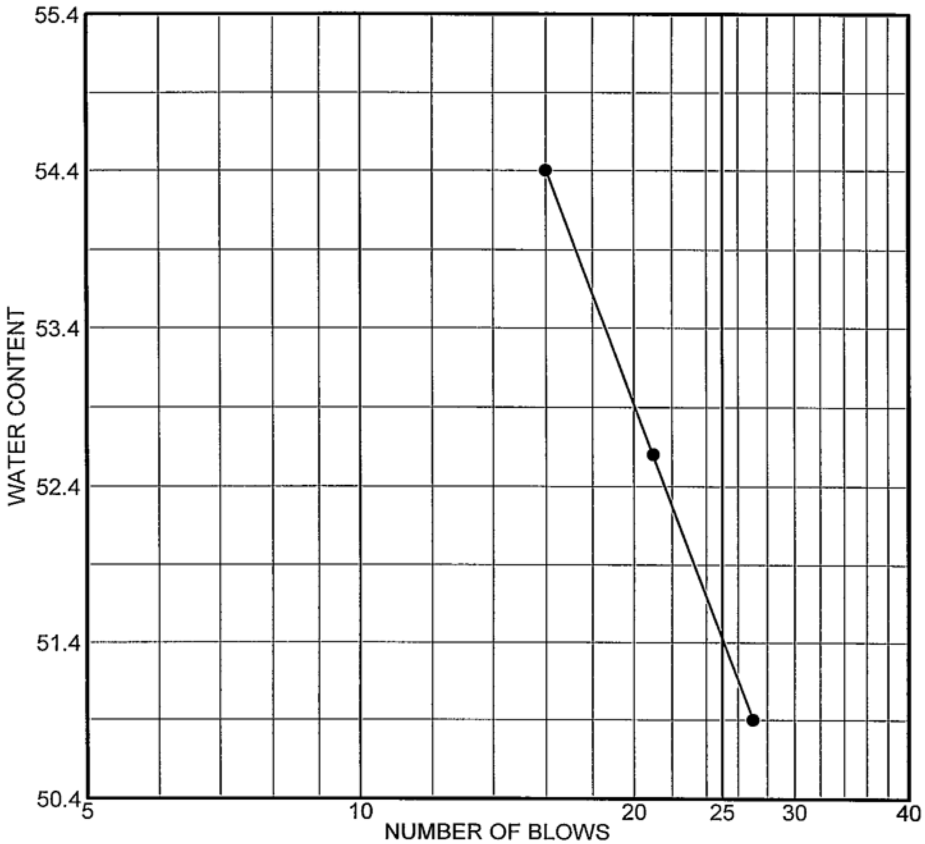
○ Tested By: Eh Reviewed By :JW

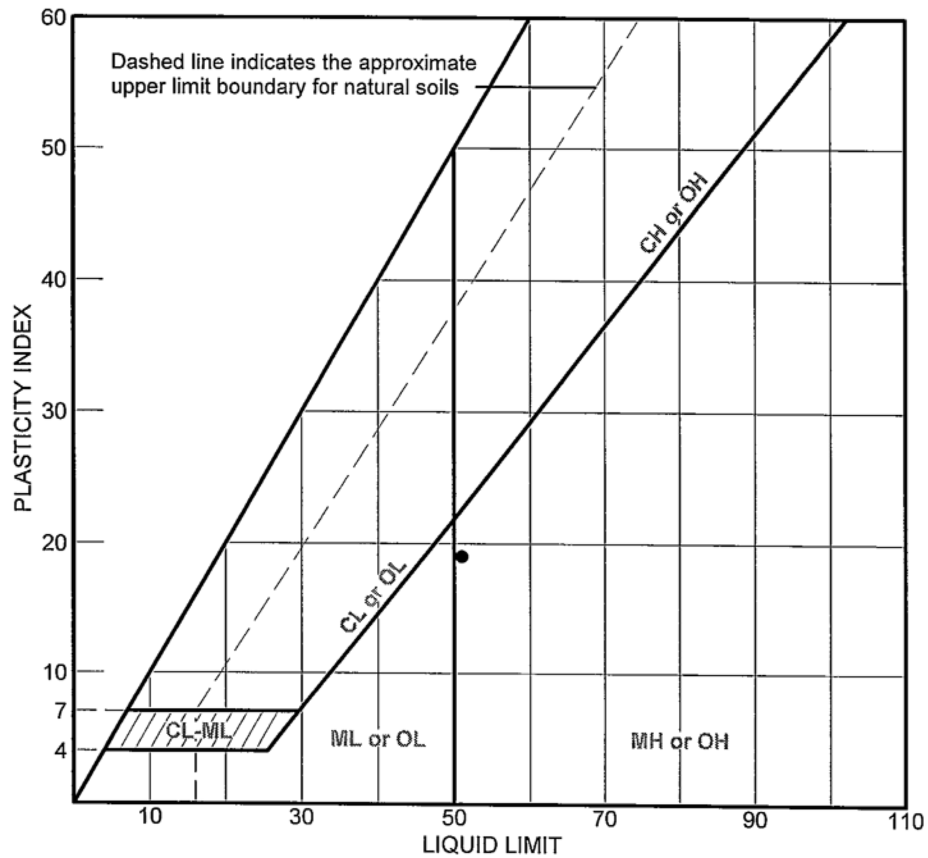
Composite , Lab No. 9545, 9546 and 9547

JW 5/18/09

B-168

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)

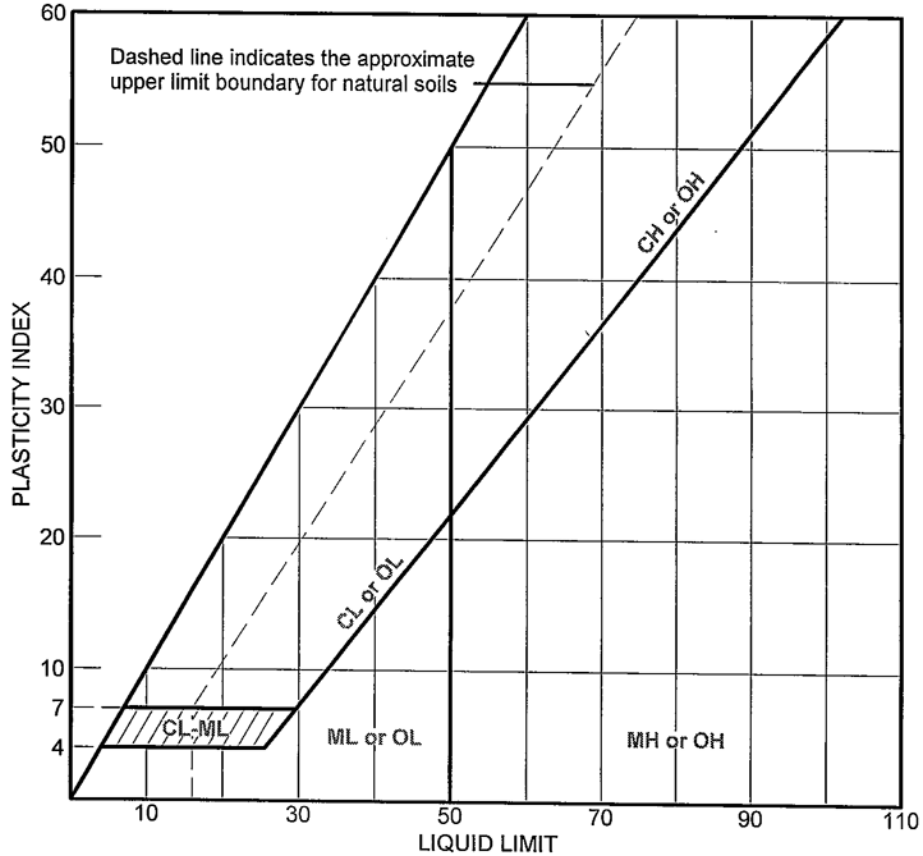




	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B03	SS28A	110-111 ft	4/10/09		Dary Grey Sandy Silt (Visual)	31.7	51	19

Client SRNS	**MACTEC ENGINEERING AND CONSULTING, INC.**	● Tested By: EH Reviewed By: JW
Project Saltstone Vaults 3 & 5		JW 5/18/09
Project No. 6155-08-0031.06 Lab No. 9551		

LIQUID AND PLASTIC LIMITS TEST REPORT ASTM D4318 (05)



	SOURCE	SAMPLE #	DEPTH/ELEV.	DATE SAMPLED	USCS	MATERIAL DESCRIPTION	NM %	LL	PI
●	Z-V3V5-B03	SS34	140-140.5 ft	4/10/09		Grey SAnd (Visual)	23.8	NV	NP

Client SRNS Project Saltstone Vaults 3 & 5 Project No. 6155-08-0031.06 Lab No. 9558	MACTEC ENGINEERING AND CONSULTING, INC.	● Tested By :EH Reviewed By: JW JW 5/18/09

MACTEC

TP-4 UNIT WEIGHT OF SAMPLE

Project No.:	6155-08-0031.06	Boring No.:	Z-V3V5-B01/B04
Project Name:	Saltstone Vaults 3&5	Depth:	Composite A
Lab No.	9465/9466/9467/9468-A	Sample ID:	0-10 ft
Tested By:	JW	Reviewed By:	JGJ
Date:	04/23/09	Date:	5/19/09

Total Sample Height, *inches*		Inside Diameter of Cut Tube, *inches*		Moisture Content		
1	2.937			Tare No.	R-35	
2	2.941	Top	2.870	Tare Weight	8.45	*grams*
3	2.936	Bottom	2.870	Wet Weight + Tare	672.71	*grams*
Average	2.938	Average	2.870	Dry Weight + Tare	619.51	*grams*
				Moisture Content	8.7	%

Total Weight of Soil + Tube Section	664.26	*grams*
Weight of Clean, Dry Tube Section	0.00	*grams*
Wet Weight of Soil	1.46	*lbs*
Volume of Sample	0.011	ft^3

RESULT SUMMARY

Moisture Content	**8.7**	%
Wet Density	**133.1**	*pcf*
Dry Density	**122.5**	*pcf*
Specific Gravity	**2.7**	
Porosity	**0.27**	

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013
Delivery Order #6

MACTEC

TP-4 UNIT WEIGHT OF SAMPLE

Project No.:	6155-08-0031.06	Boring No.:	Z-V3V5-B01/B04
Project Name:	Saltstone Vaults 3&5	Depth:	Composite B
Lab No.	9465/9466/9467/9468-B	Sample ID:	0-10 ft
Tested By:	JW	Reviewed By:	JEJ
Date:	04/23/09	Date:	5/19/09

Total Sample Height, *inches*		Inside Diameter of Cut Tube, *inches*		Moisture Content		
1	2.921			Tare No.	R-11	
2	2.92	Top	2.870	Tare Weight	8.53	*grams*
3	2.925	Bottom	2.870	Wet Weight + Tare	669.79	*grams*
Average	2.922	Average	2.870	Dry Weight + Tare	616.82	*grams*
				Moisture Content	8.7	%

Total Weight of Soil + Tube Section	661.26	*grams*
Weight of Clean, Dry Tube Section	0.00	*grams*
Wet Weight of Soil	1.46	*lbs*
Volume of Sample	0.011	ft^3

RESULT SUMMARY

Moisture Content	**8.7**	%
Wet Density	**133.3**	*pcf*
Dry Density	**122.6**	*pcf*
Specific Gravity	**2.7**	
Porosity	**0.27**	

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013
Delivery Order #6

MACTEC

TP-4 UNIT WEIGHT OF SAMPLE

Project No.:	6155-08-0031.06	Boring No.:	Z-V3V5-B04
Project Name:	Saltstone Vaults 3&5	Depth:	ST2
Lab No.	9459	Sample ID:	30-32 ft
Tested By:	JW	Reviewed By:	JEJ
Date:	04/08/09	Date:	5/19/09

Total Sample Height, *inches*		Inside Diameter of Cut Tube, *inches*		Moisture Content		
1	4.631			Tare No.	X-15	
2	4.605	Top	2.875	Tare Weight	46.77	*grams*
3	4.59	Bottom	2.864	Wet Weight + Tare	993.26	*grams*
Average	4.609	Average	2.870	Dry Weight + Tare	877.86	*grams*
				Moisture Content	13.9	%

Total Weight of Soil + Tube Section	946.49	*grams*
Weight of Clean, Dry Tube Section	0.00	*grams*
Wet Weight of Soil	2.09	*lbs*
Volume of Sample	0.017	ft^3

RESULT SUMMARY

Moisture Content	**13.9**	%
Wet Density	**121.0**	*pcf*
Dry Density	**106.2**	*pcf*
Specific Gravity	**2.67**	
Porosity	**0.36**	

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013
Delivery Order #6

MACTEC

TP-4 UNIT WEIGHT OF SAMPLE

Project No.:	6155-08-0031.06	Boring No.:	Z-V3V5-B04
Project Name:	Saltstone Vaults 3&5	Depth:	ST5
Lab No.	9462	Sample ID:	55-57 ft
Tested By:	JW	Reviewed By:	JEJ
Date:	04/16/09	Date:	5/19/09

Total Sample Height, *inches*		Inside Diameter of Cut Tube, *inches*		Moisture Content		
1	5.636			Tare No.	AB-23	
2	5.636	Top	2.889	Tare Weight	83.92	*grams*
3	5.632	Bottom	2.882	Wet Weight + Tare	989.44	*grams*
Average	5.635	Average	2.886	Dry Weight + Tare	619.31	*grams*
				Moisture Content	69.1	%

Total Weight of Soil + Tube Section	905.71	*grams*
Weight of Clean, Dry Tube Section	0.00	*grams*
Wet Weight of Soil	2.00	*lbs*
Volume of Sample	0.021	ft^3

RESULT SUMMARY

Moisture Content	**69.1**	%
Wet Density	**93.6**	*pcf*
Dry Density	**55.4**	*pcf*

Remarks:
Subcontract No. AC54317N
Specification No. K-SPC-G-0013
Delivery Order #6

MACTEC

TP-4 UNIT WEIGHT OF SAMPLE

Project No.:	6155-08-0031.06	Boring No.:	Z-V3V5-B04
Project Name:	Saltstone Vaults 3&5	Depth:	ST6
Lab No.	9463	Sample ID:	84-86 ft
Tested By:	JW	Reviewed By:	[signature]
Date:	04/16/09	Date:	5/19/09

Total Sample Height, *inches*		Inside Diameter of Cut Tube, *inches*		Moisture Content		
1	6.045			Tare No.	K-7	
2	6.05	Top	2.888	Tare Weight	4.21	*grams*
3	6.035	Bottom	2.881	Wet Weight + Tare	192.85	*grams*
Average	6.043	Average	2.885	Dry Weight + Tare	145.79	*grams*
				Moisture Content	33.2	%

Total Weight of Soil + Tube Section	1194.89	*grams*
Weight of Clean, Dry Tube Section	0.00	*grams*
Wet Weight of Soil	2.63	*lbs*
Volume of Sample	0.023	ft^3

RESULT SUMMARY

Moisture Content	**33.2**	%
Wet Density	**115.3**	*pcf*
Dry Density	**86.5**	*pcf*

Remarks:
Subcontract No. AC54317N
Specification No. K-SPC-G-0013
Delivery Order #6

MACTEC

TP-4 UNIT WEIGHT OF SAMPLE

Project No.:	6155-08-0031.06	Boring No.:	Z-V3V5-B01
Project Name:	Saltstone Vaults 3&5	Depth:	ST2
Lab No.	9477	Sample ID:	30-32 ft
Tested By:	JW	Reviewed By:	JEJ
Date:	04/08/09	Date:	5/19/09

Total Sample Height, *inches*		Inside Diameter of Cut Tube, *inches*		Moisture Content		
1	4.728			Tare No.	AB-11	
2	4.665	Top	2.854	Tare Weight	85.92	*grams*
3	4.694	Bottom	2.843	Wet Weight + Tare	951.10	*grams*
Average	4.696	Average	2.849	Dry Weight + Tare	845.16	*grams*
				Moisture Content	14.0	%

Total Weight of Soil + Tube Section	865.18	*grams*
Weight of Clean, Dry Tube Section	0.00	*grams*
Wet Weight of Soil	1.91	*lbs*
Volume of Sample	0.017	ft^3

RESULT SUMMARY

Moisture Content	**14.0**	%
Wet Density	**110.1**	*pcf*
Dry Density	**96.7**	*pcf*
Specific Gravity	**2.68**	
Porosity	**0.42**	

Remarks:
Subcontract No. AC54317N
Specification No. K-SPC-G-0013
Delivery Order #6

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TP-4 UNIT WEIGHT OF SAMPLE

Project No.:	6155-08-0031.06	Boring No.:	Z-V3V5-B01
Project Name:	Saltstone Vaults 3&5	Depth:	ST7
Lab No.	9482	Sample ID:	78-80 ft
Tested By:	JW	Reviewed By:	JGJ
Date:	04/22/09	Date:	5/19/09

Total Sample Height, *inches*		**Inside Diameter of Cut Tube, *inches***		**Moisture Content**		
1	1.881			Tare No.	F-25	
2	1.894	Top	2.802	Tare Weight	4.23	*grams*
3	1.895	Bottom	2.778	Wet Weight + Tare	84.34	*grams*
Average	1.890	Average	2.790	Dry Weight + Tare	63.54	*grams*
				Moisture Content	35.1	%

Total Weight of Soil + Tube Section	337.86	*grams*
Weight of Clean, Dry Tube Section	0.00	*grams*
Wet Weight of Soil	0.74	*lbs*
Volume of Sample	0.007	ft^3

RESULT SUMMARY

Moisture Content	**35.1**	%
Wet Density	**111.4**	*pcf*
Dry Density	**82.5**	*pcf*

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013
Delivery Order #6

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TP-4 UNIT WEIGHT OF SAMPLE

Project No.:	6155-08-0031.06	Boring No.:	Z-V3V5-B01
Project Name:	Saltstone Vaults 3&5	Depth:	ST8
Lab No.	9483	Sample ID:	81-83 ft
Tested By:	JW	Reviewed By:	JEJ
Date:	04/22/09	Date:	5/19/09

Total Sample Height, *inches*		Inside Diameter of Cut Tube, *inches*		Moisture Content		
1	2.508			Tare No.	F-34	
2	2.391	Top	2.840	Tare Weight	4.31	*grams*
3	2.324	Bottom	2.842	Wet Weight + Tare	165.60	*grams*
Average	2.408	Average	2.841	Dry Weight + Tare	125.74	*grams*
				Moisture Content	32.8	%

Total Weight of Soil + Tube Section	450.84	*grams*
Weight of Clean, Dry Tube Section	0.00	*grams*
Wet Weight of Soil	0.99	*lbs*
Volume of Sample	0.009	ft^3

RESULT SUMMARY

Moisture Content	**32.8**	%
Wet Density	**112.5**	*pcf*
Dry Density	**84.7**	*pcf*

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013
Delivery Order #6

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.06*	Tested By	*JW*
Project Name	*Saltstone Vaults 3&5*	Test Date	*4/23/2009*
Boring No.	*Z-V3V5-B01/B04*	Reviewed By	JEJ
Sample No.	*Composite A*	Review Date	5/19/09
Sample Depth	*0-10 Ft.*	Lab No.	*9465/9466/9467 /9468-A*
Sample Description			

ASTM D5084-03 - (Method C Falling Head RisingTail)

Sample Type:	*Remolded*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*8.7*
Wet Unit Weight, pcf:	*133.2*
Dry Unit Weight, pcf:	*122.5*
Compaction, %:	*96.6*
Hydraulic Conductivity, cm/sec. @20 °C	***1.4E-05***

Remarks: AC54317N
Specification No. K-SPC-G-0013
Delivery Order #6

PERMEABILITY TEST
(ASTM D5084 - 03) (Method C, Increasing Tailwater Level)

MACTEC

Project Number	6155-08-0031.06	Tested By	JW
Project Name	Saltstone Vaults 3&5	Test Date	04/23/09
Boring No.	Z-V3V5-B01/B04	Reviewed By	JEJ
Sample No.	Composite A	Review Date	5/19/09
Sample Depth	0-10 Ft.	Lab No.	9465/9466/9467 /9468-A
Sample Description			

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	R-35
Location 1	2.937	Location 1	2.870	Wet Soil+Pan, g	691.22
Location 2	2.941	Location 2	2.870	Dry Soil + Pan, g	619.51
Location3	2.936	Location 3	2.870	Pan Weight, g	8.45
Average	2.938	Average	2.870	Moisture Content, %	11.7
Volume, in^3	19.01	Wet Soil + Tare, g	664.26	Dry Unit Weight, pcf	123.8
SG Measured	2.7	Tare Weight, g	0.00	Saturation, %	87.9
Soil Sample Wt., g	664.26	Dry Soil + Tare, g	611.06	Diameter, in.	N/A
Dry UW, pcf	122.5	Moisture Content, %	8.7	Length, in.	N/A
Saturation, %	62.6			Volume, in^3	N/A

Consolidation	
Chamber Pressure, psi	74
Back Pressure, psi	64
Confining Pressure, psi	10
Initial Burette Reading	16.8
Finial Burette Reading	13.4
Volume Change, cc	3.4
Permeant used	Water

Time (sec)	H_a (cm)	H_1 (cm)	H_b (cm)	H_2 (cm)	Temp (°C)	Initial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
390	10.1	101.1	25.3	85.0	24.2	12.2	8.0	1.55E-05	1.40E-05
1387	10.1	101.1	45.2	65.9	24.2	12.2	2.8	1.53E-05	1.38E-05
1800	10.1	101.1	48.1	62.3	24.2	12.2	1.9	1.48E-05	1.34E-05
300	18.7	101.1	30.2	89.4	24.2	11.0	7.9	1.58E-05	1.43E-05
780	18.7	101.1	42.2	77.5	24.2	11.0	4.7	1.55E-05	1.41E-05

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
5	Remolded	126.8	96.6	Vertical

Avg. k at 20 °C 1.39E-05 cm/sec

a = area of burette in cm²
L = length of sample in cm
A = area of sample in cm²

Ha = initial inlet head in cm
H_1 = initial outlet head in cm
t = time in seconds

H_b = final inlet head in cm
H_2 = final outlet head in cm

a = 0.16 cm²
A = 41.74 cm²
L = 7.46 cm

Remarks: AC54317N
Specification No. K-SPC-G-(
Delivery Order #6

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.06*	Tested By	*JW*
Project Name	*Saltstone Vaults 3&5*	Test Date	*4/29/2009*
Boring No.	*Z-V3V5-B01/B04*	Reviewed By	JLF
Sample No.	*Composite*	Review Date	5/19/09
Sample Depth	*0-10 Ft.*	Lab No.	*9465/9466/9467 /9468B*
Sample Description			

ASTM D5084-03 - (Method C Falling Head RisingTail)

Sample Type:	*Remolded*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*8.7*
Wet Unit Weight, pcf:	*133.3*
Dry Unit Weight, pcf:	*122.6*
Compaction, %:	*96.7*
Hydraulic Conductivity, cm/sec. @20 °C	***3.8E-05***

Remarks: AC54317N
Specification No. K-SPC-G-0013
Delivery Order #6

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.06*	Tested By	*JW*
Project Name	*Satlstone Vaults 3&5*	Test Date	*4/8/2009*
Boring No.	*Z-V3V5-B04*	Reviewed By	JCR
Sample No.	*ST2*	Review Date	5/19/09
Sample Depth	*30-32 ft*	Lab No.	*9459*
Sample Description	*Brown Poorly Graded Sand with Clay*		

ASTM D5084-03 - (Method C Falling Head RisingTail)

Sample Type:	*UD*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*13.9*
Wet Unit Weight, pcf:	*120.8*
Dry Unit Weight, pcf:	*106.1*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***9.9E-04***

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013
Delivery Order #6

PERMEABILITY TEST
(ASTM D5084 - 03) (Method C, Increasing Tailwater Level)

MACTEC

Project Number	6155-08-0031.06	Tested By	JW
Project Name	Satlstone Vaults 3&5	Test Date	04/08/09
Boring No.	Z-V3V5-B04	Reviewed By	JEJ
Sample No.	ST2	Review Date	5/19/09
Sample Depth	30-32 ft	Lab No.	9459

Sample Description: Brown Poorly Graded Sand with Clay

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	X-15
Location 1	4.631	Location 1	2.878	Wet Soil+Pan, g	1032.61
Location 2	4.605	Location 2	2.872	Dry Soil + Pan, g	877.86
Location3	4.590	Location 3	2.864	Pan Weight, g	46.77
Average	4.609	Average	2.871	Moisture Content, %	18.6
Volume, in^3	29.84	Wet Soil + Tare, g	946.49	Dry Unit Weight, pcf	107.3
SG Measured	2.67	Tare Weight, g	0.00	Saturation, %	89.9
Soil Sample Wt., g	946.49	Dry Soil + Tare, g	831.09	Diameter, in.	N/M
Dry UW, pcf	106.1	Moisture Content, %	13.9	Length, in.	N/M
Saturation, %	65.0			Volume, in^3	N/A

Consolidation	
Chamber Pressure, psi	69
Back Pressure, psi	59
Confining Pressure, psi	10
Initial Burette Reading	16.2
Finial Burette Reading	10.8
Volume Change, cc	5.4
Permeant used	Water

Time (sec)	H_a (cm)	H_1 (cm)	H_b (cm)	H_2 (cm)	Temp (°C)	Initial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
43	26.2	91.8	54.4	62.8	23.3	5.6	0.7	1.07E-03	9.91E-04
60	25.4	90.4	56.2	59.9	23.3	5.6	0.3	1.07E-03	9.90E-04
57	24.1	91.2	55.6	59.7	23.3	5.7	0.4	1.10E-03	1.02E-03
53	23.3	90.5	54.3	59.7	23.3	5.7	0.5	1.07E-03	9.86E-04
48	27.6	91.5	56.1	62.9	23.3	5.5	0.6	1.05E-03	9.67E-04

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
5	UD	N/A	N/A	Vertical

Avg. k at 20 °C 9.90E-04 cm/sec

a = area of burette in cm²
L = length of sample in cm
A = area of sample in cm²

Ha = initial inlet head in cm
H_1 = initial outlet head in cm
t = time in seconds

H_b = final inlet head in cm
H_2 = final outlet head in cm

a = 0.16 cm²
A = 41.78 cm²
L = 11.71 cm

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013
Delivery Order #6

MACTEC

HYDRAULIC CONDUCTIVITY

Project No.	*6155-08-0031.06*	Tested By	*JW*
Project Name	*Satlstone Vaults 3&5*	Test Date	*4/8/2009*
Boring No.	*Z-V3V5-B01*	Reviewed By	JEJ
Sample No.	*ST2*	Review Date	5/19/09
Sample Depth	*30-32 ft*	Lab No.	*9477*
Sample Description	***Reddish Brown Well Graded Sand with Clay***		

ASTM D5084-03 - (Method C Falling Head RisingTail)

Sample Type:	*UD*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*14.0*
Wet Unit Weight, pcf:	*110.0*
Dry Unit Weight, pcf:	*96.6*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***4.3E-04***

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013
Delivery Order #6

PERMEABILITY TEST
(ASTM D5084 - 03) (Method C, Increasing Tailwater Level)

MACTEC

Project Number	6155-08-0031.06	Tested By	JW
Project Name	Satlstone Vaults 3&5	Test Date	04/08/09
Boring No.	Z-V3V5-B01	Reviewed By	JEJ
Sample No.	ST2	Review Date	5/19/09
Sample Depth	30-32 ft	Lab No.	9477
Sample Description	Reddish Brown Well Graded Sand with Clay		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	Ab-11
Location 1	4.728	Location 1	2.856	Wet Soil+Pan, g	1013.45
Location 2	4.665	Location 2	2.851	Dry Soil + Pan, g	845.16
Location3	4.694	Location 3	2.843	Pan Weight, g	85.92
Average	4.696	Average	2.850	Moisture Content, %	22.2
Volume, in^3	29.96	Wet Soil + Tare, g	865.18	Dry Unit Weight, pcf	98.0
SG Measured	2.68	Tare Weight, g	0.00	Saturation, %	84.0
Soil Sample Wt., g	865.18	Dry Soil + Tare, g	759.24	Diameter, in.	N/M
Dry UW, pcf	96.6	Moisture Content, %	14.0	Length, in.	N/M
Saturation, %	51.1			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	69
Back Pressure, psi	59
Confining Pressure, psi	10
Initial Burette Reading	16.3
Finial Burette Reading	9.3
Volume Change, cc	7.0
Permeant used	Water

B-185

Time (sec)	H_a (cm)	H_1 (cm)	H_b (cm)	H_2 (cm)	Temp (°C)	Initial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
60	22.5	103.0	51.3	76.3	23.3	6.7	2.1	4.52E-04	4.18E-04
60	28.7	98.4	53.4	74.8	23.3	5.8	1.8	4.56E-04	4.22E-04
60	33.1	93.9	54.5	73.3	23.3	5.1	1.6	4.54E-04	4.19E-04
60	31.8	94.2	53.8	72.8	23.3	5.2	1.6	4.59E-04	4.25E-04
60	31.3	97.4	55.0	74.1	23.3	5.5	1.6	4.80E-04	4.44E-04

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
5	UD	N/A	N/A	Vertical

Avg. k at 20 °C 4.25E-04 cm/sec

a = area of burette in cm²
L = length of sample in cm
A = area of sample in cm²

Ha = initial inlet head in cm
H_1 = initial outlet head in cm
t = time in seconds

H_b = final inlet head in cm
H_2 = final outlet head in cm

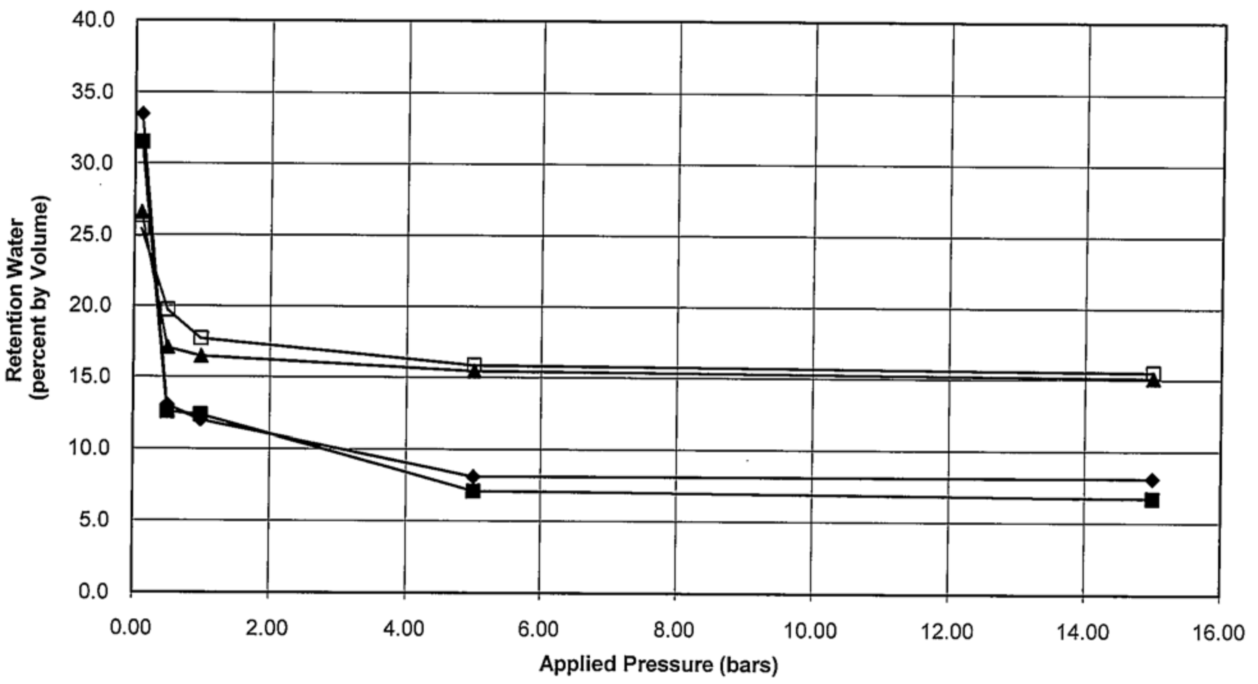
a = 0.16 cm²
A = 41.16 cm²
L = 11.93 cm

Remarks: Subcontract No. AC54317N
Specification No. K-SPC-G-0013
Delivery Order #6

MACTEC

Water Retention Test
(ASTM D3152)

Project No	6155-08-0031.06	Project Name	Saltstone Vaults 3&5
Tested By	JW	Test Date	4/27/09
Reviewed By	JEL	Review Date	5/19/09



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars)									
			0.10	0.50	1.0	5.0	15.0					
			Retained Water (percent by volume)									
Z-V3V5-B04,30-32	20.2	97.2	33.5	13.0	12.0	8.1	8.1					
Z-V3V5-B01,30-32	22.1	97.9	31.5	12.6	12.3	7.1	6.7					
Composite A,0-10	16.1	120.1	26.6	17.1	16.5	15.5	15.1					
Composite B ,0-10	16.2	120.7	25.4	19.7	17.7	15.9	15.5					

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water.
When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

AC54317N
Specification No. K-SPC-G-0013
Delivery Order #6

MACTEC

Water Retention Test
(ASTM D3152)

Project No	6155-08-0031.06	Project Name	Saltstone Vaults 3&5
Tested By	JW	Test Date	4/27/2009
Reviewed By	JEJ	Review Date	5/19/09

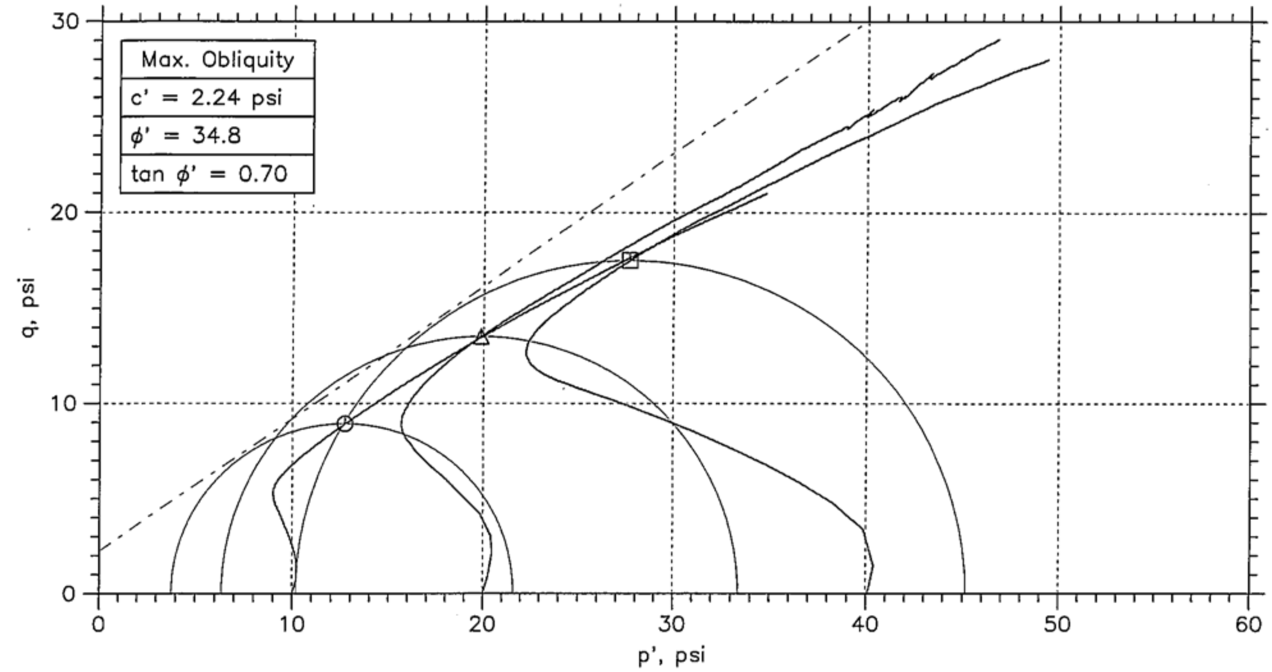
Boring No.	Z-V3V5-B04	Z-V3V5-B01	Composite A	Composite B	
Sample No.	ST2	ST2	Z-V3V5-B01&04	Z-V3V5-B01&04	
Depth (ft)	30-32	30-32	0-10	0-10	
Lab No.	9459	9477	9465/66/67A	9465/66/67B	
Ring No.	8-14	63	9	8-3	
Container Weight. (g)	71.01	73.50	74.97	70.90	
Container Diameter (cm)	5.39	5.38	5.28	5.34	
Container Height, (cm)	3.01	3.03	3.03	3.00	
Container Volume (cm^3)	68.61	68.76	66.25	67.17	
Wt. of Wet Soil + Container (g)	191.77	196.63	213.15	211.72	
Wt. of Dry Soil + Container (g)	177.88	181.40	202.50	200.87	
Moisture Content (%)	13.0	14.1	8.4	8.3	
Dry Unit Weight (pcf)	97.20	97.92	120.11	120.75	
Initial Wt.Wet Soil + Container (g)	191.77	196.63	213.15	211.72	
Initial Wt. Container (g)	71.01	73.50	74.97	70.90	
Initial Moisture, % by Volume	20.2	22.1	16.1	16.2	

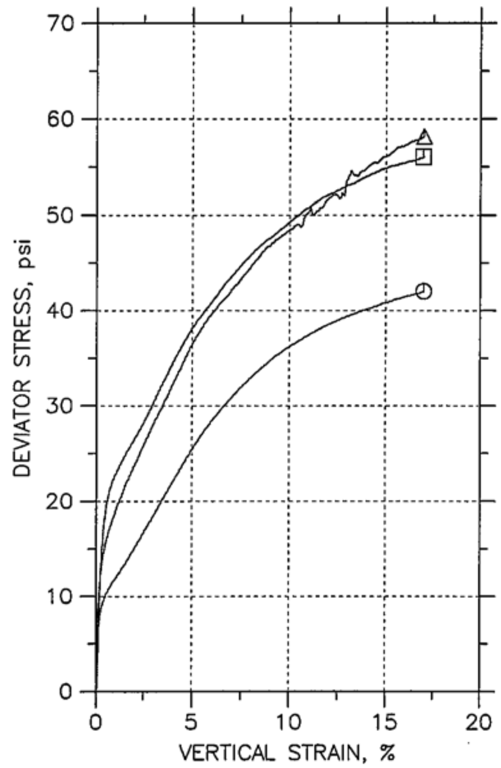
Remarks: AC54317N
Specification No. K-SPC-G-0013
Delivery Order #6

Lab No.												
	Pressure psi	1.45	7.26	14.51	72.55	217.65						
	bars	0.1	0.50	1.0	5.0	15.0						
	Date / Read By											
9459	Weight of Soil + Ring	200.91	186.87	186.15	183.49	183.49						
	Weight of Ring	71.07	71.07	71.07	71.07	71.07						
	Retained Water (%)	33.5	13.0	12.0	8.1	8.1						
9477	Weight of Soil + Ring	203.07	190.04	189.89	186.28	186.02						
	Weight of Ring	73.5	73.5	73.5	73.5	73.5						
	Retained Water (%)	31.5	12.6	12.3	7.1	6.7						
9465/66/67A	Weight of Soil + Ring	220.11	213.81	213.41	212.75	212.52						
	Weight of Ring	74.97	74.97	74.97	74.97	74.97						
	Retained Water (%)	26.6	17.1	16.5	15.5	15.1						
9465/66/67B	Weight of Soil + Ring	217.94	214.11	212.77	211.53	211.3						
	Weight of Ring	70.9	70.9	70.9	70.9	70.9						
	Retained Water (%)	25.4	19.7	17.7	15.9	15.5						

No. of Samples 4
No. of Tests per Sample 5

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767





Symbol		○	△	□	
Sample No.		ST1	ST1	ST1	
Test No.		9458.1	9458.2	9458.3	
Depth		20-22 ft	20-22 ft	20-22 ft	
Initial	Diameter, in	2.858	2.848	2.868	
	Height, in	5.964	5.986	5.978	
	Water Content, %	19.1	19.1	19.8	
	Dry Density, pcf	108.4	109.2	107.4	
	Saturation, %	96.0	98.2	96.9	
	Void Ratio	0.526	0.515	0.54	
Before Shear	Water Content, %	18.6	18.7	18.7	
	Dry Density, pcf	110.7	110.5	110.6	
	Saturation*, %	100.0	100.0	100.0	
	Void Ratio	0.494	0.497	0.496	
	Back Press., psi	130.	112.	100.	
Ver. Eff. Cons. Stress, psi		9.996	19.99	39.99	
Shear Strength, psi		21.01	29.08	28.	
Strain at Failure, %		17	17	17	
Strain Rate, %/min		0.02	0.02	0.02	
B-Value		0.96	0.96	0.97	
Estimated Specific Gravity		2.65	2.65	2.65	
Liquid Limit		42	42	42	
Plastic Limit		23	23	23	

MACTEC

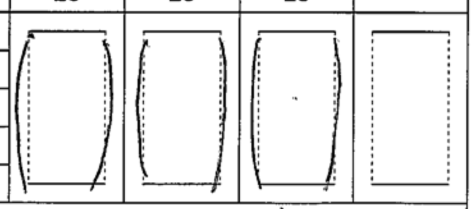
Project: Saltstone Vaults3&5

Location: ZV3V5-B04, 20-22 ft

Project No.: 6155080031

Boring No.: Z-V3V5-B04

Sample Type: Undisturbed



Description: Reddish Brown Clayey Sand (SC)

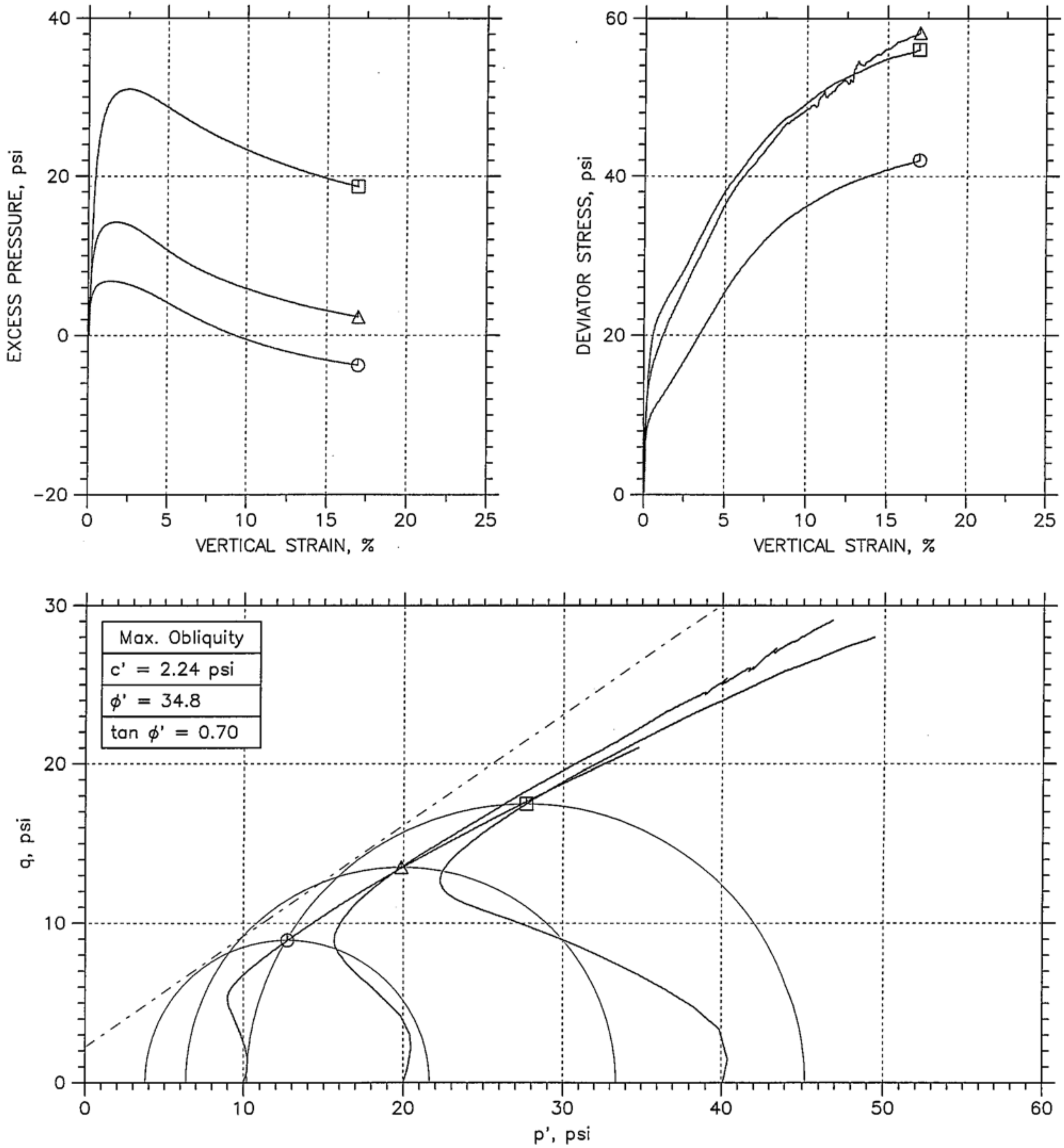
Remarks: ASTM D4767-04

Phase calculations based on start and end of test.

* Saturation is set to 100% for phase calculations.

Thu, 23-APR-2009 12:14:04

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767

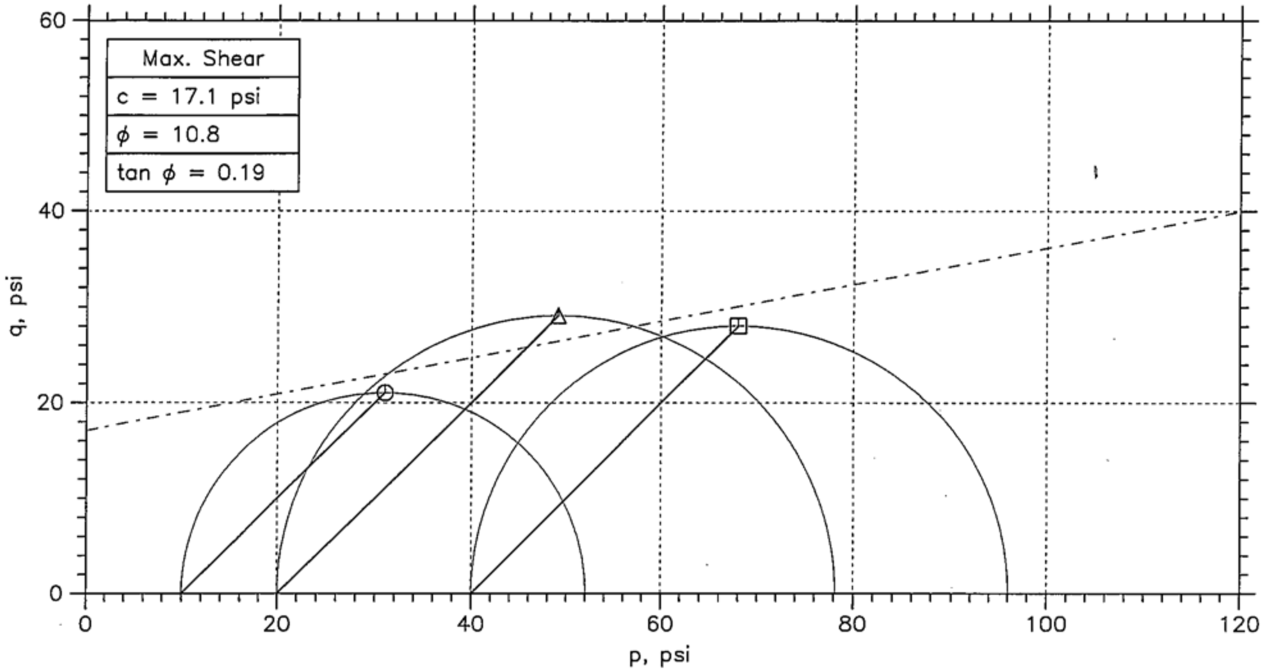


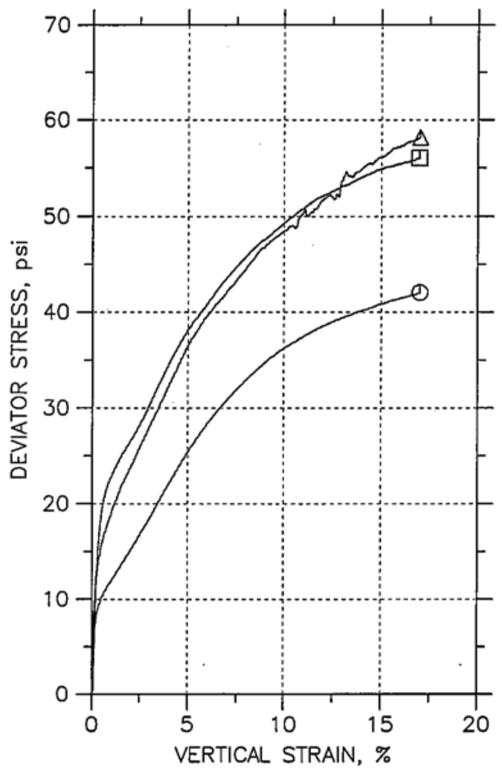
	Sample No.	Test No.	Depth	Tested By	Test Date	Checked By	Check Date	Test File
○	ST1	9458.1	20-22 ft	JW	3/31/09	JGJ	5/19/09	9458.1_2581.dat
△	ST1	9458.2	20-22 ft	JW	3/31/09	↓	↓	9458.2_2582.dat
□	ST1	9458.3	20-22 ft	JW	3/31/09	↓	↓	9458.3_2583.dat

MACTEC			
	Project: Saltstone Vaults3&5	Location: ZV3V5-B04, 20-22 ft	Project No.: 6155080031
	Boring No.: Z-V3V5-B04	Sample Type: Undisturbed	
	Description: Reddish Brown Clayey Sand (SC)		
	Remarks: ASTM D4767-04		

Thu, 23-APR-2009 12:14:04

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767

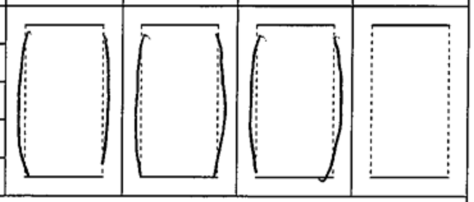




	Symbol	○	△	□	
	Sample No.	ST1	ST1	ST1	
	Test No.	9458.1	9458.2	9458.3	
	Depth	20-22 ft	20-22 ft	20-22 ft	
Initial	Diameter, in	2.858	2.848	2.868	
Initial	Height, in	5.964	5.986	5.978	
Initial	Water Content, %	19.1	19.1	19.8	
Initial	Dry Density, pcf	108.4	109.2	107.4	
Initial	Saturation, %	96.0	98.2	96.9	
Initial	Void Ratio	0.526	0.515	0.54	
Before Shear	Water Content, %	18.6	18.7	18.7	
Before Shear	Dry Density, pcf	110.7	110.5	110.6	
Before Shear	Saturation*, %	100.0	100.0	100.0	
Before Shear	Void Ratio	0.494	0.497	0.496	
Before Shear	Back Press., psi	130.	112.	100.	
	Ver. Eff. Cons. Stress, psi	9.996	19.99	39.99	
	Shear Strength, psi	21.01	29.08	28.	
	Strain at Failure, %	17	17	17	
	Strain Rate, %/min	0.02	0.02	0.02	
	B-Value	0.96	0.96	0.97	
	Estimated Specific Gravity	2.65	2.65	2.65	
	Liquid Limit	42	42	42	
	Plastic Limit	23	23	23	

MACTEC

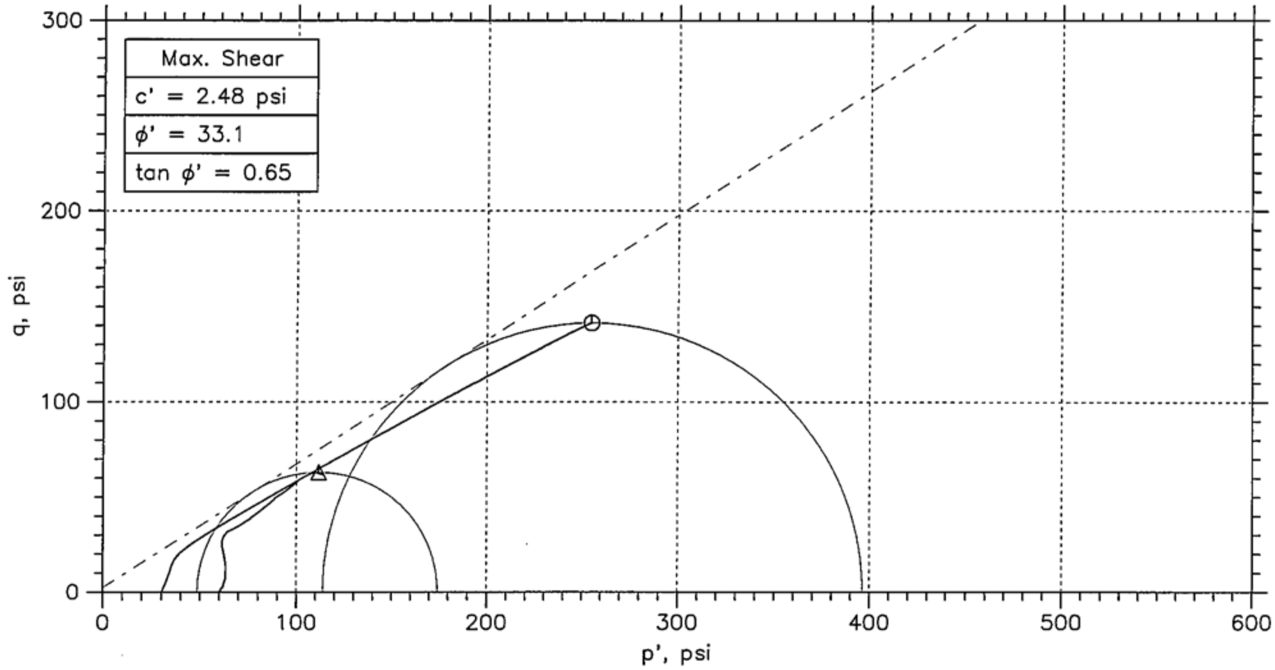
Project: Saltstone Vaults3&5
Location: ZV3V5-B04, 20-22 ft
Project No.: 6155080031
Boring No.: Z-V3V5-B04
Sample Type: Undisturbed
Description: Reddish Brown Clayey Sand (SC)
Remarks: ASTM D4767-04

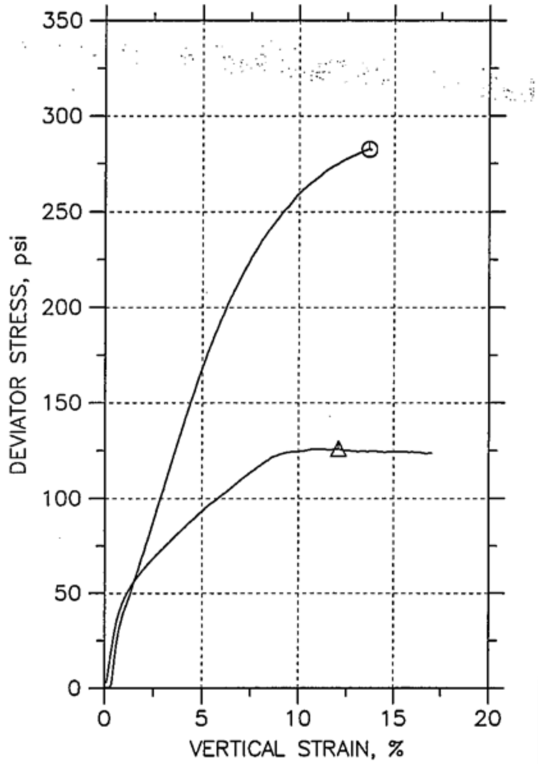


Phase calculations based on start and end of test.
* Saturation is set to 100% for phase calculations.

Thu, 23-APR-2009 12:14:18

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767

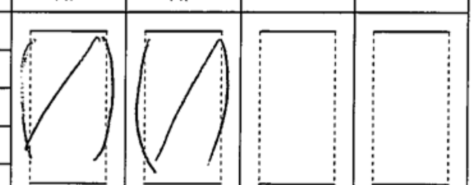




Symbol		O	Δ		
Sample No.		ST3	ST3		
Test No.		9460.1	9460.2		
Depth		35-37 ft	35-37 ft		
Initial	Diameter, in	2.882	2.88		
	Height, in	5.688	5.67		
	Water Content, %	20.6	16.1		
	Dry Density, pcf	96.74	99.51		
	Saturation, %	77.0	64.6		
	Void Ratio	0.71	0.662		
Before Shear	Water Content, %	20.9	20.9		
	Dry Density, pcf	106.5	106.5		
	Saturation*, %	100.0	100.0		
	Void Ratio	0.554	0.554		
	Back Press., psi	114.	90.		
Ver. Eff. Cons. Stress, psi		30.	60.		
Shear Strength, psi		141.2	62.92		
Strain at Failure, %		13.7	12.1		
Strain Rate, %/min		0.05	0.05		
B-Value		0.96	0.89		
Estimated Specific Gravity		2.65	2.65		
Liquid Limit		NP	NP		
Plastic Limit		NP	NP		

MACTEC

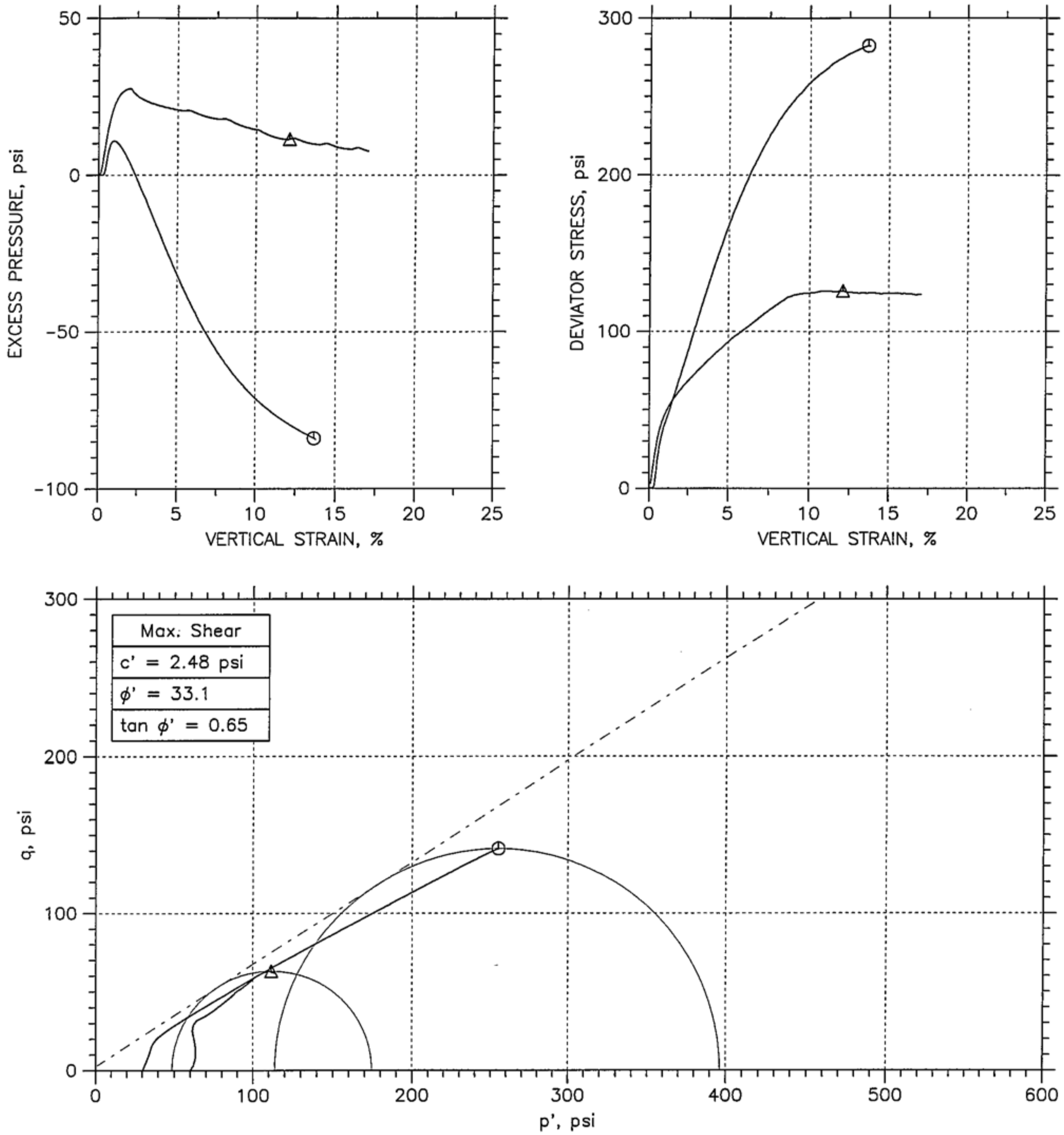
Project: Saltstone Vaults 3&5
Location: Z-V3V5-B04, 35-37 ft
Project No.: 6155080031
Boring No.: Z-V3V5-B04
Sample Type: Undisturbed
Description: Brown Poorly Graded Sand with Silt (SP-SM)
Remarks: ASTM D4767-04



Phase calculations based on start and end of test.
* Saturation is set to 100% for phase calculations.

Mon, 18-MAY-2009 14:24:27

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767

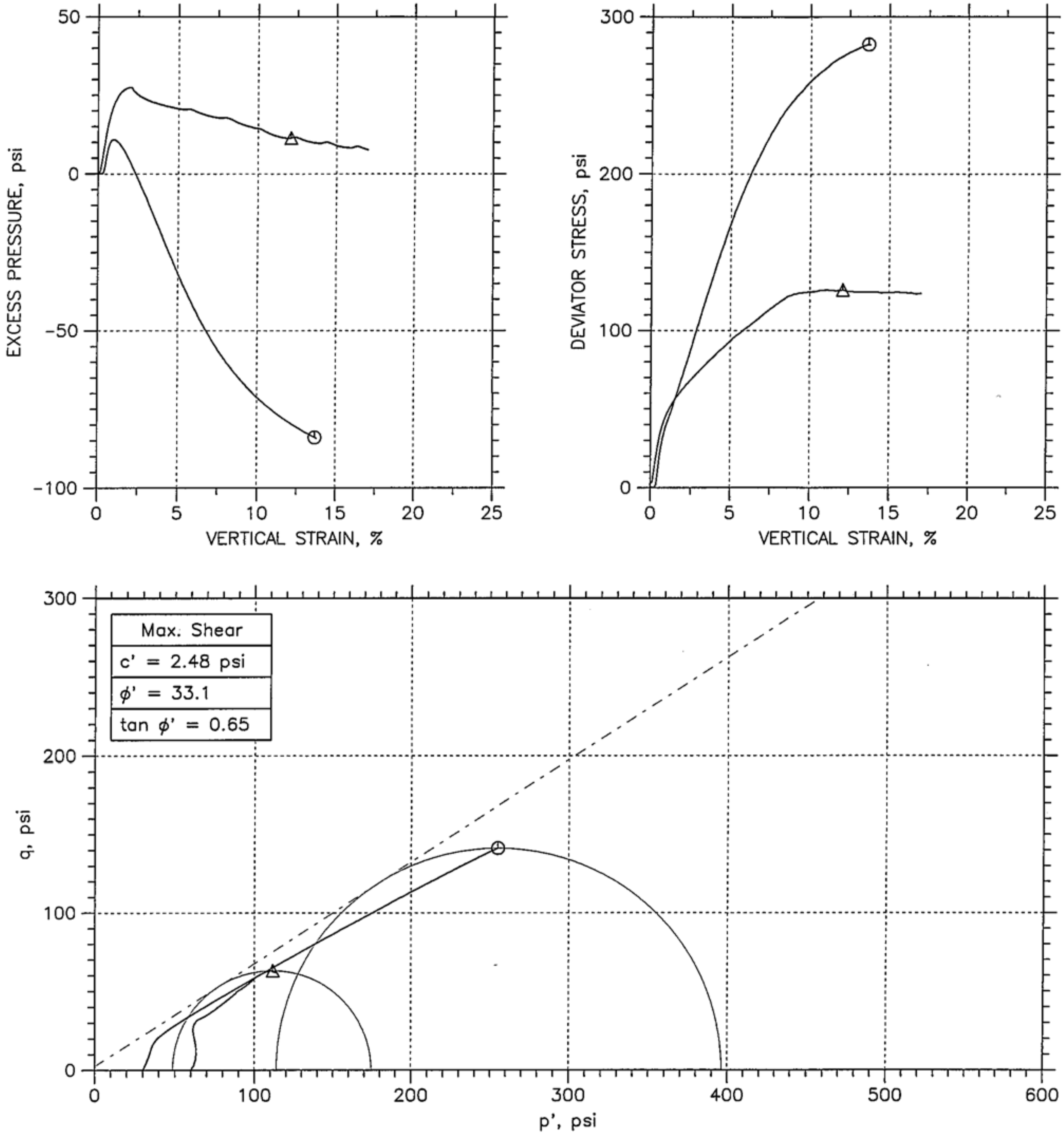


	Sample No.	Test No.	Depth	Tested By	Test Date	Checked By	Check Date	Test File
○	ST3	9460.1	35-37 ft	JW	4/3/09	[illegible]	5/19/09	9460.1a_2583.dat
△	ST3	9460.2	35-37 ft	JW	4/3/09	↓	↓	9460.2_2582.dat

MACTEC	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B04, 35-37 ft	Project No.: 6155080031
	Boring No.: Z-V3V5-B04	Sample Type: Undisturbed	
	Description: Brown Poorly Graded Sand with Silt (SP-SM)		
	Remarks: ASTM D4767-04		

Mon, 18-MAY-2009 14:24:28

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767



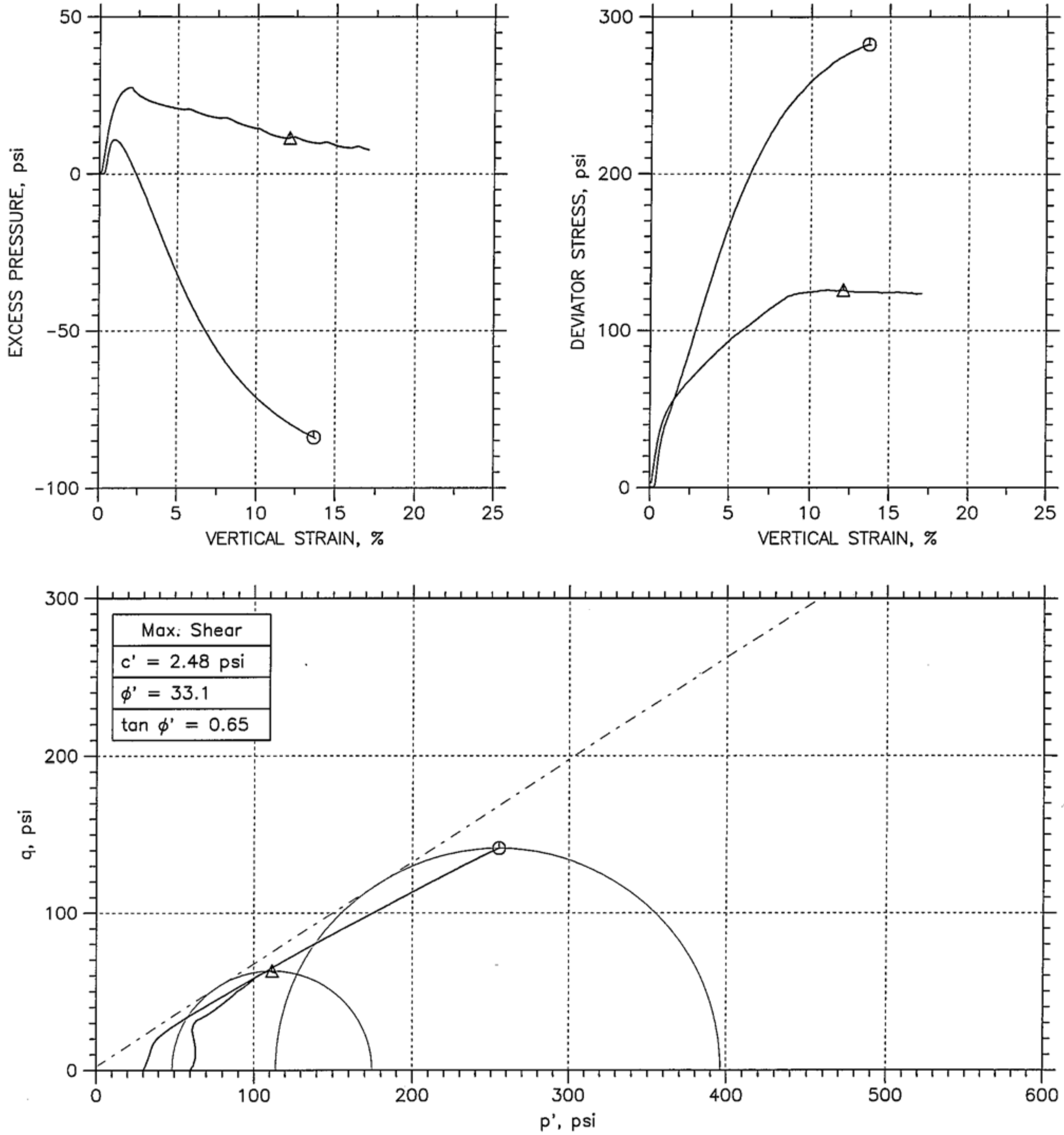
	Sample No.	Test No.	Depth	Tested By	Test Date	Checked By	Check Date	Test File
⊙	ST3	9460.1	35-37 ft	JW	4/3/09	[illegible]	5/19/09	9460.1a_2583.dat
△	ST3	9460.2	35-37 ft	JW	4/3/09	↓	↓	9460.2_2582.dat

MACTEC

Project: Saltstone Vaults 3&5	Location: Z-V3V5-B04, 35-37 ft	Project No.: 6155080031
Boring No.: Z-V3V5-B04	Sample Type: Undisturbed	
Description: Brown Poorly Graded Sand with Silt (SP-SM)		
Remarks: ASTM D4767-04		

Mon, 18-MAY-2009 14:24:28

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767



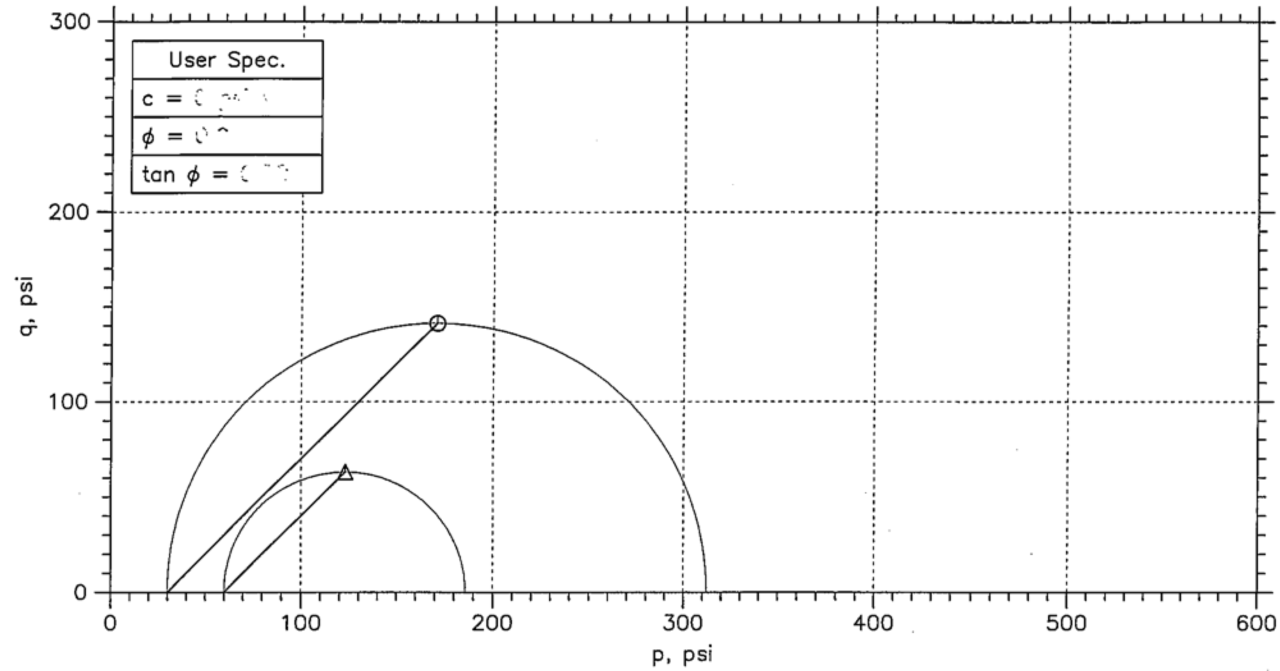
	Sample No.	Test No.	Depth	Tested By	Test Date	Checked By	Check Date	Test File
○	ST3	9460.1	35-37 ft	JW	4/3/09	JGJ	5/19/09	9460.1a_2583.dat
△	ST3	9460.2	35-37 ft	JW	4/3/09	↓	↓	9460.2_2582.dat

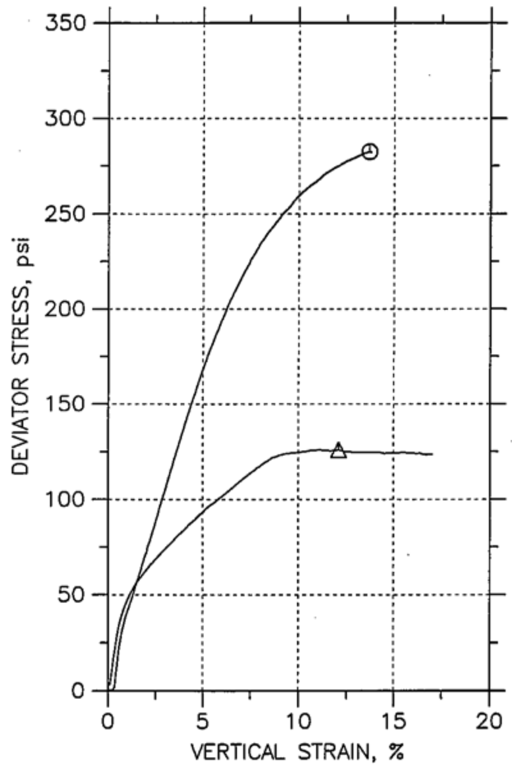
MACTEC

Project: Saltstone Vaults 3&5	Location: Z-V3V5-B04, 35-37 ft	Project No.: 6155080031
Boring No.: Z-V3V5-B04	Sample Type: Undisturbed	
Description: Brown Poorly Graded Sand with Silt (SP-SM)		
Remarks: ASTM D4767-04		

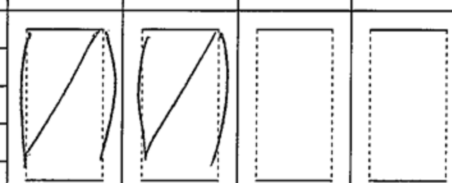
Mon, 18-MAY-2009 14:24:28

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767





Symbol		○	△		
Sample No.		ST3	ST3		
Test No.		9460.1	9460.2		
Depth		35-37 ft	35-37 ft		
Initial	Diameter, in	2.882	2.88		
	Height, in	5.688	5.67		
	Water Content, %	20.6	16.1		
	Dry Density, pcf	96.74	99.51		
	Saturation, %	77.0	64.6		
	Void Ratio	0.71	0.662		
Before Shear	Water Content, %	20.9	20.9		
	Dry Density, pcf	106.5	106.5		
	Saturation*, %	100.0	100.0		
	Void Ratio	0.554	0.554		
	Back Press., psi	114.	90.		
Ver. Eff. Cons. Stress, psi		30.	60.		
Shear Strength, psi		141.2	62.92		
Strain at Failure, %		13.7	12.1		
Strain Rate, %/min		0.05	0.05		
B-Value		0.96	0.89		
Estimated Specific Gravity		2.65	2.65		
Liquid Limit		NP	NP		
Plastic Limit		NP	NP		



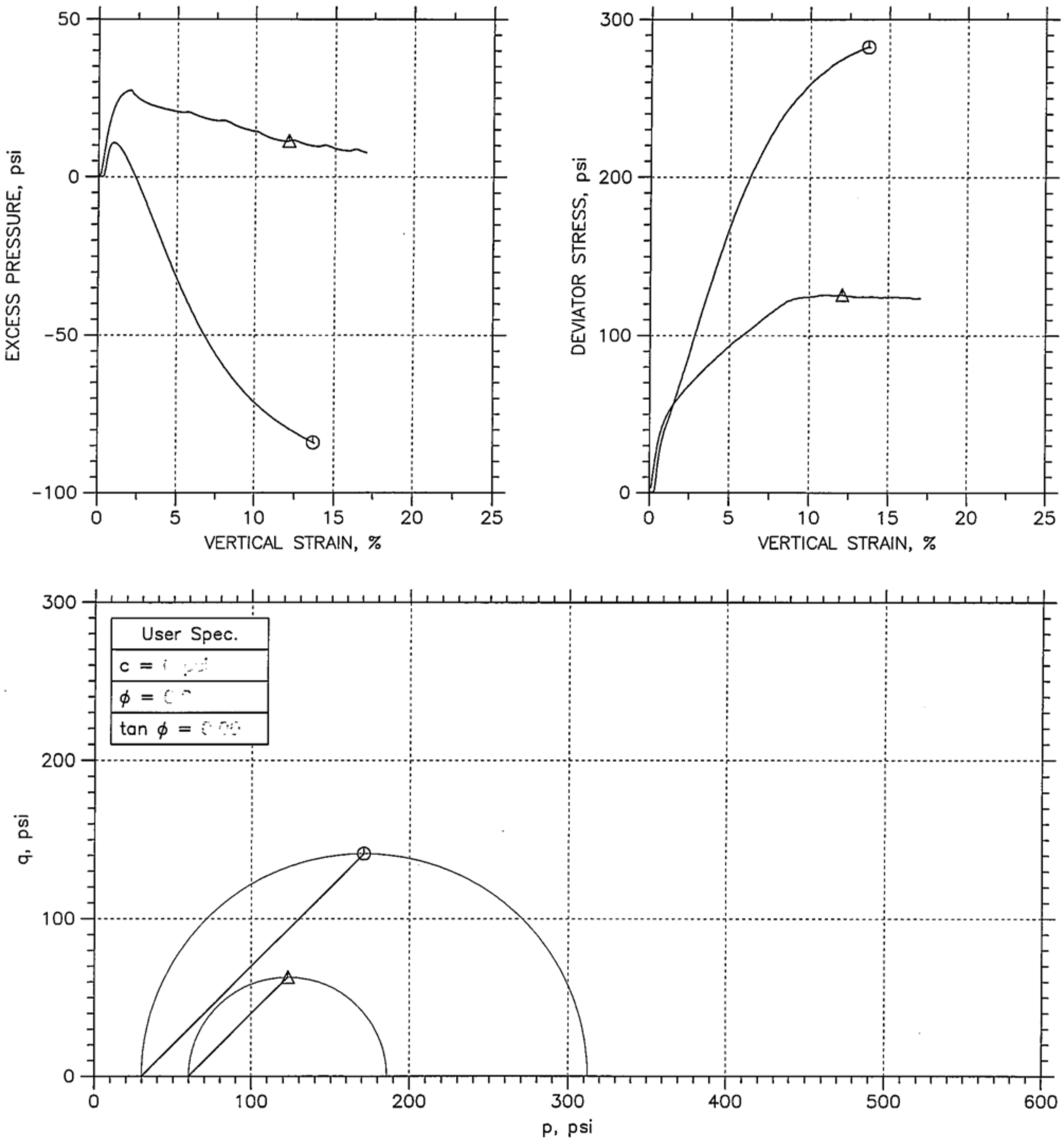
MACTEC

Project: Saltstone Vaults 3&5
Location: Z-V3V5-B04, 35-37 ft
Project No.: 6155080031
Boring No.: Z-V3V5-B04
Sample Type: Undisturbed
Description: Brown Poorly Graded Sand with Silt (SP-SM)
Remarks: ASTM D4767-04

Mon, 18-MAY-2009 14:25:10

Phase calculations based on start and end of test.
* Saturation is set to 100% for phase calculations.

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767



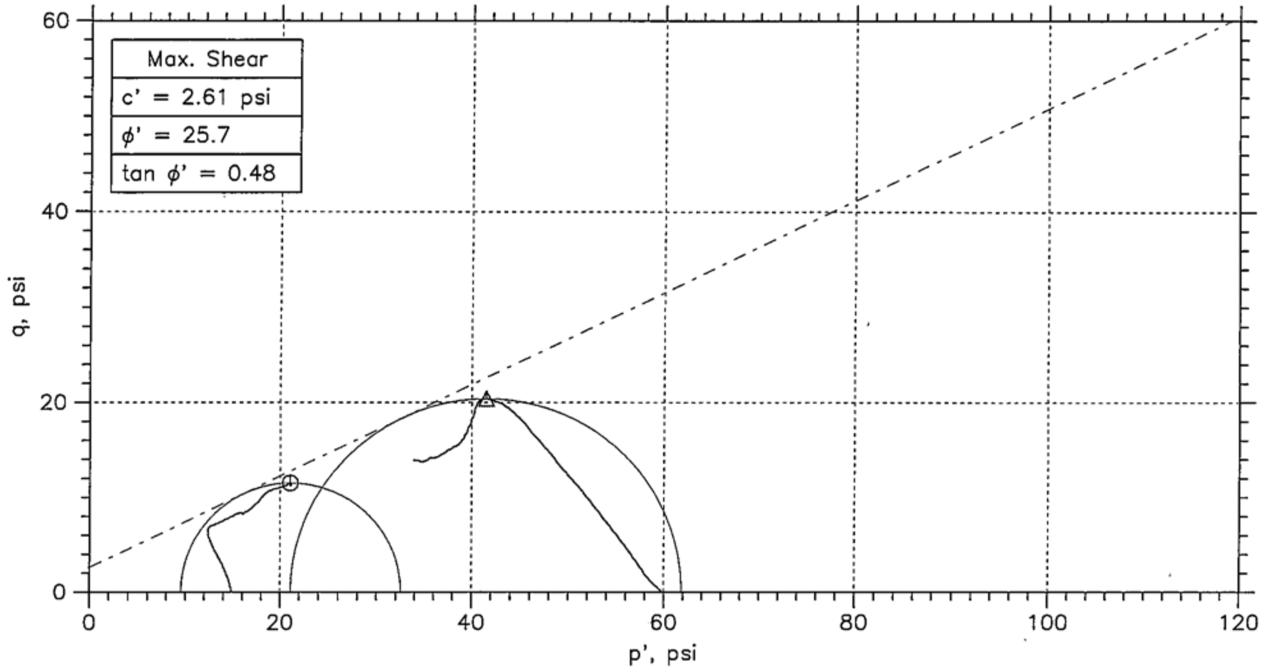
	Sample No.	Test No.	Depth	Tested By	Test Date	Checked By	Check Date	Test File
⊙	ST3	9460.1	35-37 ft	JW	4/3/09	JEJ	5/19/09	9460.1a_2583.dat
△	ST3	9460.2	35-37 ft	JW	4/3/09	↓	↓	9460.2_2582.dat

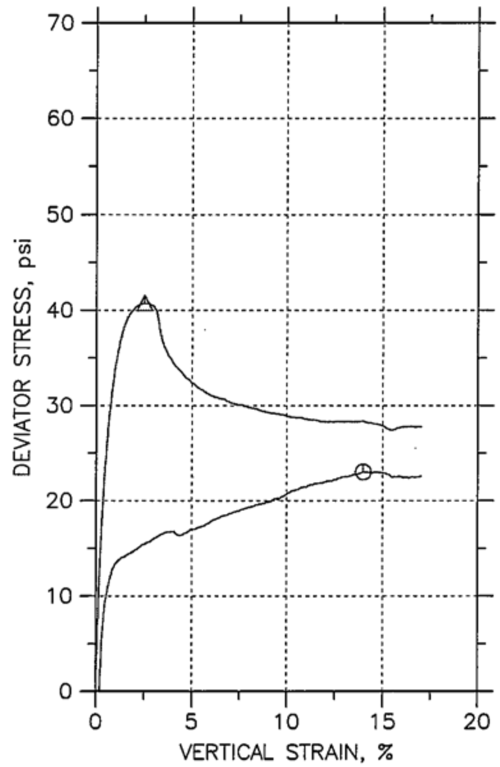
MACTEC

Project: Saltstone Vaults 3&5	Location: Z-V3V5-B04, 35-37 ft	Project No.: 6155080031
Boring No.: Z-V3V5-B04	Sample Type: Undisturbed	
Description: Brown Poorly Graded Sand with Silt (SP-SM)		
Remarks: ASTM D4767-04		

Mon, 18-MAY-2009 14:25:10

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767





Symbol		○	△		
Sample No.		ST4	ST4		
Test No.		9461.1	9461.3		
Depth		50-52 ft	50-52 ft		
Initial	Diameter, in	2.882	2.85		
	Height, in	5.947	5.984		
	Water Content, %	70.7	60.2		
	Dry Density, pcf	51.69	63.91		
	Saturation, %	85.1	100.5		
	Void Ratio	2.2	1.59		
Before Shear	Water Content, %	70.6	59.4		
	Dry Density, pcf	57.64	64.24		
	Saturation*, %	100.0	100.0		
	Void Ratio	1.87	1.58		
	Back Press., psi	129.9	140.		
Ver. Eff. Cons. Stress, psi		14.99	59.99		
Shear Strength, psi		11.49	20.37		
Strain at Failure, %		14	2.51		
Strain Rate, %/min		0.01	0.01		
B-Value		0.95	0.96		
Estimated Specific Gravity		2.65	2.65		
Liquid Limit		74	74		
Plastic Limit		40	40		

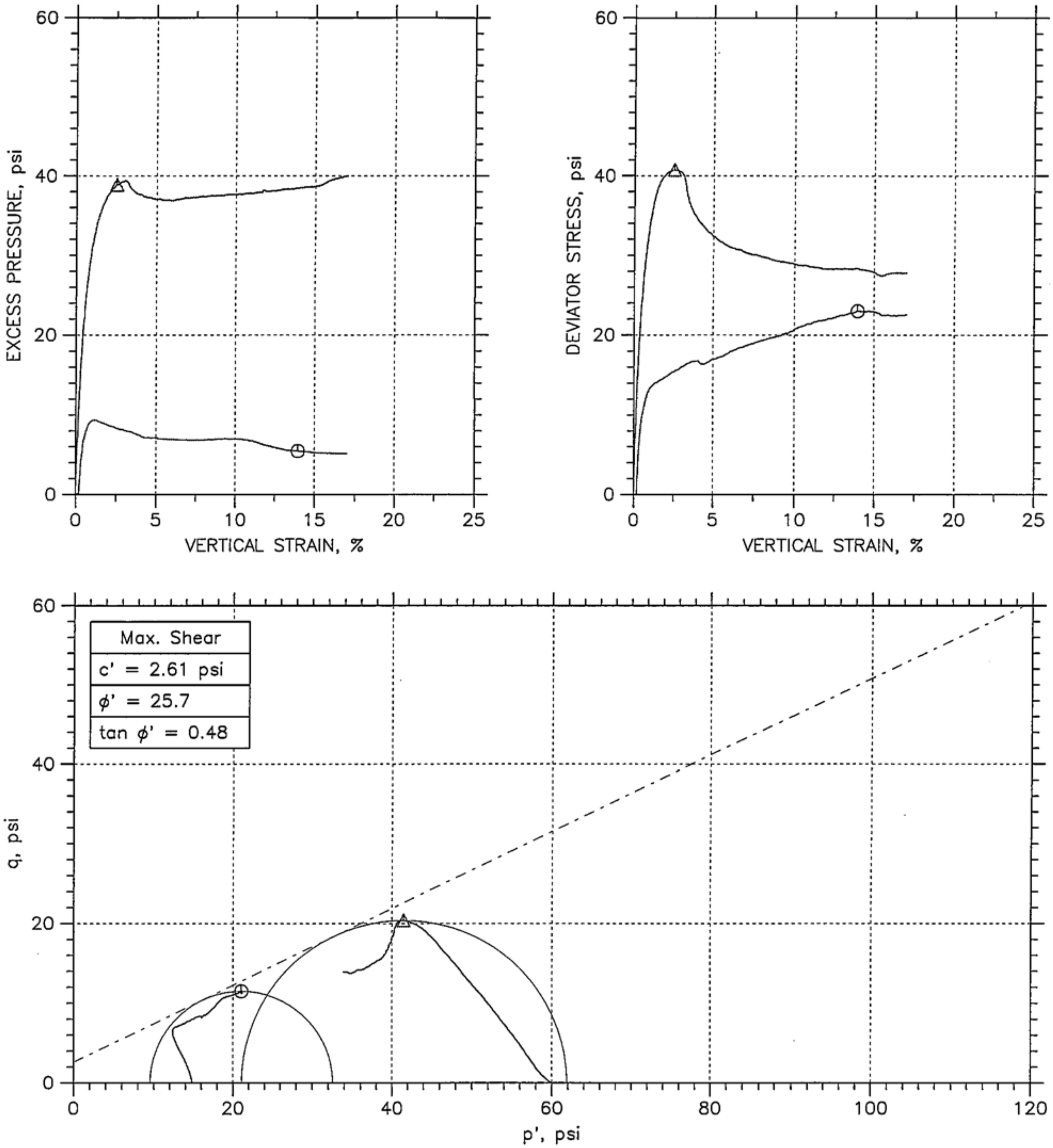
MACTEC	
	Project: Saltstone Vaults 3&5
	Location: Z-V3V5-B04, 50-52 ft
	Project No.: 6155080031
	Boring No.: Z-V3V5-B04
	Sample Type: Undisturbed
	Description: Tan Silty Sand (SM)
	Remarks: ASTM D4767-04

Phase calculations based on start and end of test.

Thu, 23-APR-2009 12:12:49

* Saturation is set to 100% for phase calculations.

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767

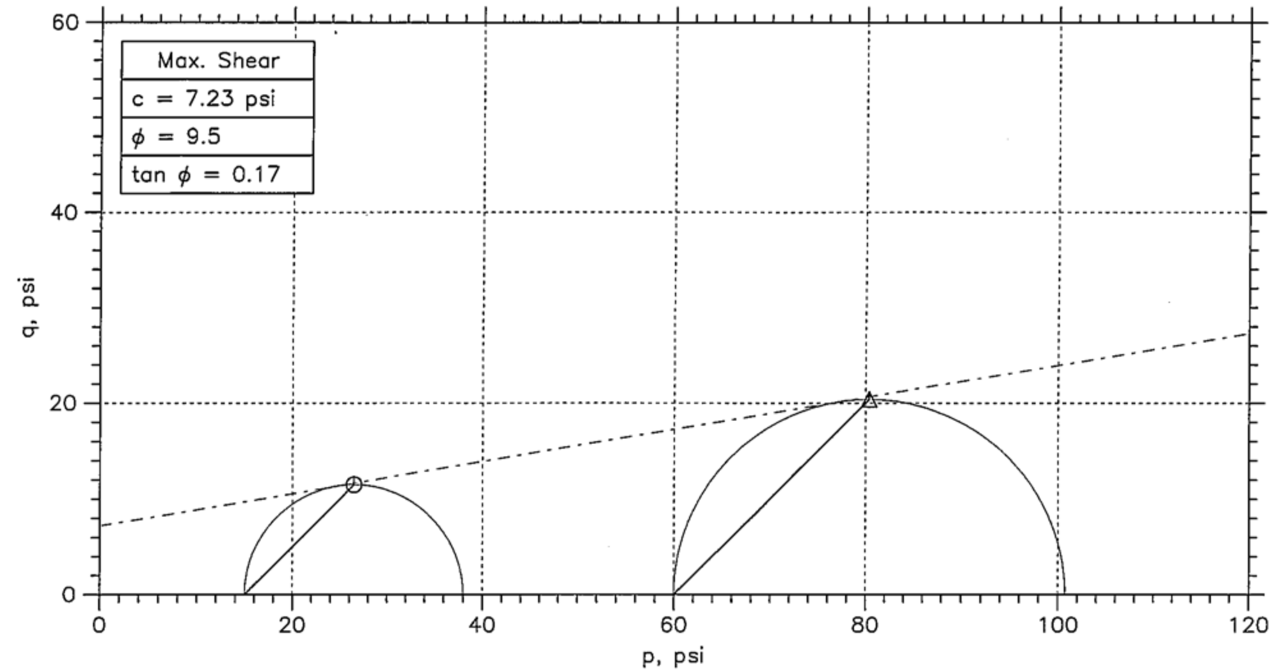


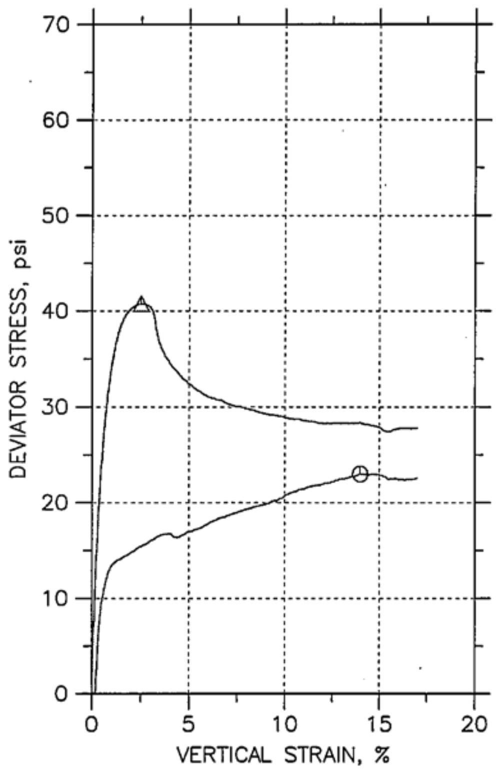
	Sample No.	Test No.	Depth	Tested By	Test Date	Checked By	Check Date	Test File
⦶	ST4	9461.1	50-52 ft	JW	3/25/09	JGJ	5/19/09	9461.1_2581.dat
△	ST4	9461.3	50-52 ft	JW	3/25/09	↓	↓	9461.3_2583.dat

MACTEC			
	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B04, 50-52 ft	Project No.: 6155080031
	Boring No.: Z-V3V5-B04	Sample Type: Undisturbed	
	Description: Tan Silty Sand (SM)		
	Remarks: ASTM D4767-04		

Thu, 23-APR-2009 12:12:49

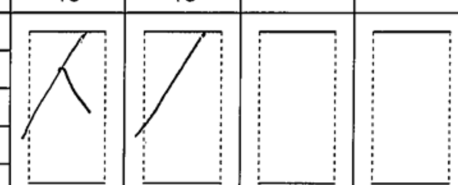
CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767





	Symbol	○	△		
	Sample No.	ST4	ST4		
	Test No.	9461.1	9461.3		
	Depth	50-52 ft	50-52 ft		
Initial	Diameter, in	2.882	2.85		
Initial	Height, in	5.947	5.984		
Initial	Water Content, %	70.7	60.2		
Initial	Dry Density, pcf	51.69	63.91		
Initial	Saturation, %	85.1	100.5		
Initial	Void Ratio	2.2	1.59		
Before Shear	Water Content, %	70.6	59.4		
Before Shear	Dry Density, pcf	57.64	64.24		
Before Shear	Saturation*, %	100.0	100.0		
Before Shear	Void Ratio	1.87	1.58		
Before Shear	Back Press., psi	129.9	140.		
	Ver. Eff. Cons. Stress, psi	14.99	59.99		
	Shear Strength, psi	11.49	20.37		
	Strain at Failure, %	14	2.51		
	Strain Rate, %/min	0.01	0.01		
	B-Value	0.95	0.96		
	Estimated Specific Gravity	2.65	2.65		
	Liquid Limit	74	74		
	Plastic Limit	40	40		

MACTEC	Project: Saltstone Vaults 3&5
	Location: Z-V3V5-B04, 50-52 ft
	Project No.: 6155080031
	Boring No.: Z-V3V5-B04
	Sample Type: Undisturbed
	Description: Tan Silty Sand (SM)
	Remarks: ASTM D4767-04

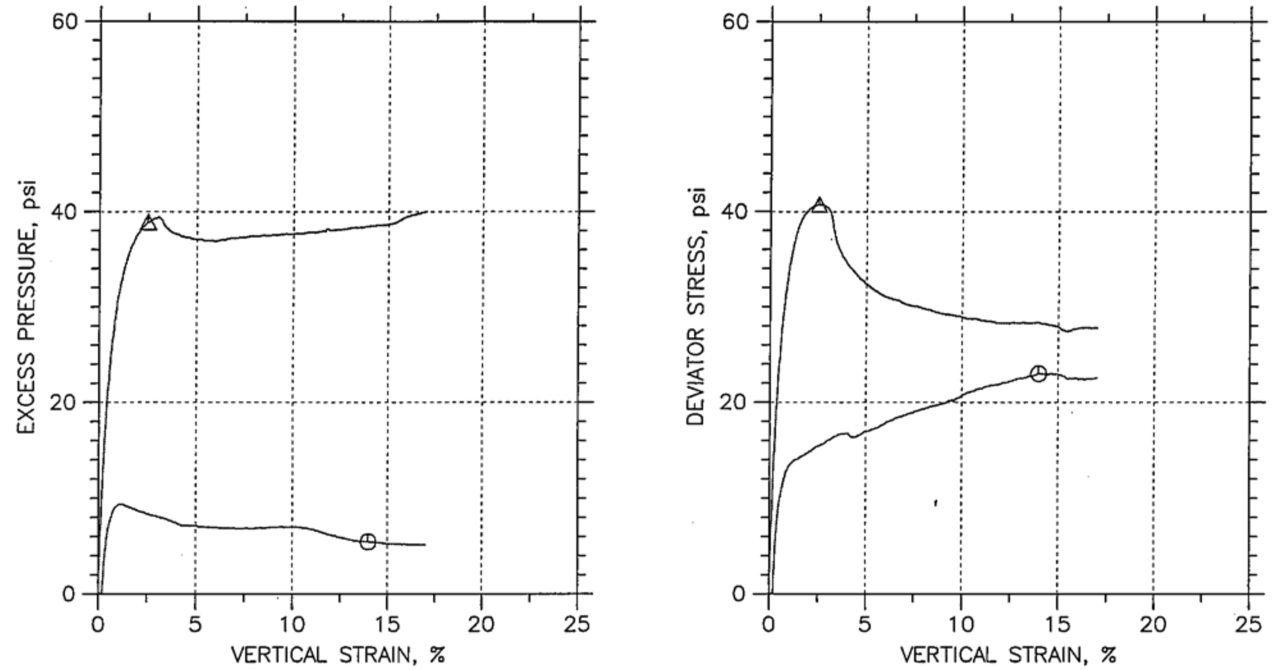


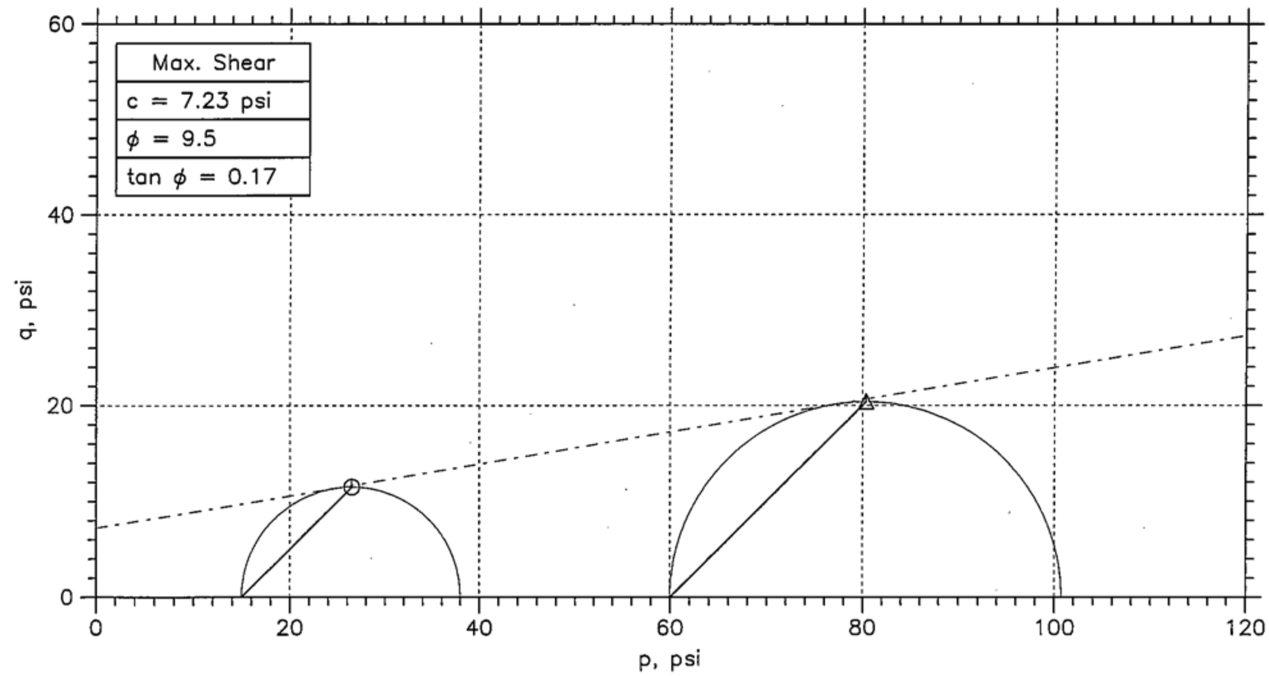
Phase calculations based on start and end of test.

* Saturation is set to 100% for phase calculations.

Thu, 23-APR-2009 12:12:54

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767



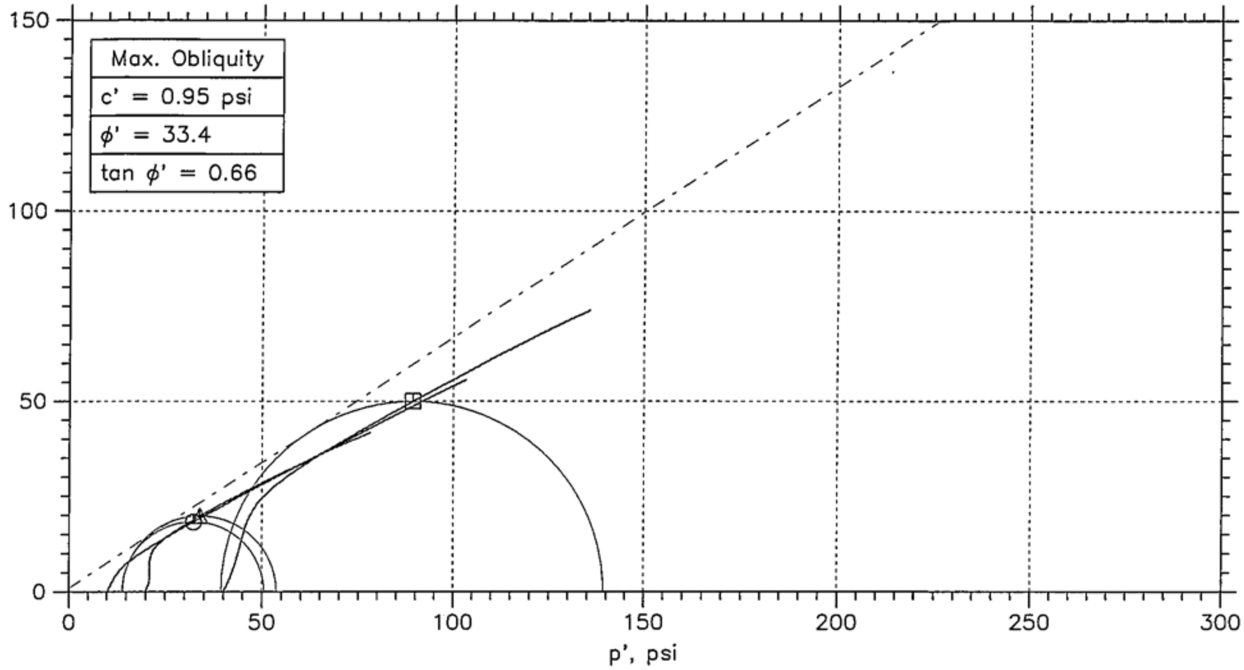


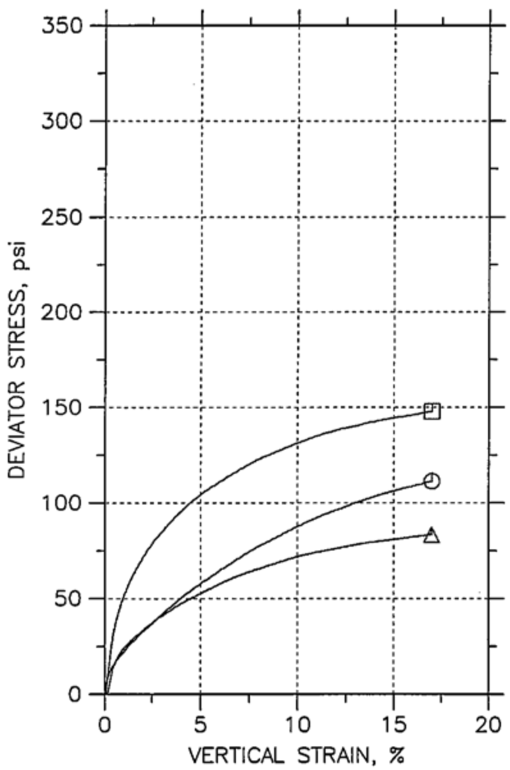
	Sample No.	Test No.	Depth	Tested By	Test Date	Checked By	Check Date	Test File
⊙	ST4	9461.1	50-52 ft	JW	3/25/09	JEJ	5/19/09	9461.1_2581.dat
△	ST4	9461.3	50-52 ft	JW	3/25/09	↓	↓	9461.3_2583.dat

MACTEC			
	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B04, 50-52 ft	Project No.: 6155080031
	Boring No.: Z-V3V5-B04	Sample Type: Undisturbed	
	Description: Tan Silty Sand (SM)		
	Remarks: ASTM D4767-04		

Thu, 23-APR-2009 12:12:54

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767

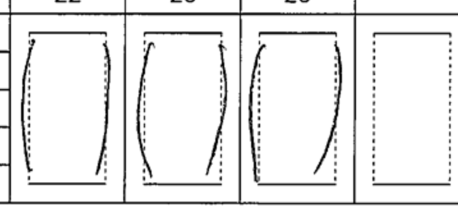




		Symbol	○	△	□	
		Sample No.	ST1	ST1	ST1	
		Test No.	9476.1	9476.2	9476.3	
		Depth	20-22 ft	20-22 ft	20-22 ft	
Initial		Diameter, in	2.802	2.856	2.878	
		Height, in	6.034	6.035	6.033	
		Water Content, %	11.7	14.2	12.4	
		Dry Density, pcf	104.9	102.6	106.4	
		Saturation, %	53.6	61.6	59.1	
		Void Ratio	0.578	0.613	0.555	
Before Shear		Water Content, %	20.0	19.7	19.4	
		Dry Density, pcf	108.1	108.7	109.3	
		Saturation*, %	100.0	100.0	100.0	
		Void Ratio	0.531	0.522	0.514	
		Back Press., psi	134.	124.	110.	
		Ver. Eff. Cons. Stress, psi	9.999	20.	40.	
		Shear Strength, psi	55.6	41.65	73.86	
		Strain at Failure, %	17	17	17	
		Strain Rate, %/min	0.05	0.05	0.05	
		B-Value	0.95	0.95	0.97	
		Estimated Specific Gravity	2.65	2.65	2.65	
		Liquid Limit	31	31	31	
		Plastic Limit	22	20	20	

MACTEC

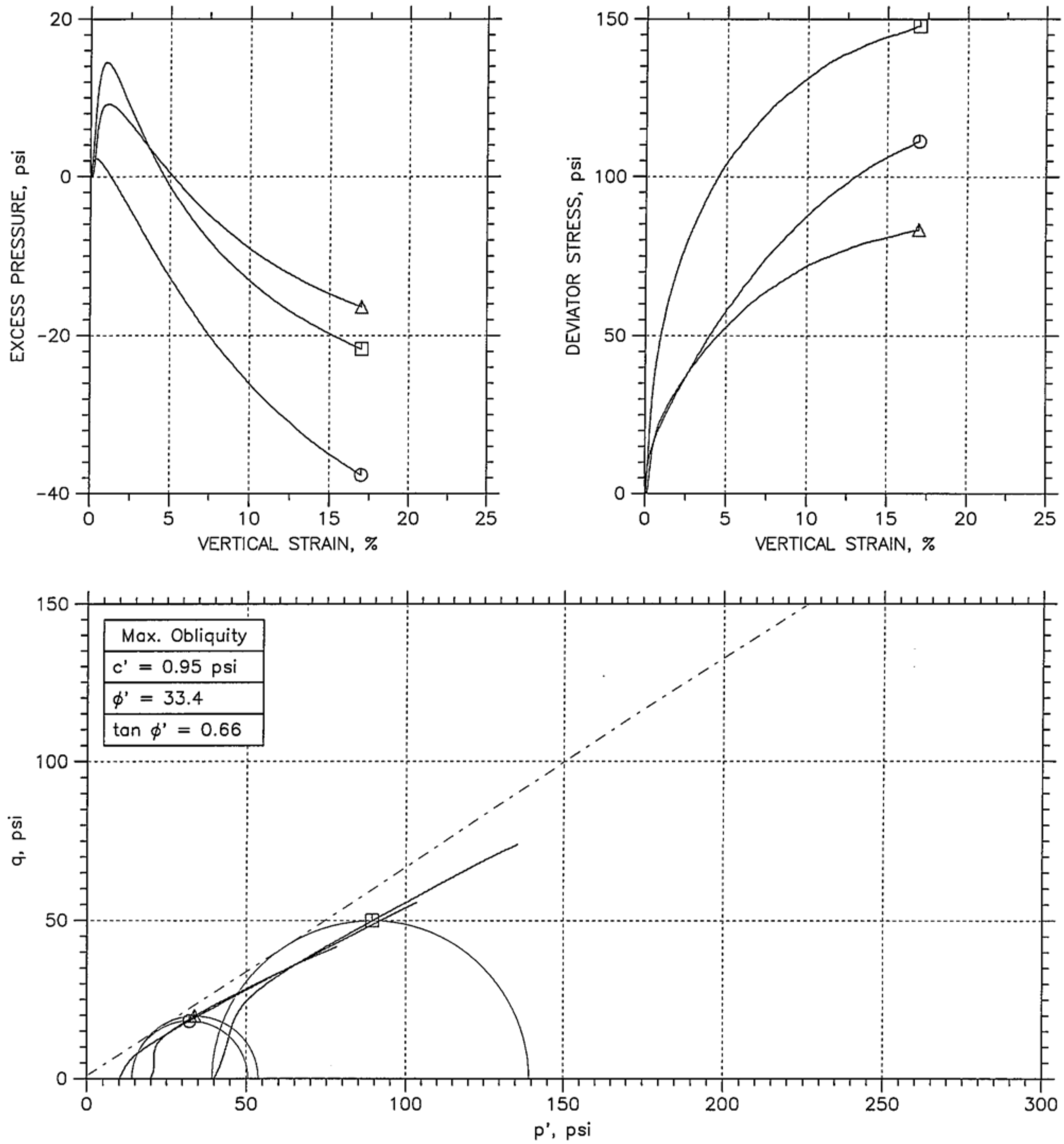
Project: Saltstone Vaults 3&5
Location: Z-V3V5-B01, 20-22 ft
Project No.: 6155080031
Boring No.: Z-V3V5-B01
Sample Type: Undisturbed
Description: Brown Poorly Graded Sand with Clay (SP-SC)
Remarks: ASTM D4767-04



Thu, 23-APR-2009 11:16:55

Phase calculations based on start and end of test.
* Saturation is set to 100% for phase calculations.

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767

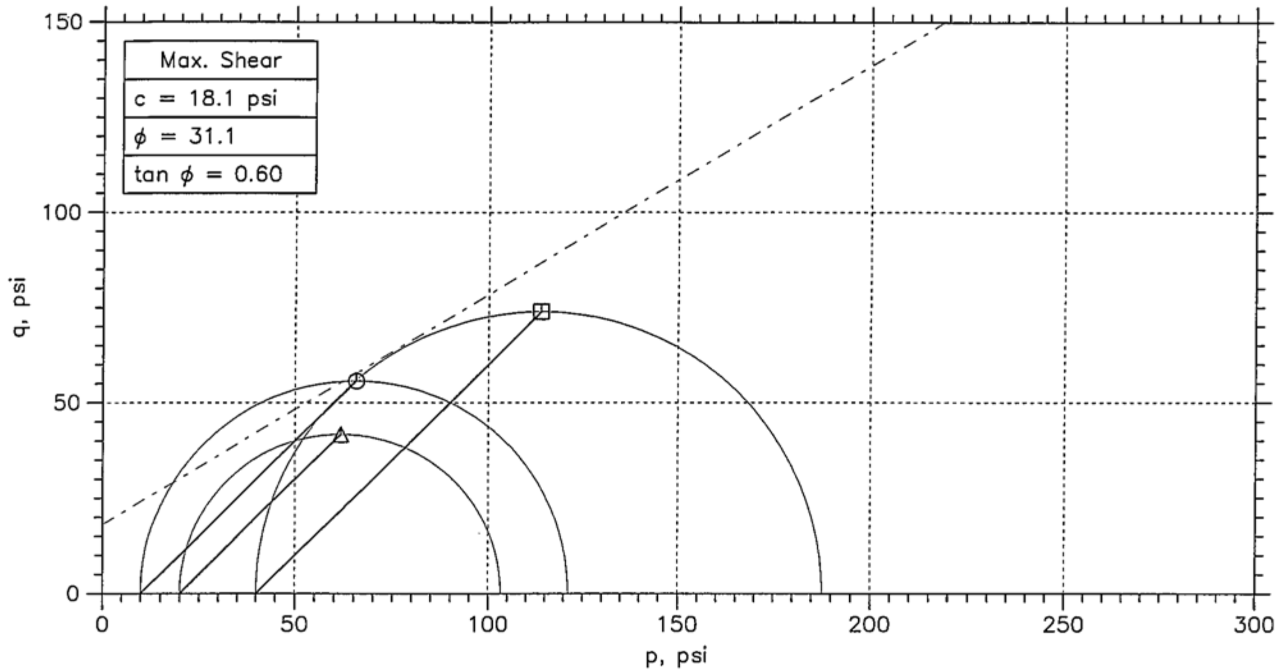


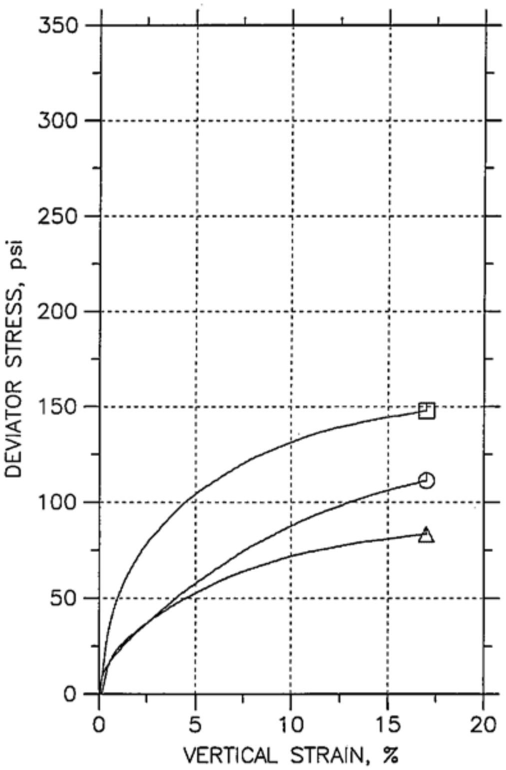
	Sample No.	Test No.	Depth	Tested By	Test Date	Checked By	Check Date	Test File
○	ST1	9476.1	20-22 ft	JW	4/6/09	JEJ	5/19/09	9476.1_2547.dat
△	ST1	9476.2	20-22 ft	JW	4/6/09	↓	↓	9476.2_2546.dat
□	ST1	9476.3	20-22 ft	JW	4/6/09	↓	↓	9476.3_2580.dat

MACTEC			
	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B01, 20-22 ft	Project No.: 6155080031
	Boring No.: Z-V3V5-B01	Sample Type: Undisturbed	
	Description: Brown Poorly Graded Sand with Clay (SP-SC)		
	Remarks: ASTM D4767-04		

Thu, 23-APR-2009 11:16:55

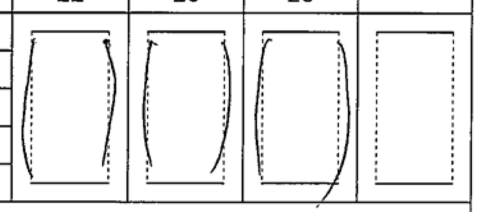
CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767





Symbol		○	△	□	
Sample No.		ST1	ST1	ST1	
Test No.		9476.1	9476.2	9476.3	
Depth		20-22 ft	20-22 ft	20-22 ft	
Initial	Diameter, in	2.802	2.856	2.878	
	Height, in	6.034	6.035	6.033	
	Water Content, %	11.7	14.2	12.4	
	Dry Density, pcf	104.9	102.6	106.4	
	Saturation, %	53.6	61.6	59.1	
	Void Ratio	0.578	0.613	0.555	
Before Shear	Water Content, %	20.0	19.7	19.4	
	Dry Density, pcf	108.1	108.7	109.3	
	Saturation*, %	100.0	100.0	100.0	
	Void Ratio	0.531	0.522	0.514	
	Back Press., psi	134.	124.	110.	
Ver. Eff. Cons. Stress, psi		9.999	20.	40.	
Shear Strength, psi		55.6	41.65	73.86	
Strain at Failure, %		17	17	17	
Strain Rate, %/min		0.05	0.05	0.05	
B-Value		0.95	0.95	0.97	
Estimated Specific Gravity		2.65	2.65	2.65	
Liquid Limit		31	31	31	
Plastic Limit		22	20	20	

MACTEC	Project: Saltstone Vaults 3&5
	Location: Z-V3V5-B01, 20-22 ft
	Project No.: 6155080031
	Boring No.: Z-V3V5-B01
	Sample Type: Undisturbed
	Description: Brown Poorly Graded Sand with Clay (SP-SC)
	Remarks: ASTM D4767-04

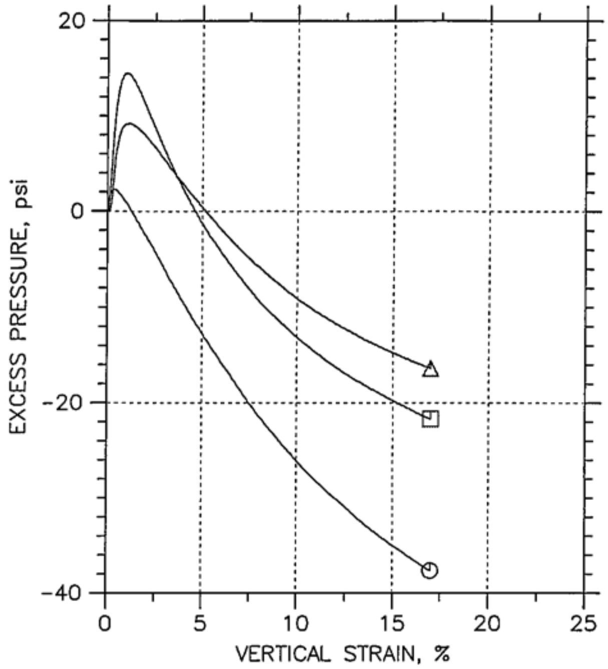


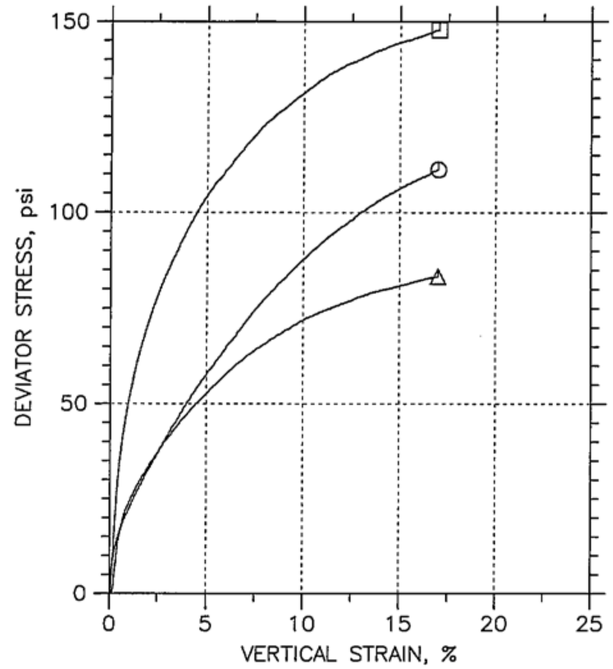
Thu, 23-APR-2009 11:17:07

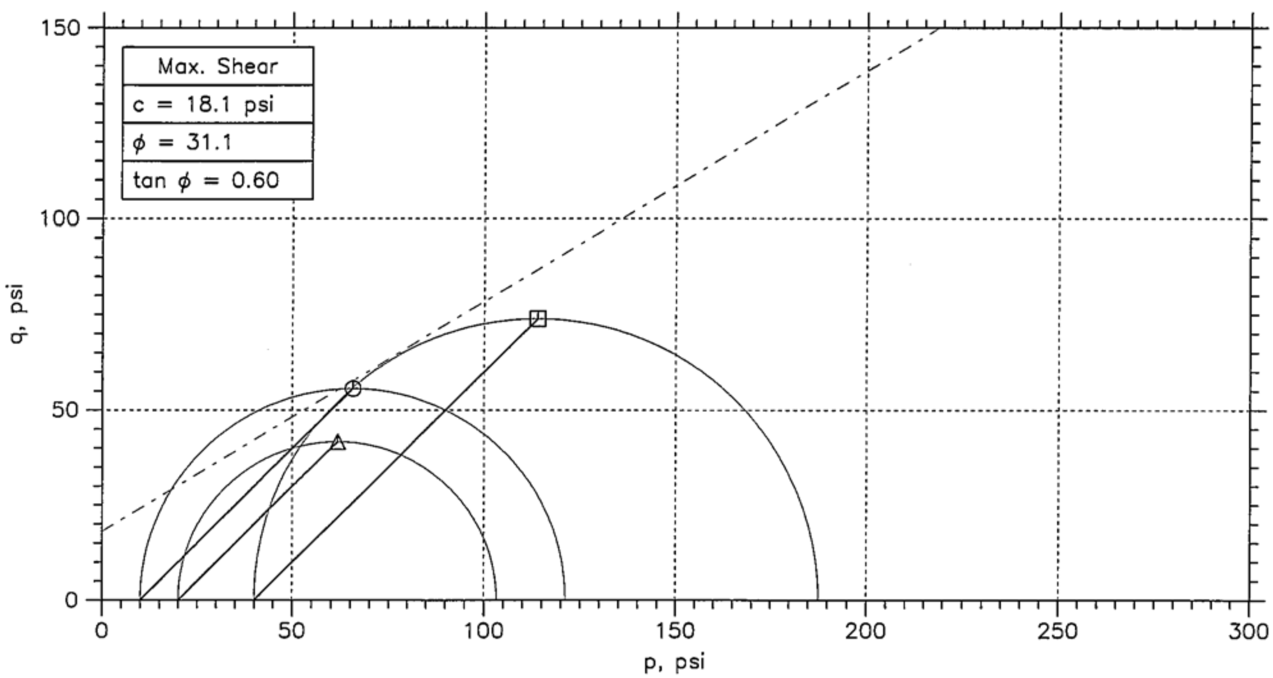
Phase calculations based on start and end of test.

* Saturation is set to 100% for phase calculations.

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767





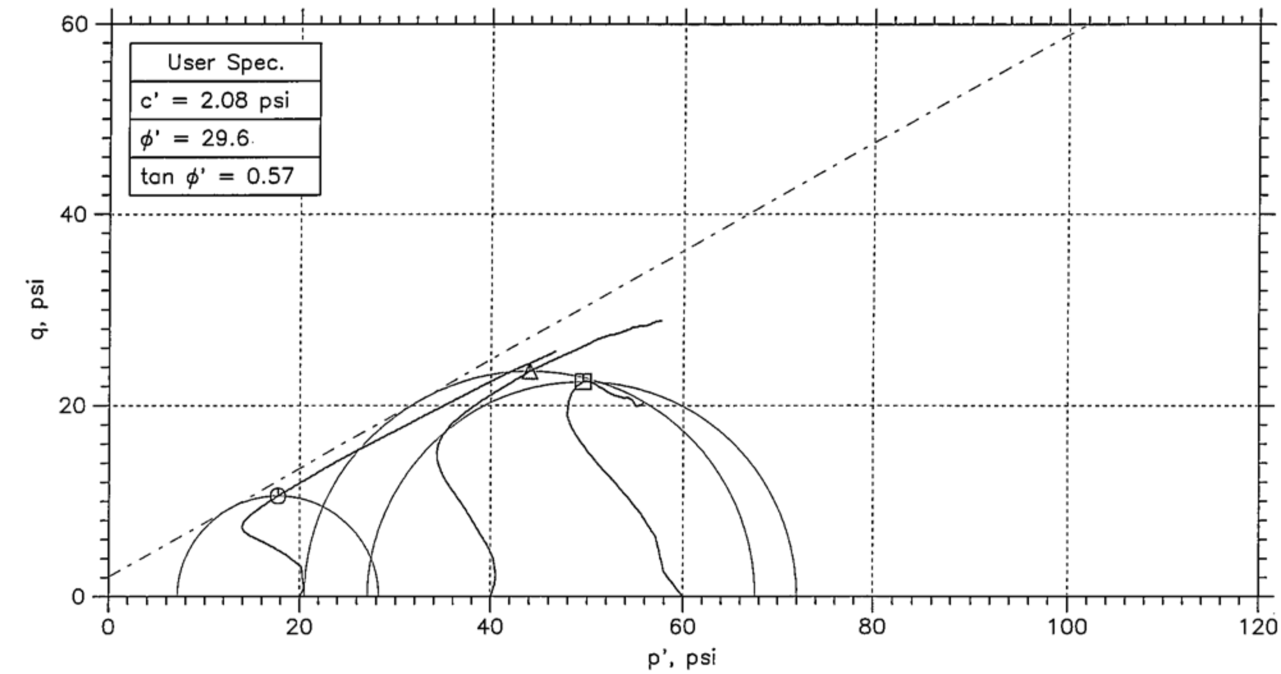


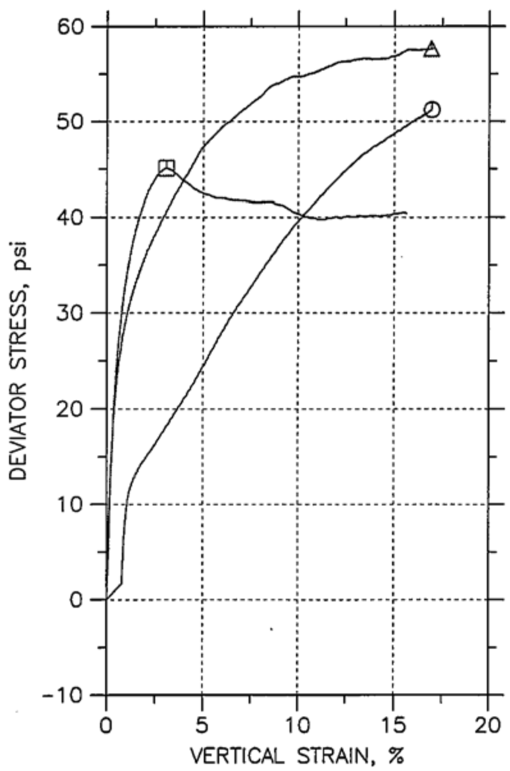
	Sample No.	Test No.	Depth	Tested By	Test Date	Checked By	Check Date	Test File
○	ST1	9476.1	20-22 ft	JW	4/6/09	JEJ	5/19/09	9476.1_2547.dat
△	ST1	9476.2	20-22 ft	JW	4/6/09	↓	↓	9476.2_2546.dat
□	ST1	9476.3	20-22 ft	JW	4/6/09	↓	↓	9476.3_2580.dat

MACTEC			
	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B01, 20-22 ft	Project No.: 6155080031
	Boring No.: Z-V3V5-B01	Sample Type: Undisturbed	
	Description: Brown Poorly Graded Sand with Clay (SP-SC)		
	Remarks: ASTM D4767-04		

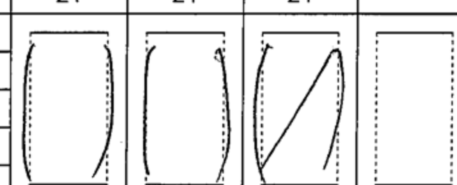
Thu, 23-APR-2009 11:17:08

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767





	Symbol	○	△	□	
	Sample No.	ST3	ST3	ST3	
	Test No.	9478.1	9478.2	9478.3	
	Depth	37-39 ft	37-39 ft	37-39 ft	
Initial	Diameter, in	2.878	2.881	2.874	
Initial	Height, in	5.506	5.599	5.611	
Initial	Water Content, %	16.2	18.8	28.8	
Initial	Dry Density, pcf	98.41	98.46	90.94	
Initial	Saturation, %	62.9	73.3	93.2	
Initial	Void Ratio	0.681	0.68	0.819	
Before Shear	Water Content, %	22.0	23.4	29.3	
Before Shear	Dry Density, pcf	104.5	102.1	93.1	
Before Shear	Saturation*, %	100.0	100.0	100.0	
Before Shear	Void Ratio	0.583	0.62	0.777	
Before Shear	Back Press., psi	120.	110.	90.	
	Ver. Eff. Cons. Stress, psi	20.	40.	59.99	
	Shear Strength, psi	25.6	28.82	22.52	
	Strain at Failure, %	17	16.9	3.08	
	Strain Rate, %/min	0.05	0.05	0.05	
	B-Value	0.91	0.94	0.91	
	Estimated Specific Gravity	2.65	2.65	2.65	
	Liquid Limit	53	53	53	
	Plastic Limit	21	21	21	



MACTEC

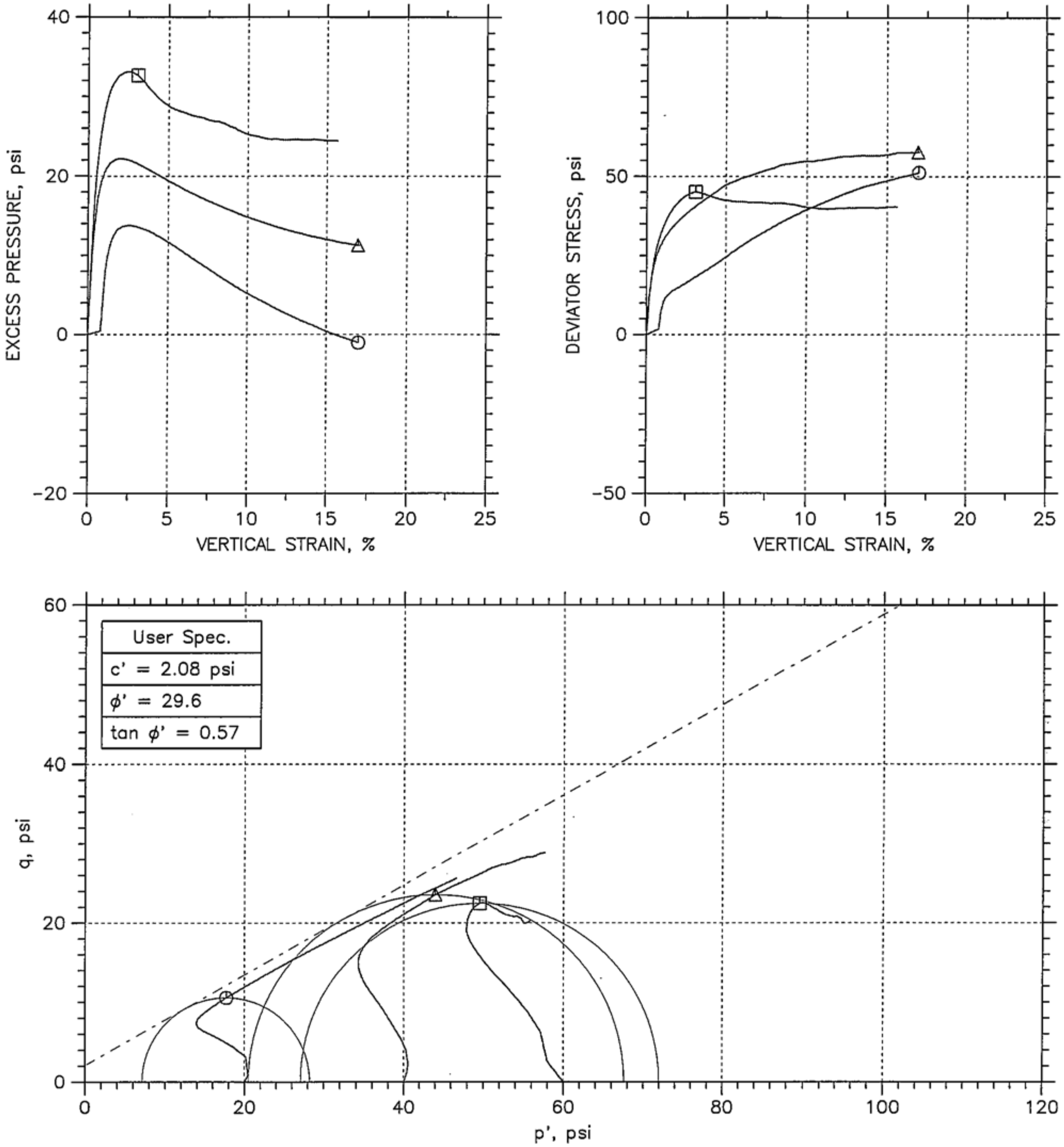
Project: Saltstone Vaults 3&5
Location: Z-V3V5-B01, 37-39 ft
Project No.: 6155080031
Boring No.: Z-V3V5-B01
Sample Type: Undisturbed
Description: Brown Clayey Sand (SC)
Remarks: ASTM D4767-04

Thu, 23-APR-2009 12:06:44

Phase calculations based on start and end of test.

* Saturation is set to 100% for phase calculations.

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767

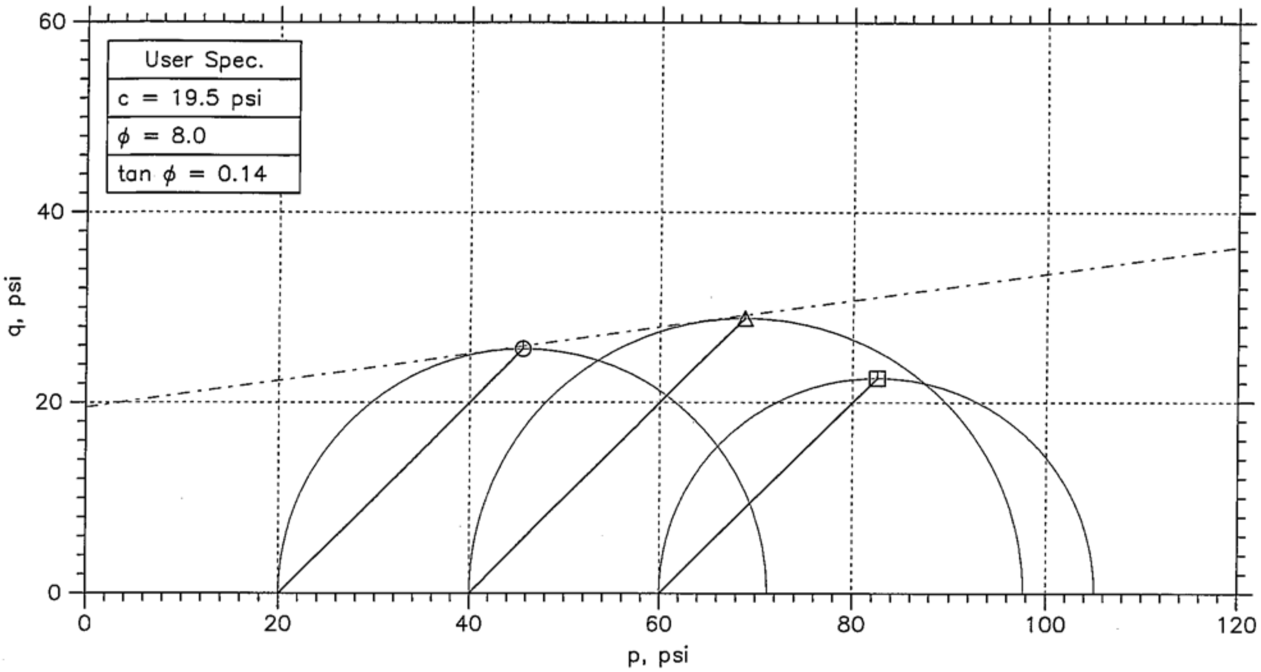


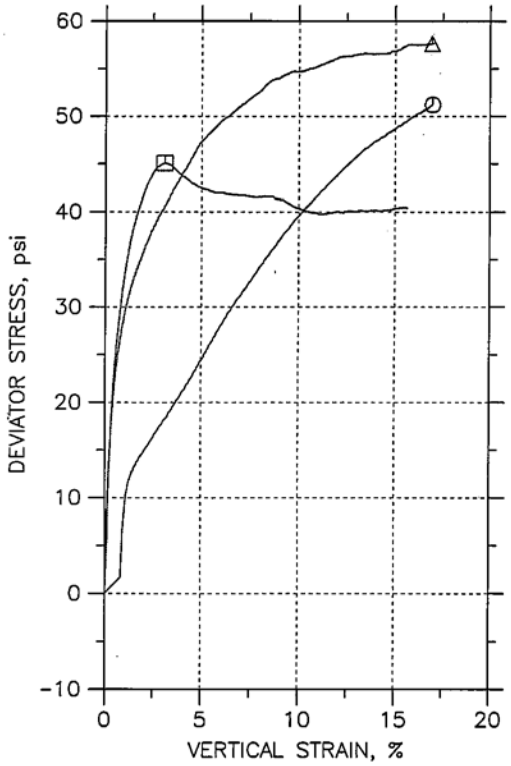
	Sample No.	Test No.	Depth	Tested By	Test Date	Checked By	Check Date	Test File
O	ST3	9478.1	37-39 ft	JW	4/7/09	JEJ	5/19/09	9478.1a_2583.dat
△	ST3	9478.2	37-39 ft	JW	4/7/09	↓	↓	9478.2_2582.dat
◫	ST3	9478.3	37-39 ft	JW	4/7/09			9478.3a_2581.dat

MACTEC	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B01, 37-39 ft	Project No.: 6155080031
	Boring No.: Z-V3V5-B01	Sample Type: Undisturbed	
	Description: Brown Clayey Sand (SC)		
	Remarks: ASTM D4767-04		

Thu, 23-APR-2009 12:06:44

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767

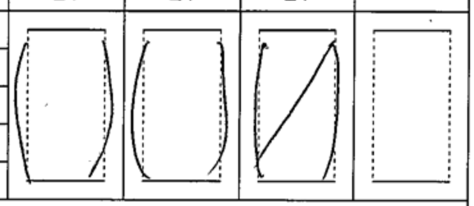




	Symbol	○	△	□	
	Sample No.	ST3	ST3	ST3	
	Test No.	9478.1	9478.2	9478.3	
	Depth	37-39 ft	37-39 ft	37-39 ft	
Initial	Diameter, in	2.878	2.881	2.874	
	Height, in	5.506	5.599	5.611	
	Water Content, %	16.2	18.8	28.8	
	Dry Density, pcf	98.41	98.46	90.94	
	Saturation, %	62.9	73.3	93.2	
	Void Ratio	0.681	0.68	0.819	
Before Shear	Water Content, %	22.0	23.4	29.3	
	Dry Density, pcf	104.5	102.1	93.1	
	Saturation*, %	100.0	100.0	100.0	
	Void Ratio	0.583	0.62	0.777	
	Back Press., psi	120.	110.	90.	
	Ver. Eff. Cons. Stress, psi	20.	40.	59.99	
	Shear Strength, psi	25.6	28.82	22.52	
	Strain at Failure, %	17	16.9	3.08	
	Strain Rate, %/min	0.05	0.05	0.05	
	B-Value	0.91	0.94	0.91	
	Estimated Specific Gravity	2.65	2.65	2.65	
	Liquid Limit	53	53	53	
	Plastic Limit	21	21	21	

MACTEC

Project: Saltstone Vaults 3&5	
Location: Z-V3V5-B01, 37-39 ft	
Project No.: 6155080031	
Boring No.: Z-V3V5-B01	
Sample Type: Undisturbed	
Description: Brown Clayey Sand (SC)	
Remarks: ASTM D4767-04	

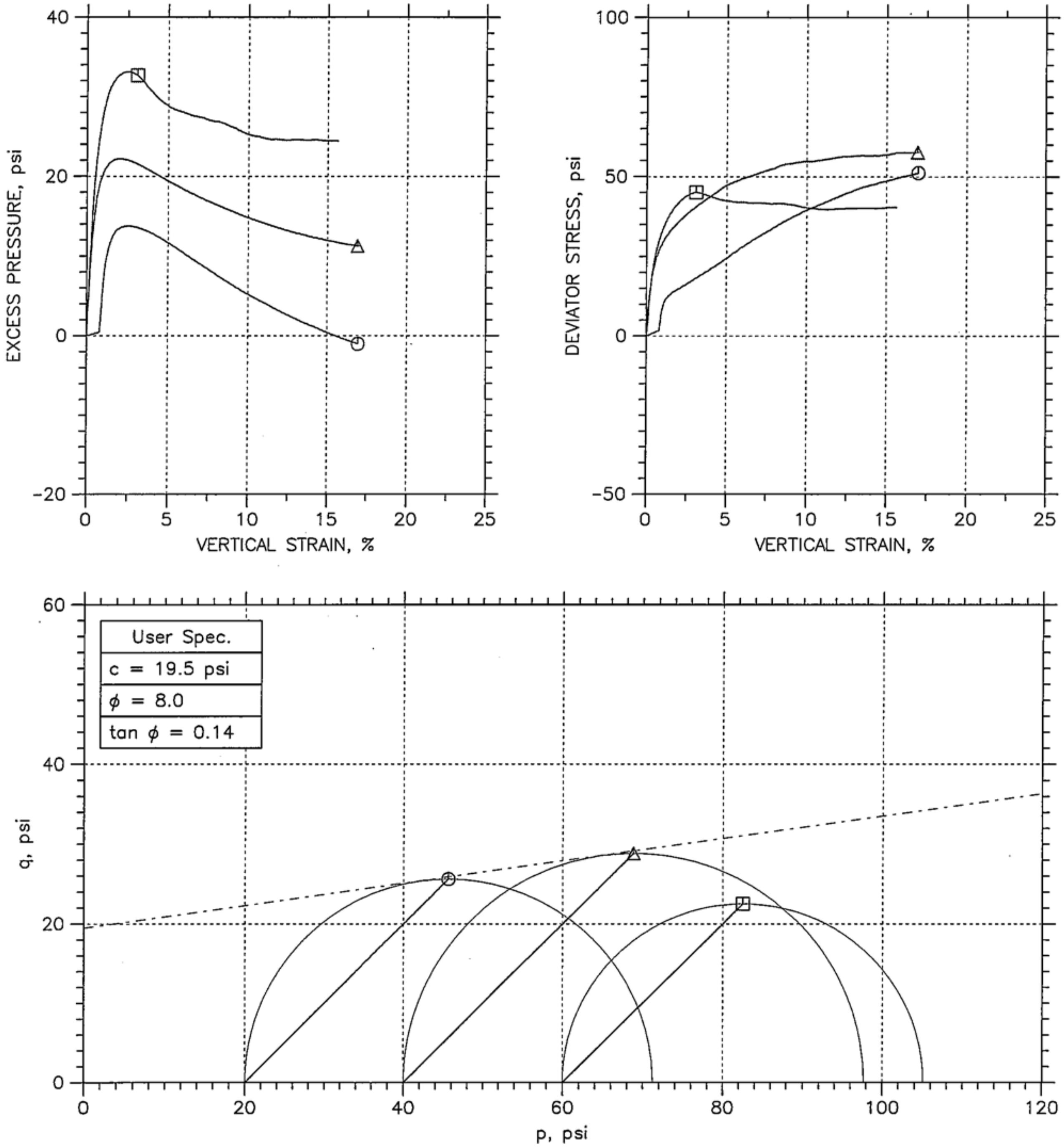


Thu, 23-APR-2009 12:10:28

Phase calculations based on start and end of test.

* Saturation is set to 100% for phase calculations.

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767



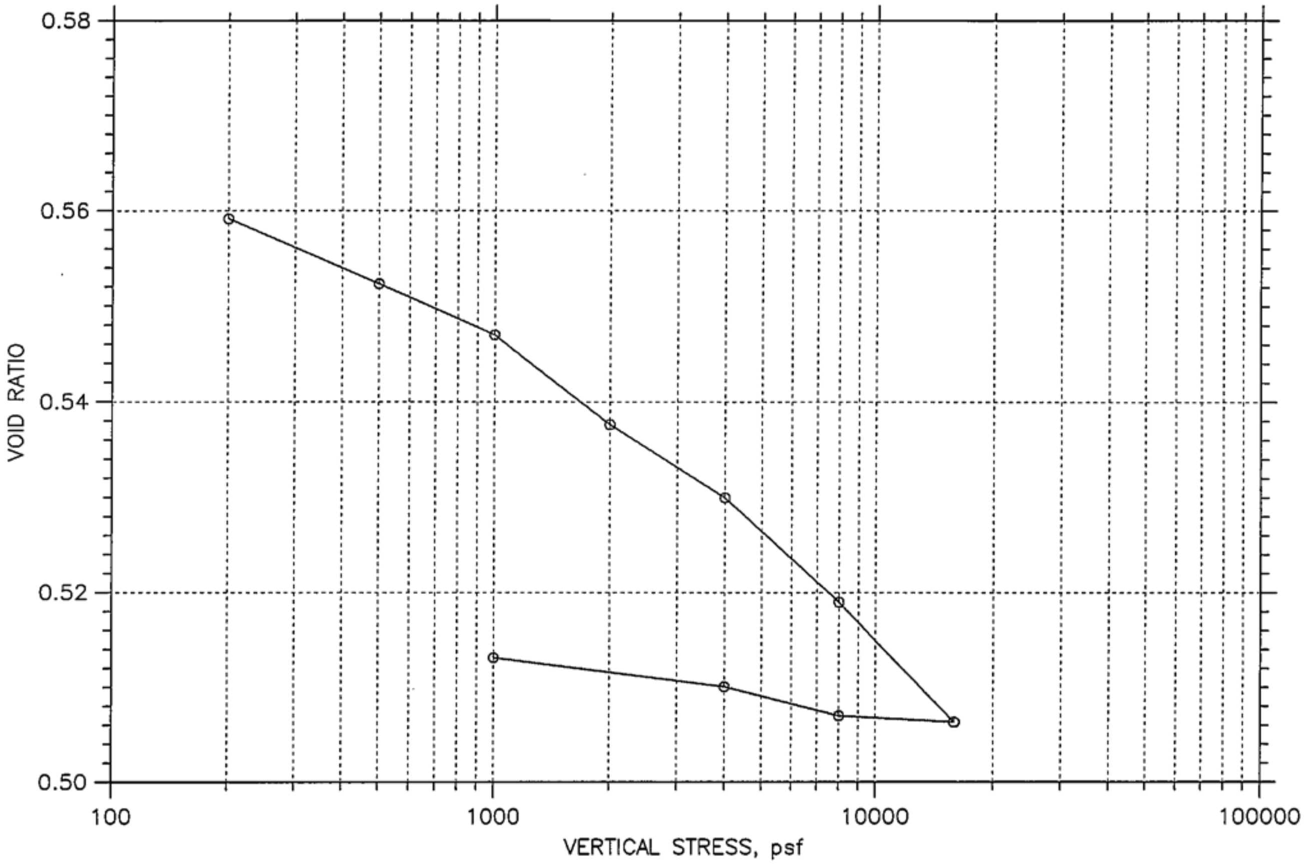
	Sample No.	Test No.	Depth	Tested By	Test Date	Checked By	Check Date	Test File
○	ST3	9478.1	37-39 ft	JW	4/7/09	[illegible]	5/19/09	9478.1a_2583.dat
△	ST3	9478.2	37-39 ft	JW	4/7/09	↓	↓	9478.2_2582.dat
□	ST3	9478.3	37-39 ft	JW	4/7/09	↓	↓	9478.3a_2581.dat

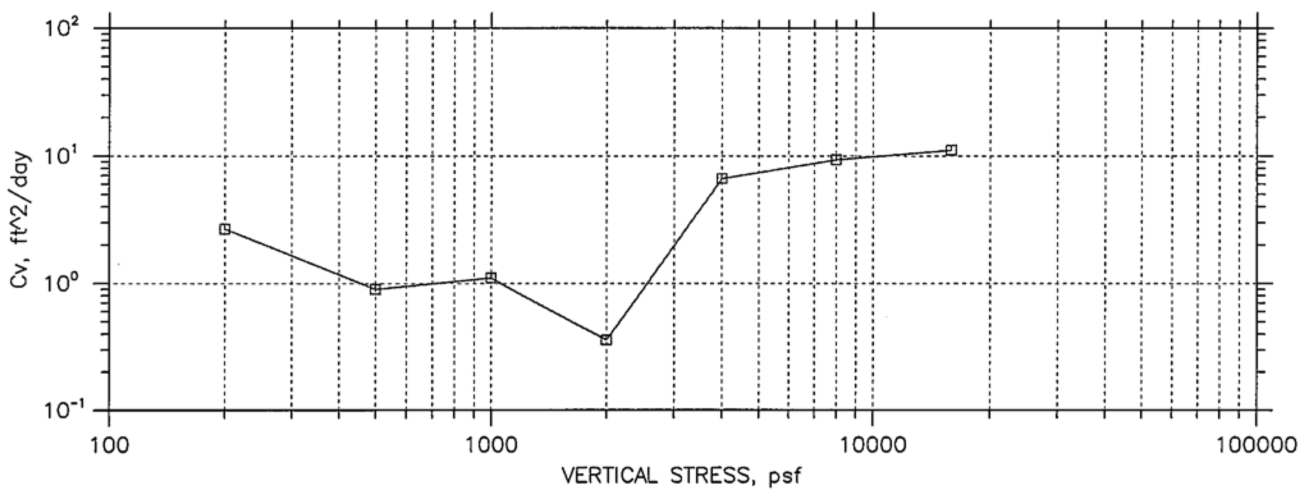
MACTEC			
	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B01, 37-39 ft	Project No.: 6155080031
	Boring No.: Z-V3V5-B01	Sample Type: Undisturbed	
	Description: Brown Clayey Sand (SC)		
	Remarks: ASTM D4767-04		

Thu, 23-APR-2009 12:10:28

CONSOLIDATION TEST DATA

SUMMARY REPORT



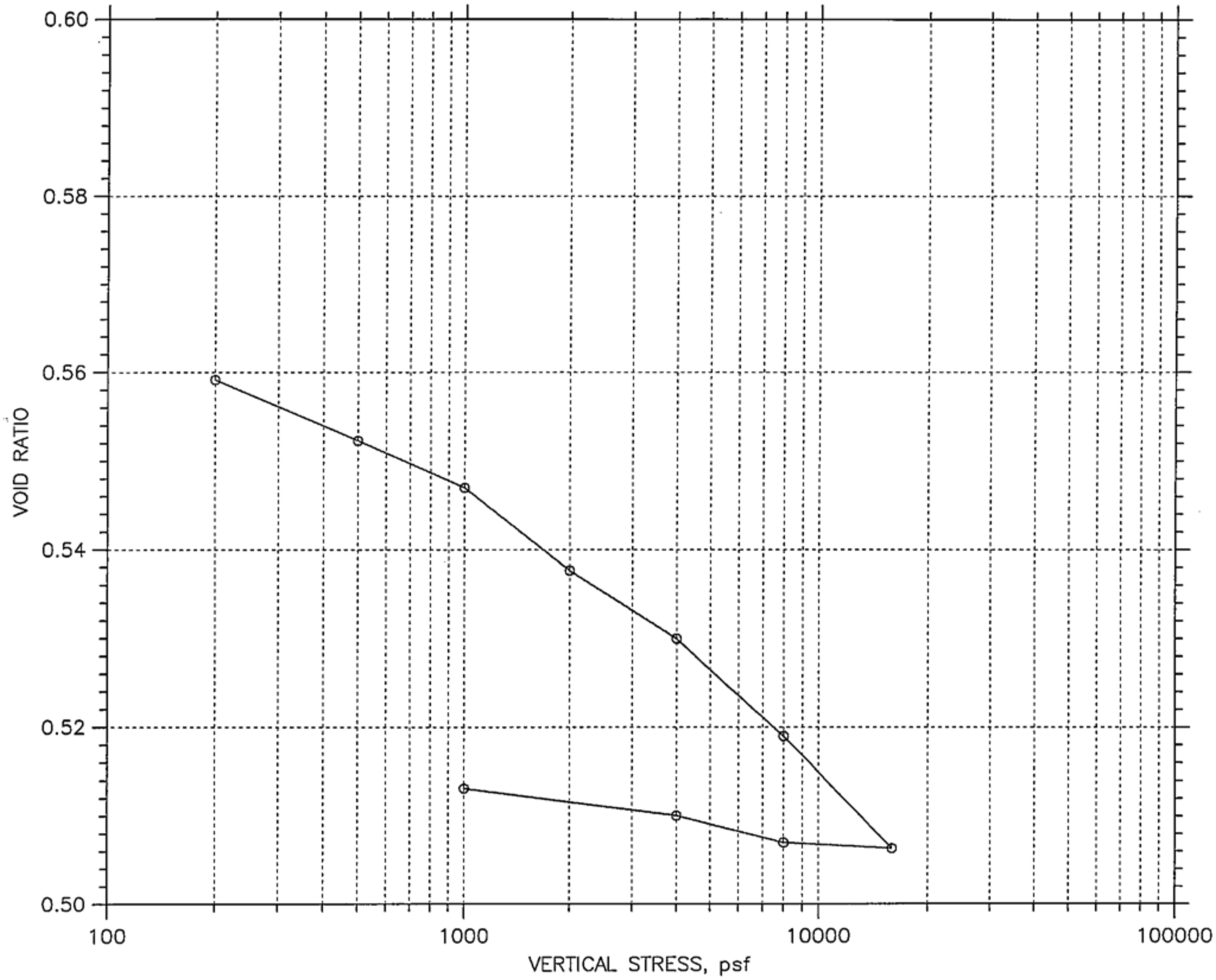


MACTEC			
	Project: Saltstone Vault 3&5	Location: Z-V3V5-B04, 30-32 ft	Project No.: 6055080031
	Boring No.: Z-V3V5-B04	Tested By: JW	Checked By: JEJ
	Sample No.: ST2	Test Date: 3/25/09	Depth: 30-32 ft
	Test No.: 9459	Sample Type: Undisturbed	Elevation: N/A
	Description: Brown Poorly Graded Sand with Clay (SP-SC)		
	Remarks: ASTM D2435-04		

Thu, 23-APR-2009 10:32:41

CONSOLIDATION TEST DATA

SUMMARY REPORT



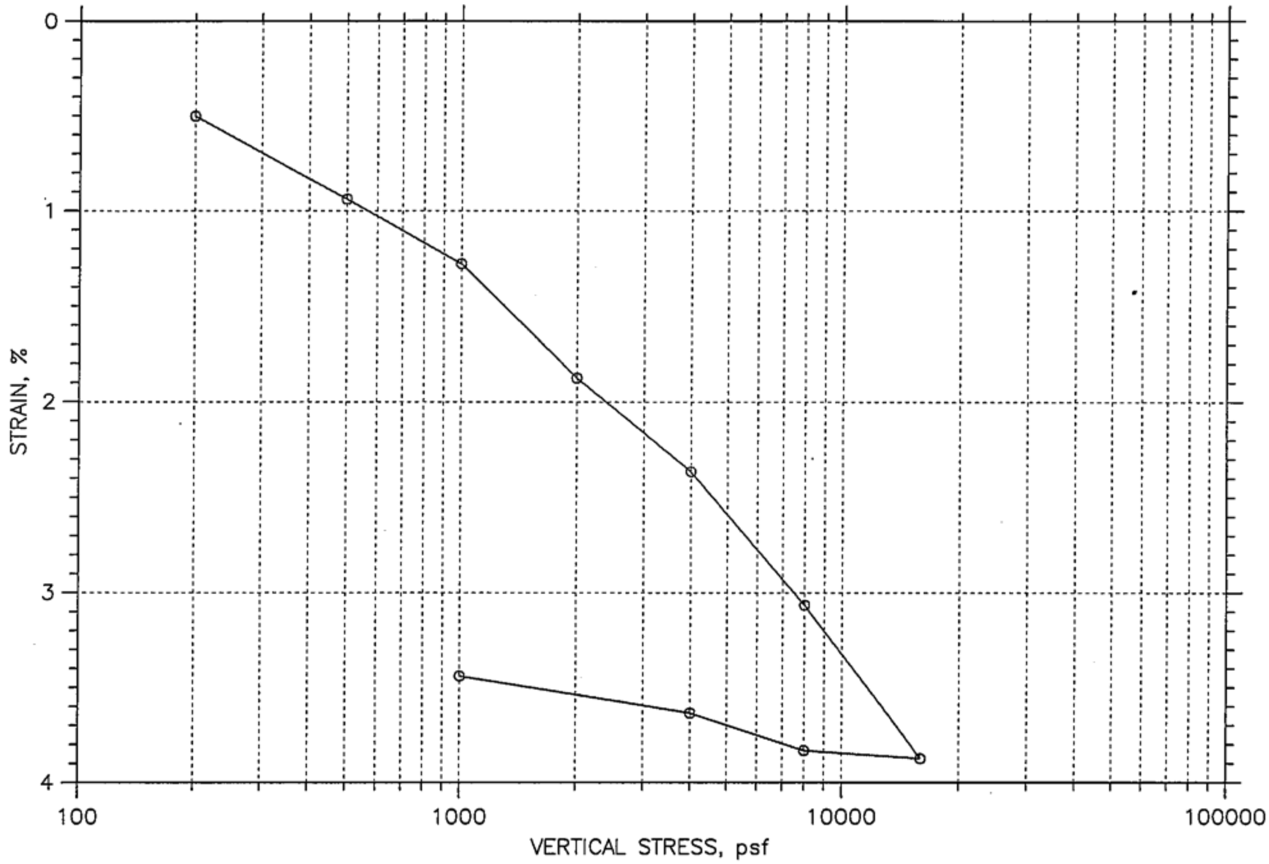
					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	15.78	16.16
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	106.4	110.2
Compression Index: 0				Saturation, %	74.32	84.10
Diameter: 2.499 in		Height: 1.003 in		Void Ratio	0.57	0.51
LL: 39	PL: 22	PI: 17	GS: 2.67			

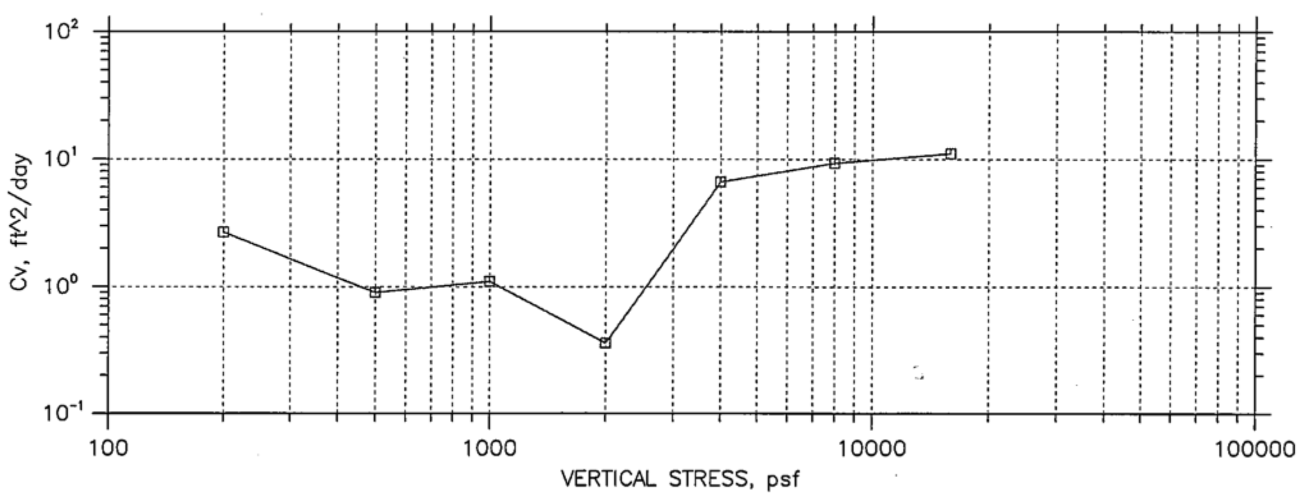
MACTEC	Project: Saltstone Vault 3&5	Location: Z-V3V5-B04, 30-32 ft	Project No.: 6055080031
	Boring No.: Z-V3V5-B04	Tested By: JW	Checked By: JEJ
	Sample No.: ST2	Test Date: 3/25/09	Depth: 30-32 ft
	Test No.: 9459	Sample Type: Undisturbed	Elevation: N/A
	Description: Brown Poorly Graded Sand with Clay (SP-SC)		
	Remarks: ASTM D2435-04		

Thu, 23-APR-2009 10:32:42

CONSOLIDATION TEST DATA

SUMMARY REPORT

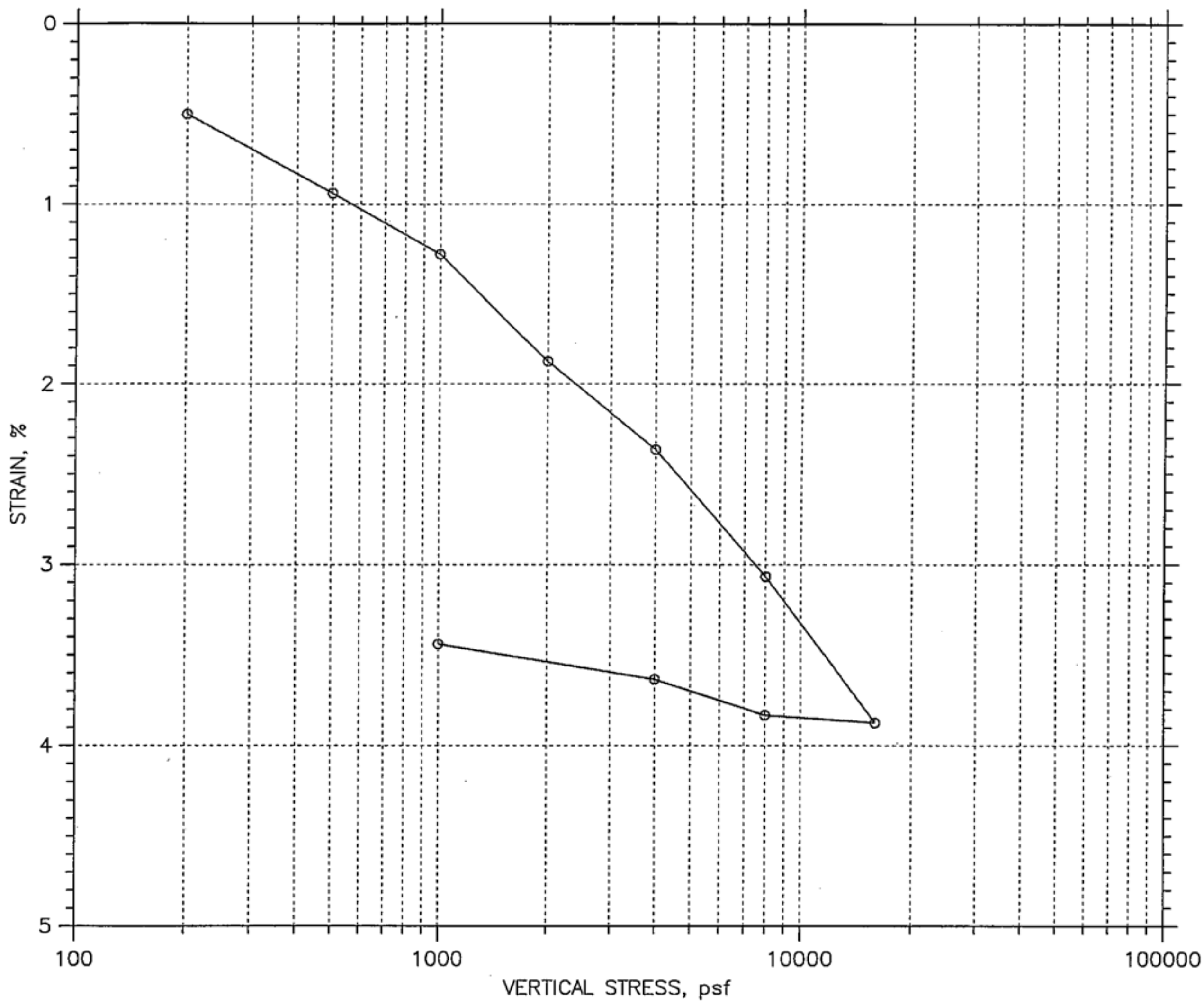




MACTEC			
	Project: Saltstone Vault 3&5	Location: Z-V3V5-B04, 30-32 ft	Project No.: 6055080031
	Boring No.: Z-V3V5-B04	Tested By: JW	Checked By: JEJ
	Sample No.: ST2	Test Date: 3/25/09	Depth: 30-32 ft
	Test No.: 9459	Sample Type: Undisturbed	Elevation: N/A
	Description: Brown Poorly Graded Sand with Clay (SP-SC)		
	Remarks: ASTM D2435-04		

Thu, 23-APR-2009 10:32:52

CONSOLIDATION TEST DATA
SUMMARY REPORT



					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	15.78	16.16
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	106.4	110.2
Compression Index: 0				Saturation, %	74.32	84.10
Diameter: 2.499 in		Height: 1.003 in		Void Ratio	0.57	0.51
LL: 39	PL: 22	PI: 17	GS: 2.67			

MACTEC	Project: Saltstone Vault 3&5	Location: Z-V3V5-B04, 30-32 ft	Project No.: 6055080031
	Boring No.: Z-V3V5-B04	Tested By: JW	Checked By: JGJ
	Sample No.: ST2	Test Date: 3/25/09	Depth: 30-32 ft
	Test No.: 9459	Sample Type: Undisturbed	Elevation: N/A
	Description: Brown Poorly Graded Sand with Clay (SP-SC)		
	Remarks: ASTM D2435-04		

Thu, 23-APR-2009 10:32:52

CONSOLIDATION TEST DATA

Project: Saltstone Vault 3&5
Boring No.: Z-V3V5-B04
Sample No.: ST2
Test No.: 9459

Location: Z-V3V5-B04, 30-32 ft
Tested By: JW
Test Date: 3/25/09
Sample Type: Undisturbed

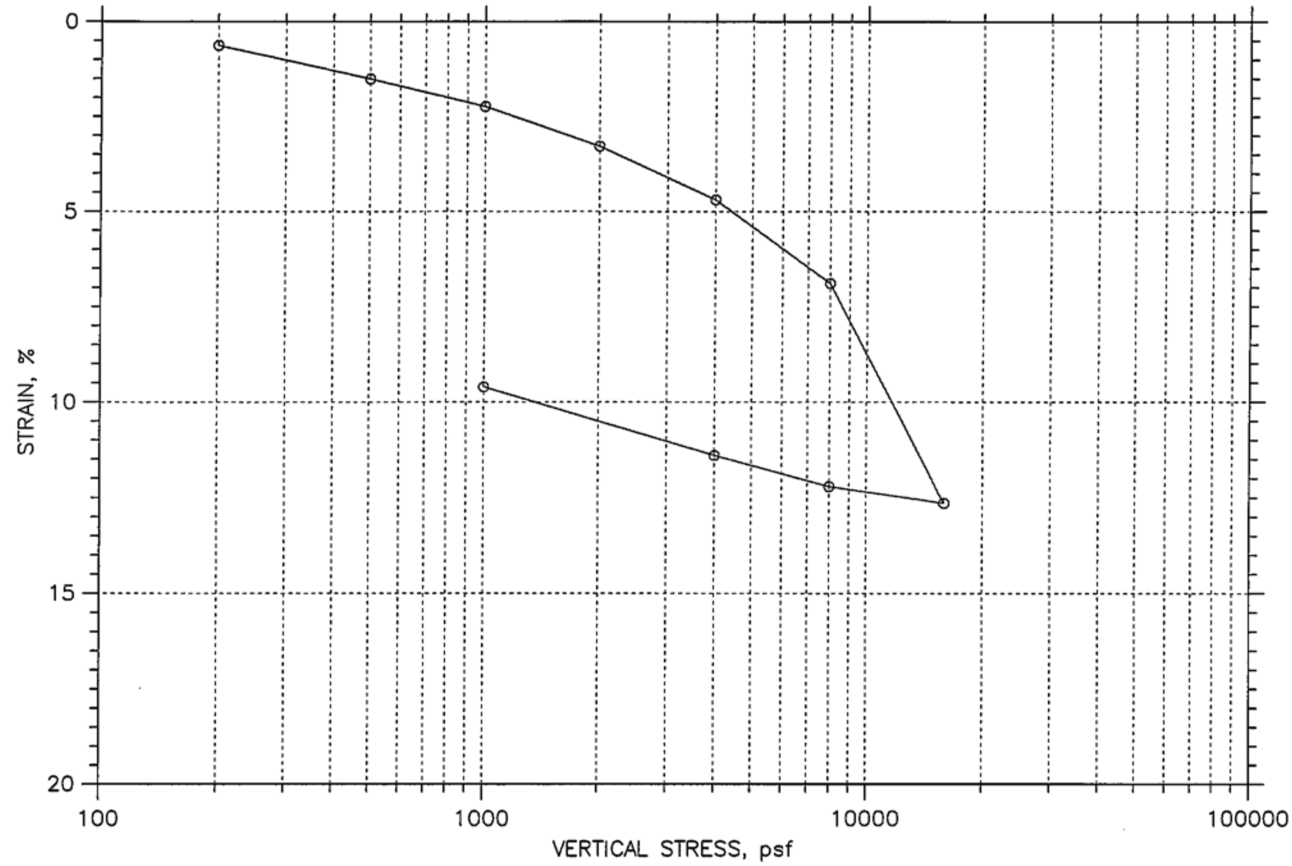
Project No.: 6055080031
Checked By:
Depth: 30-32 ft
Elevation: N/A

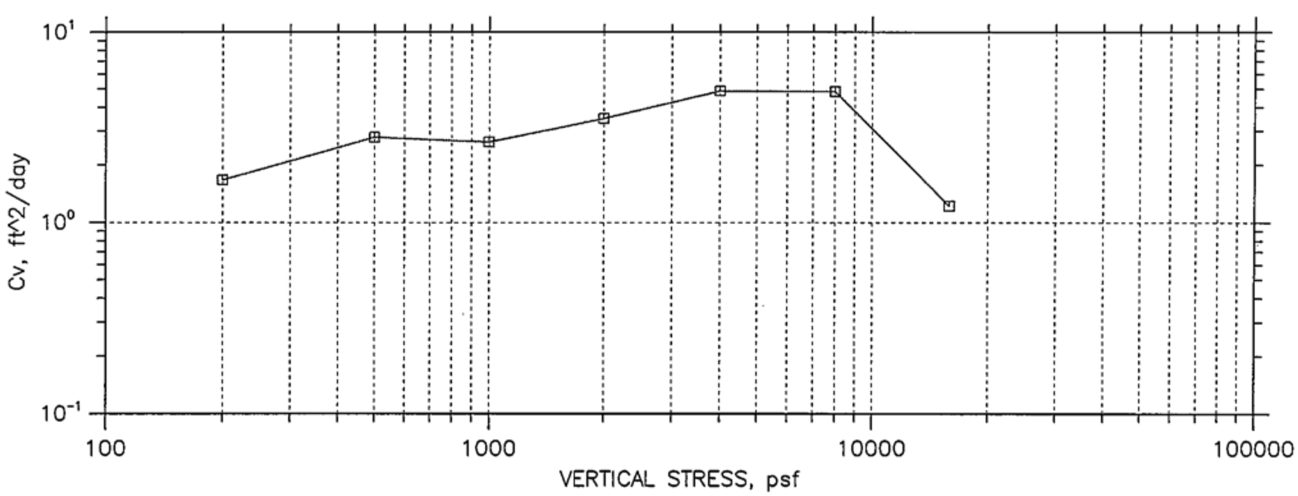
Soil Description: Brown Poorly Graded Sand with Clay (SP-SC)
Remarks: ASTM D2435-04

	Applied Stress psf	Final Displacement in	Void Ratio	Strain at End %	T50 Fitting Sq.Rt. min	T50 Fitting Log min	Coefficient of Consolidation Sq.Rt. ft^2/day	Coefficient of Consolidation Log ft^2/day	Coefficient of Consolidation Ave. ft^2/day
1	200	0.005046	0.559	0.50	0.2	0.2	2.33e+000	3.14e+000	2.67e+000
2	500	0.009421	0.552	0.94	0.5	0.0	8.98e-001	0.00e+000	8.98e-001
3	1e+003	0.01283	0.547	1.28	0.4	0.0	1.10e+000	0.00e+000	1.10e+000
4	2e+003	0.01882	0.538	1.88	1.3	0.0	3.57e-001	0.00e+000	3.57e-001
5	4e+003	0.02373	0.530	2.37	0.1	0.1	6.36e+000	6.89e+000	6.62e+000
6	8e+003	0.03076	0.519	3.07	0.0	0.1	9.92e+000	8.71e+000	9.28e+000
7	1.6e+004	0.03886	0.506	3.87	0.0	0.0	1.12e+001	1.09e+001	1.11e+001
8	8e+003	0.03844	0.507	3.83	0.0	0.0	1.41e+001	0.00e+000	1.41e+001
9	4e+003	0.03647	0.510	3.64	0.0	0.0	1.12e+001	0.00e+000	1.12e+001
10	1e+003	0.03451	0.513	3.44	0.1	0.0	8.21e+000	0.00e+000	8.21e+000

CONSOLIDATION TEST DATA

SUMMARY REPORT



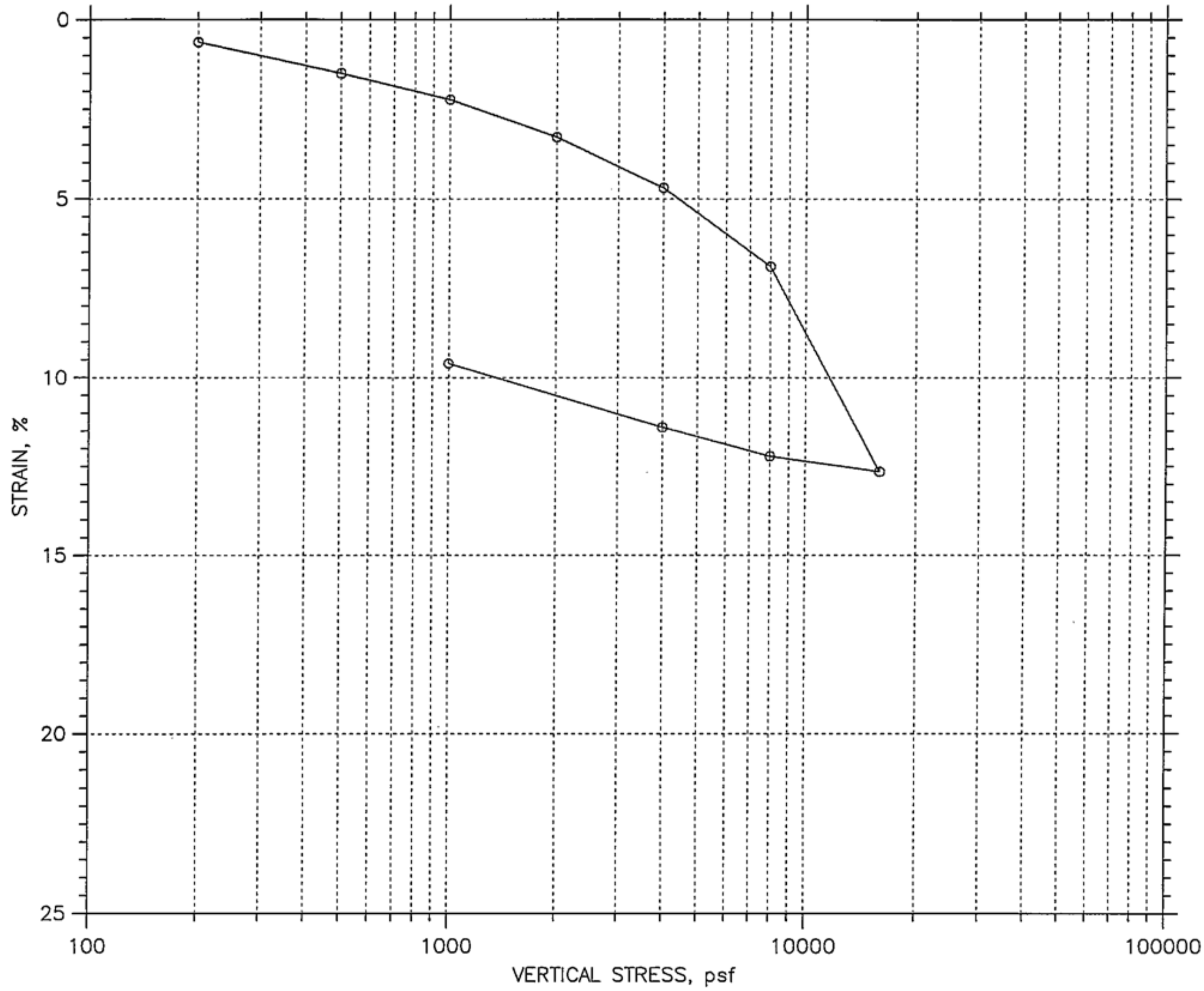


MACTEC	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B04	Project No.: 6155080031
	Boring No.: Z-V3V5-B04	Tested By: JW	Checked By: JEJ
	Sample No.: ST4	Test Date: 3/25/09	Depth: 50-52 ft
	Test No.: 9461	Sample Type: Undisturbed	Elevation: N/A
	Description: Tan Clayey Sand (SM)		
	Remarks: ASTM D2435-04		

Thu, 23-APR-2009 10:57:09

CONSOLIDATION TEST DATA

SUMMARY REPORT



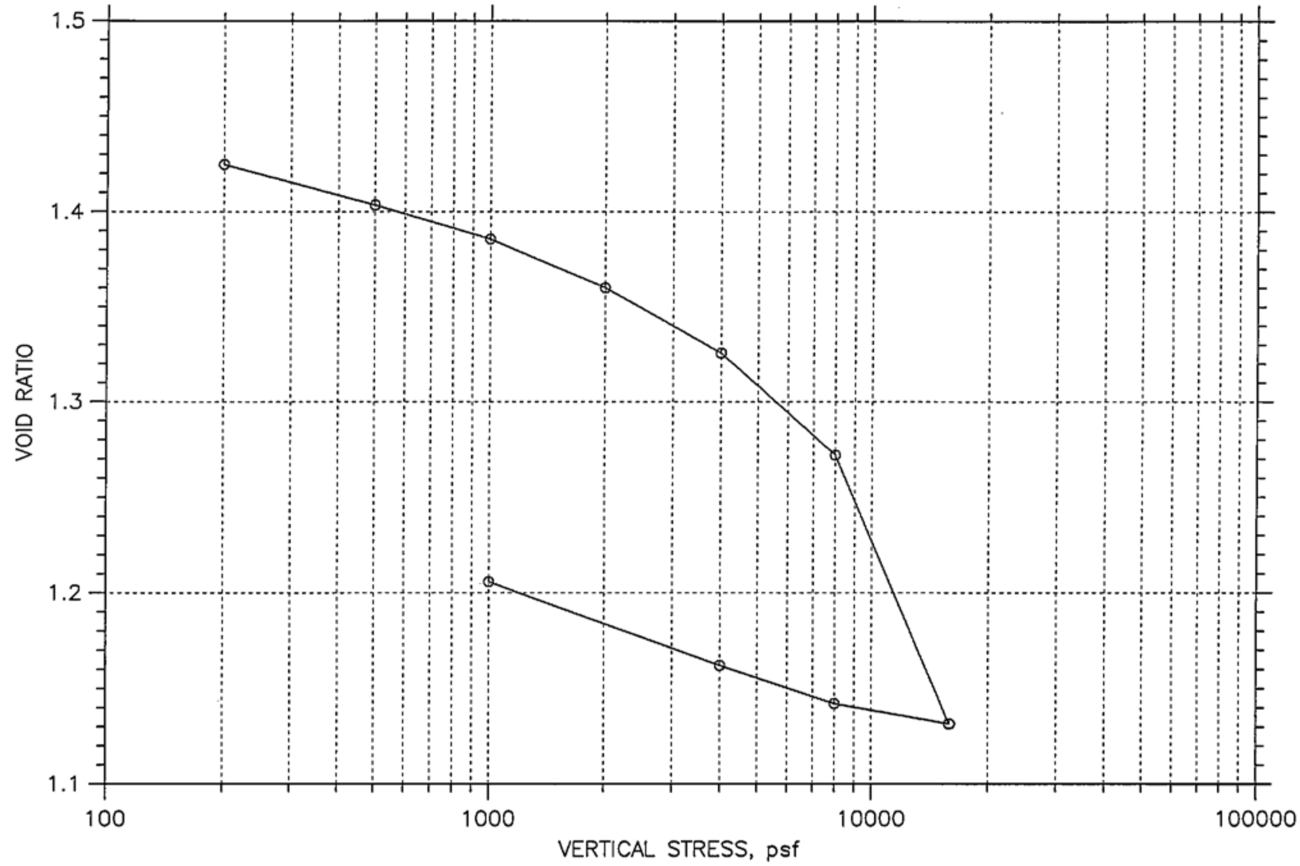
					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	50.34	44.43
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	69.08	76.42
Compression Index: 0				Saturation, %	94.37	99.49
Diameter: 2.5 in		Height: 1.006 in		Void Ratio	1.44	1.21
LL: 74	PL: 40	PI: 34	GS: 2.70			

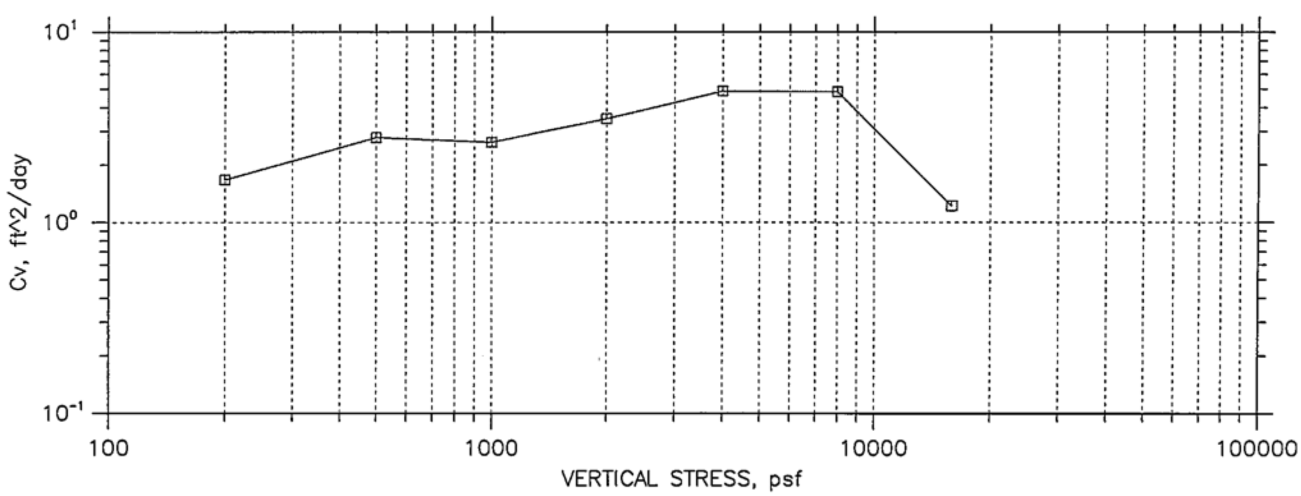
MACTEC			
	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B04	Project No.: 6155080031
	Boring No.: Z-V3V5-B04	Tested By: JW	Checked By: JEJ
	Sample No.: ST4	Test Date: 3/25/09	Depth: 50-52 ft
	Test No.: 9461	Sample Type: Undisturbed	Elevation: N/A
	Description: Tan Clayey Sand (SM)		
	Remarks: ASTM D2435-04		

Thu, 23-APR-2009 10:57:09

CONSOLIDATION TEST DATA

SUMMARY REPORT



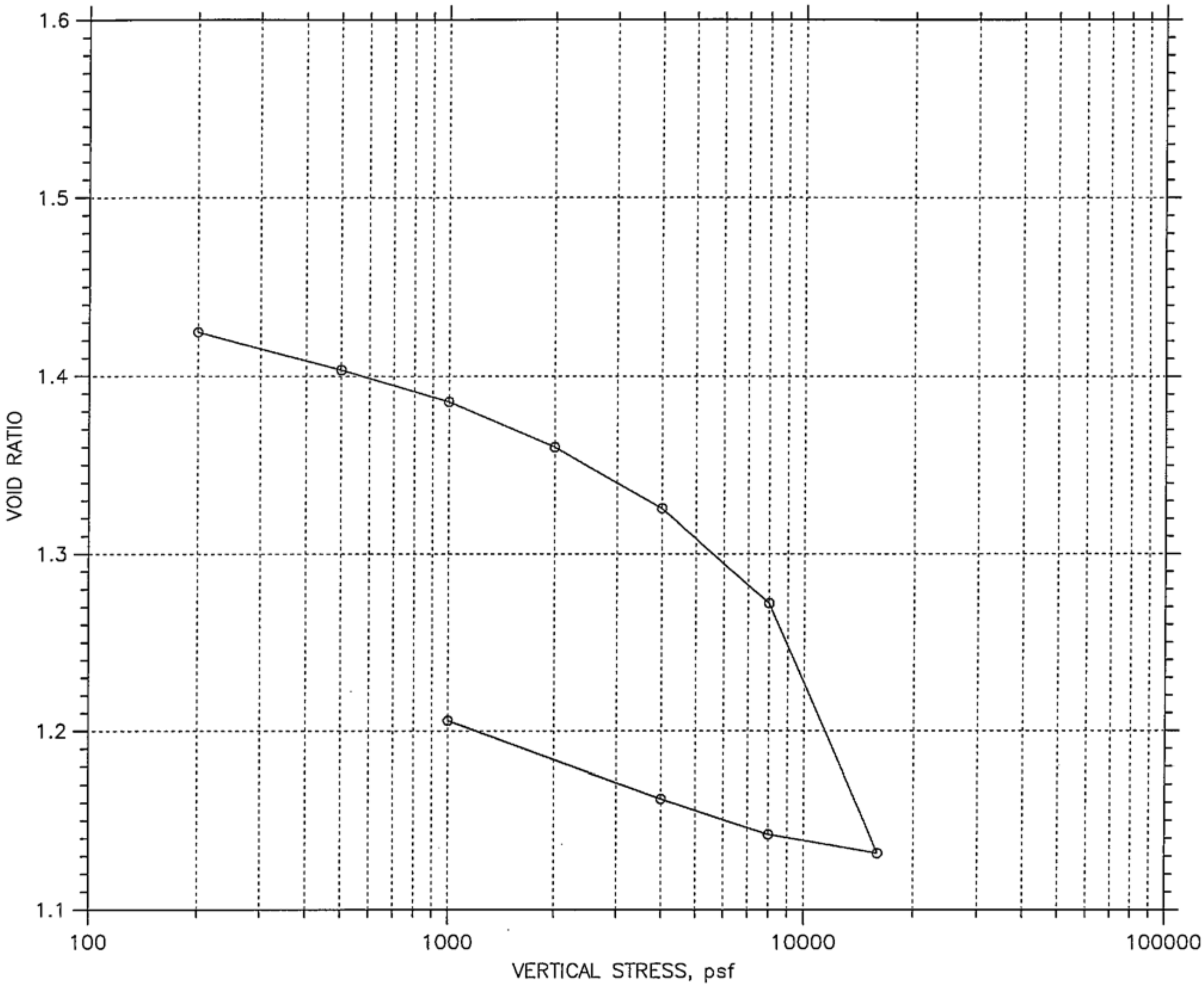


MACTEC	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B04	Project No.: 6155080031
	Boring No.: Z-V3V5-B04	Tested By: JW	Checked By: JEJ
	Sample No.: ST4	Test Date: 3/25/09	Depth: 50-52 ft
	Test No.: 9461	Sample Type: Undisturbed	Elevation: N/A
	Description: Tan Clayey Sand (SM)		
	Remarks: ASTM D2435-04		

Thu, 23-APR-2009 10:57:16

CONSOLIDATION TEST DATA

SUMMARY REPORT



					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	50.34	44.43
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	69.08	76.42
Compression Index: 0				Saturation, %	94.37	99.49
Diameter: 2.5 in		Height: 1.006 in		Void Ratio	1.44	1.21
LL: 74	PL: 40	PI: 34	GS: 2.70			

MACTEC	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B04	Project No.: 6155080031
	Boring No.: Z-V3V5-B04	Tested By: JW	Checked By: JGY
	Sample No.: ST4	Test Date: 3/25/09	Depth: 50-52 ft
	Test No.: 9461	Sample Type: Undisturbed	Elevation: N/A
	Description: Tan Clayey Sand (SM)		
	Remarks: ASTM D2435-04		

Thu, 23-APR-2009 10:57:16

CONSOLIDATION TEST DATA

Project: Saltstone Vaults 3&5
Boring No.: Z-V3V5-B04
Sample No.: ST4
Test No.: 9461

Location: Z-V3V5-B04
Tested By: JW
Test Date: 3/25/09
Sample Type: Undisturbed

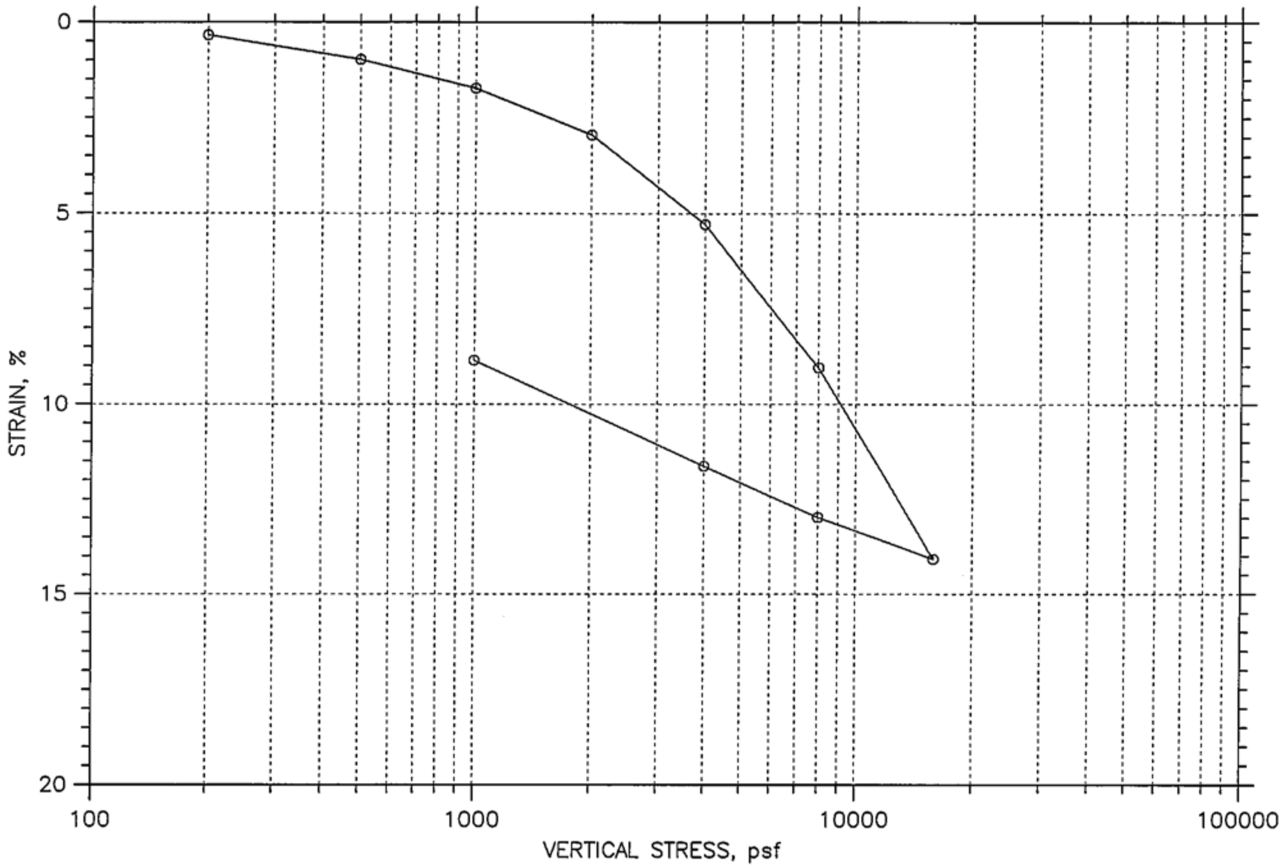
Project No.: 6155080031
Checked By:
Depth: 50-52 ft
Elevation: N/A

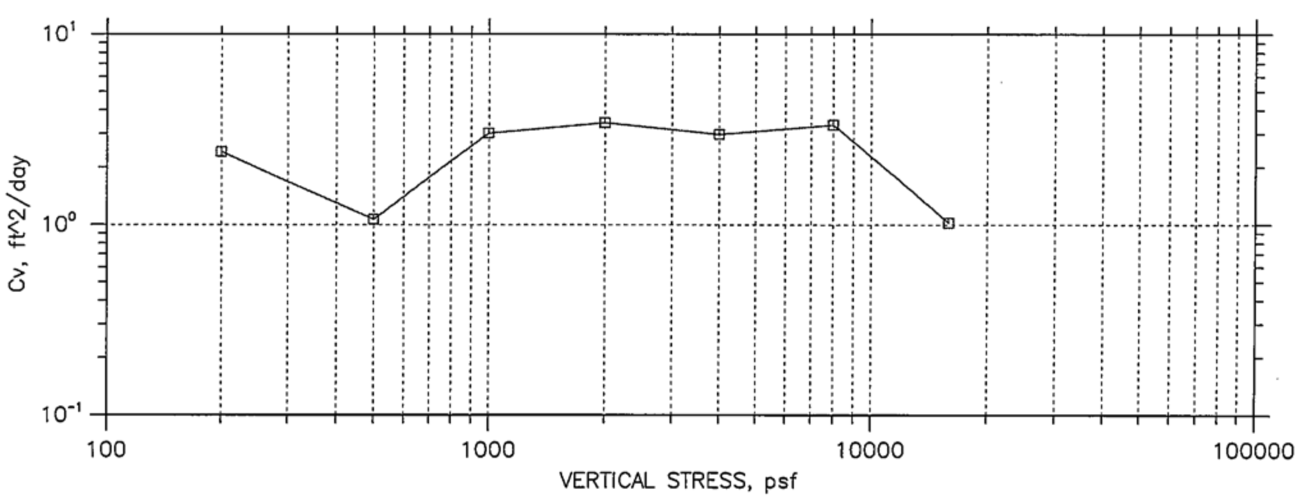
Soil Description: Tan Clayey Sand (SM)
Remarks: ASTM D2435-04

	Applied Stress psf	Final Displacement in	Void Ratio	Strain at End %	T50 Fitting Sq.Rt. min	T50 Fitting Log min	Coefficient of Consolidation Sq.Rt. ft^2/day	Coefficient of Consolidation Log ft^2/day	Coefficient of Consolidation Ave. ft^2/day
1	200	0.006318	1.425	0.63	0.3	0.0	1.67e+000	0.00e+000	1.67e+000
2	500	0.01514	1.403	1.51	0.2	0.0	2.80e+000	0.00e+000	2.80e+000
3	1e+003	0.0225	1.386	2.24	0.2	0.0	2.63e+000	0.00e+000	2.63e+000
4	2e+003	0.03303	1.360	3.28	0.1	0.1	3.18e+000	3.91e+000	3.50e+000
5	4e+003	0.04721	1.326	4.69	0.1	0.1	4.82e+000	4.95e+000	4.88e+000
6	8e+003	0.06933	1.272	6.89	0.1	0.1	4.55e+000	5.19e+000	4.85e+000
7	1.6e+004	0.1272	1.132	12.65	0.4	0.3	9.79e-001	1.62e+000	1.22e+000
8	8e+003	0.1229	1.142	12.21	0.1	0.0	3.42e+000	0.00e+000	3.42e+000
9	4e+003	0.1147	1.162	11.40	0.3	0.2	1.42e+000	2.29e+000	1.75e+000
10	1e+003	0.09666	1.206	9.61	1.0	0.9	3.97e-001	4.40e-001	4.17e-001

CONSOLIDATION TEST DATA

SUMMARY REPORT



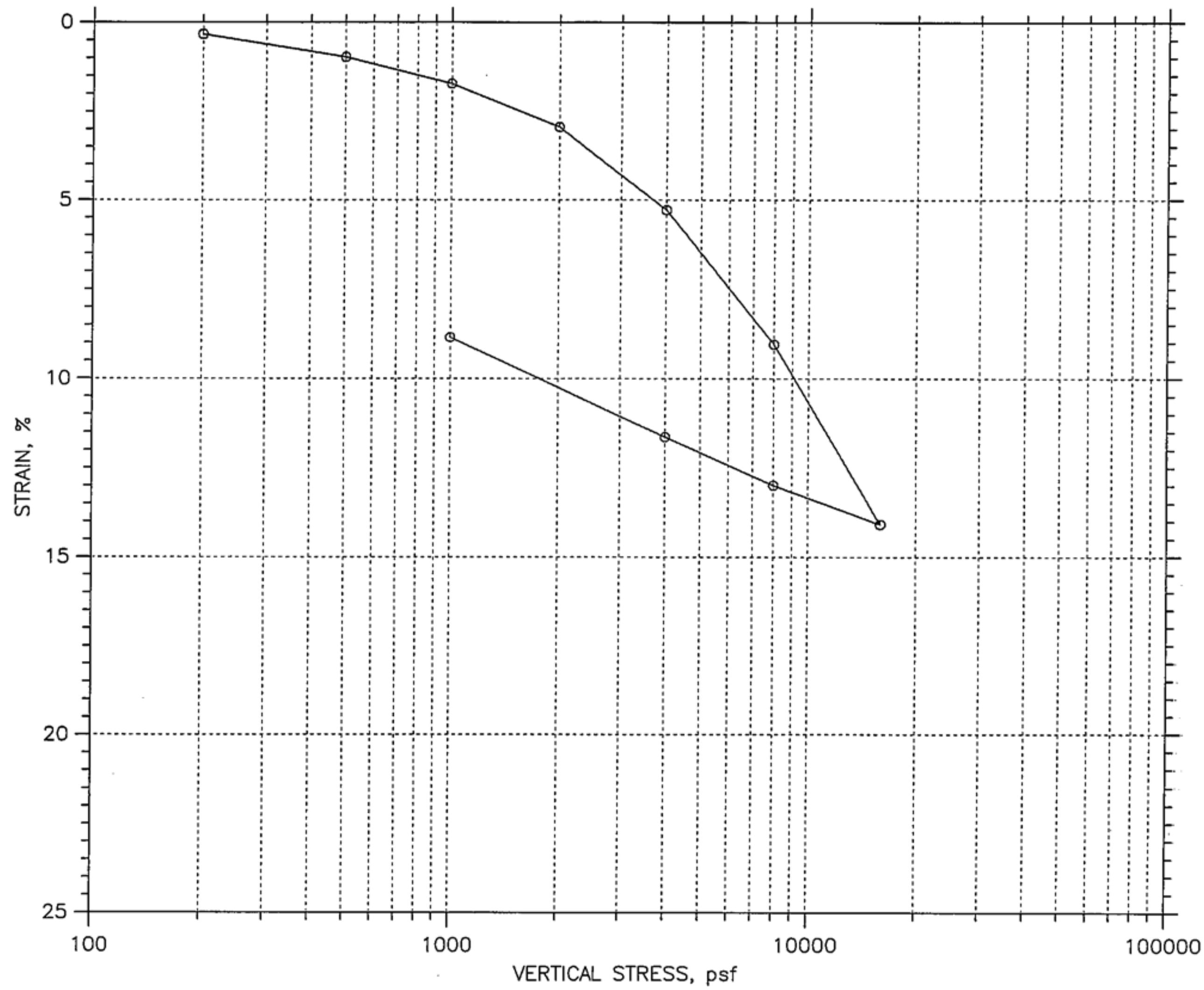


MACTEC	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B04, 55-57 ft	Project No.: 6155080031
	Boring No.: Z-V3V5-B04	Tested By: JW	Checked By: JCJ
	Sample No.: ST5	Test Date: 3/25/09	Depth: 55-57 ft
	Test No.: 9462	Sample Type: Undisturbed	Elevation: N/A
	Description: Yellowish Brown Elastic Silt with Sand (MH)		
	Remarks: ASTM D2435-04		

Thu, 23-APR-2009 10:57:47

CONSOLIDATION TEST DATA

SUMMARY REPORT



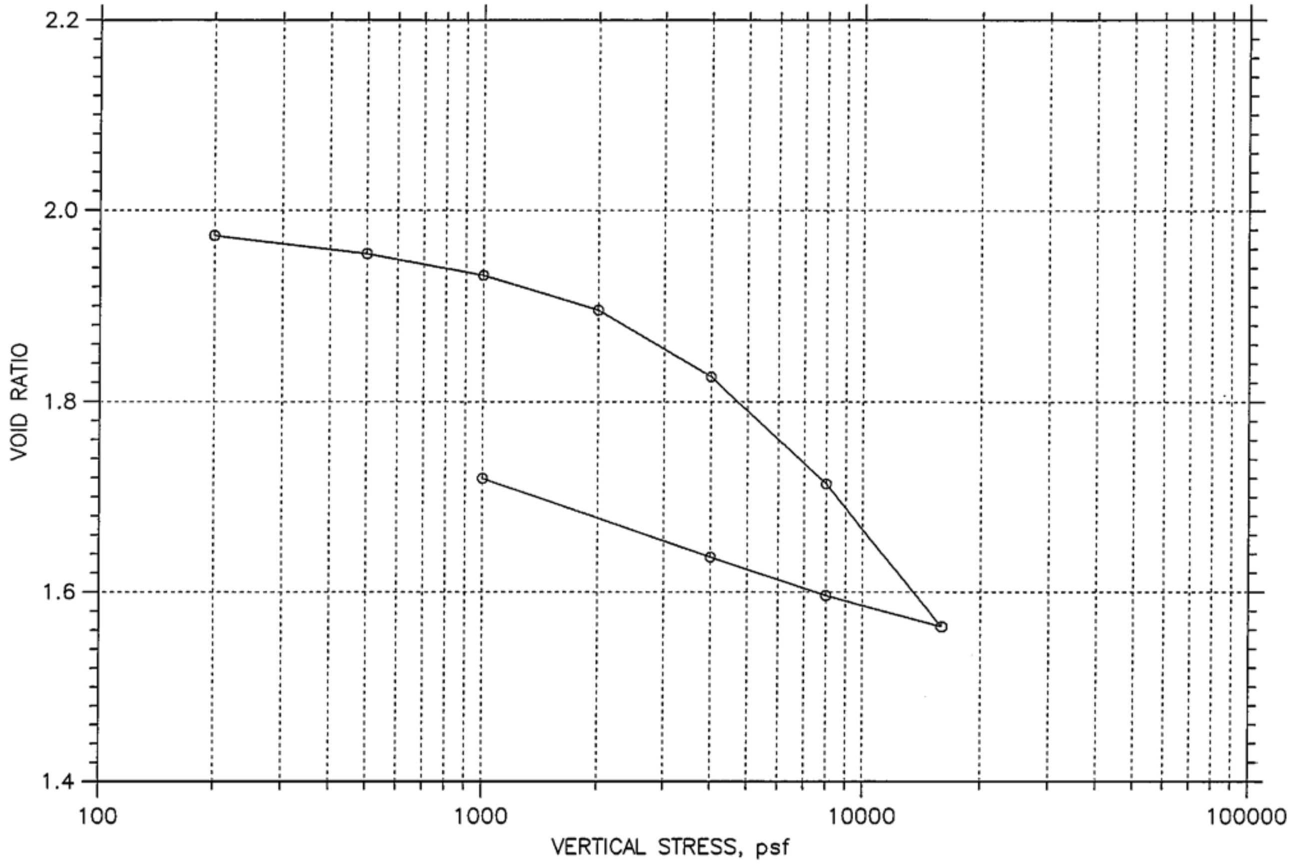
					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	64.28	63.40
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	56.49	61.98
Compression Index: 0				Saturation, %	87.49	99.54
Diameter: 2.5 in		Height: 1.007 in		Void Ratio	1.98	1.72
LL: 128	PL: 54	PI: 74	GS: 2.70			

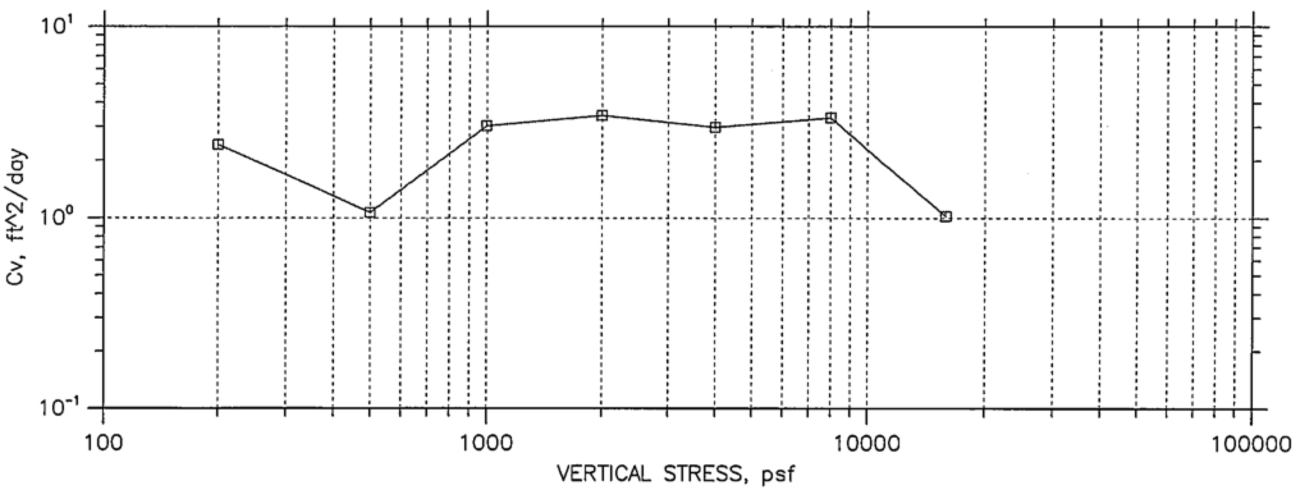
MACTEC	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B04, 55-57 ft	Project No.: 6155080031
	Boring No.: Z-V3V5-B04	Tested By: JW	Checked By: JEJ
	Sample No.: ST5	Test Date: 3/25/09	Depth: 55-57 ft
	Test No.: 9462	Sample Type: Undisturbed	Elevation: N/A
	Description: Yellowish Brown Elastic Silt with Sand (MH)		
	Remarks: ASTM D2435-04		

Thu, 23-APR-2009 10:57:47

CONSOLIDATION TEST DATA

SUMMARY REPORT



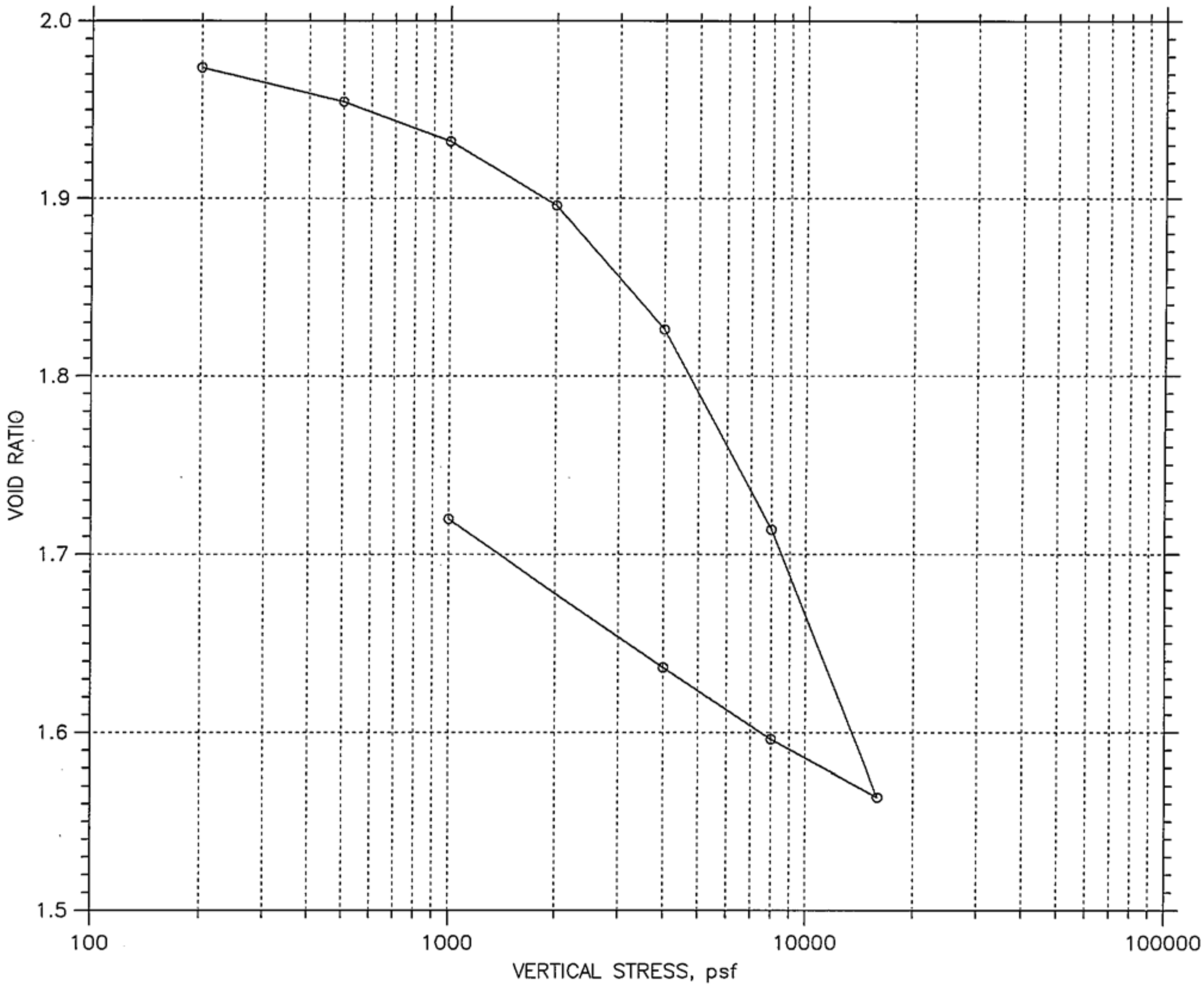


MACTEC			
	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B04, 55-57 ft	Project No.: 6155080031
	Boring No.: Z-V3V5-B04	Tested By: JW	Checked By: JEJ
	Sample No.: ST5	Test Date: 3/25/09	Depth: 55-57 ft
	Test No.: 9462	Sample Type: Undisturbed	Elevation: N/A
	Description: Yellowish Brown Elastic Silt with Sand (MH)		
	Remarks: ASTM D2435-04		

Thu, 23-APR-2009 10:57:55

CONSOLIDATION TEST DATA

SUMMARY REPORT



					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	64.28	63.40
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	56.49	61.98
Compression Index: 0				Saturation, %	87.49	99.54
Diameter: 2.5 in		Height: 1.007 in		Void Ratio	1.98	1.72
LL: 128	PL: 54	PI: 74	GS: 2.70			

MACTEC	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B04, 55-57 ft	Project No.: 6155080031
	Boring No.: Z-V3V5-B04	Tested By: JW	Checked By: JEJ
	Sample No.: ST5	Test Date: 3/25/09	Depth: 55-57 ft
	Test No.: 9462	Sample Type: Undisturbed	Elevation: N/A
	Description: Yellowish Brown Elastic Silt with Sand (MH)		
	Remarks: ASTM D2435-04		

Thu, 23-APR-2009 10:57:55

CONSOLIDATION TEST DATA

Project: Saltstone Vaults 3&5
Boring No.: Z-V3V5-B04
Sample No.: ST5
Test No.: 9462

Location: Z-V3V5-B04, 55-57 ft
Tested By: JW
Test Date: 3/25/09
Sample Type: Undisturbed

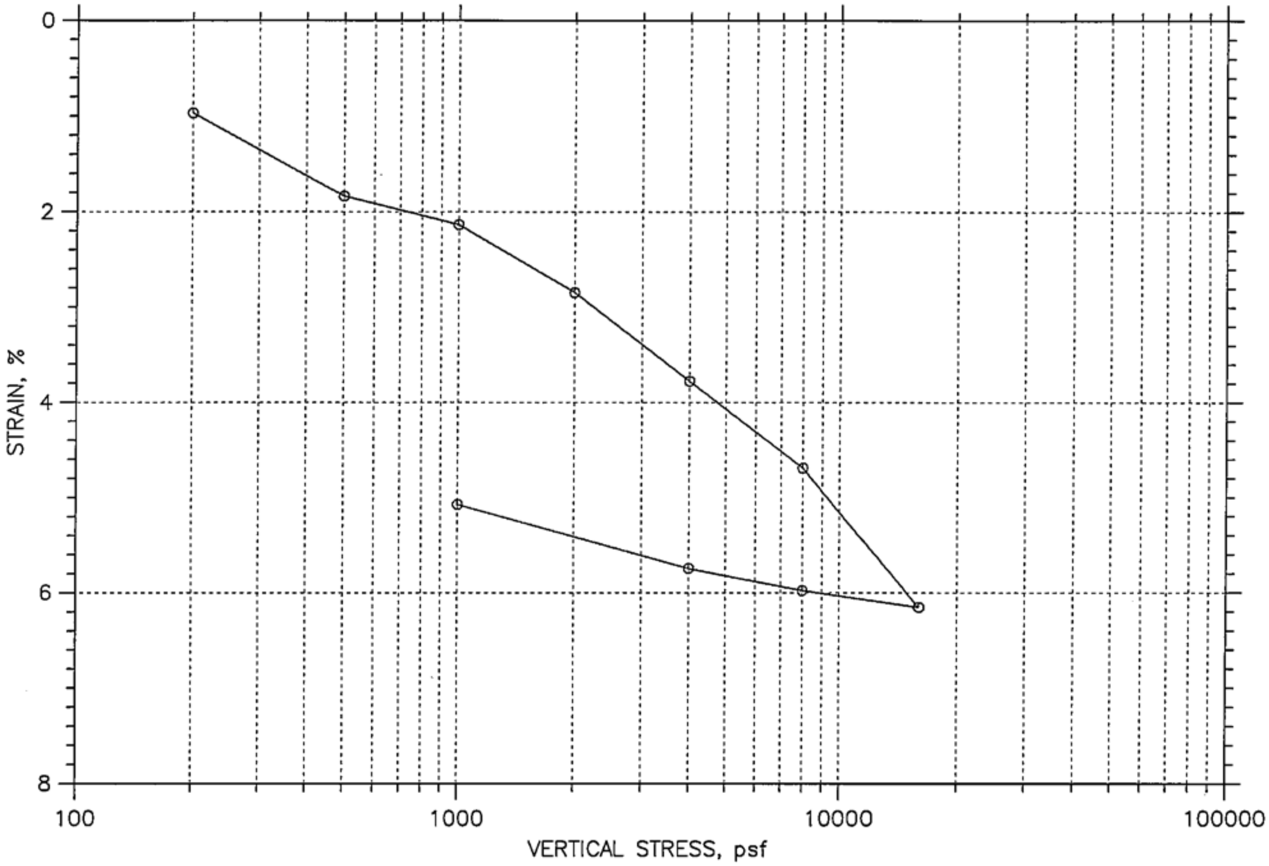
Project No.: 6155080031
Checked By:
Depth: 55-57 ft
Elevation: N/A

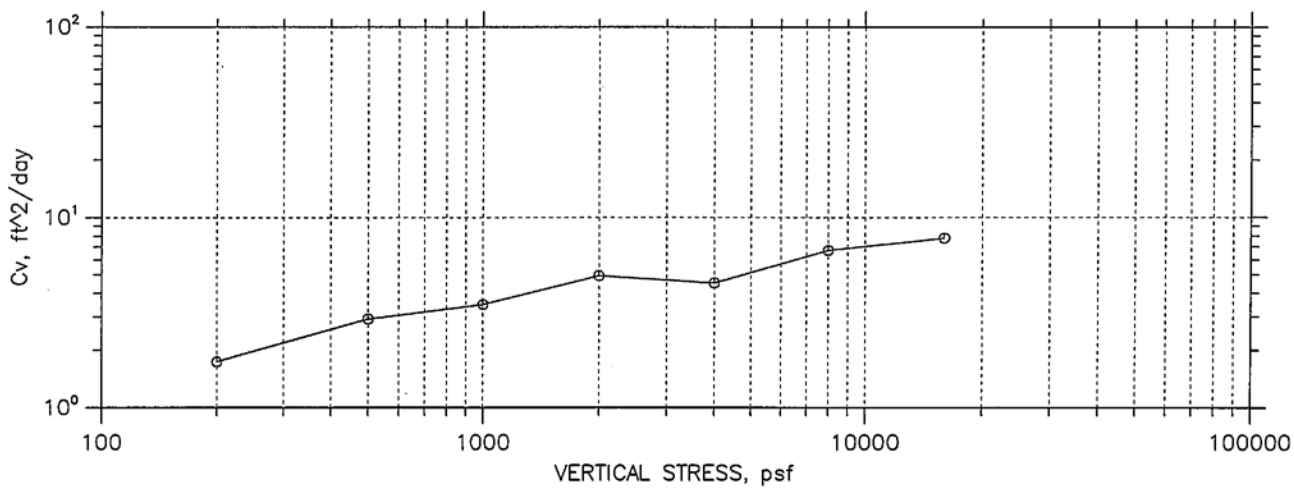
Soil Description: Yellowish Brown Elastic Silt with Sand (MH)
Remarks: ASTM D2435-04

	Applied Stress	Final Displacement	Void Ratio	Strain at End	T50 Fitting		Coefficient of Consolidation		
					Sq.Rt.	Log	Sq.Rt.	Log	Ave.
	psf	in		%	min	min	ft^2/day	ft^2/day	ft^2/day
1	200	0.003401	1.974	0.34	0.2	0.0	2.41e+000	0.00e+000	2.41e+000
2	500	0.009868	1.954	0.98	0.8	0.2	6.51e-001	2.92e+000	1.06e+000
3	1e+003	0.01745	1.932	1.73	0.2	0.2	3.03e+000	3.03e+000	3.03e+000
4	2e+003	0.02967	1.896	2.95	0.1	0.1	3.22e+000	3.66e+000	3.43e+000
5	4e+003	0.05323	1.826	5.29	0.2	0.2	3.02e+000	2.93e+000	2.98e+000
6	8e+003	0.09112	1.714	9.05	0.1	0.1	3.16e+000	3.55e+000	3.34e+000
7	1.6e+004	0.1418	1.563	14.08	0.6	0.1	6.23e-001	2.86e+000	1.02e+000
8	8e+003	0.1308	1.596	12.99	0.9	0.0	4.04e-001	0.00e+000	4.04e-001
9	4e+003	0.1172	1.636	11.64	3.1	0.0	1.23e-001	0.00e+000	1.23e-001
10	1e+003	0.08914	1.720	8.85	3.3	0.0	1.21e-001	0.00e+000	1.21e-001

CONSOLIDATION TEST DATA

SUMMARY REPORT



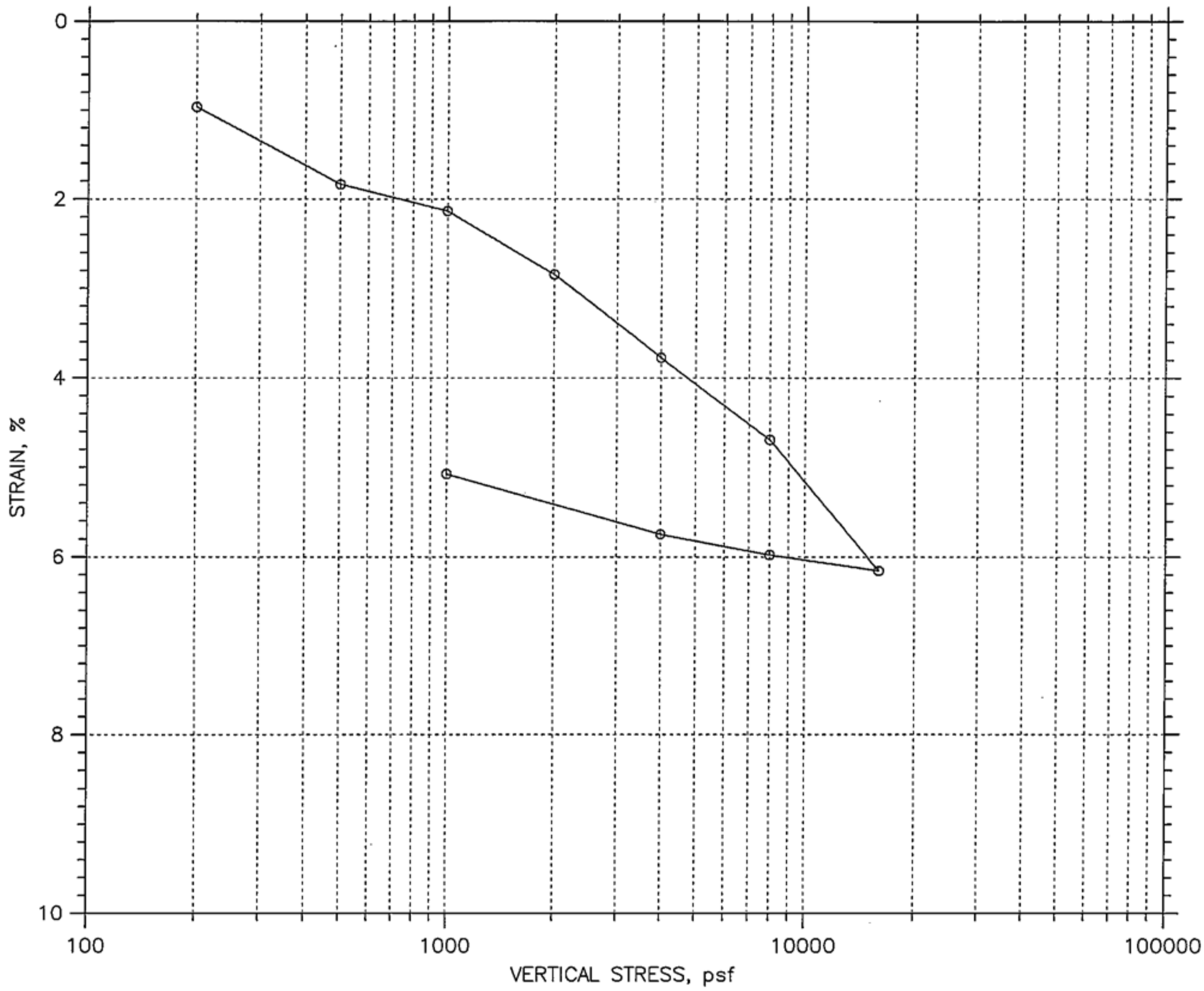


MACTEC	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B04, 84-86 ft	Project No.: 6155080031
	Boring No.: Z-V3V5-B04	Tested By: JW	Checked By: JEJ
	Sample No.: ST6	Test Date: 3/25/09	Depth: 84-86 ft
	Test No.: 9463	Sample Type: Undisturbed	Elevation: N/A
	Description: Tan Silty Sand (SM)		
	Remarks: ASTM D2435-04		

Thu, 23-APR-2009 10:59:51

CONSOLIDATION TEST DATA

SUMMARY REPORT



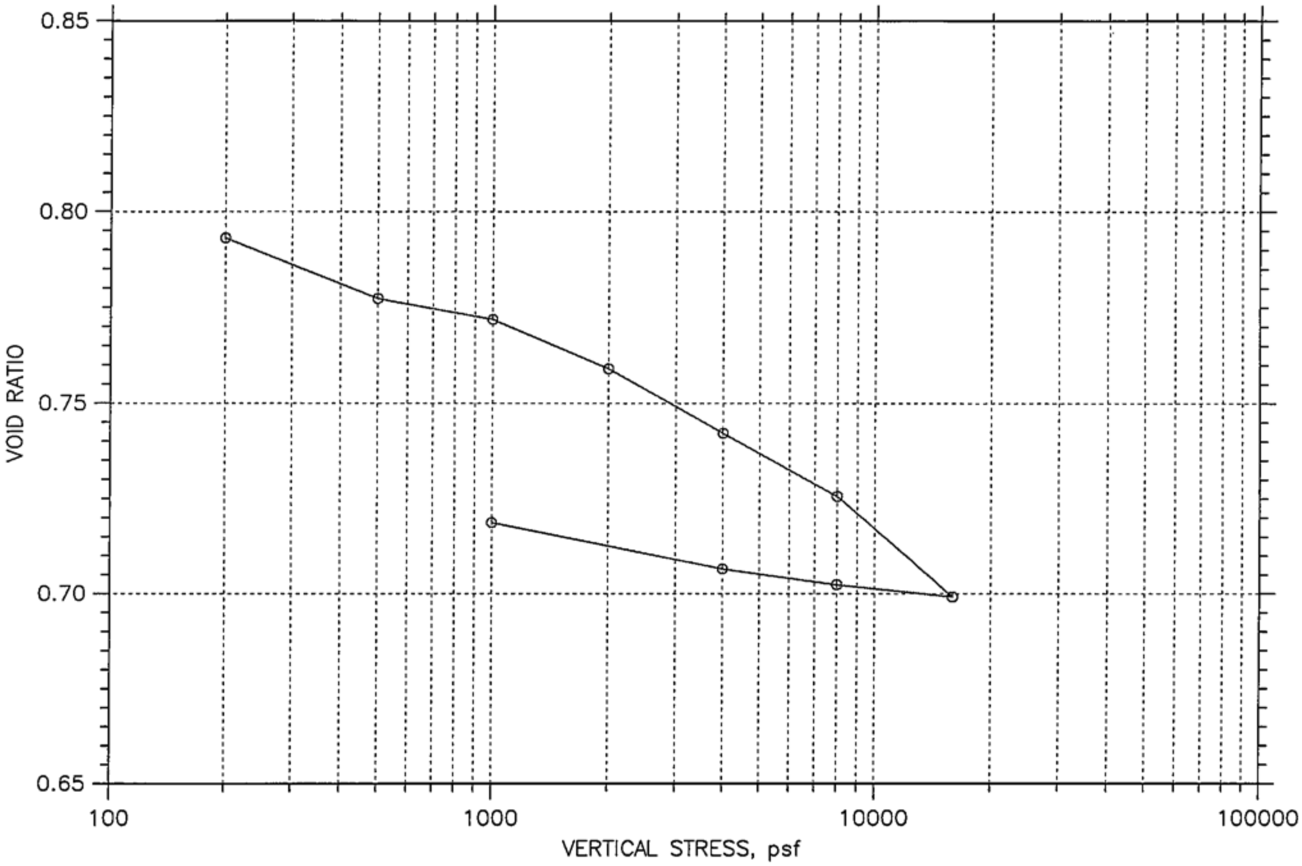
					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	29.76	26.58
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	91.37	96.26
Compression Index: 0				Saturation, %	97.28	98.01
Diameter: 2.499 in		Height: 1.009 in		Void Ratio	0.81	0.72
LL: ---	PL: ---	PI: ---	GS: 2.65			

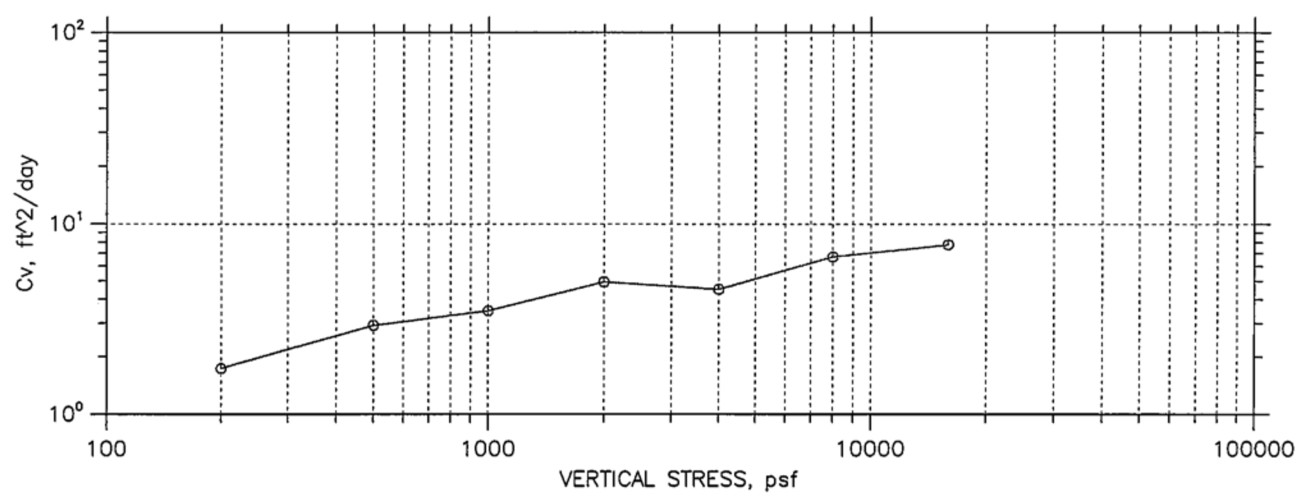
MACTEC			
	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B04, 84-86 ft	Project No.: 6155080031
	Boring No.: Z-V3V5-B04	Tested By: JW	Checked By: JEJ
	Sample No.: ST6	Test Date: 3/25/09	Depth: 84-86 ft
	Test No.: 9463	Sample Type: Undisturbed	Elevation: N/A
	Description: Tan Silty Sand (SM)		
	Remarks: ASTM D2435-04		

Thu, 23-APR-2009 10:59:51

CONSOLIDATION TEST DATA

SUMMARY REPORT



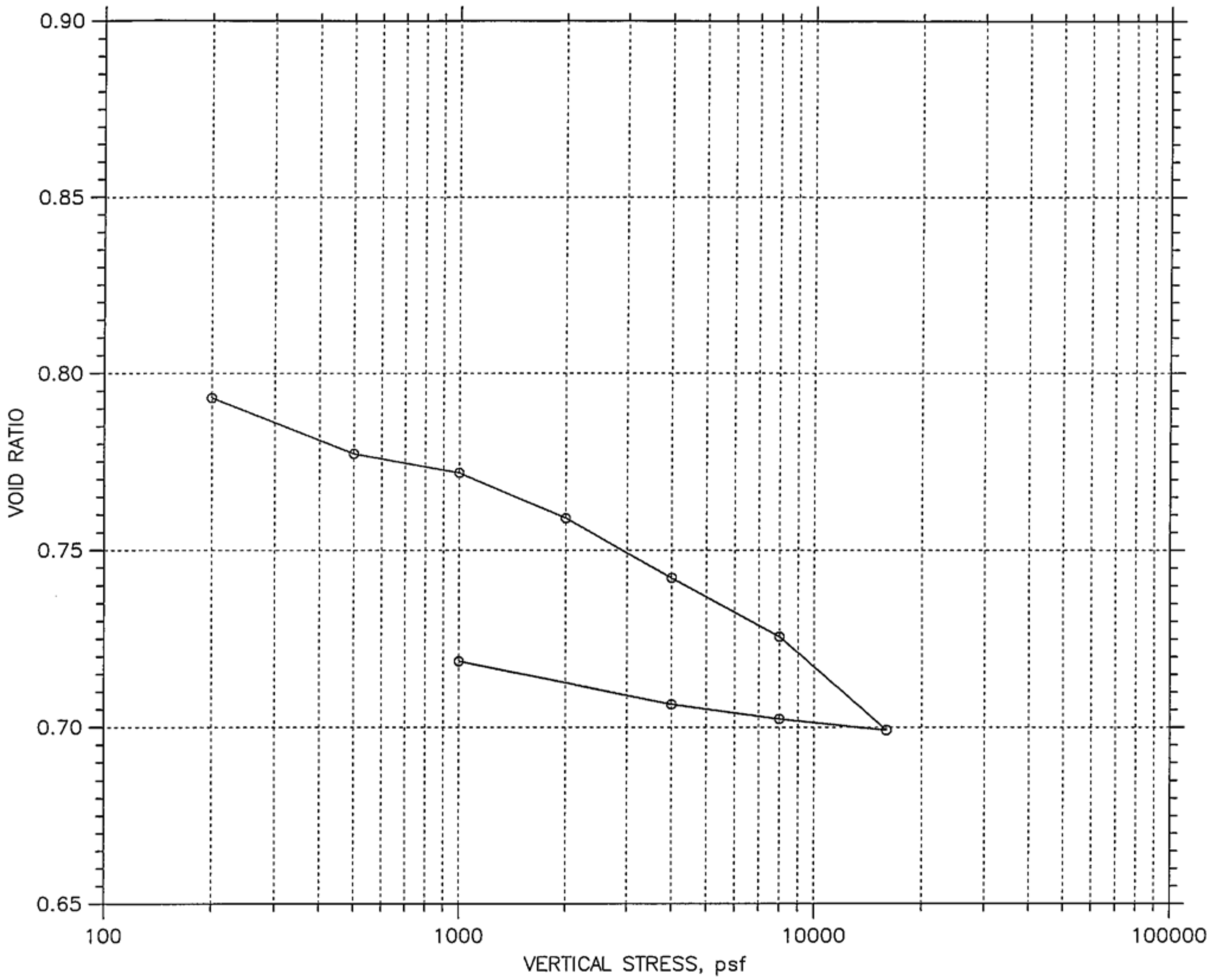


MACTEC			
	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B04, 84-86 ft	Project No.: 6155080031
	Boring No.: Z-V3V5-B04	Tested By: JW	Checked By: JEJ
	Sample No.: ST6	Test Date: 3/25/09	Depth: 84-86 ft
	Test No.: 9463	Sample Type: Undisturbed	Elevation: N/A
	Description: Tan Silty Sand (SM)		
	Remarks: ASTM D2435-04		

Thu, 23-APR-2009 11:00:03

CONSOLIDATION TEST DATA

SUMMARY REPORT



					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	29.76	26.58
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	91.37	96.26
Compression Index: 0				Saturation, %	97.28	98.01
Diameter: 2.499 in		Height: 1.009 in		Void Ratio	0.81	0.72
LL: ---	PL: ---	PI: ---	GS: 2.65			

MACTEC			
	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B04, 84-86 ft	Project No.: 6155080031
	Boring No.: Z-V3V5-B04	Tested By: JW	Checked By: JEJ
	Sample No.: ST6	Test Date: 3/25/09	Depth: 84-86 ft
	Test No.: 9463	Sample Type: Undisturbed	Elevation: N/A
	Description: Tan Silty Sand (SM)		
	Remarks: ASTM D2435-04		

Thu, 23-APR-2009 11:00:03

CONSOLIDATION TEST DATA

Project: Saltstone Vaults 3&5
Boring No.: Z-V3V5-B04
Sample No.: ST6
Test No.: 9463

Location: Z-V3V5-B04, 84-86 ft
Tested By: JW
Test Date: 3/25/09
Sample Type: Undisturbed

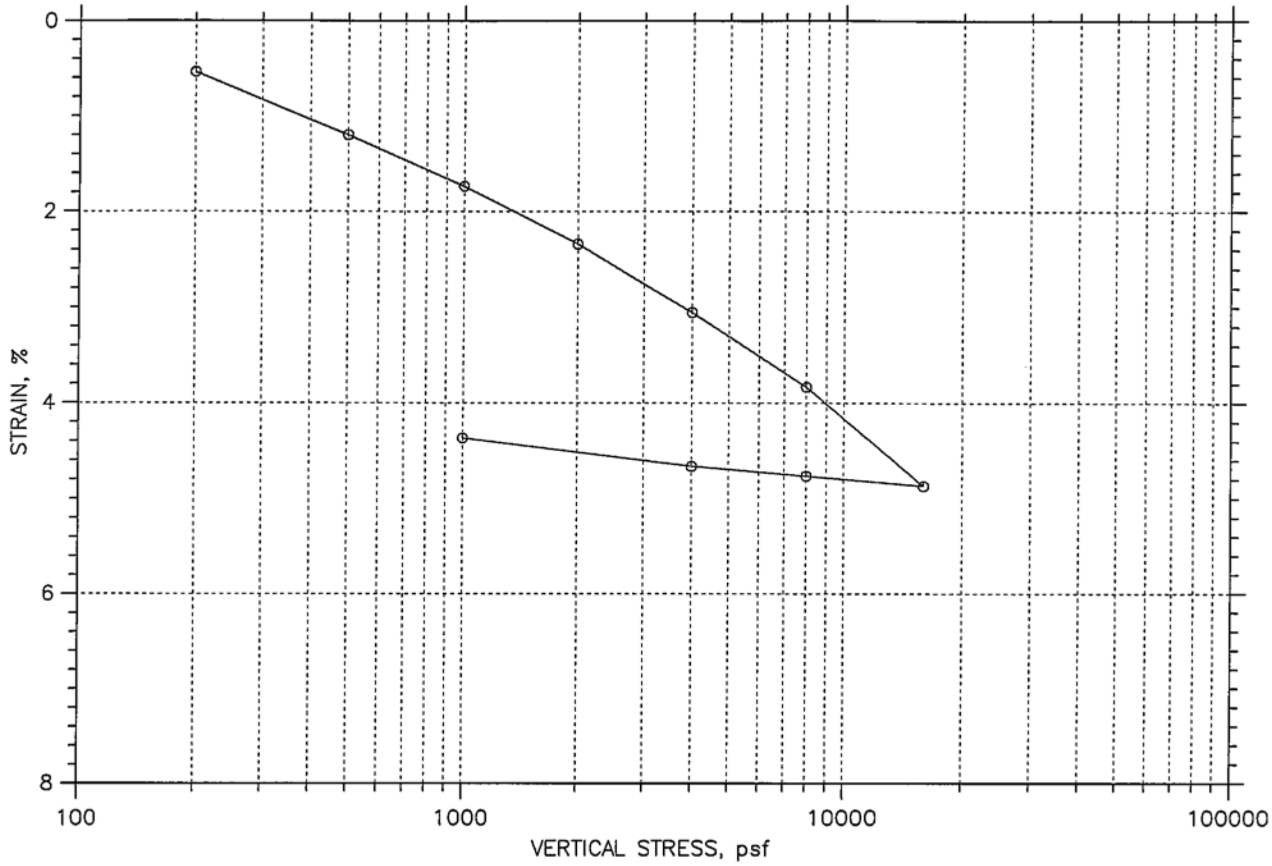
Project No.: 6155080031
Checked By:
Depth: 84-86 ft
Elevation: N/A

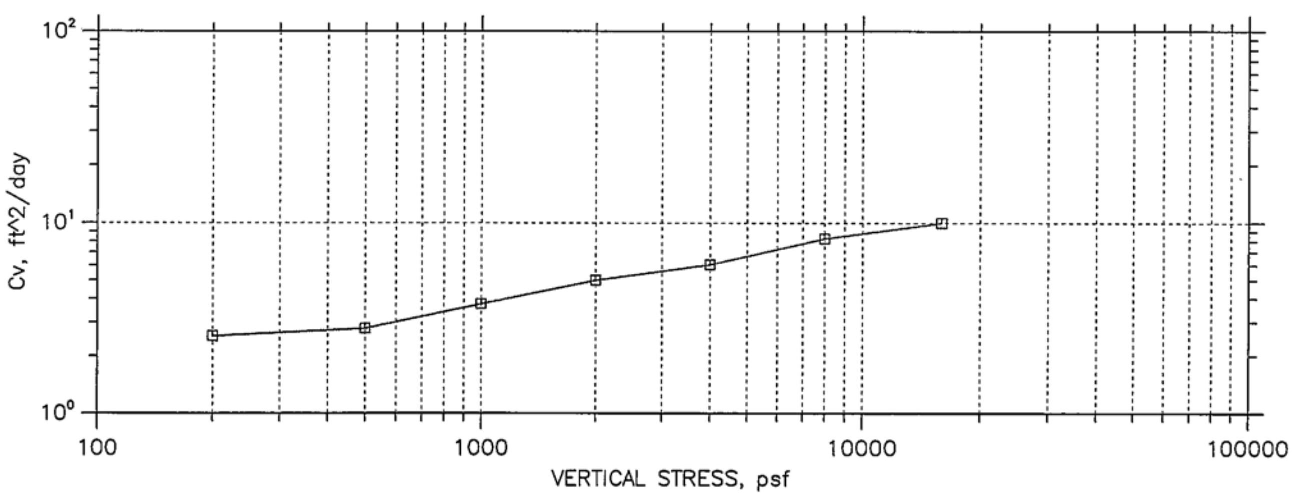
Soil Description: Tan Silty Sand (SM)
Remarks: ASTM D2435-04

	Applied Stress psf	Final Displacement in	Void Ratio	Strain at End %	T50 Fitting Sq.Rt. min	T50 Fitting Log min	Coefficient of Consolidation Sq.Rt. ft^2/day	Coefficient of Consolidation Log ft^2/day	Coefficient of Consolidation Ave. ft^2/day
1	200	0.009773	0.793	0.97	0.3	0.0	1.74e+000	0.00e+000	1.74e+000
2	500	0.01852	0.777	1.84	0.2	0.2	2.92e+000	3.17e+000	3.04e+000
3	1e+003	0.02155	0.772	2.14	0.1	0.1	3.49e+000	3.41e+000	3.45e+000
4	2e+003	0.02872	0.759	2.85	0.1	0.1	4.95e+000	4.67e+000	4.80e+000
5	4e+003	0.03811	0.742	3.78	0.1	0.1	4.53e+000	6.51e+000	5.34e+000
6	8e+003	0.04734	0.726	4.69	0.1	0.1	6.72e+000	7.05e+000	6.88e+000
7	1.6e+004	0.06209	0.699	6.15	0.1	0.1	7.79e+000	8.58e+000	8.17e+000
8	8e+003	0.06032	0.702	5.98	0.0	0.0	1.27e+001	0.00e+000	1.27e+001
9	4e+003	0.05799	0.706	5.75	0.0	0.0	9.50e+000	0.00e+000	9.50e+000
10	1e+003	0.0512	0.719	5.07	0.1	0.1	5.08e+000	7.10e+000	5.93e+000

CONSOLIDATION TEST DATA

SUMMARY REPORT





MACTEC			
	Project: Saltstone Vault 3&5 Lab	Location: Z-V3V5-B01, 50-52 ft	Project No.: 6055080031
	Boring No.: Z-V3V5-B01	Tested By: JW	Checked By: JEF
	Sample No.: ST4	Test Date: 4/3/09	Depth: 50-52 ft
	Test No.: 9479	Sample Type: Undisturbed	Elevation: N/A
	Description: Brown Poorly Graded Sand (SP)		
	Remarks: ASTM D2435-04		

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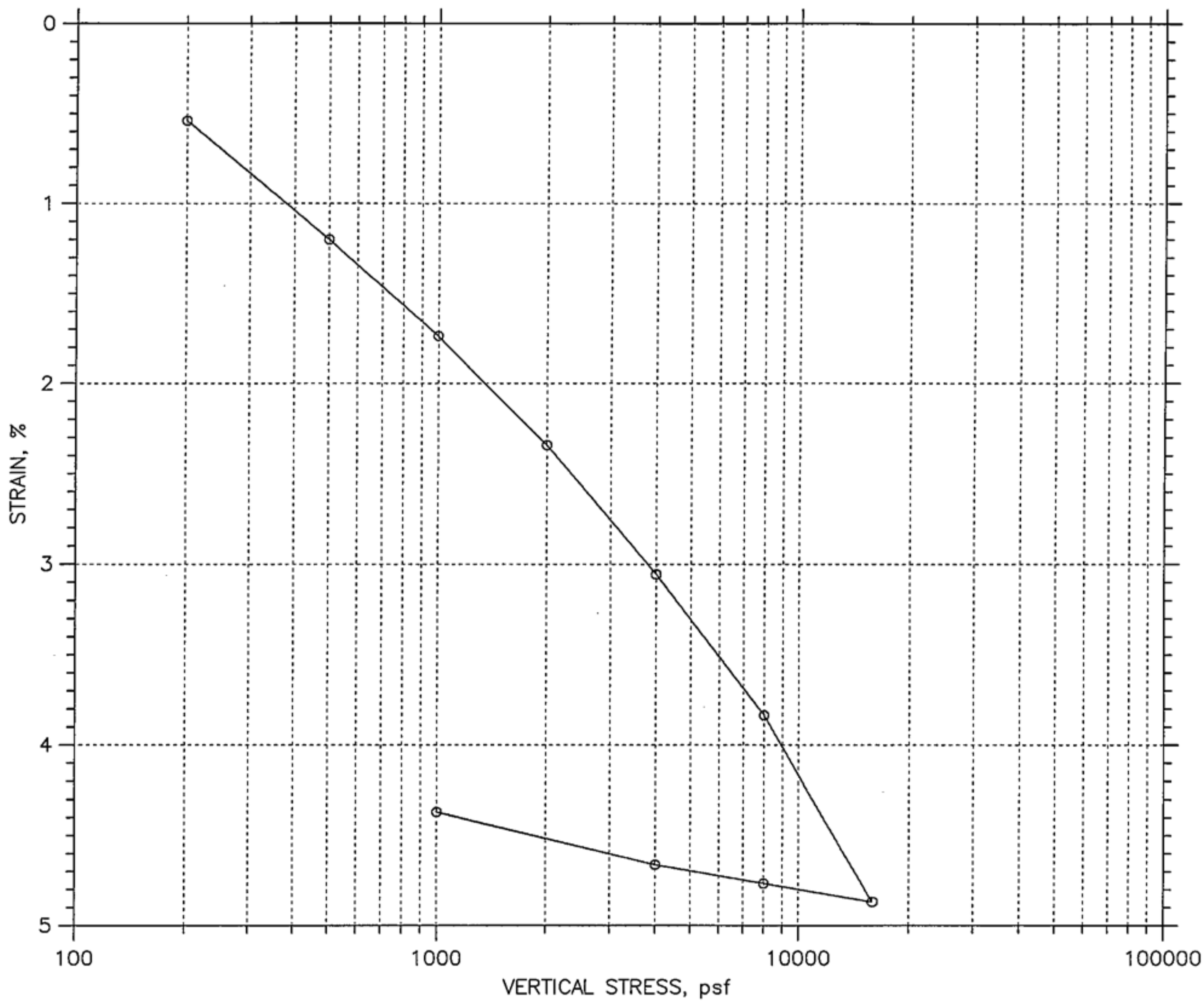
CONSOLIDATION TEST DATA

SUMMARY REPORT



					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	13.29	22.42
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	94.41	98.73
Compression Index: 0				Saturation, %	46.81	87.92
Diameter: 2.499 in		Height: 1.003 in		Void Ratio	0.75	0.68
LL: NP	PL: NP	PI: NP	GS: 2.65			

MACTEC	Project: Saltstone Vault 3&5 Lab	Location: Z-V3V5-B01, 50-52 ft	Project No.: 6055080031
	Boring No.: Z-V3V5-B01	Tested By: JW	Checked By: JGJ
	Sample No.: ST4	Test Date: 4/3/09	Depth: 50-52 ft
	Test No.: 9479	Sample Type: Undisturbed	Elevation: N/A
	Description: Brown Poorly Graded Sand (SP)		
	Remarks: ASTM D2435-04		

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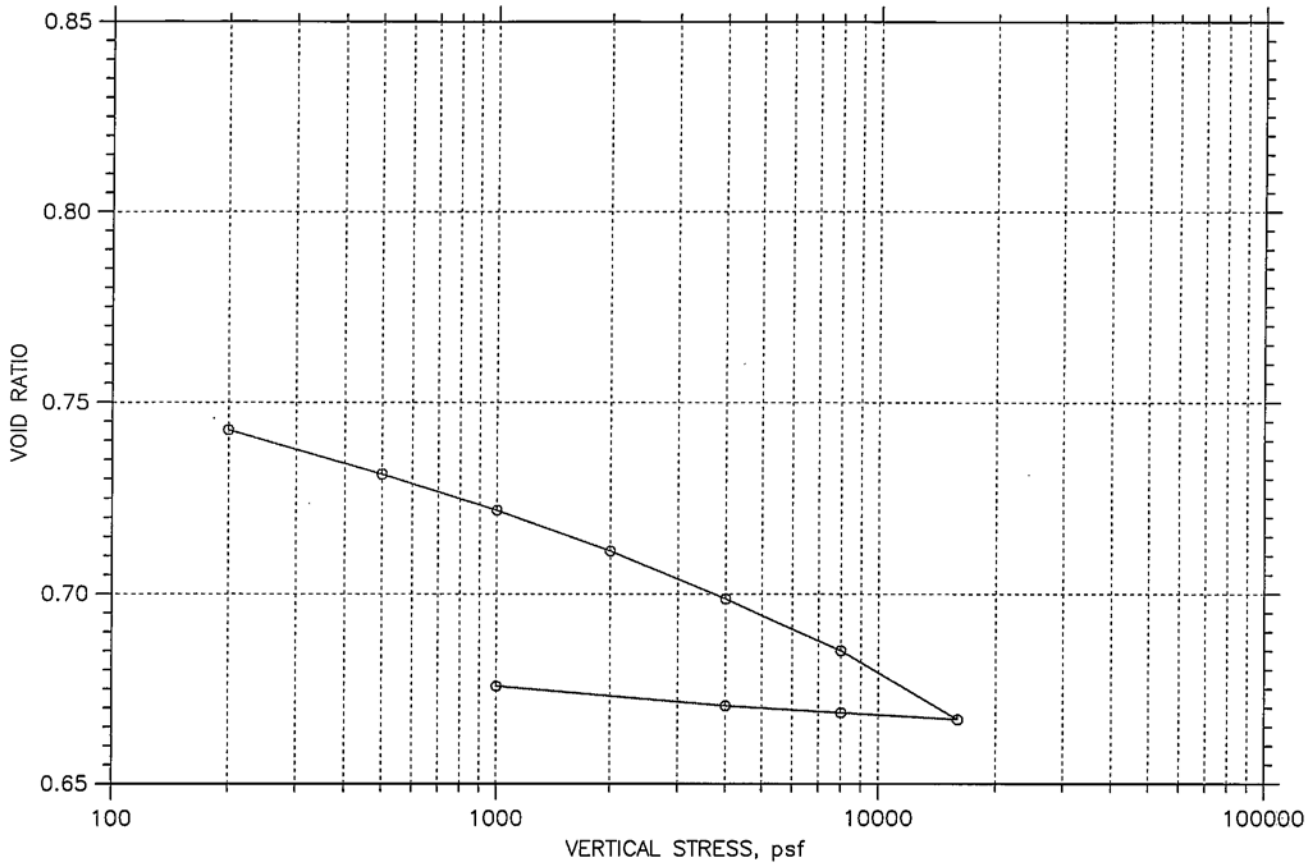

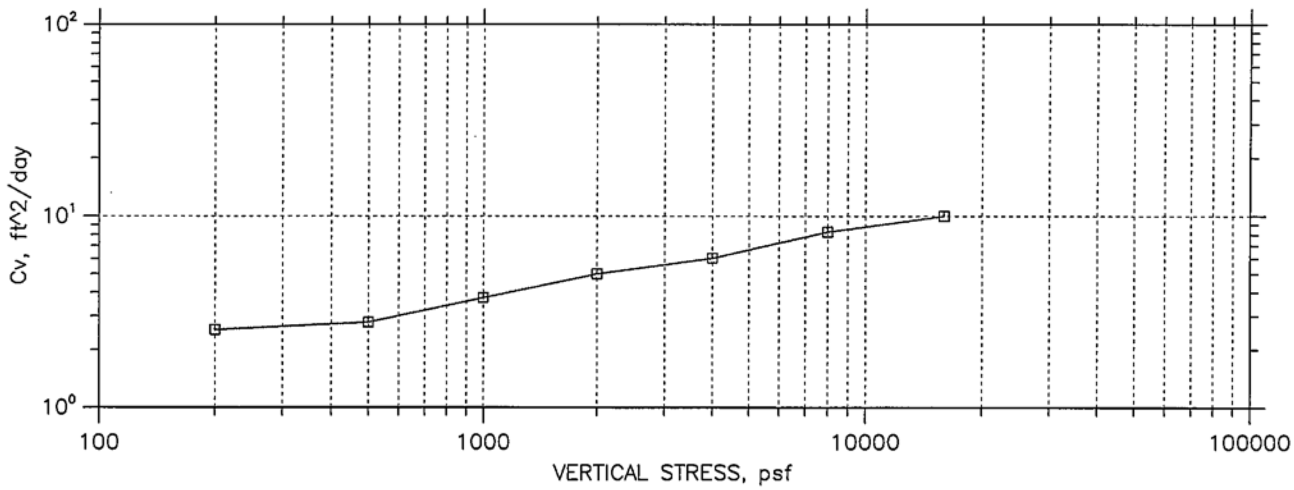

MACTEC	Project: Saltstone Vault 3&5 Lab	Location: Z-V3V5-B01, 50-52 ft	Project No.: 6055080031
	Boring No.: Z-V3V5-B01	Tested By: JW	Checked By: JEJ
	Sample No.: ST4	Test Date: 4/3/09	Depth: 50-52 ft
	Test No.: 9479	Sample Type: Undisturbed	Elevation: N/A
	Description: Brown Poorly Graded Sand (SP)		
	Remarks: ASTM D2435-04		

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CONSOLIDATION TEST DATA

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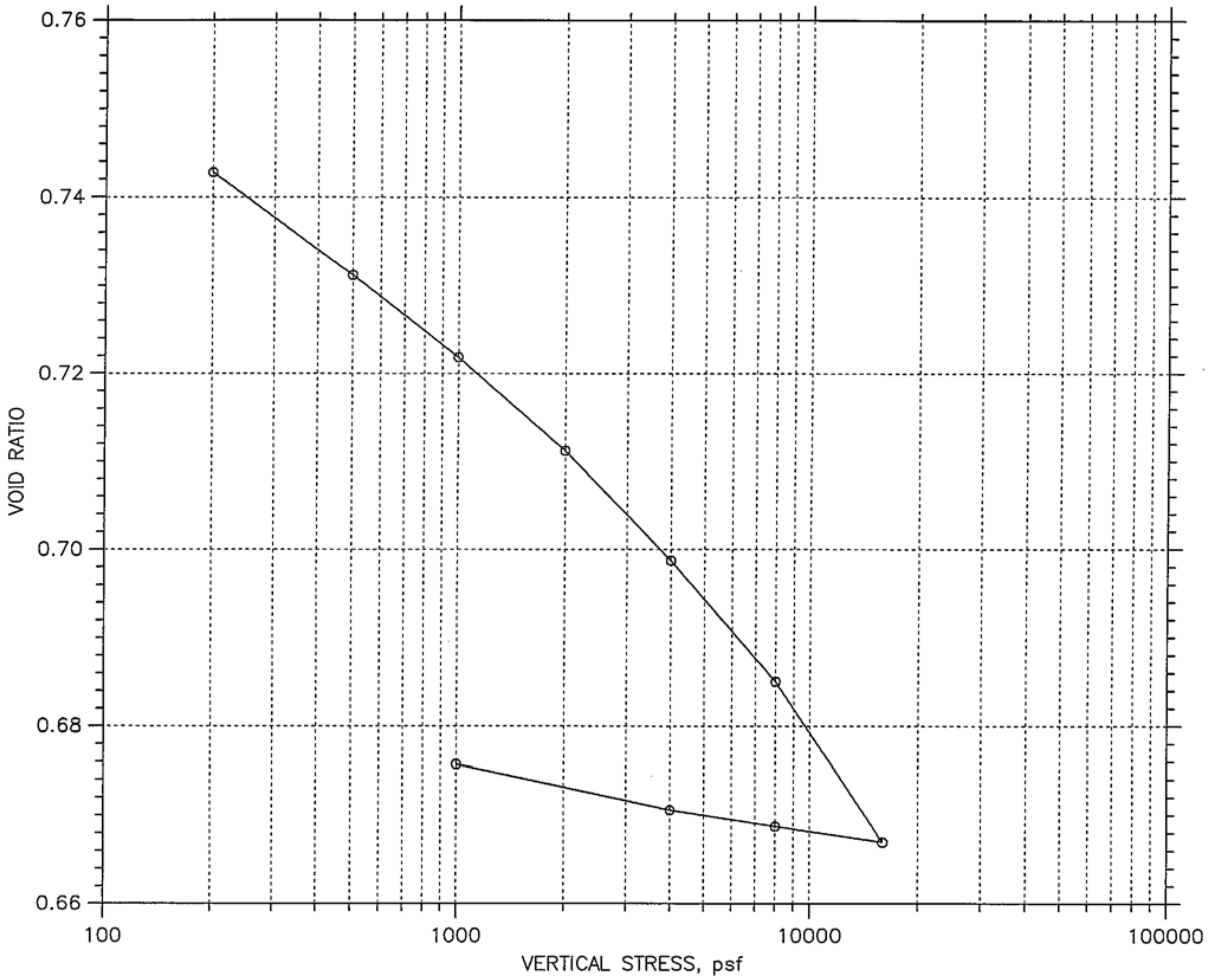

					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	13.29	22.42
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	94.41	98.73
Compression Index: 0				Saturation, %	46.81	87.92
Diameter: 2.499 in		Height: 1.003 in		Void Ratio	0.75	0.68
LL: NP	PL: NP	PI: NP	GS: 2.65			

MACTEC	Project: Saltstone Vault 3&5 Lab	Location: Z-V3V5-B01, 50-52 ft	Project No.: 6055080031
	Boring No.: Z-V3V5-B01	Tested By: JW	Checked By: JEJ
	Sample No.: ST4	Test Date: 4/3/09	Depth: 50-52 ft
	Test No.: 9479	Sample Type: Undisturbed	Elevation: N/A
	Description: Brown Poorly Graded Sand (SP)		
	Remarks: ASTM D2435-04		

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CONSOLIDATION TEST DATA

Project: Saltstone Vault 3&5 Lab T
Boring No.: Z-V3V5-B01
Sample No.: ST4
Test No.: 9479

Location: Z-V3V5-B01, 50-52 ft
Tested By: JW
Test Date: 4/3/09
Sample Type: Undisturbed

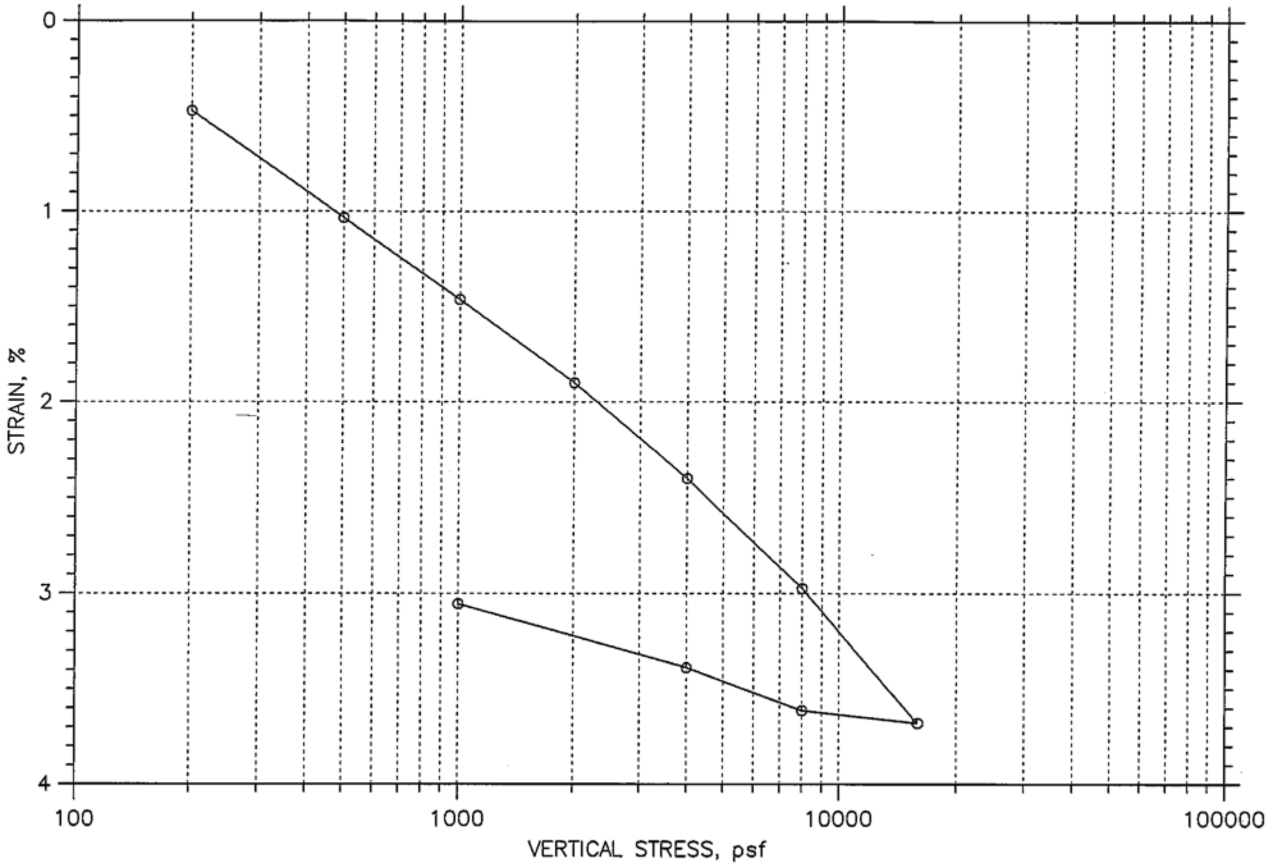
Project No.: 6055080031
Checked By:
Depth: 50-52 ft
Elevation: N/A

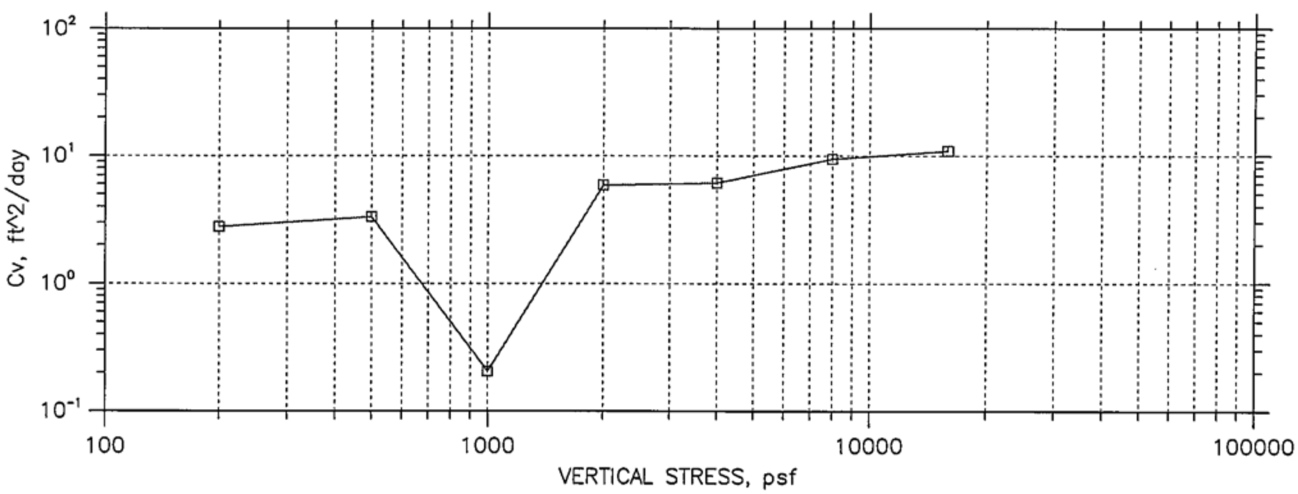
Soil Description: Brown Poorly Graded Sand (SP)
Remarks: ASTM D2435-04

	Applied Stress psf	Final Displacement in	Void Ratio	Strain at End %	T50 Fitting Sq.Rt. min	T50 Fitting Log min	Coefficient of Consolidation Sq.Rt. ft^2/day	Coefficient of Consolidation Log ft^2/day	Coefficient of Consolidation Ave. ft^2/day
1	200	0.00542	0.743	0.54	0.2	0.1	2.06e+000	3.32e+000	2.54e+000
2	500	0.01204	0.731	1.20	0.2	0.0	2.79e+000	0.00e+000	2.79e+000
3	1e+003	0.01742	0.722	1.74	0.1	0.1	3.64e+000	3.88e+000	3.76e+000
4	2e+003	0.0235	0.711	2.34	0.1	0.1	5.00e+000	4.99e+000	5.00e+000
5	4e+003	0.03066	0.699	3.06	0.1	0.1	5.41e+000	6.81e+000	6.03e+000
6	8e+003	0.03848	0.685	3.84	0.1	0.1	8.11e+000	8.42e+000	8.26e+000
7	1.6e+004	0.04883	0.667	4.87	0.1	0.0	8.96e+000	1.12e+001	9.97e+000
8	8e+003	0.0478	0.669	4.77	0.0	0.0	1.33e+001	0.00e+000	1.33e+001
9	4e+003	0.04677	0.671	4.66	0.0	0.0	9.70e+000	0.00e+000	9.70e+000
10	1e+003	0.04383	0.676	4.37	0.1	0.1	7.68e+000	8.78e+000	8.20e+000

CONSOLIDATION TEST DATA

SUMMARY REPORT





MACTEC			
	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B01	Project No.: 6155080031
	Boring No.: Z-V3V5-B01	Tested By: JW	Checked By: JEJ
	Sample No.: ST5	Test Date: 4/3/09	Depth: 55-57 ft
	Test No.: 9480	Sample Type: Undisturbed	Elevation: N/A
	Description: Brown Poorly Graded Sand with Silt (SP-SM)		
	Remarks: ASTM D2435-04		

Thu, 23-APR-2009 10:59:01

CONSOLIDATION TEST DATA
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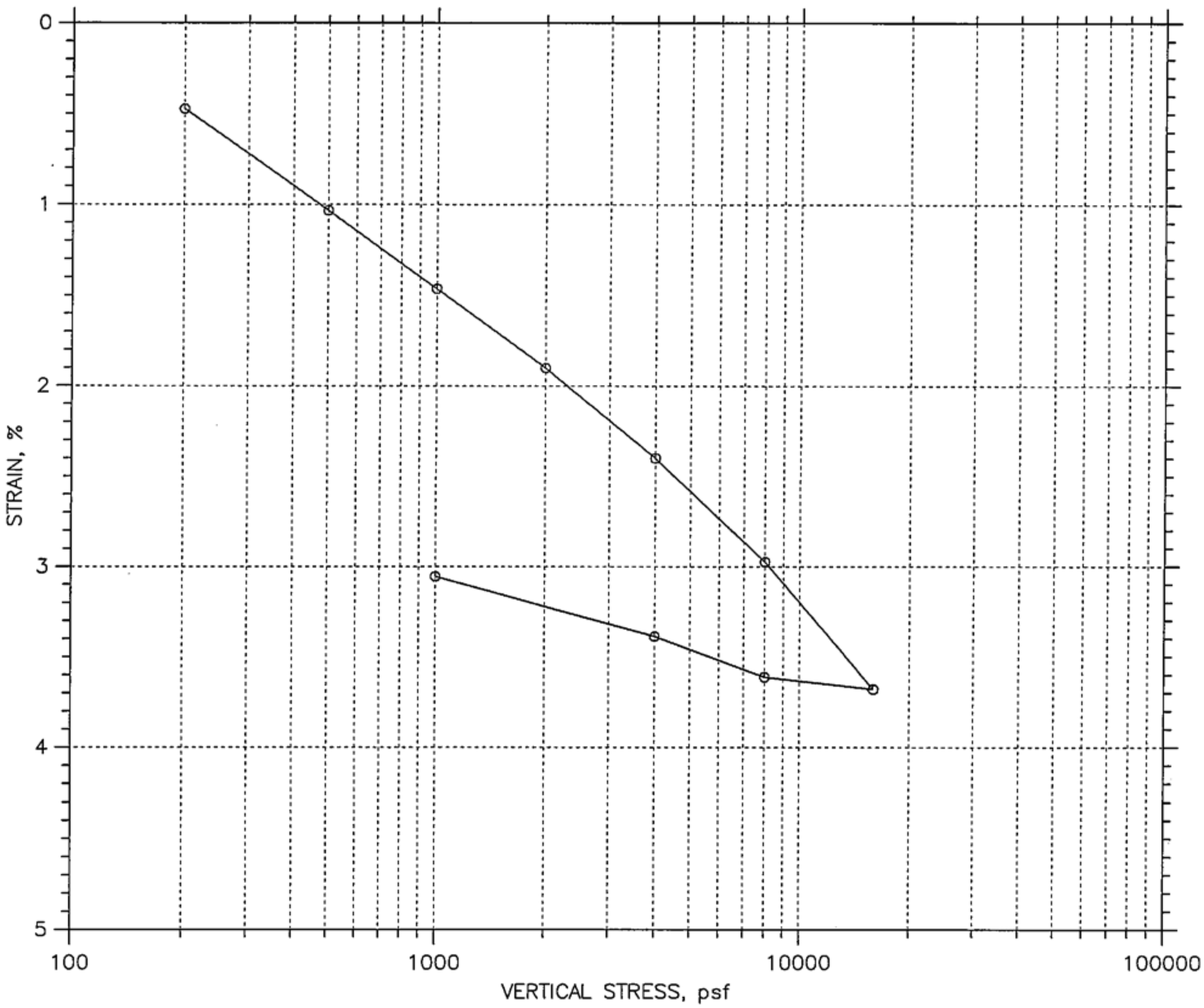

					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	17.91	19.80
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	103.5	106.7
Compression Index: 0				Saturation, %	79.27	95.42
Diameter: 2.5 in		Height: 1.008 in		Void Ratio	0.60	0.55
LL: NP	PL: NP	PI: NP	GS: 2.65			

MACTEC	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B01	Project No.: 6155080031
	Boring No.: Z-V3V5-B01	Tested By: JW	Checked By: JEJ
	Sample No.: ST5	Test Date: 4/3/09	Depth: 55-57 ft
	Test No.: 9480	Sample Type: Undisturbed	Elevation: N/A
	Description: Brown Poorly Graded Sand with Silt (SP-SM)		
	Remarks: ASTM D2435-04		

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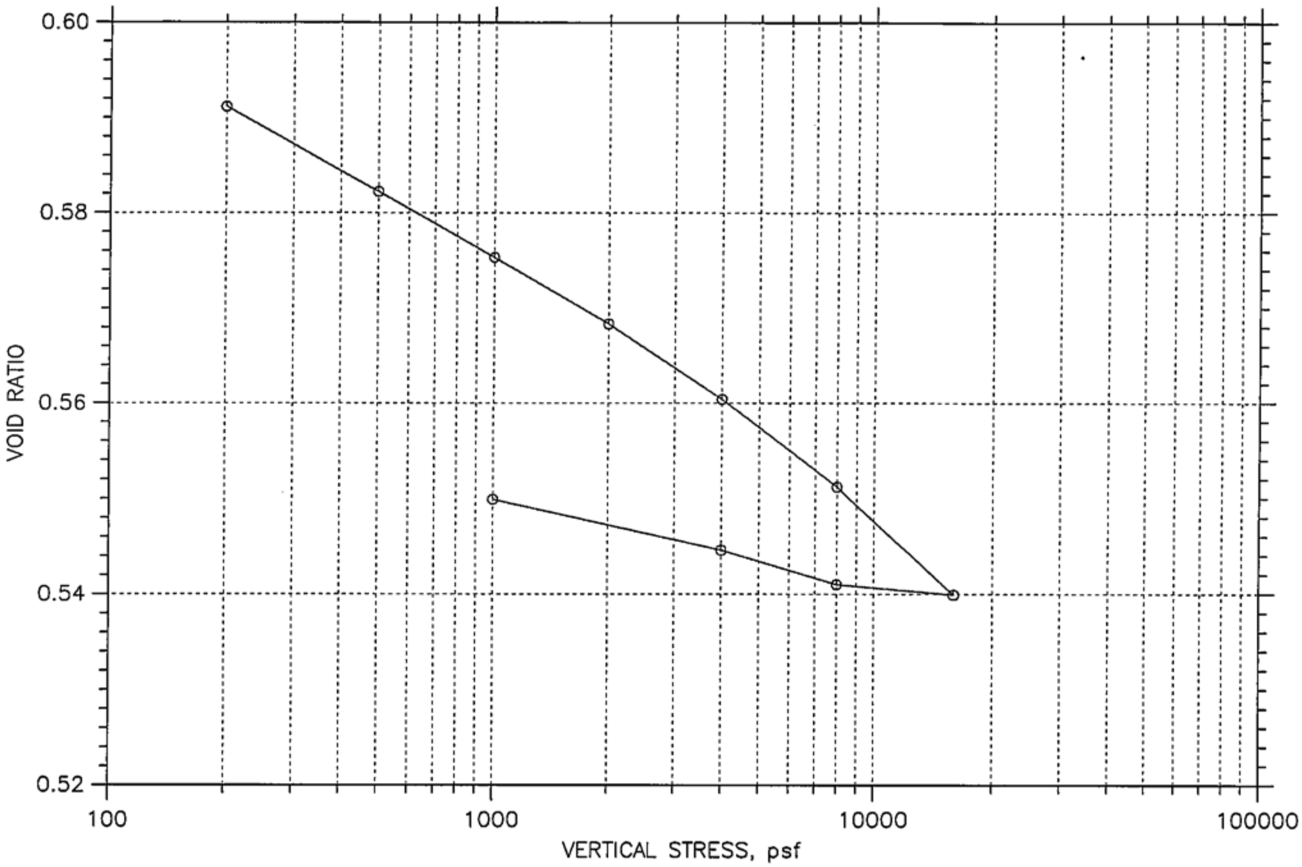

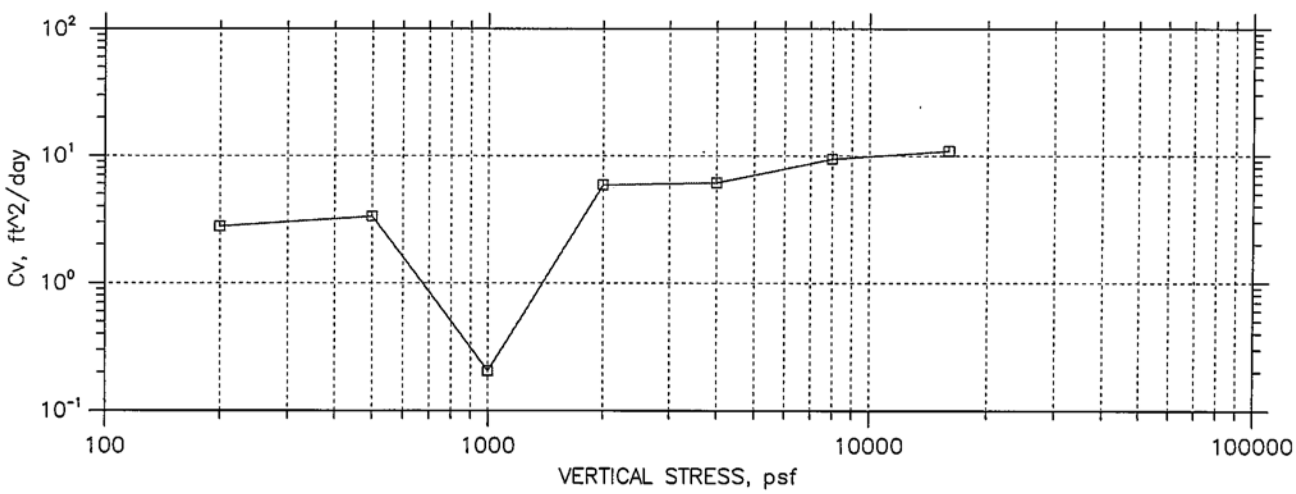

MACTEC			
	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B01	Project No.: 6155080031
	Boring No.: Z-V3V5-B01	Tested By: JW	Checked By: JEJ
	Sample No.: ST5	Test Date: 4/3/09	Depth: 55-57 ft
	Test No.: 9480	Sample Type: Undisturbed	Elevation: N/A
	Description: Brown Poorly Graded Sand with Silt (SP-SM)		
	Remarks: ASTM D2435-04		

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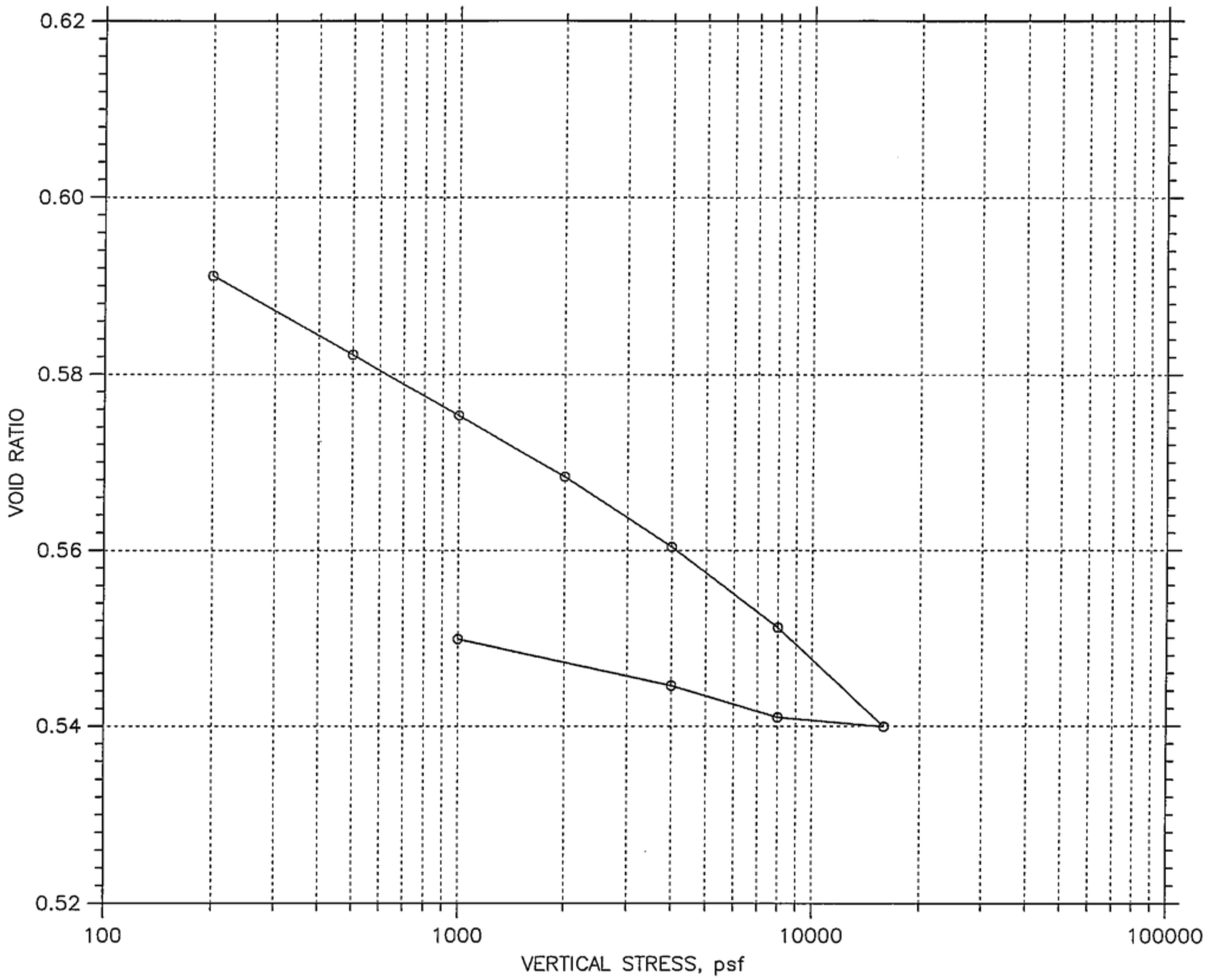


					Before Test	After Test
Overburden Pressure: 0 psf				Water Content, %	17.91	19.80
Preconsolidation Pressure: 0 psf				Dry Unit Weight, pcf	103.5	106.7
Compression Index: 0				Saturation, %	79.27	95.42
Diameter: 2.5 in		Height: 1.008 in		Void Ratio	0.60	0.55
LL: NP	PL: NP	PI: NP	GS: 2.65			

MACTEC	Project: Saltstone Vaults 3&5	Location: Z-V3V5-B01	Project No.: 6155080031
	Boring No.: Z-V3V5-B01	Tested By: JW	Checked By: JGJ
	Sample No.: ST5	Test Date: 4/3/09	Depth: 55-57 ft
	Test No.: 9480	Sample Type: Undisturbed	Elevation: N/A
	Description: Brown Poorly Graded Sand with Silt (SP-SM)		
	Remarks: ASTM D2435-04		

Thu, 23-APR-2009 10:59:11

CONSOLIDATION TEST DATA

Project: Saltstone Vaults 3&5
Boring No.: Z-V3V5-B01
Sample No.: ST5
Test No.: 9480

Location: Z-V3V5-B01
Tested By: JW
Test Date: 4/3/09
Sample Type: Undisturbed

Project No.: 6155080031
Checked By:
Depth: 55-57 ft
Elevation: N/A

Soil Description: Brown Poorly Graded Sand with Silt (SP-SM)
Remarks: ASTM D2435-04

	Applied Stress psf	Final Displacement in	Void Ratio	Strain at End %	T50 Fitting Sq.Rt. min	T50 Fitting Log min	Coefficient of Consolidation Sq.Rt. ft^2/day	Coefficient of Consolidation Log ft^2/day	Coefficient of Consolidation Ave. ft^2/day
1	200	0.004787	0.591	0.47	0.2	0.2	2.46e+000	3.19e+000	2.77e+000
2	500	0.01042	0.582	1.03	0.1	0.1	3.33e+000	3.32e+000	3.33e+000
3	1e+003	0.01476	0.575	1.46	2.4	0.0	2.04e-001	0.00e+000	2.04e-001
4	2e+003	0.01917	0.568	1.90	0.1	0.1	5.86e+000	5.87e+000	5.86e+000
5	4e+003	0.02419	0.560	2.40	0.1	0.0	6.13e+000	0.00e+000	6.13e+000
6	8e+003	0.02998	0.551	2.97	0.1	0.0	8.02e+000	1.14e+001	9.43e+000
7	1.6e+004	0.03709	0.540	3.68	0.0	0.0	9.87e+000	1.20e+001	1.08e+001
8	8e+003	0.03641	0.541	3.61	0.0	0.0	2.29e+001	0.00e+000	2.29e+001
9	4e+003	0.03415	0.545	3.39	0.0	0.0	1.78e+001	0.00e+000	1.78e+001
10	1e+003	0.0308	0.550	3.06	0.0	0.0	1.04e+001	0.00e+000	1.04e+001

ATTACHMENT 2

Equipment List
WSRC Delivery Order No. 6
Subcontract No. AC54317N

Equipment Name	Laboratory ID
Oven	144
Pressure Transducer	2773/2774
Caliper	2424
Pressure Gage	2633/2634
Balance	416/418
Thermometer	2759
Geocomp	2583/2582/2581
Geocomp	2547/2546/2580
Geocomp	2581/2545/2575/2578/2579
Sieve Shaker	529
Hydrometer	2151
Liquid Limit Device	101
Mechanical Rammer	2021
Proctor Mold	2216

Appendix C – Bearing Capacity and Static Settlements

K-CLC-Z-00014, Rev. 0

July 2009

Bearing Capacity and Static Settlement Calculations for Saltstone Disposal Cells 3 and 5

(96 pages)

CALCULATION COVER SHEET

Project **Disposal Cells 3 and 5**	Calculation No. **K-CLC-Z-00014**	Project Number Y546
Title **Bearing Capacity and Static Settlement Calculations for Saltstone Disposal Cells 3 and 5**	Functional Classification **PS** Discipline **Geotechnical**	Sheet 1 of 95
Calc Level ☒ Type 1 ☐ Type 2	Type 1 Calc Status ☐ Preliminary ☒ Confirmed	
Computer Program No. ☒ N/A	Version / Release No. N/A	
Purpose and Objective The purpose of this calculation is to provide bearing capacity and static settlement analysis for the Saltstone Disposal Cells 3 and 5 project.	DC/RO UNCLASSIFIED DOES NOT CONTAIN UNCLASSIFIED CONTROLLED NUCLEAR INFORMATION ADC & Reviewing Official: A.A. Siddall (Name) Date: 7/23/2009	

Summary of Conclusion

See the Results and Conclusions Section.

Revision

Rev. No.	Revision Description
0	Original

Sign Off

Rev. No.	Originator (Print) Sign / Date	Verification / Checking Method	Verifier / Checker (Print) Sign / Date	Manager (Print) Sign / Date
0	Rucker J. Williams 7-20-09	Document Review	John Lydon 7.21.09	William T. Li 7-21-09

Additional Reviewer (Print)	Signature	Date
N/A		
Design Authority (Print)	**Signature**	**Date**
N/A		
Release to Outside Agency (Print)	**Signature**	**Date**
N/A		

Security Classification of the Calculation
Unclassified

TABLE OF CONTENTS

1. Introduction

The purpose of this calculation is to provide the bearing capacity and the static settlement for the Saltstone Disposal Cells 3 and 5 facilities. See Figure 1 for the general location of Disposal Cells 3 and 5. This calculation was performed to support the permitting and engineering design of Disposal Cells 3 and 5.

2. Input

2.1 Facility Configuration

Each of the disposal cells consists of two 150' diameter reinforced concrete tanks.

The following are used for Disposal Cells 3 and 5:

- Bottom of Mud Mat Elevation: 261 ft, msl (Ref. 1)
- Excavation Dimensions: 400 ft by 450 ft (Ref. 1)
- Tank diameter: 150 ft (Ref. 2, 3.2.1.7)
- Tank height: 22 ft (Ref. 2, 3.2.1.7)
- Weight of fluid Saltstone: 110 psf (Ref. 2, 3.1.2.1)
- Closure Cap Thickness: 10 ft to 23.5 ft (Ref. 2 & 3, 3.2.1.3)

Note, the excavation dimensions are approximate. The values given in Appendix A are 390 feet by 430 feet.

2.2 Stratigraphy

The ground surface elevation at the project site ranges from 263 ft to 275 ft, msl, based on CPT surface elevations and SRS topographic maps. Groundwater elevation at the site ranges from 215 to 220 ft, msl (Ref. 4). See Figures 1 and 2 for a site location plan and the layout of the disposal cells.

Four (4) geotechnical borings, two undisturbed borings and 2 Standard Penetration Test (SPT) borings, were performed for the Disposal Cells 3 and 5 site, see Figure 2. Stratigraphic interpretations were made for the two SPT borings. Seventeen (17) CPTs and and SCPTs were pushed for the Disposal Cells 3 and 5 site, see Figure 2. Stratigraphic interpretations of the borings, CPTs, and SCPTs are summarized below (Ref. 5).

ID	CPT Type	SRS Northing	SRS Easting	Elevation ft, msl	Elevation Top Pick (ft, msl) C2 Layer	S3 Layer	S4 Layer	Congaree
ZV3V5C1	SCPT	78429	66907	264.9	NP	224	185	
ZV3V5C2	CPT	78267	66960	268.6	221	215	184	
ZV3V5C3	CPT	78477	66813	263.9	NP	219	190	
ZV3V5C4	SCPT	78405	66836	266.8	NP	221	186	
ZV3V5C5	CPT	78325	66863	268.8	226	221	186	
ZV3V5C6	SCPT	78244	66889	268.8	229	217	187	144
ZV3V5C7	SCPT	78173	66913	268.2	233	223	NDE	
ZV3V5C8	CPT	78374	66741	267.7	220	216	186	
ZV3V5C9	SCPT	78293	66768	270.4	225	216	173	
ZV3V5C10	CPT	78213	66794	270.7	227	211	178	144
ZV3V5C11	SCPT	78414	66623	264.7	218	215	185	
ZV3V5C12	SCPT	78343	66646	268.1	219	216	186	
ZV3V5C13	CPT	78262	66673	272.0	225	221	184	
ZV3V5C14	SCPT	78181	66699	273.0	228	216	186	
ZV3V5C15	CPT	78110	66723	271.6	231	220	178	
ZV3V5C16	CPT	78319	66575	268.7	NP	228	186	
ZV3V5C17	SCPT	78158	66628	274.6	228	219	186	
ZV3V5B01	Boring	78395	66839	266.9	No Stratigraphy – Undisturbed Sampling			
ZV3V5B02	Boring	78235	66894	269.9	228	218	188	145
ZV3V5B03	Boring	78333	66649	268.3	221	216	183	148
ZV3V5B04	Boring	78171	66702	272.8	No Stratigraphy – Undisturbed Sampling			

2.3 Soil Properties

Total unit weights for soils beneath Disposal Cells 3 and 5 range from 92 to 130 pcf. The recommended value for in situ soils is 120 pcf (Ref. 6). The recommended maximum dry density for compacted fill material is 120 pcf (Ref. 6), however a conservative estimate of 125 pcf will be used to estimate overburden pressures.

Shear stress parameters for effective stress conditions are summarized in the table below. The shear strength values are based on the data provided in Reference 6.

Unit Weight	
Undisturbed Soils	120 pcf
Compacted Fill	125 pcf

Effective Shear Strength (All layers except Fill)	
Effective Friction Angle	30°
Effective Cohesion	200 psf

Consolidation Parameters (C2 Layer only))	
Compression Index	0.42
Recompression Index	0.11

3. Computations

The following sections provide the bearing capacity and static settlement calculations for an individual tank (150 feet diameter) and for the excavation (400 feet by 450 feet).

3.1 Bearing Capacity

This section provides the bearing capacity parameters including ultimate bearing capacity, allowable static bearing capacity, design bearing capacity, allowable dynamic bearing capacity, and the strength reduction factor. Bearing capacity results are summarized in Table 1.

3.1.1 Ultimate Bearing Capacity

For $\phi > 0°$, the ultimate bearing capacity q_u is computed using the equations originated by Terzaghi and later modified by others. Hansen's correction factors were used for this calculation, as they result in more conservative estimates of bearing capacity (Ref. 7).

$$q_u = cN_c S_c D_c I_c G_c B_c + q_q N_q S_q D_q I_q G_q B_q + \frac{\gamma_z B}{2} N_\gamma S_\gamma D_\gamma I_\gamma G_\gamma B_\gamma r \quad \text{(Terzaghi)}$$

where c = cohesion,

q_q = overburden or surcharge pressure at the foundation base,

γ_z = effective unit weight of soil below the foundation base,

B = foundation width,

r_γ = foundation width reduction factor.

N_c, N_q, and N_γ are bearing capacity factors; S_c, S_q, and S_γ are foundation shape factors; D_c, D_q, and D_γ are depth factors; I_c, I_q, and I_γ are load inclination factors; B_c, B_q, and B_γ are foundation base inclination factors; and G_c, G_q, and G_γ are ground inclination factors.

The bearing capacity factors N_c, N_q, and N_γ suggested by Hansen are:

$$N_c = \cot\phi (N_q - 1)$$

$$N_q = e^{\pi \tan\phi} \tan^2\left(45° + \frac{\phi}{2}\right)$$

$$N_\gamma = 1.5(N_q - 1)\tan\phi$$

The shape factors S_c, S_q, and S_γ suggested by Hansen are:

$S_c = 0$ For $L/B \geq 10$, any ϕ

$S_c = 0.2\dfrac{B}{L}$ For $\phi = 0°$, $L/B < 10$

$S_c = 1 + \dfrac{B}{L}\dfrac{N_q}{N_c}$ For $\phi > 0°$, $L/B < 10$

$S_q = 1 + \dfrac{B}{L}\tan\phi$ For any ϕ

$S_\gamma = 1$ For $\phi = 0°$

$S_\gamma = 1 - 0.4\dfrac{B}{L}$ For $\phi > 0°$

The depth factors D_c, D_q, and D_γ for D < B suggested by Hansen are:

$D_c = 0.4k$ For $\phi = 0°$

$D_c = 1 + 0.4k$ For $\phi > 0°$

$D_q = 1 + 2\tan\phi(1 - \sin\phi)^2 k$

$D_\gamma = 1$

$$k = \frac{D}{B} \text{ for } \frac{D}{B} \leq 1 \text{ or } \tan^{-1}\left(\frac{D}{B}\right) \text{ for } \frac{D}{B} > 1 \text{ (in radians)}$$

For this calculation level ground surface, and uniform loading were used; i.e. ground inclination (G_c, G_q, and G_γ), load inclination (I_c, I_q, and I_γ), and base inclination (B_c, B_q, and B_γ) factors are 1.0 for $\phi > 0°$ (Ref. 7).

Since the distance to the groundwater table is less than the width of the foundation, the effective unit weight of the soil beneath the foundation is determined by the following equation (Ref. 8):

$$\gamma_z = (\gamma_{bf} - \gamma_w) + \frac{D_w - D}{B}\gamma_w$$

For foundation widths less than 6 feet, the r_γ is 1.0. For foundation widths greater than or equal to 6 feet, the following reduction factor is applied to the calculated ultimate bearing capacity (Ref. 7):

$$r_\gamma = 1 - \frac{\log(B/6)}{4}$$

3.1.2 Allowable Static Bearing Capacity

The allowable bearing capacity is calculated by applying a factor of safety to the ultimate bearing capacity. The factor of safety used in this calculation is 3.0 (Ref. 9).

$$q_a = \frac{q_u}{FS}$$

3.1.3 Allowable Dynamic Bearing Capacity

The dynamic bearing capacity is determined by increasing the allowable static bearing capacity by a factor of one-third (Ref. 9).

$$q_{dyn} = 1\tfrac{1}{3} q_a$$

3.1.4 Design Bearing Capacity

The design bearing capacity q_Φ, used for Load and Resistance Factored Design (LRFD), was computed with the same equations as the ultimate bearing capacity. A strength reduction factor was applied to the soil strength parameters cohesion and effective friction angle. A cohesion reduction factor (f_c) of 0.5 was applied to the cohesion and a friction reduction factor (f_ϕ) of 0.8 was applied to the tangent of the friction angle as shown in the following equations (Ref. 8):

$$c_{red} = f_c c$$

$$\phi_{red} = \tan^{-1}\left(f_\phi \tan\phi\right)$$

$$q_\Phi = c_{red} N_c S_c D_c I_c G_c B_c + q_q N_q S_q D_q I_q G_q B_q + \frac{\gamma_z B}{2} N_\gamma S_\gamma D_\gamma I_\gamma G_\gamma B_\gamma r \quad \text{(Terzaghi)}$$

The bearing capacity factors, shape factors, and depth factors are calculated using the reduced cohesion and reduced friction angle to determine the design bearing capacity.

3.1.5 Strength Reduction Factor

The strength reduction factor, Φ, is computed based on the ultimate bearing capacity and the design bearing capacity (Ref. 9). The strength reduction factor is given by the equation:

$$\Phi = q_\Phi / q_u$$

3.2 Static Settlement

The following sections discuss the static loadings and the computation of settlement. Settlements were computed considering the excavation (400 ft by 450 ft). Settlements were also checked considering an individual tank (150 ft diameter), but are not included in the calculation as the settlements based on the overall excavation control (4 tanks).

3.2.1 Static Loading

The current surface elevations range from 263 to 275 ft, msl. During excavation, 2 to 14 feet of soil will be removed to reach elevation 261 ft, msl. This is a decrease in overburden pressures of 240 to 1,680 psf at the bottom of the excavation.

At the end of construction, approximately 24 feet of structural fill will be placed around the

tanks, with an overburden pressure of approximately 3,000 psf (125 pcf × 24 ft). The bearing pressure of the foundation (including empty weight of the tank) and the mud mat is approximately 500 psf. When the tank is filled with Saltstone (22 ft × 110 pcf) and grouted (100 psf), the total foundation bearing pressure will be approximately 3,020 psf. A pre-closure bearing pressure of 3,000 psf was used for this analysis at elevation 261 ft, msl.

During closure operations, a soil cover, ranging from 10 to 23.5 feet thick, will be placed over the tanks. This additional soil cover will result in an additional overburden of approximately 1,250 to 2,937 psf; values of 1,300 and 3,000 are used for this analysis. The total bearing pressure (at elevation 261 ft, msl) after closure operations are completed range from 4,300 to 6,000 psf.

	Overburden Pressure at Elevation 261 ft, msl			
	Existing	End of Excavation	Pre Closure	Post Closure
Minimum	240 psf	0	3,000 psf	4,300 psf
Maximum	1,680 psf	0	3,000 psf	6,000 psf

3.2.2 Layer Thickness

The Saltstone Disposal Cells 3 and 5 site stratigraphy is similar to the stratigraphy of the Saltstone Vault 2 site, located 1,000 feet to the southeast. However, as noted in the stratigraphy calculation (Ref. 5), the C2 tends to thin out and ultimately “pinch” out in the northwestern part of the site, where the C2 layer averages less than 5 feet as opposed to 11 feet beneath the southeastern tanks.

3.2.3 Historical Settlement and Heave Data

Heave data is available from the Vault 2 excavation; however settlement data is not yet available. During the excavation at Vault 2 (approximately 250 ft by 400 ft excavated; 7 to 19 feet deep), the amount of heave ranged from ¼ inch to 1 inch. Based on this data, the modulus of subgrade reaction for the Vault 2 excavation is 15 to 25 pci (discussed in Section 3.3). Subgrade moduli of other large structures at SRS range from 10 to 25 pci (Section 3.3).

The loading cases presented in Section 3.2.1 and a subgrade modulus range of 10 to 25 pci are considered to estimate potential settlements. The results are:

	Minimum Settlement (inches)	Maximum Settlement (inches)	Average Settlement (inches)
Heave	-0.1	-2.5	-1.3
Operation Complete	0.8	2.1	1.5
Closure Cap Complete	1.7	4.2	3.0

3.2.4 Settlement in Cohesionless Soils

The following sections will discuss the methods used to determine the settlement of the soil column using cohesionless soil settlement analyses.

3.2.4.1. Burland and Burbidge

The Burland and Burbidge method estimates the immediate settlement, S_0, based on SPT data. The soil is assumed to be consolidated to the overburden pressure prior to excavation (Ref. 10).

$S_0 = f_s \times f_1 \times q' \times B^{0.7} \times I_c$ for a normally consolidated sand

$S_0 = f_s \times f_1 \times \left(q' - \frac{2}{3}\sigma'_{vo}\right) \times B^{0.7} \times I_c$ for $q' > \sigma'_{vo}$ (Equations 1, 2, 3)

$S_0 = f_s \times f_1 \times q' \times B^{0.7} \times \frac{I_c}{3}$ for $q' < \sigma'_{vo}$

where f_s = shape factor, $f_s = \left(\frac{1.25 \times L/B}{(L/B) + 0.25}\right)^2$

f_i = layer correction factor, $f_1 = H/Z_1\left(2 - H/Z_1\right)$

q' = average effective bearing pressure

σ'_{vo} = effective overburden

H = thickness of the layer

Z_1 = depth of influence of loaded area

= $1.35B^{0.75}$ for constant or increasing N_{ave} with depth

= 2B for decreasing N_{ave} with depth

N_{ave} = average SPT blow count over depth of influence

I_c =compressibility influence factor, $0.23/N_{ave}^{1.4}$

The measured blow counts were corrected to N_{60} values for use in this calculation. No corrections were made for gravelly or silty soils below the water table.

Settlement can be further estimated by changing I_c to achieve upper and lower bound estimates of settlement. The lower and upper bounds are defined below (Ref. 11).

Lower bound settlement is computed using $I_{cmin} = 0.08/N_{ave}^{1.3}$

Upper bound settlement is computed using $I_{cmax} = 1.34/N_{ave}^{1.67}$

Settlement after time *t*, at least 3 years following construction, may be estimated by:

$S_t = f_t S_0$ (Equation 4)

where $f_t = 1 + R_3 + R_c \log(t/3)$

R_i and R_c are the time–dependent settlement ratios, for *t* = 30 years

R_3 = 0.3 for static loads or 0.7 fluctuating loads

R_c = 0.2 for static loads or 0.8 fluctuating loads

Assuming static loads,

$f_t = 1 + 0.3 + 0.2 \log(30/3) = 1.5$

Therefore, total settlement at *t* = 30 years is:

$S_t = 1.5\ S_0$

The depth of influence for the excavation is approximately 120 feet using the Burland and Burbidge method. The immediate settlement calculated immediately prior to cap installation (pre-closure) is based on original excavation depths of 2 and 14 feet. Settlements after the completion of the cap (and 30 years after) are based on the original excavation depths (2 and 14 feet) and two cap thicknesses (10 and 23.5 feet).

The lower bound, upper bound, and average settlements were computed using I_{cmin}, I_{cmax}, and I_c as described earlier. For phases after closure cap completed, lower bound settlements are computed by averaging the 4 lower bound settlements using minimum and maximum excavations and minimum and maximum cap thicknesses, while upper bound settlements were computed by averaging the 4 upper bound settlements. The average settlement is the average of four settlements computed using the average I_c.

The average, lower, and upper bound settlements are given in the table below for the different phases of construction and operation. Due to the cohesive nature of the soil, settlements associated with the C2 layer were not included. The settlement for the C2 layer was determined by setting H equal to the depth at the top and bottom of the C2 layer and calculating the difference. This difference was then subtracted from the total soil column settlement that included the C2 layer. The following table presents the settlement values using the Burland and Burbidge method.

	Lower Bound Settlement (inches)	**Upper Bound Settlement (inches)**	**Average Settlement (inches)**
Immediate After Operation is Complete	0.9	4.6	1.9
Immediate After Closure Cap is Complete	1.8	8.8	3.7
30 Years After Closure Cap is Complete	2.7	13.1	5.5

3.2.4.2. Schmertmann Method

The Schmertmann method estimates the immediate settlement S_0 based on CPT data (Ref. 11):

$$S_0 = C_1 \times C_t \times \Delta P \times \sum_{i=1}^{n} \frac{\Delta z_i}{E_{si}} \times I_{zi} \qquad \text{(Equation 5)}$$

where C_1 = strain relief from embedment correction factor, $C_1 = 1 - 0.5\ \sigma'_{vo} / \Delta p \geq 0.5$,

C_t = correction for time-dependent increase in settlement and $C_t = 1 + 0.2 \log (t/0.1)$

t = in years,

for *t* = 30 years, $C_t = 1 + 0.2 \log (30/0.1) = 1.5$

ΔP = net applied footing pressure

Δz_i = depth increment *i*,

σ'_{od} = effective overburden at base of foundation

I_{zp} = peak influence factor

$$= 0.5 + 0.1\left(\frac{\Delta P}{\sigma'_{Izp}}\right)^{0.5}$$

I_{zi} = influence factor of soil layer *i*

E_{si} = elastic modulus of soil layer *i*

= 2.5 q_c for L/B = 1

= 3.5 q_c for L/B ≥ 10

where q_c is the average tip stress of soil layer *i* in tsf. For this evaluation, thickness of each soil layer (depth increment) is 1 foot. The depth was determined relative to the foundation elevation, 261 ft, msl. The influence factor of a soil layer can be calculated based on the geometry of the foundation as follows (Ref. 12):

For square and circular foundations (L/B = 1)

$$I_{zs} = 0.1 + \left(\frac{z_i}{B}\right)\left(2I_{zp} - 0.2\right) \quad \text{For } z_i = 0 \text{ - } B/2$$

$$I_{zs} = 0.667 + I_{zp}\left(2 - \frac{z_i}{B}\right) \quad \text{For } z_i = B/2 \text{ - } B$$

(Equations 6, 7)

For continuous foundations (L/B ≥ 10)

$$I_{zc} = 0.2 + \left(\frac{z_i}{B}\right)\left(I_{zp} - 0.2\right) \quad \text{For } z_i = 0 \text{ - } B$$

$$I_{zc} = 0.333 + I_{zp}\left(4 - \frac{z_i}{B}\right) \quad \text{For } z_i = B \text{ - } 4B$$

(Equations 8, 9)

For rectangular foundations (1 < L/B < 10)

$$I_{zr} = I_{zs} + 0.111\left(I_{zc} - I_{zs}\right)\left(\frac{L}{B} - 1\right)$$

(Equation 10)

Previous analyses performed for the Vitrification Building, 221-S, found that the estimated Schmertmann settlements were more than double the measured settlements, likely due to the methodology underestimating the elastic modulus for the cohesionless soils present at SRS (Ref. 13). Realistic results may be obtained by dividing the Schmertmann result by a conservative adjustment factor of 2.

The soils in the Congaree Formation and below are considered too dense for a significant heave / settlement response. The Congaree Formation is located approximately 116 feet below the bottom of the excavation. Energy corrected SPT blow counts in the Congaree Formation range from 70 to refusal (50 blows over 6 inch interval) and CPTs refused on the top of the Congaree Formation (approximately 700 tsf, Z-V3V5-C10). A value of 350 tsf tip stress was used in this analysis for Congaree Formation soils.

The Schmertmann settlement analysis was performed for all 17 CPTs and SCPTs. Average tip

stresses were computed on 1-foot intervals, relative to the depth below the bottom of the foundation (i.e. 261 ft, msl). A 6-foot deep hand auger is performed prior to each CPT test, thus no CPT data is available in the first 6 feet. For CPTs where the 6-foot hand auger extends below the foundation elevation, 1-foot intervals with no data were supplemented with the average tip stress values from the remaining CPTs for the corresponding 1-foot intervals. CPTs which terminated above the Congaree Formation were supplemented with the average tip stress values from the remaining CPTs for the corresponding 1-foot intervals.

Due to the cohesive nature of the soil, settlements associated with the C2 layer were excluded by setting I_{zi} equal to 0 for each C2 1-foot interval. The following table presents the settlement values using the Schmertmann method. Lower and upper bound settlements are the minimum and maximum CPT specific settlements, respectively. For closure cap scenarios, the average values are computed using both 10-foot and 23.5-foot thick caps.

	Lower Bound Settlement (inches)	**Upper Bound Settlement (inches)**	**Average Settlement (inches)**
Immediate After Operation is Complete	2.9	3.7	3.2
Immediate After Closure Cap is Complete	4.2	7.7	5.7
30 Years After Closure Cap is Complete	6.3	11.5	8.5

Additionally, settlement analysis was also performed for all CPTs where the average tip stress of the bottom 2 feet of the individual CPT were applied to all soils between the bottom of the CPT and the top of the Congaree Formation. Also, the average of the top two feet of the CPT tip stresses immediately below the bottom of the hand auger was applied to the soil column from the ground surface to the bottom of the hand auger. Similarly, an average tip stress value of 350 tsf was used for the Congaree Formation. Both independent analyses yielded similar results.

3.2.5 Consolidation of Cohesive Layer (C2)

Settlement of the cohesive layer C2 was computed using one dimensional consolidation theory.

For normally consolidated soils:

$$S = \frac{C_c H}{1 + e_o} \log\left(\frac{\sigma_o' + \Delta\sigma'}{\sigma_o'}\right)$$

For over consolidated soils

where $\sigma_o' + \Delta\sigma' < \sigma_p'$

$$S = \frac{C_r H}{1 + e_o} \log\left(\frac{\sigma_o' + \Delta\sigma'}{\sigma_o'}\right)$$

where $\sigma_o' + \Delta\sigma' > \sigma_p'$

$$S = \frac{C_r H}{1+e_o}\log\left(\frac{\sigma_p^{'}}{\sigma_o^{'}}\right) + \frac{C_c H}{1+e_o}\log\left(\frac{\sigma_o^{'} + \Delta\sigma^{'}}{\sigma_p^{'}}\right)$$

where

- H = thickness of cohesive layer
- C_c = virgin compression index
- C_r = recompression index
- $\sigma_o^{'}$ = initial effective overburden pressure
- $\sigma_p^{'}$ = preconsolidation pressure
- $\Delta\sigma^{'}$ = change in effective pressure
- e_o = initial void ratio

Beneath the southeastern tanks (Tanks #3B and #5B) the C2 layer is approximately 11 feet thick and 33 feet below the bottom of the excavation. Beneath the northwestern tanks (#3A and #5A) the C2 layer is approximately 5 feet thick and 39 feet below the bottom of the excavation. Beneath the northern tank (#3A), the C2 layer is only present under half of the tank and ranges from 0 to 4 feet thick.

Maximum consolidation settlement within the C2 layer occurs where the C2 layer has the greatest thickness (southeast corner of the site, Tank #5B). The C2 layer “pinches out” towards the northwestern corner (Tank #3A) of the site. Thus the minimum consolidation settlement of the C2 layer is zero. Average C_c and C_r values for the C2 layer used in this calculation are 0.50 and 0.11, respectively. These values were interpreted from two consolidation tests within the site, as well as testing from the Vault 2 subsurface investigation (Ref. 6 and 14). Overconsolidation ratios (OCR) for the C2 layer indicated the layer is normally consolidated (Ref. 6). Estimated settlements of the C2 layer are summarized in the table below.

	Minimum Settlement (inches)	Maximum Settlement (inches)	Average Settlement (inches)
Heave After Excavation	0	-0.6	-0.4
Settlement After Operation is Complete	0	1.8	1.8
Settlement After Closure Cap is Complete	0	5.1	3.8

Experience in H and S Areas also indicates that the rate of secondary compression for the SRS is small, on the order of ¼ inch over 30 years, for structural loading ranging from 3 to 6 ksf (Ref. 13).

3.2.6 Summary of Settlement and Heave

Estimation of settlement and heave was determined by combining computed settlements for the cohesionless and cohesive layers. For all of the loading cases, the settlement (consolidation) of the C2 layer is expected to occur shortly after loading, thus the same values for settlement (consolidation) for the C2 layer were applied to both short term and long term (30 year) cases. The consolidation settlement of the C2 layer was added to both the Burland and Burbidge

settlement and the Schmertmann settlement. The average of the Burland and Burbigde settlement plus C2 consolidation settlement and the Schmertmann settlement plus C2 consolidation settlement was computed and is summarized in the Table 2.

The differential settlement is to be taken as the same as the total settlement (Table 2) for a given phase of the project.

If each of the four tanks is being filled with Saltstone at various rates, differential settlement between tanks will occur due to different loading patterns. This type of differential settlement was not directly considered in this calculation.

Due to the large overburden pressure, settlements were predicted with a fair amount of deviation. In order to verify the estimated settlements, it is recommended that heave and settlement monitoring points be installed and surveyed during construction of the disposal cells. Settlement data will provide important information, which can be used to verify and calibrate settlement analysis methods and may result in more accurate settlement estimations in the future.

3.3 Subgrade Modulus

The subgrade modulus is a foundation specific value and is not a specific soil property. The subgrade modulus correlates foundation pressure and settlement by

$$k_s = \frac{p}{\Delta}$$

where p = foundation contact pressure (pounds per square inch, psi)

Δ = foundation settlement (inches)

The subscript s refers to the foundation size. For example, k_1 refers to the subgrade modulus for a 1-foot square foundation. When no subscript is used, the value refers to the subgrade modulus for the entire foundation.

The subgrade modulus depends on the size and shape of the loaded area. This calculation will estimate the subgrade modulus for Disposal Cells 3 and 5 based on SPT/CPT correlations and historical data.

3.3.1 Historical Data

Heave data from the excavation of Vault 2 (approximately 250 ft by 400 ft; 7.3 to 19 feet deep,), indicates movement ranging from ¼ inch to 1 inch. Based on this data, the subgrade modulus for a large excavation could range from 15 to 25 pci.

Based on values for other large facilities around the SRS, including the In Tank Precipitation (ITP) tanks, DWPF, and the Remote Handling Building (RHB) subgrade modulus (k) values range from approximately 10 to 25 pci. Converting these values to k_1 results in values of 55 to 100 pci (Ref. 15).

3.3.2 CPT and SPT Correlations

Subgrade modulus at the project site was estimated based on CPT uncorrected tip stress (q_c, kPa) and friction ratio (R_f, %). These average values were taken as the average CPT values from K-CLC-Z-00013 (Ref. 6). Figure 3 correlates the empirical formula $q_c/100R_f$ (kPa/%) to modulus of subgrade reaction, k_1. The subgrade modulus, k_1, based on the average CPT data is 240 pci.

	Average Tip Stress qc (tsf)	Average Tip Stress qc (kPa)	Average Friction Ratio Rf (%)	qc/100Rf (kPa/%)
Average	120	11491	2.5	46
			k_1	240 pci

Average SPT blow counts (N_{55}) and uncorrected CPT tip stresses were also used to estimate the subgrade modulus (Ref. 9). Measured blow counts were converted to energy-corrected blow counts, N_{55}, which corresponding to 55% of input energy using the following equation (Ref 7):

$$N'_{rb} = N * \eta_1 * \eta_2 * \eta_3 * \eta_4 * C_N, \quad \text{(Eq. 1)}$$

where N = measured blow count,

N'_{rb} = energy corrected blow count,

η_1 = energy correction factor, E_r / E_{rb} = 1.47

where E_r = actual energy ratio = 81

E_{rb} = standard energy ratio = 55

η_2 = rod length correction = 1.00

η_3 = sampler correction = 1.00

η_4 = borehole diameter correction = 1.00

C_N = overburden correction, $(p_o'' / p_o')^{0.5}$ = 0.53

where p_o'' = 2.0 ksf or 1 kg/cm^2, = 2.0

p_o' = average effective overburden pressure. = 7.2

Thus,

$N_{55} = 0.85 * N$.

The energy ratio for the boreholes conducted at Disposal Cells 3 and 5 is approximately 81% (Ref. 16). The average tip stress and N values were taken from K-CLC-Z-00013 (Ref. 6). Figure 3 correlates the empirical formula $q_c/100N_{55}$ (kPa) to modulus of subgrade reaction, k_1. Figure 3 indicates that a small change in $q_c/100N_{55}$ results in a large change in subgrade modulus. Therefore the minimum $q_c/100N_{55}$ value was used to give a conservative estimation of the subgrade modulus. The modulus of subgrade reaction, k_1, based on CPT and SPT data is 260 pci.

	Average Tip Stress q_c (tsf)	Average Tip Stress q_c (kPa)	Average Blow Count N	Average Blow Count N_{55}	$q_c/100N_{55}$ (kPa)
Average	120	11491	28	22	5.2
				k_1	260 pci

Based on the above computations, the range of k_1 is approximately 240 to 260 pci. To find the subgrade modulus for a 30 inch diameter plate as required by the ACI code (Ref. 17), the following equation is used:

$$k_s = [(B + 1)/(2B)]^2 * k_1$$

where B is the width of the load (30 inches or 2.5 feet in this case). Therefore,

$$k_{2.5} = 0.49\ k_1$$

Using the ACI Code for design, the range of subgrade modulus, $k_{2.5}$ (i.e., subgrade modulus for a 30 inch diameter plate) is between about 120 to 130 pci. This applies to point loads or loads on smaller areas.

Using the equation for k_s above, k approaches 0.25 k_1 as B increases. Therefore, for large foundations the subgrade modulus ranges from 60 to 65 pci, based on theoretical analysis. These values are greater than the value back-calculated from other large structures at SRS (10 to 25 pci).

3.4 Lateral Earth Pressure

The friction angle (ϕ) of the compacted fill is estimated to be between 30° and 35°, depending on the material source and the level of compaction. The lateral earth coefficients are computed as follows:

Active earth pressure $k_a = \tan^2\left(45 - \phi/2\right) = 0.27 - 0.33$

Passive earth pressure $k_p = \tan^2\left(45 + \phi/2\right) = 3.00 - 3.69$

At-rest earth pressure $k_0 = 1 - \sin\phi$ For $\phi \le 30°$; $k_0 = 0.5$ For $\phi > 30°$ $= 0.5$

Consideration was given to compaction induced lateral earth pressures. The method recommended by Duncan et. al (Ref. 18 & 19) determines σ_h' graphically based on depth, compaction effort, and the method of compaction. The site specific σ_h' is calculated by applying correction factors to σ_h' based on lift thickness (t), distance of from the wall (x), friction angle (ϕ), and roller width (w). Higher ϕ values result in increased compaction induced lateral earth pressures when utilizing the method recommended by Duncan et. al, therefore ϕ = 35° was analyzed.

For the purposes of this analysis, 6-inch lifts will be compacted with a 600 lb/in, 7-foot roller

within half a foot of the tank wall. The induced pressures below 16 feet were considered to extend linearly to intersect the K_0 line, at approximately 22 feet, below which K_0 conditions control, Figure 4. The compaction induced lateral earth pressures are summarized in the Table 3.

4. Results and Conclusions

Bearing Capacity – Appendix A

- Ultimate Bearing Capacity 72,000 psf
- Design Bearing Capacity 30,200 psf
- Strength Reduction Factor 0.41
- Allowable Bearing Capacity – Static 24,000 psf
- Allowable Bearing Capacity – Dynamic 32,100 psf

Settlement – Appendix B

- Average heave after excavation is less than 1 inch.
- Average settlements after operations are complete are approximately 4 inches.
- Average settlements after the closure cap is complete are approximately 9 inches.
- Average settlements 30 years after the closure cap is complete are approximately 11 inches.
- Differential settlement is considered to be equal to the total settlement.

Subgrade Modulus

- The recommended k_1 value is 100 pci, based on historical and theoretical values.

Lateral Earth Pressure

- Active earth pressure, k_a = 0.27 – 0.33
- Passive earth pressure, k_p = 3.00 – 3.69
- At-rest earth pressure, k_0 = 0.5
- Compaction induced lateral earth pressures are summarized in Table 3

5. References

1. Email from William Bruss – July 1, 2009.
2. M-TC-Z-00007, Rev. 0, Saltstone Facility Disposal Units #3 & #5 Project, November 2008.
3. M-TC-Z-00004, Rev. 1, Saltstone Facility Cylindrical Vault #2 Project, November 2005.
4. WSRC-2003-00250, Rev. 0, An Updated Regional Water Table of the Savannah River Site and Related Coverages, December 2003.
5. K-CLC-Z-00012, Rev. 0, Stratigraphy for Saltstone Vaults No. 3 and 5, May 2009
6. K-CLC-Z-00013, Rev. 0, Test Data Evaluation for Saltstone Disposal Cells No. 3 and 5, June 2009.
7. Bowles, Joseph E., *Foundation Analysis and Design*, 4th Edition, McGraw-Hill Publishing Co., 1988.
8. Fang, Foundation Engineering Handbook, 2nd Edition, 1991.
9. Engineering Standard No. 1060, Rev. 8, Savannah River Site, October 2006.
10. "Settlement of Foundations on Sand and Gravel," *Proc. Institution of Civil Engineers*, Part 1, 78, December 1985.
11. US Army Corps of Engineers, EM 1110-1-1904, Settlement Analysis, September 1990.
12. Coduto, Donald P., *Foundation Design, Principles and Practices*, 1994.
13. K-ESR-S-00006, Rev. 2, Glass Waste Storage Building #2 Geotechnical Baseline and Evaluation Report, December 2007.
14. K-CLC-Z-00008, Rev. 0, Evaluation of Test Data, February 2006.
15. K-ESR-G-00011, Rev. 0, Static Modulus of Subgrade Reaction for Large Structures at Savannah River Site, May 2007.
16. Subcontract No. C002332N, Rev. 0, SOW FP-301-0R5724, Rev. 0, For Geotechnical Drilling and Technical Oversight Services for the Saltstone Vaults 3 and 5 Geotechnical Investigation, April 2009.
17. Concrete Institute, *Design of Slabs on Grade*, ACI 360R-92, Reapproved 1997.
18. Duncan, Williams, Sehn, and Seed, Estimation Earth Pressures Due to Compaction, Journal of Geotechnical Engineering, Vol. 117, No. 12 December 1991.
19. Duncan, Williams, Sehn, and Seed, Closure of "Estimation Earth Pressures Due to Compaction", Journal of Geotechnical Engineering, Vol. 119, No. 7 July 1993.

Tables

Table 1: Calculated Bearing Capacities

	Ultimate Bearing Capacity (psf)	Allowable Static Bearing Capacity (psf)	Design Bearing Capacity (psf)	Allowable Dynamic Bearing Capacity (psf)	Φ (psf)
Excavation	76000	25,300	31,900	33,800	0.42
Individual Tank	41,000	13,900	16,900	18,500	0.41

Table 2: Summary of Static Settlement

	Minimum Settlement (inches)	**Maximum Settlement (inches)**	**Average Settlement (inches)**
Heave	¼	1	½
Operation Complete	2	6	4
Closure Cap Complete	3	13	9
Closure Cap Complete + 30 Yrs	5	18	11

Note: the settlements listed above include the recompression of heave.

Table 3: Compaction Induced Lateral Earth Pressures

Depth (feet)	$\sigma_{H\ Design}$ (psf)
0	0
2	525
4	640
8	735
14	900

K_0 controls at 14 feet and below

Figures

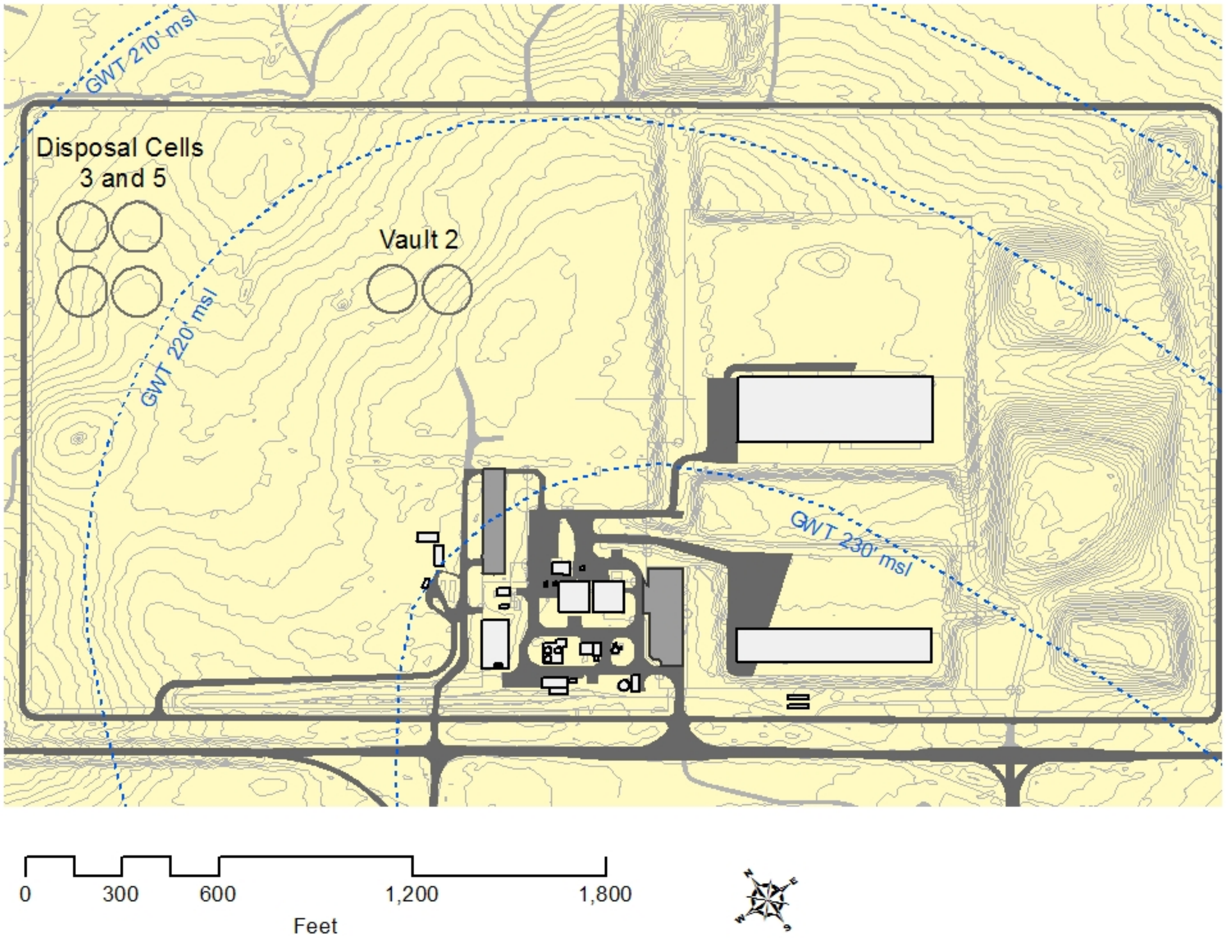


Figure 1: Location of Disposal Cells 3 and 5

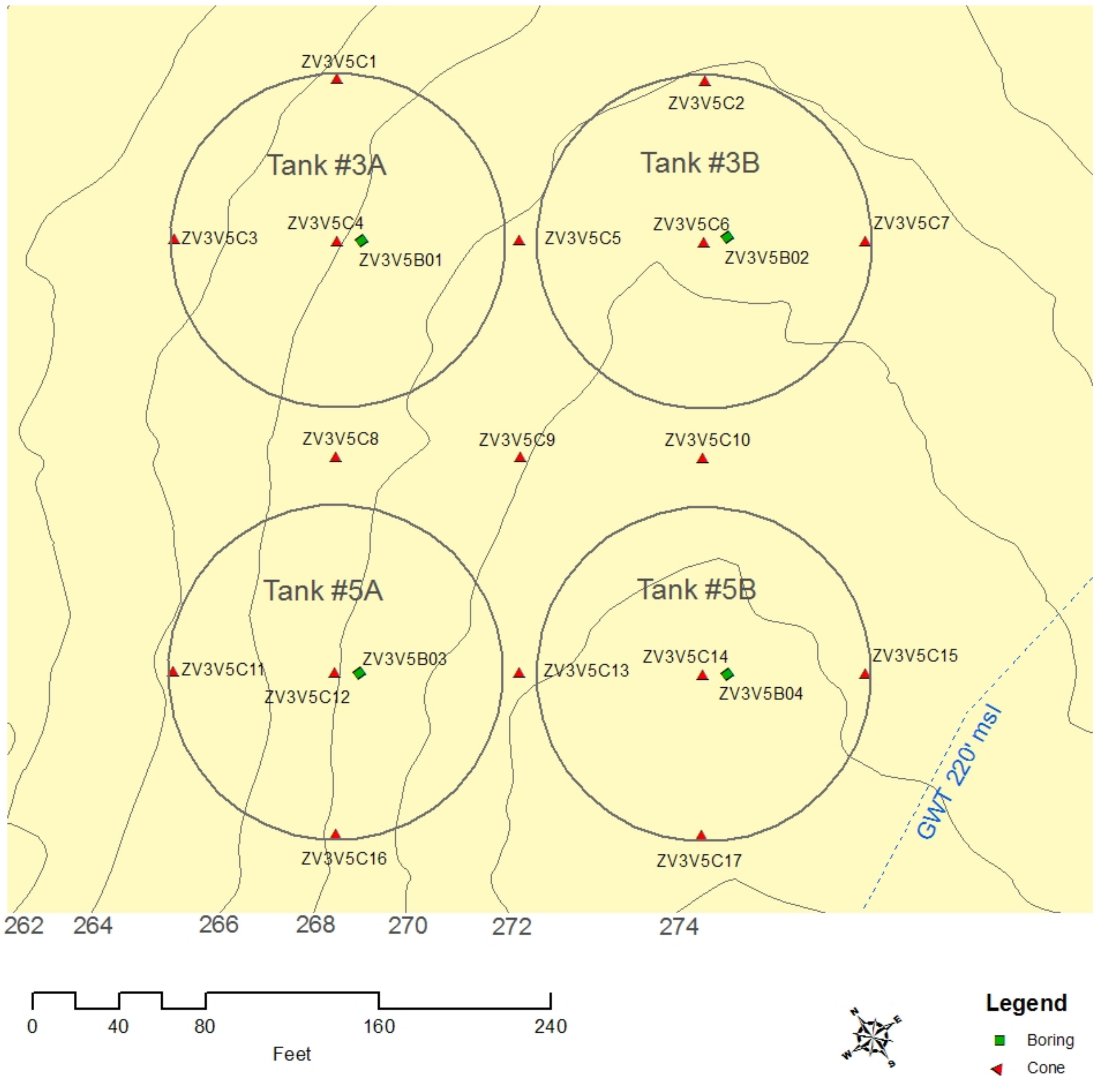


Figure 2: Disposal Cells 3 and 5 Geotechnical Exploration Locations with Topography

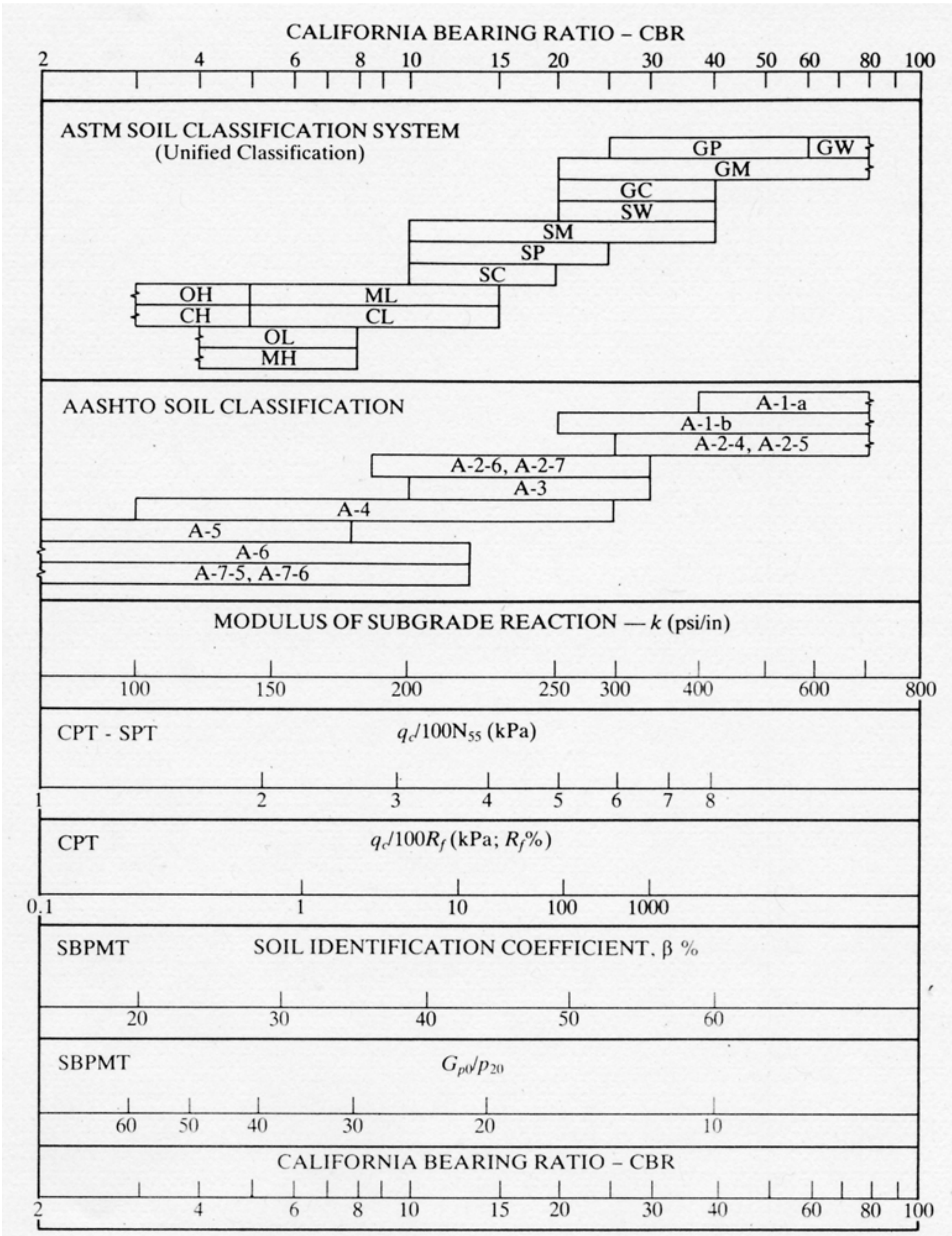


Figure 3: Correlation between CPT and SPT data and Subgrade Modulus

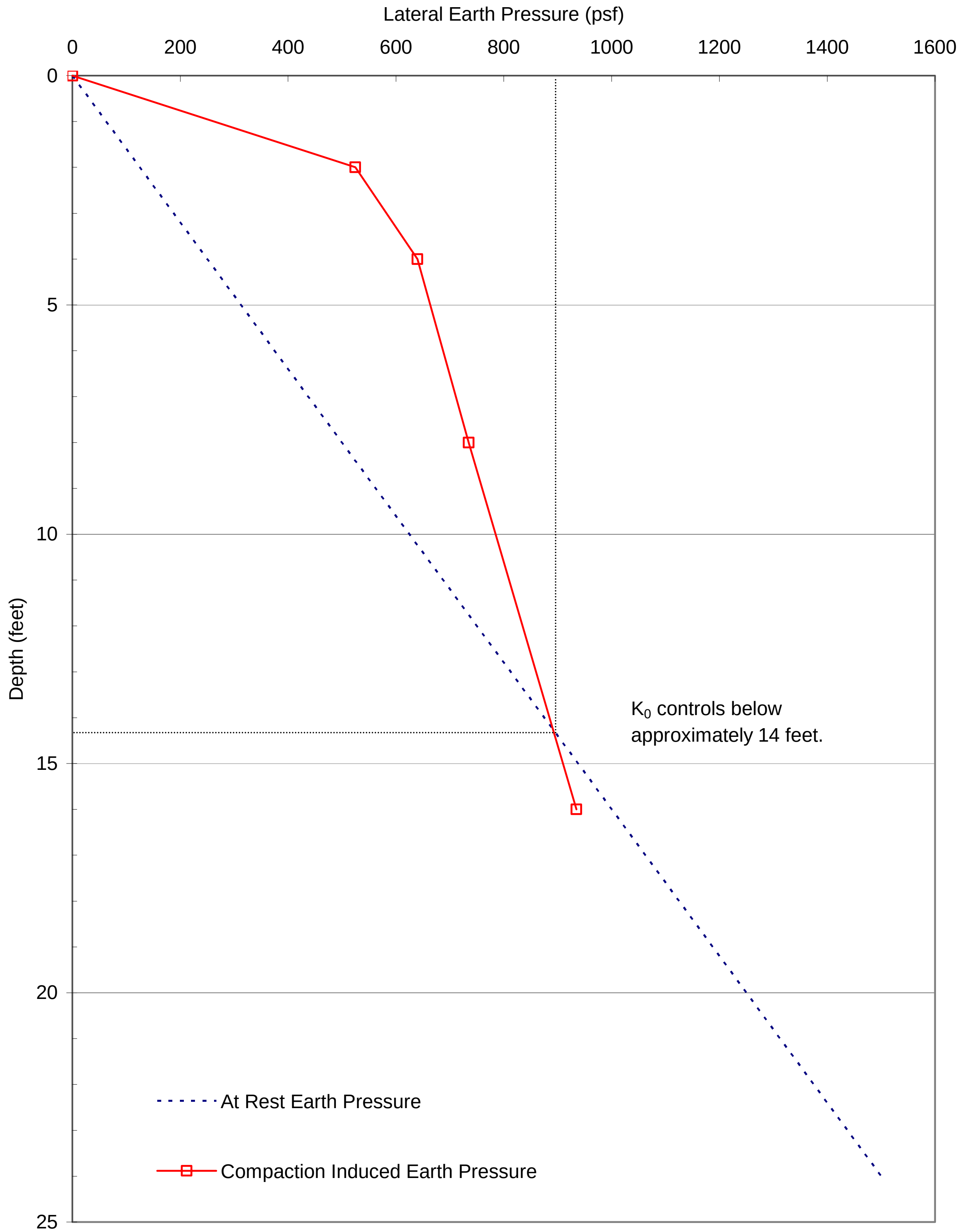


Figure 4: Compaction Induced Lateral Earth Pressures

Appendix A – Preliminary Excavation Details

William Bruss/SRR/Srs
07/01/2009 10:22 AM

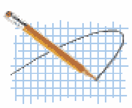
To Rucker Williams/SRNS/Srs@Srs
cc Max Howard/SRR/Srs@Srs, Bernard Enevoldsen/SRR/Srs@srs, Wilson Miles/SRR/Srs@Srs
bcc
Subject Re: Disposal Cells 3 and 5

We had a drawing review meeting yesterday at the WGI offices to discuss Vault 3/5 excavation plans. The bottom of excavation elevation was talked about in great detail. Many stormwater drainage issues can be resolved if this elevation is raised 1' above what the performance assessment currently shows as the bottom of the lower mud mat. Design Authority has requested the PA group to evaluate any impact to raising this elevation to 261 ft. Barring any unforeseen issues from the PA, the project would like us all to use 261' as the bottom of excavation. From our discussion on the phone, changing this elevation should not have any impact to your Geotech calculation results beyond referencing the new bottom of excavation elevation. WGI will revise their drawings after we get agreement from everyone that this change is okay.

I have also attached the WGI excavation drawings used in our review for your information. These drawings show the area of the excavation to be about 430' x 390' at the bottom. Let us know if you need any other information to complete approval of the Geotech design documents. Thanks.

29872-12-11-415-011_A.pdf 29872-12-11-415-009_A.pdf 29872-12-11-415-010_A.pdf

Rucker Williams/SRNS/Srs



Rucker Williams/SRNS/Srs
06/25/2009 09:35 AM

To William Bruss/SRR/Srs@Srs
cc
Subject Disposal Cells 3 and 5

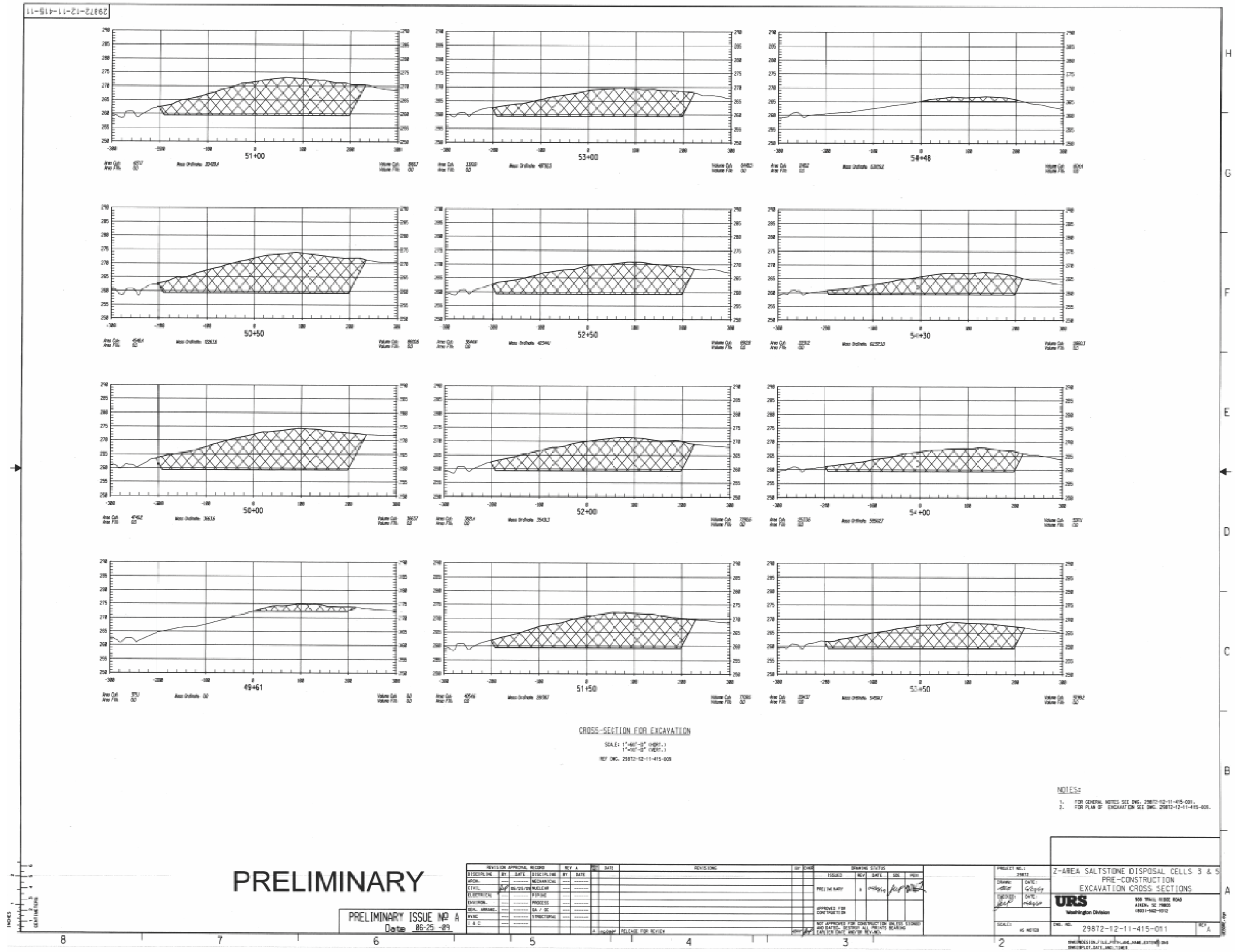
Bill,

To follow up on our conversation this morning, could you help me confirm the following?

Bottom Elevation of Excavation - 258 ft, msl
Excavation Dimensions - 450 ft by 450 ft

____

Rucker J. Williams
Geotechnical Engineering
Savannah River Site
Aiken, SC 29808
(803) 952-9879


29872-12-11-415-11
51+00
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49+61
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53+50
CROSS-SECTION FOR EXCAVATION
NOTES:
1. FOR GENERAL NOTES SEE DWG. 29872-12-11-415-001.
2. FOR PLAN OF EXCAVATION SEE DWG. 29872-12-11-415-005.
PRELIMINARY
PRELIMINARY ISSUE NO. A
Date 06-25-09
Z-AREA SALTSTONE DISPOSAL CELLS 3 & 5
PRE-CONSTRUCTION
EXCAVATION CROSS SECTIONS
URS
Washington Division
29872-12-11-415-011
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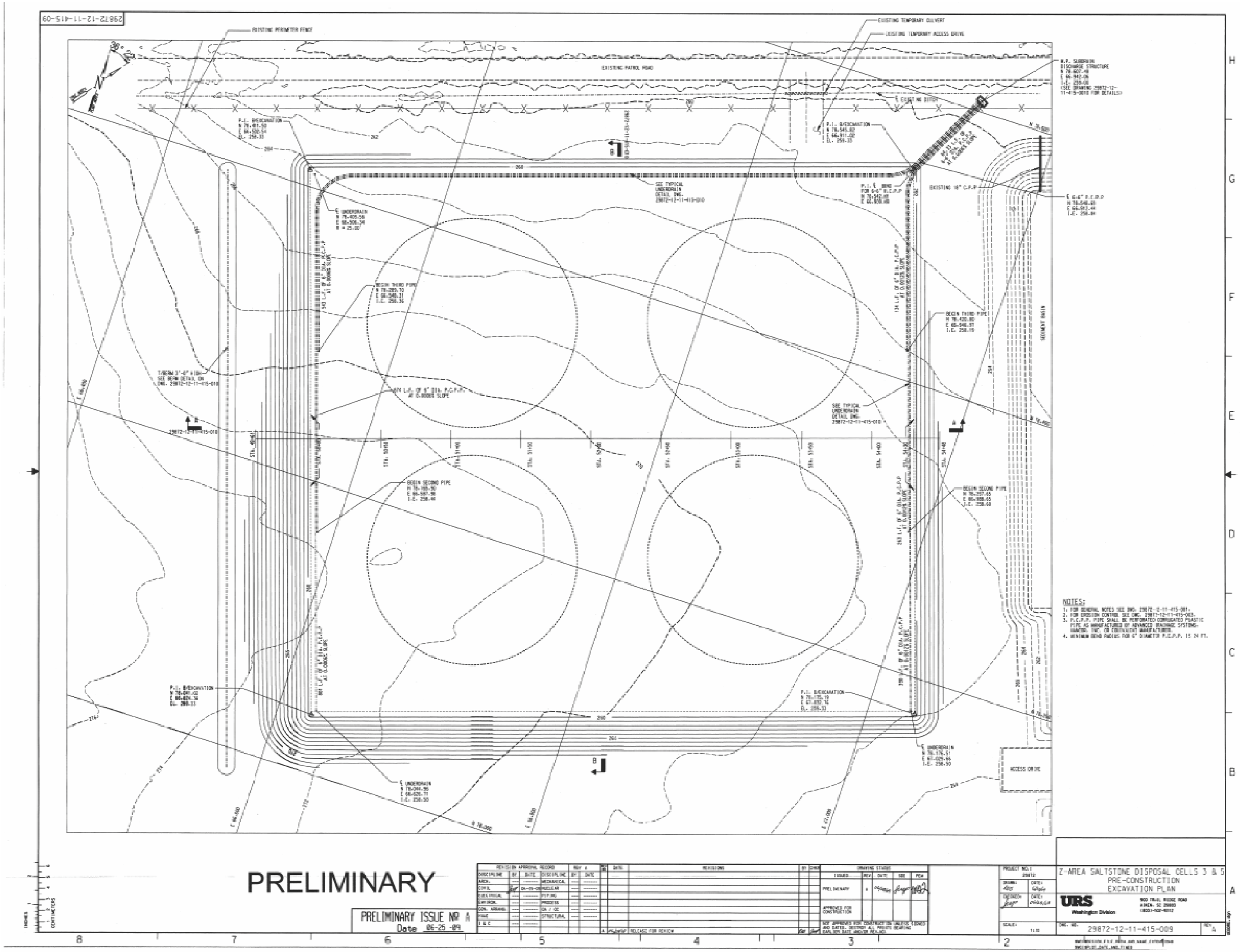
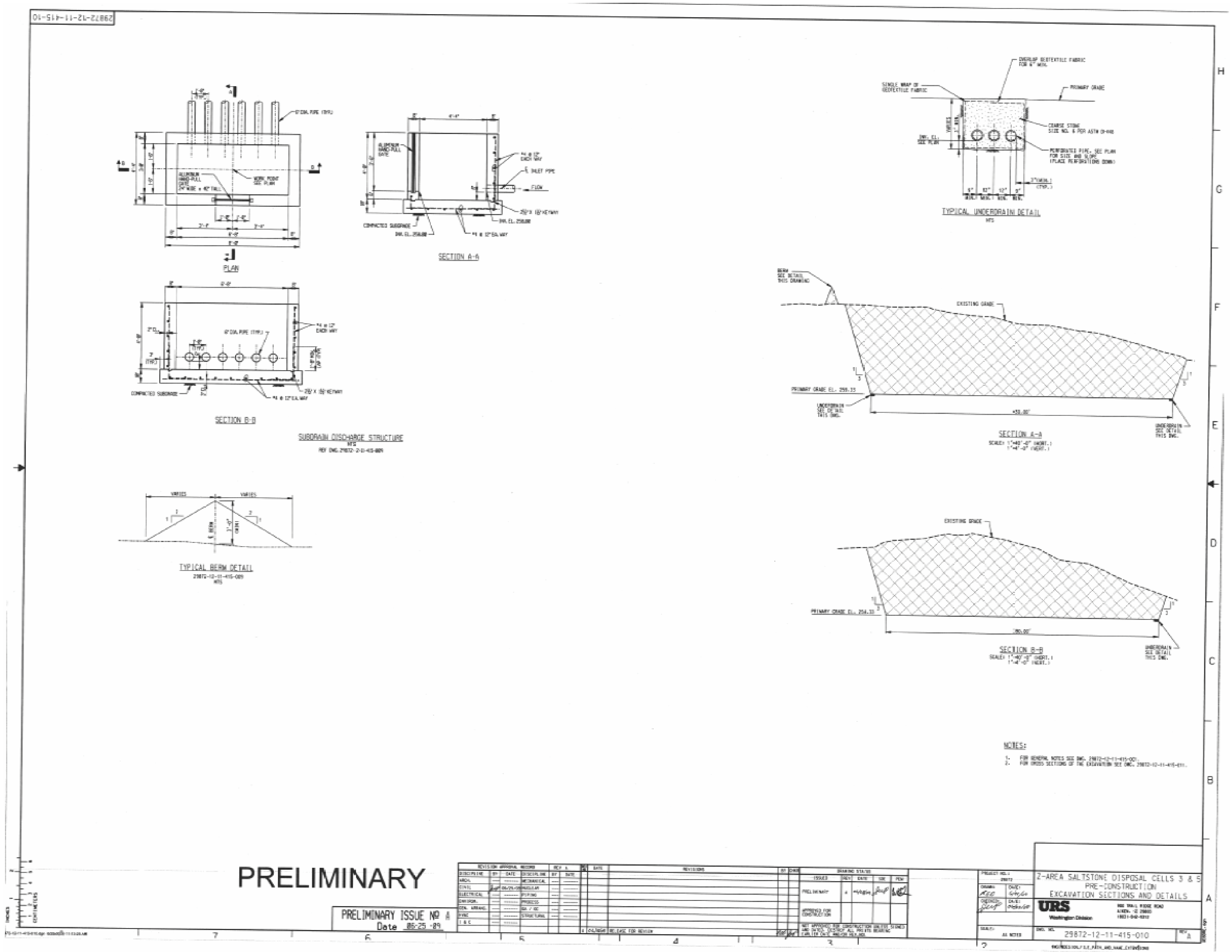

29872-12-11-415-09
EXISTING PERIMETER FENCE
EXISTING TEMPORARY CULVERT
EXISTING TEMPORARY ACCESS DRIVE
EXISTING PATROL ROAD
EXISTING 18" C.P.P.
SEDIMENT BASIN
ACCESS DRIVE
NOTES:
PRELIMINARY
PRELIMINARY ISSUE № A
Date 06-25-09
Z-AREA SALTSTONE DISPOSAL CELLS 3 & 5
PRE-CONSTRUCTION
EXCAVATION PLAN
URS
Washington Division
PROJECT NO.:
DWG. NO.
29872-12-11-415-009
REV. A


29872-12-11-415-10
PLAN
SECTION A-A
SECTION B-B
SUBDRAIN DISCHARGE STRUCTURE
TYPICAL BERM DETAIL
TYPICAL UNDERDRAIN DETAIL
EXISTING GRADE
SECTION A-A
SECTION B-B
NOTES:
PRELIMINARY
PRELIMINARY ISSUE Nº A
Date 06-25-09
Z-AREA SALTSTONE DISPOSAL CELLS 3 & 5
PRE-CONSTRUCTION
EXCAVATION SECTIONS AND DETAILS
URS
29872-12-11-415-010

Appendix B – Bearing Capacity Calculation Worksheets

Excerpts from Fang

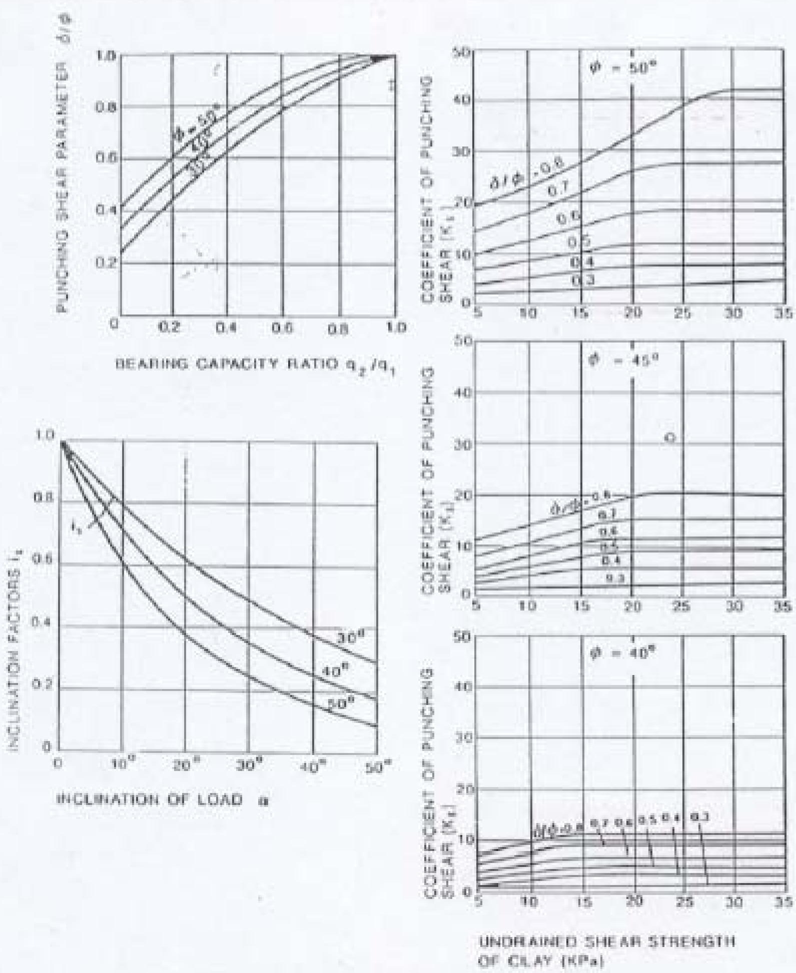


Fig. 4.17 Graphical aids for Meyerhof and Hanna solution to layered foundation.

4.9 INFLUENCE OF GROUNDWATER TABLE

The position of the groundwater table may have a significant effect on the bearing capacity of shallow foundations. Generally the submergence of soils will cause loss of the apparent cohesion due to capillary stresses or weak cementation bonds. At the same time the effective unit weight of submerged soils will be reduced to about one-half the weight of the same soils above water. Thus, through submergence, all three terms involved in the bearing capacity equation are reduced. For this reason, it is essential that the bearing capacity analysis be made assuming the highest possible groundwater level at the particular level for the expected lifetime of the structure. The assessment of this level must be made taking into consideration the probability of temporary high levels that could be expected in some locations during heavy rainstorms or floods, although they may not appear in the official records.

If the highest groundwater level is within the depth $z_w < B$ below the foundation level (Fig. 4.18) the effective weight γ of the soil below the foundation base should be taken as

$$\gamma = \gamma' + \frac{z_w}{B}(\gamma_m - \gamma') \qquad (4.28)$$

where γ' is the submerged unit weight and γ_m is the moist unit weight of soil, corresponding to the minimum moisture content of the soil above the water table (Meyerhof, 1953). If the water

TABLE 4.8 VALUES OF MINIMUM PARTIAL FACTORS[a].

Category	*Item*	*Load Factor*	*Resistance Factor*
Loads	Dead loads Live loads, wind or earthquake Water pressures	(f_d) 1.25 (0.85) (f_l) 1.5 (f_u) 1.25 (0.85)	
Shear strength	Cohesion (c) (stability; earth pressures) Cohesion (c) (foundations) Friction ($\tan \phi$)		(f_c) 0.65 (f_c) 0.5 (f_ϕ) 0.8

Note: Load factors given in parentheses apply to dead loads and water pressures when their effects are beneficial, as for dead loads resisting instability by sliding, overturning or uplift.

[a] Meyerhof (1984).

factors) given in Table 4.8. The higher values in Table 4.7 are applied to the normal loads and service conditions, while the lower values are applied to the maximum loads and worst environmental conditions.

The basic philosophy using total factors of safety is that the foundation should be capable of resisting a load F_s times greater than the design load. The load and resistance factor design (LRFD) method applies separate or partial factors to the loads and soil resistance. The load factors are provided mainly for variability and pattern of loading, which differ for dead loads, live loads, environmental loads, and water pressures. The resistance factors consider the variability and uncertainty of assessment of soil resistance, which differ for the cohesive and friction components. Thus, the factored shear strength of soil at the ultimate limit state may be expressed as

$$\tau = f_c c + \sigma_n f_\phi \tan \phi \qquad (4.33)$$

for the Coulomb criterion. The factors f_c and f_ϕ are the resistance factors for the cohesive and friction components, respectively. It is evident from Equation 4.33 that the total factor of safety obtained will depend on the relative contributions of the cohesive and friction components.

Whitman (1984) has recently reviewed the application of the related topic of risk analysis to geotechnical engineering.

4.13 EXAMPLE PROBLEMS

EXAMPLE 4.1

A rectangular footing (Fig. 4.21) 28 ft wide and 84 ft long is to be placed at a depth of 10 ft in a deep stratum of soft, saturated clay (bulk unit weight 105 lb/ft^3). The water table is at 8 ft below ground surface. Find the ultimate bearing capacity under the following two conditions:

a. assuming that the rate of application of dead and live loads is fast in comparison with the rate of dissipation of excess pore-water pressures caused by loads, so that undrained conditions prevail at failure;

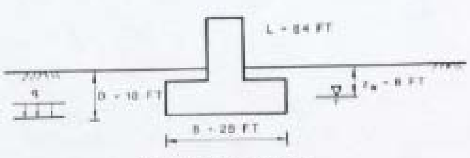


Fig. 4.21 Footing geometry.

b. assuming, as the other extreme, that the rate of loading is slow enough that no excess pore-water pressures are introduced in the foundation soil.

The strength parameters of the soil, obtained from unconsolidated, undrained tests are $c_u = 0.22$ ton/ft^2, $\phi_u = 0$. Consolidated, drained tests give $c_d = 0.04$ ton/ft^2, $\phi_d = 23°$.

CONDITION (a)

Submerged unit weight of soil: $\gamma' = 105 - 62 = 43$ lb/ft^3.
Overburden stress: $q = [(8)(105) + (2)(43)]/(2000) = 0.463$ ton/ft^2.
Bearing capacity factors (Table 4.1): $N_c = 5.14$; $N_q = 1$; $N_\gamma = 0$.

Shape factors (Table 4.4, Brinch Hansen):

$$s_c = 1 + \frac{B}{L}\frac{N_q}{N_c} = 1 + (1/3)(0.19) = 1.065$$

$$s_q = 1.00$$

Ultimate bearing pressure (Eq. 4.24):

$$q_0 = cN_c s_c + qN_q s_q$$

$$q_0 = (0.22)(5.14)(1.065) + (0.463)(1)(1.00)$$

$$= 1.21 + 0.46 = 1.67 \text{ ton/ft}^2$$

CONDITION (b)

Bearing capacity factors: $N_c = 18.05$; $N_q = 8.66$; $N_\gamma = 9.70$.
Shape factors:

$$s_c = 1 + \frac{B}{L}\frac{N_q}{N_c} = 1 + (1/3)(0.48) = 1.16$$

$$s_q = 1 + \frac{B}{L}\tan \phi = 1 + (1/3)(0.42) = 1.14$$

$$s_\gamma = 1 - 0.4\frac{B}{L} = 1 - (0.4)(1/3) = 0.87$$

Ultimate bearing pressure:

$$q_0 = cN_c s_c + qN_q s_q + \frac{\gamma B}{2} N_\gamma s_\gamma$$

$$q_0 = (0.04)(18.05)(1.16) + (0.463)(8.66)(1.14) + (1/2)(43)(28)(9.7)(0.87)/(2000)$$

$$= 0.72 + 4.57 + 2.54 = 7.83 \text{ ton/ft}^2$$

Excerpts from Bowles

ing reduction factor (revised from the previous edition) as follows:

$$r_{\gamma} = 1 - 0.25 \log\left(\frac{B}{\kappa}\right) \qquad B \geqq 6 \text{ ft or } 2 \text{ m}$$

where $\kappa = 6.0$ for fps and 2.0 for SI

This gives:

$B = 2$	2.5	3	3.5	4	5	10	20	100 m
$r_{\gamma} = 1.0$	0.97	0.95	0.93	0.92	0.90	0.82	0.75	0.57

One can use this reduction factor with any of the bearing capacity methods to give

$$0.5\gamma BN_{\gamma}s_{\gamma}d_{\gamma}r_{\gamma}$$

This equation is particularly applicable for large bases at small D/B ratios where the BN_{γ} term is predominating.

General observations about the bearing-capacity equations may be made as follows:

1. The cohesion term predominates in cohesive soil.
2. The depth term ($\bar{q}N_q$) predominates in cohesionless soils. Only a small D increases q_{ult} substantially.
3. The base width term $0.5\gamma BN_{\gamma}$ provides some increase in bearing capacity for both cohesive and cohensionless soils. In cases where $B < 3$ to 4 m this term could be neglected with little error.
4. No one would place a footing on the ground surface of a cohesionless soil mass.
5. It is highly unlikely that one would place a footing on a cohesionless soil with a D_r (Table 3-4) less than 0.5. If the soil is loose, it would be compacted in some manner to a higher density prior to placing footings in it.
6. Where the soil beneath the footing is not homogeneous or is stratified, som judgment must be applied to determining the bearing capacity. In the case of stratification, later sections will consider several cases.
7. When a base must be designed for a particular load, except for the Terzagh method, one must use an iterative procedure since the shape, depth, and inclination factors depend on B. A computer program such as B-31 is mo useful for this type problem. It should be set to increment the base by 0.075 m o 0.25 ft (3 in) steps as this is a common multiple of base dimensions.
8. Inspection of Table 4-1 indicates that the Terzaghi equation is much easier t use than the other methods (see also Example 4-1) so that it has great appeal fo many practitioners—particularly for bases with only vertical loads and $D/B \leqq$ Its form is also widely used for deep foundations but with adjusted N factor
9. Vesić (1973) recommends that depth factors d_i not be used for shallo foundations ($D/B \leqq 1$) because of uncertainties in quality of the overburd

TABLE 4-1 Bearing-capacity equations by the several authors indicated

Terzaghi (see Table 4-2 for typical values and for $K_{p\gamma}$ values)

$$q_{ult} = cN_c s_c + \bar{q}N_q + 0.5\gamma BN_\gamma s_\gamma \qquad N_q = \frac{a^2}{2\cos^2(45 + \phi/2)}$$

$$a = e^{(0.75\pi - \phi/2)\tan\phi}$$

$$N_c = (N_q - 1)\cot\phi$$

$$N_\gamma = \frac{\tan\phi}{2}\left(\frac{K_{p\gamma}}{\cos^2\phi} - 1\right)$$

For:	strip	round	square
$s_c =$	1.0	1.3	1.3
$s_\gamma =$	1.0	0.6	0.8

Meyerhof (see Table 4-3 for shape, depth, and inclination factors)

Vertical load: $q_{ult} = cN_c s_c d_c + \bar{q}N_q s_q d_q + 0.5\gamma BN_\gamma s_\gamma d_\gamma$

Inclined load: $q_{ult} = cN_c d_c i_c + \bar{q}N_q d_q i_q + 0.5\gamma BN_\gamma d_\gamma i_\gamma$

$$N_q = e^{\pi\tan\phi}\tan^2\left(45 + \frac{\phi}{2}\right)$$

$$N_c = (N_q - 1)\cot\phi$$

$$N_\gamma = (N_q - 1)\tan(1.4\phi)$$

Hansen (see Table 4-5 for shape, depth, and other factors)

General: $q_{ult} = cN_c s_c d_c i_c g_c b_c + \bar{q}N_q s_q d_q i_q g_q b_q + 0.5\gamma BN_\gamma s_\gamma d_\gamma i_\gamma g_\gamma b_\gamma$

when $\phi = 0$

use $q_{ult}\ 5.14 s_u(1 + s'_c + d'_c - i'_c - b'_c - g'_c) + \bar{q}$

$N_q =$ same as Meyerhof above

$N_c =$ same as Meyerhof above

$N_\gamma = 1.5(N_q - 1)\tan\phi$

Vesić (see Table 4-5 for shape, depth, and other factors)

Use Hansen's equations above

$N_q =$ same as Meyerhof above

$N_c =$ same as Meyerhof above

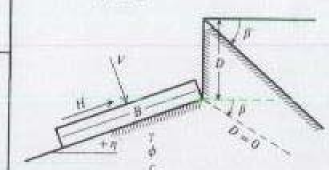
$N_\gamma = 2(N_q + 1)\tan\phi$

He also proposed using inclination factors to reduce the bearing capaci[ty] when the load resultant was inclined from the vertical by the angle θ.

Up to about $D = B$ of Fig. 4-3a Meyerhof's q_{ult} is not greatly different fro[m] the Terzaghi value. The difference is more pronounced at larger D/B ratios.

TABLE 4-5

Shape, depth, inclination, ground and base factors for use in either the Hansen (1970) or Vesić (1973) bearing-capacity equations of Table 4-1. Factors apply to either method unless subscripted with (H) or (V). Use primed factors when $\phi = 0$

Shape factors	Depth factors	Inclination factors	Ground factors (base on slope)
$s'_c = 0.2 \cdot \frac{B}{L}$ $s_c = 1 + \frac{N_q}{N_c} \cdot \frac{B}{L}$ $s_c = 1$ for strip	$d'_c = 0.4k$ $d_c = 1 + 0.4k$	$i'_{c(H)} = 0.5 - 0.5\sqrt{1 - \frac{H}{A_f c_a}}$ = 0 $i'_{c(V)} = 1 - \frac{mH}{A_f c_a N_c}$ $i_c = i_q - \frac{1 - i_q}{N_q - 1}$ (Hansen and Vesić)	$g'_c = \frac{\beta°}{147°}$ = 0 for Vesić use $N_\gamma = -2 \sin\beta$ for $\phi = 0$ $g_c = 1 - \frac{\beta°}{147°}$ 0
$s_q = 1 + \frac{B}{L} \tan\phi$	$d_q = 1 + 2\tan\phi(1 - \sin\phi)k$		$g_{q(H)} = g_{\gamma(H)} = (1 - 0.5\tan\beta)^5$
$s_\gamma = 1 - 0.4 \cdot \frac{B}{L}$	$d_\gamma = 1.00$ for all ϕ	$i_{q(H)} = \left(1 - \frac{0.5H}{V + A_f c_a \cot\phi}\right)^5$	$g_{q(V)} = g_{\gamma(V)} = (1 - \tan\beta)^2$
$s'_c = 0$ for strip ($B/L \approx 0$)	$k = \frac{D}{B}$ for $\frac{D}{B} \le 1$ $k = \tan^{-1}\frac{D}{B}$ for $\frac{D}{B} > 1$ (rad)	$i_{q(V)} = \left(1 - \frac{H}{V + A_f c_a \cot\phi}\right)^m$	**Base factors (tilted base)** $b'_c = \frac{\eta°}{147°}$ $b_c = 1 - \frac{\eta°}{147°}$
Where A_f = effective footing area $B' \times L'$ (see Fig. 4-4) c_a = adhesion to base = cohesion or a reduced value D = depth of footing in ground (used with B and not B') e_B, e_L = eccentricity of load with respect to center of footing area H = horizontal component of footing load with $H \le V \tan\delta + c_a A_f$ V = total vertical load on footing β = slope of ground away from base with downward = (+) δ = friction angle between base and soil—usually $\delta = \phi$ for concrete on soil η = tilt angle of base from horizontal with (+) upward as usual case		$i_{\gamma(H)} = \left(1 - \frac{0.7H}{V + A_f c_a \cot\phi}\right)^5$ $(\eta = 0)$ $i_{\gamma(H)} = \left(1 - \frac{(0.7 - \eta°/450)H}{V + A_f c_a \cot\phi}\right)^5$ $(\eta > 0)$ $i_{\gamma(V)} = \left(1 - \frac{H}{V + A_f c_a \cot\phi}\right)^{m+1}$	$b_{q(H)} = \exp(-2\eta\tan\phi)$ $b_{\gamma(H)} = \exp(-2.7\eta\tan\phi)$ $b_{q(V)} = b_{\gamma(V)} = (1 - \eta\tan\phi)^2$ *Notes:* $\beta + \eta \le 90°$ $\beta \le \phi$
General: 1. Do not use s_i in combination with i_i. 2. Can use s_i in combination with d_i, g_i, and b_i. 3. For $L/B \le 2$ use ϕ_{tr} For $L/B > 2$ use $\phi_{ps} = 1.5\phi_{tr} - 17$ For $\phi \le 34°$ use $\phi_{ps} = \phi_{tr}$		$m = m_B = \frac{2 + B/L}{1 + B/L}$ H parallel to B $m = m_L = \frac{2 + L/B}{1 + L/B}$ H parallel to L *Note:* $i_q, i_\gamma > 0$	

Calculation Worksheets

Input Parameters			**Foundation**	Individual Tank	
Effective Friction Angle (deg)	ϕ :	30	Footing Width (ft)	B :	150
Cohesion (psf)	c :	200	Footing Length (ft)	L :	150
Total Unit Weight of Soil Above Foundation (pcf)	γ_{af} :	125	Footing Depth (ft)	D :	0
			Depth to Groundwater (ft)	D_w :	36
Total Unit Weight of Soil Below Foundation (pcf)	γ_{bf} :	120	Unit Weight of Water (pcf)	γ_w :	62.4
Factor of Safety	FS :	3	Cohesion Reduction Factor	f_c :	0.5
			Friction Angle Reduction Factor	f_ϕ :	0.8

Effective Unit Weight of Soil Above the Foundation (γ_D)

For $D < D_w$ $\quad \gamma_D = \gamma_{af}$

For $D > D_w$ $\quad \gamma_D = \gamma_{af} - \frac{D - D_w}{D} \gamma_w$ $\qquad \gamma_D =$ 125 pcf

$q_q = \gamma_D * D$ $\qquad$ Overburden at base of foundation: $q_q =$ 0 psf

Effective Unit Weight of Soil Below the Foundation (γ_z)

For $D_w < D$ $\quad \gamma_z = \gamma_{bf} - \gamma_w$

For $D_w > D + B$ $\quad \gamma_z = \gamma_{bf}$

For $D_w < D + B$ $\quad \gamma_z = (\gamma_{bf} - \gamma_w) + \frac{D_w - D}{B} \gamma_w$ $\qquad \gamma_z =$ 72.6 pcf

Ultimate Bearing Capacity (q_u)

$$q_u = cN_c S_c D_c G_c + q_q N_q S_q D_q G_q + \frac{\gamma_z B}{2} N_\gamma S_\gamma D_\gamma G_\gamma r_\gamma$$

$q_u =$ 41724 psf

Ultimate Bearing Capacity : 41,000 psf

Allowable Static Bearing Capacity (q_a)

$$q_u = \frac{cN_c S_c D_c G_c + q_q N_q S_q D_q G_q + \frac{\gamma_z B}{2} N_\gamma S_\gamma D_\gamma G_\gamma r_\gamma}{FS}$$

$q_a =$ 13908 psf

Allowable Static Bearing Capacity: 13,900 psf

Allowable Dynamic Bearing Capacity

$$q_{dyn} = 1\tfrac{1}{3}\, q_a$$

$q_{dyn} =$ 18544 psf

Allowable Dynamic Bearing Capacity : 18,500 psf

Foundation Individual Tank

Bearing Capacity Factors

$$N_c = \cot\phi(N_q - 1)$$ $N_c = 30.14$

$$N_q = e^{\pi \tan\phi} \tan^2\left(45° + \frac{\phi}{2}\right)$$ $N_q = 18.40$

$$N_\gamma = 1.5(N_q - 1)\tan\phi$$ $N_\gamma = 15.07$

Shape Factors

$S_c = 0.2\frac{B}{L}$ For $\phi = 0°$

$S_c = 1 + \frac{B}{L}\frac{N_q}{N_c}$ For $\phi > 0°$

$S_q = 1 + \frac{B}{L}\tan\phi$

$S_\gamma = 1$ For $\phi = 0°$

$S_\gamma = 1 - 0.4\frac{B}{L}$ For $\phi > 0°$

$S_c = 1.61$
$S_q = 1.58$
$S_\gamma = 0.60$

Depth Factors

$D_c = 0.4k$ For $\phi = 0°$

$D_c = 1 + 0.4k$ For $\phi > 0°$ $D_c = 1.00$

$D_q = 1 + 2\tan\phi(1 - \sin\phi)^2 k$ $D_q = 1.00$

$D_\gamma = 1$ $D_\gamma = 1.00$

$k = \frac{D}{B}$ for $\frac{D}{B} \le 1$ or $\tan^{-1}\left(\frac{D}{B}\right)$ for $\frac{D}{B} > 1$ (in radians) $k = 0.000$

Inclination Factors

$G_c = 1.0$
$G_q = 1.0$
$G_\gamma = 1.0$

Foundation Width Correction

For foundation widths less than 6 feet, $r_\gamma = 1$
For foundation widths greater than 6 feet:

$$r_\gamma = 1 - \frac{\log(B/6)}{4}$$

$r_\gamma =$ 0.651

Reduced Soil Strength Parameters

$c_{red} = f_c c$

$\phi_{red} = \tan^{-1}(f_\phi \tan\phi)$ ϕ_{red} = 24.79

c_{red} = 100 psf

$N_c = 20.42$	$S_c = 1.511$
$N_q = 10.43$	$S_q = 1.462$
$N_\gamma = 6.53$	$S_\gamma = 0.600$
$D_c = 1.00$	$G_c = 1.00$
$D_q = 1.00$	$G_q = 1.00$
$D_\gamma = 1.00$	$G_\gamma = 1.00$

Design Bearing Capacity (q_Φ)

$$q_\Phi = cN_cS_cD_cG_c + q_qN_qS_qD_qG_q + \frac{\gamma_z B}{2}N_\gamma S_\gamma D_\gamma G_\gamma r_\gamma$$ $q_\Phi =$ 16966 psf

Design Bearing Capacity: 16,900 psf

Input Parameters			**Foundation**	Excavation	
Effective Friction Angle (deg)	ϕ :	30	Footing Width (ft)	B :	400
Cohesion (psf)	c :	200	Footing Length (ft)	L :	450
Total Unit Weight of Soil Above Foundation (pcf)	γ_{af} :	125	Footing Depth (ft)	D :	0
			Depth to Groundwater (ft)	D_w :	36
Total Unit Weight of Soil Below Foundation (pcf)	γ_{bf} :	120	Unit Weight of Water (pcf)	γ_w :	62.4
Factor of Safety	FS :	3	Cohesion Reduction Factor	f_c :	0.5
			Friction Angle Reduction Factor	f_ϕ :	0.8

Effective Unit Weight of Soil Above the Foundation (γ_D)

For $D < D_w$ $\quad \gamma_D = \gamma_{af}$

For $D > D_w$ $\quad \gamma_D = \gamma_{af} - \frac{D - D_w}{D}\gamma_w$

γ_D = 125 pcf

$q_q = \gamma_D * D$

Overburden at base of foundation: q_q = 0 psf

Effective Unit Weight of Soil Below the Foundation (γ_z)

For $D_w < D$ $\quad \gamma_z = \gamma_{bf} - \gamma_w$

For $D_w > D + B$ $\quad \gamma_z = \gamma_{bf}$

For $D_w < D + B$ $\quad \gamma_z = (\gamma_{bf} - \gamma_w) + \frac{D_w - D}{B}\gamma_w$

γ_z = 63.2 pcf

Ultimate Bearing Capacity (q_u)

$$q_u = cN_cS_cD_cG_c + q_qN_qS_qD_qG_q + \frac{\gamma_z B}{2}N_\gamma S_\gamma D_\gamma G_\gamma r_\gamma$$

q_u = 76098 psf

Ultimate Bearing Capacity : 76,000 psf

Allowable Static Bearing Capacity (q_a)

$$q_u = \frac{cN_cS_cD_cG_c + q_qN_qS_qD_qG_q + \frac{\gamma_z B}{2}N_\gamma S_\gamma D_\gamma G_\gamma r_\gamma}{FS}$$

q_a = 25366 psf

Allowable Static Bearing Capacity: 25,300 psf

Allowable Dynamic Bearing Capacity

$$q_{dyn} = 1\tfrac{1}{3}\, q_a$$

q_{dyn} = 33821 psf

Allowable Dynamic Bearing Capacity : 33,800 psf

	Foundation	Excavation

Bearing Capacity Factors

$N_c = \cot\phi(N_q - 1)$ — $N_c = 30.14$

$N_q = e^{\pi \tan\phi} \tan^2\left(45° + \frac{\phi}{2}\right)$ — $N_q = 18.40$

$N_\gamma = 1.5(N_q - 1)\tan\phi$ — $N_\gamma = 15.07$

Shape Factors

$S_c = 0.2\frac{B}{L}$ For $\phi = 0°$

$S_c = 1 + \frac{B}{L}\frac{N_q}{N_c}$ For $\phi > 0°$

$S_q = 1 + \frac{B}{L}\tan\phi$

$S_\gamma = 1$ For $\phi = 0°$

$S_\gamma = 1 - 0.4\frac{B}{L}$ For $\phi > 0°$

$S_c = 1.54$

$S_q = 1.51$

$S_\gamma = 0.64$

Depth Factors

$D_c = 0.4k$ For $\phi = 0°$

$D_c = 1 + 0.4k$ For $\phi > 0°$ — $D_c = 1.00$

$D_q = 1 + 2\tan\phi(1 - \sin\phi)^2 k$ — $D_q = 1.00$

$D_\gamma = 1$ — $D_\gamma = 1.00$

$k = \frac{D}{B}$ for $\frac{D}{B} \le 1$ or $\tan^{-1}\left(\frac{D}{B}\right)$ for $\frac{D}{B} > 1$ (in radians) — k = 0.000

Inclination Factors

$G_c = 1.0$

$G_q = 1.0$

$G_\gamma = 1.0$

Foundation Width Correction

For foundation widths less than 6 feet, $r_\gamma = 1$

For foundation widths greater than 6 feet:

$$r_\gamma = 1 - \frac{\log(B/6)}{4}$$

$r_\gamma =$ 0.544

Reduced Soil Strength Parameters

$c_{red} = f_c c$

$\phi_{red} = \tan^{-1}(f_\phi \tan\phi)$

$\phi_{red} =$ 24.79

$c_{red} =$ 100 psf

$N_c = 20.42$	$S_c = 1.454$
$N_q = 10.43$	$S_q = 1.411$
$N_\gamma = 6.53$	$S_\gamma = 0.644$
$D_c = 1.00$	$G_c = 1.00$
$D_q = 1.00$	$G_q = 1.00$
$D_\gamma = 1.00$	$G_\gamma = 1.00$

Design Bearing Capacity (q_Φ)

$$q_\Phi = cN_cS_cD_cG_c + q_qN_qS_qD_qG_q + \frac{\gamma_z B}{2}N_\gamma S_\gamma D_\gamma G_\gamma r_\gamma$$

$q_\Phi =$ 31931 psf

Design Bearing Capacity: 31,900 psf

Appendix C – Settlement Calculation Worksheets

Footing width	B =		400.0 ft	ZV3V5C01		
Footing length	L =		450.0 ft		Immediate	
Ground elevation			261.0 ft		Settlement (in.)	
Foundation elevation			261.0 ft		(S_0 / 2)	
Ground Water elevation			225.0 ft		Load	S_0 =
Excavated or embedded depth	D =		0.0 ft			3.3
Depth to Groundwater			36.0 ft		3.0	3.3
Unit weight	γ =		120.0 pcf		4.3	4.8
Net applied footing pressure	Δp =		3.000 ksf		6.0	6.7
	L/B =		1.13 -			
					30 Year	
Computation					Settlement (in.)	
Settlement	ρ_I =	$C_1\ C_t\ \Delta p\ \Sigma(\Delta z_i\ I_{zi}/E_{si})$	0.545 ft	Column I	(S_{30} / 2)	
	ρ_I =		**6.536 in**	4.235	Load	S_0 =
	S(t) =		0.814 ft			4.9
	S(t) =		**9.774 in**		4.3	7.1
Correction for strain relief	C_1 =	1 - 0.5(σ'_D/q')	1.000 -		6.0	10.1
Effective vertical overburden pressure at D	σ'_{vo} =	γ D	0.000 ksf			
Correction for time dependent increase	C_t =	1 + 0.2 log(t / 0.1)	1.50 -			
	t =		30.00 years			
Elastic modulus of soil layer i	E_{si} =	2.5 q_c	see Column H	if L/B = 1		
	E_{si} =	3.5 q_c	see Column H	If L/B ≥ 10		
Depth increment i	Δz_i		see Column D			
Influence factor of soil layer i	I_{zi}	Figure 3-4	see Column G			
Peak depth influence factor	I_{zp} =	$0.5 + 0.1\ (\Delta p/\sigma'_{Izp})^{1/2}$	0.546 -			
	z_p =	0.5B + D	200.00 ft	If L/B = 1		
	z_p =	B + D	400.00 ft	If L/B ≥ 10		
	z_p =		202.78 ft	for L/B=1.13		
Effective overburden pressure at depth Izp	σ'_{Izp} =		13.93 ksf			
Elastic Modulus	E_{si} =		2.50 q_c	If L/B = 1		
	E_{si} =		3.50 q_c	If L/B ≥ 10		
	E_{si} =		2.51 q_c	for L/B=1.13		

A	B	C	D	E	F	G	H	I	J	K
Layer No.	Layer top depth (ft)	Layer bottom depth (ft)	Layer thickness Δz_i (ft)	Mid-layer depth z_{ave} (ft)	Average tip stress q_c (tsf)	I_{zi}	Elastic modulus E_{si} (ksf)	$\Delta z_i\ I_{zi}/E_{si}$	$\Delta z_i\ I_{zi}/E_{si}$	Notes
1	0.0	1.0	1.0	0.5	129.0	0.102	648.5	0.00016	0.00016	
2	1.0	2.0	1.0	1.5	123.2	0.105	619.3	0.00017	0.00017	
3	2.0	3.0	1.0	2.5	229.2	0.107	1152.3	0.00009	0.00009	
4	3.0	4.0	1.0	3.5	251.8	0.109	1266.1	0.00009	0.00009	
5	4.0	5.0	1.0	4.5	234.7	0.111	1179.9	0.00009	0.00009	
6	5.0	6.0	1.0	5.5	219.0	0.114	1101.2	0.00010	0.00010	
7	6.0	7.0	1.0	6.5	158.8	0.116	798.2	0.00015	0.00015	
8	7.0	8.0	1.0	7.5	118.3	0.118	594.9	0.00020	0.00020	
9	8.0	9.0	1.0	8.5	106.3	0.120	534.6	0.00022	0.00022	
10	9.0	10.0	1.0	9.5	85.8	0.122	431.2	0.00028	0.00028	
11	10.0	11.0	1.0	10.5	97.4	0.125	489.9	0.00025	0.00025	
12	11.0	12.0	1.0	11.5	120.3	0.127	604.8	0.00021	0.00021	
13	12.0	13.0	1.0	12.5	116.0	0.129	583.0	0.00022	0.00022	
14	13.0	14.0	1.0	13.5	120.2	0.131	604.5	0.00022	0.00022	
15	14.0	15.0	1.0	14.5	126.4	0.133	635.3	0.00021	0.00021	
16	15.0	16.0	1.0	15.5	138.3	0.136	695.4	0.00020	0.00020	
17	16.0	17.0	1.0	16.5	158.6	0.138	797.5	0.00017	0.00017	
18	17.0	18.0	1.0	17.5	153.9	0.140	773.8	0.00018	0.00018	
19	18.0	19.0	1.0	18.5	158.4	0.142	796.4	0.00018	0.00018	
20	19.0	20.0	1.0	19.5	159.2	0.145	800.5	0.00018	0.00018	
21	20.0	21.0	1.0	20.5	172.5	0.147	867.3	0.00017	0.00017	
22	21.0	22.0	1.0	21.5	185.6	0.149	933.3	0.00016	0.00016	
23	22.0	23.0	1.0	22.5	200.6	0.151	1008.3	0.00015	0.00015	
24	23.0	24.0	1.0	23.5	231.5	0.153	1164.1	0.00013	0.00013	
25	24.0	25.0	1.0	24.5	255.3	0.156	1283.7	0.00012	0.00012	
26	25.0	26.0	1.0	25.5	200.3	0.158	1006.9	0.00016	0.00016	
27	26.0	27.0	1.0	26.5	110.9	0.160	557.4	0.00029	0.00029	
28	27.0	28.0	1.0	27.5	82.6	0.162	415.5	0.00039	0.00039	
29	28.0	29.0	1.0	28.5	74.5	0.164	374.6	0.00044	0.00044	
30	29.0	30.0	1.0	29.5	82.1	0.167	412.5	0.00040	0.00040	
31	30.0	31.0	1.0	30.5	95.2	0.169	478.8	0.00035	0.00035	
32	31.0	32.0	1.0	31.5	90.6	0.171	455.3	0.00038	0.00038	
33	32.0	33.0	1.0	32.5	90.7	0.173	456.2	0.00038	0.00038	

34	33.0	34.0	1.0	33.5	52.4	0.176	263.6	0.00067	0.00067
35	34.0	35.0	1.0	34.5	40.6	0.178	204.3	0.00087	0.00087
36	35.0	36.0	1.0	35.5	111.1	0.180	558.5	0.00032	0.00032
37	36.0	37.0	1.0	36.5	181.7	0.182	913.4	0.00020	0.00020
38	37.0	38.0	1.0	37.5	211.6	0.184	1063.7	0.00017	0.00017
39	38.0	39.0	1.0	38.5	183.9	0.187	924.8	0.00020	0.00020
40	39.0	40.0	1.0	39.5	184.5	0.189	927.7	0.00020	0.00020
41	40.0	41.0	1.0	40.5	197.9	0.191	994.9	0.00019	0.00019
42	41.0	42.0	1.0	41.5	232.6	0.193	1169.5	0.00017	0.00017
43	42.0	43.0	1.0	42.5	200.7	0.195	1009.2	0.00019	0.00019
44	43.0	44.0	1.0	43.5	168.9	0.198	849.0	0.00023	0.00023
45	44.0	45.0	1.0	44.5	197.8	0.200	994.7	0.00020	0.00020
46	45.0	46.0	1.0	45.5	235.6	0.202	1184.8	0.00017	0.00017
47	46.0	47.0	1.0	46.5	252.9	0.204	1271.8	0.00016	0.00016
48	47.0	48.0	1.0	47.5	252.8	0.207	1270.9	0.00016	0.00016
49	48.0	49.0	1.0	48.5	266.1	0.209	1337.7	0.00016	0.00016
50	49.0	50.0	1.0	49.5	277.3	0.211	1394.0	0.00015	0.00015
51	50.0	51.0	1.0	50.5	268.1	0.213	1348.0	0.00016	0.00016
52	51.0	52.0	1.0	51.5	245.0	0.215	1231.6	0.00017	0.00017
53	52.0	53.0	1.0	52.5	185.6	0.218	933.0	0.00023	0.00023
54	53.0	54.0	1.0	53.5	83.3	0.220	418.9	0.00052	0.00052
55	54.0	55.0	1.0	54.5	115.6	0.222	581.4	0.00038	0.00038
56	55.0	56.0	1.0	55.5	104.1	0.224	523.6	0.00043	0.00043
57	56.0	57.0	1.0	56.5	72.4	0.226	364.0	0.00062	0.00062
58	57.0	58.0	1.0	57.5	155.5	0.229	781.8	0.00029	0.00029
59	58.0	59.0	1.0	58.5	226.1	0.231	1136.7	0.00020	0.00020
60	59.0	60.0	1.0	59.5	268.2	0.233	1348.7	0.00017	0.00017
61	60.0	61.0	1.0	60.5	299.0	0.235	1503.3	0.00016	0.00016
62	61.0	62.0	1.0	61.5	204.7	0.237	1029.0	0.00023	0.00023
63	62.0	63.0	1.0	62.5	157.6	0.240	792.3	0.00030	0.00030
64	63.0	64.0	1.0	63.5	127.9	0.242	643.2	0.00038	0.00038
65	64.0	65.0	1.0	64.5	23.9	0.244	120.0	0.00203	0.00203
66	65.0	66.0	1.0	65.5	22.1	0.246	111.3	0.00221	0.00221
67	66.0	67.0	1.0	66.5	10.9	0.249	54.7	0.00454	0.00454
68	67.0	68.0	1.0	67.5	13.7	0.251	69.0	0.00363	0.00363
69	68.0	69.0	1.0	68.5	21.2	0.253	106.7	0.00237	0.00237
70	69.0	70.0	1.0	69.5	21.7	0.255	109.0	0.00234	0.00234
71	70.0	71.0	1.0	70.5	41.6	0.257	209.3	0.00123	0.00123
72	71.0	72.0	1.0	71.5	43.2	0.260	217.2	0.00120	0.00120
73	72.0	73.0	1.0	72.5	22.3	0.262	112.4	0.00233	0.00233
74	73.0	74.0	1.0	73.5	37.9	0.264	190.6	0.00139	0.00139
75	74.0	75.0	1.0	74.5	81.6	0.266	410.4	0.00065	0.00065
76	75.0	76.0	1.0	75.5	161.6	0.268	812.3	0.00033	0.00033
77	76.0	77.0	1.0	76.5	68.9	0.271	346.6	0.00078	0.00078
78	77.0	78.0	1.0	77.5	332.3	0.273	1671.0	0.00016	0.00016
79	78.0	79.0	1.0	78.5	475.8	0.275	2392.4	0.00011	0.00011
80	79.0	80.0	1.0	79.5	148.3	0.277	745.4	0.00037	0.00037
81	80.0	81.0	1.0	80.5	105.5	0.280	530.3	0.00053	0.00053
82	81.0	82.0	1.0	81.5	87.5	0.282	440.0	0.00064	0.00064
83	82.0	83.0	1.0	82.5	130.2	0.284	654.4	0.00043	0.00043
84	83.0	84.0	1.0	83.5	162.1	0.286	814.8	0.00035	0.00035
85	84.0	85.0	1.0	84.5	163.0	0.288	819.4	0.00035	0.00035
86	85.0	86.0	1.0	85.5	100.2	0.291	503.6	0.00058	0.00058
87	86.0	87.0	1.0	86.5	90.6	0.293	455.3	0.00064	0.00064
88	87.0	88.0	1.0	87.5	96.0	0.295	482.6	0.00061	0.00061
89	88.0	89.0	1.0	88.5	192.0	0.297	965.4	0.00031	0.00031
90	89.0	90.0	1.0	89.5	154.4	0.299	776.5	0.00039	0.00039
91	90.0	91.0	1.0	90.5	146.3	0.302	735.7	0.00041	0.00041
92	91.0	92.0	1.0	91.5	115.3	0.304	579.8	0.00052	0.00052
93	92.0	93.0	1.0	92.5	108.6	0.306	545.9	0.00056	0.00056
94	93.0	94.0	1.0	93.5	123.9	0.308	623.1	0.00049	0.00049
95	94.0	95.0	1.0	94.5	139.2	0.311	699.9	0.00044	0.00044
96	95.0	96.0	1.0	95.5	165.6	0.313	832.6	0.00038	0.00038
97	96.0	97.0	1.0	96.5	230.6	0.315	1159.5	0.00027	0.00027
98	97.0	98.0	1.0	97.5	255.1	0.317	1282.6	0.00025	0.00025
99	98.0	99.0	1.0	98.5	244.4	0.319	1229.0	0.00026	0.00026
100	99.0	100.0	1.0	99.5	212.2	0.322	1066.8	0.00030	0.00030
101	100.0	101.0	1.0	100.5	156.6	0.324	787.3	0.00041	0.00041
102	101.0	102.0	1.0	101.5	44.4	0.326	223.3	0.00146	0.00146
103	102.0	103.0	1.0	102.5	70.2	0.328	353.0	0.00093	0.00093
104	103.0	104.0	1.0	103.5	91.8	0.330	461.6	0.00072	0.00072
105	104.0	105.0	1.0	104.5	94.4	0.333	474.6	0.00070	0.00070
106	105.0	106.0	1.0	105.5	98.0	0.335	492.7	0.00068	0.00068
107	106.0	107.0	1.0	106.5	88.6	0.337	445.5	0.00076	0.00076
108	107.0	108.0	1.0	107.5	83.8	0.339	421.2	0.00081	0.00081
109	108.0	109.0	1.0	108.5	69.2	0.342	347.7	0.00098	0.00098
110	109.0	110.0	1.0	109.5	59.8	0.344	300.5	0.00114	0.00114

111	110.0	111.0	1.0	110.5	58.3	0.346	293.2	0.00118	0.00118
112	111.0	112.0	1.0	111.5	60.5	0.348	304.0	0.00115	0.00115
113	112.0	113.0	1.0	112.5	59.6	0.350	299.5	0.00117	0.00117
114	113.0	114.0	1.0	113.5	58.2	0.353	292.7	0.00120	0.00120
115	114.0	115.0	1.0	114.5	58.0	0.355	291.7	0.00122	0.00122
116	115.0	116.0	1.0	115.5	168.8	0.357	848.7	0.00042	0.00042
117	116.0	117.0	1.0	116.5	80.9	0.359	406.8	0.00088	0.00088
118	117.0	118.0	1.0	117.5	350.0	0.361	1759.7	0.00021	0.00021
119	118.0	119.0	1.0	118.5	350.0	0.364	1759.7	0.00021	0.00021
120	119.0	120.0	1.0	119.5	350.0	0.366	1759.7	0.00021	0.00021
121	120.0	150.0	30.0	135.0	350.0	0.400	1759.7	0.00682	0.00682
122	150.0	200.0	50.0	175.0	350.0	0.489	1759.7	0.01389	0.01389
123	200.0	202.8	2.8	201.4	350.0	0.546	1759.7	0.00086	0.00086
124	202.8	300.0	97.2	251.4	350.0	0.501	1759.7	0.02769	0.02769
125	300.0	400.0	100.0	350.0	350.0	0.412	1759.7	0.02341	0.02341
126	400.0	500.0	100.0	450.0	350.0	0.322	1759.7	0.01827	0.01827
127	500.0	600.0	100.0	550.0	350.0	0.231	1759.7	0.01314	0.01314
128	600.0	700.0	100.0	650.0	350.0	0.141	1759.7	0.00800	0.00800
129	700.0	800.0	100.0	750.0	350.0	0.050	1759.7	0.00286	0.00286
130	800.0	900.0	100.0	850.0	350.0	0.000	1759.7	0.00000	0.00000
Σ =									0.18155

I_{zr} ($1 < L/B < 10$):	$I_{zr} = I_{zs} + 0.111\,(I_{zc} - I_{zs})\,(L/B - 1)$
I_{zs} ($L/B = 1$):	
For $z_{ave} = 0$ to $B/2$:	$I_{zs} = 0.1 + (z_{ave}/B)(2I_{zp} - 0.2)$
For $z_{ave} = B/2$ to $2B$:	$I_{zs} = 0.667\,I_{zp}\,(2 - z_{ave}/B)$
I_{zc} ($L/B \geq 10$):	
For $z_{ave} = 0$ to B:	$I_{zc} = 0.2 + (z_{ave}/B)(I_{zp} - 0.2)$
For $z_{ave} = B$ to $4B$:	$I_{zc} = 0.333\,I_{zp}\,(4 - z_{ave}/B)$ (Coduto p.228.)

Footing width	B =		400.0	ft	ZV3V5C02
Footing length	L =		450.0	ft	
Ground elevation			261.0	ft	
Foundation elevation			261.0	ft	
Ground Water elevation			225.0	ft	
Excavated or embedded depth	D =		0.0	ft	
Depth to Groundwater			36.0	ft	
Unit weight	γ =		120.0	pcf	
Net applied footing pressure	Δp =		3.000	ksf	
	L/B =		1.13	-	

Immediate Settlement (in.) ($S_0 / 2$)	
Load	S_0 =
	3.3
3.0	3.3
4.3	4.8
6.0	6.7

30 Year Settlement (in.) ($S_{30} / 2$)	
Load	S_0 =
	4.9
4.3	7.1
6.0	10.1

Computation

Settlement	ρ_i =	$C_1 C_t \Delta p \Sigma(\Delta z_i I_{zi}/E_{si})$	0.545	ft	Column I
	ρ_i =		**6.538**	**in**	
	S(t) =		0.815	ft	0.81473655
	S(t) =		**9.777**	**in**	
Correction for strain relief	C_1 =	$1 - 0.5(\sigma'_D/q')$	1.000	-	
Effective vertical overburden pressure at D	σ'_{vo} =	γ D	0.000	ksf	
Correction for time dependent increase	C_t =	1 + 0.2 log(t / 0.1)	1.50	-	
	t =		30.00	years	
Elastic modulus of soil layer i	E_{si} =	2.5 q_c		see Column H	if L/B = 1
	E_{si} =	3.5 q_c		see Column H	If L/B ≥ 10
Depth increment i	Δz_i			see Column D	
Influence factor of soil layer i	I_{zi}	Figure 3-4		see Column G	
Peak depth influence factor	I_{zp} =	$0.5 + 0.1 (\Delta p/\sigma'_{izp})^{1/2}$	0.546	-	
	z_p =	0.5B + D	200.00	ft	If L/B = 1
	z_p =	B + D	400.00	ft	If L/B ≥ 10
	z_p =		202.78	ft	for L/B=1.13
Effective overburden pressure at depth Izp	σ'_{izp} =		13.93	ksf	
Elastic Modulus	E_{si} =		2.50	q_c	If L/B = 1
	E_{si} =		3.50	q_c	If L/B ≥ 10
	E_{si} =		2.51	q_c	for L/B=1.13

A	B	C	D	E	F	G	H	I	J	K
Layer No.	Layer top depth (ft)	Layer bottom depth (ft)	Layer thickness Δz_i (ft)	Mid-layer depth z_{ave} (ft)	Average tip stress q_c (tsf)	I_{zi}	Elastic modulus E_{si} (ksf)	$\Delta z_i I_{zi}/E_{si}$	$\Delta z_i I_{zi}/E_{si}$	Notes
1	0.0	1.0	1.0	0.5	111.1	0.102	558.7	0.00018	0.00018	
2	1.0	2.0	1.0	1.5	139.4	0.105	700.7	0.00015	0.00015	
3	2.0	3.0	1.0	2.5	112.9	0.107	567.7	0.00019	0.00019	
4	3.0	4.0	1.0	3.5	144.4	0.109	725.9	0.00015	0.00015	
5	4.0	5.0	1.0	4.5	100.1	0.111	503.3	0.00022	0.00022	
6	5.0	6.0	1.0	5.5	115.8	0.114	582.2	0.00020	0.00020	
7	6.0	7.0	1.0	6.5	94.4	0.116	474.4	0.00024	0.00024	
8	7.0	8.0	1.0	7.5	139.7	0.118	702.5	0.00017	0.00017	
9	8.0	9.0	1.0	8.5	153.5	0.120	771.8	0.00016	0.00016	
10	9.0	10.0	1.0	9.5	135.1	0.122	679.2	0.00018	0.00018	
11	10.0	11.0	1.0	10.5	119.7	0.125	601.9	0.00021	0.00021	
12	11.0	12.0	1.0	11.5	108.3	0.127	544.7	0.00023	0.00023	
13	12.0	13.0	1.0	12.5	79.4	0.129	399.0	0.00032	0.00032	
14	13.0	14.0	1.0	13.5	72.4	0.131	363.9	0.00036	0.00036	
15	14.0	15.0	1.0	14.5	70.9	0.133	356.5	0.00037	0.00037	
16	15.0	16.0	1.0	15.5	79.3	0.136	398.9	0.00034	0.00034	
17	16.0	17.0	1.0	16.5	107.0	0.138	538.2	0.00026	0.00026	
18	17.0	18.0	1.0	17.5	129.4	0.140	650.8	0.00022	0.00022	
19	18.0	19.0	1.0	18.5	149.1	0.142	749.5	0.00019	0.00019	
20	19.0	20.0	1.0	19.5	217.4	0.145	1092.9	0.00013	0.00013	
21	20.0	21.0	1.0	20.5	247.7	0.147	1245.6	0.00012	0.00012	
22	21.0	22.0	1.0	21.5	220.7	0.149	1109.6	0.00013	0.00013	
23	22.0	23.0	1.0	22.5	207.3	0.151	1042.3	0.00015	0.00015	
24	23.0	24.0	1.0	23.5	190.6	0.153	958.1	0.00016	0.00016	
25	24.0	25.0	1.0	24.5	175.3	0.156	881.1	0.00018	0.00018	
26	25.0	26.0	1.0	25.5	160.7	0.158	807.9	0.00020	0.00020	
27	26.0	27.0	1.0	26.5	145.9	0.160	733.6	0.00022	0.00022	
28	27.0	28.0	1.0	27.5	136.2	0.162	684.9	0.00024	0.00024	
29	28.0	29.0	1.0	28.5	62.9	0.164	316.2	0.00052	0.00052	
30	29.0	30.0	1.0	29.5	63.0	0.167	316.9	0.00053	0.00053	
31	30.0	31.0	1.0	30.5	78.2	0.169	393.0	0.00043	0.00043	
32	31.0	32.0	1.0	31.5	78.8	0.171	396.0	0.00043	0.00043	
33	32.0	33.0	1.0	32.5	41.2	0.173	207.3	0.00084	0.00084	

34	33.0	34.0	1.0	33.5	67.8	0.176	341.0	0.00051	0.00051	
35	34.0	35.0	1.0	34.5	106.5	0.178	535.7	0.00033	0.00033	
36	35.0	36.0	1.0	35.5	100.7	0.180	506.5	0.00036	0.00036	
37	36.0	37.0	1.0	36.5	88.8	0.182	446.5	0.00041	0.00041	
38	37.0	38.0	1.0	37.5	74.5	0.184	374.6	0.00049	0.00049	
39	38.0	39.0	1.0	38.5	49.7	0.187	249.9	0.00075	0.00075	
40	39.0	40.0	1.0	39.5	14.6	0.189	73.2	0.00258	0.00258	
41	40.0	41.0	1.0	40.5	14.8	0.191	74.6	0.00256	0.00256	C2
42	41.0	42.0	1.0	41.5	15.2	0.193	76.6	0.00252	0.00252	C2
43	42.0	43.0	1.0	42.5	15.0	0.195	75.3	0.00259	0.00259	C2
44	43.0	44.0	1.0	43.5	16.2	0.198	81.4	0.00243	0.00243	C2
45	44.0	45.0	1.0	44.5	16.3	0.200	82.2	0.00243	0.00243	C2
46	45.0	46.0	1.0	45.5	112.0	0.202	563.2	0.00036	0.00036	C2
47	46.0	47.0	1.0	46.5	119.8	0.204	602.1	0.00034	0.00034	C2
48	47.0	48.0	1.0	47.5	80.7	0.207	405.9	0.00051	0.00051	
49	48.0	49.0	1.0	48.5	143.7	0.209	722.4	0.00029	0.00029	
50	49.0	50.0	1.0	49.5	176.1	0.211	885.3	0.00024	0.00024	
51	50.0	51.0	1.0	50.5	174.2	0.213	875.9	0.00024	0.00024	
52	51.0	52.0	1.0	51.5	160.2	0.215	805.4	0.00027	0.00027	
53	52.0	53.0	1.0	52.5	104.6	0.218	525.9	0.00041	0.00041	
54	53.0	54.0	1.0	53.5	76.9	0.220	386.7	0.00057	0.00057	
55	54.0	55.0	1.0	54.5	39.2	0.222	197.0	0.00113	0.00113	
56	55.0	56.0	1.0	55.5	37.5	0.224	188.6	0.00119	0.00119	
57	56.0	57.0	1.0	56.5	50.2	0.226	252.6	0.00090	0.00090	
58	57.0	58.0	1.0	57.5	20.4	0.229	102.6	0.00223	0.00223	
59	58.0	59.0	1.0	58.5	50.0	0.231	251.6	0.00092	0.00092	
60	59.0	60.0	1.0	59.5	195.8	0.233	984.4	0.00024	0.00024	
61	60.0	61.0	1.0	60.5	278.4	0.235	1399.9	0.00017	0.00017	
62	61.0	62.0	1.0	61.5	324.9	0.237	1633.3	0.00015	0.00015	
63	62.0	63.0	1.0	62.5	324.9	0.240	1633.3	0.00015	0.00015	
64	63.0	64.0	1.0	63.5	296.2	0.242	1489.3	0.00016	0.00016	
65	64.0	65.0	1.0	64.5	197.6	0.244	993.7	0.00025	0.00025	
66	65.0	66.0	1.0	65.5	26.0	0.246	130.5	0.00189	0.00189	
67	66.0	67.0	1.0	66.5	17.2	0.249	86.5	0.00287	0.00287	
68	67.0	68.0	1.0	67.5	20.5	0.251	103.2	0.00243	0.00243	
69	68.0	69.0	1.0	68.5	31.8	0.253	159.8	0.00158	0.00158	
70	69.0	70.0	1.0	69.5	33.2	0.255	167.1	0.00153	0.00153	
71	70.0	71.0	1.0	70.5	38.6	0.257	194.0	0.00133	0.00133	
72	71.0	72.0	1.0	71.5	46.8	0.260	235.1	0.00110	0.00110	
73	72.0	73.0	1.0	72.5	75.4	0.262	379.2	0.00069	0.00069	
74	73.0	74.0	1.0	73.5	67.2	0.264	337.7	0.00078	0.00078	
75	74.0	75.0	1.0	74.5	42.0	0.266	210.9	0.00126	0.00126	
76	75.0	76.0	1.0	75.5	65.4	0.268	328.8	0.00082	0.00082	
77	76.0	77.0	1.0	76.5	200.2	0.271	1006.7	0.00027	0.00027	
78	77.0	78.0	1.0	77.5	246.4	0.273	1239.0	0.00022	0.00022	
79	78.0	79.0	1.0	78.5	115.0	0.275	578.1	0.00048	0.00048	
80	79.0	80.0	1.0	79.5	212.8	0.277	1069.7	0.00026	0.00026	
81	80.0	81.0	1.0	80.5	105.5	0.280	530.3	0.00053	0.00053	
82	81.0	82.0	1.0	81.5	87.5	0.282	440.0	0.00064	0.00064	
83	82.0	83.0	1.0	82.5	130.2	0.284	654.4	0.00043	0.00043	
84	83.0	84.0	1.0	83.5	162.1	0.286	814.8	0.00035	0.00035	
85	84.0	85.0	1.0	84.5	163.0	0.288	819.4	0.00035	0.00035	
86	85.0	86.0	1.0	85.5	100.2	0.291	503.6	0.00058	0.00058	
87	86.0	87.0	1.0	86.5	90.6	0.293	455.3	0.00064	0.00064	
88	87.0	88.0	1.0	87.5	96.0	0.295	482.6	0.00061	0.00061	
89	88.0	89.0	1.0	88.5	192.0	0.297	965.4	0.00031	0.00031	
90	89.0	90.0	1.0	89.5	154.4	0.299	776.5	0.00039	0.00039	
91	90.0	91.0	1.0	90.5	146.3	0.302	735.7	0.00041	0.00041	
92	91.0	92.0	1.0	91.5	115.3	0.304	579.8	0.00052	0.00052	
93	92.0	93.0	1.0	92.5	108.6	0.306	545.9	0.00056	0.00056	
94	93.0	94.0	1.0	93.5	123.9	0.308	623.1	0.00049	0.00049	
95	94.0	95.0	1.0	94.5	139.2	0.311	699.9	0.00044	0.00044	
96	95.0	96.0	1.0	95.5	165.6	0.313	832.6	0.00038	0.00038	
97	96.0	97.0	1.0	96.5	230.6	0.315	1159.5	0.00027	0.00027	
98	97.0	98.0	1.0	97.5	255.1	0.317	1282.6	0.00025	0.00025	
99	98.0	99.0	1.0	98.5	244.4	0.319	1229.0	0.00026	0.00026	
100	99.0	100.0	1.0	99.5	212.2	0.322	1066.8	0.00030	0.00030	
101	100.0	101.0	1.0	100.5	156.6	0.324	787.3	0.00041	0.00041	
102	101.0	102.0	1.0	101.5	44.4	0.326	223.3	0.00146	0.00146	
103	102.0	103.0	1.0	102.5	70.2	0.328	353.0	0.00093	0.00093	
104	103.0	104.0	1.0	103.5	91.8	0.330	461.6	0.00072	0.00072	
105	104.0	105.0	1.0	104.5	94.4	0.333	474.6	0.00070	0.00070	
106	105.0	106.0	1.0	105.5	98.0	0.335	492.7	0.00068	0.00068	
107	106.0	107.0	1.0	106.5	88.6	0.337	445.5	0.00076	0.00076	
108	107.0	108.0	1.0	107.5	83.8	0.339	421.2	0.00081	0.00081	
109	108.0	109.0	1.0	108.5	69.2	0.342	347.7	0.00098	0.00098	
110	109.0	110.0	1.0	109.5	59.8	0.344	300.5	0.00114	0.00114	

111	110.0	111.0	1.0	110.5	58.3	0.346	293.2	0.00118	0.00118
112	111.0	112.0	1.0	111.5	60.5	0.348	304.0	0.00115	0.00115
113	112.0	113.0	1.0	112.5	59.6	0.350	299.5	0.00117	0.00117
114	113.0	114.0	1.0	113.5	58.2	0.353	292.7	0.00120	0.00120
115	114.0	115.0	1.0	114.5	58.0	0.355	291.7	0.00122	0.00122
116	115.0	116.0	1.0	115.5	168.8	0.357	848.7	0.00042	0.00042
117	116.0	117.0	1.0	116.5	80.9	0.359	406.8	0.00088	0.00088
118	117.0	118.0	1.0	117.5	350.0	0.361	1759.7	0.00021	0.00021
119	118.0	119.0	1.0	118.5	350.0	0.364	1759.7	0.00021	0.00021
120	119.0	120.0	1.0	119.5	350.0	0.366	1759.7	0.00021	0.00021
121	120.0	150.0	30.0	135.0	350.0	0.400	1759.7	0.00682	0.00682
122	150.0	200.0	50.0	175.0	350.0	0.489	1759.7	0.01389	0.01389
123	200.0	202.8	2.8	201.4	350.0	0.546	1759.7	0.00086	0.00086
124	202.8	300.0	97.2	251.4	350.0	0.501	1759.7	0.02769	0.02769
125	300.0	400.0	100.0	350.0	350.0	0.412	1759.7	0.02341	0.02341
126	400.0	500.0	100.0	450.0	350.0	0.322	1759.7	0.01827	0.01827
127	500.0	600.0	100.0	550.0	350.0	0.231	1759.7	0.01314	0.01314
128	600.0	700.0	100.0	650.0	350.0	0.141	1759.7	0.00800	0.00800
129	700.0	800.0	100.0	750.0	350.0	0.050	1759.7	0.00286	0.00286
130	800.0	900.0	100.0	850.0	350.0	0.000	1759.7	0.00000	0.00000
Σ =									0.19484

I_{zr} $(1 < L/B < 10)$:	$I_{zr} = I_{zs} + 0.111\,(I_{zc} - I_{zs})\,(L/B - 1)$
I_{zs} $(L/B = 1)$:	
For $z_{ave} = 0$ to $B/2$:	$I_{zs} = 0.1 + (z_{ave}/B)(2I_{zp} - 0.2)$
For $z_{ave} = B/2$ to $2B$:	$I_{zs} = 0.667\,I_{zp}\,(2 - z_{ave}/B)$
I_{zc} $(L/B \geq 10)$:	
For $z_{ave} = 0$ to B:	$I_{zc} = 0.2 + (z_{ave}/B)(I_{zp} - 0.2)$
For $z_{ave} = B$ to $4B$:	$I_{zc} = 0.333\,I_{zp}\,(4 - z_{ave}/B)$ (Coduto p.228.)

Footing width	B =		400.0 ft	ZV3V5C03	
Footing length	L =		450.0 ft		Immediate
Ground elevation			261.0 ft		Settlement (in.)
Foundation elevation			261.0 ft		$(S_0 / 2)$
Ground Water elevation			225.0 ft		Load S_0 =
Excavated or embedded depth	D =		0.0 ft		3.1
Depth to Groundwater			36.0 ft		3.0 3.1
Unit weight	γ =		120.0 pcf		4.3 4.5
Net applied footing pressure	Δp =		3.000 ksf		6.0 6.3
	L/B =		1.13 -		
					30 Year
Computation					Settlement (in.)
Settlement	ρ_i =	$C_1 C_t \Delta p \Sigma(\Delta z_i I_{zi}/E_{si})$	0.511 ft	Column I	$(S_{30} / 2)$
	ρ_i =		6.136 in		Load S_0 =
	S(t) =		0.765 ft		4.6
	S(t) =		9.176 in		4.3 6.7
Correction for strain relief	C_1 =	$1 - 0.5(\sigma'_D/q')$	1.000 -		6.0 9.5
Effective vertical overburden pressure at D	σ'_{vo} =	γ D	0.000 ksf		
Correction for time dependent increase	C_t =	$1 + 0.2 \log(t / 0.1)$	1.50 -		
	t =		30.00 years		
Elastic modulus of soil layer i	E_{si} =	2.5 q_c	see Column H	if L/B = 1	
	E_{si} =	3.5 q_c	see Column H	If L/B ≥ 10	
Depth increment i	Δz_i		see Column D		
Influence factor of soil layer i	I_{zi}	Figure 3-4	see Column G		
Peak depth influence factor	I_{zp} =	$0.5 + 0.1 (\Delta p/\sigma'_{izp})^{1/2}$	0.546 -		
	z_p =	0.5B + D	200.00 ft	If L/B = 1	
	z_p =	B + D	400.00 ft	If L/B ≥ 10	
	z_p =		202.78 ft	for L/B=1.13	
Effective overburden pressure at depth Izp	σ'_{izp} =		13.93 ksf		
Elastic Modulus	E_{si} =		2.50 q_c	If L/B = 1	
	E_{si} =		3.50 q_c	If L/B ≥ 10	
	E_{si} =		2.51 q_c	for L/B=1.13	

A	B	C	D	E	F	G	H	I	J	K
Layer No.	Layer top depth (ft)	Layer bottom depth (ft)	Layer thickness Δz_i (ft)	Mid-layer depth z_{ave} (ft)	Average tip stress q_c (tsf)	I_{zi}	Elastic modulus E_{si} (ksf)	$\Delta z_i I_{zi}/E_{si}$	$\Delta z_i I_{zi}/E_{si}$	Notes
1	0.0	1.0	1.0	0.5	47.6	0.102	239.2	0.00043	0.00043	
2	1.0	2.0	1.0	1.5	66.5	0.105	334.5	0.00031	0.00031	
3	2.0	3.0	1.0	2.5	107.0	0.107	538.0	0.00020	0.00020	
4	3.0	4.0	1.0	3.5	129.7	0.109	652.1	0.00017	0.00017	
5	4.0	5.0	1.0	4.5	172.4	0.111	867.0	0.00013	0.00013	
6	5.0	6.0	1.0	5.5	244.0	0.114	1226.9	0.00009	0.00009	
7	6.0	7.0	1.0	6.5	240.7	0.116	1210.0	0.00010	0.00010	
8	7.0	8.0	1.0	7.5	220.1	0.118	1106.6	0.00011	0.00011	
9	8.0	9.0	1.0	8.5	154.8	0.120	778.1	0.00015	0.00015	
10	9.0	10.0	1.0	9.5	118.2	0.122	594.3	0.00021	0.00021	
11	10.0	11.0	1.0	10.5	113.1	0.125	568.8	0.00022	0.00022	
12	11.0	12.0	1.0	11.5	113.4	0.127	570.2	0.00022	0.00022	
13	12.0	13.0	1.0	12.5	103.6	0.129	521.0	0.00025	0.00025	
14	13.0	14.0	1.0	13.5	108.9	0.131	547.6	0.00024	0.00024	
15	14.0	15.0	1.0	14.5	107.7	0.133	541.4	0.00025	0.00025	
16	15.0	16.0	1.0	15.5	116.9	0.136	588.0	0.00023	0.00023	
17	16.0	17.0	1.0	16.5	112.9	0.138	567.8	0.00024	0.00024	
18	17.0	18.0	1.0	17.5	134.8	0.140	677.5	0.00021	0.00021	
19	18.0	19.0	1.0	18.5	103.1	0.142	518.2	0.00027	0.00027	
20	19.0	20.0	1.0	19.5	115.6	0.145	581.0	0.00025	0.00025	
21	20.0	21.0	1.0	20.5	71.7	0.147	360.7	0.00041	0.00041	
22	21.0	22.0	1.0	21.5	93.0	0.149	467.4	0.00032	0.00032	
23	22.0	23.0	1.0	22.5	92.7	0.151	466.1	0.00032	0.00032	
24	23.0	24.0	1.0	23.5	91.7	0.153	460.8	0.00033	0.00033	
25	24.0	25.0	1.0	24.5	97.1	0.156	488.1	0.00032	0.00032	
26	25.0	26.0	1.0	25.5	118.5	0.158	596.0	0.00026	0.00026	
27	26.0	27.0	1.0	26.5	139.1	0.160	699.4	0.00023	0.00023	
28	27.0	28.0	1.0	27.5	124.6	0.162	626.6	0.00026	0.00026	
29	28.0	29.0	1.0	28.5	138.6	0.164	696.7	0.00024	0.00024	
30	29.0	30.0	1.0	29.5	164.8	0.167	828.7	0.00020	0.00020	
31	30.0	31.0	1.0	30.5	166.2	0.169	835.9	0.00020	0.00020	
32	31.0	32.0	1.0	31.5	156.0	0.171	784.1	0.00022	0.00022	
33	32.0	33.0	1.0	32.5	130.2	0.173	654.6	0.00026	0.00026	

34	33.0	34.0	1.0	33.5	128.9	0.176	648.1	0.00027	0.00027
35	34.0	35.0	1.0	34.5	160.5	0.178	806.9	0.00022	0.00022
36	35.0	36.0	1.0	35.5	163.1	0.180	819.9	0.00022	0.00022
37	36.0	37.0	1.0	36.5	108.9	0.182	547.4	0.00033	0.00033
38	37.0	38.0	1.0	37.5	173.1	0.184	870.1	0.00021	0.00021
39	38.0	39.0	1.0	38.5	218.1	0.187	1096.5	0.00017	0.00017
40	39.0	40.0	1.0	39.5	233.8	0.189	1175.4	0.00016	0.00016
41	40.0	41.0	1.0	40.5	255.3	0.191	1283.4	0.00015	0.00015
42	41.0	42.0	1.0	41.5	265.8	0.193	1336.4	0.00014	0.00014
43	42.0	43.0	1.0	42.5	274.7	0.195	1381.0	0.00014	0.00014
44	43.0	44.0	1.0	43.5	302.6	0.198	1521.3	0.00013	0.00013
45	44.0	45.0	1.0	44.5	285.2	0.200	1433.9	0.00014	0.00014
46	45.0	46.0	1.0	45.5	247.4	0.202	1244.0	0.00016	0.00016
47	46.0	47.0	1.0	46.5	225.1	0.204	1131.9	0.00018	0.00018
48	47.0	48.0	1.0	47.5	178.8	0.207	899.2	0.00023	0.00023
49	48.0	49.0	1.0	48.5	133.1	0.209	669.4	0.00031	0.00031
50	49.0	50.0	1.0	49.5	47.9	0.211	241.0	0.00088	0.00088
51	50.0	51.0	1.0	50.5	34.5	0.213	173.5	0.00123	0.00123
52	51.0	52.0	1.0	51.5	38.4	0.215	193.1	0.00112	0.00112
53	52.0	53.0	1.0	52.5	80.4	0.218	404.3	0.00054	0.00054
54	53.0	54.0	1.0	53.5	164.2	0.220	825.6	0.00027	0.00027
55	54.0	55.0	1.0	54.5	234.1	0.222	1177.2	0.00019	0.00019
56	55.0	56.0	1.0	55.5	213.7	0.224	1074.4	0.00021	0.00021
57	56.0	57.0	1.0	56.5	172.5	0.226	867.4	0.00026	0.00026
58	57.0	58.0	1.0	57.5	211.4	0.229	1063.1	0.00022	0.00022
59	58.0	59.0	1.0	58.5	264.1	0.231	1327.9	0.00017	0.00017
60	59.0	60.0	1.0	59.5	331.9	0.233	1668.9	0.00014	0.00014
61	60.0	61.0	1.0	60.5	231.4	0.235	1163.6	0.00020	0.00020
62	61.0	62.0	1.0	61.5	164.1	0.237	825.2	0.00029	0.00029
63	62.0	63.0	1.0	62.5	109.7	0.240	551.6	0.00043	0.00043
64	63.0	64.0	1.0	63.5	52.4	0.242	263.7	0.00092	0.00092
65	64.0	65.0	1.0	64.5	34.4	0.244	173.0	0.00141	0.00141
66	65.0	66.0	1.0	65.5	35.9	0.246	180.7	0.00136	0.00136
67	66.0	67.0	1.0	66.5	20.0	0.249	100.5	0.00247	0.00247
68	67.0	68.0	1.0	67.5	148.9	0.251	748.5	0.00034	0.00034
69	68.0	69.0	1.0	68.5	92.1	0.253	463.3	0.00055	0.00055
70	69.0	70.0	1.0	69.5	49.6	0.255	249.4	0.00102	0.00102
71	70.0	71.0	1.0	70.5	81.9	0.257	411.7	0.00063	0.00063
72	71.0	72.0	1.0	71.5	364.0	0.260	1830.3	0.00014	0.00014
73	72.0	73.0	1.0	72.5	403.7	0.262	2029.9	0.00013	0.00013
74	73.0	74.0	1.0	73.5	46.9	0.264	235.8	0.00112	0.00112
75	74.0	75.0	1.0	74.5	74.3	0.266	373.6	0.00071	0.00071
76	75.0	76.0	1.0	75.5	93.7	0.268	471.1	0.00057	0.00057
77	76.0	77.0	1.0	76.5	90.0	0.271	452.4	0.00060	0.00060
78	77.0	78.0	1.0	77.5	123.8	0.273	622.6	0.00044	0.00044
79	78.0	79.0	1.0	78.5	126.3	0.275	634.8	0.00043	0.00043
80	79.0	80.0	1.0	79.5	148.3	0.277	745.4	0.00037	0.00037
81	80.0	81.0	1.0	80.5	105.5	0.280	530.3	0.00053	0.00053
82	81.0	82.0	1.0	81.5	87.5	0.282	440.0	0.00064	0.00064
83	82.0	83.0	1.0	82.5	130.2	0.284	654.4	0.00043	0.00043
84	83.0	84.0	1.0	83.5	162.1	0.286	814.8	0.00035	0.00035
85	84.0	85.0	1.0	84.5	163.0	0.288	819.4	0.00035	0.00035
86	85.0	86.0	1.0	85.5	100.2	0.291	503.6	0.00058	0.00058
87	86.0	87.0	1.0	86.5	90.6	0.293	455.3	0.00064	0.00064
88	87.0	88.0	1.0	87.5	96.0	0.295	482.6	0.00061	0.00061
89	88.0	89.0	1.0	88.5	192.0	0.297	965.4	0.00031	0.00031
90	89.0	90.0	1.0	89.5	154.4	0.299	776.5	0.00039	0.00039
91	90.0	91.0	1.0	90.5	146.3	0.302	735.7	0.00041	0.00041
92	91.0	92.0	1.0	91.5	115.3	0.304	579.8	0.00052	0.00052
93	92.0	93.0	1.0	92.5	108.6	0.306	545.9	0.00056	0.00056
94	93.0	94.0	1.0	93.5	123.9	0.308	623.1	0.00049	0.00049
95	94.0	95.0	1.0	94.5	139.2	0.311	699.9	0.00044	0.00044
96	95.0	96.0	1.0	95.5	165.6	0.313	832.6	0.00038	0.00038
97	96.0	97.0	1.0	96.5	230.6	0.315	1159.5	0.00027	0.00027
98	97.0	98.0	1.0	97.5	255.1	0.317	1282.6	0.00025	0.00025
99	98.0	99.0	1.0	98.5	244.4	0.319	1229.0	0.00026	0.00026
100	99.0	100.0	1.0	99.5	212.2	0.322	1066.8	0.00030	0.00030
101	100.0	101.0	1.0	100.5	156.6	0.324	787.3	0.00041	0.00041
102	101.0	102.0	1.0	101.5	44.4	0.326	223.3	0.00146	0.00146
103	102.0	103.0	1.0	102.5	70.2	0.328	353.0	0.00093	0.00093
104	103.0	104.0	1.0	103.5	91.8	0.330	461.6	0.00072	0.00072
105	104.0	105.0	1.0	104.5	94.4	0.333	474.6	0.00070	0.00070
106	105.0	106.0	1.0	105.5	98.0	0.335	492.7	0.00068	0.00068
107	106.0	107.0	1.0	106.5	88.6	0.337	445.5	0.00076	0.00076
108	107.0	108.0	1.0	107.5	83.8	0.339	421.2	0.00081	0.00081
109	108.0	109.0	1.0	108.5	69.2	0.342	347.7	0.00098	0.00098
110	109.0	110.0	1.0	109.5	59.8	0.344	300.5	0.00114	0.00114

111	110.0	111.0	1.0	110.5	58.3	0.346	293.2	0.00118	0.00118	
112	111.0	112.0	1.0	111.5	60.5	0.348	304.0	0.00115	0.00115	
113	112.0	113.0	1.0	112.5	59.6	0.350	299.5	0.00117	0.00117	
114	113.0	114.0	1.0	113.5	58.2	0.353	292.7	0.00120	0.00120	
115	114.0	115.0	1.0	114.5	58.0	0.355	291.7	0.00122	0.00122	
116	115.0	116.0	1.0	115.5	168.8	0.357	848.7	0.00042	0.00042	
117	116.0	117.0	1.0	116.5	80.9	0.359	406.8	0.00088	0.00088	
118	117.0	118.0	1.0	117.5	350.0	0.361	1759.7	0.00021	0.00021	
119	118.0	119.0	1.0	118.5	350.0	0.364	1759.7	0.00021	0.00021	
120	119.0	120.0	1.0	119.5	350.0	0.366	1759.7	0.00021	0.00021	
121	120.0	150.0	30.0	135.0	350.0	0.400	1759.7	0.00682	0.00682	
122	150.0	200.0	50.0	175.0	350.0	0.489	1759.7	0.01389	0.01389	
123	200.0	202.8	2.8	201.4	350.0	0.546	1759.7	0.00086	0.00086	
124	202.8	300.0	97.2	251.4	350.0	0.501	1759.7	0.02769	0.02769	
125	300.0	400.0	100.0	350.0	350.0	0.412	1759.7	0.02341	0.02341	
126	400.0	500.0	100.0	450.0	350.0	0.322	1759.7	0.01827	0.01827	
127	500.0	600.0	100.0	550.0	350.0	0.231	1759.7	0.01314	0.01314	
128	600.0	700.0	100.0	650.0	350.0	0.141	1759.7	0.00800	0.00800	
129	700.0	800.0	100.0	750.0	350.0	0.050	1759.7	0.00286	0.00286	
130	800.0	900.0	100.0	850.0	350.0	0.000	1759.7	0.00000	0.00000	
Σ =									0.17045	

I_{zr} $(1 < L/B < 10)$: $I_{zr} = I_{zs} + 0.111\,(I_{zc} - I_{zs})\,(L/B - 1)$

I_{zs} $(L/B = 1)$:

For $z_{ave} = 0$ to $B/2$: $I_{zs} = 0.1 + (z_{ave}/B)(2I_{zp} - 0.2)$

For $z_{ave} = B/2$ to $2B$: $I_{zs} = 0.667\, I_{zp}\,(2 - z_{ave}/B)$

I_{zc} $(L/B \geq 10)$:

For $z_{ave} = 0$ to B: $I_{zc} = 0.2 + (z_{ave}/B)(I_{zp} - 0.2)$

For $z_{ave} = B$ to $4B$: $I_{zc} = 0.333\, I_{zp}\,(4 - z_{ave}/B)$ (Coduto p.228.)

Footing width	B =		400.0 ft	ZV3V5C04	
Footing length	L =		450.0 ft		Immediate Settlement (in.) (S_0 / 2)
Ground elevation			261.0 ft		
Foundation elevation			261.0 ft		
Ground Water elevation			225.0 ft		Load S_0 =
Excavated or embedded depth	D =		0.0 ft		3.2
Depth to Groundwater			36.0 ft		3.0 3.2
Unit weight	γ =		120.0 pcf		4.3 4.7
Net applied footing pressure	Δp =		3.000 ksf		6.0 6.7
	L/B =		1.13 -		
					30 Year Settlement (in.) (S_{30} / 2)
Computation					
Settlement	ρ_i =	$C_1\ C_t\ \Delta p\ \Sigma(\Delta z_i\ I_{zi}/E_{si})$	0.539 ft	Column I	Load S_0 =
	ρ_i =		**6.468 in**		4.8
	S(t) =		0.806 ft		4.3 7.0
	S(t) =		**9.673 in**		6.0 10.0
Correction for strain relief	C_1 =	1 - 0.5(σ'$_D$/q')	1.000 -		
Effective vertical overburden pressure at D	σ'$_{vo}$ =	γ D	0.000 ksf		
Correction for time dependent increase	C_t =	1 + 0.2 log(t / 0.1)	1.50 -		
	t =		30.00 years		
Elastic modulus of soil layer i	E_{si} =	2.5 q_c	see Column H	if L/B = 1	
	E_{si} =	3.5 q_c	see Column H	If L/B ≥ 10	
Depth increment i	Δz_i		see Column D		
Influence factor of soil layer i	I_{zi}	Figure 3-4	see Column G		
Peak depth influence factor	I_{zp} =	$0.5 + 0.1\ (\Delta p/\sigma'_{Izp})^{1/2}$	0.546 -		
	z_p =	0.5B + D	200.00 ft	If L/B = 1	
	z_p =	B + D	400.00 ft	If L/B ≥ 10	
	z_p =		202.78 ft	for L/B=1.13	
Effective overburden pressure at depth Izp	σ'$_{Izp}$ =		13.93 ksf		
Elastic Modulus	E_{si} =		2.50 q_c	If L/B = 1	
	E_{si} =		3.50 q_c	If L/B ≥ 10	
	E_{si} =		2.51 q_c	for L/B=1.13	

A	B	C	D	E	F	G	H	I	J	K
Layer No.	Layer top depth (ft)	Layer bottom depth (ft)	Layer thickness Δz_i (ft)	Mid-layer depth z_{ave} (ft)	Average tip stress q_c (tsf)	I_{zi}	Elastic modulus E_{si} (ksf)	$\Delta z_i\ I_{zi}/E_{si}$	$\Delta z_i\ I_{zi}/E_{si}$	Notes
1	0.0	1.0	1.0	0.5	254.1	0.102	1277.8	0.00008	0.00008	
2	1.0	2.0	1.0	1.5	195.0	0.105	980.6	0.00011	0.00011	
3	2.0	3.0	1.0	2.5	166.6	0.107	837.8	0.00013	0.00013	
4	3.0	4.0	1.0	3.5	120.8	0.109	607.3	0.00018	0.00018	
5	4.0	5.0	1.0	4.5	114.0	0.111	573.1	0.00019	0.00019	
6	5.0	6.0	1.0	5.5	115.8	0.114	582.1	0.00020	0.00020	
7	6.0	7.0	1.0	6.5	95.9	0.116	482.0	0.00024	0.00024	
8	7.0	8.0	1.0	7.5	85.9	0.118	432.1	0.00027	0.00027	
9	8.0	9.0	1.0	8.5	101.5	0.120	510.2	0.00024	0.00024	
10	9.0	10.0	1.0	9.5	89.5	0.122	450.0	0.00027	0.00027	
11	10.0	11.0	1.0	10.5	103.1	0.125	518.4	0.00024	0.00024	
12	11.0	12.0	1.0	11.5	118.0	0.127	593.3	0.00021	0.00021	
13	12.0	13.0	1.0	12.5	121.6	0.129	611.6	0.00021	0.00021	
14	13.0	14.0	1.0	13.5	104.3	0.131	524.3	0.00025	0.00025	
15	14.0	15.0	1.0	14.5	113.2	0.133	569.0	0.00023	0.00023	
16	15.0	16.0	1.0	15.5	110.4	0.136	554.9	0.00024	0.00024	
17	16.0	17.0	1.0	16.5	111.7	0.138	561.7	0.00025	0.00025	
18	17.0	18.0	1.0	17.5	129.8	0.140	652.7	0.00021	0.00021	
19	18.0	19.0	1.0	18.5	141.9	0.142	713.5	0.00020	0.00020	
20	19.0	20.0	1.0	19.5	156.1	0.145	784.6	0.00018	0.00018	
21	20.0	21.0	1.0	20.5	141.3	0.147	710.5	0.00021	0.00021	
22	21.0	22.0	1.0	21.5	131.2	0.149	659.4	0.00023	0.00023	
23	22.0	23.0	1.0	22.5	121.3	0.151	609.7	0.00025	0.00025	
24	23.0	24.0	1.0	23.5	126.6	0.153	636.6	0.00024	0.00024	
25	24.0	25.0	1.0	24.5	118.1	0.156	593.7	0.00026	0.00026	
26	25.0	26.0	1.0	25.5	134.0	0.158	673.7	0.00023	0.00023	
27	26.0	27.0	1.0	26.5	106.8	0.160	536.9	0.00030	0.00030	
28	27.0	28.0	1.0	27.5	133.2	0.162	669.8	0.00024	0.00024	
29	28.0	29.0	1.0	28.5	174.6	0.164	877.7	0.00019	0.00019	
30	29.0	30.0	1.0	29.5	147.8	0.167	743.0	0.00022	0.00022	
31	30.0	31.0	1.0	30.5	78.0	0.169	392.1	0.00043	0.00043	
32	31.0	32.0	1.0	31.5	85.6	0.171	430.3	0.00040	0.00040	
33	32.0	33.0	1.0	32.5	126.8	0.173	637.3	0.00027	0.00027	

34	33.0	34.0	1.0	33.5	146.0	0.176	734.0	0.00024	0.00024
35	34.0	35.0	1.0	34.5	165.8	0.178	833.7	0.00021	0.00021
36	35.0	36.0	1.0	35.5	182.5	0.180	917.4	0.00020	0.00020
37	36.0	37.0	1.0	36.5	196.8	0.182	989.6	0.00018	0.00018
38	37.0	38.0	1.0	37.5	197.0	0.184	990.3	0.00019	0.00019
39	38.0	39.0	1.0	38.5	219.6	0.187	1104.3	0.00017	0.00017
40	39.0	40.0	1.0	39.5	255.7	0.189	1285.5	0.00015	0.00015
41	40.0	41.0	1.0	40.5	273.8	0.191	1376.6	0.00014	0.00014
42	41.0	42.0	1.0	41.5	261.8	0.193	1316.4	0.00015	0.00015
43	42.0	43.0	1.0	42.5	229.3	0.195	1152.8	0.00017	0.00017
44	43.0	44.0	1.0	43.5	120.2	0.198	604.5	0.00033	0.00033
45	44.0	45.0	1.0	44.5	202.9	0.200	1019.9	0.00020	0.00020
46	45.0	46.0	1.0	45.5	211.3	0.202	1062.5	0.00019	0.00019
47	46.0	47.0	1.0	46.5	215.0	0.204	1081.0	0.00019	0.00019
48	47.0	48.0	1.0	47.5	232.8	0.207	1170.2	0.00018	0.00018
49	48.0	49.0	1.0	48.5	219.7	0.209	1104.4	0.00019	0.00019
50	49.0	50.0	1.0	49.5	214.3	0.211	1077.2	0.00020	0.00020
51	50.0	51.0	1.0	50.5	257.0	0.213	1292.0	0.00016	0.00016
52	51.0	52.0	1.0	51.5	264.0	0.215	1327.3	0.00016	0.00016
53	52.0	53.0	1.0	52.5	259.4	0.218	1304.1	0.00017	0.00017
54	53.0	54.0	1.0	53.5	242.2	0.220	1217.7	0.00018	0.00018
55	54.0	55.0	1.0	54.5	231.6	0.222	1164.5	0.00019	0.00019
56	55.0	56.0	1.0	55.5	160.4	0.224	806.5	0.00028	0.00028
57	56.0	57.0	1.0	56.5	90.5	0.226	455.2	0.00050	0.00050
58	57.0	58.0	1.0	57.5	239.5	0.229	1203.9	0.00019	0.00019
59	58.0	59.0	1.0	58.5	281.4	0.231	1415.0	0.00016	0.00016
60	59.0	60.0	1.0	59.5	258.2	0.233	1298.1	0.00018	0.00018
61	60.0	61.0	1.0	60.5	280.1	0.235	1408.5	0.00017	0.00017
62	61.0	62.0	1.0	61.5	262.7	0.237	1320.7	0.00018	0.00018
63	62.0	63.0	1.0	62.5	129.7	0.240	652.0	0.00037	0.00037
64	63.0	64.0	1.0	63.5	183.2	0.242	920.9	0.00026	0.00026
65	64.0	65.0	1.0	64.5	258.4	0.244	1299.1	0.00019	0.00019
66	65.0	66.0	1.0	65.5	180.1	0.246	905.7	0.00027	0.00027
67	66.0	67.0	1.0	66.5	24.0	0.249	120.5	0.00206	0.00206
68	67.0	68.0	1.0	67.5	17.2	0.251	86.5	0.00290	0.00290
69	68.0	69.0	1.0	68.5	21.5	0.253	108.2	0.00234	0.00234
70	69.0	70.0	1.0	69.5	16.4	0.255	82.4	0.00310	0.00310
71	70.0	71.0	1.0	70.5	13.9	0.257	69.7	0.00369	0.00369
72	71.0	72.0	1.0	71.5	32.2	0.260	162.0	0.00160	0.00160
73	72.0	73.0	1.0	72.5	19.0	0.262	95.3	0.00275	0.00275
74	73.0	74.0	1.0	73.5	12.8	0.264	64.1	0.00412	0.00412
75	74.0	75.0	1.0	74.5	55.1	0.266	276.9	0.00096	0.00096
76	75.0	76.0	1.0	75.5	132.1	0.268	664.0	0.00040	0.00040
77	76.0	77.0	1.0	76.5	125.0	0.271	628.3	0.00043	0.00043
78	77.0	78.0	1.0	77.5	203.4	0.273	1022.7	0.00027	0.00027
79	78.0	79.0	1.0	78.5	140.6	0.275	707.0	0.00039	0.00039
80	79.0	80.0	1.0	79.5	513.4	0.277	2581.3	0.00011	0.00011
81	80.0	81.0	1.0	80.5	105.5	0.280	530.3	0.00053	0.00053
82	81.0	82.0	1.0	81.5	87.5	0.282	440.0	0.00064	0.00064
83	82.0	83.0	1.0	82.5	130.2	0.284	654.4	0.00043	0.00043
84	83.0	84.0	1.0	83.5	162.1	0.286	814.8	0.00035	0.00035
85	84.0	85.0	1.0	84.5	163.0	0.288	819.4	0.00035	0.00035
86	85.0	86.0	1.0	85.5	100.2	0.291	503.6	0.00058	0.00058
87	86.0	87.0	1.0	86.5	90.6	0.293	455.3	0.00064	0.00064
88	87.0	88.0	1.0	87.5	96.0	0.295	482.6	0.00061	0.00061
89	88.0	89.0	1.0	88.5	192.0	0.297	965.4	0.00031	0.00031
90	89.0	90.0	1.0	89.5	154.4	0.299	776.5	0.00039	0.00039
91	90.0	91.0	1.0	90.5	146.3	0.302	735.7	0.00041	0.00041
92	91.0	92.0	1.0	91.5	115.3	0.304	579.8	0.00052	0.00052
93	92.0	93.0	1.0	92.5	108.6	0.306	545.9	0.00056	0.00056
94	93.0	94.0	1.0	93.5	123.9	0.308	623.1	0.00049	0.00049
95	94.0	95.0	1.0	94.5	139.2	0.311	699.9	0.00044	0.00044
96	95.0	96.0	1.0	95.5	165.6	0.313	832.6	0.00038	0.00038
97	96.0	97.0	1.0	96.5	230.6	0.315	1159.5	0.00027	0.00027
98	97.0	98.0	1.0	97.5	255.1	0.317	1282.6	0.00025	0.00025
99	98.0	99.0	1.0	98.5	244.4	0.319	1229.0	0.00026	0.00026
100	99.0	100.0	1.0	99.5	212.2	0.322	1066.8	0.00030	0.00030
101	100.0	101.0	1.0	100.5	156.6	0.324	787.3	0.00041	0.00041
102	101.0	102.0	1.0	101.5	44.4	0.326	223.3	0.00146	0.00146
103	102.0	103.0	1.0	102.5	70.2	0.328	353.0	0.00093	0.00093
104	103.0	104.0	1.0	103.5	91.8	0.330	461.6	0.00072	0.00072
105	104.0	105.0	1.0	104.5	94.4	0.333	474.6	0.00070	0.00070
106	105.0	106.0	1.0	105.5	98.0	0.335	492.7	0.00068	0.00068
107	106.0	107.0	1.0	106.5	88.6	0.337	445.5	0.00076	0.00076
108	107.0	108.0	1.0	107.5	83.8	0.339	421.2	0.00081	0.00081
109	108.0	109.0	1.0	108.5	69.2	0.342	347.7	0.00098	0.00098
110	109.0	110.0	1.0	109.5	59.8	0.344	300.5	0.00114	0.00114

111	110.0	111.0	1.0	110.5	58.3	0.346	293.2	0.00118	0.00118	
112	111.0	112.0	1.0	111.5	60.5	0.348	304.0	0.00115	0.00115	
113	112.0	113.0	1.0	112.5	59.6	0.350	299.5	0.00117	0.00117	
114	113.0	114.0	1.0	113.5	58.2	0.353	292.7	0.00120	0.00120	
115	114.0	115.0	1.0	114.5	58.0	0.355	291.7	0.00122	0.00122	
116	115.0	116.0	1.0	115.5	168.8	0.357	848.7	0.00042	0.00042	
117	116.0	117.0	1.0	116.5	80.9	0.359	406.8	0.00088	0.00088	
118	117.0	118.0	1.0	117.5	350.0	0.361	1759.7	0.00021	0.00021	
119	118.0	119.0	1.0	118.5	350.0	0.364	1759.7	0.00021	0.00021	
120	119.0	120.0	1.0	119.5	350.0	0.366	1759.7	0.00021	0.00021	
121	120.0	150.0	30.0	135.0	350.0	0.400	1759.7	0.00682	0.00682	
122	150.0	200.0	50.0	175.0	350.0	0.489	1759.7	0.01389	0.01389	
123	200.0	202.8	2.8	201.4	350.0	0.546	1759.7	0.00086	0.00086	
124	202.8	300.0	97.2	251.4	350.0	0.501	1759.7	0.02769	0.02769	
125	300.0	400.0	100.0	350.0	350.0	0.412	1759.7	0.02341	0.02341	
126	400.0	500.0	100.0	450.0	350.0	0.322	1759.7	0.01827	0.01827	
127	500.0	600.0	100.0	550.0	350.0	0.231	1759.7	0.01314	0.01314	
128	600.0	700.0	100.0	650.0	350.0	0.141	1759.7	0.00800	0.00800	
129	700.0	800.0	100.0	750.0	350.0	0.050	1759.7	0.00286	0.00286	
130	800.0	900.0	100.0	850.0	350.0	0.000	1759.7	0.00000	0.00000	
Σ =									0.17968	

I_{zr} *(1 < L/B < 10):*	$I_{zr} = I_{zs} + 0.111\,(I_{zc} - I_{zs})\,(L/B - 1)$
I_{zs} *(L/B = 1):*	
For z_{ave} *= 0 to B/2:*	$I_{zs} = 0.1 + (z_{ave}/B)(2I_{zp} - 0.2)$
For z_{ave} *= B/2 to 2B:*	$I_{zs} = 0.667\,I_{zp}\,(2 - z_{ave}/B)$
I_{zc} *(L/B ≥ 10):*	
For z_{ave} *= 0 to B:*	$I_{zc} = 0.2 + (z_{ave}/B)(I_{zp} - 0.2)$
For z_{ave} *= B to 4B:*	$I_{zc} = 0.333\,I_{zp}\,(4 - z_{ave}/B)$ (Coduto p.228.)

Footing width	B =		400.0	ft	ZV3V5C05
Footing length	L =		450.0	ft	
Ground elevation			261.0	ft	
Foundation elevation			261.0	ft	
Ground Water elevation			225.0	ft	
Excavated or embedded depth	D =		0.0	ft	
Depth to Groundwater			36.0	ft	
Unit weight	γ =		120.0	pcf	
Net applied footing pressure	Δp =		3.000	ksf	
	L/B =		1.13	-	
Computation					
Settlement	ρ_i =	$C_1\ C_t\ \Delta p\ \Sigma(\Delta z_i\ I_{zi}/E_{si})$	0.522	ft	Column I
	ρ_i =		**6.263**	**in**	
	S(t) =		0.780	ft	
	S(t) =		**9.366**	**in**	
Correction for strain relief	C_1 =	$1 - 0.5(\sigma'_D/q')$	1.000	-	
Effective vertical overburden pressure at D	σ'_{vo} =	γ D	0.000	ksf	
Correction for time dependent increase	C_t =	$1 + 0.2 \log(t / 0.1)$	1.50	-	
	t =		30.00	years	
Elastic modulus of soil layer i	E_{si} =	$2.5\ q_c$		see Column H	if L/B = 1
	E_{si} =	$3.5\ q_c$		see Column H	If L/B ≥ 10
Depth increment i	Δz_i			see Column D	
Influence factor of soil layer i	I_{zi}	Figure 3-4		see Column G	
Peak depth influence factor	I_{zp} =	$0.5 + 0.1\ (\Delta p/\sigma'_{Izp})^{1/2}$	0.546	-	
	z_p =	0.5B + D	200.00	ft	If L/B = 1
	z_p =	B + D	400.00	ft	If L/B ≥ 10
	z_p =		202.78	ft	for L/B=1.13
Effective overburden pressure at depth Izp	σ'_{Izp} =		13.93	ksf	
Elastic Modulus	E_{si} =		2.50	q_c	If L/B = 1
	E_{si} =		3.50	q_c	If L/B ≥ 10
	E_{si} =		2.51	q_c	for L/B=1.13

Immediate Settlement (in.) (S_0 / 2)

Load	S_0 =
	3.1
3.0	3.1
4.3	4.6
6.0	6.5

30 Year Settlement (in.) (S_{30} / 2)

Load	S_0 =
	4.7
4.3	6.8
6.0	9.7

A	B	C	D	E	F	G	H	I	J	K
Layer No.	Layer top depth (ft)	Layer bottom depth (ft)	Layer thickness Δz_i (ft)	Mid-layer depth z_{ave} (ft)	Average tip stress q_c (tsf)	I_{zi}	Elastic modulus E_{si} (ksf)	$\Delta z_i\ I_{zi}/E_{si}$	$\Delta z_i\ I_{zi}/E_{si}$	Notes
1	0.0	1.0	1.0	0.5	361.5	0.102	1817.6	0.00006	0.00006	
2	1.0	2.0	1.0	1.5	367.4	0.105	1847.4	0.00006	0.00006	
3	2.0	3.0	1.0	2.5	271.5	0.107	1365.0	0.00008	0.00008	
4	3.0	4.0	1.0	3.5	328.5	0.109	1651.6	0.00007	0.00007	
5	4.0	5.0	1.0	4.5	219.5	0.111	1103.8	0.00010	0.00010	
6	5.0	6.0	1.0	5.5	159.2	0.114	800.5	0.00014	0.00014	
7	6.0	7.0	1.0	6.5	154.9	0.116	778.6	0.00015	0.00015	
8	7.0	8.0	1.0	7.5	132.2	0.118	664.8	0.00018	0.00018	
9	8.0	9.0	1.0	8.5	200.4	0.120	1007.6	0.00012	0.00012	
10	9.0	10.0	1.0	9.5	219.3	0.122	1102.7	0.00011	0.00011	
11	10.0	11.0	1.0	10.5	225.4	0.125	1133.4	0.00011	0.00011	
12	11.0	12.0	1.0	11.5	224.7	0.127	1129.6	0.00011	0.00011	
13	12.0	13.0	1.0	12.5	221.4	0.129	1113.1	0.00012	0.00012	
14	13.0	14.0	1.0	13.5	194.9	0.131	979.7	0.00013	0.00013	
15	14.0	15.0	1.0	14.5	176.0	0.133	884.8	0.00015	0.00015	
16	15.0	16.0	1.0	15.5	176.4	0.136	886.8	0.00015	0.00015	
17	16.0	17.0	1.0	16.5	192.5	0.138	967.8	0.00014	0.00014	
18	17.0	18.0	1.0	17.5	196.6	0.140	988.4	0.00014	0.00014	
19	18.0	19.0	1.0	18.5	210.8	0.142	1059.8	0.00013	0.00013	
20	19.0	20.0	1.0	19.5	227.1	0.145	1141.7	0.00013	0.00013	
21	20.0	21.0	1.0	20.5	234.8	0.147	1180.5	0.00012	0.00012	
22	21.0	22.0	1.0	21.5	239.6	0.149	1204.9	0.00012	0.00012	
23	22.0	23.0	1.0	22.5	253.3	0.151	1273.6	0.00012	0.00012	
24	23.0	24.0	1.0	23.5	246.9	0.153	1241.2	0.00012	0.00012	
25	24.0	25.0	1.0	24.5	243.1	0.156	1222.2	0.00013	0.00013	
26	25.0	26.0	1.0	25.5	234.9	0.158	1181.0	0.00013	0.00013	
27	26.0	27.0	1.0	26.5	236.5	0.160	1189.1	0.00013	0.00013	
28	27.0	28.0	1.0	27.5	211.2	0.162	1062.1	0.00015	0.00015	
29	28.0	29.0	1.0	28.5	179.9	0.164	904.5	0.00018	0.00018	
30	29.0	30.0	1.0	29.5	146.1	0.167	734.6	0.00023	0.00023	
31	30.0	31.0	1.0	30.5	92.5	0.169	465.1	0.00036	0.00036	
32	31.0	32.0	1.0	31.5	147.2	0.171	740.0	0.00023	0.00023	
33	32.0	33.0	1.0	32.5	183.7	0.173	923.7	0.00019	0.00019	

34	33.0	34.0	1.0	33.5	170.4	0.176	856.9	0.00020	0.00020	
35	34.0	35.0	1.0	34.5	141.7	0.178	712.4	0.00025	0.00025	
36	35.0	36.0	1.0	35.5	92.6	0.180	465.7	0.00039	0.00039	
37	36.0	37.0	1.0	36.5	24.9	0.182	125.1	0.00146	0.00146	C2
38	37.0	38.0	1.0	37.5	17.2	0.184	86.5	0.00213	0.00213	C2
39	38.0	39.0	1.0	38.5	16.6	0.187	83.7	0.00223	0.00223	C2
40	39.0	40.0	1.0	39.5	47.7	0.189	239.6	0.00079	0.00079	C2
41	40.0	41.0	1.0	40.5	263.1	0.191	1322.7	0.00014	0.00014	C2
42	41.0	42.0	1.0	41.5	304.0	0.193	1528.5	0.00013	0.00013	
43	42.0	43.0	1.0	42.5	266.8	0.195	1341.2	0.00015	0.00015	
44	43.0	44.0	1.0	43.5	171.4	0.198	861.6	0.00023	0.00023	
45	44.0	45.0	1.0	44.5	139.6	0.200	701.8	0.00028	0.00028	
46	45.0	46.0	1.0	45.5	246.7	0.202	1240.3	0.00016	0.00016	
47	46.0	47.0	1.0	46.5	329.2	0.204	1655.3	0.00012	0.00012	
48	47.0	48.0	1.0	47.5	324.2	0.207	1629.9	0.00013	0.00013	
49	48.0	49.0	1.0	48.5	323.0	0.209	1623.9	0.00013	0.00013	
50	49.0	50.0	1.0	49.5	302.4	0.211	1520.4	0.00014	0.00014	
51	50.0	51.0	1.0	50.5	280.1	0.213	1408.4	0.00015	0.00015	
52	51.0	52.0	1.0	51.5	246.5	0.215	1239.2	0.00017	0.00017	
53	52.0	53.0	1.0	52.5	169.2	0.218	850.6	0.00026	0.00026	
54	53.0	54.0	1.0	53.5	40.1	0.220	201.5	0.00109	0.00109	
55	54.0	55.0	1.0	54.5	168.1	0.222	845.0	0.00026	0.00026	
56	55.0	56.0	1.0	55.5	112.2	0.224	564.1	0.00040	0.00040	
57	56.0	57.0	1.0	56.5	28.4	0.226	142.5	0.00159	0.00159	
58	57.0	58.0	1.0	57.5	110.4	0.229	555.3	0.00041	0.00041	
59	58.0	59.0	1.0	58.5	253.3	0.231	1273.8	0.00018	0.00018	
60	59.0	60.0	1.0	59.5	283.8	0.233	1426.6	0.00016	0.00016	
61	60.0	61.0	1.0	60.5	263.6	0.235	1325.4	0.00018	0.00018	
62	61.0	62.0	1.0	61.5	288.9	0.237	1452.6	0.00016	0.00016	
63	62.0	63.0	1.0	62.5	273.9	0.240	1377.1	0.00017	0.00017	
64	63.0	64.0	1.0	63.5	196.4	0.242	987.6	0.00024	0.00024	
65	64.0	65.0	1.0	64.5	93.9	0.244	471.9	0.00052	0.00052	
66	65.0	66.0	1.0	65.5	17.2	0.246	86.5	0.00285	0.00285	
67	66.0	67.0	1.0	66.5	16.8	0.249	84.6	0.00294	0.00294	
68	67.0	68.0	1.0	67.5	23.0	0.251	115.5	0.00217	0.00217	
69	68.0	69.0	1.0	68.5	23.1	0.253	116.0	0.00218	0.00218	
70	69.0	70.0	1.0	69.5	27.5	0.255	138.3	0.00184	0.00184	
71	70.0	71.0	1.0	70.5	32.5	0.257	163.5	0.00157	0.00157	
72	71.0	72.0	1.0	71.5	34.9	0.260	175.3	0.00148	0.00148	
73	72.0	73.0	1.0	72.5	36.1	0.262	181.3	0.00144	0.00144	
74	73.0	74.0	1.0	73.5	83.2	0.264	418.2	0.00063	0.00063	
75	74.0	75.0	1.0	74.5	49.5	0.266	248.9	0.00107	0.00107	
76	75.0	76.0	1.0	75.5	42.1	0.268	211.9	0.00127	0.00127	
77	76.0	77.0	1.0	76.5	99.2	0.271	498.5	0.00054	0.00054	
78	77.0	78.0	1.0	77.5	129.2	0.273	649.4	0.00042	0.00042	
79	78.0	79.0	1.0	78.5	88.1	0.275	442.9	0.00062	0.00062	
80	79.0	80.0	1.0	79.5	85.7	0.277	431.0	0.00064	0.00064	
81	80.0	81.0	1.0	80.5	152.7	0.280	767.8	0.00036	0.00036	
82	81.0	82.0	1.0	81.5	92.2	0.282	463.4	0.00061	0.00061	
83	82.0	83.0	1.0	82.5	45.0	0.284	226.1	0.00126	0.00126	
84	83.0	84.0	1.0	83.5	300.4	0.286	1510.5	0.00019	0.00019	
85	84.0	85.0	1.0	84.5	286.4	0.288	1439.9	0.00020	0.00020	
86	85.0	86.0	1.0	85.5	288.5	0.291	1450.6	0.00020	0.00020	
87	86.0	87.0	1.0	86.5	166.7	0.293	838.2	0.00035	0.00035	
88	87.0	88.0	1.0	87.5	176.4	0.295	886.8	0.00033	0.00033	
89	88.0	89.0	1.0	88.5	210.0	0.297	1055.7	0.00028	0.00028	
90	89.0	90.0	1.0	89.5	154.4	0.299	776.5	0.00039	0.00039	
91	90.0	91.0	1.0	90.5	146.3	0.302	735.7	0.00041	0.00041	
92	91.0	92.0	1.0	91.5	115.3	0.304	579.8	0.00052	0.00052	
93	92.0	93.0	1.0	92.5	108.6	0.306	545.9	0.00056	0.00056	
94	93.0	94.0	1.0	93.5	123.9	0.308	623.1	0.00049	0.00049	
95	94.0	95.0	1.0	94.5	139.2	0.311	699.9	0.00044	0.00044	
96	95.0	96.0	1.0	95.5	165.6	0.313	832.6	0.00038	0.00038	
97	96.0	97.0	1.0	96.5	230.6	0.315	1159.5	0.00027	0.00027	
98	97.0	98.0	1.0	97.5	255.1	0.317	1282.6	0.00025	0.00025	
99	98.0	99.0	1.0	98.5	244.4	0.319	1229.0	0.00026	0.00026	
100	99.0	100.0	1.0	99.5	212.2	0.322	1066.8	0.00030	0.00030	
101	100.0	101.0	1.0	100.5	156.6	0.324	787.3	0.00041	0.00041	
102	101.0	102.0	1.0	101.5	44.4	0.326	223.3	0.00146	0.00146	
103	102.0	103.0	1.0	102.5	70.2	0.328	353.0	0.00093	0.00093	
104	103.0	104.0	1.0	103.5	91.8	0.330	461.6	0.00072	0.00072	
105	104.0	105.0	1.0	104.5	94.4	0.333	474.6	0.00070	0.00070	
106	105.0	106.0	1.0	105.5	98.0	0.335	492.7	0.00068	0.00068	
107	106.0	107.0	1.0	106.5	88.6	0.337	445.5	0.00076	0.00076	
108	107.0	108.0	1.0	107.5	83.8	0.339	421.2	0.00081	0.00081	
109	108.0	109.0	1.0	108.5	69.2	0.342	347.7	0.00098	0.00098	
110	109.0	110.0	1.0	109.5	59.8	0.344	300.5	0.00114	0.00114	

111	110.0	111.0	1.0	110.5	58.3	0.346	293.2	0.00118	0.00118	
112	111.0	112.0	1.0	111.5	60.5	0.348	304.0	0.00115	0.00115	
113	112.0	113.0	1.0	112.5	59.6	0.350	299.5	0.00117	0.00117	
114	113.0	114.0	1.0	113.5	58.2	0.353	292.7	0.00120	0.00120	
115	114.0	115.0	1.0	114.5	58.0	0.355	291.7	0.00122	0.00122	
116	115.0	116.0	1.0	115.5	168.8	0.357	848.7	0.00042	0.00042	
117	116.0	117.0	1.0	116.5	80.9	0.359	406.8	0.00088	0.00088	
118	117.0	118.0	1.0	117.5	350.0	0.361	1759.7	0.00021	0.00021	
119	118.0	119.0	1.0	118.5	350.0	0.364	1759.7	0.00021	0.00021	
120	119.0	120.0	1.0	119.5	350.0	0.366	1759.7	0.00021	0.00021	
121	120.0	150.0	30.0	135.0	350.0	0.400	1759.7	0.00682	0.00682	
122	150.0	200.0	50.0	175.0	350.0	0.489	1759.7	0.01389	0.01389	
123	200.0	202.8	2.8	201.4	350.0	0.546	1759.7	0.00086	0.00086	
124	202.8	300.0	97.2	251.4	350.0	0.501	1759.7	0.02769	0.02769	
125	300.0	400.0	100.0	350.0	350.0	0.412	1759.7	0.02341	0.02341	
126	400.0	500.0	100.0	450.0	350.0	0.322	1759.7	0.01827	0.01827	
127	500.0	600.0	100.0	550.0	350.0	0.231	1759.7	0.01314	0.01314	
128	600.0	700.0	100.0	650.0	350.0	0.141	1759.7	0.00800	0.00800	
129	700.0	800.0	100.0	750.0	350.0	0.050	1759.7	0.00286	0.00286	
130	800.0	900.0	100.0	850.0	350.0	0.000	1759.7	0.00000	0.00000	
Σ =									0.18072	

I_{zr} $(1 < L/B < 10)$:	$I_{zr} = I_{zs} + 0.111\,(I_{zc} - I_{zs})\,(L/B - 1)$
I_{zs} $(L/B = 1)$:	
For $z_{ave} = 0$ to $B/2$:	$I_{zs} = 0.1 + (z_{ave}/B)(2I_{zp} - 0.2)$
For $z_{ave} = B/2$ to $2B$:	$I_{zs} = 0.667\,I_{zp}\,(2 - z_{ave}/B)$
I_{zc} $(L/B \geq 10)$:	
For $z_{ave} = 0$ to B:	$I_{zc} = 0.2 + (z_{ave}/B)(I_{zp} - 0.2)$
For $z_{ave} = B$ to $4B$:	$I_{zc} = 0.333\,I_{zp}\,(4 - z_{ave}/B)$ (Coduto p.228.)

Footing width	B =		400.0	ft	ZV3V5C06
Footing length	L =		450.0	ft	
Ground elevation			261.0	ft	
Foundation elevation			261.0	ft	
Ground Water elevation			225.0	ft	
Excavated or embedded depth	D =		0.0	ft	
Depth to Groundwater			36.0	ft	
Unit weight	γ =		120.0	pcf	
Net applied footing pressure	Δp =		3.000	ksf	
	L/B =		1.13	-	

Immediate Settlement (in.) $(S_0 / 2)$

Load	S_0 =
	3.7
3.0	3.7
4.3	5.4
6.0	7.7

30 Year Settlement (in.) $(S_{30} / 2)$

Load	S_0 =
	5.6
4.3	8.1
6.0	11.5

Computation

Settlement	ρ_i =	$C_1 C_t \Delta p \Sigma(\Delta z_i I_{zi}/E_{si})$	0.622	ft	Column I
	ρ_i =		**7.466**	**in**	
	S(t) =		0.930	ft	
	S(t) =		**11.164**	**in**	
Correction for strain relief	C_1 =	$1 - 0.5(\sigma'_D/q')$	1.000	-	
Effective vertical overburden pressure at D	σ'_{vo} =	γ D	0.000	ksf	
Correction for time dependent increase	C_t =	1 + 0.2 log(t / 0.1)	1.50	-	
	t =		30.00	years	
Elastic modulus of soil layer i	E_{si} =	2.5 q_c	see Column H		If L/B = 1
	E_{si} =	3.5 q_c	see Column H		If L/B ≥ 10
Depth increment i	Δz_i		see Column D		
Influence factor of soil layer i	I_{zi}	Figure 3-4	see Column G		
Peak depth influence factor	I_{zp} =	$0.5 + 0.1 (\Delta p/\sigma'_{izp})^{1/2}$	0.546	-	
	z_p =	0.5B + D	200.00	ft	If L/B = 1
	z_p =	B + D	400.00	ft	If L/B ≥ 10
	z_p =		202.78	ft	for L/B=1.13
Effective overburden pressure at depth Izp	σ'_{izp} =		13.93	ksf	
Elastic Modulus	E_{si} =		2.50	q_c	If L/B = 1
	E_{si} =		3.50	q_c	If L/B ≥ 10
	E_{si} =		2.51	q_c	for L/B=1.13

A Layer No.	B Layer top depth (ft)	C Layer bottom depth (ft)	D Layer thickness Δz_i (ft)	E Mid-layer depth z_{ave} (ft)	F Average tip stress q_c (tsf)	G I_{zi}	H Elastic modulus E_{si} (ksf)	I $\Delta z_i I_{zi}/E_{si}$	J $\Delta z_i I_{zi}/E_{si}$	K Notes
1	0.0	1.0	1.0	0.5	138.9	0.102	698.6	0.00015	0.00015	
2	1.0	2.0	1.0	1.5	104.6	0.105	525.7	0.00020	0.00020	
3	2.0	3.0	1.0	2.5	96.0	0.107	482.8	0.00022	0.00022	
4	3.0	4.0	1.0	3.5	84.3	0.109	423.8	0.00026	0.00026	
5	4.0	5.0	1.0	4.5	87.4	0.111	439.5	0.00025	0.00025	
6	5.0	6.0	1.0	5.5	150.7	0.114	757.7	0.00015	0.00015	
7	6.0	7.0	1.0	6.5	186.6	0.116	938.4	0.00012	0.00012	
8	7.0	8.0	1.0	7.5	189.1	0.118	950.7	0.00012	0.00012	
9	8.0	9.0	1.0	8.5	178.2	0.120	895.9	0.00013	0.00013	
10	9.0	10.0	1.0	9.5	175.7	0.122	883.3	0.00014	0.00014	
11	10.0	11.0	1.0	10.5	164.5	0.125	826.8	0.00015	0.00015	
12	11.0	12.0	1.0	11.5	154.4	0.127	776.2	0.00016	0.00016	
13	12.0	13.0	1.0	12.5	140.0	0.129	704.1	0.00018	0.00018	
14	13.0	14.0	1.0	13.5	126.9	0.131	638.1	0.00021	0.00021	
15	14.0	15.0	1.0	14.5	131.2	0.133	659.9	0.00020	0.00020	
16	15.0	16.0	1.0	15.5	150.7	0.136	757.6	0.00018	0.00018	
17	16.0	17.0	1.0	16.5	186.4	0.138	937.0	0.00015	0.00015	
18	17.0	18.0	1.0	17.5	189.6	0.140	953.1	0.00015	0.00015	
19	18.0	19.0	1.0	18.5	210.0	0.142	1055.6	0.00013	0.00013	
20	19.0	20.0	1.0	19.5	233.3	0.145	1173.0	0.00012	0.00012	
21	20.0	21.0	1.0	20.5	237.4	0.147	1193.7	0.00012	0.00012	
22	21.0	22.0	1.0	21.5	260.5	0.149	1309.8	0.00011	0.00011	
23	22.0	23.0	1.0	22.5	232.2	0.151	1167.6	0.00013	0.00013	
24	23.0	24.0	1.0	23.5	241.9	0.153	1216.0	0.00013	0.00013	
25	24.0	25.0	1.0	24.5	235.0	0.156	1181.4	0.00013	0.00013	
26	25.0	26.0	1.0	25.5	246.8	0.158	1240.7	0.00013	0.00013	
27	26.0	27.0	1.0	26.5	216.0	0.160	1086.1	0.00015	0.00015	
28	27.0	28.0	1.0	27.5	186.4	0.162	937.1	0.00017	0.00017	
29	28.0	29.0	1.0	28.5	204.3	0.164	1027.3	0.00016	0.00016	
30	29.0	30.0	1.0	29.5	103.5	0.167	520.6	0.00032	0.00032	
31	30.0	31.0	1.0	30.5	67.4	0.169	338.9	0.00050	0.00050	
32	31.0	32.0	1.0	31.5	42.7	0.171	214.6	0.00080	0.00080	
33	32.0	33.0	1.0	32.5	23.4	0.173	117.6	0.00147	0.00147	C2

34	33.0	34.0	1.0	33.5	76.2	0.176	383.1	0.00046	0.00046	C2
35	34.0	35.0	1.0	34.5	95.6	0.178	480.9	0.00037	0.00037	C2
36	35.0	36.0	1.0	35.5	66.0	0.180	332.1	0.00054	0.00054	C2
37	36.0	37.0	1.0	36.5	17.9	0.182	89.8	0.00203	0.00203	C2
38	37.0	38.0	1.0	37.5	10.2	0.184	51.5	0.00358	0.00358	C2
39	38.0	39.0	1.0	38.5	10.9	0.187	55.0	0.00339	0.00339	C2
40	39.0	40.0	1.0	39.5	11.7	0.189	58.8	0.00321	0.00321	C2
41	40.0	41.0	1.0	40.5	13.1	0.191	65.8	0.00290	0.00290	C2
42	41.0	42.0	1.0	41.5	14.5	0.193	72.9	0.00265	0.00265	C2
43	42.0	43.0	1.0	42.5	15.6	0.195	78.5	0.00249	0.00249	C2
44	43.0	44.0	1.0	43.5	99.6	0.198	500.7	0.00039	0.00039	C2
45	44.0	45.0	1.0	44.5	246.6	0.200	1239.8	0.00016	0.00016	C2
46	45.0	46.0	1.0	45.5	187.9	0.202	944.9	0.00021	0.00021	
47	46.0	47.0	1.0	46.5	111.1	0.204	558.8	0.00037	0.00037	
48	47.0	48.0	1.0	47.5	178.1	0.207	895.6	0.00023	0.00023	
49	48.0	49.0	1.0	48.5	188.4	0.209	947.4	0.00022	0.00022	
50	49.0	50.0	1.0	49.5	172.3	0.211	866.5	0.00024	0.00024	
51	50.0	51.0	1.0	50.5	156.2	0.213	785.4	0.00027	0.00027	
52	51.0	52.0	1.0	51.5	122.5	0.215	615.8	0.00035	0.00035	
53	52.0	53.0	1.0	52.5	72.4	0.218	363.8	0.00060	0.00060	
54	53.0	54.0	1.0	53.5	25.9	0.220	130.4	0.00168	0.00168	
55	54.0	55.0	1.0	54.5	10.3	0.222	51.8	0.00429	0.00429	
56	55.0	56.0	1.0	55.5	24.4	0.224	122.4	0.00183	0.00183	
57	56.0	57.0	1.0	56.5	6.3	0.226	31.6	0.00717	0.00717	
58	57.0	58.0	1.0	57.5	5.8	0.229	29.3	0.00781	0.00781	
59	58.0	59.0	1.0	58.5	19.9	0.231	99.8	0.00231	0.00231	
60	59.0	60.0	1.0	59.5	29.6	0.233	149.0	0.00156	0.00156	
61	60.0	61.0	1.0	60.5	55.1	0.235	277.1	0.00085	0.00085	
62	61.0	62.0	1.0	61.5	121.4	0.237	610.3	0.00039	0.00039	
63	62.0	63.0	1.0	62.5	193.2	0.240	971.3	0.00025	0.00025	
64	63.0	64.0	1.0	63.5	351.7	0.242	1768.0	0.00014	0.00014	
65	64.0	65.0	1.0	64.5	328.7	0.244	1652.8	0.00015	0.00015	
66	65.0	66.0	1.0	65.5	243.3	0.246	1223.3	0.00020	0.00020	
67	66.0	67.0	1.0	66.5	54.6	0.249	274.5	0.00091	0.00091	
68	67.0	68.0	1.0	67.5	28.4	0.251	142.8	0.00176	0.00176	
69	68.0	69.0	1.0	68.5	22.9	0.253	115.1	0.00220	0.00220	
70	69.0	70.0	1.0	69.5	31.2	0.255	156.7	0.00163	0.00163	
71	70.0	71.0	1.0	70.5	26.0	0.257	130.9	0.00197	0.00197	
72	71.0	72.0	1.0	71.5	36.6	0.260	183.8	0.00141	0.00141	
73	72.0	73.0	1.0	72.5	43.4	0.262	218.1	0.00120	0.00120	
74	73.0	74.0	1.0	73.5	124.2	0.264	624.4	0.00042	0.00042	
75	74.0	75.0	1.0	74.5	233.9	0.266	1176.1	0.00023	0.00023	
76	75.0	76.0	1.0	75.5	218.5	0.268	1098.6	0.00024	0.00024	
77	76.0	77.0	1.0	76.5	34.7	0.271	174.4	0.00155	0.00155	
78	77.0	78.0	1.0	77.5	34.1	0.273	171.6	0.00159	0.00159	
79	78.0	79.0	1.0	78.5	231.4	0.275	1163.3	0.00024	0.00024	
80	79.0	80.0	1.0	79.5	142.2	0.277	715.2	0.00039	0.00039	
81	80.0	81.0	1.0	80.5	91.6	0.280	460.6	0.00061	0.00061	
82	81.0	82.0	1.0	81.5	120.4	0.282	605.4	0.00047	0.00047	
83	82.0	83.0	1.0	82.5	101.8	0.284	511.9	0.00055	0.00055	
84	83.0	84.0	1.0	83.5	85.0	0.286	427.6	0.00067	0.00067	
85	84.0	85.0	1.0	84.5	46.2	0.288	232.3	0.00124	0.00124	
86	85.0	86.0	1.0	85.5	45.7	0.291	229.6	0.00127	0.00127	
87	86.0	87.0	1.0	86.5	58.7	0.293	294.9	0.00099	0.00099	
88	87.0	88.0	1.0	87.5	22.1	0.295	111.2	0.00265	0.00265	
89	88.0	89.0	1.0	88.5	33.8	0.297	170.1	0.00175	0.00175	
90	89.0	90.0	1.0	89.5	38.6	0.299	194.3	0.00154	0.00154	
91	90.0	91.0	1.0	90.5	291.3	0.302	1464.6	0.00021	0.00021	
92	91.0	92.0	1.0	91.5	79.4	0.304	399.2	0.00076	0.00076	
93	92.0	93.0	1.0	92.5	95.9	0.306	481.9	0.00064	0.00064	
94	93.0	94.0	1.0	93.5	47.7	0.308	239.6	0.00129	0.00129	
95	94.0	95.0	1.0	94.5	41.8	0.311	210.1	0.00148	0.00148	
96	95.0	96.0	1.0	95.5	55.0	0.313	276.5	0.00113	0.00113	
97	96.0	97.0	1.0	96.5	124.3	0.315	625.0	0.00050	0.00050	
98	97.0	98.0	1.0	97.5	165.9	0.317	834.3	0.00038	0.00038	
99	98.0	99.0	1.0	98.5	80.7	0.319	405.7	0.00079	0.00079	
100	99.0	100.0	1.0	99.5	49.2	0.322	247.3	0.00130	0.00130	
101	100.0	101.0	1.0	100.5	23.7	0.324	119.2	0.00272	0.00272	
102	101.0	102.0	1.0	101.5	40.7	0.326	204.7	0.00159	0.00159	
103	102.0	103.0	1.0	102.5	71.3	0.328	358.6	0.00092	0.00092	
104	103.0	104.0	1.0	103.5	75.8	0.330	381.0	0.00087	0.00087	
105	104.0	105.0	1.0	104.5	91.6	0.333	460.8	0.00072	0.00072	
106	105.0	106.0	1.0	105.5	96.9	0.335	487.2	0.00069	0.00069	
107	106.0	107.0	1.0	106.5	84.4	0.337	424.2	0.00079	0.00079	
108	107.0	108.0	1.0	107.5	78.1	0.339	392.8	0.00086	0.00086	
109	108.0	109.0	1.0	108.5	57.3	0.342	288.1	0.00119	0.00119	
110	109.0	110.0	1.0	109.5	59.4	0.344	298.8	0.00115	0.00115	

111	110.0	111.0	1.0	110.5	61.1	0.346	307.2	0.00113	0.00113	
112	111.0	112.0	1.0	111.5	62.4	0.348	313.9	0.00111	0.00111	
113	112.0	113.0	1.0	112.5	56.9	0.350	286.3	0.00122	0.00122	
114	113.0	114.0	1.0	113.5	59.4	0.353	298.5	0.00118	0.00118	
115	114.0	115.0	1.0	114.5	56.1	0.355	281.9	0.00126	0.00126	
116	115.0	116.0	1.0	115.5	284.4	0.357	1430.1	0.00025	0.00025	
117	116.0	117.0	1.0	116.5	80.9	0.359	406.8	0.00088	0.00088	
118	117.0	118.0	1.0	117.5	350.0	0.361	1759.7	0.00021	0.00021	
119	118.0	119.0	1.0	118.5	350.0	0.364	1759.7	0.00021	0.00021	
120	119.0	120.0	1.0	119.5	350.0	0.366	1759.7	0.00021	0.00021	
121	120.0	150.0	30.0	135.0	350.0	0.400	1759.7	0.00682	0.00682	
122	150.0	200.0	50.0	175.0	350.0	0.489	1759.7	0.01389	0.01389	
123	200.0	202.8	2.8	201.4	350.0	0.546	1759.7	0.00086	0.00086	
124	202.8	300.0	97.2	251.4	350.0	0.501	1759.7	0.02769	0.02769	
125	300.0	400.0	100.0	350.0	350.0	0.412	1759.7	0.02341	0.02341	
126	400.0	500.0	100.0	450.0	350.0	0.322	1759.7	0.01827	0.01827	
127	500.0	600.0	100.0	550.0	350.0	0.231	1759.7	0.01314	0.01314	
128	600.0	700.0	100.0	650.0	350.0	0.141	1759.7	0.00800	0.00800	
129	700.0	800.0	100.0	750.0	350.0	0.050	1759.7	0.00286	0.00286	
130	800.0	900.0	100.0	850.0	350.0	0.000	1759.7	0.00000	0.00000	
Σ =									0.23103	

I_{zr} (1 < L/B < 10):	$I_{zr} = I_{zs} + 0.111 (I_{zc} - I_{zs}) (L/B - 1)$
I_{zs} (L/B = 1):	
For z_{ave} = 0 to B/2:	$I_{zs} = 0.1 + (z_{ave}/B)(2I_{zp} - 0.2)$
For z_{ave} = B/2 to 2B:	$I_{zs} = 0.667\, I_{zp} (2 - z_{ave}/B)$
I_{zc} (L/B ≥ 10):	
For z_{ave} = 0 to B:	$I_{zc} = 0.2 + (z_{ave}/B)(I_{zp} - 0.2)$
For z_{ave} = B to 4B:	$I_{zc} = 0.333\, I_{zp} (4 - z_{ave}/B)$ (Coduto p.228.)

Footing width	B =		400.0 ft	ZV3V5C07		
Footing length	L =		450.0 ft		Immediate	
Ground elevation			261.0 ft		Settlement (in.)	
Foundation elevation			261.0 ft		(S_0 / 2)	
Ground Water elevation			225.0 ft		Load	S_0 =
Excavated or embedded depth	D =		0.0 ft			3.1
Depth to Groundwater			36.0 ft		3.0	3.1
Unit weight	γ =		120.0 pcf		4.3	4.5
Net applied footing pressure	Δp =		3.000 ksf		6.0	6.4
	L/B =		1.13 -			
					30 Year	
Computation					Settlement (in.)	
Settlement	ρ_i =	$C_1\ C_t\ \Delta p\ \Sigma(\Delta z_i\ I_{zi}/E_{si})$	0.516 ft	Column I	(S_{30} / 2)	
	ρ_i =		6.195 in		Load	S_0 =
	S(t) =		0.772 ft			4.6
	S(t) =		9.264 in		4.3	6.7
Correction for strain relief	C_1 =	$1 - 0.5(\sigma'_D/q')$	1.000 -		6.0	9.6
Effective vertical overburden pressure at D	σ'_{vo} =	γ D	0.000 ksf			
Correction for time dependent increase	C_t =	$1 + 0.2 \log(t / 0.1)$	1.50 -			
	t =		30.00 years			
Elastic modulus of soil layer i	E_{si} =	2.5 q_c	see Column H	if L/B = 1		
	E_{si} =	3.5 q_c	see Column H	If L/B ≥ 10		
Depth increment i	Δz_i		see Column D			
Influence factor of soil layer i	I_{zi}	Figure 3-4	see Column G			
Peak depth influence factor	I_{zp} =	$0.5 + 0.1 (\Delta p/\sigma'_{izp})^{1/2}$	0.546 -			
	z_p =	0.5B + D	200.00 ft	If L/B = 1		
	z_p =	B + D	400.00 ft	If L/B ≥ 10		
	z_p =		202.78 ft	for L/B=1.13		
Effective overburden pressure at depth Izp	σ'_{izp} =		13.93 ksf			
Elastic Modulus	E_{si} =		2.50 q_c	If L/B = 1		
	E_{si} =		3.50 q_c	If L/B ≥ 10		
	E_{si} =		2.51 q_c	for L/B=1.13		

A	B	C	D	E	F	G	H	I	J	K
Layer No.	Layer top depth (ft)	Layer bottom depth (ft)	Layer thickness Δz_i (ft)	Mid-layer depth z_{ave} (ft)	Average tip stress q_c (tsf)	I_{zi}	Elastic modulus E_{si} (ksf)	$\Delta z_i\ I_{zi}/E_{si}$	$\Delta z_i\ I_{zi}/E_{si}$	Notes
1	0.0	1.0	1.0	0.5	77.2	0.102	388.1	0.00026	0.00026	
2	1.0	2.0	1.0	1.5	83.4	0.105	419.5	0.00025	0.00025	
3	2.0	3.0	1.0	2.5	75.5	0.107	379.6	0.00028	0.00028	
4	3.0	4.0	1.0	3.5	72.2	0.109	363.1	0.00030	0.00030	
5	4.0	5.0	1.0	4.5	85.2	0.111	428.3	0.00026	0.00026	
6	5.0	6.0	1.0	5.5	92.0	0.114	462.7	0.00025	0.00025	
7	6.0	7.0	1.0	6.5	138.8	0.116	698.1	0.00017	0.00017	
8	7.0	8.0	1.0	7.5	180.4	0.118	907.1	0.00013	0.00013	
9	8.0	9.0	1.0	8.5	139.5	0.120	701.4	0.00017	0.00017	
10	9.0	10.0	1.0	9.5	132.8	0.122	667.8	0.00018	0.00018	
11	10.0	11.0	1.0	10.5	92.2	0.125	463.5	0.00027	0.00027	
12	11.0	12.0	1.0	11.5	82.9	0.127	416.6	0.00030	0.00030	
13	12.0	13.0	1.0	12.5	192.0	0.129	965.5	0.00013	0.00013	
14	13.0	14.0	1.0	13.5	256.0	0.131	1287.0	0.00010	0.00010	
15	14.0	15.0	1.0	14.5	289.3	0.133	1454.4	0.00009	0.00009	
16	15.0	16.0	1.0	15.5	291.9	0.136	1467.5	0.00009	0.00009	
17	16.0	17.0	1.0	16.5	235.6	0.138	1184.4	0.00012	0.00012	
18	17.0	18.0	1.0	17.5	262.8	0.140	1321.1	0.00011	0.00011	
19	18.0	19.0	1.0	18.5	200.6	0.142	1008.4	0.00014	0.00014	
20	19.0	20.0	1.0	19.5	205.5	0.145	1033.2	0.00014	0.00014	
21	20.0	21.0	1.0	20.5	251.4	0.147	1263.8	0.00012	0.00012	
22	21.0	22.0	1.0	21.5	240.6	0.149	1209.5	0.00012	0.00012	
23	22.0	23.0	1.0	22.5	188.0	0.151	945.2	0.00016	0.00016	
24	23.0	24.0	1.0	23.5	149.3	0.153	750.8	0.00020	0.00020	
25	24.0	25.0	1.0	24.5	69.5	0.156	349.3	0.00045	0.00045	
26	25.0	26.0	1.0	25.5	67.9	0.158	341.3	0.00046	0.00046	
27	26.0	27.0	1.0	26.5	38.5	0.160	193.7	0.00083	0.00083	
28	27.0	28.0	1.0	27.5	24.9	0.162	125.4	0.00129	0.00129	
29	28.0	29.0	1.0	28.5	37.0	0.164	185.9	0.00088	0.00088	C2
30	29.0	30.0	1.0	29.5	28.0	0.167	140.8	0.00118	0.00118	C2
31	30.0	31.0	1.0	30.5	9.2	0.169	46.2	0.00366	0.00366	C2
32	31.0	32.0	1.0	31.5	9.2	0.171	46.3	0.00369	0.00369	C2
33	32.0	33.0	1.0	32.5	9.7	0.173	48.7	0.00356	0.00356	C2

34	33.0	34.0	1.0	33.5	11.3	0.176	56.7	0.00309	0.00309	C2
35	34.0	35.0	1.0	34.5	14.4	0.178	72.6	0.00245	0.00245	C2
36	35.0	36.0	1.0	35.5	12.8	0.180	64.2	0.00280	0.00280	C2
37	36.0	37.0	1.0	36.5	16.5	0.182	83.1	0.00219	0.00219	C2
38	37.0	38.0	1.0	37.5	94.4	0.184	474.5	0.00039	0.00039	C2
39	38.0	39.0	1.0	38.5	172.2	0.187	865.7	0.00022	0.00022	
40	39.0	40.0	1.0	39.5	168.5	0.189	847.1	0.00022	0.00022	
41	40.0	41.0	1.0	40.5	269.0	0.191	1352.4	0.00014	0.00014	
42	41.0	42.0	1.0	41.5	318.8	0.193	1602.7	0.00012	0.00012	
43	42.0	43.0	1.0	42.5	360.5	0.195	1812.3	0.00011	0.00011	
44	43.0	44.0	1.0	43.5	279.8	0.198	1406.8	0.00014	0.00014	
45	44.0	45.0	1.0	44.5	231.5	0.200	1164.2	0.00017	0.00017	
46	45.0	46.0	1.0	45.5	156.4	0.202	786.4	0.00026	0.00026	
47	46.0	47.0	1.0	46.5	134.9	0.204	678.3	0.00030	0.00030	
48	47.0	48.0	1.0	47.5	174.2	0.207	876.0	0.00024	0.00024	
49	48.0	49.0	1.0	48.5	196.5	0.209	987.9	0.00021	0.00021	
50	49.0	50.0	1.0	49.5	169.8	0.211	853.7	0.00025	0.00025	
51	50.0	51.0	1.0	50.5	163.7	0.213	823.1	0.00026	0.00026	
52	51.0	52.0	1.0	51.5	152.9	0.215	768.9	0.00028	0.00028	
53	52.0	53.0	1.0	52.5	119.6	0.218	601.5	0.00036	0.00036	
54	53.0	54.0	1.0	53.5	41.1	0.220	206.7	0.00106	0.00106	
55	54.0	55.0	1.0	54.5	23.6	0.222	118.5	0.00187	0.00187	
56	55.0	56.0	1.0	55.5	25.5	0.224	128.4	0.00175	0.00175	
57	56.0	57.0	1.0	56.5	16.6	0.226	83.4	0.00272	0.00272	
58	57.0	58.0	1.0	57.5	38.3	0.229	192.7	0.00119	0.00119	
59	58.0	59.0	1.0	58.5	133.3	0.231	670.2	0.00034	0.00034	
60	59.0	60.0	1.0	59.5	370.8	0.233	1864.4	0.00013	0.00013	
61	60.0	61.0	1.0	60.5	443.0	0.235	2227.2	0.00011	0.00011	
62	61.0	62.0	1.0	61.5	463.0	0.237	2328.0	0.00010	0.00010	
63	62.0	63.0	1.0	62.5	490.4	0.240	2465.7	0.00010	0.00010	
64	63.0	64.0	1.0	63.5	451.7	0.242	2270.9	0.00011	0.00011	
65	64.0	65.0	1.0	64.5	69.8	0.244	350.8	0.00070	0.00070	
66	65.0	66.0	1.0	65.5	33.4	0.246	167.9	0.00147	0.00147	
67	66.0	67.0	1.0	66.5	38.1	0.249	191.4	0.00130	0.00130	
68	67.0	68.0	1.0	67.5	64.0	0.251	321.7	0.00078	0.00078	
69	68.0	69.0	1.0	68.5	71.2	0.253	358.1	0.00071	0.00071	
70	69.0	70.0	1.0	69.5	56.4	0.255	283.7	0.00090	0.00090	
71	70.0	71.0	1.0	70.5	72.8	0.257	365.8	0.00070	0.00070	
72	71.0	72.0	1.0	71.5	294.6	0.260	1481.3	0.00018	0.00018	
73	72.0	73.0	1.0	72.5	57.8	0.262	290.5	0.00090	0.00090	
74	73.0	74.0	1.0	73.5	46.9	0.264	235.8	0.00112	0.00112	
75	74.0	75.0	1.0	74.5	74.3	0.266	373.6	0.00071	0.00071	
76	75.0	76.0	1.0	75.5	93.7	0.268	471.1	0.00057	0.00057	
77	76.0	77.0	1.0	76.5	90.0	0.271	452.4	0.00060	0.00060	
78	77.0	78.0	1.0	77.5	123.8	0.273	622.6	0.00044	0.00044	
79	78.0	79.0	1.0	78.5	126.3	0.275	634.8	0.00043	0.00043	
80	79.0	80.0	1.0	79.5	148.3	0.277	745.4	0.00037	0.00037	
81	80.0	81.0	1.0	80.5	105.5	0.280	530.3	0.00053	0.00053	
82	81.0	82.0	1.0	81.5	87.5	0.282	440.0	0.00064	0.00064	
83	82.0	83.0	1.0	82.5	130.2	0.284	654.4	0.00043	0.00043	
84	83.0	84.0	1.0	83.5	162.1	0.286	814.8	0.00035	0.00035	
85	84.0	85.0	1.0	84.5	163.0	0.288	819.4	0.00035	0.00035	
86	85.0	86.0	1.0	85.5	100.2	0.291	503.6	0.00058	0.00058	
87	86.0	87.0	1.0	86.5	90.6	0.293	455.3	0.00064	0.00064	
88	87.0	88.0	1.0	87.5	96.0	0.295	482.6	0.00061	0.00061	
89	88.0	89.0	1.0	88.5	192.0	0.297	965.4	0.00031	0.00031	
90	89.0	90.0	1.0	89.5	154.4	0.299	776.5	0.00039	0.00039	
91	90.0	91.0	1.0	90.5	146.3	0.302	735.7	0.00041	0.00041	
92	91.0	92.0	1.0	91.5	115.3	0.304	579.8	0.00052	0.00052	
93	92.0	93.0	1.0	92.5	108.6	0.306	545.9	0.00056	0.00056	
94	93.0	94.0	1.0	93.5	123.9	0.308	623.1	0.00049	0.00049	
95	94.0	95.0	1.0	94.5	139.2	0.311	699.9	0.00044	0.00044	
96	95.0	96.0	1.0	95.5	165.6	0.313	832.6	0.00038	0.00038	
97	96.0	97.0	1.0	96.5	230.6	0.315	1159.5	0.00027	0.00027	
98	97.0	98.0	1.0	97.5	255.1	0.317	1282.6	0.00025	0.00025	
99	98.0	99.0	1.0	98.5	244.4	0.319	1229.0	0.00026	0.00026	
100	99.0	100.0	1.0	99.5	212.2	0.322	1066.8	0.00030	0.00030	
101	100.0	101.0	1.0	100.5	156.6	0.324	787.3	0.00041	0.00041	
102	101.0	102.0	1.0	101.5	44.4	0.326	223.3	0.00146	0.00146	
103	102.0	103.0	1.0	102.5	70.2	0.328	353.0	0.00093	0.00093	
104	103.0	104.0	1.0	103.5	91.8	0.330	461.6	0.00072	0.00072	
105	104.0	105.0	1.0	104.5	94.4	0.333	474.6	0.00070	0.00070	
106	105.0	106.0	1.0	105.5	98.0	0.335	492.7	0.00068	0.00068	
107	106.0	107.0	1.0	106.5	88.6	0.337	445.5	0.00076	0.00076	
108	107.0	108.0	1.0	107.5	83.8	0.339	421.2	0.00081	0.00081	
109	108.0	109.0	1.0	108.5	69.2	0.342	347.7	0.00098	0.00098	
110	109.0	110.0	1.0	109.5	59.8	0.344	300.5	0.00114	0.00114	

111	110.0	111.0	1.0	110.5	58.3	0.346	293.2	0.00118	0.00118	
112	111.0	112.0	1.0	111.5	60.5	0.348	304.0	0.00115	0.00115	
113	112.0	113.0	1.0	112.5	59.6	0.350	299.5	0.00117	0.00117	
114	113.0	114.0	1.0	113.5	58.2	0.353	292.7	0.00120	0.00120	
115	114.0	115.0	1.0	114.5	58.0	0.355	291.7	0.00122	0.00122	
116	115.0	116.0	1.0	115.5	168.8	0.357	848.7	0.00042	0.00042	
117	116.0	117.0	1.0	116.5	80.9	0.359	406.8	0.00088	0.00088	
118	117.0	118.0	1.0	117.5	350.0	0.361	1759.7	0.00021	0.00021	
119	118.0	119.0	1.0	118.5	350.0	0.364	1759.7	0.00021	0.00021	
120	119.0	120.0	1.0	119.5	350.0	0.366	1759.7	0.00021	0.00021	
121	120.0	150.0	30.0	135.0	350.0	0.400	1759.7	0.00682	0.00682	
122	150.0	200.0	50.0	175.0	350.0	0.489	1759.7	0.01389	0.01389	
123	200.0	202.8	2.8	201.4	350.0	0.546	1759.7	0.00086	0.00086	
124	202.8	300.0	97.2	251.4	350.0	0.501	1759.7	0.02769	0.02769	
125	300.0	400.0	100.0	350.0	350.0	0.412	1759.7	0.02341	0.02341	
126	400.0	500.0	100.0	450.0	350.0	0.322	1759.7	0.01827	0.01827	
127	500.0	600.0	100.0	550.0	350.0	0.231	1759.7	0.01314	0.01314	
128	600.0	700.0	100.0	650.0	350.0	0.141	1759.7	0.00800	0.00800	
129	700.0	800.0	100.0	750.0	350.0	0.050	1759.7	0.00286	0.00286	
130	800.0	900.0	100.0	850.0	350.0	0.000	1759.7	0.00000	0.00000	
Σ =									0.19598	

I_{zr} (1 < L/B < 10):	$I_{zr} = I_{zs} + 0.111\,(I_{zc} - I_{zs})\,(L/B - 1)$
I_{zs} (L/B = 1):	
For z_{ave} = 0 to B/2:	$I_{zs} = 0.1 + (z_{ave}/B)(2I_{zp} - 0.2)$
For z_{ave} = B/2 to 2B:	$I_{zs} = 0.667\,I_{zp}\,(2 - z_{ave}/B)$
I_{zc} (L/B $\geq$ 10):	
For z_{ave} = 0 to B:	$I_{zc} = 0.2 + (z_{ave}/B)(I_{zp} - 0.2)$
For z_{ave} = B to 4B:	$I_{zc} = 0.333\,I_{zp}\,(4 - z_{ave}/B)$ (Coduto p.228.)

Footing width	B =		400.0	ft	ZV3V5C08
Footing length	L =		450.0	ft	
Ground elevation			261.0	ft	
Foundation elevation			261.0	ft	
Ground Water elevation			225.0	ft	
Excavated or embedded depth	D =		0.0	ft	
Depth to Groundwater			36.0	ft	
Unit weight	γ =		120.0	pcf	
Net applied footing pressure	Δp =		3.000	ksf	
	L/B =		1.13	-	
Computation					
Settlement	ρ_i =	$C_1 C_t \Delta p \Sigma(\Delta z_i I_{zi}/E_{si})$	0.535	ft	Column I
	ρ_i =		6.418	in	
	S(t) =		0.800	ft	
	S(t) =		9.598	in	
Correction for strain relief	C_1 =	$1 - 0.5(\sigma'_D/q')$	1.000	-	
Effective vertical overburden pressure at D	σ'_{vo} =	γ D	0.000	ksf	
Correction for time dependent increase	C_t =	1 + 0.2 log(t / 0.1)	1.50	-	
	t =		30.00	years	
Elastic modulus of soil layer i	E_{si} =	2.5 q_c	see Column H		If L/B = 1
	E_{si} =	3.5 q_c	see Column H		If L/B ≥ 10
Depth increment i	Δz_i		see Column D		
Influence factor of soil layer i	I_{zi}	Figure 3-4	see Column G		
Peak depth influence factor	I_{zp} =	$0.5 + 0.1\ (\Delta p/\sigma'_{izp})^{1/2}$	0.546	-	
	z_p =	0.5B + D	200.00	ft	If L/B = 1
	z_p =	B + D	400.00	ft	If L/B ≥ 10
	z_p =		202.78	ft	for L/B=1.13
Effective overburden pressure at depth Izp	σ'_{izp} =		13.93	ksf	
Elastic Modulus	E_{si} =		2.50	q_c	If L/B = 1
	E_{si} =		3.50	q_c	If L/B ≥ 10
	E_{si} =		2.51	q_c	for L/B=1.13

Immediate Settlement (in.) (S_0 / 2)

Load	S_0 =
	3.2
3.0	3.2
4.3	4.7
6.0	6.6

30 Year Settlement (in.) (S_{30} / 2)

Load	S_0 =
	4.8
4.3	7.0
6.0	9.9

A	B	C	D	E	F	G	H	I	J	K
Layer No.	Layer top depth (ft)	Layer bottom depth (ft)	Layer thickness Δz_i (ft)	Mid-layer depth z_{ave} (ft)	Average tip stress q_c (tsf)	I_{zi}	Elastic modulus E_{si} (ksf)	$\Delta z_i I_{zi}/E_{si}$	$\Delta z_i I_{zi}/E_{si}$	Notes
1	0.0	1.0	1.0	0.5	86.7	0.102	435.8	0.00024	0.00024	
2	1.0	2.0	1.0	1.5	181.4	0.105	911.9	0.00011	0.00011	
3	2.0	3.0	1.0	2.5	142.1	0.107	714.5	0.00015	0.00015	
4	3.0	4.0	1.0	3.5	106.3	0.109	534.4	0.00020	0.00020	
5	4.0	5.0	1.0	4.5	168.2	0.111	845.6	0.00013	0.00013	
6	5.0	6.0	1.0	5.5	148.2	0.114	745.0	0.00015	0.00015	
7	6.0	7.0	1.0	6.5	131.4	0.116	660.6	0.00018	0.00018	
8	7.0	8.0	1.0	7.5	99.2	0.118	498.6	0.00024	0.00024	
9	8.0	9.0	1.0	8.5	189.7	0.120	954.0	0.00013	0.00013	
10	9.0	10.0	1.0	9.5	249.4	0.122	1254.0	0.00010	0.00010	
11	10.0	11.0	1.0	10.5	251.6	0.125	1264.9	0.00010	0.00010	
12	11.0	12.0	1.0	11.5	183.5	0.127	922.8	0.00014	0.00014	
13	12.0	13.0	1.0	12.5	153.2	0.129	770.5	0.00017	0.00017	
14	13.0	14.0	1.0	13.5	171.3	0.131	861.2	0.00015	0.00015	
15	14.0	15.0	1.0	14.5	184.1	0.133	925.8	0.00014	0.00014	
16	15.0	16.0	1.0	15.5	188.5	0.136	947.6	0.00014	0.00014	
17	16.0	17.0	1.0	16.5	193.3	0.138	972.0	0.00014	0.00014	
18	17.0	18.0	1.0	17.5	261.7	0.140	1315.5	0.00011	0.00011	
19	18.0	19.0	1.0	18.5	268.9	0.142	1351.7	0.00011	0.00011	
20	19.0	20.0	1.0	19.5	246.7	0.145	1240.4	0.00012	0.00012	
21	20.0	21.0	1.0	20.5	237.5	0.147	1194.3	0.00012	0.00012	
22	21.0	22.0	1.0	21.5	248.4	0.149	1249.1	0.00012	0.00012	
23	22.0	23.0	1.0	22.5	249.3	0.151	1253.2	0.00012	0.00012	
24	23.0	24.0	1.0	23.5	212.1	0.153	1066.3	0.00014	0.00014	
25	24.0	25.0	1.0	24.5	187.2	0.156	941.1	0.00017	0.00017	
26	25.0	26.0	1.0	25.5	96.6	0.158	485.6	0.00032	0.00032	
27	26.0	27.0	1.0	26.5	229.6	0.160	1154.6	0.00014	0.00014	
28	27.0	28.0	1.0	27.5	288.8	0.162	1451.9	0.00011	0.00011	
29	28.0	29.0	1.0	28.5	210.4	0.164	1057.9	0.00016	0.00016	
30	29.0	30.0	1.0	29.5	171.1	0.167	860.2	0.00019	0.00019	
31	30.0	31.0	1.0	30.5	130.6	0.169	656.8	0.00026	0.00026	
32	31.0	32.0	1.0	31.5	84.3	0.171	424.0	0.00040	0.00040	
33	32.0	33.0	1.0	32.5	181.1	0.173	910.7	0.00019	0.00019	

34	33.0	34.0	1.0	33.5	206.3	0.176	1037.4	0.00017	0.00017	
35	34.0	35.0	1.0	34.5	192.3	0.178	967.0	0.00018	0.00018	
36	35.0	36.0	1.0	35.5	155.3	0.180	780.7	0.00023	0.00023	
37	36.0	37.0	1.0	36.5	161.0	0.182	809.7	0.00022	0.00022	
38	37.0	38.0	1.0	37.5	189.0	0.184	950.5	0.00019	0.00019	
39	38.0	39.0	1.0	38.5	194.9	0.187	979.8	0.00019	0.00019	
40	39.0	40.0	1.0	39.5	49.3	0.189	248.1	0.00076	0.00076	
41	40.0	41.0	1.0	40.5	22.3	0.191	112.0	0.00171	0.00171	
42	41.0	42.0	1.0	41.5	25.7	0.193	129.4	0.00149	0.00149	C2
43	42.0	43.0	1.0	42.5	28.4	0.195	142.7	0.00137	0.00137	C2
44	43.0	44.0	1.0	43.5	21.1	0.198	106.3	0.00186	0.00186	C2
45	44.0	45.0	1.0	44.5	58.1	0.200	291.9	0.00068	0.00068	C2
46	45.0	46.0	1.0	45.5	245.4	0.202	1233.9	0.00016	0.00016	
47	46.0	47.0	1.0	46.5	281.6	0.204	1415.8	0.00014	0.00014	
48	47.0	48.0	1.0	47.5	274.8	0.207	1381.6	0.00015	0.00015	
49	48.0	49.0	1.0	48.5	255.8	0.209	1286.0	0.00016	0.00016	
50	49.0	50.0	1.0	49.5	251.1	0.211	1262.5	0.00017	0.00017	
51	50.0	51.0	1.0	50.5	205.5	0.213	1033.4	0.00021	0.00021	
52	51.0	52.0	1.0	51.5	134.9	0.215	678.2	0.00032	0.00032	
53	52.0	53.0	1.0	52.5	79.9	0.218	401.5	0.00054	0.00054	
54	53.0	54.0	1.0	53.5	57.5	0.220	289.1	0.00076	0.00076	
55	54.0	55.0	1.0	54.5	72.2	0.222	363.0	0.00061	0.00061	
56	55.0	56.0	1.0	55.5	45.6	0.224	229.1	0.00098	0.00098	
57	56.0	57.0	1.0	56.5	143.0	0.226	719.2	0.00031	0.00031	
58	57.0	58.0	1.0	57.5	34.6	0.229	173.8	0.00132	0.00132	
59	58.0	59.0	1.0	58.5	11.0	0.231	55.1	0.00419	0.00419	
60	59.0	60.0	1.0	59.5	36.1	0.233	181.6	0.00128	0.00128	
61	60.0	61.0	1.0	60.5	106.3	0.235	534.2	0.00044	0.00044	
62	61.0	62.0	1.0	61.5	238.8	0.237	1200.5	0.00020	0.00020	
63	62.0	63.0	1.0	62.5	242.1	0.240	1217.0	0.00020	0.00020	
64	63.0	64.0	1.0	63.5	157.2	0.242	790.1	0.00031	0.00031	
65	64.0	65.0	1.0	64.5	211.7	0.244	1064.5	0.00023	0.00023	
66	65.0	66.0	1.0	65.5	197.0	0.246	990.4	0.00025	0.00025	
67	66.0	67.0	1.0	66.5	144.1	0.249	724.4	0.00034	0.00034	
68	67.0	68.0	1.0	67.5	65.1	0.251	327.1	0.00077	0.00077	
69	68.0	69.0	1.0	68.5	45.5	0.253	228.5	0.00111	0.00111	
70	69.0	70.0	1.0	69.5	33.9	0.255	170.3	0.00150	0.00150	
71	70.0	71.0	1.0	70.5	22.4	0.257	112.5	0.00229	0.00229	
72	71.0	72.0	1.0	71.5	20.7	0.260	104.1	0.00249	0.00249	
73	72.0	73.0	1.0	72.5	21.6	0.262	108.5	0.00241	0.00241	
74	73.0	74.0	1.0	73.5	28.6	0.264	143.8	0.00184	0.00184	
75	74.0	75.0	1.0	74.5	102.8	0.266	516.9	0.00052	0.00052	
76	75.0	76.0	1.0	75.5	58.5	0.268	294.0	0.00091	0.00091	
77	76.0	77.0	1.0	76.5	121.8	0.271	612.1	0.00044	0.00044	
78	77.0	78.0	1.0	77.5	191.0	0.273	960.5	0.00028	0.00028	
79	78.0	79.0	1.0	78.5	176.9	0.275	889.6	0.00031	0.00031	
80	79.0	80.0	1.0	79.5	122.9	0.277	618.1	0.00045	0.00045	
81	80.0	81.0	1.0	80.5	67.4	0.280	339.1	0.00082	0.00082	
82	81.0	82.0	1.0	81.5	165.1	0.282	830.0	0.00034	0.00034	
83	82.0	83.0	1.0	82.5	52.6	0.284	264.6	0.00107	0.00107	
84	83.0	84.0	1.0	83.5	201.7	0.286	1014.0	0.00028	0.00028	
85	84.0	85.0	1.0	84.5	163.0	0.288	819.4	0.00035	0.00035	
86	85.0	86.0	1.0	85.5	100.2	0.291	503.6	0.00058	0.00058	
87	86.0	87.0	1.0	86.5	90.6	0.293	455.3	0.00064	0.00064	
88	87.0	88.0	1.0	87.5	96.0	0.295	482.6	0.00061	0.00061	
89	88.0	89.0	1.0	88.5	192.0	0.297	965.4	0.00031	0.00031	
90	89.0	90.0	1.0	89.5	154.4	0.299	776.5	0.00039	0.00039	
91	90.0	91.0	1.0	90.5	146.3	0.302	735.7	0.00041	0.00041	
92	91.0	92.0	1.0	91.5	115.3	0.304	579.8	0.00052	0.00052	
93	92.0	93.0	1.0	92.5	108.6	0.306	545.9	0.00056	0.00056	
94	93.0	94.0	1.0	93.5	123.9	0.308	623.1	0.00049	0.00049	
95	94.0	95.0	1.0	94.5	139.2	0.311	699.9	0.00044	0.00044	
96	95.0	96.0	1.0	95.5	165.6	0.313	832.6	0.00038	0.00038	
97	96.0	97.0	1.0	96.5	230.6	0.315	1159.5	0.00027	0.00027	
98	97.0	98.0	1.0	97.5	255.1	0.317	1282.6	0.00025	0.00025	
99	98.0	99.0	1.0	98.5	244.4	0.319	1229.0	0.00026	0.00026	
100	99.0	100.0	1.0	99.5	212.2	0.322	1066.8	0.00030	0.00030	
101	100.0	101.0	1.0	100.5	156.6	0.324	787.3	0.00041	0.00041	
102	101.0	102.0	1.0	101.5	44.4	0.326	223.3	0.00146	0.00146	
103	102.0	103.0	1.0	102.5	70.2	0.328	353.0	0.00093	0.00093	
104	103.0	104.0	1.0	103.5	91.8	0.330	461.6	0.00072	0.00072	
105	104.0	105.0	1.0	104.5	94.4	0.333	474.6	0.00070	0.00070	
106	105.0	106.0	1.0	105.5	98.0	0.335	492.7	0.00068	0.00068	
107	106.0	107.0	1.0	106.5	88.6	0.337	445.5	0.00076	0.00076	
108	107.0	108.0	1.0	107.5	83.8	0.339	421.2	0.00081	0.00081	
109	108.0	109.0	1.0	108.5	69.2	0.342	347.7	0.00098	0.00098	
110	109.0	110.0	1.0	109.5	59.8	0.344	300.5	0.00114	0.00114	

111	110.0	111.0	1.0	110.5	58.3	0.346	293.2	0.00118	0.00118	
112	111.0	112.0	1.0	111.5	60.5	0.348	304.0	0.00115	0.00115	
113	112.0	113.0	1.0	112.5	59.6	0.350	299.5	0.00117	0.00117	
114	113.0	114.0	1.0	113.5	58.2	0.353	292.7	0.00120	0.00120	
115	114.0	115.0	1.0	114.5	58.0	0.355	291.7	0.00122	0.00122	
116	115.0	116.0	1.0	115.5	168.8	0.357	848.7	0.00042	0.00042	
117	116.0	117.0	1.0	116.5	80.9	0.359	406.8	0.00088	0.00088	
118	117.0	118.0	1.0	117.5	350.0	0.361	1759.7	0.00021	0.00021	
119	118.0	119.0	1.0	118.5	350.0	0.364	1759.7	0.00021	0.00021	
120	119.0	120.0	1.0	119.5	350.0	0.366	1759.7	0.00021	0.00021	
121	120.0	150.0	30.0	135.0	350.0	0.400	1759.7	0.00682	0.00682	
122	150.0	200.0	50.0	175.0	350.0	0.489	1759.7	0.01389	0.01389	
123	200.0	202.8	2.8	201.4	350.0	0.546	1759.7	0.00086	0.00086	
124	202.8	300.0	97.2	251.4	350.0	0.501	1759.7	0.02769	0.02769	
125	300.0	400.0	100.0	350.0	350.0	0.412	1759.7	0.02341	0.02341	
126	400.0	500.0	100.0	450.0	350.0	0.322	1759.7	0.01827	0.01827	
127	500.0	600.0	100.0	550.0	350.0	0.231	1759.7	0.01314	0.01314	
128	600.0	700.0	100.0	650.0	350.0	0.141	1759.7	0.00800	0.00800	
129	700.0	800.0	100.0	750.0	350.0	0.050	1759.7	0.00286	0.00286	
130	800.0	900.0	100.0	850.0	350.0	0.000	1759.7	0.00000	0.00000	
Σ =									0.18369	

I_{zr} (1 < L/B < 10):	$I_{zr} = I_{zs} + 0.111 (I_{zc} - I_{zs}) (L/B - 1)$
I_{zs} (L/B = 1):	
For z_{ave} = 0 to B/2:	$I_{zs} = 0.1 + (z_{ave}/B)(2I_{zp} - 0.2)$
For z_{ave} = B/2 to 2B:	$I_{zs} = 0.667\, I_{zp} (2 - z_{ave}/B)$
I_{zc} (L/B ≥ 10):	
For z_{ave} = 0 to B:	$I_{zc} = 0.2 + (z_{ave}/B)(I_{zp} - 0.2)$
For z_{ave} = B to 4B:	$I_{zc} = 0.333\, I_{zp} (4 - z_{ave}/B)$ (Coduto p.228.)

Footing width	B =		400.0 ft	ZV3V5C09		
Footing length	L =		450.0 ft		Immediate	
Ground elevation			261.0 ft		Settlement (in.)	
Foundation elevation			261.0 ft		$(S_0 / 2)$	
Ground Water elevation			225.0 ft		Load	S_0 =
Excavated or embedded depth	D =		0.0 ft			3.6
Depth to Groundwater			36.0 ft		3.0	3.6
Unit weight	γ =		120.0 pcf		4.3	5.2
Net applied footing pressure	Δp =		3.000 ksf		6.0	7.4
	L/B =		1.13 -			
					30 Year	
Computation					Settlement (in.)	
Settlement	ρ_i =	$C_1\, C_t\, \Delta p\, \Sigma(\Delta z_i\, I_{zi}/E_{si})$	0.599 ft	Column I	$(S_{30} / 2)$	
	ρ_i =		7.182 in		Load	S_0 =
	S(t) =		0.896 ft			5.4
	S(t) =		10.741 in		4.3	7.8
Correction for strain relief	C_1 =	$1 - 0.5(\sigma'_D/q')$	1.000 -		6.0	11.1
Effective vertical overburden pressure at D	σ'_{vo} =	γ D	0.000 ksf			
Correction for time dependent increase	C_t =	1 + 0.2 log(t / 0.1)	1.50 -			
	t =		30.00 years			
Elastic modulus of soil layer i	E_{si} =	2.5 q_c	see Column H	if L/B = 1		
	E_{si} =	3.5 q_c	see Column H	if L/B ≥ 10		
Depth increment i	Δz_i		see Column D			
Influence factor of soil layer i	I_{zi}	Figure 3-4	see Column G			
Peak depth influence factor	I_{zp} =	$0.5 + 0.1\,(\Delta p/\sigma'_{izp})^{1/2}$	0.546 -			
	z_p =	0.5B + D	200.00 ft	If L/B = 1		
	z_p =	B + D	400.00 ft	If L/B ≥ 10		
	z_p =		202.78 ft	for L/B=1.13		
Effective overburden pressure at depth Izp	σ'izp =		13.93 ksf			
Elastic Modulus	E_{si} =		2.50 q_c	If L/B = 1		
	E_{si} =		3.50 q_c	If L/B ≥ 10		
	E_{si} =		2.51 q_c	for L/B=1.13		

A	B	C	D	E	F	G	H	I	J	K
Layer No.	Layer top depth (ft)	Layer bottom depth (ft)	Layer thickness Δz_i (ft)	Mid-layer depth z_{ave} (ft)	Average tip stress q_c (tsf)	I_{zi}	Elastic modulus E_{si} (ksf)	$\Delta z_i\, I_{zi}/E_{si}$	$\Delta z_i\, I_{zi}/E_{si}$	Notes
1	0.0	1.0	1.0	0.5	83.7	0.102	420.9	0.00024	0.00024	
2	1.0	2.0	1.0	1.5	5.4	0.105	27.0	0.00388	0.00388	
3	2.0	3.0	1.0	2.5	208.8	0.107	1049.6	0.00010	0.00010	
4	3.0	4.0	1.0	3.5	186.2	0.109	936.3	0.00012	0.00012	
5	4.0	5.0	1.0	4.5	269.0	0.111	1352.2	0.00008	0.00008	
6	5.0	6.0	1.0	5.5	292.1	0.114	1468.6	0.00008	0.00008	
7	6.0	7.0	1.0	6.5	297.7	0.116	1496.7	0.00008	0.00008	
8	7.0	8.0	1.0	7.5	275.6	0.118	1385.8	0.00009	0.00009	
9	8.0	9.0	1.0	8.5	231.3	0.120	1162.8	0.00010	0.00010	
10	9.0	10.0	1.0	9.5	165.2	0.122	830.7	0.00015	0.00015	
11	10.0	11.0	1.0	10.5	188.8	0.125	949.2	0.00013	0.00013	
12	11.0	12.0	1.0	11.5	212.3	0.127	1067.2	0.00012	0.00012	
13	12.0	13.0	1.0	12.5	184.4	0.129	927.2	0.00014	0.00014	
14	13.0	14.0	1.0	13.5	186.6	0.131	938.0	0.00014	0.00014	
15	14.0	15.0	1.0	14.5	155.0	0.133	779.5	0.00017	0.00017	
16	15.0	16.0	1.0	15.5	125.0	0.136	628.6	0.00022	0.00022	
17	16.0	17.0	1.0	16.5	93.7	0.138	470.9	0.00029	0.00029	
18	17.0	18.0	1.0	17.5	140.5	0.140	706.6	0.00020	0.00020	
19	18.0	19.0	1.0	18.5	174.4	0.142	876.7	0.00016	0.00016	
20	19.0	20.0	1.0	19.5	179.1	0.145	900.5	0.00016	0.00016	
21	20.0	21.0	1.0	20.5	195.1	0.147	981.1	0.00015	0.00015	
22	21.0	22.0	1.0	21.5	225.5	0.149	1133.5	0.00013	0.00013	
23	22.0	23.0	1.0	22.5	233.4	0.151	1173.4	0.00013	0.00013	
24	23.0	24.0	1.0	23.5	215.4	0.153	1083.0	0.00014	0.00014	
25	24.0	25.0	1.0	24.5	253.7	0.156	1275.8	0.00012	0.00012	
26	25.0	26.0	1.0	25.5	288.8	0.158	1452.0	0.00011	0.00011	
27	26.0	27.0	1.0	26.5	312.3	0.160	1570.4	0.00010	0.00010	
28	27.0	28.0	1.0	27.5	284.8	0.162	1432.1	0.00011	0.00011	
29	28.0	29.0	1.0	28.5	280.8	0.164	1411.9	0.00012	0.00012	
30	29.0	30.0	1.0	29.5	208.1	0.167	1046.1	0.00016	0.00016	
31	30.0	31.0	1.0	30.5	230.1	0.169	1156.6	0.00015	0.00015	
32	31.0	32.0	1.0	31.5	192.1	0.171	965.9	0.00018	0.00018	
33	32.0	33.0	1.0	32.5	171.4	0.173	861.8	0.00020	0.00020	

34	33.0	34.0	1.0	33.5	143.0	0.176	719.0	0.00024	0.00024	
35	34.0	35.0	1.0	34.5	59.2	0.178	297.7	0.00060	0.00060	
36	35.0	36.0	1.0	35.5	18.7	0.180	93.9	0.00192	0.00192	
37	36.0	37.0	1.0	36.5	69.9	0.182	351.6	0.00052	0.00052	C2
38	37.0	38.0	1.0	37.5	74.3	0.184	373.5	0.00049	0.00049	C2
39	38.0	39.0	1.0	38.5	10.8	0.187	54.1	0.00345	0.00345	C2
40	39.0	40.0	1.0	39.5	10.4	0.189	52.1	0.00363	0.00363	C2
41	40.0	41.0	1.0	40.5	11.7	0.191	58.8	0.00325	0.00325	C2
42	41.0	42.0	1.0	41.5	12.1	0.193	60.6	0.00319	0.00319	C2
43	42.0	43.0	1.0	42.5	9.7	0.195	48.9	0.00399	0.00399	C2
44	43.0	44.0	1.0	43.5	66.6	0.198	334.7	0.00059	0.00059	C2
45	44.0	45.0	1.0	44.5	165.7	0.200	833.3	0.00024	0.00024	C2
46	45.0	46.0	1.0	45.5	271.7	0.202	1365.8	0.00015	0.00015	
47	46.0	47.0	1.0	46.5	296.7	0.204	1491.6	0.00014	0.00014	
48	47.0	48.0	1.0	47.5	251.7	0.207	1265.6	0.00016	0.00016	
49	48.0	49.0	1.0	48.5	249.8	0.209	1255.8	0.00017	0.00017	
50	49.0	50.0	1.0	49.5	224.3	0.211	1127.6	0.00019	0.00019	
51	50.0	51.0	1.0	50.5	209.3	0.213	1052.3	0.00020	0.00020	
52	51.0	52.0	1.0	51.5	102.2	0.215	513.6	0.00042	0.00042	
53	52.0	53.0	1.0	52.5	180.6	0.218	907.9	0.00024	0.00024	
54	53.0	54.0	1.0	53.5	226.1	0.220	1137.0	0.00019	0.00019	
55	54.0	55.0	1.0	54.5	208.5	0.222	1048.5	0.00021	0.00021	
56	55.0	56.0	1.0	55.5	168.6	0.224	847.8	0.00026	0.00026	
57	56.0	57.0	1.0	56.5	127.1	0.226	638.9	0.00035	0.00035	
58	57.0	58.0	1.0	57.5	90.6	0.229	455.4	0.00050	0.00050	
59	58.0	59.0	1.0	58.5	56.3	0.231	283.0	0.00082	0.00082	
60	59.0	60.0	1.0	59.5	54.1	0.233	271.8	0.00086	0.00086	
61	60.0	61.0	1.0	60.5	50.7	0.235	254.7	0.00092	0.00092	
62	61.0	62.0	1.0	61.5	49.1	0.237	246.9	0.00096	0.00096	
63	62.0	63.0	1.0	62.5	141.3	0.240	710.6	0.00034	0.00034	
64	63.0	64.0	1.0	63.5	196.9	0.242	990.1	0.00024	0.00024	
65	64.0	65.0	1.0	64.5	317.9	0.244	1598.1	0.00015	0.00015	
66	65.0	66.0	1.0	65.5	247.8	0.246	1246.1	0.00020	0.00020	
67	66.0	67.0	1.0	66.5	104.8	0.249	526.8	0.00047	0.00047	
68	67.0	68.0	1.0	67.5	157.0	0.251	789.3	0.00032	0.00032	
69	68.0	69.0	1.0	68.5	184.5	0.253	927.8	0.00027	0.00027	
70	69.0	70.0	1.0	69.5	96.3	0.255	484.1	0.00053	0.00053	
71	70.0	71.0	1.0	70.5	23.6	0.257	118.8	0.00217	0.00217	
72	71.0	72.0	1.0	71.5	17.6	0.260	88.3	0.00294	0.00294	
73	72.0	73.0	1.0	72.5	18.7	0.262	93.8	0.00279	0.00279	
74	73.0	74.0	1.0	73.5	14.0	0.264	70.1	0.00376	0.00376	
75	74.0	75.0	1.0	74.5	8.5	0.266	42.7	0.00624	0.00624	
76	75.0	76.0	1.0	75.5	9.5	0.268	47.6	0.00564	0.00564	
77	76.0	77.0	1.0	76.5	23.3	0.271	117.0	0.00231	0.00231	
78	77.0	78.0	1.0	77.5	33.2	0.273	166.9	0.00163	0.00163	
79	78.0	79.0	1.0	78.5	45.2	0.275	227.3	0.00121	0.00121	
80	79.0	80.0	1.0	79.5	48.0	0.277	241.6	0.00115	0.00115	
81	80.0	81.0	1.0	80.5	40.6	0.280	204.1	0.00137	0.00137	
82	81.0	82.0	1.0	81.5	37.6	0.282	189.2	0.00149	0.00149	
83	82.0	83.0	1.0	82.5	66.0	0.284	332.0	0.00086	0.00086	
84	83.0	84.0	1.0	83.5	28.7	0.286	144.5	0.00198	0.00198	
85	84.0	85.0	1.0	84.5	16.7	0.288	84.0	0.00343	0.00343	
86	85.0	86.0	1.0	85.5	28.5	0.291	143.1	0.00203	0.00203	
87	86.0	87.0	1.0	86.5	49.3	0.293	248.1	0.00118	0.00118	
88	87.0	88.0	1.0	87.5	68.8	0.295	345.7	0.00085	0.00085	
89	88.0	89.0	1.0	88.5	401.8	0.297	2020.1	0.00015	0.00015	
90	89.0	90.0	1.0	89.5	204.8	0.299	1029.6	0.00029	0.00029	
91	90.0	91.0	1.0	90.5	61.0	0.302	306.7	0.00098	0.00098	
92	91.0	92.0	1.0	91.5	232.7	0.304	1169.7	0.00026	0.00026	
93	92.0	93.0	1.0	92.5	108.6	0.306	545.9	0.00056	0.00056	
94	93.0	94.0	1.0	93.5	123.9	0.308	623.1	0.00049	0.00049	
95	94.0	95.0	1.0	94.5	139.2	0.311	699.9	0.00044	0.00044	
96	95.0	96.0	1.0	95.5	165.6	0.313	832.6	0.00038	0.00038	
97	96.0	97.0	1.0	96.5	230.6	0.315	1159.5	0.00027	0.00027	
98	97.0	98.0	1.0	97.5	255.1	0.317	1282.6	0.00025	0.00025	
99	98.0	99.0	1.0	98.5	244.4	0.319	1229.0	0.00026	0.00026	
100	99.0	100.0	1.0	99.5	212.2	0.322	1066.8	0.00030	0.00030	
101	100.0	101.0	1.0	100.5	156.6	0.324	787.3	0.00041	0.00041	
102	101.0	102.0	1.0	101.5	44.4	0.326	223.3	0.00146	0.00146	
103	102.0	103.0	1.0	102.5	70.2	0.328	353.0	0.00093	0.00093	
104	103.0	104.0	1.0	103.5	91.8	0.330	461.6	0.00072	0.00072	
105	104.0	105.0	1.0	104.5	94.4	0.333	474.6	0.00070	0.00070	
106	105.0	106.0	1.0	105.5	98.0	0.335	492.7	0.00068	0.00068	
107	106.0	107.0	1.0	106.5	88.6	0.337	445.5	0.00076	0.00076	
108	107.0	108.0	1.0	107.5	83.8	0.339	421.2	0.00081	0.00081	
109	108.0	109.0	1.0	108.5	69.2	0.342	347.7	0.00098	0.00098	
110	109.0	110.0	1.0	109.5	59.8	0.344	300.5	0.00114	0.00114	

111	110.0	111.0	1.0	110.5	58.3	0.346	293.2	0.00118	0.00118	
112	111.0	112.0	1.0	111.5	60.5	0.348	304.0	0.00115	0.00115	
113	112.0	113.0	1.0	112.5	59.6	0.350	299.5	0.00117	0.00117	
114	113.0	114.0	1.0	113.5	58.2	0.353	292.7	0.00120	0.00120	
115	114.0	115.0	1.0	114.5	58.0	0.355	291.7	0.00122	0.00122	
116	115.0	116.0	1.0	115.5	168.8	0.357	848.7	0.00042	0.00042	
117	116.0	117.0	1.0	116.5	80.9	0.359	406.8	0.00088	0.00088	
118	117.0	118.0	1.0	117.5	350.0	0.361	1759.7	0.00021	0.00021	
119	118.0	119.0	1.0	118.5	350.0	0.364	1759.7	0.00021	0.00021	
120	119.0	120.0	1.0	119.5	350.0	0.366	1759.7	0.00021	0.00021	
121	120.0	150.0	30.0	135.0	350.0	0.400	1759.7	0.00682	0.00682	
122	150.0	200.0	50.0	175.0	350.0	0.489	1759.7	0.01389	0.01389	
123	200.0	202.8	2.8	201.4	350.0	0.546	1759.7	0.00086	0.00086	
124	202.8	300.0	97.2	251.4	350.0	0.501	1759.7	0.02769	0.02769	
125	300.0	400.0	100.0	350.0	350.0	0.412	1759.7	0.02341	0.02341	
126	400.0	500.0	100.0	450.0	350.0	0.322	1759.7	0.01827	0.01827	
127	500.0	600.0	100.0	550.0	350.0	0.231	1759.7	0.01314	0.01314	
128	600.0	700.0	100.0	650.0	350.0	0.141	1759.7	0.00800	0.00800	
129	700.0	800.0	100.0	750.0	350.0	0.050	1759.7	0.00286	0.00286	
130	800.0	900.0	100.0	850.0	350.0	0.000	1759.7	0.00000	0.00000	
Σ =									0.21885	

I_{zr} ($1 < L/B < 10$):	$I_{zr} = I_{zs} + 0.111 (I_{zc} - I_{zs}) (L/B - 1)$
I_{zs} ($L/B = 1$):	
For z_{ave} = 0 to B/2:	$I_{zs} = 0.1 + (z_{ave}/B)(2I_{zp} - 0.2)$
For z_{ave} = B/2 to 2B:	$I_{zs} = 0.667\, I_{zp} (2 - z_{ave}/B)$
I_{zc} ($L/B \geq 10$):	
For z_{ave} = 0 to B:	$I_{zc} = 0.2 + (z_{ave}/B)(I_{zp} - 0.2)$
For z_{ave} = B to 4B:	$I_{zc} = 0.333\, I_{zp} (4 - z_{ave}/B)$ (Coduto p.228.)

Footing width	B =		400.0	ft	ZV3V5C10
Footing length	L =		450.0	ft	
Ground elevation			261.0	ft	
Foundation elevation			261.0	ft	
Ground Water elevation			225.0	ft	
Excavated or embedded depth	D =		0.0	ft	
Depth to Groundwater			36.0	ft	
Unit weight	γ =		120.0	pcf	
Net applied footing pressure	Δp =		3.000	ksf	
	L/B =		1.13	-	

Immediate Settlement (in.) (S_0 / 2)

Load	S_0 =
	3.3
3.0	3.3
4.3	4.8
6.0	6.8

Computation

Settlement	ρ_i =	$C_1 C_t \Delta p\ \Sigma(\Delta z_i I_{zi}/E_{si})$	0.549	ft	Column I
	ρ_i =		**6.587**	**in**	
	S(t) =		0.821	ft	
	S(t) =		**9.850**	**in**	
Correction for strain relief	C_1 =	$1 - 0.5(\sigma'_D/q')$	1.000	-	
Effective vertical overburden pressure at D	σ'_{vo} =	γ D	0.000	ksf	
Correction for time dependent increase	C_t =	1 + 0.2 log(t / 0.1)	1.50	-	
	t =		30.00	years	
Elastic modulus of soil layer i	E_{si} =	2.5 q_c		see Column H	If L/B = 1
	E_{si} =	3.5 q_c		see Column H	If L/B ≥ 10
Depth increment i	Δz_i			see Column D	
Influence factor of soil layer i	I_{zi}	Figure 3-4		see Column G	
Peak depth influence factor	I_{zp} =	$0.5 + 0.1\ (\Delta p/\sigma'_{izp})^{1/2}$	0.546	-	
	z_p =	0.5B + D	200.00	ft	If L/B = 1
	z_p =	B + D	400.00	ft	If L/B ≥ 10
	z_p =		202.78	ft	for L/B=1.13
Effective overburden pressure at depth Izp	σ'_{izp} =		13.93	ksf	
Elastic Modulus	E_{si} =		2.50	q_c	If L/B = 1
	E_{si} =		3.50	q_c	If L/B ≥ 10
	E_{si} =		2.51	q_c	for L/B=1.13

30 Year Settlement (in.) (S_{30} / 2)

Load	S_0 =
	4.9
4.3	7.2
6.0	10.2

A	B	C	D	E	F	G	H	I	J	K
Layer No.	Layer top depth (ft)	Layer bottom depth (ft)	Layer thickness Δz_i (ft)	Mid-layer depth z_{ave} (ft)	Average tip stress q_c (tsf)	I_{zi}	Elastic modulus E_{si} (ksf)	$\Delta z_i I_{zi}/E_{si}$	$\Delta z_i I_{zi}/E_{si}$	Notes
1	0.0	1.0	1.0	0.5	75.8	0.102	381.0	0.00027	0.00027	
2	1.0	2.0	1.0	1.5	72.9	0.105	366.7	0.00029	0.00029	
3	2.0	3.0	1.0	2.5	90.7	0.107	455.8	0.00023	0.00023	
4	3.0	4.0	1.0	3.5	146.0	0.109	734.0	0.00015	0.00015	
5	4.0	5.0	1.0	4.5	137.5	0.111	691.1	0.00016	0.00016	
6	5.0	6.0	1.0	5.5	138.8	0.114	698.0	0.00016	0.00016	
7	6.0	7.0	1.0	6.5	198.9	0.116	999.8	0.00012	0.00012	
8	7.0	8.0	1.0	7.5	170.0	0.118	854.9	0.00014	0.00014	
9	8.0	9.0	1.0	8.5	169.0	0.120	849.5	0.00014	0.00014	
10	9.0	10.0	1.0	9.5	119.5	0.122	601.0	0.00020	0.00020	
11	10.0	11.0	1.0	10.5	151.5	0.125	761.6	0.00016	0.00016	
12	11.0	12.0	1.0	11.5	158.2	0.127	795.6	0.00016	0.00016	
13	12.0	13.0	1.0	12.5	218.5	0.129	1098.5	0.00012	0.00012	
14	13.0	14.0	1.0	13.5	169.2	0.131	850.8	0.00015	0.00015	
15	14.0	15.0	1.0	14.5	199.7	0.133	1004.2	0.00013	0.00013	
16	15.0	16.0	1.0	15.5	199.5	0.136	1003.2	0.00014	0.00014	
17	16.0	17.0	1.0	16.5	188.7	0.138	948.6	0.00015	0.00015	
18	17.0	18.0	1.0	17.5	154.9	0.140	778.9	0.00018	0.00018	
19	18.0	19.0	1.0	18.5	119.0	0.142	598.5	0.00024	0.00024	
20	19.0	20.0	1.0	19.5	116.6	0.145	586.0	0.00025	0.00025	
21	20.0	21.0	1.0	20.5	130.5	0.147	656.0	0.00022	0.00022	
22	21.0	22.0	1.0	21.5	150.6	0.149	757.3	0.00020	0.00020	
23	22.0	23.0	1.0	22.5	184.7	0.151	928.4	0.00016	0.00016	
24	23.0	24.0	1.0	23.5	268.3	0.153	1348.8	0.00011	0.00011	
25	24.0	25.0	1.0	24.5	336.6	0.156	1692.4	0.00009	0.00009	
26	25.0	26.0	1.0	25.5	351.1	0.158	1765.4	0.00009	0.00009	
27	26.0	27.0	1.0	26.5	265.6	0.160	1335.3	0.00012	0.00012	
28	27.0	28.0	1.0	27.5	226.0	0.162	1136.0	0.00014	0.00014	
29	28.0	29.0	1.0	28.5	167.7	0.164	843.1	0.00020	0.00020	
30	29.0	30.0	1.0	29.5	91.5	0.167	459.8	0.00036	0.00036	
31	30.0	31.0	1.0	30.5	91.0	0.169	457.3	0.00037	0.00037	
32	31.0	32.0	1.0	31.5	179.4	0.171	901.9	0.00019	0.00019	
33	32.0	33.0	1.0	32.5	80.1	0.173	402.6	0.00043	0.00043	

34	33.0	34.0	1.0	33.5	29.5	0.176	148.5	0.00118	0.00118	
35	34.0	35.0	1.0	34.5	30.8	0.178	154.9	0.00115	0.00115	C2
36	35.0	36.0	1.0	35.5	18.6	0.180	93.8	0.00192	0.00192	C2
37	36.0	37.0	1.0	36.5	23.6	0.182	118.5	0.00154	0.00154	C2
38	37.0	38.0	1.0	37.5	47.8	0.184	240.2	0.00077	0.00077	C2
39	38.0	39.0	1.0	38.5	18.2	0.187	91.3	0.00204	0.00204	C2
40	39.0	40.0	1.0	39.5	13.0	0.189	65.6	0.00288	0.00288	C2
41	40.0	41.0	1.0	40.5	15.5	0.191	77.8	0.00246	0.00246	C2
42	41.0	42.0	1.0	41.5	15.4	0.193	77.5	0.00249	0.00249	C2
43	42.0	43.0	1.0	42.5	15.4	0.195	77.2	0.00253	0.00253	C2
44	43.0	44.0	1.0	43.5	15.4	0.198	77.3	0.00256	0.00256	C2
45	44.0	45.0	1.0	44.5	16.4	0.200	82.3	0.00243	0.00243	C2
46	45.0	46.0	1.0	45.5	19.8	0.202	99.6	0.00203	0.00203	C2
47	46.0	47.0	1.0	46.5	19.6	0.204	98.3	0.00208	0.00208	C2
48	47.0	48.0	1.0	47.5	20.7	0.207	104.0	0.00199	0.00199	C2
49	48.0	49.0	1.0	48.5	27.8	0.209	139.8	0.00149	0.00149	C2
50	49.0	50.0	1.0	49.5	33.7	0.211	169.5	0.00124	0.00124	C2
51	50.0	51.0	1.0	50.5	127.0	0.213	638.4	0.00033	0.00033	
52	51.0	52.0	1.0	51.5	285.7	0.215	1436.2	0.00015	0.00015	
53	52.0	53.0	1.0	52.5	269.0	0.218	1352.5	0.00016	0.00016	
54	53.0	54.0	1.0	53.5	145.4	0.220	730.9	0.00030	0.00030	
55	54.0	55.0	1.0	54.5	194.6	0.222	978.4	0.00023	0.00023	
56	55.0	56.0	1.0	55.5	257.8	0.224	1295.9	0.00017	0.00017	
57	56.0	57.0	1.0	56.5	231.9	0.226	1165.8	0.00019	0.00019	
58	57.0	58.0	1.0	57.5	211.0	0.229	1060.8	0.00022	0.00022	
59	58.0	59.0	1.0	58.5	97.8	0.231	491.5	0.00047	0.00047	
60	59.0	60.0	1.0	59.5	27.9	0.233	140.3	0.00166	0.00166	
61	60.0	61.0	1.0	60.5	20.8	0.235	104.4	0.00225	0.00225	
62	61.0	62.0	1.0	61.5	17.1	0.237	85.7	0.00277	0.00277	
63	62.0	63.0	1.0	62.5	17.6	0.240	88.7	0.00270	0.00270	
64	63.0	64.0	1.0	63.5	29.8	0.242	150.1	0.00161	0.00161	
65	64.0	65.0	1.0	64.5	190.6	0.244	958.4	0.00025	0.00025	
66	65.0	66.0	1.0	65.5	239.4	0.246	1203.5	0.00020	0.00020	
67	66.0	67.0	1.0	66.5	145.7	0.249	732.8	0.00034	0.00034	
68	67.0	68.0	1.0	67.5	146.0	0.251	734.2	0.00034	0.00034	
69	68.0	69.0	1.0	68.5	189.9	0.253	954.7	0.00026	0.00026	
70	69.0	70.0	1.0	69.5	68.2	0.255	342.7	0.00074	0.00074	
71	70.0	71.0	1.0	70.5	34.4	0.257	173.1	0.00149	0.00149	
72	71.0	72.0	1.0	71.5	43.6	0.260	219.1	0.00118	0.00118	
73	72.0	73.0	1.0	72.5	38.4	0.262	193.2	0.00136	0.00136	
74	73.0	74.0	1.0	73.5	24.4	0.264	122.8	0.00215	0.00215	
75	74.0	75.0	1.0	74.5	35.6	0.266	178.8	0.00149	0.00149	
76	75.0	76.0	1.0	75.5	30.7	0.268	154.2	0.00174	0.00174	
77	76.0	77.0	1.0	76.5	36.2	0.271	182.2	0.00149	0.00149	
78	77.0	78.0	1.0	77.5	45.5	0.273	228.5	0.00119	0.00119	
79	78.0	79.0	1.0	78.5	60.1	0.275	301.9	0.00091	0.00091	
80	79.0	80.0	1.0	79.5	31.1	0.277	156.5	0.00177	0.00177	
81	80.0	81.0	1.0	80.5	28.9	0.280	145.5	0.00192	0.00192	
82	81.0	82.0	1.0	81.5	38.2	0.282	192.0	0.00147	0.00147	
83	82.0	83.0	1.0	82.5	66.0	0.284	332.0	0.00086	0.00086	
84	83.0	84.0	1.0	83.5	90.3	0.286	453.8	0.00063	0.00063	
85	84.0	85.0	1.0	84.5	106.5	0.288	535.6	0.00054	0.00054	
86	85.0	86.0	1.0	85.5	65.1	0.291	327.1	0.00089	0.00089	
87	86.0	87.0	1.0	86.5	85.6	0.293	430.4	0.00068	0.00068	
88	87.0	88.0	1.0	87.5	122.9	0.295	618.0	0.00048	0.00048	
89	88.0	89.0	1.0	88.5	221.4	0.297	1113.0	0.00027	0.00027	
90	89.0	90.0	1.0	89.5	273.2	0.299	1373.8	0.00022	0.00022	
91	90.0	91.0	1.0	90.5	114.5	0.302	575.5	0.00052	0.00052	
92	91.0	92.0	1.0	91.5	75.3	0.304	378.4	0.00080	0.00080	
93	92.0	93.0	1.0	92.5	175.1	0.306	880.3	0.00035	0.00035	
94	93.0	94.0	1.0	93.5	208.5	0.308	1048.2	0.00029	0.00029	
95	94.0	95.0	1.0	94.5	86.5	0.311	434.7	0.00071	0.00071	
96	95.0	96.0	1.0	95.5	119.6	0.313	601.3	0.00052	0.00052	
97	96.0	97.0	1.0	96.5	83.2	0.315	418.4	0.00075	0.00075	
98	97.0	98.0	1.0	97.5	143.3	0.317	720.3	0.00044	0.00044	
99	98.0	99.0	1.0	98.5	310.4	0.319	1560.6	0.00020	0.00020	
100	99.0	100.0	1.0	99.5	232.5	0.322	1168.8	0.00028	0.00028	
101	100.0	101.0	1.0	100.5	55.7	0.324	280.0	0.00116	0.00116	
102	101.0	102.0	1.0	101.5	48.1	0.326	241.9	0.00135	0.00135	
103	102.0	103.0	1.0	102.5	69.1	0.328	347.3	0.00095	0.00095	
104	103.0	104.0	1.0	103.5	107.8	0.330	542.1	0.00061	0.00061	
105	104.0	105.0	1.0	104.5	97.1	0.333	488.4	0.00068	0.00068	
106	105.0	106.0	1.0	105.5	99.1	0.335	498.1	0.00067	0.00067	
107	106.0	107.0	1.0	106.5	92.9	0.337	466.9	0.00072	0.00072	
108	107.0	108.0	1.0	107.5	89.4	0.339	449.5	0.00075	0.00075	
109	108.0	109.0	1.0	108.5	81.0	0.342	407.3	0.00084	0.00084	
110	109.0	110.0	1.0	109.5	60.1	0.344	302.2	0.00114	0.00114	

111	110.0	111.0	1.0	110.5	55.5	0.346	279.3	0.00124	0.00124	
112	111.0	112.0	1.0	111.5	58.5	0.348	294.0	0.00118	0.00118	
113	112.0	113.0	1.0	112.5	62.2	0.350	312.7	0.00112	0.00112	
114	113.0	114.0	1.0	113.5	57.1	0.353	286.9	0.00123	0.00123	
115	114.0	115.0	1.0	114.5	60.0	0.355	301.5	0.00118	0.00118	
116	115.0	116.0	1.0	115.5	53.1	0.357	267.2	0.00134	0.00134	
117	116.0	117.0	1.0	116.5	80.9	0.359	406.8	0.00088	0.00088	
118	117.0	118.0	1.0	117.5	350.0	0.361	1759.7	0.00021	0.00021	
119	118.0	119.0	1.0	118.5	350.0	0.364	1759.7	0.00021	0.00021	
120	119.0	120.0	1.0	119.5	350.0	0.366	1759.7	0.00021	0.00021	
121	120.0	150.0	30.0	135.0	350.0	0.400	1759.7	0.00682	0.00682	
122	150.0	200.0	50.0	175.0	350.0	0.489	1759.7	0.01389	0.01389	
123	200.0	202.8	2.8	201.4	350.0	0.546	1759.7	0.00086	0.00086	
124	202.8	300.0	97.2	251.4	350.0	0.501	1759.7	0.02769	0.02769	
125	300.0	400.0	100.0	350.0	350.0	0.412	1759.7	0.02341	0.02341	
126	400.0	500.0	100.0	450.0	350.0	0.322	1759.7	0.01827	0.01827	
127	500.0	600.0	100.0	550.0	350.0	0.231	1759.7	0.01314	0.01314	
128	600.0	700.0	100.0	650.0	350.0	0.141	1759.7	0.00800	0.00800	
129	700.0	800.0	100.0	750.0	350.0	0.050	1759.7	0.00286	0.00286	
130	800.0	900.0	100.0	850.0	350.0	0.000	1759.7	0.00000	0.00000	
Σ =									0.21455	

I_{zr} (1 < L/B < 10):	$I_{zr} = I_{zs} + 0.111 (I_{zc} - I_{zs}) (L/B - 1)$
I_{zs} (L/B = 1):	
For z_{ave} = 0 to B/2:	$I_{zs} = 0.1 + (z_{ave}/B)(2I_{zp} - 0.2)$
For z_{ave} = B/2 to 2B:	$I_{zs} = 0.667\, I_{zp} (2 - z_{ave}/B)$
I_{zc} (L/B ≥ 10):	
For z_{ave} = 0 to B:	$I_{zc} = 0.2 + (z_{ave}/B)(I_{zp} - 0.2)$
For z_{ave} = B to 4B:	$I_{zc} = 0.333\, I_{zp} (4 - z_{ave}/B)$

(Coduto p.228.)

ZV3V5C11

Footing width	B =		400.0 ft	
Footing length	L =		450.0 ft	
Ground elevation			261.0 ft	
Foundation elevation			261.0 ft	
Ground Water elevation			225.0 ft	
Excavated or embedded depth	D =		0.0 ft	
Depth to Groundwater			36.0 ft	
Unit weight	γ =		120.0 pcf	
Net applied footing pressure	Δp =		3.000 ksf	
	L/B =		1.13 -	
Computation				
Settlement	ρ_i =	$C_1\ C_t\ \Delta p\ \Sigma(\Delta z_i\ I_{zi}/E_{si})$	0.486 ft	Column I
	ρ_i =		5.830 in	
	S(t) =		0.727 ft	
	S(t) =		8.718 in	
Correction for strain relief	C_1 =	$1 - 0.5(\sigma'_D/q')$	1.000 -	
Effective vertical overburden pressure at D	σ'_{vo} =	γ D	0.000 ksf	
Correction for time dependent increase	C_t =	1 + 0.2 log(t / 0.1)	1.50 -	
	t =		30.00 years	
Elastic modulus of soil layer i	E_{si} =	2.5 q_c	see Column H	if L/B = 1
	E_{si} =	3.5 q_c	see Column H	If L/B ≥ 10
Depth increment i	Δz_i		see Column D	
Influence factor of soil layer i	I_{zi}	Figure 3-4	see Column G	
Peak depth influence factor	I_{zp} =	$0.5 + 0.1\ (\Delta p/\sigma'_{izp})^{1/2}$	0.546 -	
	z_p =	0.5B + D	200.00 ft	If L/B = 1
	z_p =	B + D	400.00 ft	If L/B ≥ 10
	z_p =		202.78 ft	for L/B=1.13
Effective overburden pressure at depth Izp	σ'_{izp} =		13.93 ksf	
Elastic Modulus	E_{si} =		2.50 q_c	If L/B = 1
	E_{si} =		3.50 q_c	If L/B ≥ 10
	E_{si} =		2.51 q_c	for L/B=1.13

Immediate Settlement (in.) (S_0 / 2)

Load	S_0 =
	2.9
3.0	2.9
4.3	4.2
6.0	6.0

30 Year Settlement (in.) (S_{30} / 2)

Load	S_0 =
	4.4
4.3	6.3
6.0	9.0

A	B	C	D	E	F	G	H	I	J	K
Layer No.	Layer top depth (ft)	Layer bottom depth (ft)	Layer thickness Δz_i (ft)	Mid-layer depth z_{ave} (ft)	Average tip stress q_c (tsf)	I_{zi}	Elastic modulus E_{si} (ksf)	$\Delta z_i\ I_{zi}/E_{si}$	$\Delta z_i\ I_{zi}/E_{si}$	Notes
1	0.0	1.0	1.0	0.5	129.0	0.102	648.5	0.00016	0.00016	
2	1.0	2.0	1.0	1.5	64.7	0.105	325.5	0.00032	0.00032	
3	2.0	3.0	1.0	2.5	75.9	0.107	381.5	0.00028	0.00028	
4	3.0	4.0	1.0	3.5	166.0	0.109	834.4	0.00013	0.00013	
5	4.0	5.0	1.0	4.5	196.9	0.111	990.0	0.00011	0.00011	
6	5.0	6.0	1.0	5.5	222.2	0.114	1117.0	0.00010	0.00010	
7	6.0	7.0	1.0	6.5	224.4	0.116	1128.0	0.00010	0.00010	
8	7.0	8.0	1.0	7.5	252.8	0.118	1270.9	0.00009	0.00009	
9	8.0	9.0	1.0	8.5	216.7	0.120	1089.8	0.00011	0.00011	
10	9.0	10.0	1.0	9.5	210.3	0.122	1057.5	0.00012	0.00012	
11	10.0	11.0	1.0	10.5	167.9	0.125	844.2	0.00015	0.00015	
12	11.0	12.0	1.0	11.5	120.7	0.127	606.7	0.00021	0.00021	
13	12.0	13.0	1.0	12.5	103.7	0.129	521.3	0.00025	0.00025	
14	13.0	14.0	1.0	13.5	98.1	0.131	493.3	0.00027	0.00027	
15	14.0	15.0	1.0	14.5	85.2	0.133	428.4	0.00031	0.00031	
16	15.0	16.0	1.0	15.5	103.1	0.136	518.5	0.00026	0.00026	
17	16.0	17.0	1.0	16.5	123.8	0.138	622.3	0.00022	0.00022	
18	17.0	18.0	1.0	17.5	123.4	0.140	620.6	0.00023	0.00023	
19	18.0	19.0	1.0	18.5	140.6	0.142	706.9	0.00020	0.00020	
20	19.0	20.0	1.0	19.5	148.2	0.145	745.2	0.00019	0.00019	
21	20.0	21.0	1.0	20.5	145.3	0.147	730.5	0.00020	0.00020	
22	21.0	22.0	1.0	21.5	117.7	0.149	591.7	0.00025	0.00025	
23	22.0	23.0	1.0	22.5	152.3	0.151	765.8	0.00020	0.00020	
24	23.0	24.0	1.0	23.5	152.0	0.153	764.3	0.00020	0.00020	
25	24.0	25.0	1.0	24.5	160.9	0.156	809.0	0.00019	0.00019	
26	25.0	26.0	1.0	25.5	92.5	0.158	464.9	0.00034	0.00034	
27	26.0	27.0	1.0	26.5	96.1	0.160	483.1	0.00033	0.00033	
28	27.0	28.0	1.0	27.5	86.5	0.162	435.0	0.00037	0.00037	
29	28.0	29.0	1.0	28.5	158.4	0.164	796.5	0.00021	0.00021	
30	29.0	30.0	1.0	29.5	166.1	0.167	835.0	0.00020	0.00020	
31	30.0	31.0	1.0	30.5	89.3	0.169	449.0	0.00038	0.00038	
32	31.0	32.0	1.0	31.5	102.5	0.171	515.2	0.00033	0.00033	
33	32.0	33.0	1.0	32.5	132.1	0.173	664.3	0.00026	0.00026	

34	33.0	34.0	1.0	33.5	193.7	0.176	974.1	0.00018	0.00018		
35	34.0	35.0	1.0	34.5	250.1	0.178	1257.2	0.00014	0.00014		
36	35.0	36.0	1.0	35.5	226.3	0.180	1137.6	0.00016	0.00016		
37	36.0	37.0	1.0	36.5	283.7	0.182	1426.2	0.00013	0.00013		
38	37.0	38.0	1.0	37.5	448.7	0.184	2256.0	0.00008	0.00008		
39	38.0	39.0	1.0	38.5	552.0	0.187	2775.1	0.00007	0.00007		
40	39.0	40.0	1.0	39.5	541.7	0.189	2723.7	0.00007	0.00007		
41	40.0	41.0	1.0	40.5	492.8	0.191	2477.7	0.00008	0.00008		
42	41.0	42.0	1.0	41.5	303.5	0.193	1526.1	0.00013	0.00013		
43	42.0	43.0	1.0	42.5	113.5	0.195	570.5	0.00034	0.00034		
44	43.0	44.0	1.0	43.5	43.7	0.198	219.6	0.00090	0.00090	C2	
45	44.0	45.0	1.0	44.5	166.1	0.200	835.2	0.00024	0.00024	C2	
46	45.0	46.0	1.0	45.5	288.6	0.202	1451.0	0.00014	0.00014	C2	
47	46.0	47.0	1.0	46.5	312.3	0.204	1570.1	0.00013	0.00013		
48	47.0	48.0	1.0	47.5	341.2	0.207	1715.3	0.00012	0.00012		
49	48.0	49.0	1.0	48.5	357.8	0.209	1798.9	0.00012	0.00012		
50	49.0	50.0	1.0	49.5	370.4	0.211	1862.2	0.00011	0.00011		
51	50.0	51.0	1.0	50.5	355.3	0.213	1786.4	0.00012	0.00012		
52	51.0	52.0	1.0	51.5	338.0	0.215	1699.5	0.00013	0.00013		
53	52.0	53.0	1.0	52.5	283.6	0.218	1426.0	0.00015	0.00015		
54	53.0	54.0	1.0	53.5	230.3	0.220	1157.7	0.00019	0.00019		
55	54.0	55.0	1.0	54.5	228.0	0.222	1146.2	0.00019	0.00019		
56	55.0	56.0	1.0	55.5	178.8	0.224	898.8	0.00025	0.00025		
57	56.0	57.0	1.0	56.5	94.1	0.226	473.4	0.00048	0.00048		
58	57.0	58.0	1.0	57.5	81.2	0.229	408.0	0.00056	0.00056		
59	58.0	59.0	1.0	58.5	54.6	0.231	274.7	0.00084	0.00084		
60	59.0	60.0	1.0	59.5	87.9	0.233	441.9	0.00053	0.00053		
61	60.0	61.0	1.0	60.5	137.9	0.235	693.2	0.00034	0.00034		
62	61.0	62.0	1.0	61.5	165.9	0.237	834.0	0.00028	0.00028		
63	62.0	63.0	1.0	62.5	193.8	0.240	974.6	0.00025	0.00025		
64	63.0	64.0	1.0	63.5	215.2	0.242	1081.8	0.00022	0.00022		
65	64.0	65.0	1.0	64.5	186.8	0.244	939.3	0.00026	0.00026		
66	65.0	66.0	1.0	65.5	185.8	0.246	934.4	0.00026	0.00026		
67	66.0	67.0	1.0	66.5	206.4	0.249	1037.6	0.00024	0.00024		
68	67.0	68.0	1.0	67.5	218.9	0.251	1100.4	0.00023	0.00023		
69	68.0	69.0	1.0	68.5	176.9	0.253	889.3	0.00028	0.00028		
70	69.0	70.0	1.0	69.5	129.2	0.255	649.8	0.00039	0.00039		
71	70.0	71.0	1.0	70.5	47.9	0.257	241.0	0.00107	0.00107		
72	71.0	72.0	1.0	71.5	29.2	0.260	146.8	0.00177	0.00177		
73	72.0	73.0	1.0	72.5	46.1	0.262	232.0	0.00113	0.00113		
74	73.0	74.0	1.0	73.5	98.2	0.264	493.6	0.00053	0.00053		
75	74.0	75.0	1.0	74.5	84.4	0.266	424.2	0.00063	0.00063		
76	75.0	76.0	1.0	75.5	236.6	0.268	1189.5	0.00023	0.00023		
77	76.0	77.0	1.0	76.5	263.3	0.271	1323.9	0.00020	0.00020		
78	77.0	78.0	1.0	77.5	254.9	0.273	1281.3	0.00021	0.00021		
79	78.0	79.0	1.0	78.5	192.4	0.275	967.4	0.00028	0.00028		
80	79.0	80.0	1.0	79.5	238.8	0.277	1200.6	0.00023	0.00023		
81	80.0	81.0	1.0	80.5	253.8	0.280	1275.9	0.00022	0.00022		
82	81.0	82.0	1.0	81.5	91.9	0.282	462.1	0.00061	0.00061		
83	82.0	83.0	1.0	82.5	81.9	0.284	411.9	0.00069	0.00069		
84	83.0	84.0	1.0	83.5	88.1	0.286	442.7	0.00065	0.00065		
85	84.0	85.0	1.0	84.5	149.1	0.288	749.8	0.00038	0.00038		
86	85.0	86.0	1.0	85.5	100.2	0.291	503.6	0.00058	0.00058		
87	86.0	87.0	1.0	86.5	90.6	0.293	455.3	0.00064	0.00064		
88	87.0	88.0	1.0	87.5	96.0	0.295	482.6	0.00061	0.00061		
89	88.0	89.0	1.0	88.5	192.0	0.297	965.4	0.00031	0.00031		
90	89.0	90.0	1.0	89.5	154.4	0.299	776.5	0.00039	0.00039		
91	90.0	91.0	1.0	90.5	146.3	0.302	735.7	0.00041	0.00041		
92	91.0	92.0	1.0	91.5	115.3	0.304	579.8	0.00052	0.00052		
93	92.0	93.0	1.0	92.5	108.6	0.306	545.9	0.00056	0.00056		
94	93.0	94.0	1.0	93.5	123.9	0.308	623.1	0.00049	0.00049		
95	94.0	95.0	1.0	94.5	139.2	0.311	699.9	0.00044	0.00044		
96	95.0	96.0	1.0	95.5	165.6	0.313	832.6	0.00038	0.00038		
97	96.0	97.0	1.0	96.5	230.6	0.315	1159.5	0.00027	0.00027		
98	97.0	98.0	1.0	97.5	255.1	0.317	1282.6	0.00025	0.00025		
99	98.0	99.0	1.0	98.5	244.4	0.319	1229.0	0.00026	0.00026		
100	99.0	100.0	1.0	99.5	212.2	0.322	1066.8	0.00030	0.00030		
101	100.0	101.0	1.0	100.5	156.6	0.324	787.3	0.00041	0.00041		
102	101.0	102.0	1.0	101.5	44.4	0.326	223.3	0.00146	0.00146		
103	102.0	103.0	1.0	102.5	70.2	0.328	353.0	0.00093	0.00093		
104	103.0	104.0	1.0	103.5	91.8	0.330	461.6	0.00072	0.00072		
105	104.0	105.0	1.0	104.5	94.4	0.333	474.6	0.00070	0.00070		
106	105.0	106.0	1.0	105.5	98.0	0.335	492.7	0.00068	0.00068		
107	106.0	107.0	1.0	106.5	88.6	0.337	445.5	0.00076	0.00076		
108	107.0	108.0	1.0	107.5	83.8	0.339	421.2	0.00081	0.00081		
109	108.0	109.0	1.0	108.5	69.2	0.342	347.7	0.00098	0.00098		
110	109.0	110.0	1.0	109.5	59.8	0.344	300.5	0.00114	0.00114		

111	110.0	111.0	1.0	110.5	58.3	0.346	293.2	0.00118	0.00118	
112	111.0	112.0	1.0	111.5	60.5	0.348	304.0	0.00115	0.00115	
113	112.0	113.0	1.0	112.5	59.6	0.350	299.5	0.00117	0.00117	
114	113.0	114.0	1.0	113.5	58.2	0.353	292.7	0.00120	0.00120	
115	114.0	115.0	1.0	114.5	58.0	0.355	291.7	0.00122	0.00122	
116	115.0	116.0	1.0	115.5	168.8	0.357	848.7	0.00042	0.00042	
117	116.0	117.0	1.0	116.5	80.9	0.359	406.8	0.00088	0.00088	
118	117.0	118.0	1.0	117.5	350.0	0.361	1759.7	0.00021	0.00021	
119	118.0	119.0	1.0	118.5	350.0	0.364	1759.7	0.00021	0.00021	
120	119.0	120.0	1.0	119.5	350.0	0.366	1759.7	0.00021	0.00021	
121	120.0	150.0	30.0	135.0	350.0	0.400	1759.7	0.00682	0.00682	
122	150.0	200.0	50.0	175.0	350.0	0.489	1759.7	0.01389	0.01389	
123	200.0	202.8	2.8	201.4	350.0	0.546	1759.7	0.00086	0.00086	
124	202.8	300.0	97.2	251.4	350.0	0.501	1759.7	0.02769	0.02769	
125	300.0	400.0	100.0	350.0	350.0	0.412	1759.7	0.02341	0.02341	
126	400.0	500.0	100.0	450.0	350.0	0.322	1759.7	0.01827	0.01827	
127	500.0	600.0	100.0	550.0	350.0	0.231	1759.7	0.01314	0.01314	
128	600.0	700.0	100.0	650.0	350.0	0.141	1759.7	0.00800	0.00800	
129	700.0	800.0	100.0	750.0	350.0	0.050	1759.7	0.00286	0.00286	
130	800.0	900.0	100.0	850.0	350.0	0.000	1759.7	0.00000	0.00000	
Σ =									0.16322	

I_{zr} ($1 < L/B < 10$):	$I_{zr} = I_{zs} + 0.111\,(I_{zc} - I_{zs})\,(L/B - 1)$
I_{zs} ($L/B = 1$):	
For z_{ave} = 0 to B/2:	$I_{zs} = 0.1 + (z_{ave}/B)(2I_{zp} - 0.2)$
For z_{ave} = B/2 to 2B:	$I_{zs} = 0.667\, I_{zp}\,(2 - z_{ave}/B)$
I_{zc} ($L/B \geq 10$):	
For z_{ave} = 0 to B:	$I_{zc} = 0.2 + (z_{ave}/B)(I_{zp} - 0.2)$
For z_{ave} = B to 4B:	$I_{zc} = 0.333\, I_{zp}\,(4 - z_{ave}/B)$ (Coduto p.228.)

Footing width	B =		400.0	ft	ZV3V5C12
Footing length	L =		450.0	ft	
Ground elevation			261.0	ft	
Foundation elevation			261.0	ft	
Ground Water elevation			225.0	ft	
Excavated or embedded depth	D =		0.0	ft	
Depth to Groundwater			36.0	ft	
Unit weight	γ =		120.0	pcf	
Net applied footing pressure	Δp =		3.000	ksf	
	L/B =		1.13	-	
Computation					
Settlement	ρ_i =	$C_1\, C_t\, \Delta p\, \Sigma(\Delta z_i\, I_{zi}/E_{si})$	0.543	ft	Column I
	ρ_i =		6.510	in	
	S(t) =		0.811	ft	
	S(t) =		9.736	in	
Correction for strain relief	C_1 =	$1 - 0.5(\sigma'_D/q')$	1.000	-	
Effective vertical overburden pressure at D	σ'_{vo} =	γ D	0.000	ksf	
Correction for time dependent increase	C_t =	1 + 0.2 log(t / 0.1)	1.50	-	
	t =		30.00	years	
Elastic modulus of soil layer i	E_{si} =	2.5 q_c	see Column H		if L/B = 1
	E_{si} =	3.5 q_c	see Column H		If L/B ≥ 10
Depth increment i	Δz_i		see Column D		
Influence factor of soil layer i	I_{zi}	Figure 3-4	see Column G		
Peak depth influence factor	I_{zp} =	$0.5 + 0.1\,(\Delta p/\sigma'_{izp})^{1/2}$	0.546	-	
	z_p =	0.5B + D	200.00	ft	If L/B = 1
	z_p =	B + D	400.00	ft	If L/B ≥ 10
	z_p =		202.78	ft	for L/B=1.13
Effective overburden pressure at depth Izp	σ'_{izp} =		13.93	ksf	
Elastic Modulus	E_{si} =		2.50	q_c	If L/B = 1
	E_{si} =		3.50	q_c	If L/B ≥ 10
	E_{si} =		2.51	q_c	for L/B=1.13

Immediate Settlement (in.) (S_0 / 2)

Load	S_0 =
	3.3
3.0	3.3
4.3	4.7
6.0	6.7

30 Year Settlement (in.) (S_{30} / 2)

Load	S_0 =
	4.9
4.3	7.1
6.0	10.0

A	B	C	D	E	F	G	H	I	J	K
Layer No.	Layer top depth (ft)	Layer bottom depth (ft)	Layer thickness Δz_i (ft)	Mid-layer depth z_{ave} (ft)	Average tip stress q_c (tsf)	I_{zi}	Elastic modulus E_{si} (ksf)	$\Delta z_i\, I_{zi}/E_{si}$	$\Delta z_i\, I_{zi}/E_{si}$	Notes
1	0.0	1.0	1.0	0.5	143.1	0.102	719.6	0.00014	0.00014	
2	1.0	2.0	1.0	1.5	161.3	0.105	811.1	0.00013	0.00013	
3	2.0	3.0	1.0	2.5	164.6	0.107	827.8	0.00013	0.00013	
4	3.0	4.0	1.0	3.5	185.5	0.109	932.7	0.00012	0.00012	
5	4.0	5.0	1.0	4.5	194.6	0.111	978.5	0.00011	0.00011	
6	5.0	6.0	1.0	5.5	189.1	0.114	950.8	0.00012	0.00012	
7	6.0	7.0	1.0	6.5	220.5	0.116	1108.6	0.00010	0.00010	
8	7.0	8.0	1.0	7.5	223.1	0.118	1121.9	0.00011	0.00011	
9	8.0	9.0	1.0	8.5	230.2	0.120	1157.5	0.00010	0.00010	
10	9.0	10.0	1.0	9.5	258.0	0.122	1296.9	0.00009	0.00009	
11	10.0	11.0	1.0	10.5	231.4	0.125	1163.3	0.00011	0.00011	
12	11.0	12.0	1.0	11.5	268.1	0.127	1347.7	0.00009	0.00009	
13	12.0	13.0	1.0	12.5	294.8	0.129	1482.2	0.00009	0.00009	
14	13.0	14.0	1.0	13.5	305.0	0.131	1533.7	0.00009	0.00009	
15	14.0	15.0	1.0	14.5	251.8	0.133	1266.0	0.00011	0.00011	
16	15.0	16.0	1.0	15.5	219.3	0.136	1102.6	0.00012	0.00012	
17	16.0	17.0	1.0	16.5	224.4	0.138	1128.3	0.00012	0.00012	
18	17.0	18.0	1.0	17.5	224.3	0.140	1127.6	0.00012	0.00012	
19	18.0	19.0	1.0	18.5	209.0	0.142	1050.7	0.00014	0.00014	
20	19.0	20.0	1.0	19.5	220.6	0.145	1108.9	0.00013	0.00013	
21	20.0	21.0	1.0	20.5	234.3	0.147	1177.8	0.00012	0.00012	
22	21.0	22.0	1.0	21.5	220.7	0.149	1109.6	0.00013	0.00013	
23	22.0	23.0	1.0	22.5	195.2	0.151	981.5	0.00015	0.00015	
24	23.0	24.0	1.0	23.5	185.2	0.153	931.0	0.00016	0.00016	
25	24.0	25.0	1.0	24.5	185.5	0.156	932.7	0.00017	0.00017	
26	25.0	26.0	1.0	25.5	207.6	0.158	1043.7	0.00015	0.00015	
27	26.0	27.0	1.0	26.5	125.6	0.160	631.5	0.00025	0.00025	
28	27.0	28.0	1.0	27.5	125.5	0.162	630.9	0.00026	0.00026	
29	28.0	29.0	1.0	28.5	114.7	0.164	576.6	0.00029	0.00029	
30	29.0	30.0	1.0	29.5	179.7	0.167	903.7	0.00018	0.00018	
31	30.0	31.0	1.0	30.5	184.5	0.169	927.8	0.00018	0.00018	
32	31.0	32.0	1.0	31.5	138.1	0.171	694.5	0.00025	0.00025	
33	32.0	33.0	1.0	32.5	122.9	0.173	617.7	0.00028	0.00028	

34	33.0	34.0	1.0	33.5	182.2	0.176	916.1	0.00019	0.00019	
35	34.0	35.0	1.0	34.5	202.5	0.178	1018.1	0.00017	0.00017	
36	35.0	36.0	1.0	35.5	220.2	0.180	1107.1	0.00016	0.00016	
37	36.0	37.0	1.0	36.5	242.3	0.182	1218.4	0.00015	0.00015	
38	37.0	38.0	1.0	37.5	222.2	0.184	1117.2	0.00017	0.00017	
39	38.0	39.0	1.0	38.5	263.2	0.187	1323.5	0.00014	0.00014	
40	39.0	40.0	1.0	39.5	287.3	0.189	1444.5	0.00013	0.00013	
41	40.0	41.0	1.0	40.5	235.4	0.191	1183.5	0.00016	0.00016	
42	41.0	42.0	1.0	41.5	71.1	0.193	357.5	0.00054	0.00054	
43	42.0	43.0	1.0	42.5	21.0	0.195	105.5	0.00185	0.00185	C2
44	43.0	44.0	1.0	43.5	51.8	0.198	260.2	0.00076	0.00076	C2
45	44.0	45.0	1.0	44.5	256.4	0.200	1288.9	0.00016	0.00016	C2
46	45.0	46.0	1.0	45.5	332.4	0.202	1671.3	0.00012	0.00012	
47	46.0	47.0	1.0	46.5	342.9	0.204	1723.8	0.00012	0.00012	
48	47.0	48.0	1.0	47.5	328.7	0.207	1652.7	0.00012	0.00012	
49	48.0	49.0	1.0	48.5	294.0	0.209	1478.2	0.00014	0.00014	
50	49.0	50.0	1.0	49.5	229.8	0.211	1155.6	0.00018	0.00018	
51	50.0	51.0	1.0	50.5	129.4	0.213	650.6	0.00033	0.00033	
52	51.0	52.0	1.0	51.5	35.1	0.215	176.3	0.00122	0.00122	
53	52.0	53.0	1.0	52.5	51.4	0.218	258.2	0.00084	0.00084	
54	53.0	54.0	1.0	53.5	177.8	0.220	893.7	0.00025	0.00025	
55	54.0	55.0	1.0	54.5	40.3	0.222	202.4	0.00110	0.00110	
56	55.0	56.0	1.0	55.5	11.6	0.224	58.3	0.00384	0.00384	
57	56.0	57.0	1.0	56.5	17.5	0.226	87.8	0.00258	0.00258	
58	57.0	58.0	1.0	57.5	44.8	0.229	225.2	0.00102	0.00102	
59	58.0	59.0	1.0	58.5	106.4	0.231	535.0	0.00043	0.00043	
60	59.0	60.0	1.0	59.5	136.9	0.233	688.3	0.00034	0.00034	
61	60.0	61.0	1.0	60.5	163.5	0.235	822.2	0.00029	0.00029	
62	61.0	62.0	1.0	61.5	150.0	0.237	754.2	0.00031	0.00031	
63	62.0	63.0	1.0	62.5	175.7	0.240	883.2	0.00027	0.00027	
64	63.0	64.0	1.0	63.5	159.2	0.242	800.4	0.00030	0.00030	
65	64.0	65.0	1.0	64.5	150.4	0.244	756.3	0.00032	0.00032	
66	65.0	66.0	1.0	65.5	140.8	0.246	707.7	0.00035	0.00035	
67	66.0	67.0	1.0	66.5	116.9	0.249	587.9	0.00042	0.00042	
68	67.0	68.0	1.0	67.5	48.8	0.251	245.4	0.00102	0.00102	
69	68.0	69.0	1.0	68.5	30.2	0.253	152.0	0.00166	0.00166	
70	69.0	70.0	1.0	69.5	15.1	0.255	75.9	0.00336	0.00336	
71	70.0	71.0	1.0	70.5	17.8	0.257	89.5	0.00288	0.00288	
72	71.0	72.0	1.0	71.5	30.0	0.260	151.0	0.00172	0.00172	
73	72.0	73.0	1.0	72.5	27.0	0.262	135.9	0.00193	0.00193	
74	73.0	74.0	1.0	73.5	29.8	0.264	149.9	0.00176	0.00176	
75	74.0	75.0	1.0	74.5	149.2	0.266	750.4	0.00035	0.00035	
76	75.0	76.0	1.0	75.5	136.5	0.268	686.1	0.00039	0.00039	
77	76.0	77.0	1.0	76.5	48.5	0.271	244.0	0.00111	0.00111	
78	77.0	78.0	1.0	77.5	45.8	0.273	230.2	0.00119	0.00119	
79	78.0	79.0	1.0	78.5	49.4	0.275	248.4	0.00111	0.00111	
80	79.0	80.0	1.0	79.5	77.4	0.277	389.0	0.00071	0.00071	
81	80.0	81.0	1.0	80.5	104.4	0.280	524.8	0.00053	0.00053	
82	81.0	82.0	1.0	81.5	105.8	0.282	531.8	0.00053	0.00053	
83	82.0	83.0	1.0	82.5	83.6	0.284	420.3	0.00068	0.00068	
84	83.0	84.0	1.0	83.5	281.5	0.286	1415.6	0.00020	0.00020	
85	84.0	85.0	1.0	84.5	163.0	0.288	819.4	0.00035	0.00035	
86	85.0	86.0	1.0	85.5	100.2	0.291	503.6	0.00058	0.00058	
87	86.0	87.0	1.0	86.5	90.6	0.293	455.3	0.00064	0.00064	
88	87.0	88.0	1.0	87.5	96.0	0.295	482.6	0.00061	0.00061	
89	88.0	89.0	1.0	88.5	192.0	0.297	965.4	0.00031	0.00031	
90	89.0	90.0	1.0	89.5	154.4	0.299	776.5	0.00039	0.00039	
91	90.0	91.0	1.0	90.5	146.3	0.302	735.7	0.00041	0.00041	
92	91.0	92.0	1.0	91.5	115.3	0.304	579.8	0.00052	0.00052	
93	92.0	93.0	1.0	92.5	108.6	0.306	545.9	0.00056	0.00056	
94	93.0	94.0	1.0	93.5	123.9	0.308	623.1	0.00049	0.00049	
95	94.0	95.0	1.0	94.5	139.2	0.311	699.9	0.00044	0.00044	
96	95.0	96.0	1.0	95.5	165.6	0.313	832.6	0.00038	0.00038	
97	96.0	97.0	1.0	96.5	230.6	0.315	1159.5	0.00027	0.00027	
98	97.0	98.0	1.0	97.5	255.1	0.317	1282.6	0.00025	0.00025	
99	98.0	99.0	1.0	98.5	244.4	0.319	1229.0	0.00026	0.00026	
100	99.0	100.0	1.0	99.5	212.2	0.322	1066.8	0.00030	0.00030	
101	100.0	101.0	1.0	100.5	156.6	0.324	787.3	0.00041	0.00041	
102	101.0	102.0	1.0	101.5	44.4	0.326	223.3	0.00146	0.00146	
103	102.0	103.0	1.0	102.5	70.2	0.328	353.0	0.00093	0.00093	
104	103.0	104.0	1.0	103.5	91.8	0.330	461.6	0.00072	0.00072	
105	104.0	105.0	1.0	104.5	94.4	0.333	474.6	0.00070	0.00070	
106	105.0	106.0	1.0	105.5	98.0	0.335	492.7	0.00068	0.00068	
107	106.0	107.0	1.0	106.5	88.6	0.337	445.5	0.00076	0.00076	
108	107.0	108.0	1.0	107.5	83.8	0.339	421.2	0.00081	0.00081	
109	108.0	109.0	1.0	108.5	69.2	0.342	347.7	0.00098	0.00098	
110	109.0	110.0	1.0	109.5	59.8	0.344	300.5	0.00114	0.00114	

111	110.0	111.0	1.0	110.5	58.3	0.346	293.2	0.00118	0.00118	
112	111.0	112.0	1.0	111.5	60.5	0.348	304.0	0.00115	0.00115	
113	112.0	113.0	1.0	112.5	59.6	0.350	299.5	0.00117	0.00117	
114	113.0	114.0	1.0	113.5	58.2	0.353	292.7	0.00120	0.00120	
115	114.0	115.0	1.0	114.5	58.0	0.355	291.7	0.00122	0.00122	
116	115.0	116.0	1.0	115.5	168.8	0.357	848.7	0.00042	0.00042	
117	116.0	117.0	1.0	116.5	80.9	0.359	406.8	0.00088	0.00088	
118	117.0	118.0	1.0	117.5	350.0	0.361	1759.7	0.00021	0.00021	
119	118.0	119.0	1.0	118.5	350.0	0.364	1759.7	0.00021	0.00021	
120	119.0	120.0	1.0	119.5	350.0	0.366	1759.7	0.00021	0.00021	
121	120.0	150.0	30.0	135.0	350.0	0.400	1759.7	0.00682	0.00682	
122	150.0	200.0	50.0	175.0	350.0	0.489	1759.7	0.01389	0.01389	
123	200.0	202.8	2.8	201.4	350.0	0.546	1759.7	0.00086	0.00086	
124	202.8	300.0	97.2	251.4	350.0	0.501	1759.7	0.02769	0.02769	
125	300.0	400.0	100.0	350.0	350.0	0.412	1759.7	0.02341	0.02341	
126	400.0	500.0	100.0	450.0	350.0	0.322	1759.7	0.01827	0.01827	
127	500.0	600.0	100.0	550.0	350.0	0.231	1759.7	0.01314	0.01314	
128	600.0	700.0	100.0	650.0	350.0	0.141	1759.7	0.00800	0.00800	
129	700.0	800.0	100.0	750.0	350.0	0.050	1759.7	0.00286	0.00286	
130	800.0	900.0	100.0	850.0	350.0	0.000	1759.7	0.00000	0.00000	
Σ =									0.18361	

I_{zr} ($1 < L/B < 10$):	$I_{zr} = I_{zs} + 0.111 (I_{zc} - I_{zs}) (L/B - 1)$
I_{zs} ($L/B = 1$):	
For z_{ave} = 0 to B/2:	$I_{zs} = 0.1 + (z_{ave}/B)(2I_{zp} - 0.2)$
For z_{ave} = B/2 to 2B:	$I_{zs} = 0.667\, I_{zp} (2 - z_{ave}/B)$
I_{zc} ($L/B \geq 10$):	
For z_{ave} = 0 to B:	$I_{zc} = 0.2 + (z_{ave}/B)(I_{zp} - 0.2)$
For z_{ave} = B to 4B:	$I_{zc} = 0.333\, I_{zp} (4 - z_{ave}/B)$ (Coduto p.228.)

Footing width	B =		400.0 ft	ZV3V5C13
Footing length	L =		450.0 ft	
Ground elevation			261.0 ft	
Foundation elevation			261.0 ft	
Ground Water elevation			225.0 ft	
Excavated or embedded depth	D =		0.0 ft	
Depth to Groundwater			36.0 ft	
Unit weight	γ =		120.0 pcf	
Net applied footing pressure	Δp =		3.000 ksf	
	L/B =		1.13 -	

Immediate Settlement (in.) (S_0 / 2)

Load	S_0 =
	2.9
3.0	2.9
4.3	4.2
6.0	6.0

Computation

Settlement	ρ_i =	$C_1 C_t \Delta p\ \Sigma(\Delta z_i I_{zi}/E_{si})$	0.486 ft	Column I
	ρ_i =		**5.831 in**	
	S(t) =		0.727 ft	
	S(t) =		**8.720 in**	
Correction for strain relief	C_1 =	$1 - 0.5(\sigma'_D/q')$	1.000 -	
Effective vertical overburden pressure at D	σ'_{vo} =	γ D	0.000 ksf	
Correction for time dependent increase	C_t =	$1 + 0.2 \log(t / 0.1)$	1.50 -	
	t =		30.00 years	
Elastic modulus of soil layer i	E_{si} =	2.5 q_c	see Column H	If L/B = 1
	E_{si} =	3.5 q_c	see Column H	If L/B ≥ 10
Depth increment i	Δz_i		see Column D	
Influence factor of soil layer i	I_{zi}	Figure 3-4	see Column G	
Peak depth influence factor	I_{zp} =	$0.5 + 0.1\ (\Delta p/\sigma'_{izp})^{1/2}$	0.546 -	
	z_p =	0.5B + D	200.00 ft	If L/B = 1
	z_p =	B + D	400.00 ft	If L/B ≥ 10
	z_p =		202.78 ft	for L/B=1.13
Effective overburden pressure at depth Izp	σ'_{izp} =		13.93 ksf	
Elastic Modulus	E_{si} =		2.50 q_c	If L/B = 1
	E_{si} =		3.50 q_c	If L/B ≥ 10
	E_{si} =		2.51 q_c	for L/B=1.13

30 Year Settlement (in.) (S_{30} / 2)

Load	S_0 =
	4.4
4.3	6.3
6.0	9.0

A	B	C	D	E	F	G	H	I	J	K
Layer No.	Layer top depth (ft)	Layer bottom depth (ft)	Layer thickness Δz_i (ft)	Mid-layer depth z_{ave} (ft)	Average tip stress q_c (tsf)	I_{zi}	Elastic modulus E_{si} (ksf)	$\Delta z_i I_{zi}/E_{si}$	$\Delta z_i I_{zi}/E_{si}$	Notes
1	0.0	1.0	1.0	0.5	147.4	0.102	741.3	0.00014	0.00014	
2	1.0	2.0	1.0	1.5	163.8	0.105	823.8	0.00013	0.00013	
3	2.0	3.0	1.0	2.5	139.9	0.107	703.3	0.00015	0.00015	
4	3.0	4.0	1.0	3.5	145.1	0.109	729.5	0.00015	0.00015	
5	4.0	5.0	1.0	4.5	126.7	0.111	636.9	0.00017	0.00017	
6	5.0	6.0	1.0	5.5	118.3	0.114	594.6	0.00019	0.00019	
7	6.0	7.0	1.0	6.5	176.2	0.116	885.9	0.00013	0.00013	
8	7.0	8.0	1.0	7.5	175.2	0.118	880.7	0.00013	0.00013	
9	8.0	9.0	1.0	8.5	193.0	0.120	970.3	0.00012	0.00012	
10	9.0	10.0	1.0	9.5	206.9	0.122	1040.2	0.00012	0.00012	
11	10.0	11.0	1.0	10.5	157.5	0.125	792.0	0.00016	0.00016	
12	11.0	12.0	1.0	11.5	177.5	0.127	892.3	0.00014	0.00014	
13	12.0	13.0	1.0	12.5	192.9	0.129	969.6	0.00013	0.00013	
14	13.0	14.0	1.0	13.5	210.8	0.131	1059.8	0.00012	0.00012	
15	14.0	15.0	1.0	14.5	251.8	0.133	1266.0	0.00011	0.00011	
16	15.0	16.0	1.0	15.5	243.5	0.136	1224.2	0.00011	0.00011	
17	16.0	17.0	1.0	16.5	278.9	0.138	1402.3	0.00010	0.00010	
18	17.0	18.0	1.0	17.5	344.2	0.140	1730.3	0.00008	0.00008	
19	18.0	19.0	1.0	18.5	384.3	0.142	1932.4	0.00007	0.00007	
20	19.0	20.0	1.0	19.5	427.9	0.145	2151.6	0.00007	0.00007	
21	20.0	21.0	1.0	20.5	399.2	0.147	2007.3	0.00007	0.00007	
22	21.0	22.0	1.0	21.5	237.0	0.149	1191.8	0.00013	0.00013	
23	22.0	23.0	1.0	22.5	193.7	0.151	973.8	0.00016	0.00016	
24	23.0	24.0	1.0	23.5	185.1	0.153	930.8	0.00016	0.00016	
25	24.0	25.0	1.0	24.5	217.7	0.156	1094.5	0.00014	0.00014	
26	25.0	26.0	1.0	25.5	241.1	0.158	1212.4	0.00013	0.00013	
27	26.0	27.0	1.0	26.5	264.5	0.160	1329.8	0.00012	0.00012	
28	27.0	28.0	1.0	27.5	218.2	0.162	1097.0	0.00015	0.00015	
29	28.0	29.0	1.0	28.5	273.0	0.164	1372.5	0.00012	0.00012	
30	29.0	30.0	1.0	29.5	256.6	0.167	1290.3	0.00013	0.00013	
31	30.0	31.0	1.0	30.5	180.6	0.169	908.2	0.00019	0.00019	
32	31.0	32.0	1.0	31.5	166.5	0.171	836.9	0.00020	0.00020	
33	32.0	33.0	1.0	32.5	93.8	0.173	471.7	0.00037	0.00037	

34	33.0	34.0	1.0	33.5	269.2	0.176	1353.6	0.00013	0.00013	
35	34.0	35.0	1.0	34.5	282.2	0.178	1418.8	0.00013	0.00013	
36	35.0	36.0	1.0	35.5	76.7	0.180	385.7	0.00047	0.00047	
37	36.0	37.0	1.0	36.5	36.6	0.182	183.9	0.00099	0.00099	C2
38	37.0	38.0	1.0	37.5	29.5	0.184	148.4	0.00124	0.00124	C2
39	38.0	39.0	1.0	38.5	50.8	0.187	255.5	0.00073	0.00073	C2
40	39.0	40.0	1.0	39.5	186.9	0.189	939.8	0.00020	0.00020	C2
41	40.0	41.0	1.0	40.5	266.9	0.191	1342.1	0.00014	0.00014	
42	41.0	42.0	1.0	41.5	303.1	0.193	1524.1	0.00013	0.00013	
43	42.0	43.0	1.0	42.5	320.0	0.195	1608.6	0.00012	0.00012	
44	43.0	44.0	1.0	43.5	338.5	0.198	1701.9	0.00012	0.00012	
45	44.0	45.0	1.0	44.5	390.2	0.200	1961.7	0.00010	0.00010	
46	45.0	46.0	1.0	45.5	284.1	0.202	1428.3	0.00014	0.00014	
47	46.0	47.0	1.0	46.5	334.0	0.204	1679.3	0.00012	0.00012	
48	47.0	48.0	1.0	47.5	152.2	0.207	765.0	0.00027	0.00027	
49	48.0	49.0	1.0	48.5	179.5	0.209	902.7	0.00023	0.00023	
50	49.0	50.0	1.0	49.5	254.8	0.211	1280.9	0.00016	0.00016	
51	50.0	51.0	1.0	50.5	350.7	0.213	1763.1	0.00012	0.00012	
52	51.0	52.0	1.0	51.5	357.0	0.215	1794.9	0.00012	0.00012	
53	52.0	53.0	1.0	52.5	356.0	0.218	1789.8	0.00012	0.00012	
54	53.0	54.0	1.0	53.5	308.4	0.220	1550.4	0.00014	0.00014	
55	54.0	55.0	1.0	54.5	232.3	0.222	1167.7	0.00019	0.00019	
56	55.0	56.0	1.0	55.5	108.1	0.224	543.4	0.00041	0.00041	
57	56.0	57.0	1.0	56.5	32.1	0.226	161.3	0.00140	0.00140	
58	57.0	58.0	1.0	57.5	164.6	0.229	827.7	0.00028	0.00028	
59	58.0	59.0	1.0	58.5	352.1	0.231	1770.2	0.00013	0.00013	
60	59.0	60.0	1.0	59.5	235.9	0.233	1186.1	0.00020	0.00020	
61	60.0	61.0	1.0	60.5	51.9	0.235	260.8	0.00090	0.00090	
62	61.0	62.0	1.0	61.5	162.6	0.237	817.3	0.00029	0.00029	
63	62.0	63.0	1.0	62.5	162.5	0.240	816.8	0.00029	0.00029	
64	63.0	64.0	1.0	63.5	225.0	0.242	1131.1	0.00021	0.00021	
65	64.0	65.0	1.0	64.5	180.1	0.244	905.4	0.00027	0.00027	
66	65.0	66.0	1.0	65.5	161.5	0.246	811.8	0.00030	0.00030	
67	66.0	67.0	1.0	66.5	187.0	0.249	940.1	0.00026	0.00026	
68	67.0	68.0	1.0	67.5	173.5	0.251	872.5	0.00029	0.00029	
69	68.0	69.0	1.0	68.5	178.1	0.253	895.3	0.00028	0.00028	
70	69.0	70.0	1.0	69.5	195.8	0.255	984.6	0.00026	0.00026	
71	70.0	71.0	1.0	70.5	140.2	0.257	704.8	0.00037	0.00037	
72	71.0	72.0	1.0	71.5	63.6	0.260	319.6	0.00081	0.00081	
73	72.0	73.0	1.0	72.5	42.6	0.262	214.1	0.00122	0.00122	
74	73.0	74.0	1.0	73.5	31.0	0.264	155.8	0.00169	0.00169	
75	74.0	75.0	1.0	74.5	55.7	0.266	279.9	0.00095	0.00095	
76	75.0	76.0	1.0	75.5	61.0	0.268	306.6	0.00088	0.00088	
77	76.0	77.0	1.0	76.5	86.6	0.271	435.5	0.00062	0.00062	
78	77.0	78.0	1.0	77.5	94.7	0.273	476.1	0.00057	0.00057	
79	78.0	79.0	1.0	78.5	79.8	0.275	401.1	0.00069	0.00069	
80	79.0	80.0	1.0	79.5	83.3	0.277	418.6	0.00066	0.00066	
81	80.0	81.0	1.0	80.5	111.3	0.280	559.6	0.00050	0.00050	
82	81.0	82.0	1.0	81.5	66.1	0.282	332.5	0.00085	0.00085	
83	82.0	83.0	1.0	82.5	76.8	0.284	386.0	0.00074	0.00074	
84	83.0	84.0	1.0	83.5	306.7	0.286	1541.9	0.00019	0.00019	
85	84.0	85.0	1.0	84.5	433.0	0.288	2177.2	0.00013	0.00013	
86	85.0	86.0	1.0	85.5	100.2	0.291	503.6	0.00058	0.00058	
87	86.0	87.0	1.0	86.5	90.6	0.293	455.3	0.00064	0.00064	
88	87.0	88.0	1.0	87.5	96.0	0.295	482.6	0.00061	0.00061	
89	88.0	89.0	1.0	88.5	192.0	0.297	965.4	0.00031	0.00031	
90	89.0	90.0	1.0	89.5	154.4	0.299	776.5	0.00039	0.00039	
91	90.0	91.0	1.0	90.5	146.3	0.302	735.7	0.00041	0.00041	
92	91.0	92.0	1.0	91.5	115.3	0.304	579.8	0.00052	0.00052	
93	92.0	93.0	1.0	92.5	108.6	0.306	545.9	0.00056	0.00056	
94	93.0	94.0	1.0	93.5	123.9	0.308	623.1	0.00049	0.00049	
95	94.0	95.0	1.0	94.5	139.2	0.311	699.9	0.00044	0.00044	
96	95.0	96.0	1.0	95.5	165.6	0.313	832.6	0.00038	0.00038	
97	96.0	97.0	1.0	96.5	230.6	0.315	1159.5	0.00027	0.00027	
98	97.0	98.0	1.0	97.5	255.1	0.317	1282.6	0.00025	0.00025	
99	98.0	99.0	1.0	98.5	244.4	0.319	1229.0	0.00026	0.00026	
100	99.0	100.0	1.0	99.5	212.2	0.322	1066.8	0.00030	0.00030	
101	100.0	101.0	1.0	100.5	156.6	0.324	787.3	0.00041	0.00041	
102	101.0	102.0	1.0	101.5	44.4	0.326	223.3	0.00146	0.00146	
103	102.0	103.0	1.0	102.5	70.2	0.328	353.0	0.00093	0.00093	
104	103.0	104.0	1.0	103.5	91.8	0.330	461.6	0.00072	0.00072	
105	104.0	105.0	1.0	104.5	94.4	0.333	474.6	0.00070	0.00070	
106	105.0	106.0	1.0	105.5	98.0	0.335	492.7	0.00068	0.00068	
107	106.0	107.0	1.0	106.5	88.6	0.337	445.5	0.00076	0.00076	
108	107.0	108.0	1.0	107.5	83.8	0.339	421.2	0.00081	0.00081	
109	108.0	109.0	1.0	108.5	69.2	0.342	347.7	0.00098	0.00098	
110	109.0	110.0	1.0	109.5	59.8	0.344	300.5	0.00114	0.00114	

111	110.0	111.0	1.0	110.5	58.3	0.346	293.2	0.00118	0.00118	
112	111.0	112.0	1.0	111.5	60.5	0.348	304.0	0.00115	0.00115	
113	112.0	113.0	1.0	112.5	59.6	0.350	299.5	0.00117	0.00117	
114	113.0	114.0	1.0	113.5	58.2	0.353	292.7	0.00120	0.00120	
115	114.0	115.0	1.0	114.5	58.0	0.355	291.7	0.00122	0.00122	
116	115.0	116.0	1.0	115.5	168.8	0.357	848.7	0.00042	0.00042	
117	116.0	117.0	1.0	116.5	80.9	0.359	406.8	0.00088	0.00088	
118	117.0	118.0	1.0	117.5	350.0	0.361	1759.7	0.00021	0.00021	
119	118.0	119.0	1.0	118.5	350.0	0.364	1759.7	0.00021	0.00021	
120	119.0	120.0	1.0	119.5	350.0	0.366	1759.7	0.00021	0.00021	
121	120.0	150.0	30.0	135.0	350.0	0.400	1759.7	0.00682	0.00682	
122	150.0	200.0	50.0	175.0	350.0	0.489	1759.7	0.01389	0.01389	
123	200.0	202.8	2.8	201.4	350.0	0.546	1759.7	0.00086	0.00086	
124	202.8	300.0	97.2	251.4	350.0	0.501	1759.7	0.02769	0.02769	
125	300.0	400.0	100.0	350.0	350.0	0.412	1759.7	0.02341	0.02341	
126	400.0	500.0	100.0	450.0	350.0	0.322	1759.7	0.01827	0.01827	
127	500.0	600.0	100.0	550.0	350.0	0.231	1759.7	0.01314	0.01314	
128	600.0	700.0	100.0	650.0	350.0	0.141	1759.7	0.00800	0.00800	
129	700.0	800.0	100.0	750.0	350.0	0.050	1759.7	0.00286	0.00286	
130	800.0	900.0	100.0	850.0	350.0	0.000	1759.7	0.00000	0.00000	
Σ =									0.16515	

I_{zr} (1 < L/B < 10):	$I_{zr} = I_{zs} + 0.111 (I_{zc} - I_{zs}) (L/B - 1)$
I_{zs} (L/B = 1):	
For z_{ave} = 0 to B/2:	$I_{zs} = 0.1 + (z_{ave}/B)(2I_{zp} - 0.2)$
For z_{ave} = B/2 to 2B:	$I_{zs} = 0.667 I_{zp} (2 - z_{ave}/B)$
I_{zc} (L/B ≥ 10):	
For z_{ave} = 0 to B:	$I_{zc} = 0.2 + (z_{ave}/B)(I_{zp} - 0.2)$
For z_{ave} = B to 4B:	$I_{zc} = 0.333 I_{zp} (4 - z_{ave}/B)$ (Coduto p.228.)

Footing width	B =		400.0 ft	ZV3V5C14
Footing length	L =		450.0 ft	
Ground elevation			261.0 ft	
Foundation elevation			261.0 ft	
Ground Water elevation			225.0 ft	
Excavated or embedded depth	D =		0.0 ft	
Depth to Groundwater			36.0 ft	
Unit weight	γ =		120.0 pcf	
Net applied footing pressure	Δp =		3.000 ksf	
	L/B =		1.13 -	
Computation				
Settlement	ρ_i =	$C_1\ C_t\ \Delta p\ \Sigma(\Delta z_i\ I_{zi}/E_{si})$	0.560 ft	Column I
	ρ_i =		**6.717 in**	
	S(t) =		0.837 ft	
	S(t) =		**10.044 in**	
Correction for strain relief	C_1 =	$1 - 0.5(\sigma'_D/q')$	1.000 -	
Effective vertical overburden pressure at D	σ'_{vo} =	γ D	0.000 ksf	
Correction for time dependent increase	C_t =	1 + 0.2 log(t / 0.1)	1.50 -	
	t =		30.00 years	
Elastic modulus of soil layer i	E_{si} =	2.5 q_c	see Column H	if L/B = 1
	E_{si} =	3.5 q_c	see Column H	if L/B ≥ 10
Depth increment i	Δz_i		see Column D	
Influence factor of soil layer i	I_{zi}	Figure 3-4	see Column G	
Peak depth influence factor	I_{zp} =	$0.5 + 0.1\ (\Delta p/\sigma'_{izp})^{1/2}$	0.546 -	
	z_p =	0.5B + D	200.00 ft	If L/B = 1
	z_p =	B + D	400.00 ft	If L/B ≥ 10
	z_p =		202.78 ft	for L/B=1.13
Effective overburden pressure at depth Izp	σ'_{izp} =		13.93 ksf	
Elastic Modulus	E_{si} =		2.50 q_c	If L/B = 1
	E_{si} =		3.50 q_c	If L/B ≥ 10
	E_{si} =		2.51 q_c	for L/B=1.13

Immediate Settlement (in.) (S_0 / 2)

Load	S_0 =
	3.4
3.0	3.4
4.3	4.9
6.0	6.9

30 Year Settlement (in.) (S_{30} / 2)

Load	S_0 =
	5.0
4.3	7.3
6.0	10.4

A	B	C	D	E	F	G	H	I	J	K
Layer No.	Layer top depth (ft)	Layer bottom depth (ft)	Layer thickness Δz_i (ft)	Mid-layer depth z_{ave} (ft)	Average tip stress q_c (tsf)	I_{zi}	Elastic modulus E_{si} (ksf)	$\Delta z_i\ I_{zi}/E_{si}$	$\Delta z_i\ I_{zi}/E_{si}$	Notes
1	0.0	1.0	1.0	0.5	96.3	0.102	484.0	0.00021	0.00021	
2	1.0	2.0	1.0	1.5	83.0	0.105	417.5	0.00025	0.00025	
3	2.0	3.0	1.0	2.5	72.9	0.107	366.6	0.00029	0.00029	
4	3.0	4.0	1.0	3.5	62.8	0.109	315.9	0.00035	0.00035	
5	4.0	5.0	1.0	4.5	59.9	0.111	301.3	0.00037	0.00037	
6	5.0	6.0	1.0	5.5	66.4	0.114	333.8	0.00034	0.00034	
7	6.0	7.0	1.0	6.5	63.9	0.116	321.3	0.00036	0.00036	
8	7.0	8.0	1.0	7.5	60.2	0.118	302.6	0.00039	0.00039	
9	8.0	9.0	1.0	8.5	56.5	0.120	283.9	0.00042	0.00042	
10	9.0	10.0	1.0	9.5	58.6	0.122	294.8	0.00042	0.00042	
11	10.0	11.0	1.0	10.5	73.8	0.125	371.0	0.00034	0.00034	
12	11.0	12.0	1.0	11.5	65.5	0.127	329.4	0.00039	0.00039	
13	12.0	13.0	1.0	12.5	77.3	0.129	388.6	0.00033	0.00033	
14	13.0	14.0	1.0	13.5	208.1	0.131	1046.3	0.00013	0.00013	
15	14.0	15.0	1.0	14.5	276.4	0.133	1389.5	0.00010	0.00010	
16	15.0	16.0	1.0	15.5	297.4	0.136	1495.1	0.00009	0.00009	
17	16.0	17.0	1.0	16.5	270.9	0.138	1362.2	0.00010	0.00010	
18	17.0	18.0	1.0	17.5	234.9	0.140	1181.0	0.00012	0.00012	
19	18.0	19.0	1.0	18.5	244.7	0.142	1230.3	0.00012	0.00012	
20	19.0	20.0	1.0	19.5	231.6	0.145	1164.3	0.00012	0.00012	
21	20.0	21.0	1.0	20.5	236.6	0.147	1189.7	0.00012	0.00012	
22	21.0	22.0	1.0	21.5	252.5	0.149	1269.7	0.00012	0.00012	
23	22.0	23.0	1.0	22.5	233.5	0.151	1173.7	0.00013	0.00013	
24	23.0	24.0	1.0	23.5	154.3	0.153	775.8	0.00020	0.00020	
25	24.0	25.0	1.0	24.5	339.6	0.156	1707.5	0.00009	0.00009	
26	25.0	26.0	1.0	25.5	396.8	0.158	1994.9	0.00008	0.00008	
27	26.0	27.0	1.0	26.5	396.0	0.160	1991.2	0.00008	0.00008	
28	27.0	28.0	1.0	27.5	333.8	0.162	1678.0	0.00010	0.00010	
29	28.0	29.0	1.0	28.5	138.1	0.164	694.2	0.00024	0.00024	
30	29.0	30.0	1.0	29.5	90.8	0.167	456.6	0.00037	0.00037	
31	30.0	31.0	1.0	30.5	115.6	0.169	581.2	0.00029	0.00029	
32	31.0	32.0	1.0	31.5	46.6	0.171	234.2	0.00073	0.00073	
33	32.0	33.0	1.0	32.5	86.6	0.173	435.6	0.00040	0.00040	

34	33.0	34.0	1.0	33.5	69.4	0.176	348.8	0.00050	0.00050	C2
35	34.0	35.0	1.0	34.5	40.1	0.178	201.6	0.00088	0.00088	C2
36	35.0	36.0	1.0	35.5	25.1	0.180	126.2	0.00143	0.00143	C2
37	36.0	37.0	1.0	36.5	24.4	0.182	122.7	0.00148	0.00148	C2
38	37.0	38.0	1.0	37.5	23.6	0.184	118.8	0.00155	0.00155	C2
39	38.0	39.0	1.0	38.5	21.0	0.187	105.7	0.00176	0.00176	C2
40	39.0	40.0	1.0	39.5	20.9	0.189	105.0	0.00180	0.00180	C2
41	40.0	41.0	1.0	40.5	20.0	0.191	100.3	0.00190	0.00190	C2
42	41.0	42.0	1.0	41.5	22.6	0.193	113.7	0.00170	0.00170	C2
43	42.0	43.0	1.0	42.5	27.6	0.195	138.8	0.00141	0.00141	C2
44	43.0	44.0	1.0	43.5	33.9	0.198	170.3	0.00116	0.00116	C2
45	44.0	45.0	1.0	44.5	78.5	0.200	394.6	0.00051	0.00051	C2
46	45.0	46.0	1.0	45.5	217.2	0.202	1091.8	0.00019	0.00019	
47	46.0	47.0	1.0	46.5	159.1	0.204	800.0	0.00026	0.00026	
48	47.0	48.0	1.0	47.5	183.1	0.207	920.7	0.00022	0.00022	
49	48.0	49.0	1.0	48.5	162.5	0.209	816.9	0.00026	0.00026	
50	49.0	50.0	1.0	49.5	217.9	0.211	1095.6	0.00019	0.00019	
51	50.0	51.0	1.0	50.5	220.5	0.213	1108.5	0.00019	0.00019	
52	51.0	52.0	1.0	51.5	190.8	0.215	959.5	0.00022	0.00022	
53	52.0	53.0	1.0	52.5	85.1	0.218	428.0	0.00051	0.00051	
54	53.0	54.0	1.0	53.5	36.2	0.220	181.8	0.00121	0.00121	
55	54.0	55.0	1.0	54.5	50.0	0.222	251.6	0.00088	0.00088	
56	55.0	56.0	1.0	55.5	28.4	0.224	142.8	0.00157	0.00157	
57	56.0	57.0	1.0	56.5	57.8	0.226	290.5	0.00078	0.00078	
58	57.0	58.0	1.0	57.5	18.1	0.229	91.1	0.00251	0.00251	
59	58.0	59.0	1.0	58.5	9.6	0.231	48.3	0.00478	0.00478	
60	59.0	60.0	1.0	59.5	5.7	0.233	28.6	0.00814	0.00814	
61	60.0	61.0	1.0	60.5	33.0	0.235	165.9	0.00142	0.00142	
62	61.0	62.0	1.0	61.5	77.6	0.237	390.3	0.00061	0.00061	
63	62.0	63.0	1.0	62.5	136.8	0.240	687.7	0.00035	0.00035	
64	63.0	64.0	1.0	63.5	115.3	0.242	579.7	0.00042	0.00042	
65	64.0	65.0	1.0	64.5	139.8	0.244	702.8	0.00035	0.00035	
66	65.0	66.0	1.0	65.5	176.9	0.246	889.5	0.00028	0.00028	
67	66.0	67.0	1.0	66.5	231.3	0.249	1162.7	0.00021	0.00021	
68	67.0	68.0	1.0	67.5	171.2	0.251	860.9	0.00029	0.00029	
69	68.0	69.0	1.0	68.5	86.3	0.253	433.8	0.00058	0.00058	
70	69.0	70.0	1.0	69.5	54.0	0.255	271.6	0.00094	0.00094	
71	70.0	71.0	1.0	70.5	87.5	0.257	440.1	0.00058	0.00058	
72	71.0	72.0	1.0	71.5	48.3	0.260	242.9	0.00107	0.00107	
73	72.0	73.0	1.0	72.5	35.8	0.262	180.0	0.00145	0.00145	
74	73.0	74.0	1.0	73.5	46.9	0.264	235.7	0.00112	0.00112	
75	74.0	75.0	1.0	74.5	67.3	0.266	338.1	0.00079	0.00079	
76	75.0	76.0	1.0	75.5	53.8	0.268	270.4	0.00099	0.00099	
77	76.0	77.0	1.0	76.5	37.7	0.271	189.8	0.00143	0.00143	
78	77.0	78.0	1.0	77.5	51.5	0.273	259.1	0.00105	0.00105	
79	78.0	79.0	1.0	78.5	44.5	0.275	223.6	0.00123	0.00123	
80	79.0	80.0	1.0	79.5	39.9	0.277	200.4	0.00138	0.00138	
81	80.0	81.0	1.0	80.5	139.4	0.280	700.7	0.00040	0.00040	
82	81.0	82.0	1.0	81.5	87.5	0.282	440.0	0.00064	0.00064	
83	82.0	83.0	1.0	82.5	130.2	0.284	654.4	0.00043	0.00043	
84	83.0	84.0	1.0	83.5	162.1	0.286	814.8	0.00035	0.00035	
85	84.0	85.0	1.0	84.5	163.0	0.288	819.4	0.00035	0.00035	
86	85.0	86.0	1.0	85.5	100.2	0.291	503.6	0.00058	0.00058	
87	86.0	87.0	1.0	86.5	90.6	0.293	455.3	0.00064	0.00064	
88	87.0	88.0	1.0	87.5	96.0	0.295	482.6	0.00061	0.00061	
89	88.0	89.0	1.0	88.5	192.0	0.297	965.4	0.00031	0.00031	
90	89.0	90.0	1.0	89.5	154.4	0.299	776.5	0.00039	0.00039	
91	90.0	91.0	1.0	90.5	146.3	0.302	735.7	0.00041	0.00041	
92	91.0	92.0	1.0	91.5	115.3	0.304	579.8	0.00052	0.00052	
93	92.0	93.0	1.0	92.5	108.6	0.306	545.9	0.00056	0.00056	
94	93.0	94.0	1.0	93.5	123.9	0.308	623.1	0.00049	0.00049	
95	94.0	95.0	1.0	94.5	139.2	0.311	699.9	0.00044	0.00044	
96	95.0	96.0	1.0	95.5	165.6	0.313	832.6	0.00038	0.00038	
97	96.0	97.0	1.0	96.5	230.6	0.315	1159.5	0.00027	0.00027	
98	97.0	98.0	1.0	97.5	255.1	0.317	1282.6	0.00025	0.00025	
99	98.0	99.0	1.0	98.5	244.4	0.319	1229.0	0.00026	0.00026	
100	99.0	100.0	1.0	99.5	212.2	0.322	1066.8	0.00030	0.00030	
101	100.0	101.0	1.0	100.5	156.6	0.324	787.3	0.00041	0.00041	
102	101.0	102.0	1.0	101.5	44.4	0.326	223.3	0.00146	0.00146	
103	102.0	103.0	1.0	102.5	70.2	0.328	353.0	0.00093	0.00093	
104	103.0	104.0	1.0	103.5	91.8	0.330	461.6	0.00072	0.00072	
105	104.0	105.0	1.0	104.5	94.4	0.333	474.6	0.00070	0.00070	
106	105.0	106.0	1.0	105.5	98.0	0.335	492.7	0.00068	0.00068	
107	106.0	107.0	1.0	106.5	88.6	0.337	445.5	0.00076	0.00076	
108	107.0	108.0	1.0	107.5	83.8	0.339	421.2	0.00081	0.00081	
109	108.0	109.0	1.0	108.5	69.2	0.342	347.7	0.00098	0.00098	
110	109.0	110.0	1.0	109.5	59.8	0.344	300.5	0.00114	0.00114	

111	110.0	111.0	1.0	110.5	58.3	0.346	293.2	0.00118	0.00118
112	111.0	112.0	1.0	111.5	60.5	0.348	304.0	0.00115	0.00115
113	112.0	113.0	1.0	112.5	59.6	0.350	299.5	0.00117	0.00117
114	113.0	114.0	1.0	113.5	58.2	0.353	292.7	0.00120	0.00120
115	114.0	115.0	1.0	114.5	58.0	0.355	291.7	0.00122	0.00122
116	115.0	116.0	1.0	115.5	168.8	0.357	848.7	0.00042	0.00042
117	116.0	117.0	1.0	116.5	80.9	0.359	406.8	0.00088	0.00088
118	117.0	118.0	1.0	117.5	350.0	0.361	1759.7	0.00021	0.00021
119	118.0	119.0	1.0	118.5	350.0	0.364	1759.7	0.00021	0.00021
120	119.0	120.0	1.0	119.5	350.0	0.366	1759.7	0.00021	0.00021
121	120.0	150.0	30.0	135.0	350.0	0.400	1759.7	0.00682	0.00682
122	150.0	200.0	50.0	175.0	350.0	0.489	1759.7	0.01389	0.01389
123	200.0	202.8	2.8	201.4	350.0	0.546	1759.7	0.00086	0.00086
124	202.8	300.0	97.2	251.4	350.0	0.501	1759.7	0.02769	0.02769
125	300.0	400.0	100.0	350.0	350.0	0.412	1759.7	0.02341	0.02341
126	400.0	500.0	100.0	450.0	350.0	0.322	1759.7	0.01827	0.01827
127	500.0	600.0	100.0	550.0	350.0	0.231	1759.7	0.01314	0.01314
128	600.0	700.0	100.0	650.0	350.0	0.141	1759.7	0.00800	0.00800
129	700.0	800.0	100.0	750.0	350.0	0.050	1759.7	0.00286	0.00286
130	800.0	900.0	100.0	850.0	350.0	0.000	1759.7	0.00000	0.00000
Σ =									0.20266

I_{zr} $(1 < L/B < 10)$:	$I_{zr} = I_{zs} + 0.111\,(I_{zc} - I_{zs})\,(L/B - 1)$
I_{zs} $(L/B = 1)$:	
For $z_{ave} = 0$ to $B/2$:	$I_{zs} = 0.1 + (z_{ave}/B)(2I_{zp} - 0.2)$
For $z_{ave} = B/2$ to $2B$:	$I_{zs} = 0.667\,I_{zp}\,(2 - z_{ave}/B)$
I_{zc} $(L/B \geq 10)$:	
For $z_{ave} = 0$ to B:	$I_{zc} = 0.2 + (z_{ave}/B)(I_{zp} - 0.2)$
For $z_{ave} = B$ to $4B$:	$I_{zc} = 0.333\,I_{zp}\,(4 - z_{ave}/B)$ (Coduto p.228.)

Footing width	B =		400.0 ft	ZV3V5C15
Footing length	L =		450.0 ft	
Ground elevation			261.0 ft	
Foundation elevation			261.0 ft	
Ground Water elevation			225.0 ft	
Excavated or embedded depth	D =		0.0 ft	
Depth to Groundwater			36.0 ft	
Unit weight	γ =		120.0 pcf	
Net applied footing pressure	Δp =		3.000 ksf	
	L/B =		1.13 -	

Immediate Settlement (in.) (S_0 / 2)	
Load	S_0 =
	3.3
3.0	3.3
4.3	4.8
6.0	6.8

Computation

Settlement	ρ_i =	$C_1\,C_t\,\Delta p\,\Sigma(\Delta z_i\,I_{zi}/E_{si})$	0.550 ft	Column I
	ρ_i =		**6.601 in**	
	S(t) =		0.823 ft	
	S(t) =		**9.871 in**	
Correction for strain relief	C_1 =	$1 - 0.5(\sigma'_D/q')$	1.000 -	
Effective vertical overburden pressure at D	σ'_{vo} =	γ D	0.000 ksf	
Correction for time dependent increase	C_t =	$1 + 0.2\log(t / 0.1)$	1.50 -	
	t =		30.00 years	
Elastic modulus of soil layer i	E_{si} =	$2.5\ q_c$	see Column H	If L/B = 1
	E_{si} =	$3.5\ q_c$	see Column H	If L/B $\geq$ 10
Depth increment i	Δz_i		see Column D	
Influence factor of soil layer i	I_{zi}	Figure 3-4	see Column G	
Peak depth influence factor	I_{zp} =	$0.5 + 0.1\,(\Delta p/\sigma'_{izp})^{1/2}$	0.546 -	
	z_p =	0.5B + D	200.00 ft	If L/B = 1
	z_p =	B + D	400.00 ft	If L/B $\geq$ 10
	z_p =		202.78 ft	for L/B=1.13
Effective overburden pressure at depth Izp	σ'_{izp} =		13.93 ksf	
Elastic Modulus	E_{si} =		2.50 q_c	If L/B = 1
	E_{si} =		3.50 q_c	If L/B $\geq$ 10
	E_{si} =		2.51 q_c	for L/B=1.13

30 Year Settlement (in.) (S_{30} / 2)	
Load	S_0 =
	4.9
4.3	7.2
6.0	10.2

A	B	C	D	E	F	G	H	I	J	K
Layer No.	Layer top depth (ft)	Layer bottom depth (ft)	Layer thickness Δz_i (ft)	Mid-layer depth z_{ave} (ft)	Average tip stress q_c (tsf)	I_{zi}	Elastic modulus E_{si} (ksf)	$\Delta z_i\,I_{zi}/E_{si}$	$\Delta z_i\,I_{zi}/E_{si}$	Notes
1	0.0	1.0	1.0	0.5	116.6	0.102	586.4	0.00017	0.00017	
2	1.0	2.0	1.0	1.5	119.5	0.105	600.8	0.00017	0.00017	
3	2.0	3.0	1.0	2.5	103.1	0.107	518.4	0.00021	0.00021	
4	3.0	4.0	1.0	3.5	87.9	0.109	441.9	0.00025	0.00025	
5	4.0	5.0	1.0	4.5	75.5	0.111	379.4	0.00029	0.00029	
6	5.0	6.0	1.0	5.5	64.2	0.114	322.7	0.00035	0.00035	
7	6.0	7.0	1.0	6.5	62.7	0.116	315.2	0.00037	0.00037	
8	7.0	8.0	1.0	7.5	63.0	0.118	316.7	0.00037	0.00037	
9	8.0	9.0	1.0	8.5	92.4	0.120	464.6	0.00026	0.00026	
10	9.0	10.0	1.0	9.5	98.0	0.122	492.9	0.00025	0.00025	
11	10.0	11.0	1.0	10.5	142.5	0.125	716.4	0.00017	0.00017	
12	11.0	12.0	1.0	11.5	142.7	0.127	717.3	0.00018	0.00018	
13	12.0	13.0	1.0	12.5	108.0	0.129	542.8	0.00024	0.00024	
14	13.0	14.0	1.0	13.5	99.3	0.131	499.2	0.00026	0.00026	
15	14.0	15.0	1.0	14.5	129.3	0.133	650.0	0.00021	0.00021	
16	15.0	16.0	1.0	15.5	299.2	0.136	1504.6	0.00009	0.00009	
17	16.0	17.0	1.0	16.5	364.0	0.138	1830.2	0.00008	0.00008	
18	17.0	18.0	1.0	17.5	399.9	0.140	2010.5	0.00007	0.00007	
19	18.0	19.0	1.0	18.5	372.6	0.142	1873.3	0.00008	0.00008	
20	19.0	20.0	1.0	19.5	328.9	0.145	1653.8	0.00009	0.00009	
21	20.0	21.0	1.0	20.5	195.0	0.147	980.3	0.00015	0.00015	
22	21.0	22.0	1.0	21.5	144.5	0.149	726.4	0.00021	0.00021	
23	22.0	23.0	1.0	22.5	304.8	0.151	1532.5	0.00010	0.00010	
24	23.0	24.0	1.0	23.5	361.1	0.153	1815.8	0.00008	0.00008	
25	24.0	25.0	1.0	24.5	431.6	0.156	2169.7	0.00007	0.00007	
26	25.0	26.0	1.0	25.5	322.6	0.158	1622.0	0.00010	0.00010	
27	26.0	27.0	1.0	26.5	179.2	0.160	900.9	0.00018	0.00018	
28	27.0	28.0	1.0	27.5	69.1	0.162	347.4	0.00047	0.00047	
29	28.0	29.0	1.0	28.5	47.3	0.164	237.6	0.00069	0.00069	
30	29.0	30.0	1.0	29.5	29.2	0.167	147.0	0.00113	0.00113	
31	30.0	31.0	1.0	30.5	30.3	0.169	152.1	0.00111	0.00111	C2
32	31.0	32.0	1.0	31.5	30.1	0.171	151.2	0.00113	0.00113	C2
33	32.0	33.0	1.0	32.5	37.5	0.173	188.4	0.00092	0.00092	C2

34	33.0	34.0	1.0	33.5	48.2	0.176	242.3	0.00072	0.00072	C2
35	34.0	35.0	1.0	34.5	43.3	0.178	217.8	0.00082	0.00082	C2
36	35.0	36.0	1.0	35.5	35.3	0.180	177.7	0.00101	0.00101	C2
37	36.0	37.0	1.0	36.5	33.1	0.182	166.4	0.00109	0.00109	C2
38	37.0	38.0	1.0	37.5	26.5	0.184	133.2	0.00138	0.00138	C2
39	38.0	39.0	1.0	38.5	23.4	0.187	117.6	0.00159	0.00159	C2
40	39.0	40.0	1.0	39.5	26.7	0.189	134.2	0.00141	0.00141	C2
41	40.0	41.0	1.0	40.5	34.6	0.191	173.8	0.00110	0.00110	C2
42	41.0	42.0	1.0	41.5	66.8	0.193	335.8	0.00058	0.00058	
43	42.0	43.0	1.0	42.5	106.9	0.195	537.4	0.00036	0.00036	
44	43.0	44.0	1.0	43.5	118.0	0.198	593.2	0.00033	0.00033	
45	44.0	45.0	1.0	44.5	87.1	0.200	437.9	0.00046	0.00046	
46	45.0	46.0	1.0	45.5	87.9	0.202	442.1	0.00046	0.00046	
47	46.0	47.0	1.0	46.5	129.2	0.204	649.5	0.00031	0.00031	
48	47.0	48.0	1.0	47.5	123.4	0.207	620.5	0.00033	0.00033	
49	48.0	49.0	1.0	48.5	97.9	0.209	492.2	0.00042	0.00042	
50	49.0	50.0	1.0	49.5	126.3	0.211	634.9	0.00033	0.00033	
51	50.0	51.0	1.0	50.5	212.5	0.213	1068.5	0.00020	0.00020	
52	51.0	52.0	1.0	51.5	293.7	0.215	1476.9	0.00015	0.00015	
53	52.0	53.0	1.0	52.5	305.7	0.218	1536.8	0.00014	0.00014	
54	53.0	54.0	1.0	53.5	191.1	0.220	961.0	0.00023	0.00023	
55	54.0	55.0	1.0	54.5	29.0	0.222	145.9	0.00152	0.00152	
56	55.0	56.0	1.0	55.5	14.6	0.224	73.4	0.00305	0.00305	
57	56.0	57.0	1.0	56.5	55.0	0.226	276.5	0.00082	0.00082	
58	57.0	58.0	1.0	57.5	49.2	0.229	247.6	0.00092	0.00092	
59	58.0	59.0	1.0	58.5	69.0	0.231	346.9	0.00067	0.00067	
60	59.0	60.0	1.0	59.5	35.2	0.233	177.1	0.00132	0.00132	
61	60.0	61.0	1.0	60.5	49.8	0.235	250.3	0.00094	0.00094	
62	61.0	62.0	1.0	61.5	186.6	0.237	938.3	0.00025	0.00025	
63	62.0	63.0	1.0	62.5	175.5	0.240	882.4	0.00027	0.00027	
64	63.0	64.0	1.0	63.5	85.2	0.242	428.5	0.00056	0.00056	
65	64.0	65.0	1.0	64.5	110.6	0.244	556.3	0.00044	0.00044	
66	65.0	66.0	1.0	65.5	153.8	0.246	773.2	0.00032	0.00032	
67	66.0	67.0	1.0	66.5	174.3	0.249	876.5	0.00028	0.00028	
68	67.0	68.0	1.0	67.5	197.9	0.251	995.2	0.00025	0.00025	
69	68.0	69.0	1.0	68.5	155.4	0.253	781.1	0.00032	0.00032	
70	69.0	70.0	1.0	69.5	126.4	0.255	635.5	0.00040	0.00040	
71	70.0	71.0	1.0	70.5	66.1	0.257	332.3	0.00077	0.00077	
72	71.0	72.0	1.0	71.5	48.9	0.260	246.0	0.00106	0.00106	
73	72.0	73.0	1.0	72.5	32.5	0.262	163.5	0.00160	0.00160	
74	73.0	74.0	1.0	73.5	46.9	0.264	235.8	0.00112	0.00112	
75	74.0	75.0	1.0	74.5	31.9	0.266	160.5	0.00166	0.00166	
76	75.0	76.0	1.0	75.5	22.1	0.268	111.0	0.00242	0.00242	
77	76.0	77.0	1.0	76.5	37.0	0.271	185.9	0.00146	0.00146	
78	77.0	78.0	1.0	77.5	20.1	0.273	101.2	0.00270	0.00270	
79	78.0	79.0	1.0	78.5	32.8	0.275	164.9	0.00167	0.00167	
80	79.0	80.0	1.0	79.5	61.2	0.277	307.8	0.00090	0.00090	
81	80.0	81.0	1.0	80.5	28.8	0.280	145.0	0.00193	0.00193	
82	81.0	82.0	1.0	81.5	23.6	0.282	118.5	0.00238	0.00238	
83	82.0	83.0	1.0	82.5	52.6	0.284	264.4	0.00107	0.00107	
84	83.0	84.0	1.0	83.5	100.7	0.286	506.5	0.00057	0.00057	
85	84.0	85.0	1.0	84.5	190.4	0.288	957.4	0.00030	0.00030	
86	85.0	86.0	1.0	85.5	100.2	0.291	503.6	0.00058	0.00058	
87	86.0	87.0	1.0	86.5	90.6	0.293	455.3	0.00064	0.00064	
88	87.0	88.0	1.0	87.5	96.0	0.295	482.6	0.00061	0.00061	
89	88.0	89.0	1.0	88.5	192.0	0.297	965.4	0.00031	0.00031	
90	89.0	90.0	1.0	89.5	154.4	0.299	776.5	0.00039	0.00039	
91	90.0	91.0	1.0	90.5	146.3	0.302	735.7	0.00041	0.00041	
92	91.0	92.0	1.0	91.5	115.3	0.304	579.8	0.00052	0.00052	
93	92.0	93.0	1.0	92.5	108.6	0.306	545.9	0.00056	0.00056	
94	93.0	94.0	1.0	93.5	123.9	0.308	623.1	0.00049	0.00049	
95	94.0	95.0	1.0	94.5	139.2	0.311	699.9	0.00044	0.00044	
96	95.0	96.0	1.0	95.5	165.6	0.313	832.6	0.00038	0.00038	
97	96.0	97.0	1.0	96.5	230.6	0.315	1159.5	0.00027	0.00027	
98	97.0	98.0	1.0	97.5	255.1	0.317	1282.6	0.00025	0.00025	
99	98.0	99.0	1.0	98.5	244.4	0.319	1229.0	0.00026	0.00026	
100	99.0	100.0	1.0	99.5	212.2	0.322	1066.8	0.00030	0.00030	
101	100.0	101.0	1.0	100.5	156.6	0.324	787.3	0.00041	0.00041	
102	101.0	102.0	1.0	101.5	44.4	0.326	223.3	0.00146	0.00146	
103	102.0	103.0	1.0	102.5	70.2	0.328	353.0	0.00093	0.00093	
104	103.0	104.0	1.0	103.5	91.8	0.330	461.6	0.00072	0.00072	
105	104.0	105.0	1.0	104.5	94.4	0.333	474.6	0.00070	0.00070	
106	105.0	106.0	1.0	105.5	98.0	0.335	492.7	0.00068	0.00068	
107	106.0	107.0	1.0	106.5	88.6	0.337	445.5	0.00076	0.00076	
108	107.0	108.0	1.0	107.5	83.8	0.339	421.2	0.00081	0.00081	
109	108.0	109.0	1.0	108.5	69.2	0.342	347.7	0.00098	0.00098	
110	109.0	110.0	1.0	109.5	59.8	0.344	300.5	0.00114	0.00114	

111	110.0	111.0	1.0	110.5	58.3	0.346	293.2	0.00118	0.00118
112	111.0	112.0	1.0	111.5	60.5	0.348	304.0	0.00115	0.00115
113	112.0	113.0	1.0	112.5	59.6	0.350	299.5	0.00117	0.00117
114	113.0	114.0	1.0	113.5	58.2	0.353	292.7	0.00120	0.00120
115	114.0	115.0	1.0	114.5	58.0	0.355	291.7	0.00122	0.00122
116	115.0	116.0	1.0	115.5	168.8	0.357	848.7	0.00042	0.00042
117	116.0	117.0	1.0	116.5	80.9	0.359	406.8	0.00088	0.00088
118	117.0	118.0	1.0	117.5	350.0	0.361	1759.7	0.00021	0.00021
119	118.0	119.0	1.0	118.5	350.0	0.364	1759.7	0.00021	0.00021
120	119.0	120.0	1.0	119.5	350.0	0.366	1759.7	0.00021	0.00021
121	120.0	150.0	30.0	135.0	350.0	0.400	1759.7	0.00682	0.00682
122	150.0	200.0	50.0	175.0	350.0	0.489	1759.7	0.01389	0.01389
123	200.0	202.8	2.8	201.4	350.0	0.546	1759.7	0.00086	0.00086
124	202.8	300.0	97.2	251.4	350.0	0.501	1759.7	0.02769	0.02769
125	300.0	400.0	100.0	350.0	350.0	0.412	1759.7	0.02341	0.02341
126	400.0	500.0	100.0	450.0	350.0	0.322	1759.7	0.01827	0.01827
127	500.0	600.0	100.0	550.0	350.0	0.231	1759.7	0.01314	0.01314
128	600.0	700.0	100.0	650.0	350.0	0.141	1759.7	0.00800	0.00800
129	700.0	800.0	100.0	750.0	350.0	0.050	1759.7	0.00286	0.00286
130	800.0	900.0	100.0	850.0	350.0	0.000	1759.7	0.00000	0.00000
Σ =									0.19564

I_{zr} $(1 < L/B < 10)$:	$I_{zr} = I_{zs} + 0.111\,(I_{zc} - I_{zs})\,(L/B - 1)$
I_{zs} $(L/B = 1)$:	
For $z_{ave} = 0$ to $B/2$:	$I_{zs} = 0.1 + (z_{ave}/B)(2I_{zp} - 0.2)$
For $z_{ave} = B/2$ to $2B$:	$I_{zs} = 0.667\,I_{zp}\,(2 - z_{ave}/B)$
I_{zc} $(L/B \geq 10)$:	
For $z_{ave} = 0$ to B:	$I_{zc} = 0.2 + (z_{ave}/B)(I_{zp} - 0.2)$
For $z_{ave} = B$ to $4B$:	$I_{zc} = 0.333\,I_{zp}\,(4 - z_{ave}/B)$ (Coduto p.228.)

Footing width	B =		400.0 ft	ZV3V5C16		
Footing length	L =		450.0 ft		Immediate Settlement (in.)	
Ground elevation			261.0 ft		(S_0 / 2)	
Foundation elevation			261.0 ft		Load	S_0 =
Ground Water elevation			225.0 ft			3.3
Excavated or embedded depth	D =		0.0 ft		3.0	3.3
Depth to Groundwater			36.0 ft		4.3	4.8
Unit weight	γ =		120.0 pcf		6.0	6.9
Net applied footing pressure	Δp =		3.000 ksf			
	L/B =		1.13 -			
Computation					30 Year Settlement (in.)	
Settlement	ρ_i =	$C_1\,C_t\,\Delta p\,\Sigma(\Delta z_i\,I_{zi}/E_{si})$	0.556 ft	Column I	(S_{30} / 2)	
	ρ_i =		6.667 in		Load	S_0 =
	S(t) =		0.831 ft			5.0
	S(t) =		9.970 in		4.3	7.3
Correction for strain relief	C_1 =	$1 - 0.5(\sigma'_D/q')$	1.000 -		6.0	10.3
Effective vertical overburden pressure at D	σ'_{vo} =	γ D	0.000 ksf			
Correction for time dependent increase	C_t =	1 + 0.2 log(t / 0.1)	1.50 -			
	t =		30.00 years			
Elastic modulus of soil layer i	E_{si} =	2.5 q_c	see Column H	if L/B = 1		
	E_{si} =	3.5 q_c	see Column H	If L/B ≥ 10		
Depth increment i	Δz_i		see Column D			
Influence factor of soil layer i	I_{zi}	Figure 3-4	see Column G			
Peak depth influence factor	I_{zp} =	$0.5 + 0.1\,(\Delta p/\sigma'_{izp})^{1/2}$	0.546 -			
	z_p =	0.5B + D	200.00 ft	If L/B = 1		
	z_p =	B + D	400.00 ft	If L/B ≥ 10		
	z_p =		202.78 ft	for L/B=1.13		
Effective overburden pressure at depth Izp	σ'_{izp} =		13.93 ksf			
Elastic Modulus	E_{si} =		2.50 q_c	If L/B = 1		
	E_{si} =		3.50 q_c	If L/B ≥ 10		
	E_{si} =		2.51 q_c	for L/B=1.13		

A	B	C	D	E	F	G	H	I	J	K
Layer No.	Layer top depth (ft)	Layer bottom depth (ft)	Layer thickness Δz_i (ft)	Mid-layer depth z_{ave} (ft)	Average tip stress q_c (tsf)	I_{zi}	Elastic modulus E_{si} (ksf)	$\Delta z_i\,I_{zi}/E_{si}$	$\Delta z_i\,I_{zi}/E_{si}$	Notes
1	0.0	1.0	1.0	0.5	138.6	0.102	696.9	0.00015	0.00015	
2	1.0	2.0	1.0	1.5	126.3	0.105	635.1	0.00016	0.00016	
3	2.0	3.0	1.0	2.5	122.2	0.107	614.5	0.00017	0.00017	
4	3.0	4.0	1.0	3.5	129.8	0.109	652.6	0.00017	0.00017	
5	4.0	5.0	1.0	4.5	120.7	0.111	606.8	0.00018	0.00018	
6	5.0	6.0	1.0	5.5	96.5	0.114	485.0	0.00023	0.00023	
7	6.0	7.0	1.0	6.5	88.4	0.116	444.6	0.00026	0.00026	
8	7.0	8.0	1.0	7.5	96.9	0.118	487.0	0.00024	0.00024	
9	8.0	9.0	1.0	8.5	97.8	0.120	491.7	0.00024	0.00024	
10	9.0	10.0	1.0	9.5	116.1	0.122	583.8	0.00021	0.00021	
11	10.0	11.0	1.0	10.5	173.2	0.125	870.9	0.00014	0.00014	
12	11.0	12.0	1.0	11.5	235.2	0.127	1182.3	0.00011	0.00011	
13	12.0	13.0	1.0	12.5	250.1	0.129	1257.2	0.00010	0.00010	
14	13.0	14.0	1.0	13.5	140.3	0.131	705.3	0.00019	0.00019	
15	14.0	15.0	1.0	14.5	78.2	0.133	393.2	0.00034	0.00034	
16	15.0	16.0	1.0	15.5	164.2	0.136	825.6	0.00016	0.00016	
17	16.0	17.0	1.0	16.5	199.0	0.138	1000.8	0.00014	0.00014	
18	17.0	18.0	1.0	17.5	211.7	0.140	1064.2	0.00013	0.00013	
19	18.0	19.0	1.0	18.5	201.1	0.142	1011.3	0.00014	0.00014	
20	19.0	20.0	1.0	19.5	153.7	0.145	772.9	0.00019	0.00019	
21	20.0	21.0	1.0	20.5	205.6	0.147	1033.7	0.00014	0.00014	
22	21.0	22.0	1.0	21.5	241.2	0.149	1212.5	0.00012	0.00012	
23	22.0	23.0	1.0	22.5	153.1	0.151	769.5	0.00020	0.00020	
24	23.0	24.0	1.0	23.5	163.5	0.153	822.1	0.00019	0.00019	
25	24.0	25.0	1.0	24.5	145.3	0.156	730.6	0.00021	0.00021	
26	25.0	26.0	1.0	25.5	161.5	0.158	811.8	0.00019	0.00019	
27	26.0	27.0	1.0	26.5	140.9	0.160	708.2	0.00023	0.00023	
28	27.0	28.0	1.0	27.5	131.1	0.162	659.0	0.00025	0.00025	
29	28.0	29.0	1.0	28.5	83.4	0.164	419.3	0.00039	0.00039	
30	29.0	30.0	1.0	29.5	80.3	0.167	403.7	0.00041	0.00041	
31	30.0	31.0	1.0	30.5	171.1	0.169	860.3	0.00020	0.00020	
32	31.0	32.0	1.0	31.5	203.0	0.171	1020.6	0.00017	0.00017	
33	32.0	33.0	1.0	32.5	244.8	0.173	1230.9	0.00014	0.00014	

34	33.0	34.0	1.0	33.5	242.5	0.176	1219.3	0.00014	0.00014
35	34.0	35.0	1.0	34.5	207.3	0.178	1042.0	0.00017	0.00017
36	35.0	36.0	1.0	35.5	241.1	0.180	1212.0	0.00015	0.00015
37	36.0	37.0	1.0	36.5	254.0	0.182	1277.1	0.00014	0.00014
38	37.0	38.0	1.0	37.5	248.0	0.184	1246.7	0.00015	0.00015
39	38.0	39.0	1.0	38.5	191.5	0.187	962.7	0.00019	0.00019
40	39.0	40.0	1.0	39.5	191.4	0.189	962.3	0.00020	0.00020
41	40.0	41.0	1.0	40.5	225.8	0.191	1135.3	0.00017	0.00017
42	41.0	42.0	1.0	41.5	163.3	0.193	820.9	0.00024	0.00024
43	42.0	43.0	1.0	42.5	100.3	0.195	504.5	0.00039	0.00039
44	43.0	44.0	1.0	43.5	189.9	0.198	954.8	0.00021	0.00021
45	44.0	45.0	1.0	44.5	220.8	0.200	1110.2	0.00018	0.00018
46	45.0	46.0	1.0	45.5	201.6	0.202	1013.4	0.00020	0.00020
47	46.0	47.0	1.0	46.5	172.2	0.204	865.6	0.00024	0.00024
48	47.0	48.0	1.0	47.5	145.6	0.207	731.9	0.00028	0.00028
49	48.0	49.0	1.0	48.5	130.2	0.209	654.4	0.00032	0.00032
50	49.0	50.0	1.0	49.5	101.9	0.211	512.5	0.00041	0.00041
51	50.0	51.0	1.0	50.5	80.8	0.213	406.4	0.00052	0.00052
52	51.0	52.0	1.0	51.5	49.4	0.215	248.2	0.00087	0.00087
53	52.0	53.0	1.0	52.5	15.1	0.218	75.9	0.00287	0.00287
54	53.0	54.0	1.0	53.5	34.5	0.220	173.3	0.00127	0.00127
55	54.0	55.0	1.0	54.5	36.5	0.222	183.5	0.00121	0.00121
56	55.0	56.0	1.0	55.5	10.1	0.224	50.6	0.00443	0.00443
57	56.0	57.0	1.0	56.5	15.3	0.226	77.0	0.00294	0.00294
58	57.0	58.0	1.0	57.5	21.9	0.229	110.3	0.00207	0.00207
59	58.0	59.0	1.0	58.5	90.5	0.231	454.8	0.00051	0.00051
60	59.0	60.0	1.0	59.5	122.7	0.233	616.9	0.00038	0.00038
61	60.0	61.0	1.0	60.5	138.6	0.235	696.6	0.00034	0.00034
62	61.0	62.0	1.0	61.5	143.0	0.237	719.1	0.00033	0.00033
63	62.0	63.0	1.0	62.5	143.9	0.240	723.3	0.00033	0.00033
64	63.0	64.0	1.0	63.5	151.7	0.242	762.9	0.00032	0.00032
65	64.0	65.0	1.0	64.5	160.3	0.244	805.8	0.00030	0.00030
66	65.0	66.0	1.0	65.5	183.8	0.246	924.3	0.00027	0.00027
67	66.0	67.0	1.0	66.5	175.6	0.249	883.0	0.00028	0.00028
68	67.0	68.0	1.0	67.5	83.1	0.251	417.9	0.00060	0.00060
69	68.0	69.0	1.0	68.5	52.8	0.253	265.3	0.00095	0.00095
70	69.0	70.0	1.0	69.5	20.9	0.255	104.9	0.00243	0.00243
71	70.0	71.0	1.0	70.5	34.8	0.257	175.0	0.00147	0.00147
72	71.0	72.0	1.0	71.5	39.0	0.260	196.1	0.00132	0.00132
73	72.0	73.0	1.0	72.5	29.5	0.262	148.4	0.00176	0.00176
74	73.0	74.0	1.0	73.5	22.4	0.264	112.5	0.00235	0.00235
75	74.0	75.0	1.0	74.5	68.6	0.266	344.8	0.00077	0.00077
76	75.0	76.0	1.0	75.5	99.2	0.268	498.7	0.00054	0.00054
77	76.0	77.0	1.0	76.5	69.4	0.271	348.9	0.00078	0.00078
78	77.0	78.0	1.0	77.5	53.6	0.273	269.5	0.00101	0.00101
79	78.0	79.0	1.0	78.5	102.8	0.275	517.0	0.00053	0.00053
80	79.0	80.0	1.0	79.5	369.6	0.277	1858.5	0.00015	0.00015
81	80.0	81.0	1.0	80.5	210.4	0.280	1057.8	0.00026	0.00026
82	81.0	82.0	1.0	81.5	119.5	0.282	600.6	0.00047	0.00047
83	82.0	83.0	1.0	82.5	81.8	0.284	411.3	0.00069	0.00069
84	83.0	84.0	1.0	83.5	137.5	0.286	691.3	0.00041	0.00041
85	84.0	85.0	1.0	84.5	75.3	0.288	378.7	0.00076	0.00076
86	85.0	86.0	1.0	85.5	73.2	0.291	367.8	0.00079	0.00079
87	86.0	87.0	1.0	86.5	92.5	0.293	465.1	0.00063	0.00063
88	87.0	88.0	1.0	87.5	89.7	0.295	451.1	0.00065	0.00065
89	88.0	89.0	1.0	88.5	93.1	0.297	467.9	0.00064	0.00064
90	89.0	90.0	1.0	89.5	101.1	0.299	508.2	0.00059	0.00059
91	90.0	91.0	1.0	90.5	118.6	0.302	596.1	0.00051	0.00051
92	91.0	92.0	1.0	91.5	74.0	0.304	372.1	0.00082	0.00082
93	92.0	93.0	1.0	92.5	54.8	0.306	275.6	0.00111	0.00111
94	93.0	94.0	1.0	93.5	115.7	0.308	581.5	0.00053	0.00053
95	94.0	95.0	1.0	94.5	289.4	0.311	1455.0	0.00021	0.00021
96	95.0	96.0	1.0	95.5	322.2	0.313	1619.9	0.00019	0.00019
97	96.0	97.0	1.0	96.5	484.4	0.315	2435.2	0.00013	0.00013
98	97.0	98.0	1.0	97.5	456.1	0.317	2293.2	0.00014	0.00014
99	98.0	99.0	1.0	98.5	342.2	0.319	1720.7	0.00019	0.00019
100	99.0	100.0	1.0	99.5	354.9	0.322	1784.1	0.00018	0.00018
101	100.0	101.0	1.0	100.5	390.4	0.324	1962.7	0.00016	0.00016
102	101.0	102.0	1.0	101.5	44.4	0.326	223.3	0.00146	0.00146
103	102.0	103.0	1.0	102.5	70.2	0.328	353.0	0.00093	0.00093
104	103.0	104.0	1.0	103.5	91.8	0.330	461.6	0.00072	0.00072
105	104.0	105.0	1.0	104.5	94.4	0.333	474.6	0.00070	0.00070
106	105.0	106.0	1.0	105.5	98.0	0.335	492.7	0.00068	0.00068
107	106.0	107.0	1.0	106.5	88.6	0.337	445.5	0.00076	0.00076
108	107.0	108.0	1.0	107.5	83.8	0.339	421.2	0.00081	0.00081
109	108.0	109.0	1.0	108.5	69.2	0.342	347.7	0.00098	0.00098
110	109.0	110.0	1.0	109.5	59.8	0.344	300.5	0.00114	0.00114

111	110.0	111.0	1.0	110.5	58.3	0.346	293.2	0.00118	0.00118
112	111.0	112.0	1.0	111.5	60.5	0.348	304.0	0.00115	0.00115
113	112.0	113.0	1.0	112.5	59.6	0.350	299.5	0.00117	0.00117
114	113.0	114.0	1.0	113.5	58.2	0.353	292.7	0.00120	0.00120
115	114.0	115.0	1.0	114.5	58.0	0.355	291.7	0.00122	0.00122
116	115.0	116.0	1.0	115.5	168.8	0.357	848.7	0.00042	0.00042
117	116.0	117.0	1.0	116.5	80.9	0.359	406.8	0.00088	0.00088
118	117.0	118.0	1.0	117.5	350.0	0.361	1759.7	0.00021	0.00021
119	118.0	119.0	1.0	118.5	350.0	0.364	1759.7	0.00021	0.00021
120	119.0	120.0	1.0	119.5	350.0	0.366	1759.7	0.00021	0.00021
121	120.0	150.0	30.0	135.0	350.0	0.400	1759.7	0.00682	0.00682
122	150.0	200.0	50.0	175.0	350.0	0.489	1759.7	0.01389	0.01389
123	200.0	202.8	2.8	201.4	350.0	0.546	1759.7	0.00086	0.00086
124	202.8	300.0	97.2	251.4	350.0	0.501	1759.7	0.02769	0.02769
125	300.0	400.0	100.0	350.0	350.0	0.412	1759.7	0.02341	0.02341
126	400.0	500.0	100.0	450.0	350.0	0.322	1759.7	0.01827	0.01827
127	500.0	600.0	100.0	550.0	350.0	0.231	1759.7	0.01314	0.01314
128	600.0	700.0	100.0	650.0	350.0	0.141	1759.7	0.00800	0.00800
129	700.0	800.0	100.0	750.0	350.0	0.050	1759.7	0.00286	0.00286
130	800.0	900.0	100.0	850.0	350.0	0.000	1759.7	0.00000	0.00000
Σ =									0.18520

I_{zr} ($1 < L/B < 10$):	$I_{zr} = I_{zs} + 0.111 (I_{zc} - I_{zs}) (L/B - 1)$
I_{zs} ($L/B = 1$):	
For z_{ave} = 0 to B/2:	$I_{zs} = 0.1 + (z_{ave}/B)(2I_{zp} - 0.2)$
For z_{ave} = B/2 to 2B:	$I_{zs} = 0.667\, I_{zp} (2 - z_{ave}/B)$
I_{zc} ($L/B \geq 10$):	
For z_{ave} = 0 to B:	$I_{zc} = 0.2 + (z_{ave}/B)(I_{zp} - 0.2)$
For z_{ave} = B to 4B:	$I_{zc} = 0.333\, I_{zp} (4 - z_{ave}/B)$ (Coduto p.228.)

Footing width	B =		400.0 ft	ZV3V5C17	
Footing length	L =		450.0 ft		Immediate Settlement (in.)
Ground elevation			261.0 ft		(S_0 / 2)
Foundation elevation			261.0 ft		Load S_0 =
Ground Water elevation			225.0 ft		3.2
Excavated or embedded depth	D =		0.0 ft		3.0 3.2
Depth to Groundwater			36.0 ft		4.3 4.6
Unit weight	γ =		120.0 pcf		6.0 6.6
Net applied footing pressure	Δp =		3.000 ksf		
	L/B =		1.13 -		30 Year Settlement (in.)
Computation					(S_{30} / 2)
Settlement	ρ_i =	$C_1\ C_t\ \Delta p\ \Sigma(\Delta z_i\ I_{zi}/E_{si})$	0.531 ft	Column I	Load S_0 =
	ρ_i =		6.374 in		4.8
	S(t) =		0.794 ft		
	S(t) =		9.532 in		4.3 6.9
Correction for strain relief	C_1 =	$1 - 0.5(\sigma'_D/q')$	1.000 -		6.0 9.8
Effective vertical overburden pressure at D	σ'_{vo} =	γ D	0.000 ksf		
Correction for time dependent increase	C_t =	1 + 0.2 log(t / 0.1)	1.50 -		
	t =		30.00 years		
Elastic modulus of soil layer i	E_{si} =	2.5 q_c	see Column H	if L/B = 1	
	E_{si} =	3.5 q_c	see Column H	if L/B ≥ 10	
Depth increment i	Δz_i		see Column D		
Influence factor of soil layer i	I_{zi}	Figure 3-4	see Column G		
Peak depth influence factor	I_{zp} =	$0.5 + 0.1\ (\Delta p/\sigma'_{izp})^{1/2}$	0.546 -		
	z_p =	0.5B + D	200.00 ft	If L/B = 1	
	z_p =	B + D	400.00 ft	If L/B ≥ 10	
	z_p =		202.78 ft	for L/B=1.13	
Effective overburden pressure at depth Izp	σ'_{izp} =		13.93 ksf		
Elastic Modulus	E_{si} =		2.50 q_c	If L/B = 1	
	E_{si} =		3.50 q_c	If L/B ≥ 10	
	E_{si} =		2.51 q_c	for L/B=1.13	

A	B	C	D	E	F	G	H	I	J	K
Layer No.	Layer top depth (ft)	Layer bottom depth (ft)	Layer thickness Δz_i (ft)	Mid-layer depth z_{ave} (ft)	Average tip stress q_c (tsf)	I_{zi}	Elastic modulus E_{si} (ksf)	$\Delta z_i\ I_{zi}/E_{si}$	$\Delta z_i\ I_{zi}/E_{si}$	Notes
1	0.0	1.0	1.0	0.5	125.9	0.102	633.2	0.00016	0.00016	
2	1.0	2.0	1.0	1.5	93.2	0.105	468.8	0.00022	0.00022	
3	2.0	3.0	1.0	2.5	86.6	0.107	435.5	0.00025	0.00025	
4	3.0	4.0	1.0	3.5	147.0	0.109	739.2	0.00015	0.00015	
5	4.0	5.0	1.0	4.5	103.6	0.111	520.9	0.00021	0.00021	
6	5.0	6.0	1.0	5.5	128.1	0.114	644.0	0.00018	0.00018	
7	6.0	7.0	1.0	6.5	122.9	0.116	618.0	0.00019	0.00019	
8	7.0	8.0	1.0	7.5	122.7	0.118	617.0	0.00019	0.00019	
9	8.0	9.0	1.0	8.5	118.4	0.120	595.3	0.00020	0.00020	
10	9.0	10.0	1.0	9.5	112.9	0.122	567.4	0.00022	0.00022	
11	10.0	11.0	1.0	10.5	139.2	0.125	700.0	0.00018	0.00018	
12	11.0	12.0	1.0	11.5	267.7	0.127	1345.8	0.00009	0.00009	
13	12.0	13.0	1.0	12.5	288.6	0.129	1450.9	0.00009	0.00009	
14	13.0	14.0	1.0	13.5	314.6	0.131	1581.8	0.00008	0.00008	
15	14.0	15.0	1.0	14.5	307.6	0.133	1546.3	0.00009	0.00009	
16	15.0	16.0	1.0	15.5	343.7	0.136	1728.0	0.00008	0.00008	
17	16.0	17.0	1.0	16.5	373.6	0.138	1878.5	0.00007	0.00007	
18	17.0	18.0	1.0	17.5	332.8	0.140	1673.5	0.00008	0.00008	
19	18.0	19.0	1.0	18.5	382.9	0.142	1925.2	0.00007	0.00007	
20	19.0	20.0	1.0	19.5	409.0	0.145	2056.1	0.00007	0.00007	
21	20.0	21.0	1.0	20.5	395.7	0.147	1989.4	0.00007	0.00007	
22	21.0	22.0	1.0	21.5	316.4	0.149	1591.0	0.00009	0.00009	
23	22.0	23.0	1.0	22.5	255.0	0.151	1282.0	0.00012	0.00012	
24	23.0	24.0	1.0	23.5	314.3	0.153	1580.0	0.00010	0.00010	
25	24.0	25.0	1.0	24.5	299.2	0.156	1504.1	0.00010	0.00010	
26	25.0	26.0	1.0	25.5	221.7	0.158	1114.6	0.00014	0.00014	
27	26.0	27.0	1.0	26.5	213.7	0.160	1074.4	0.00015	0.00015	
28	27.0	28.0	1.0	27.5	78.0	0.162	391.9	0.00041	0.00041	
29	28.0	29.0	1.0	28.5	111.1	0.164	558.4	0.00029	0.00029	
30	29.0	30.0	1.0	29.5	68.0	0.167	341.9	0.00049	0.00049	
31	30.0	31.0	1.0	30.5	103.2	0.169	519.0	0.00033	0.00033	
32	31.0	32.0	1.0	31.5	72.7	0.171	365.5	0.00047	0.00047	
33	32.0	33.0	1.0	32.5	33.6	0.173	169.1	0.00103	0.00103	

34	33.0	34.0	1.0	33.5	24.2	0.176	121.7	0.00144	0.00144	C2
35	34.0	35.0	1.0	34.5	27.5	0.178	138.1	0.00129	0.00129	C2
36	35.0	36.0	1.0	35.5	20.5	0.180	102.9	0.00175	0.00175	C2
37	36.0	37.0	1.0	36.5	15.9	0.182	80.0	0.00228	0.00228	C2
38	37.0	38.0	1.0	37.5	16.6	0.184	83.5	0.00221	0.00221	C2
39	38.0	39.0	1.0	38.5	20.9	0.187	104.9	0.00178	0.00178	C2
40	39.0	40.0	1.0	39.5	20.3	0.189	102.3	0.00185	0.00185	C2
41	40.0	41.0	1.0	40.5	28.0	0.191	140.7	0.00136	0.00136	C2
42	41.0	42.0	1.0	41.5	75.1	0.193	377.8	0.00051	0.00051	C2
43	42.0	43.0	1.0	42.5	100.0	0.195	503.0	0.00039	0.00039	
44	43.0	44.0	1.0	43.5	87.3	0.198	438.9	0.00045	0.00045	
45	44.0	45.0	1.0	44.5	122.3	0.200	614.8	0.00033	0.00033	
46	45.0	46.0	1.0	45.5	105.0	0.202	528.0	0.00038	0.00038	
47	46.0	47.0	1.0	46.5	100.8	0.204	506.8	0.00040	0.00040	
48	47.0	48.0	1.0	47.5	133.3	0.207	670.1	0.00031	0.00031	
49	48.0	49.0	1.0	48.5	179.6	0.209	903.0	0.00023	0.00023	
50	49.0	50.0	1.0	49.5	206.5	0.211	1038.4	0.00020	0.00020	
51	50.0	51.0	1.0	50.5	202.3	0.213	1017.3	0.00021	0.00021	
52	51.0	52.0	1.0	51.5	107.2	0.215	538.8	0.00040	0.00040	
53	52.0	53.0	1.0	52.5	41.9	0.218	210.6	0.00103	0.00103	
54	53.0	54.0	1.0	53.5	56.8	0.220	285.8	0.00077	0.00077	
55	54.0	55.0	1.0	54.5	85.6	0.222	430.3	0.00052	0.00052	
56	55.0	56.0	1.0	55.5	25.5	0.224	128.1	0.00175	0.00175	
57	56.0	57.0	1.0	56.5	21.0	0.226	105.4	0.00215	0.00215	
58	57.0	58.0	1.0	57.5	30.5	0.229	153.4	0.00149	0.00149	
59	58.0	59.0	1.0	58.5	71.4	0.231	358.8	0.00064	0.00064	
60	59.0	60.0	1.0	59.5	113.7	0.233	571.4	0.00041	0.00041	
61	60.0	61.0	1.0	60.5	126.9	0.235	637.8	0.00037	0.00037	
62	61.0	62.0	1.0	61.5	151.4	0.237	761.0	0.00031	0.00031	
63	62.0	63.0	1.0	62.5	157.8	0.240	793.6	0.00030	0.00030	
64	63.0	64.0	1.0	63.5	145.2	0.242	730.0	0.00033	0.00033	
65	64.0	65.0	1.0	64.5	135.7	0.244	682.2	0.00036	0.00036	
66	65.0	66.0	1.0	65.5	141.1	0.246	709.4	0.00035	0.00035	
67	66.0	67.0	1.0	66.5	132.8	0.249	667.8	0.00037	0.00037	
68	67.0	68.0	1.0	67.5	137.3	0.251	690.2	0.00036	0.00036	
69	68.0	69.0	1.0	68.5	86.5	0.253	435.1	0.00058	0.00058	
70	69.0	70.0	1.0	69.5	31.0	0.255	155.6	0.00164	0.00164	
71	70.0	71.0	1.0	70.5	24.4	0.257	122.8	0.00210	0.00210	
72	71.0	72.0	1.0	71.5	18.8	0.260	94.6	0.00274	0.00274	
73	72.0	73.0	1.0	72.5	32.4	0.262	162.8	0.00161	0.00161	
74	73.0	74.0	1.0	73.5	36.1	0.264	181.6	0.00145	0.00145	
75	74.0	75.0	1.0	74.5	48.6	0.266	244.1	0.00109	0.00109	
76	75.0	76.0	1.0	75.5	78.2	0.268	393.4	0.00068	0.00068	
77	76.0	77.0	1.0	76.5	98.0	0.271	492.9	0.00055	0.00055	
78	77.0	78.0	1.0	77.5	121.8	0.273	612.4	0.00045	0.00045	
79	78.0	79.0	1.0	78.5	59.1	0.275	297.2	0.00093	0.00093	
80	79.0	80.0	1.0	79.5	49.3	0.277	247.8	0.00112	0.00112	
81	80.0	81.0	1.0	80.5	36.3	0.280	182.7	0.00153	0.00153	
82	81.0	82.0	1.0	81.5	102.3	0.282	514.5	0.00055	0.00055	
83	82.0	83.0	1.0	82.5	723.6	0.284	3638.0	0.00008	0.00008	
84	83.0	84.0	1.0	83.5	162.1	0.286	814.8	0.00035	0.00035	
85	84.0	85.0	1.0	84.5	163.0	0.288	819.4	0.00035	0.00035	
86	85.0	86.0	1.0	85.5	100.2	0.291	503.6	0.00058	0.00058	
87	86.0	87.0	1.0	86.5	90.6	0.293	455.3	0.00064	0.00064	
88	87.0	88.0	1.0	87.5	96.0	0.295	482.6	0.00061	0.00061	
89	88.0	89.0	1.0	88.5	192.0	0.297	965.4	0.00031	0.00031	
90	89.0	90.0	1.0	89.5	154.4	0.299	776.5	0.00039	0.00039	
91	90.0	91.0	1.0	90.5	146.3	0.302	735.7	0.00041	0.00041	
92	91.0	92.0	1.0	91.5	115.3	0.304	579.8	0.00052	0.00052	
93	92.0	93.0	1.0	92.5	108.6	0.306	545.9	0.00056	0.00056	
94	93.0	94.0	1.0	93.5	123.9	0.308	623.1	0.00049	0.00049	
95	94.0	95.0	1.0	94.5	139.2	0.311	699.9	0.00044	0.00044	
96	95.0	96.0	1.0	95.5	165.6	0.313	832.6	0.00038	0.00038	
97	96.0	97.0	1.0	96.5	230.6	0.315	1159.5	0.00027	0.00027	
98	97.0	98.0	1.0	97.5	255.1	0.317	1282.6	0.00025	0.00025	
99	98.0	99.0	1.0	98.5	244.4	0.319	1229.0	0.00026	0.00026	
100	99.0	100.0	1.0	99.5	212.2	0.322	1066.8	0.00030	0.00030	
101	100.0	101.0	1.0	100.5	156.6	0.324	787.3	0.00041	0.00041	
102	101.0	102.0	1.0	101.5	44.4	0.326	223.3	0.00146	0.00146	
103	102.0	103.0	1.0	102.5	70.2	0.328	353.0	0.00093	0.00093	
104	103.0	104.0	1.0	103.5	91.8	0.330	461.6	0.00072	0.00072	
105	104.0	105.0	1.0	104.5	94.4	0.333	474.6	0.00070	0.00070	
106	105.0	106.0	1.0	105.5	98.0	0.335	492.7	0.00068	0.00068	
107	106.0	107.0	1.0	106.5	88.6	0.337	445.5	0.00076	0.00076	
108	107.0	108.0	1.0	107.5	83.8	0.339	421.2	0.00081	0.00081	
109	108.0	109.0	1.0	108.5	69.2	0.342	347.7	0.00098	0.00098	
110	109.0	110.0	1.0	109.5	59.8	0.344	300.5	0.00114	0.00114	

111	110.0	111.0	1.0	110.5	58.3	0.346	293.2	0.00118	0.00118
112	111.0	112.0	1.0	111.5	60.5	0.348	304.0	0.00115	0.00115
113	112.0	113.0	1.0	112.5	59.6	0.350	299.5	0.00117	0.00117
114	113.0	114.0	1.0	113.5	58.2	0.353	292.7	0.00120	0.00120
115	114.0	115.0	1.0	114.5	58.0	0.355	291.7	0.00122	0.00122
116	115.0	116.0	1.0	115.5	168.8	0.357	848.7	0.00042	0.00042
117	116.0	117.0	1.0	116.5	80.9	0.359	406.8	0.00088	0.00088
118	117.0	118.0	1.0	117.5	350.0	0.361	1759.7	0.00021	0.00021
119	118.0	119.0	1.0	118.5	350.0	0.364	1759.7	0.00021	0.00021
120	119.0	120.0	1.0	119.5	350.0	0.366	1759.7	0.00021	0.00021
121	120.0	150.0	30.0	135.0	350.0	0.400	1759.7	0.00682	0.00682
122	150.0	200.0	50.0	175.0	350.0	0.489	1759.7	0.01389	0.01389
123	200.0	202.8	2.8	201.4	350.0	0.546	1759.7	0.00086	0.00086
124	202.8	300.0	97.2	251.4	350.0	0.501	1759.7	0.02769	0.02769
125	300.0	400.0	100.0	350.0	350.0	0.412	1759.7	0.02341	0.02341
126	400.0	500.0	100.0	450.0	350.0	0.322	1759.7	0.01827	0.01827
127	500.0	600.0	100.0	550.0	350.0	0.231	1759.7	0.01314	0.01314
128	600.0	700.0	100.0	650.0	350.0	0.141	1759.7	0.00800	0.00800
129	700.0	800.0	100.0	750.0	350.0	0.050	1759.7	0.00286	0.00286
130	800.0	900.0	100.0	850.0	350.0	0.000	1759.7	0.00000	0.00000
Σ =									0.19151

I_{zr} (1 < L/B < 10):	$I_{zr} = I_{zs} + 0.111\,(I_{zc} - I_{zs})\,(L/B - 1)$
I_{zs} (L/B = 1):	
For z_{ave} = 0 to B/2:	$I_{zs} = 0.1 + (z_{ave}/B)(2I_{zp} - 0.2)$
For z_{ave} = B/2 to 2B:	$I_{zs} = 0.667\,I_{zp}\,(2 - z_{ave}/B)$
I_{zc} (L/B ≥ 10):	
For z_{ave} = 0 to B:	$I_{zc} = 0.2 + (z_{ave}/B)(I_{zp} - 0.2)$
For z_{ave} = B to 4B:	$I_{zc} = 0.333\,I_{zp}\,(4 - z_{ave}/B)$ (Coduto p.228.)

Burland and Burbidge Method

	Depth of Excavation	Layer	initial height of the compressible layer	Unit weight	Blow Count	Width of Stress change	Length of Stress change	Depth of Foundation	Applied vertical Load	Depth of Influence	Shape Correction Factor	Layer Thickness Correction Factor	Average Effective Bearing Pressure	preconsolidation stress
	D_e		H_o	γ	N_{ave}	B	L	D	σ	z_1	f_s	f_i	q'	σ'_{vo}
	feet		feet	pcf	-	feet	feet	feet	ksf	feet	-	-	tsf	tsf
Over Consolidated to Effective Vertical Stress Prior to Excavation														
After Operations Complete	14.00	All	116	120	28	400.0	450.0	14.0	3.00	120.7	1.046	1.00	1.50	0.840
After Operations Complete	2.00	All	116	120	28	400.0	450.0	2.0	3.00	120.7	1.046	1.00	1.50	0.120
Cap Completed - 10 ft	14.00	All	116	120	28	400.0	450.0	14.0	4.30	120.7	1.046	1.00	2.15	0.840
Cap Completed - 23.5 ft	14.00	All	116	120	28	400.0	450.0	14.0	6.00	120.7	1.046	1.00	3.00	0.840
Cap Completed - 10 ft	2.00	All	116	120	28	400.0	450.0	2.0	4.30	120.7	1.046	1.00	2.15	0.120
Cap Completed - 23.5 ft	2.00	All	116	120	28	400.0	450.0	2.0	6.00	120.7	1.046	1.00	3.00	0.120

	Depth of Excavation	Layer	Compressibility Influence Factor	Settlement	Settlement	Lower Bound Compressibility Influence Factor	Upper Bound Compressibility Influence Factor	Lower Bound Settlement	Upper Bound Settlement	30-Year Settlement	30-Year Settlement Lower	30-Year Settlement Upper
	D_e		I_c	S_0	S_0	I_c	I_c	S_0	S_0	S_{30}	S_{30}	S_{30}
	feet			feet	in	tsf	tsf	in	in	in	in	in
After Operations Complete	14.00	All	0.0022	0.141	1.69	0.0011	0.0051	0.821	4.008	2.54	1.23	6.01
After Operations Complete	2.00	All	0.0022	0.213	2.56	0.0011	0.0051	1.240	6.055	3.83	1.86	9.08
Cap Completed - 10 ft	14.00	All	0.0022	0.238	2.86	0.0011	0.0051	1.389	6.780	4.29	2.08	10.17
Cap Completed - 23.5 ft	14.00	All	0.0022	0.366	4.39	0.0011	0.0051	2.131	10.404	6.59	3.20	15.61
Cap Completed - 10 ft	2.00	All	0.0022	0.310	3.73	0.0011	0.0051	1.808	8.827	5.59	2.71	13.24
Cap Completed - 23.5 ft	2.00	All	0.0022	0.438	5.25	0.0011	0.0051	2.551	12.451	7.88	3.83	18.68

Soil Column Settlement (includes C2 layer) - inches

	Lower Bound	Upper Bound	Average	
Operations Complete	1.0	5.0	2.1	average of two cases
Closure Cap Complete	2.0	9.6	4.1	average of 4 closure cap cases
30 Years Post Closure	3.0	14.4	6.1	average of 4 closure cap cases at 30 years

Settlements at the top and bottom of the C2 layer - inches
Created with the Table Function

			Settlement (inches)								
			Operations Complete			Cap Complete			30 Post Closure		
		Depth	Lower	Upper	Average	Lower	Upper	Average	Lower	Upper	Average
		(ft)	1.0	5.0	2.1	2.0	9.6	4.1	3.0	14.4	6.1
Top	Thick C2	33	0.5	2.4	1.0	0.9	4.5	1.9	1.4	6.8	2.9
Bottom	Thick C2	44	0.6	3.0	1.3	1.2	5.7	2.4	1.8	8.6	3.6
Top	Thin C2	39	0.6	2.7	1.2	1.1	5.2	2.2	1.6	7.8	3.3
Bottom	Thin C2	44	0.6	3.0	1.3	1.2	5.7	2.4	1.8	8.6	3.6

Settlement of the C2 Layer

		Operations Complete			Cap Complete			30 Post Closure		
		Lower	Upper	Average	Lower	Upper	Average	Lower	Upper	Average
Thick C2	11 ft	0.1	0.6	0.3	0.2	1.2	0.5	0.4	1.8	0.8
Thin C2	5 ft	0.1	0.3	0.1	0.1	0.5	0.2	0.2	0.8	0.3
Average		**0.1**	**0.4**	**0.2**	**0.2**	**0.9**	**0.4**	**0.3**	**1.3**	**0.5**

Soil Column Settlement (excluding C2 layer) inches

	Lower Bound	Upper Bound	Average
Operations Complete	0.9	4.6	1.9
Closure Cap Complete	1.8	8.8	3.7
30 Years Post Closure	2.7	13.1	5.5

Consolidation

Maximum Excavation, Maximum C2 Layer (SE Sector)

			H	e_o	C_c	C_r	OCR	B	L	σ'_o	σ'_p	F	$\Delta\sigma'$	σ'_f	Heave / Settlement H	$\sigma_f < \sigma_p$	$\sigma_f > \sigma_p$	ΔH	
			ft	---	---	---	---	ft	ft	psf	psf	---	psf	psf	inches	inches	inches	inches	
Excavation	Excavate	120	14					400	450				-1,680						
	S1/2	120	33																
	C2	58	11	1.70	0.50	0.11	1.0			5,959	5,959	0.84	-1,412	4,547	-0.63	0.00	0.00	-0.63	-0.63
Operation	Tank Ops							400	450				3,000						
	S1/2	120	33																
	C2	58	11	1.70	0.50	0.11	1.0			4,547	5,959	0.84	2,521	7,068	0.00	0.00	2.44	2.44	1.81
Cap	Backfill	125	21					400	450				3,000						
	S1/2	120	33																
	C2	58	11	1.70	0.50	0.11	1.0			7,068	7,068	0.84	2,521	9,589	0.00	0.00	3.24	3.24	5.05

Appendix D – Liquefaction Analysis

K-CLC-Z-00015, Rev. 0

June 2009

Liquefaction Analysis for Saltstone Disposal Cells 3 and 5

(96 pages)

CALCULATION COVER SHEET

Project **Saltstone Disposal Cells No. 3 and 5**	**Calculation No.** **K-CLC-Z-00015**	**Project Number** Y546
Title **Liquefaction Analysis for Saltstone Disposal Cells 3 and 5**	**Functional Classification** **PS** **Discipline** **Geotechnical**	**Sheet 1 of 95**
Calc Level ☒ Type 1 ☐ Type 2	**Type 1 Calc Status** ☐ Preliminary ☒ Confirmed	
Computer Program No. ☒ N/A	**Version / Release No.** N/A	
Purpose and Objective The purpose of this calculation is to provide an evaluation of the liquefaction potential and an estimate of settlement resulting from liquefaction and partial liquefaction for the Saltstone Disposal Cells 3 and 5 project.	**DC/RO** UNCLASSIFIED DOES NOT CONTAIN UNCLASSIFIED CONTROLLED NUCLEAR INFORMATION ADC & Reviewing Official A.A. Siddall (Name) Date: 7/23/2009	
Summary of Conclusion See the Results and Conclusions Section.		

Revision

Rev. No.	Revision Description
0	**Original**

Sign Off

Rev. No.	Originator (Print) Sign / Date	Verification / Checking Method	Verifier / Checker (Print) Sign / Date	Manager (Print) Sign / Date
0	**Rucker J. Williams** [signature] 6-24-09	**Document Review**	**Bruce Nothdurft, PE** [signature] 6/25/09	**William T. Li** [signature] 6-25-09

Additional Reviewer (Print) N/A	**Signature**	**Date**
Design Authority (Print) N/A	**Signature**	**Date**
Release to Outside Agency (Print) N/A	**Signature**	**Date**
Security Classification of the Calculation Unclassified		

TABLE OF CONTENTS

1. Introduction

The purpose of this calculation is to provide an evaluation of liquefaction potential and estimate settlements due to liquefaction and partial liquefaction. See Figure 1 for the location of Disposal Cells 3 and 5.

2. Input

2.1 Site Configuration and Soil Properties

The surface elevation at the project site ranges from 263 ft to 275 ft, msl. Groundwater elevation at the site ranges from 215 to 220 ft, msl (Ref. WSRC, 2003). See Figure 1. Estimated seasonal fluctuation is about 5 feet. Since only saturated soils are susceptible to liquefaction, a conservative water level of 225 ft, msl will be used for the computation of liquefaction potential and settlement.

Seventeen (17) CPTs and and SCPTs were pushed for the Disposal Cells 3 and 5 site, see Figure 2. Stratigraphic interpretations of the CPT and SCPTs are summarized below (Ref. SRS, 2009a). SCPT data is included in Appendix A.

ID	CPT Type	SRS Northing	SRS Easting	Elevation ft, msl	Elevation Top Pick (ft, msl)		
					C2 Layer	S3 Layer	S4 Layer
ZV3V5C1	SCPT	78429	66907	264.9		224	185
ZV3V5C2	CPT	78267	66960	268.6	221	215	184
ZV3V5C3	CPT	78477	66813	263.9		219	190
ZV3V5C4	SCPT	78405	66836	266.8		221	186
ZV3V5C5	CPT	78325	66863	268.8	226	221	186
ZV3V5C6	SCPT	78244	66889	268.8	229	217	187
ZV3V5C7	SCPT	78173	66913	268.2	233	223	
ZV3V5C8	CPT	78374	66741	267.7	220	216	186
ZV3V5C9	SCPT	78293	66768	270.4	225	216	173
ZV3V5C10	CPT	78213	66794	270.7	227	211	178
ZV3V5C11	SCPT	78414	66623	264.7	218	215	185
ZV3V5C12	SCPT	78343	66646	268.1	219	216	186
ZV3V5C13	CPT	78262	66673	272	225	221	184
ZV3V5C14	SCPT	78181	66699	273	228	216	186
ZV3V5C15	CPT	78110	66723	271.6	231	220	178
ZV3V5C16	CPT	78319	66575	268.7	NP	228	186
ZV3V5C17	SCPT	78158	66628	274.6	228	219	186

S1/S2 layer consists of the Upland Formation, Tobacco Road Formation, and the upper portion of the Dry Branch Formation. The C2 Layer is the Tan Clay Unit within the Dry Branch Formation. The S3 layer is the lower portion of the Dry Branch Formation, while the S4 layer is the Santee/Tinker Formation. For this calculation, the liquefaction analysis is performed for the saturated portions of the Tobacco Road and Dry Branch Formations (S1/S2, C2, and S3 layers). The Santee Formation (S4 layer) is assumed to be too deep for liquefaction (Ref. SRS 2006a). Dynamic settlement within the Santee Formation is due to “soft zones” and is covered in another

calculation, K-CLC-Z-00016.

Soil unit weights were determined from undisturbed samples taken during the subsurface investigation. Within the Tobacco Road and Dry Branch formations, the unit weights ranged from 115to 130 pcf. A value of 120 pcf was used for this calculation. Sieve analyses were performed on soil samples taken from geotechnical boreholes as part of the subsurface investigation. The locations of the boreholes are summarized in the table below. Table 1 summarizes the fines content of the soil samples.

ID	SRS Northing	SRS Easting	Elevation ft, msl	Adjacent CPT
ZV3V5B1	78395	66839	266.9	ZV3V5C4
ZV3V5B2	78235	66894	269.9	ZV3V5C6
ZV3V5B3	78333	66649	268.3	ZV3V5C12
ZV3V5B4	78171	66702	272.8	ZV3V5C14

2.2 Design Basis Earthquake

The design basis earthquake is based on the response spectra generated by the methodology found in the IBC Section 1613 (Ref. IBC, 2003). The peak ground acceleration (PGA) is 0.20g. The derivation of this value is found in Appendix B.

The USGS has performed a site specific Probabilistic Seismic Hazard Analysis (PSHA) for the SRS (Ref. Frankel, 1999). See Appendix C. The SRS PGA dissagregation for the 2,500 year return period is presented in Figure 3 and Table 2. The hazard dissagregation is used to establish weights for averaging earthquake results based on earthquake magnitude.

3. Computation

3.1 Liquefaction Susceptibility

In this calculation the liquefaction potential for the Saltstone Disposal Cells 3 and 5 is evaluated using a modified version of the “Simplified Procedure for Evaluating Soil Liquefaction Potential” (Ref. Seed and Idriss, 1971; NCEER, 1997; Youd et al., 2001). The simplified procedure calculates the liquefaction factor of safety as the ratio of Cyclic Resistance Ratio (CRR) to the Cyclic Stress Ratio (CSR) generated by the earthquake.

Factor of Safety = CRR / CSR

It should be noted that CRR was previously termed CSR required to induce liquefaction, but has been changed to more clearly distinguish the term from the CSR induced by the earthquake (Ref. NCEER, 1997). The CRR (soil capacity) and CSR (earthquake demand) are defined below

$$CRR = \tau_{ave} / \sigma'_{vo}$$

where:

τ_{ave} = average shear stress required to induce liquefaction
σ'_{vo} = effective vertical overburden stress

CSR is

$$CSR = \tau_{ave} / \sigma'_{vo} = 0.65 \times (a_{max} / g) \times (\sigma_{vo} / \sigma'_{vo}) \times r_d$$

where:

τ_{ave} = average shear stress induced by the earthquake
σ'_{vo} = effective vertical overburden stress

3.1.1 Earthquake Demand or Cyclic Stress Ratio (CSR)

The "Simplified Procedure for Evaluating Soil Liquefaction Potential" uses peak ground acceleration (PGA) to estimate shear stress (τ_{ave}) at ground surface and a stress reduction factor (r_d) to calculate τ_{ave} as a function of depth (Ref. Seed and Idriss, 1971; NCEER, 1997). The simplified method of CSR determination is given below.

$$CSR = \tau_{ave} / \sigma'_{vo} = 0.65 \times (a_{max} / g) \times (\sigma_{vo} / \sigma'_{vo}) \times r_d$$

where

a_{max} = maximum horizontal acceleration at ground surface
g = the gravitational acceleration
σ_{vo} = total vertical stress
σ'_{vo} = effective vertical stress
r_d = stress reduction factor as a function of depth in meters
= 1.000 – 0.00765z for $z \le 9.15$ m
= 1.174 – 0.0267z for $9.15 \text{ m} < z \le 23$ m
= 0.744 – 0.0080z for $23 \text{ m} < z \le 30$ m
= 0.500 for $z > 30$ m

3.1.2 **Soil Capacity or Cyclic Resistance Ratio (CRR)**

The original simplified procedure determines CRR using Standard Penetration Test (SPT) $N1_{60}$ values and a curve delineating liquefaction. The CRR from the curve is further modified by several factors that have been developed over time. These factors correct for: aging, static driving shear stress, overburden pressure, and earthquake magnitude. For this calculation curves based on CPTu tip stress data (q_{t1}) are used to determine CRR. The q_{t1} CRR curves were developed from testing of SRS soils in lieu of the standard SPT and CPTu liquefaction methods developed for Holocene and younger deposits. When applying the correction factors, the Factor of Safety is expressed as given below. Each of the correction factors used in this calculation for determining CRR is discussed in the following sections.

$$\text{Factor of Safety} = \frac{CRR_{7.5} \cdot K_{\sigma} \cdot K_{age} \cdot K_{\alpha} \cdot MSF}{CSR}$$

3.1.3 **Age Correction Factor K_{age}**

The q_{t1} curves used for this calculation were developed specifically for SRS using data from investigations in H-Area (Ref. BSRI, 1993; WSRC, 1995; SRS, 2007a) after extensive field and laboratory testing programs. Because the SRS q_{t1} CRR curves were developed from testing of the Tobacco Road and Dry Branch sediments, aging is incorporated into the curves. The curves may be directly applied to calculate liquefaction susceptibility without applying an age correction factor (i.e., $K_{age} = 1.0$).

3.1.4 Static Driving Shear Stress Correction Factor, K_α

Relationships proposed by Seed and Harder (1990) suggest that a static driving shear stress can increase or decrease the soil's resistance to liquefaction, depending on the magnitude of the driving stress and the relative density of the soil. A static driving shear stress correction factor ($K\alpha$) has been proposed by Seed and Harder to correct CRR (Ref. Seed and Harder, 1990). However, the proposed chart to estimate $K\alpha$ is preliminary and this correction factor is a subject of current research (Ref. NCEER, 1997, pp. 172-176). For this calculation, no K_α correction was used (i.e., $K_\alpha = 1.0$).

3.1.5 Static Effective Overburden Pressure Correction Factor, K_σ

Most of the case history data used to develop the standard liquefaction curves (Ref. Seed and Idriss, 1982 and NRC, 1985) were taken from cases of level ground with relatively small initial effective overburden stresses ($\sigma'_o \leq 1$ tsf). However, at higher effective overburden stresses ($\sigma'_o > 1$ tsf), the liquefaction susceptibility of the soil will increase for a given CSR (Ref. Seed and Harder, 1990). Thus, the CRR must be corrected for the influence of the static overburden stresses. This is done by multiplying CRR by the correction factor K_σ. The soils at SRS are much older than the case history data typically used for liquefaction studies. Therefore testing of soils at SRS has been performed to determine appropriate K_σ for SRS soils (Ref. WSRC, 1995; BSRI, 1993). Figure 4 shows the SRS K_σ curve along with data used to develop the curve (Ref. SRS, 1994a). The NCEER recommended K_σ curves (Ref. Youd et al., 2001) are also shown on Figure 4 for comparison. The polynomial representing the SRS K_σ curve shown in Figure 4 is given below.

$$K_\sigma = 1.009376 - 0.18326 \log(\sigma'_{vo}) - 0.08340 \log(\sigma'_{vo})^2$$

where:

σ'_{vo} = Effective Vertical Overburden Pressure in tsf.

Note that the K_σ used for this calculation is the site-specific relationship developed using data from investigations in H-Area (Ref. WSRC, 1995; SRS, 1994a and SRS, 2007a) and not the standard K_σ relationship proposed by NCEER (Ref. Youd et al, 2001). The SRS K_σ used is applicable for Saltstone Disposal Cells 3 and 5, but less stringent than the K_σ proposed by NCEER.

3.1.6 Earthquake Magnitude Scaling Factor, MSF

The CRR curves used for liquefaction analysis are only valid for M = 7.5 earthquakes. For earthquakes with differing magnitudes, the CRR values must be multiplied by a magnitude scaling factor (MSF).

The earthquake magnitudes from the PSHA and the appropriate MSF for each magnitude are given below. These MSFs represent the middle of the NCEER (1997) recommended values shown on Figure 5 and were used to fit an exponential curve.

Earthquake Magnitude (Mw)	Magnitude Scaling Factor
5.5	2.5
6.0	2.0
6.5	1.6
7.0	1.25
7.5	1.0
8.0	0.8
8.5	0.7

The MSF equation,

$$MSF = 27.3e^{-0.44 \times Mw}$$

is rounded to the nearest tenth (0.1) for use in calculations.

3.1.7 CRR from the SRS q_{t1} versus CRR Curves

The CRR curves utilized at SRS were reevaluated to incorporate the state of the art methods used in liquefaction analysis. Both methods of CRR determination are presented within this calculation. The new CRR curves are recommended for design, while the old CRR curves are presented for comparison.

3.1.7.1. Previous SRS CRR Curves

Figure 6 presents the old CRR curves which were developed specifically for SRS in the 1990s (Ref. SRS 1994b and SRS 2006b). The curves are defined by the equations given below.

$$CRR = 0.125721 + 0.002537\,(q_{t1}) + 0.000040\,(q_{t1})^2 \qquad \text{for FC = 30\%}$$

$$CRR = 0.093309 + 0.001757\,(q_{t1}) + 0.000029\,(q_{t1})^2 \qquad \text{for FC = 22.5\%}$$

$$CRR = 0.072666 + 0.001141\,(q_{t1}) + 0.000028\,(q_{t1})^2 \qquad \text{for FC = 15\%}$$

$$CRR = 0.046881 + 0.001190\,(q_{t1}) + 0.000015\,(q_{t1})^2 \qquad \text{for FC = 10\%}$$

$$CRR = 0.021215 + 0.001408\,(q_{t1}) + 0.000007\,(q_{t1})^2 \qquad \text{for FC = 0\%}$$

The CPTu tip stress (q_t) must be normalized (q_{t1}) for overburden stress prior to applying the CRR curves. This is done using an overburden correction factor CQ shown below (Ref. Youd et al., 2001).

$$q_{t1} = C_Q \times q_t$$

$$C_Q = (P_a / \sigma'_{vo})^n \text{ with } C_Q \leq 1.7$$

where

C_Q = CPTu Overburden Normalization Factor

Pa = Atmospheric pressure (1 atm, 1 tsf)

σ'_{vo} = Effective vertical overburden pressure at time of testing

P_a and σ'_{vo} must be in the same units

n = exponent ranges between 0.5 for clean sand and 1.0 for clays

For this calculation the exponent n was assumed to vary linearly, based on percent fines, between 0.5 for clean sand (i.e., fines ≤ 5%) and 1.0 for clays (i.e., fines ≥ 50%). It is important to note that normalization of q_t to q_{t1} is performed using effective vertical overburden pressure at

the time of data collection.

3.1.7.2. Current SRS CRR Curves

Figure 7 presents the SRS qt1 versus CRR curves (Ref. SRS, 2007b). Equations for these curves allow computer application of the SRS q_{t_1} versus CRR curves. Laboratory testing and development of the curves are discussed in SRS (2007a) and by Lewis and Arango (Ref. SRS, 2007b).

The SRS CRR relationship has adopted the shape of the Idriss and Boulanger (Ref. Idriss and Boulanger, 2004) CRR relationship. The SRS clean curve is the Idriss and Boulanger relationship multiplied by a factor of 1.3 to account for strength gain due to aging. The Idriss and Boulanger CRR clean curve (i.e., fines content ≤ 5%) is given below.

$$CRR = \exp\left[\left(\frac{(q_t)_1}{540}\right) + \left(\frac{(q_t)_1}{67}\right)^2 - \left(\frac{(q_t)_1}{80}\right)^3 + \left(\frac{(q_t)_1}{114}\right)^4 - 3\right]$$

This same curve is multiplied by increasing factors to account for aging and increased fines content. The multipliers for various fines contents are provided below.

Fines Content (%)	SRS Multiplier for CRR Curve
≤ 5	1.3
10	1.6
15	2.1
20	2.6
25	3.1
≥30	3.4

The CPTu tip stress (q_t) must be normalized (q_{t_1}) for overburden stress prior to applying the CRR curves. This is done using an overburden correction factor C_Q shown below (Ref. Youd et al).

$q_{t_1} = C_Q \times q_t$

$C_Q = (P_a / \sigma'_{vo})^n$ with $C_Q \leq 1.7$

where

C_Q = CPTu Overburden Normalization Factor

Pa = Atmospheric pressure (1 atm, 1 tsf)

σ'_{vo} = Effective vertical overburden pressure at time of testing

P_a and σ'_{vo} must be in the same units

n = exponent ranges between 0.5 for clean sand and 1.0 for clays

For this calculation the exponent n was assumed to vary linearly, based on percent fines, between 0.5 for clean sand (i.e., fines ≤ 5%) and 1.0 for clays (i.e., fines ≥ 50%). It is important to note that normalization of q_t to q_{t_1} is performed using effective vertical overburden pressure at the time of data collection.

3.1.8 Percent Fines

The SRS q_{t1} method used in this calculation requires percent fines to determine CRR. Percent fines is determined using an SRS site specific CPTu method that was developed by correlating laboratory determined fines content from borings with nearby CPTu results (Ref. SRS, 2001). The SRS method uses a classification index (I_c) to calculate percent fines. The SRS method is given below.

$$\text{Percent Fines} = 29.47(I_c)^{1.21} - 0.09$$

$$I_c = [(1.60\text{-}\log Q_t)^2 + (\log Fr + 0.41)^2]^{0.5}$$

where:

Q_t = normalized tip resistance $Q_t = (q_t\text{-}\sigma_{vo})/\ \sigma'_{vo}$
Fr = stress normalized friction ratio $Fr = [(f_s/q_t\text{-}\sigma_{vo}) \times 100]$
q_t = CPTu tip stress corrected for unequal area effects
f_s = CPTu sleeve friction
σ_{vo} = total vertical stress (unit weight of soil × depth)
σ'_{vo} = effective vertical stress

Table 1 summarizes the fines content determined from samples taken during the subsurface investigations (Ref. SRS, 2009b). The four borings at Disposal Cells 3 and 5 were each located within approximately 10 of a CPT/SCPT. Figures 8 – 11 compare the laboratory measured fines content to the CPT calculated fines content. The CPT/SCPT results provide reasonable estimates of fines content, with the exception of one point (in which case the SRS equation provides a more conservative, i.e. lower, estimation of fines content).

3.2 Dynamic Settlement Above the Santee Formation

Settlement due to liquefaction and partial liquefaction can be calculated using standard techniques from the geotechnical engineering literature or techniques based on site-specific testing. Due to the age and increased strength, it was necessary to sample and test SRS soils to quantify strain due to cyclic loading.

3.2.1 Volumetric Strain Curves

SRS specific volumetric strain curves were developed during sampling and laboratory testing programs from H-Area (SRS, 1994b; SRS, 2006b; BSRI, 1993; WSRC, 1995). The SRS volumetric strain curves (Figure 12) give volumetric strain as a function of CPTu tip resistance and factor of safety. Because the SRS volumetric strain curves were developed from testing of the Tobacco Road and Dry Branch sediments, the curves incorporate strength due to aging.

For conservatism, the SRS volumetric strain curves considered liquefaction triggered in all zones having a factor of safety less than or equal to 1.15 (BSRI, 1993 and WSRC, 1995). Soils having factors of safety between 1.15 and 2.2 are considered to be partially liquefied. Soils with a factor of safety greater than 2.2 are considered to be non-liquefiable. No settlement is expected for factors of safety greater than 2.2.

The volumetric strain curves developed for SRS using H-Area data and used in this calculation are presented in Figure 12 (SRS, 2006b; WSRC, 1995). The volumetric strain curves for various values of q_{t_1} are a function of factor of safety. These curves have been fitted with the following regression equations, which were derived and presented in calculation C-CLC-H-00815 (SRS, 2006b).

for q_{t_1} = 160, and 0.4 < FS < 1.15

$$\text{strain (\%)} = 0.65$$

for q_{t_1} = 130, and 0.4 < FS < 1.15

$$\text{strain (\%)} = 2.9883 + 10.354(FS)^4 - 30.258(FS)^3 + 30.7(FS)^2 - 13.064(FS)$$

for q_{t_1} = 100, and 0.4 < FS < 1.15

$$\text{strain (\%)} = 2.0308 + 8.3929(FS)^4 - 21.111(FS)^3 + 16.12(FS)^2 - 4.5756(FS)$$

for q_{t_1} = 50, and 0.4 < FS < 0.65

$$\text{strain (\%)} = -41.6495 - 756.666(FS)^4 + 1505.222(FS)^3 - 1123.65(FS)^2 + 371.2387(FS)$$

for q_{t_1} = 50, and 0.65 < FS < 1.15

$$\log \text{strain (\%)} = 1.256225 - 0.21100(FS)^2 - 1.01242(FS)$$

for q_{t_1} = 30, and 0.4 < FS < 0.65

$$\text{strain (\%)} = -45.4815 - 830.0000(FS)^4 + 1651.074(FS)^3 - 1231.64(FS)^2 + 406.5062(FS)$$

for q_{t_1} = 30, and 0.65 < FS < 1.15

$$\log \text{strain (\%)} = 1.181442 - 0.47909(FS)^2 - 0.63184(FS)$$

for q_{t_1} = 20, and 0.4 < FS < 0.65

$$\text{strain (\%)} = -45.2315 - 830.0000(FS)^4 + 1651.074(FS)^3 - 1231.64(FS)^2 + 406.5062(FS)$$

for q_{t_1} = 20, and 0.65 < FS < 1.15

$$\log \text{strain (\%)} = 0.679601 - 1.17026(FS)^2 + 0.616392(FS)$$

for q_{t_1} = 10, and 0.4 < FS < 0.65

$$\text{strain (\%)} = -29.6577 - 560.0000(FS)^4 + 1114.074(FS)^3 - 836.066(FS)^2 + 278.6576(FS)$$

for q_{t_1} = 10, and 0.65 < FS < 1.15

$$\log \text{strain (\%)} = 0.454166 - 1.56185(FS)^2 + 1.272068(FS)$$

for q_{t_1} = 5, and 0.4 < FS < 0.65

$$\text{strain (\%)} = -29.7775 - 566.666(FS)^4 + 1127.333(FS)^3 - 845.883(FS)^2 + 281.8638(FS)$$

for q_{t_1} = 5, and 0.65 < FS < 1.15

$$\log \text{strain (\%)} = 0.367762 - 1.73636(FS)^2 + 1.555255(FS)$$

for partial liquefaction 1.15 < FS < 1.6 and all q_{t1} values

log strain (%) = 1.256225 - 0.21100(FS)^2 - 1.01242(FS)

for partial liquefaction 1.6 < FS < 2.2 and all q_{t1} values

strain (%) = 0.728794 + 0.100221(FS)^2 - 0.54090(FS)

3.2.2 Liquefaction and Partial Liquefaction Settlement

For this calculation the volumetric strain curves were used for evaluation purposes. Dynamic settlement of unsaturated (i.e., above the water table) sands was ignored, because of their small contribution to the total dynamic settlement.

It was assumed that all liquefiable and partially liquefiable zones will settle and the resulting settlement will be cumulative at the surface. No consideration is given for dilation or bridging effects of interspersed or overlying, non-liquefied layers. This is a conservative assumption and actual settlements may be less, especially if the thickness of the non-liquefied layers is substantial. Total cumulative settlement resulting from liquefaction and partial liquefaction is estimated for the profile by summing the liquefaction settlement or partial liquefaction settlement for each increment:

$$S_{Total} = \Sigma S_{Liq} + \Sigma S_{P\ Liq} \quad \text{(Eq. 32)}$$

where:

S_{Total} = cumulative settlement,
S_{Liq} = settlement of the increment due to liquefaction, and
$S_{P\ Liq}$ = settlement of the increment due to partial liquefaction.

The value of S_{Liq} and $S_{P\ Liq}$ are calculated from:

$$S_{Liq} = \text{(volumetric strain due to liquefaction) } dz \quad \text{(Eq. 33)}$$

$$S_{P\ Liq} = \text{(volumetric strain due to partial liquefaction) } dz \quad \text{(Eq. 34)}$$

where:

dz = thickness of the increment.

3.3 Liquefaction Hazard Weighting

Table 2 summarizes the PGA hazard for the 2,500 year earthquake. (Ref. Frankel, 1999). The weight for a given magnitude range is the sum of the weights for the various distances for the given magnitude Settlement due to liquefaction and partial liquefaction, is calculated using different magnitudes. The magnitudes selected are the midpoints of the magnitude ranges given in Table 2 (i.e. 4.75, 5.25, 5.75, 6.25, 6.75, and 7.5). The results are then weighted according to the PGA hazard dissaggregation.

3.4 Shear Wave Velocity Determination of CRR

CRR values can be computed using shear wave velocity as follows (Ref. Andrus and Stokoe,

2000):

$$CRR = 0.022\left(\frac{V_{S1}}{100}\right)^2 + 2.8\left(\frac{1}{V_{S1}^* - V_{S1}} - \frac{1}{V_{S1}^*}\right)$$

where

V_{S1} = the shear wave velocity corrected for overburden stress

V_{s1}^* = the limiting value of V_{S1} for cyclic liquefaction occurrence

V_{S1} is computed by

$$V_{S1} = V_S\left(P_a / \sigma'_{vo}\right)^{0.25}$$

where

P_a = the reference stress of about atmospheric pressure

σ'_{vo} = effective vertical stress

V_{S1}^* is computed by the following

V_{S1}^* = 215 m/s for FC ≤ 5%

V_{S1}^* = 215 – 0.5(FC – 5) m/s for 5% < FC < 35%

V_{S1}^* = 200 m/s for FC ≥ 35%

where

FC = fines content (%)

Figure 13 presents the V_{S1}^* vs CRR curves.

4. Results and Conclusions

Tables 3 and 4 summarize the liquefaction induced settlement using the new CRR curves and the old CRR curves, respectively. Individual CPT settlements (for a 7.5 magnitude earthquake) range from ¼ inch to 2 inches based on the new CRR curves while settlements range from ¼ inch to 1 ¾ inches based on the old CRR curves. The weighted average using the USGS PGA hazard deaggregation for weighting is less than ½ inch for the 2,500 year earthquake. These settlements are expected to occur rather uniformly and thus not contribute significantly to differential settlement.

Liquefaction potential based on the CRR determination using shear wave velocity indicates the soil is generally only slightly susceptible to liquefaction. The minimum factors of safety from the SCPTs range from 0.55 to more than 4.0. Generally the factors of safety are in excess of 3.0 for the vast majority of the soil column. See the attached summary pages in Appendix D. Settlements were not calculated using factors of safety determined through the use of shear wave velocities since the SRS volumetric strain curves are correlated to CPT tip stresses.

5. References

1. Andrus, R.D., and Stokoe, K.H., 2000. Liquefaction Resistance of Soils from Shear-Wave Velocity, Journal of Geotechnical and Environmental Engineering, Vol. 126, No. 11.

2. Bechtel Savannah River, Inc. (BSRI), 1993. WSRC-RP-93-606, Rev. 0, Savannah River Site, Replacement Tritium Facility (233H) Geotechnical Investigation (U), April 1993.

3. Frankel, A., 1999. USGS, Letter to R.C. Lee, Re. Results of USGS calculation of SRS PSHA, March 1, 1999.

4. IBC 2006, 2006 International Building Code, January 2006.

5. Idriss, I. M. and Boulanger R. W., 2004. Semi-empirical procedures for evaluating liquefaction potential during earthquakes, Proceedings Joint 11th International Conference on Soil Dynamics and Earthquake Engineering and the 3rd International Conference on Earthquake Geotechnical Engineering, Berkeley, CA 32-56.

6. National Research Council (NRC), 1985. Liquefaction of Soils During Earthquakes, National Academy Press, Washington, D. C., 1985.

7. NCEER, 1997. Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils, National Center for Earthquake Engineering Research, Technical Report No. NCEER-97-0022, State University of New York at Buffalo, NY, December 31, 1997.

8. Seed, R. B., and Harder, L. F. Jr., 1990. SPT-Based Analysis of Cyclic Pore Pressure Generation and Undrained Residual Strength, H. Bolton Seed Memorial Symposium Proceedings, Vol. 2., Vancouver, B.C., Canada, May, 1990.

9. Seed, H.B. and Idriss, I. M., 1971. Simplified Procedure for Evaluating Soil Liquefaction Potential, Journal of the Soil Mechanics and Foundation Division, ASCE, Vol. 97, SM9, New York, NY, 1971.

10. Seed, H. B. and Idriss, I. M., 1982. Ground Motions and Soil Liquefaction During Earthquakes, Earthquake Engineering Research Center (EERC) Monogram, Berkeley, California, December 1982.

11. SRS 1994a, K-CLC-H-00062, Rev. 0, ITP – Site Specific K-sigma Factor (U), November 1994.

12. SRS 1994b, K-CLC-H-00064, Rev. 0, ITP-Volumetric Strain (U), November 1994.

13. SRS 2001, K-CLC-G-00065, Rev. 0, CPTU Fines Content Determination, August 2001.

14. SRS 2006a, K-CLC-Z-00010, Rev. 0, Liquefaction Analysis for Saltstone Vault No. 2, March 2006.

15. SRS 2006b, C-CLC-H-00815, Rev. 1, Probabilistic Liquefaction Settlement Evaluation for ITP (U), October 2006.

16. SRS 2007a, K-CLC-H-00063, Rev. 2, ITP – Cyclic Strength (U), June 2007.

17. SRS 2007b, K-ESR-G-00012, Rev. 0, Justification for Revising SRS Cyclic Resistance Ratio Curves (U), July 2007.

18. SRS 2009a, K-CLC-Z-00012, Rev. 0, Stratigraphy for Saltstone Disposal Cells 3 and 5, April 2009.

19. SRS 2009b, K-CLC-Z-00013, Rev. 0, Test Data Evaluation for Saltstone Disposal Cells 3 and 5, June 2009.

20. WSRC 1995, WSRC-TR-95-0057, Rev. 0, In-Tank Precipitation Facility (ITP) and H-Tank Farm (HTF) Geotechnical Report (U), September 1995.

21. WSRC-2003-00250, Rev. 0, An Updated Regional Water Table of the Savannah River Site and Related Coverages, December 2003.

22. Youd, T. L., Idriss, I. M., Andrus, R. D., Arango, I., Castro, G., Christian, J. T., Dobry, R., Finn, W. D., Harder Jr., L. F., Hynes, M. E., Ishihara, K., Koester, J. P., Liao, S. C., Marcuson III, W. F., Martin, G. R., Mitchell, J. K., Moriwaki, Y., Power, M. S., Robertson, P. K., Seed, R. B., and K. H. Stokoe II, 2001. Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils, Journal of Geotechnical and Environmental Engineering, Vol. 127, No. 10, October, 2001.

Tables

Table 1: Fines Content

Sample No.	Top Elevation (ft, msl)	Bottom Elevation (ft, msl)	Engineering Layer	Percent Fines
Z-V3V5-B1-ST1	246.9	244.9	S1/2	10.1
Z-V3V5-B1-ST2	236.9	234.9	S1/2	9.5
Z-V3V5-B1-ST3	229.9	227.9	S1/2	39.9
Z-V3V5-B1-ST4	216.9	215.65	S1/2	4.9
Z-V3V5-B1-ST5	211.9	209.9	S3	5.8
Z-V3V5-B2-SS9,10,11	243.9	237.9	S1/2	7.3
Z-V3V5-B3-SS1,2,3	258.3	252.3	S1/2	31.4
Z-V3V5-B3-SS7,8,9	246.3	240.3	S1/2	7.4
Z-V3V5-B4-ST1	252.8	250.8	S1/2	36.5
Z-V3V5-B4-ST2	242.8	240.8	S1/2	8.1
Z-V3V5-B4-ST3	237.8	236.14	S1/2	8.2
Z-V3V5-B4-ST4	222.8	220.8	S1/2	42.2
Z-V3V5-B4-ST5	217.8	215.8	C2	80.1
Z-V3V5-B4-ST6	188.8	186.8	S1/2	24.6

Table 2: USGS Rock Seismic Hazard: 100 Hz Oscillator Frequency, 2,500 Year Return Period, S_a = 0.15 g

Distance	Mw = 4.5 to 5.0	Mw = 5.0 to 5.5	Mw = 5.5 to 6.0	Mw = 6.0 to 6.5	Mw = 6.5 to 7.0	Mw = 7.0 to 8.0
7.5 km	7.13	3.56	1.73	0.78	0.42	0.00
20 km	4.93	3.64	2.35	1.28	0.78	0.00
37.5 km	3.11	3.90	4.04	3.24	2.72	0.00
75 km	0.33	0.93	2.05	3.24	0.00	16.45
150 km	0.03	0.14	0.59	1.68	0.00	29.25
250 km	0.00	0.00	0.00	0.04	0.00	1.63
550 km	0.00	0.00	0.00	0.00	0.00	0.08
Mw Bin Sum =	15.52	12.16	10.76	10.25	3.92	47.40

Note: ⅓ wt Frankel et al. attenuation model, ⅓ wt Toro et al. attenuation model and ⅓ wt AB95 attenuation model

Table 3: Liquefaction Based on New SRS CRR Curves

	Settlement (inches)						
	M_w = 4.75	**M_w = 5.25**	**M_w = 5.75**	**M_w = 6.25**	**M_w = 6.75**	**M_w = 7.5**	**2,500 Yr Weighting**
Z-V3V5-C01	0.00	0.00	0.00	0.01	0.07	0.49	0.24
Z-V3V5-C02	0.00	0.00	0.04	0.16	0.47	1.93	0.95
Z-V3V5-C03	0.00	0.00	0.00	0.04	0.13	0.70	0.34
Z-V3V5-C04	0.00	0.00	0.00	0.00	0.02	0.24	0.12
Z-V3V5-C05	0.00	0.00	0.00	0.01	0.05	0.43	0.21
Z-V3V5-C06	0.00	0.00	0.02	0.08	0.29	1.30	0.64
Z-V3V5-C07	0.00	0.00	0.01	0.03	0.15	0.79	0.38
Z-V3V5-C08	0.00	0.00	0.01	0.07	0.24	1.16	0.57
Z-V3V5-C09	0.00	0.00	0.02	0.11	0.34	1.68	0.82
Z-V3V5-C10	0.00	0.00	0.00	0.01	0.10	0.78	0.38
Z-V3V5-C11	0.00	0.00	0.00	0.01	0.04	0.38	0.18
Z-V3V5-C12	0.00	0.00	0.01	0.05	0.19	1.00	0.49
Z-V3V5-C13	0.00	0.00	0.00	0.01	0.07	0.50	0.24
Z-V3V5-C14	0.00	0.00	0.00	0.03	0.13	0.88	0.43
Z-V3V5-C15	0.00	0.00	0.00	0.05	0.20	1.22	0.59
Z-V3V5-C16	0.00	0.00	0.02	0.10	0.32	1.48	0.73
Z-V3V5-C17	0.00	0.00	0.01	0.10	0.32	1.64	0.80
					Average	0.98	0.48

Table 4: Liquefaction Based on Old SRS CRR Curves

	Settlement (inches)						
	M_w = 4.75	M_w = 5.25	M_w = 5.75	M_w = 6.25	M_w = 6.75	M_w = 7.5	2,500 Yr Weighting
Z-V3V5-C01	0.00	0.00	0.00	0.02	0.10	0.58	0.28
Z-V3V5-C02	0.00	0.00	0.01	0.10	0.33	1.66	0.81
Z-V3V5-C03	0.00	0.00	0.00	0.02	0.10	0.54	0.26
Z-V3V5-C04	0.00	0.00	0.00	0.02	0.08	0.41	0.20
Z-V3V5-C05	0.00	0.00	0.00	0.01	0.11	0.61	0.30
Z-V3V5-C06	0.00	0.00	0.01	0.11	0.33	1.65	0.81
Z-V3V5-C07	0.00	0.00	0.00	0.04	0.14	0.78	0.38
Z-V3V5-C08	0.00	0.00	0.00	0.06	0.24	1.22	0.59
Z-V3V5-C09	0.00	0.00	0.00	0.09	0.34	1.78	0.87
Z-V3V5-C10	0.00	0.00	0.00	0.04	0.24	1.31	0.64
Z-V3V5-C11	0.00	0.00	0.00	0.00	0.03	0.21	0.10
Z-V3V5-C12	0.00	0.00	0.00	0.04	0.17	0.94	0.45
Z-V3V5-C13	0.00	0.00	0.00	0.01	0.06	0.39	0.19
Z-V3V5-C14	0.00	0.00	0.00	0.03	0.19	1.06	0.51
Z-V3V5-C15	0.00	0.00	0.00	0.03	0.20	1.13	0.55
Z-V3V5-C16	0.00	0.00	0.01	0.07	0.24	1.21	0.59
Z-V3V5-C17	0.00	0.00	0.00	0.03	0.21	1.16	0.56
					Average	0.98	0.48

Figures

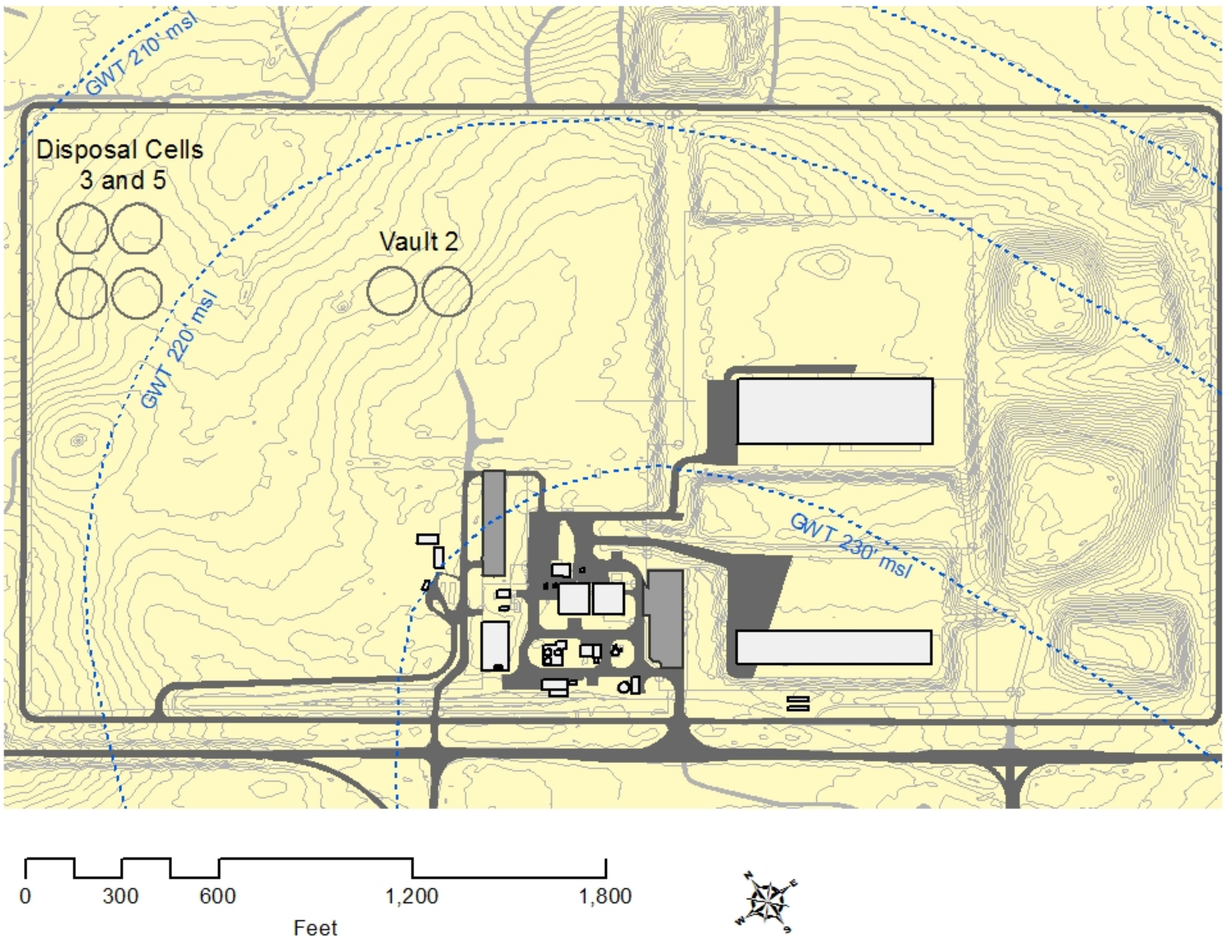


Figure 1: Location of Disposal Cells 3 and 5

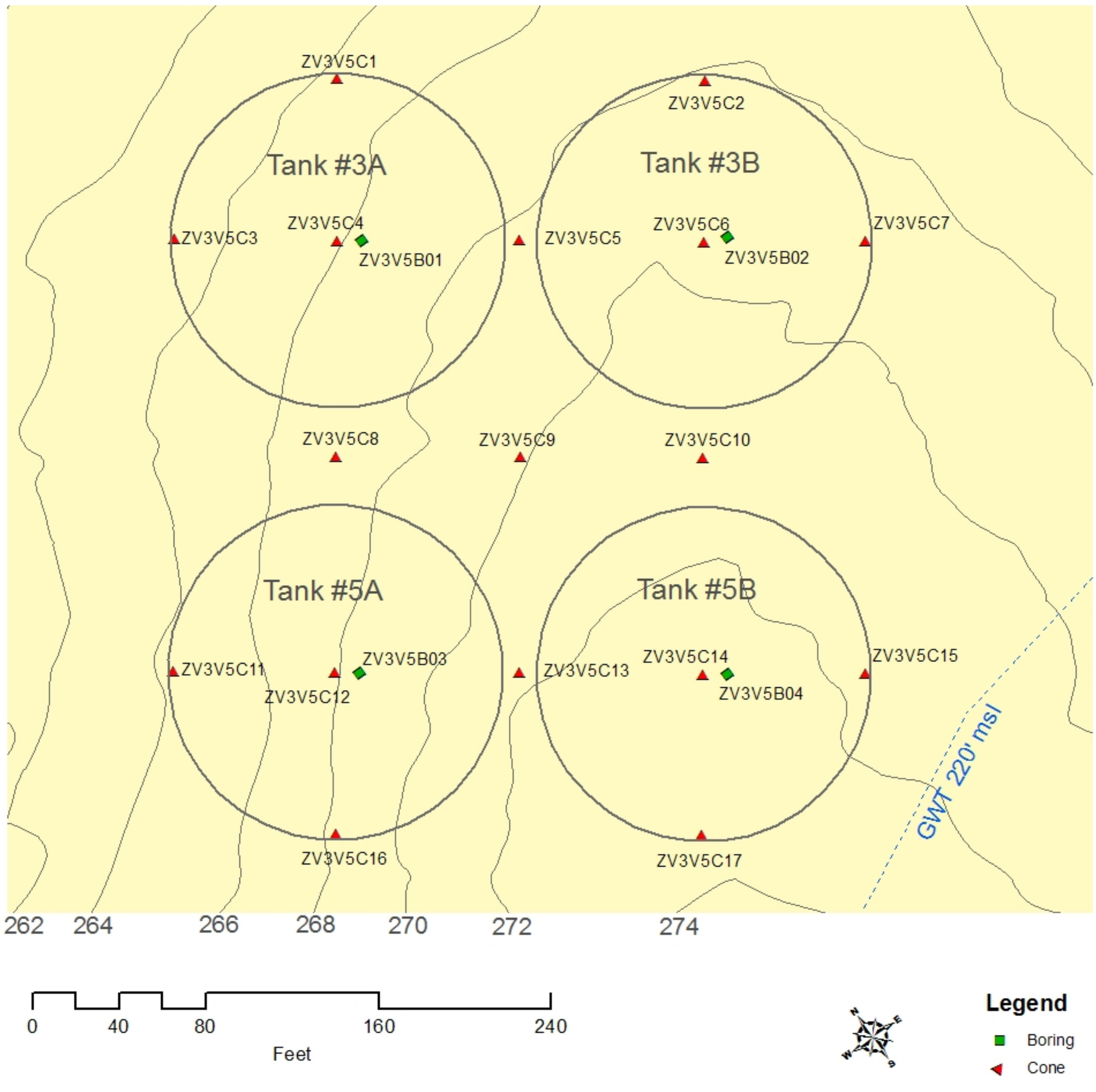


Figure 2: Saltstone Disposal Cells 3 and 5 Geotechnical Exploration Locations

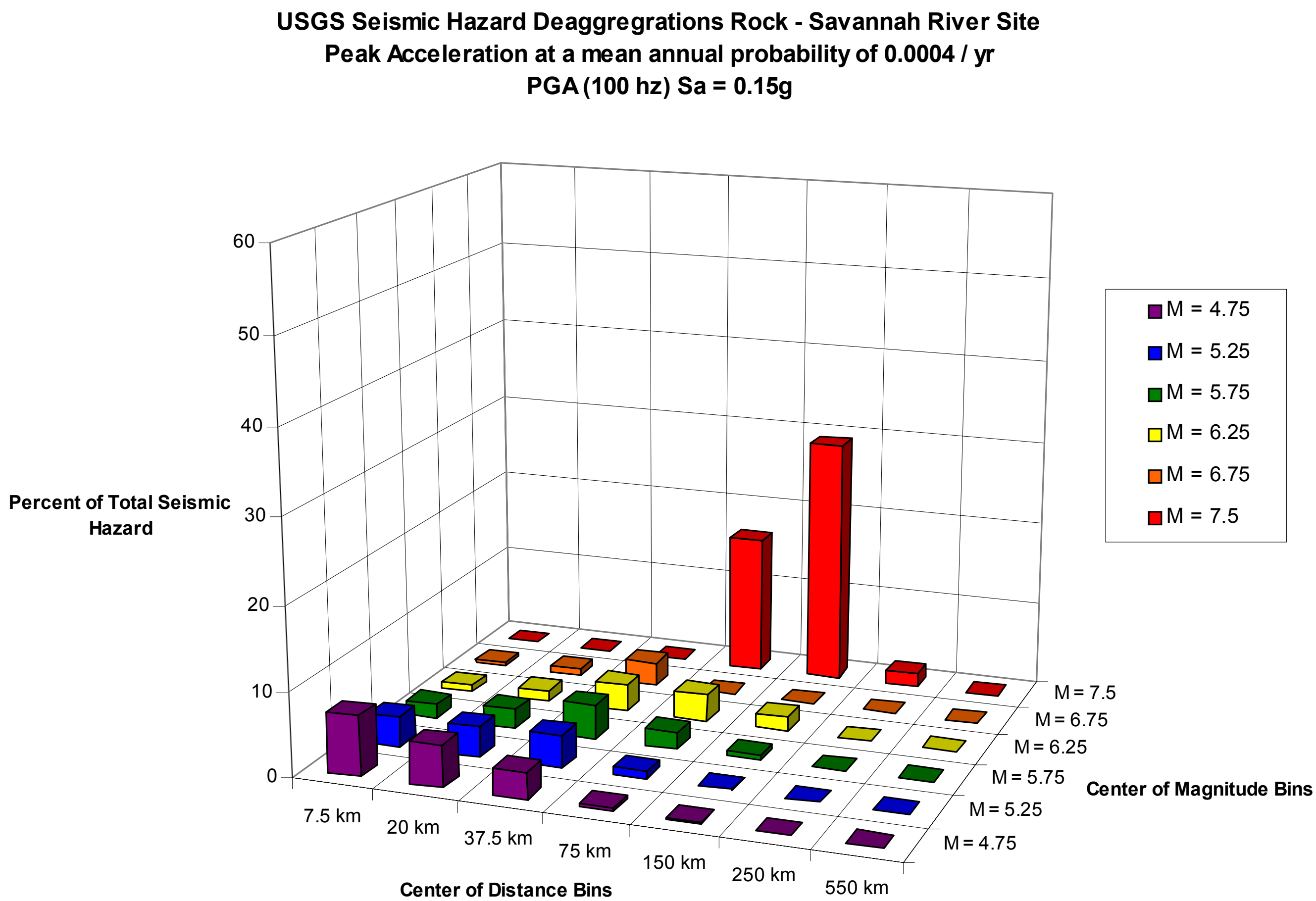


Figure 3: USGS Rock Seismic Hazard Deaggregation: 100 Hz, 2,500 Year Return, S_a = 0.15g

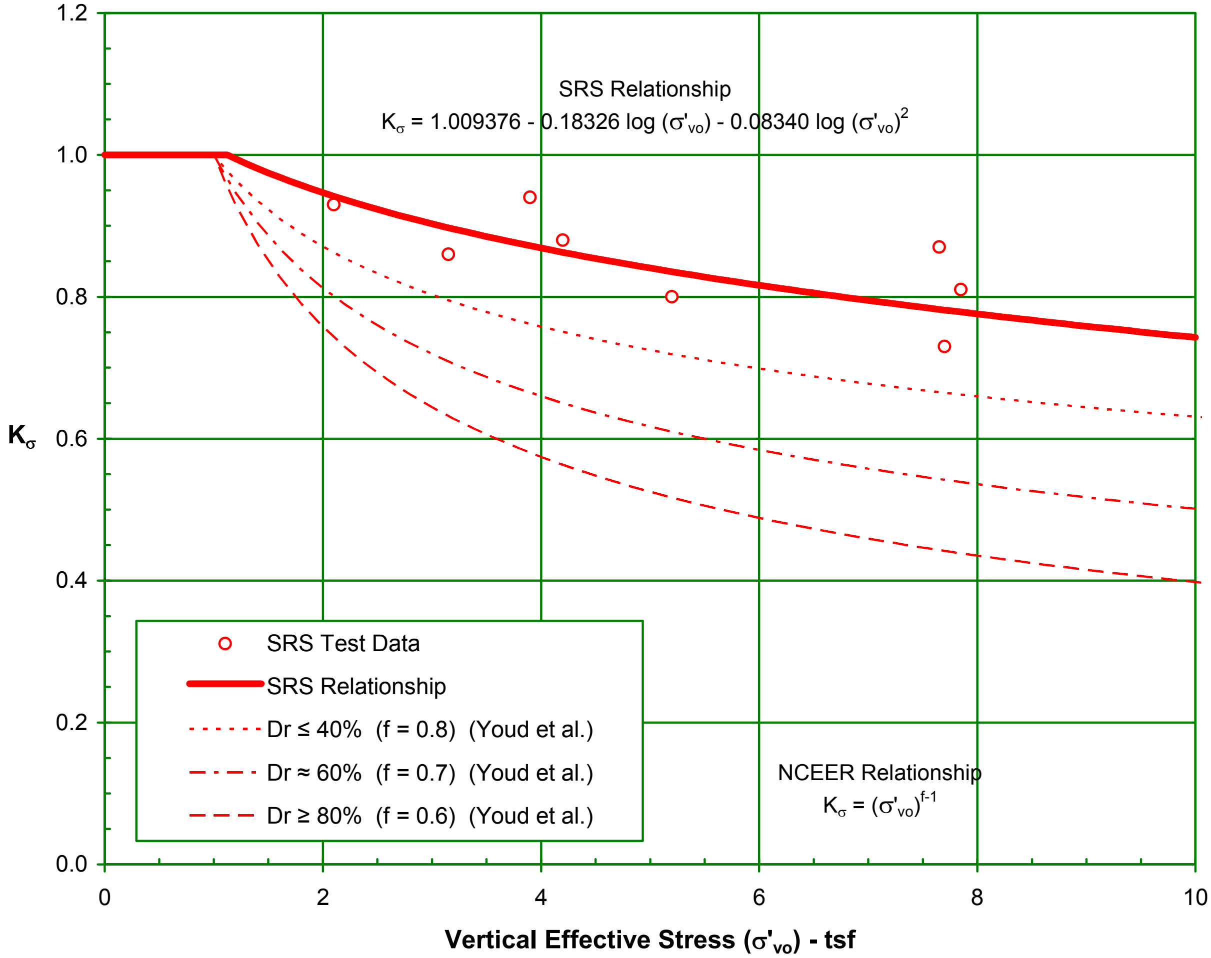


Figure 4: Comparison of NCEER Kσ with SRS Kσ

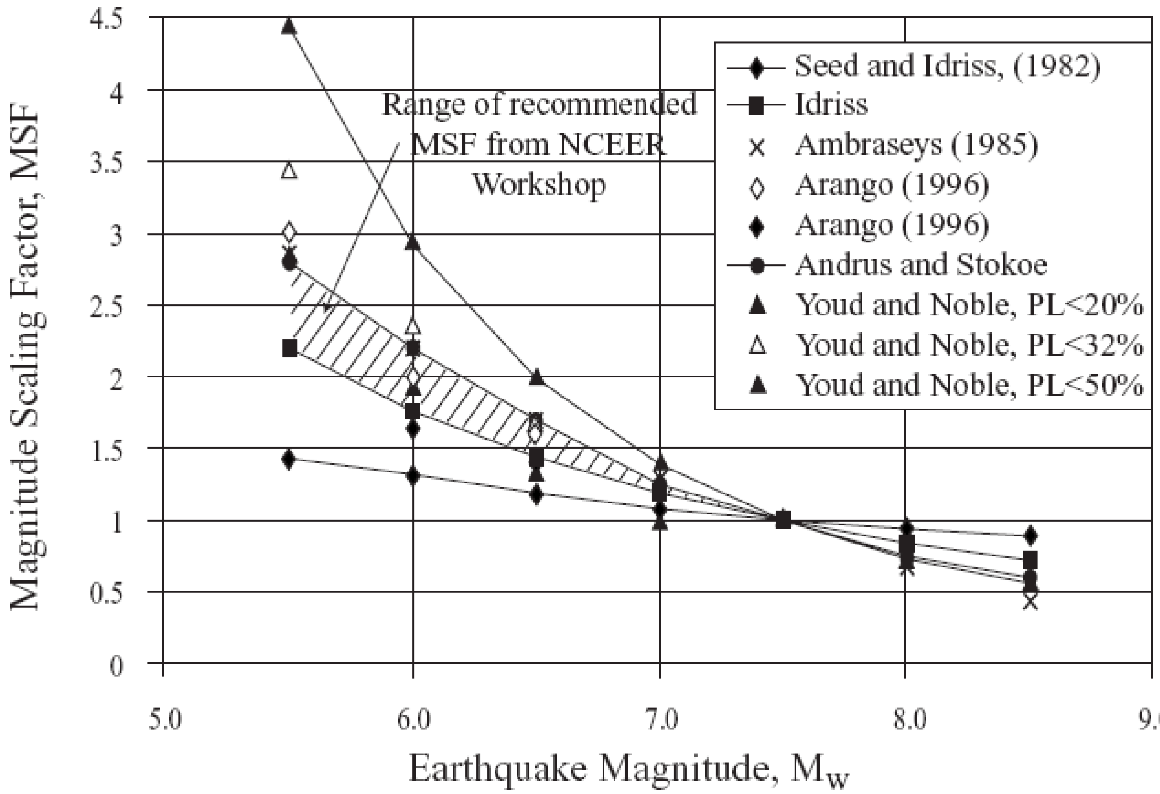


Figure 5: Magnitude Scaling Factor Recommendations Presented by NCEER

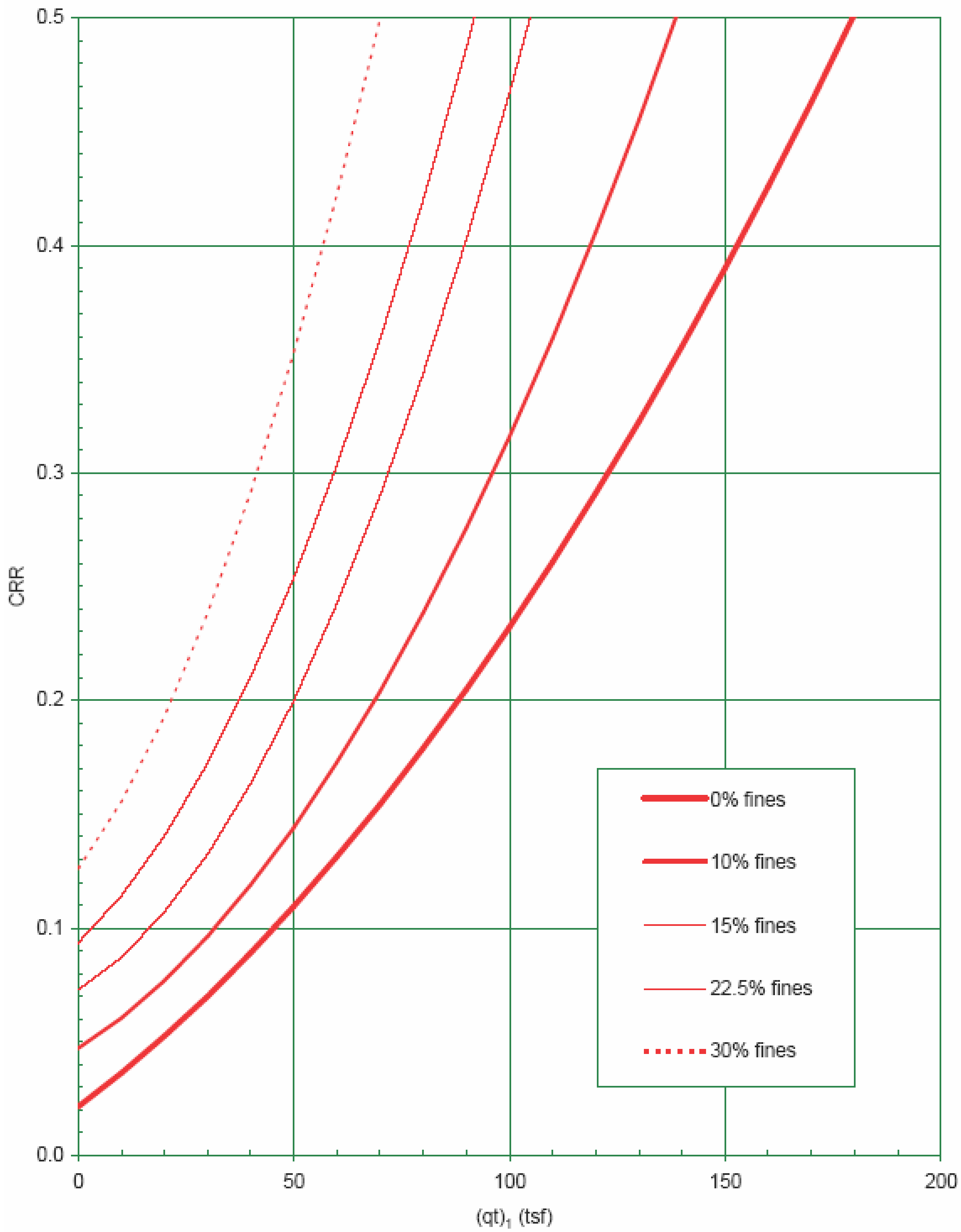


Figure 6: Old SRS Cyclic Resistance Ratio (CRR) Curves

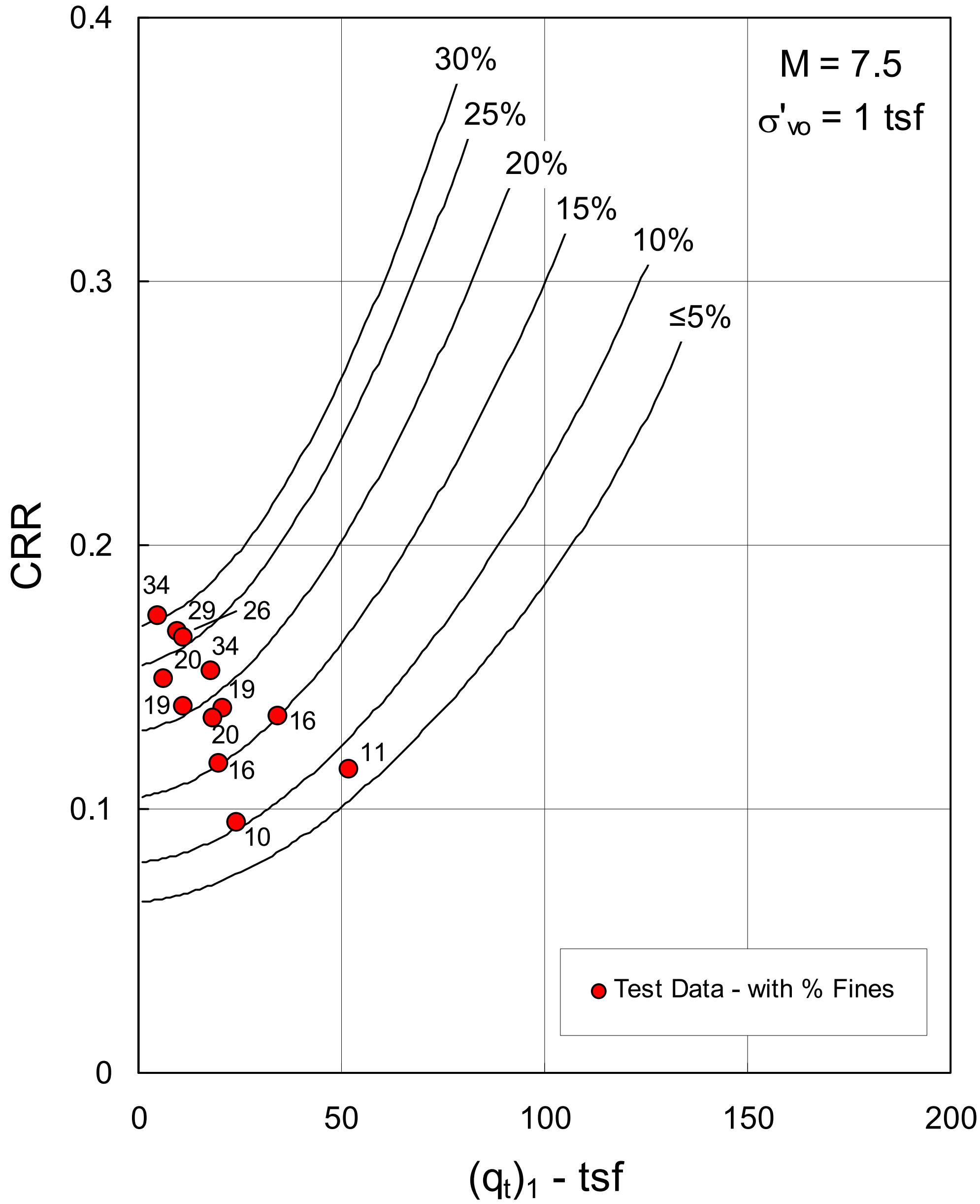


Figure 7: New SRS Cyclic Resistance Ratio (CRR) Curves

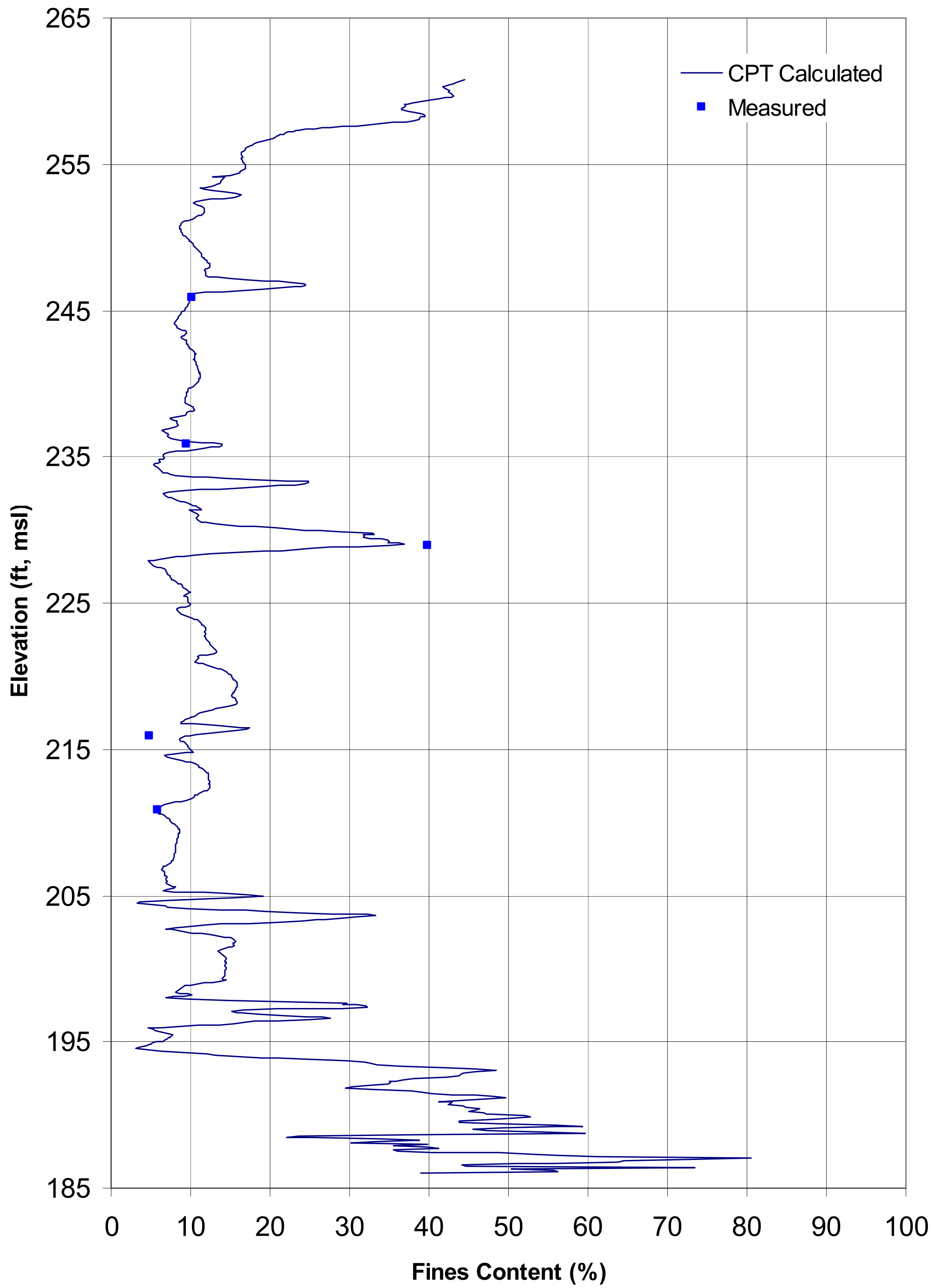


Figure 8: Comparison of Fine Content from Z-V3V5-C04 and Z-V3V5-B01

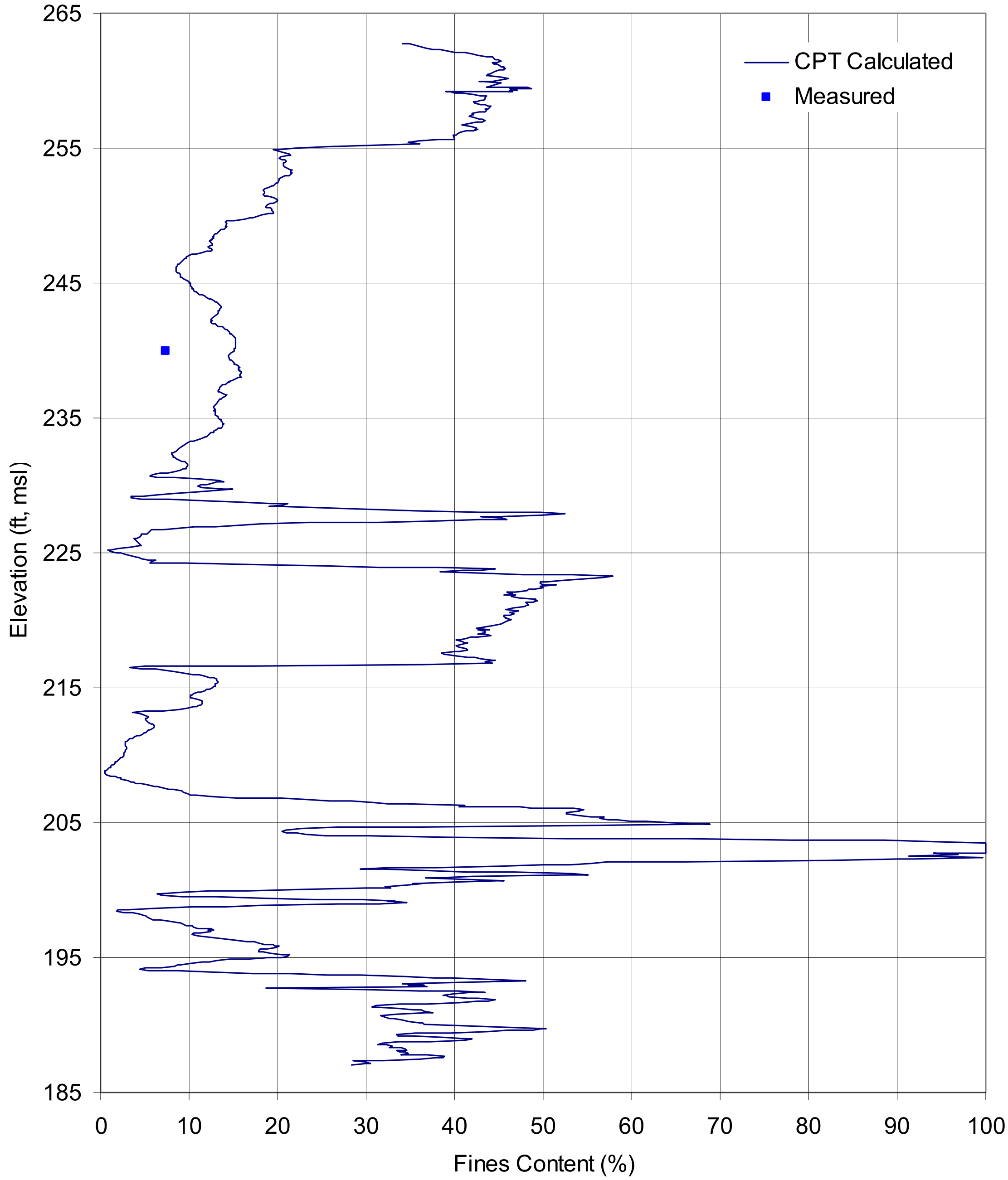


Figure 9: Comparison of Fine Content from Z-V3V5-C06 and Z-V3V5-B02

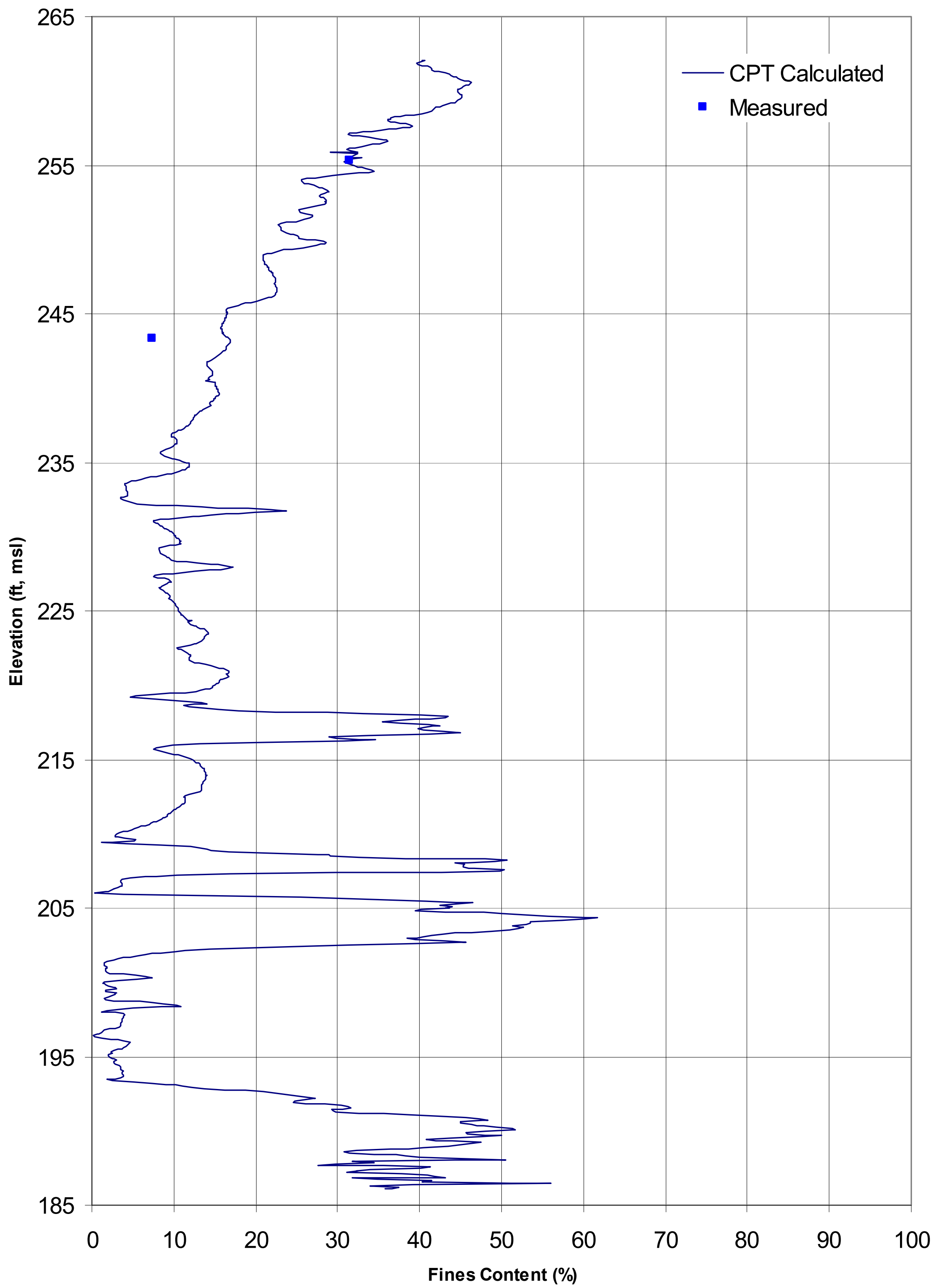


Figure 10: Comparison of Fine Content from Z-V3V5-C12 and Z-V3V5-B03

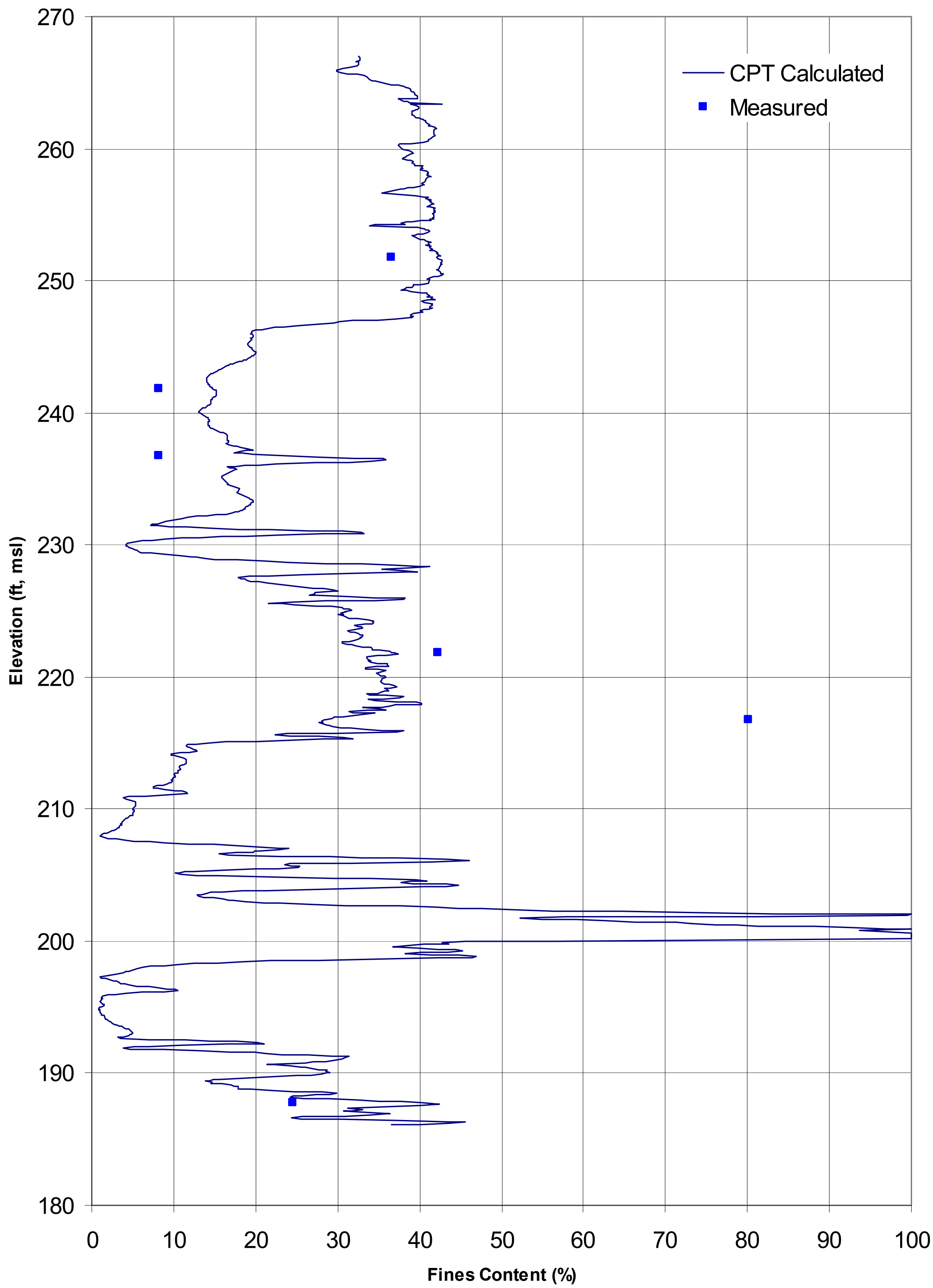


Figure 11: Comparison of Fine Content from Z-V3V5-C14 and Z-V3V5-B04

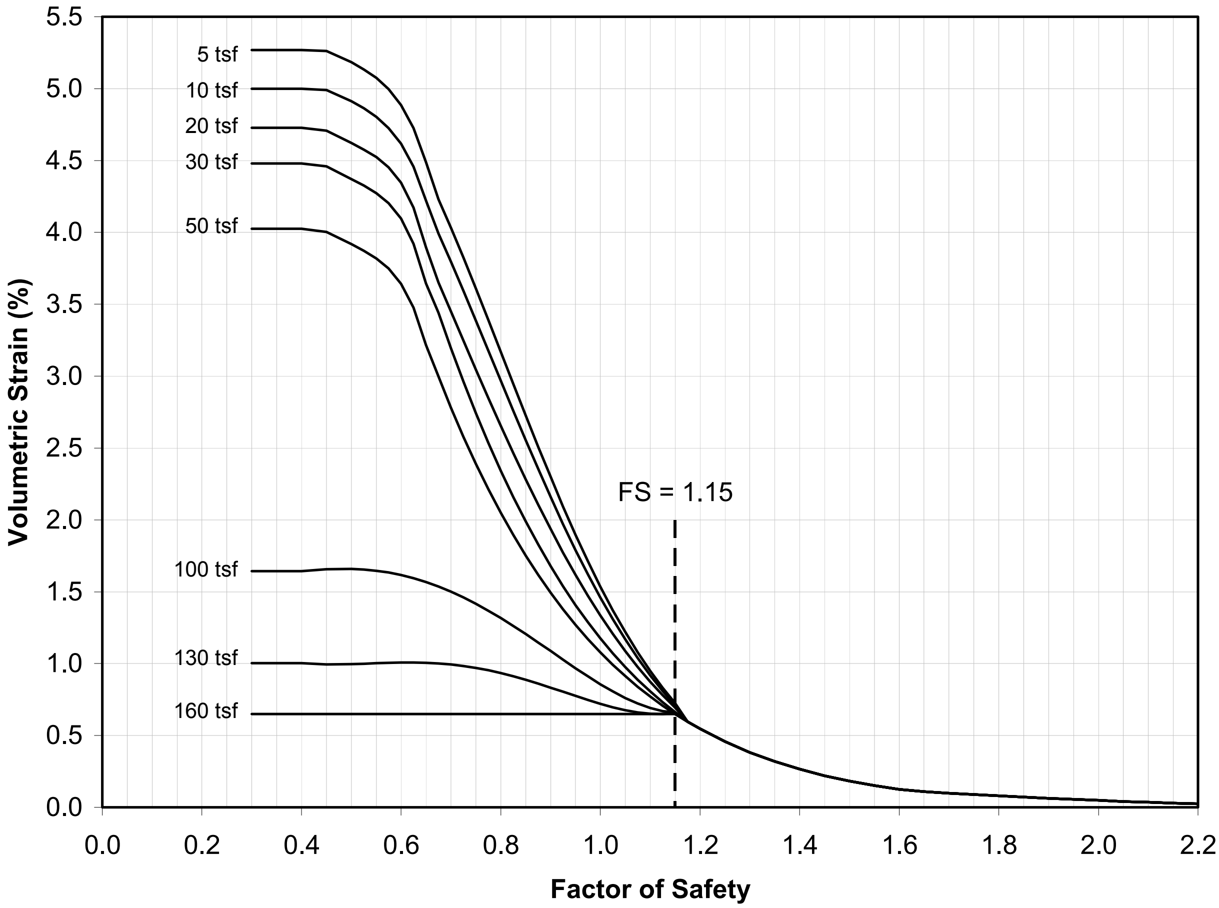


Figure 12: SRS Volumetric Strain Curves for Liquefaction Analysis

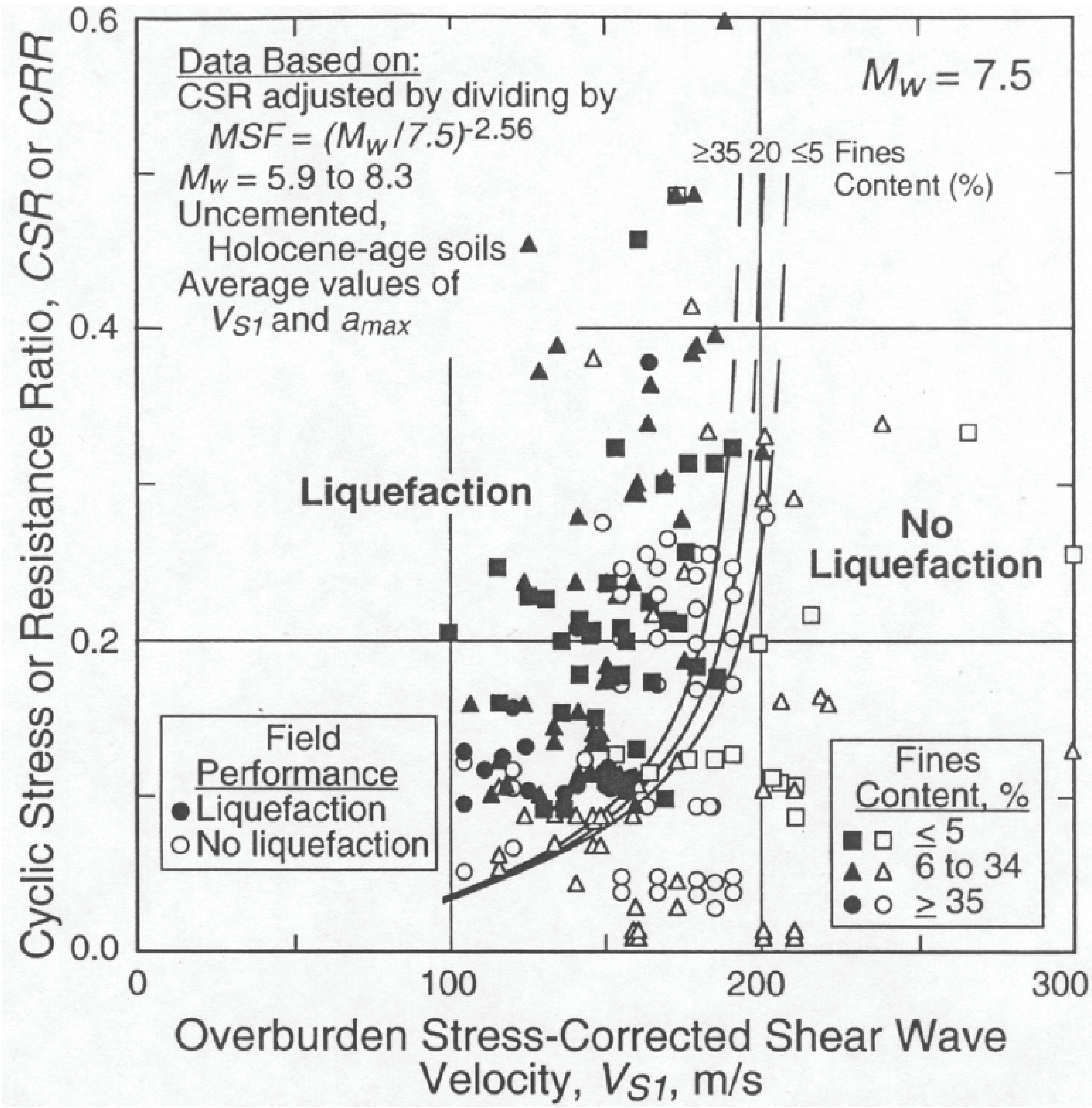
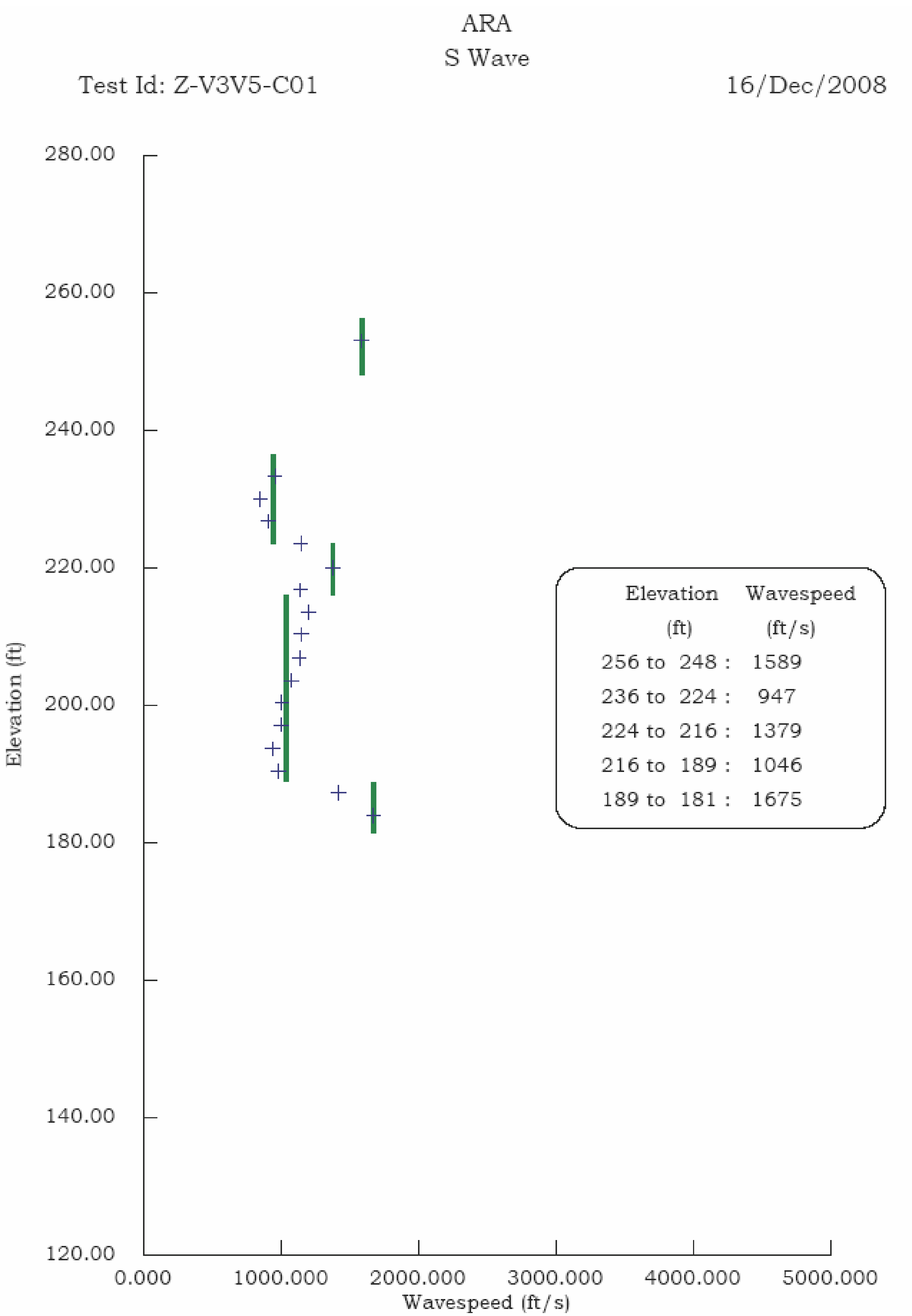
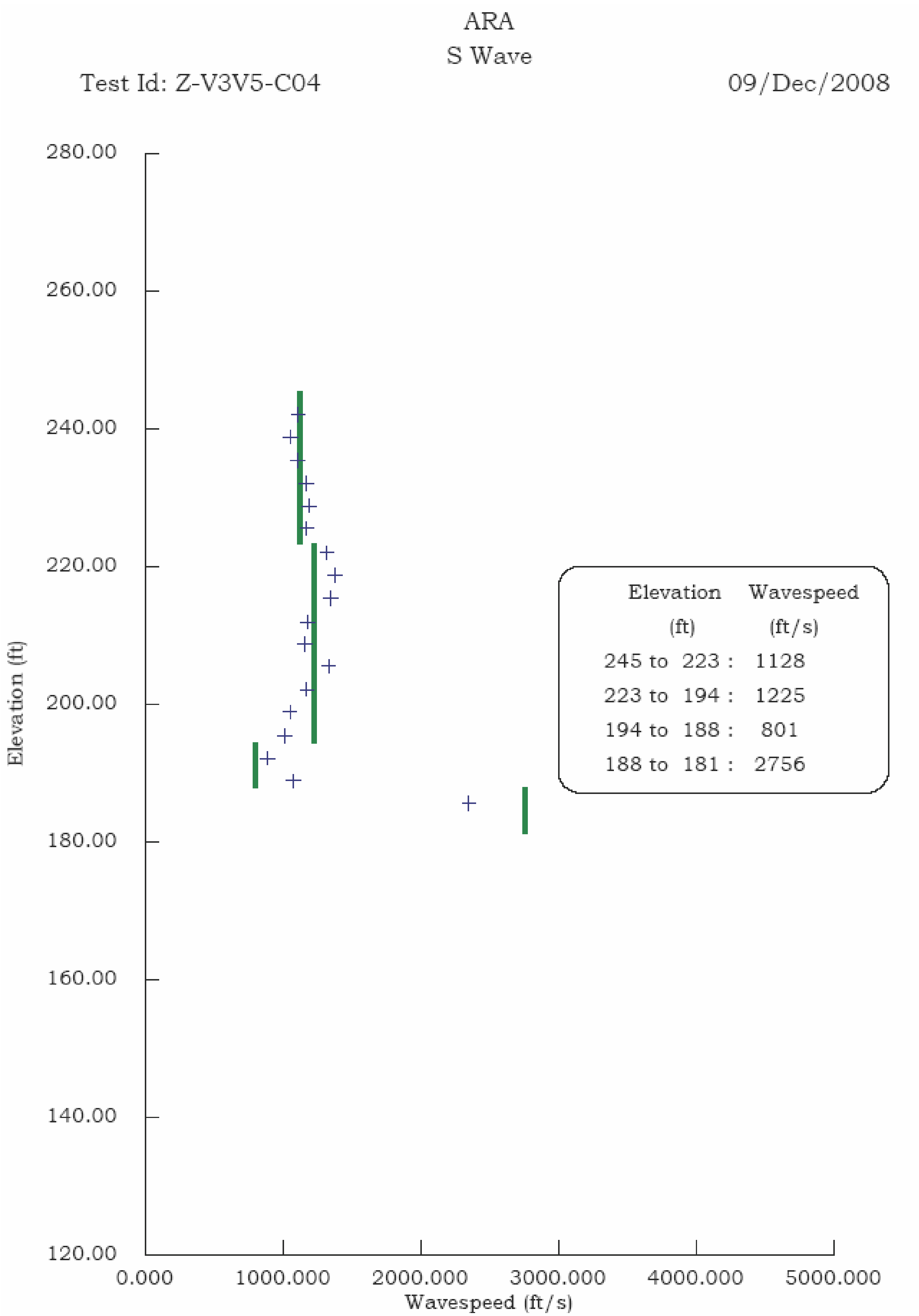


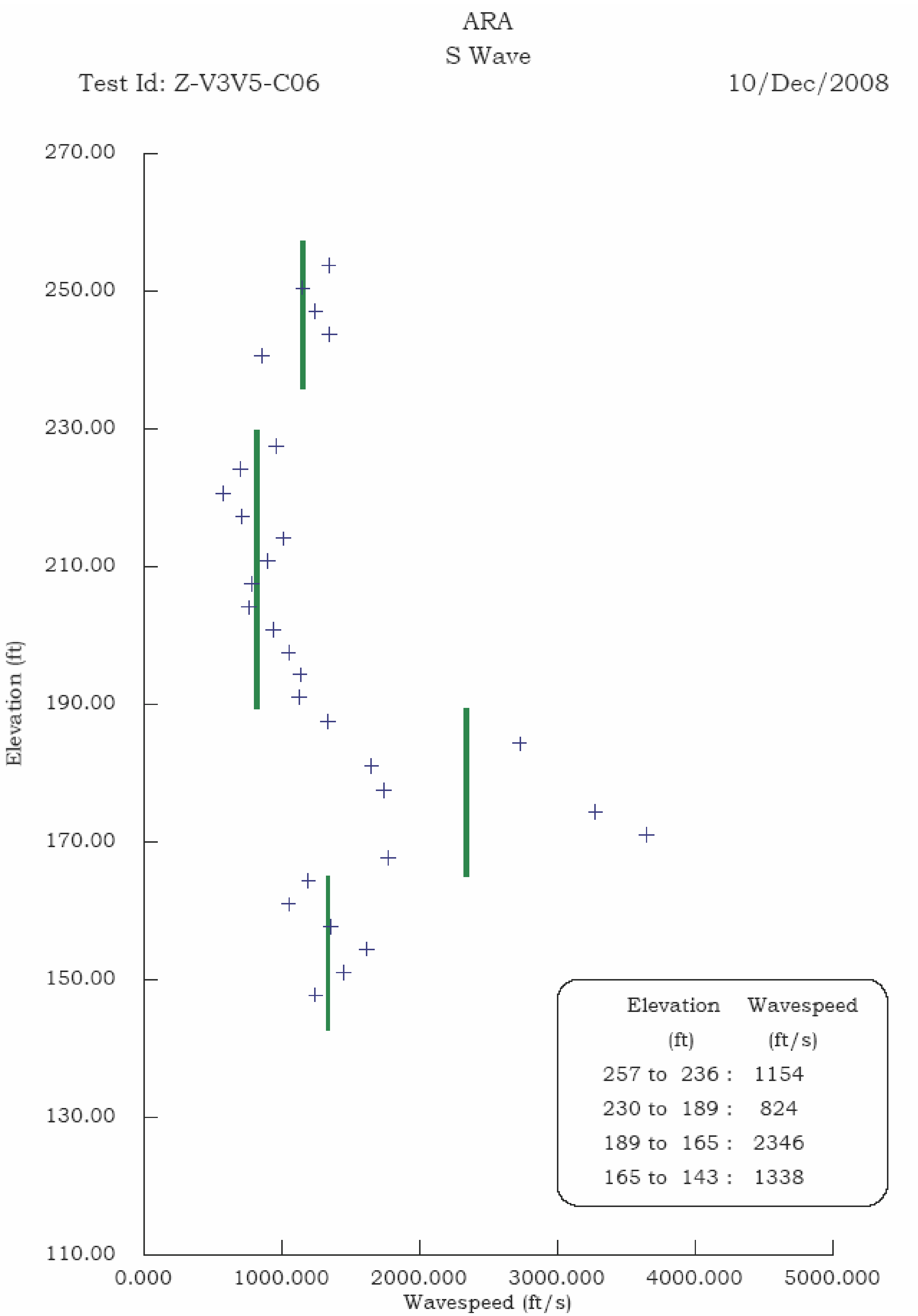
Figure 13: Relationship between CRR and V_{S1}*[*]

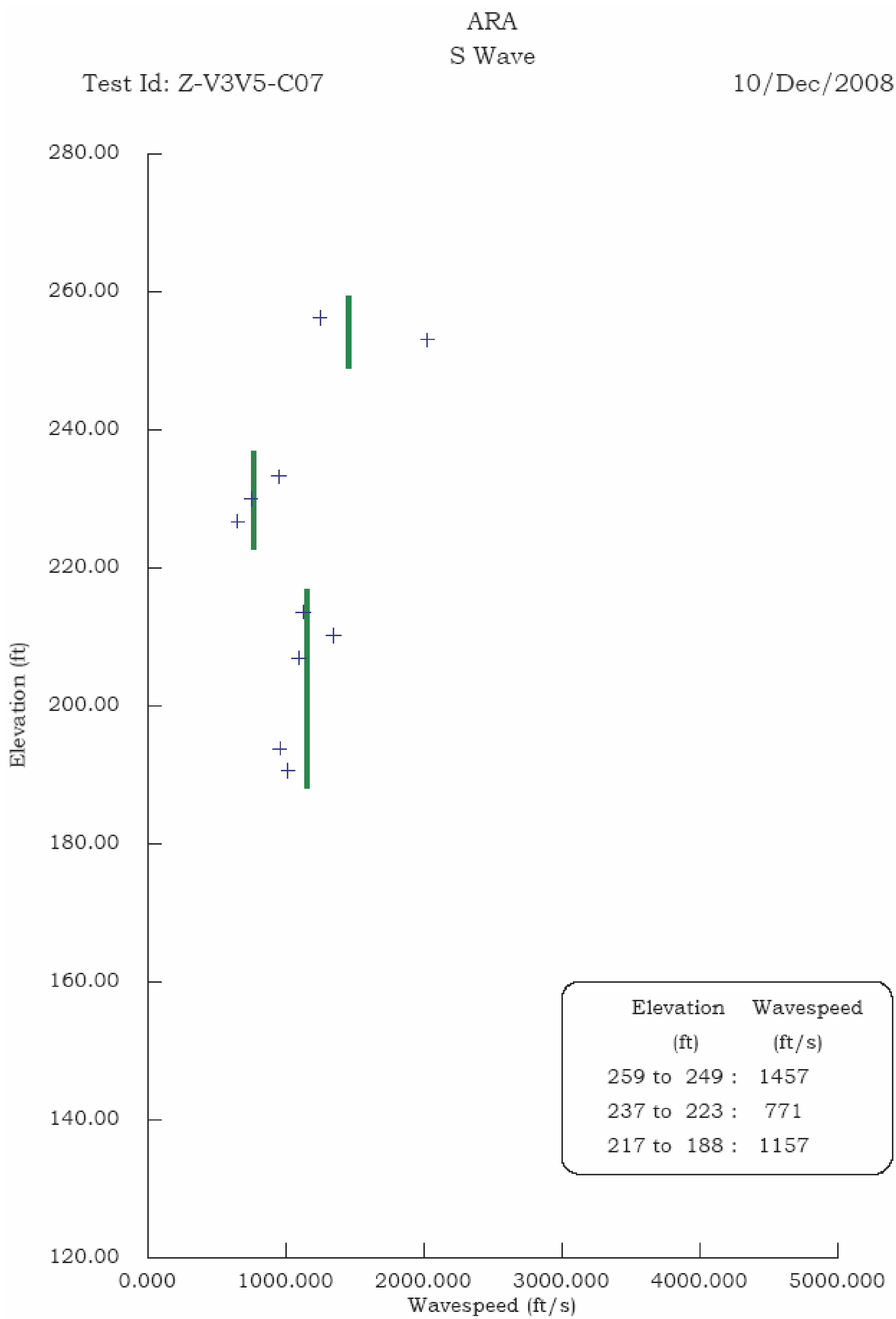
Appendix A – Seismic Data

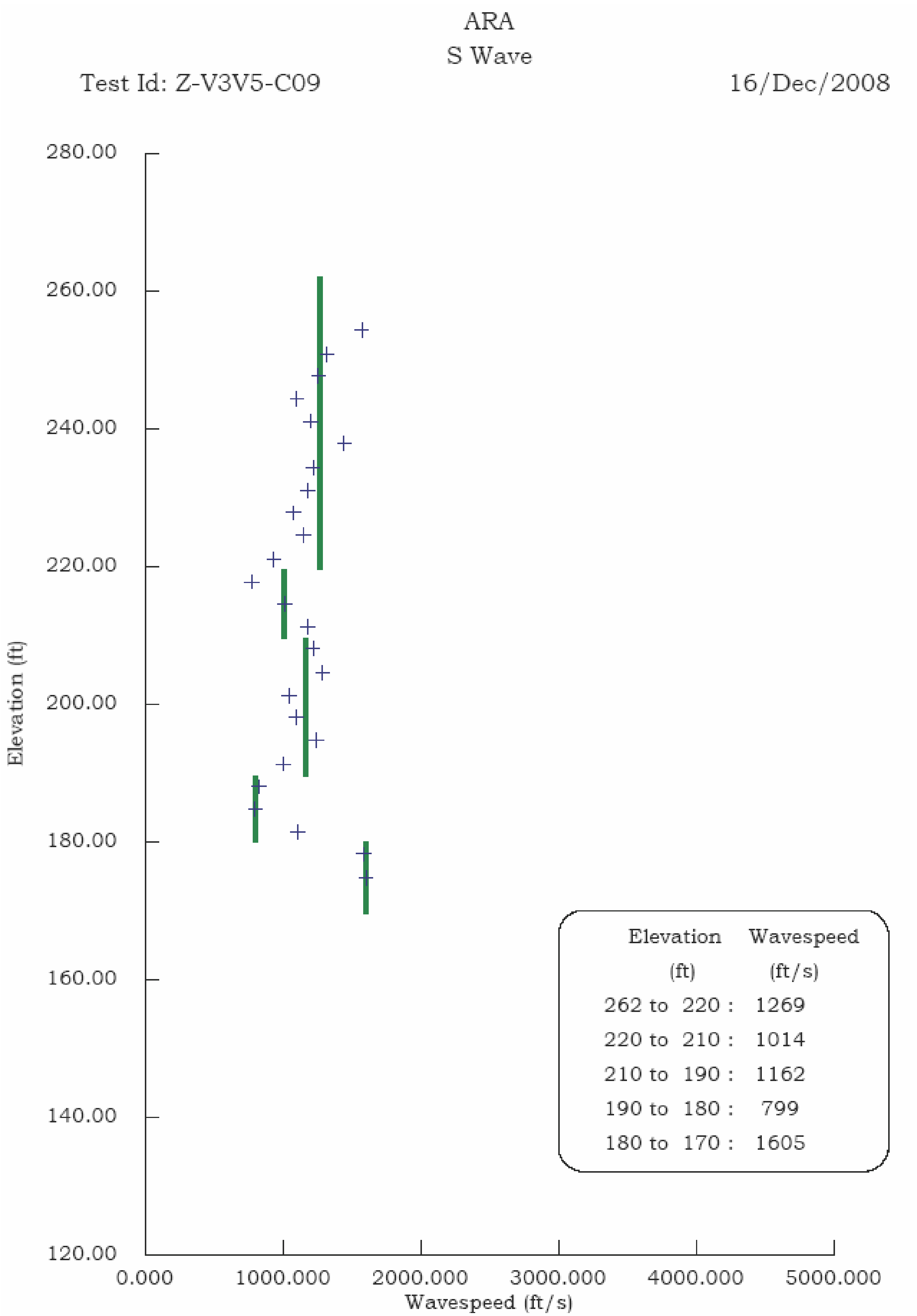


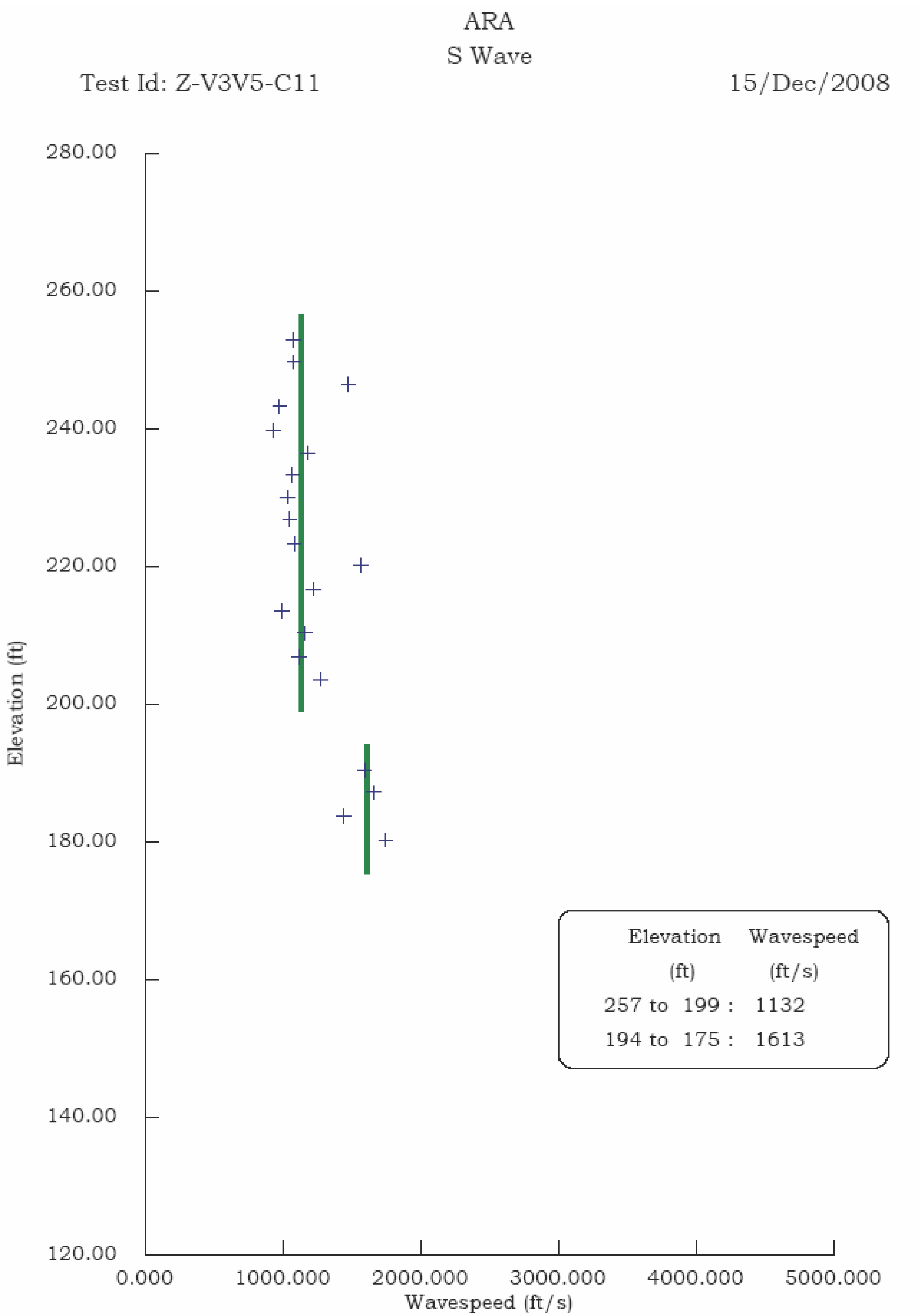
Elevation (ft)	Wavespeed (ft/s)
256 to 248 :	1589
236 to 224 :	947
224 to 216 :	1379
216 to 189 :	1046
189 to 181 :	1675

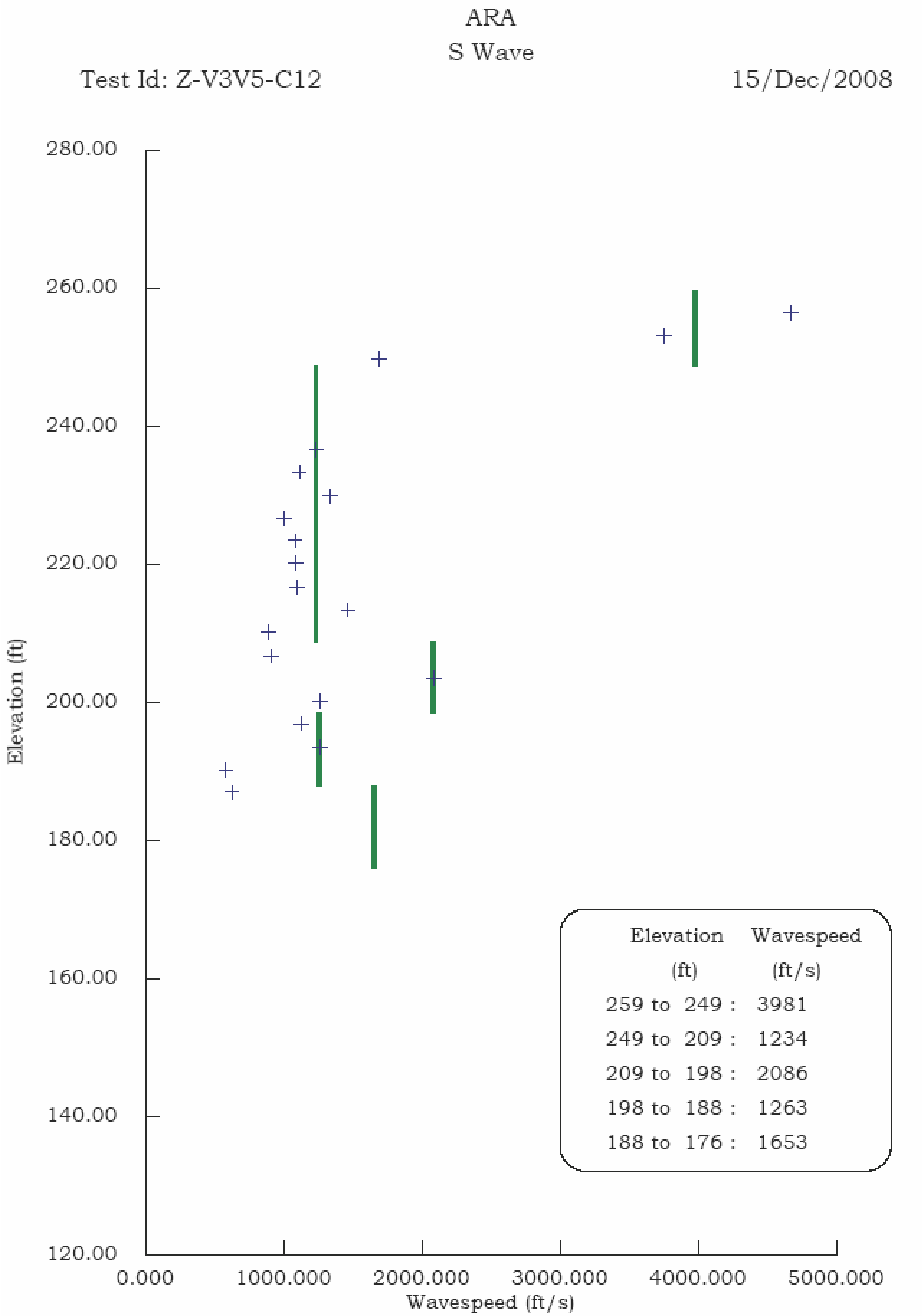

ARA
S Wave
Test Id: Z-V3V5-C04
09/Dec/2008
Elevation (ft)
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
0.000
1000.000
2000.000
3000.000
4000.000
5000.000
Wavespeed (ft/s)
Elevation (ft)
Wavespeed (ft/s)
245 to 223 : 1128
223 to 194 : 1225
194 to 188 : 801
188 to 181 : 2756

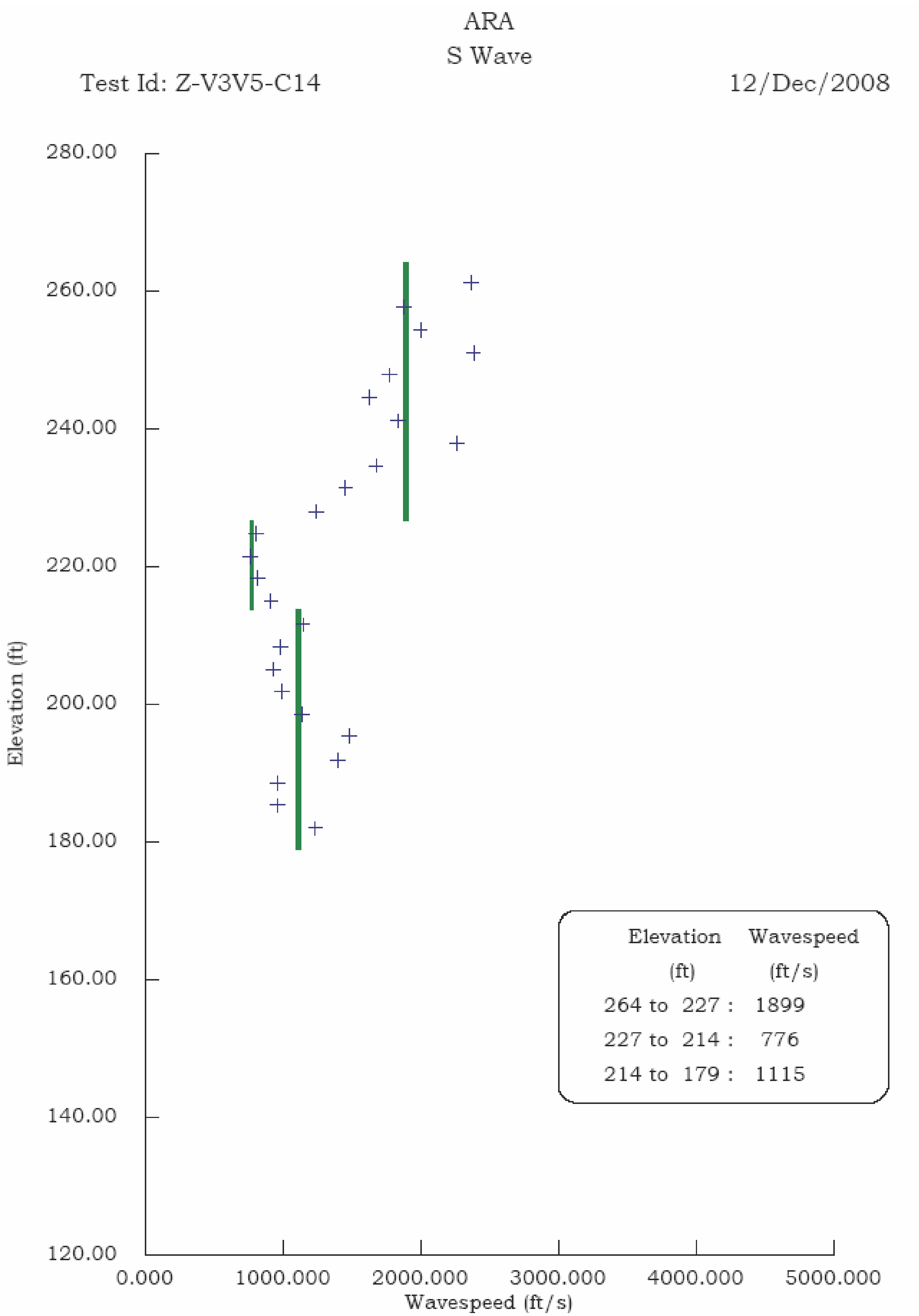

ARA
S Wave
Test Id: Z-V3V5-C06
10/Dec/2008
270.00
250.00
230.00
210.00
190.00
170.00
150.00
130.00
110.00
Elevation (ft)
0.000
1000.000
2000.000
3000.000
4000.000
5000.000
Wavespeed (ft/s)
Elevation (ft)
Wavespeed (ft/s)
257 to 236 : 1154
230 to 189 : 824
189 to 165 : 2346
165 to 143 : 1338

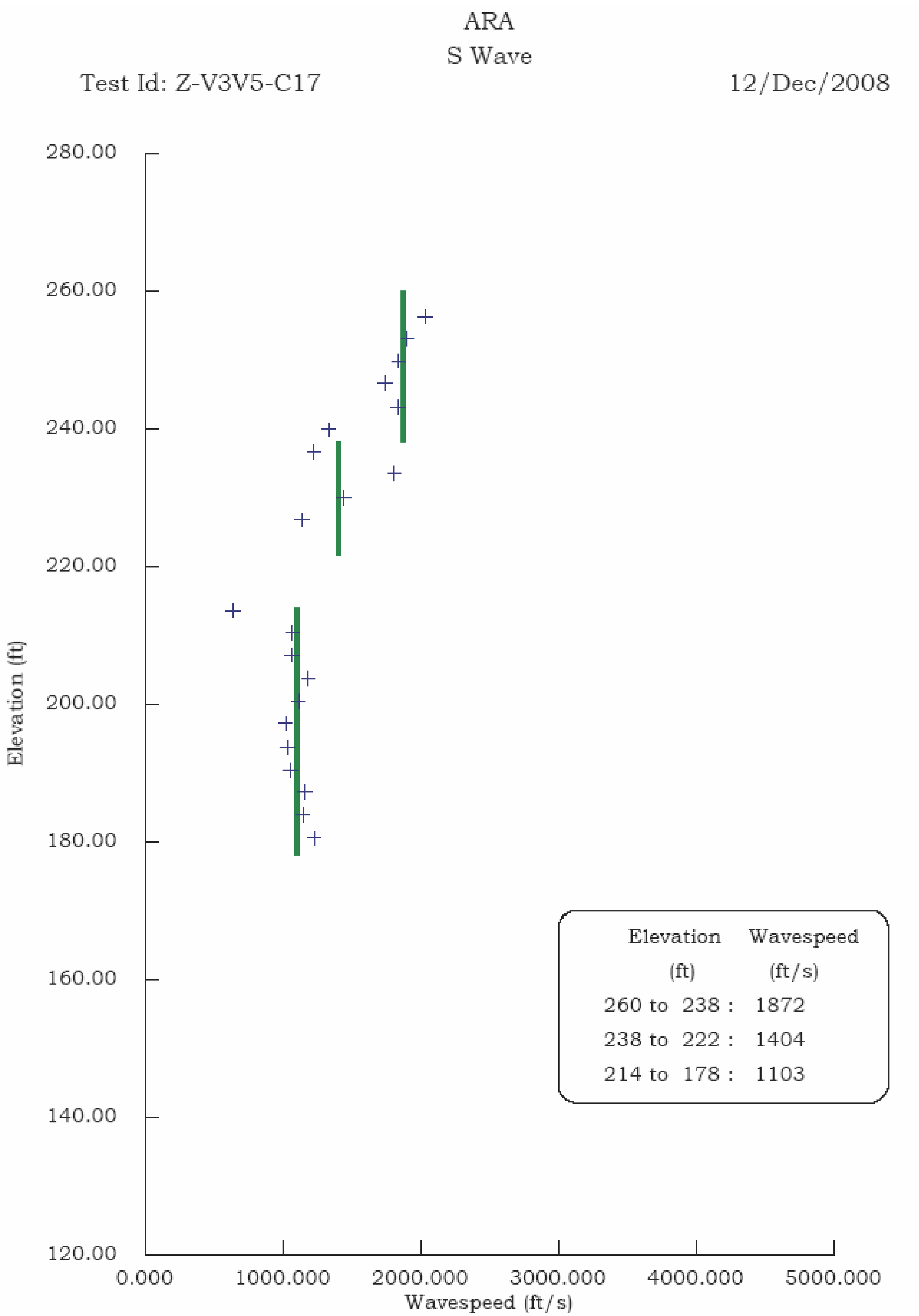

ARA
S Wave
Test Id: Z-V3V5-C07
10/Dec/2008
Elevation (ft)
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
0.000
1000.000
2000.000
3000.000
4000.000
5000.000
Wavespeed (ft/s)
Elevation (ft) Wavespeed (ft/s)
259 to 249 : 1457
237 to 223 : 771
217 to 188 : 1157


ARA
S Wave
Test Id: Z-V3V5-C09
16/Dec/2008
Elevation (ft)
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
0.000
1000.000
2000.000
3000.000
4000.000
5000.000
Wavespeed (ft/s)
Elevation (ft)
Wavespeed (ft/s)
262 to 220 : 1269
220 to 210 : 1014
210 to 190 : 1162
190 to 180 : 799
180 to 170 : 1605


ARA
S Wave
Test Id: Z-V3V5-C11
15/Dec/2008
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
Elevation (ft)
0.000
1000.000
2000.000
3000.000
4000.000
5000.000
Wavespeed (ft/s)
Elevation (ft)
Wavespeed (ft/s)
257 to 199 : 1132
194 to 175 : 1613


ARA
S Wave
Test Id: Z-V3V5-C12
15/Dec/2008
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
Elevation (ft)
0.000
1000.000
2000.000
3000.000
4000.000
5000.000
Wavespeed (ft/s)
Elevation (ft)
Wavespeed (ft/s)
259 to 249 : 3981
249 to 209 : 1234
209 to 198 : 2086
198 to 188 : 1263
188 to 176 : 1653


ARA
S Wave
Test Id: Z-V3V5-C14
12/Dec/2008
Elevation (ft)
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
0.000
1000.000
2000.000
3000.000
4000.000
5000.000
Wavespeed (ft/s)
Elevation (ft) Wavespeed (ft/s)
264 to 227 : 1899
227 to 214 : 776
214 to 179 : 1115


ARA
S Wave
Test Id: Z-V3V5-C17
12/Dec/2008
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
Elevation (ft)
0.000
1000.000
2000.000
3000.000
4000.000
5000.000
Wavespeed (ft/s)
Elevation (ft)
Wavespeed (ft/s)
260 to 238 : 1872
238 to 222 : 1404
214 to 178 : 1103

Appendix B – Response Spectra

Response Spectra Based on IBC 2006

S_S = 0.446 IBC Figure 1613.5(9) or USGS Website
S_1 = 0.129 IBC Figure 1613.5(9) or USGS Website

F_A = 1.443 IBC Table 1613.5.3(1) Site Class D
F_V = 2.284 IBC Table 1613.5.3(2) Site Class D

S_{MS} = 0.644 IBC Equation 16-37: $S_{MS} = F_a \times S_S$
S_{M1} = 0.295 IBC Equation 16-38: $S_{M1} = F_v \times S_1$

S_{DS} = 0.429 IBC Equation 16-39: $S_{DS} = (2/3)\ S_{MS}$
S_{D1} = 0.196 IBC Equation 16-40: $S_{D1} = (2/3)\ S_{M1}$

T_0 = 0.092 *SRS Standard 1060: $T_0 = 0.2\ (S_{D1}/S_{DS})$
T_S = 0.458 *SRS Standard 1060: $T_S = (S_{D1}/S_{DS})$

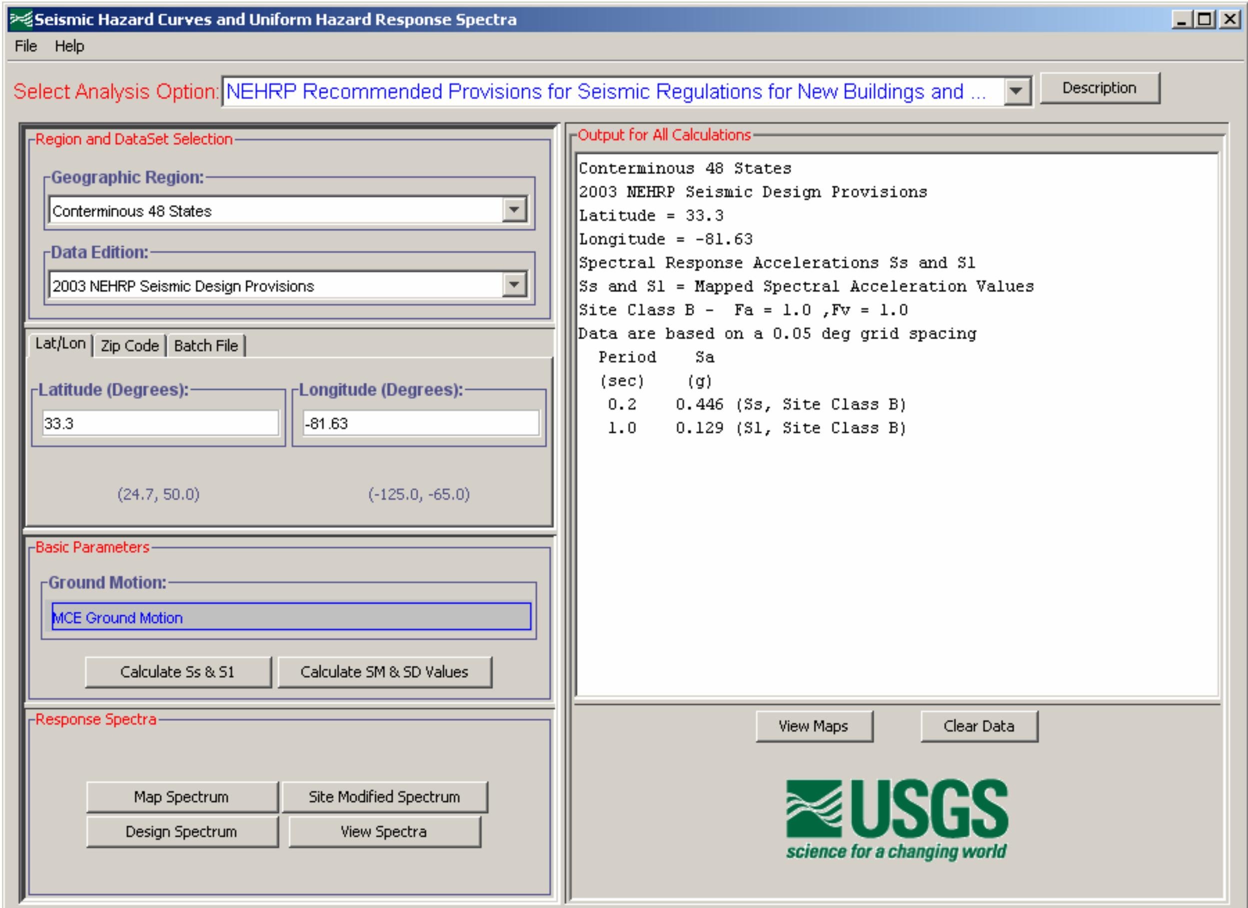
Period T (s)	Freq. (Hz)	Spectral Acceleration (g) IBC
0.00	---	0.172
0.01	100.00	0.200
0.02	50.00	0.228
0.03	33.33	0.256
0.04	25.00	0.284
0.05	20.00	0.312
0.06	16.67	0.340
0.07	14.29	0.369
0.08	12.50	0.397
0.092	10.92	0.429
0.458	2.18	0.429
0.6	1.67	0.327
0.7	1.43	0.281
0.8	1.25	0.246
0.9	1.11	0.218
1.0	1.00	0.196
1.1	0.91	0.179
1.2	0.83	0.164
1.3	0.77	0.151
1.4	0.71	0.140
1.5	0.67	0.131
1.6	0.63	0.123
1.7	0.59	0.116
1.8	0.56	0.109
1.9	0.53	0.103
2.0	0.50	0.098

Notes

S_s and S_1 values taken from the USGS website
Latitude: 33.3
Longitude: -81.63

PGA is taken at 100 Hz

*T_0 and T_s were determined using SRS Standard 1060
SRS 1060 based on IBC 2003 Section 1615.1.4



Conterminous 48 States
2003 NEHRP Seismic Design Provisions
Latitude = 33.3
Longitude = -81.63
Spectral Response Accelerations Ss and S1
Ss and S1 = Mapped Spectral Acceleration Values
Site Class B - Fa = 1.0 ,Fv = 1.0
Data are based on a 0.05 deg grid spacing

Period (sec)	Sa (g)
0.2	0.446 (Ss, Site Class B)
1.0	0.129 (S1, Site Class B)

Appendix C – PSHA Letter from A. Frankel

United States Department of the Interior

U.S. GEOLOGICAL SURVEY

Arthur Frankel
U.S. Geological Survey
MS 966, Box 25046
Denver Federal Center
Denver, CO 80225
303-273-8556, fax 303-273-8600
afrankel@usgs.gov
Mar. 1, 1999

Richard Lee
1092 Sizemore Rd.
Aiken, SC 29803

Dear Rich,

Enclosed is a Zip disk with the de-aggregation tables for the Savannah River Site. See the Srs directory on the disk. I have also printed out the contents of the Readme.txt file on the disk. If you want this in some other format, let me know. If we have missed some particular rates of exceedance that you need, let me know. We'll be happy to answer any questions you have about these results.

Sincerely,

Arthur Frankel

UNCLASSIFIED
DOES NOT CONTAIN
UNCLASSIFIED CONTROLLED
NUCLEAR INFORMATION
Reviewing Official: G.Q. Reeves, RO
(Name and Title)
Date: 7/24/01

Readme.txt

Notes on De-aggregations for Savannah River Site

The output files give relative contributions in percent (to 1 decimal place), and include all rows with no data (no sources). There are 3 header lines per file and 42 data (or dataless) lines per file.

The output files' names give a clue about the contents. The only information about the attenuation model used is in the file name.

The file names start with psavrivab (for AB95 attenuation),
psavrivfr (for Frankel et al attenuation),
psavrivto (for Toro et al attenuation), and
psavrivtfa (for 1/3 wt Frankel, Toro and AB95 attenuation models combined).

The internal part of the name gives a clue about the return time, eg, 1Meg means 1,000,000 years, 33Me means 33,333,333 years, etc.
The final part (suffix) of name gives the PSA frequency (eg, 10hz) or is pga for pga.(see below)

De-aggregations are calculated based on annual frequency of exceedance for the case of three attenuation relations with equal weight. De-aggregations at any given freq. of exceed. and ground motion frequency is based on the same ground motion value.

Annual Rates of Exceedance and 4 letter code embedded in filename:

1e-2	100y
5e-3	200y
3e-3	333y
2e-3	500y
1e-3	1000
5e-4	2000
4e-4	2500
3e-4	3333
2e-4	5000
1e-4	10ky
5e-5	20ky
3e-5	33ky
2e-5	50ky
1e-5	100k
5e-6	200k
4e-6	250k
3e-6	333k
2e-6	500k
1e-6	1meg
5e-7	2meg
3e-7	3meg
2e-7	5meg
1e-7	10me
5e-7	20me
3e-7	33me
2e-7	50me
1e-8	100m

The second header line tells the approx. return time.
See table above for exact annual frequency of exceedance for that filename.
The middle of the second line shows the ground motion value used in the de-aggrgeation. This value was derived from using the mean hazard curve from the 3 attenuation relations.
The end of the second line shows the annual frequency of exceedance for that attenuation relation for the given ground motion value.
When the de-aggregation is for the 3 atten reln. mean, this value equals the annual freq. of exceedance.

Page 1

Readme.txt

Steve Harmsen harmsen@usgs.gov
Art Frankel afrankel@usgs.gov

Appendix D– Liquefaction Analysis Output

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C01

	DBE					
Magnitudes	4.75	5.25	5.75	6.25	6.75	7.5
Settlement Above Santee	0.00 in.	0.00 in.	0.00 in.	0.01 in.	0.07 in.	0.49 in.

Weighted DBE Settlements

SCPTu ID	2,500 Year Average for all Magnitudes (100 Hz)
Z-V3V5-C01	0.24 in.

DBE Mw =7.5 CPT (tip stress) and Shear Wave Velocity Factor of Safety Comparison

CPT Approach

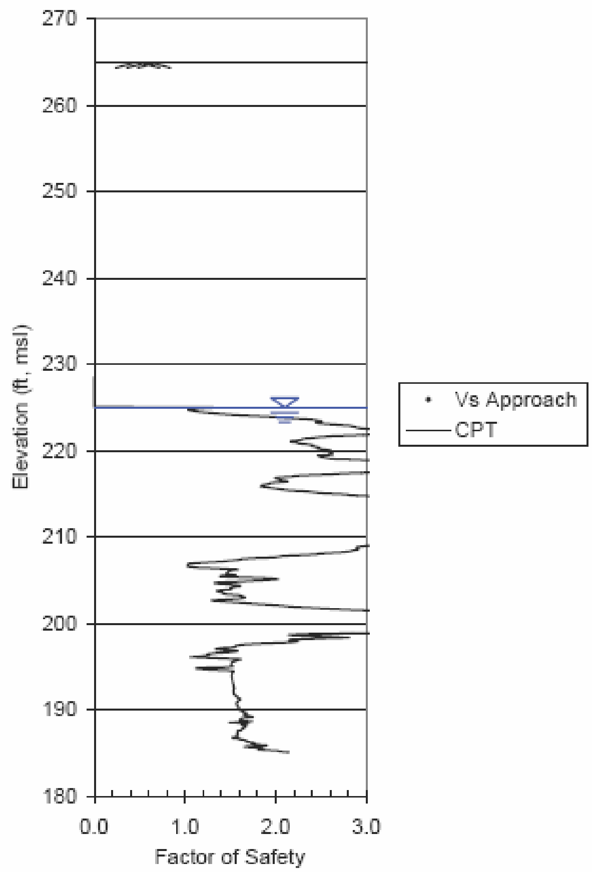
Min. Factor of Safety
1.02

Average Factor of Safety
2.32

Vs Approach

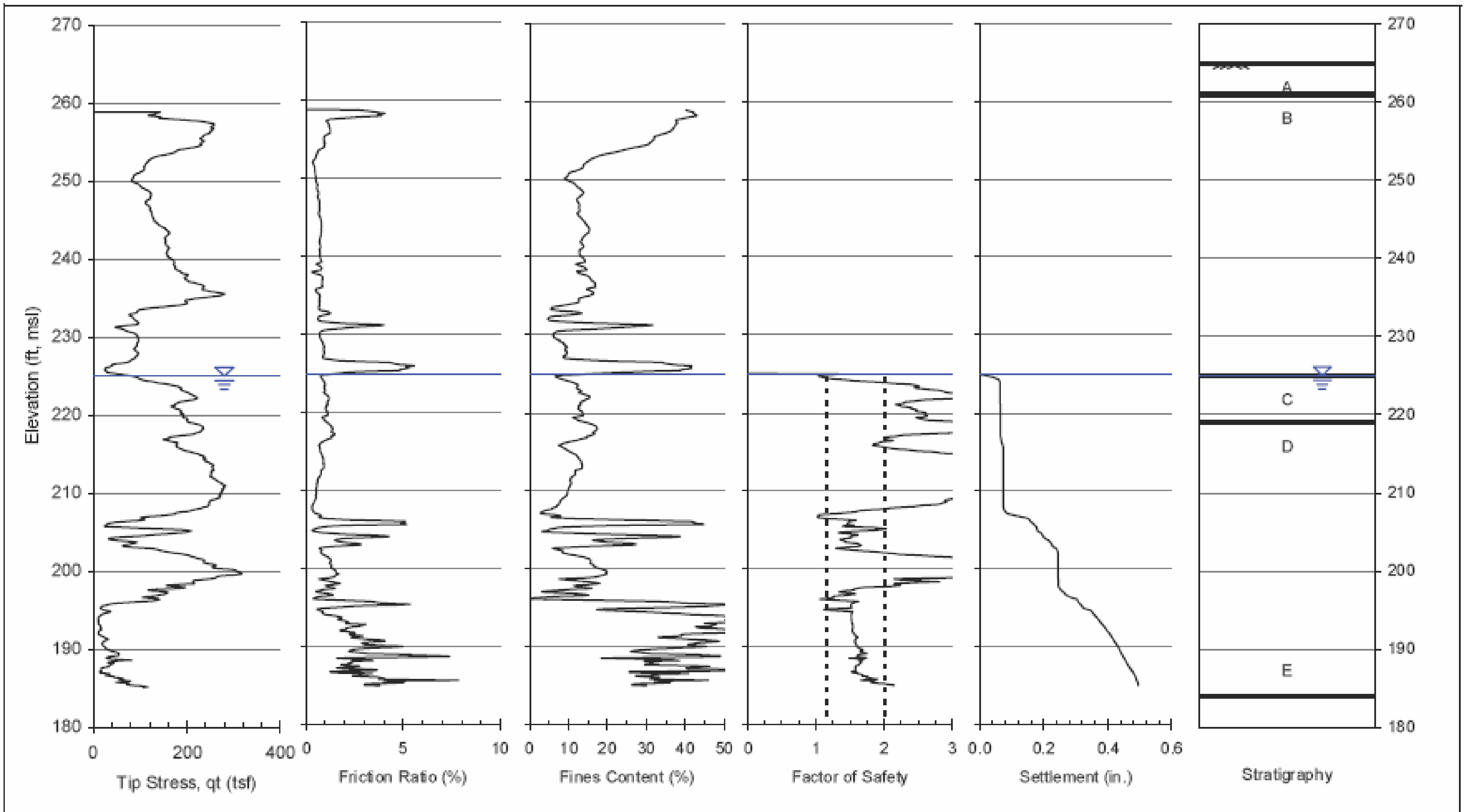
Min. Factor of Safety
4.11

Average Factor of Safety
4.27



Project: Vaults 3 and 5
Cone ID: Z-V3V5-C01

Design Basis Earthquake - Volumetric Strain

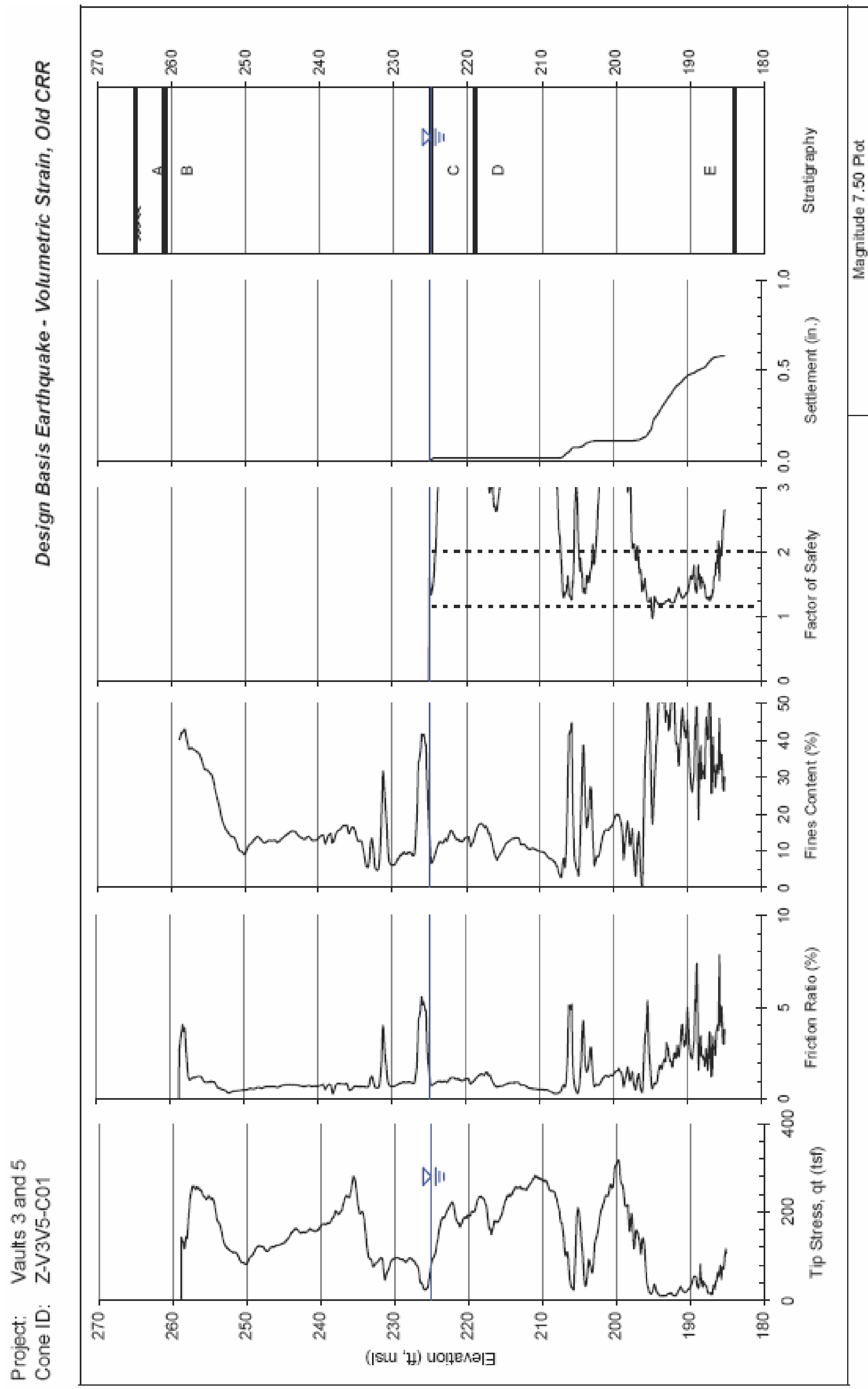


Magnitude 7.50 Plot

Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	3.48	2.77	2.25	1.74	1.43	1.02
Average Factor of Safety	7.89	6.26	5.10	3.94	3.25	2.32
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.01 in.	0.07 in.	0.49 in.

2,500 Year Weighted Average Settlement	0.24 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4



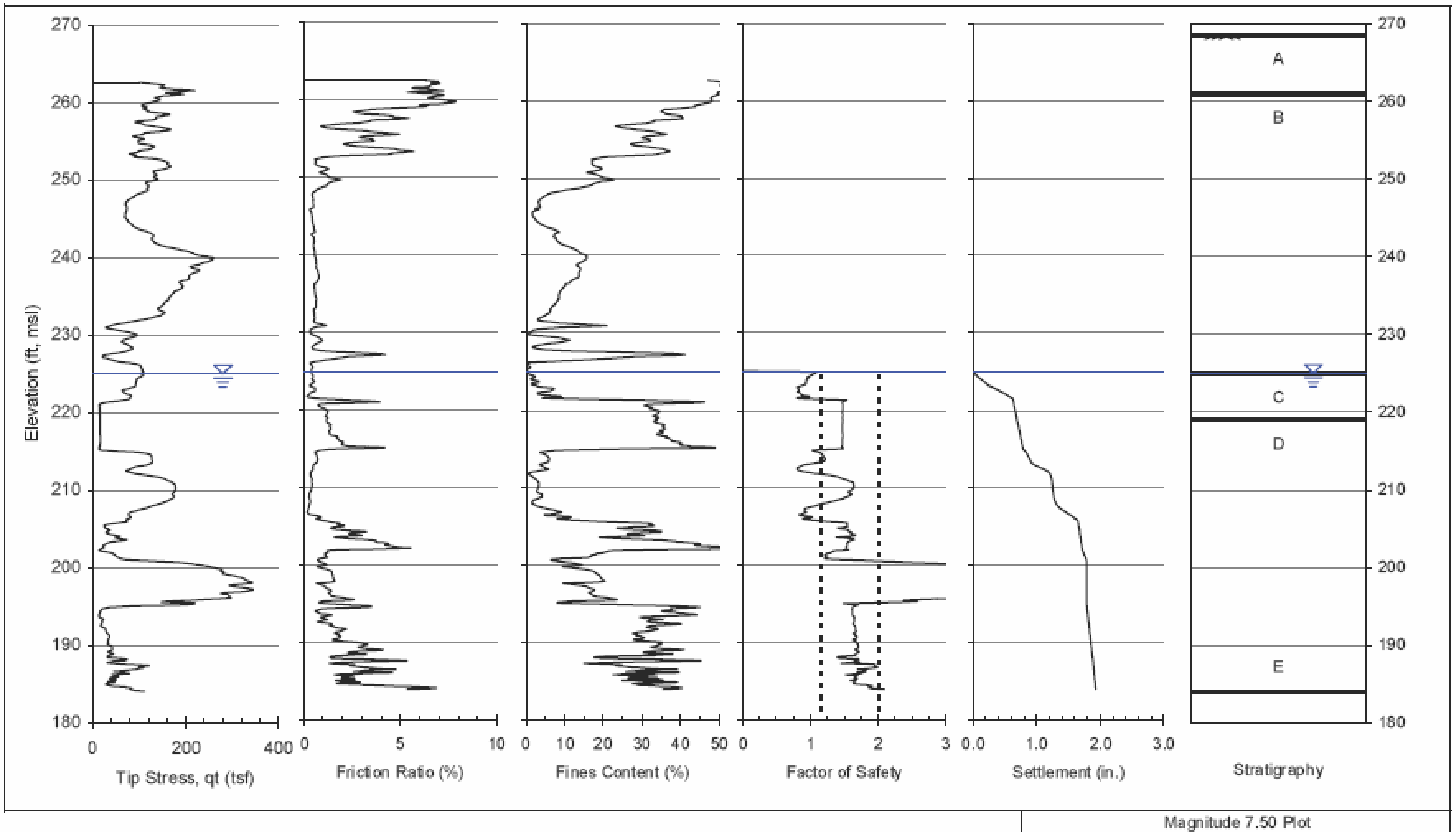
Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	3.30	2.62	2.13	1.65	1.36	0.97
Average Factor of Safety	10.67	8.47	6.90	5.33	4.39	3.14
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.02 in.	0.10 in.	0.58 in.

2,500 Year Weighted Average Settlement	0.28 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C02

Design Basis Earthquake - Volumetric Strain



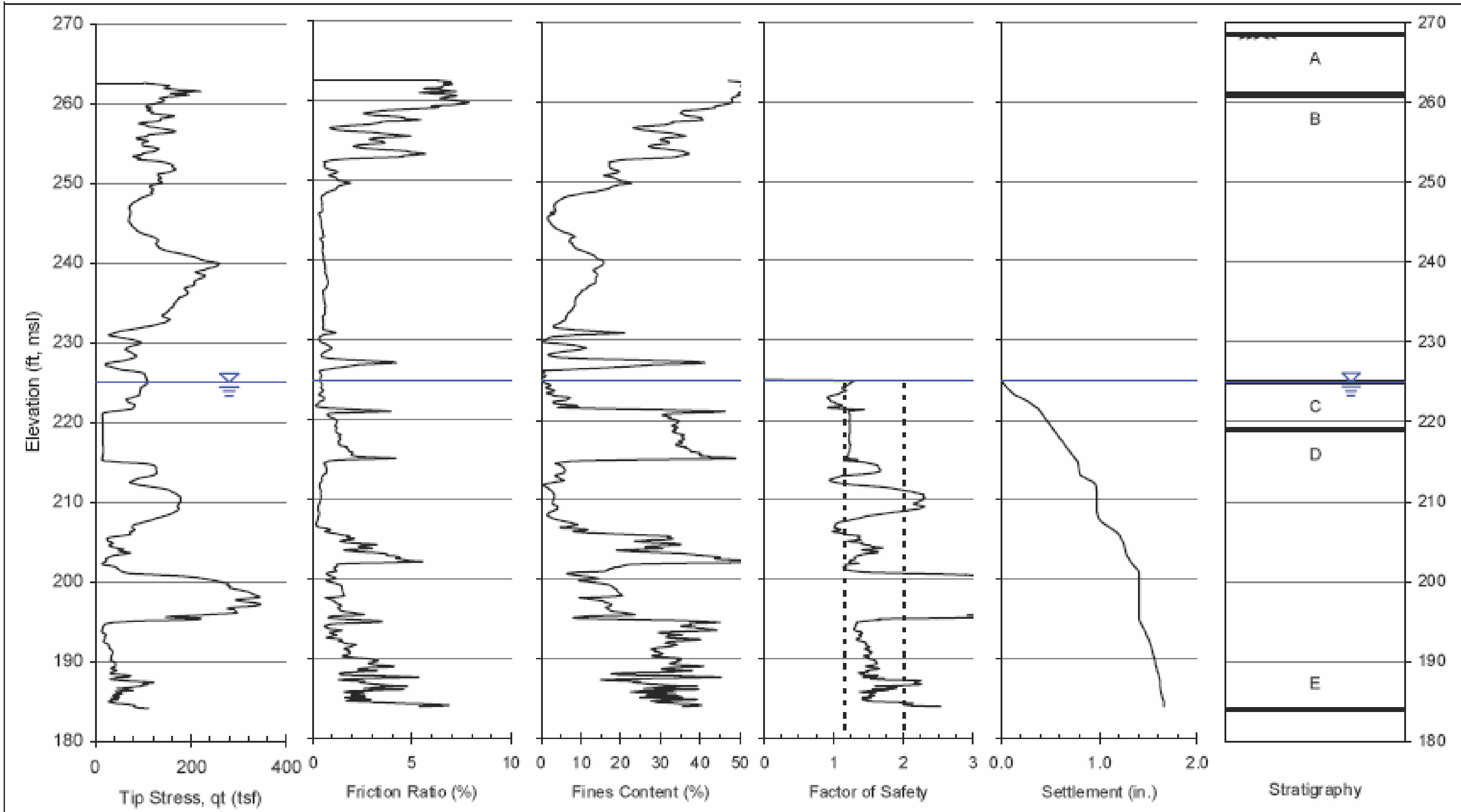
Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	2.69	2.14	1.74	1.35	1.11	0.79
Average Factor of Safety	5.85	4.65	3.79	2.92	2.41	1.72
Maximum Settlement	0.00 in.	0.00 in.	0.04 in.	0.16 in.	0.47 in.	1.93 in.

2,500 Year Weighted Average Settlement	0.95 in.

Stratigraphy / Layer Description		
A	S1/S2	
B	Bottom of Excavation	
C	C2	
D	S3	
E	S4	

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C02

Design Basis Earthquake - Volumetric Strain, Old CRR



Magnitude 7.50 Plot

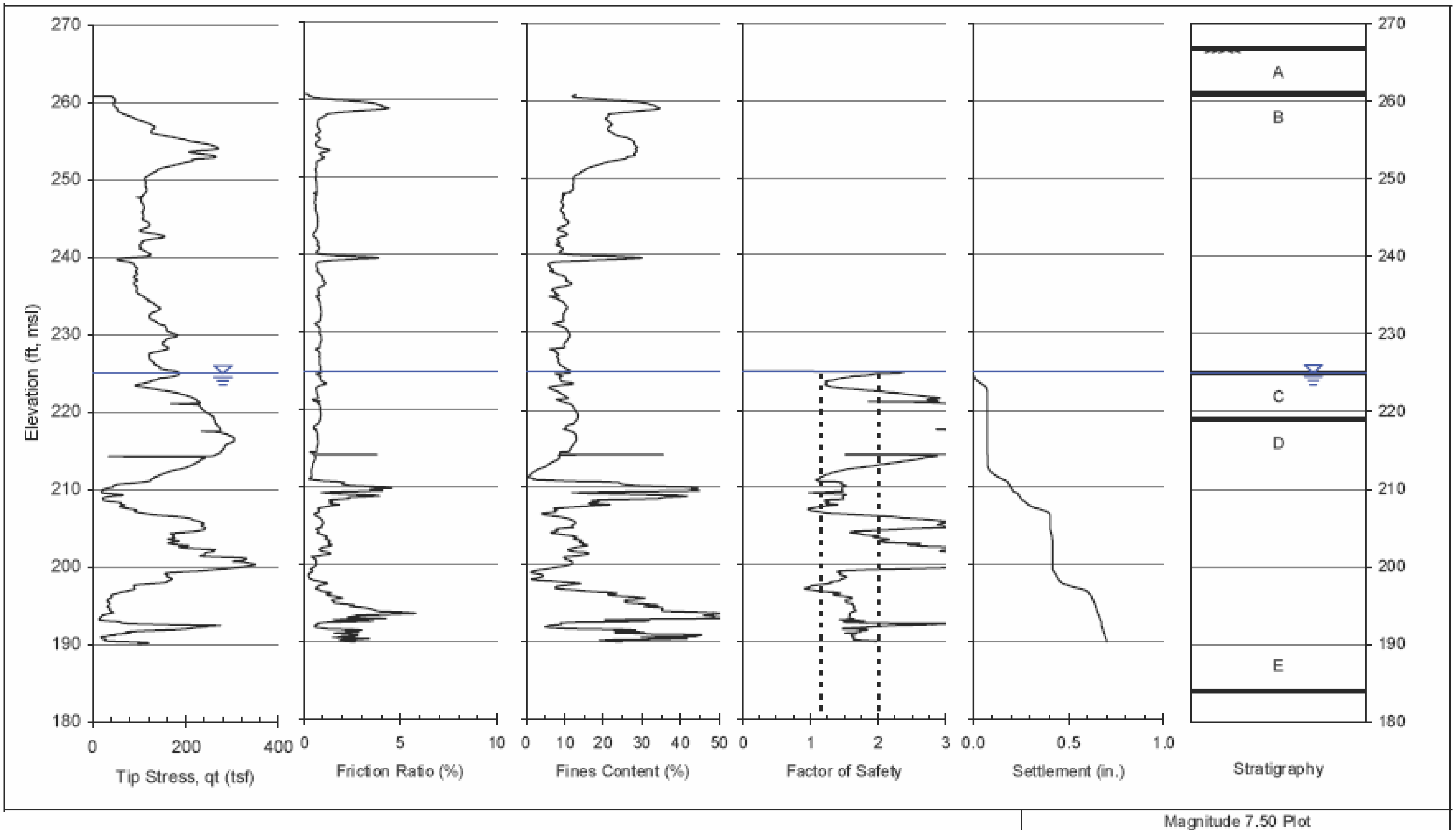
Magnitude	*4.75*	*5.25*	*5.75*	*6.25*	*6.75*	*7.5*
Minimum Factor of Safety	3.07	2.44	1.99	1.53	1.26	0.90
Average Factor of Safety	6.95	5.52	4.50	3.47	2.86	2.04
Maximum Settlement	0.00 in.	0.00 in.	0.01 in.	0.10 in.	0.33 in.	1.66 in.

2,500 Year Weighted Average Settlement	0.81 in.

Stratigraphy / Layer Description		
A	S1/S2	
B	Bottom of Excavation	
C	C2	
D	S3	
E	S4	

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C03

Design Basis Earthquake - Volumetric Strain



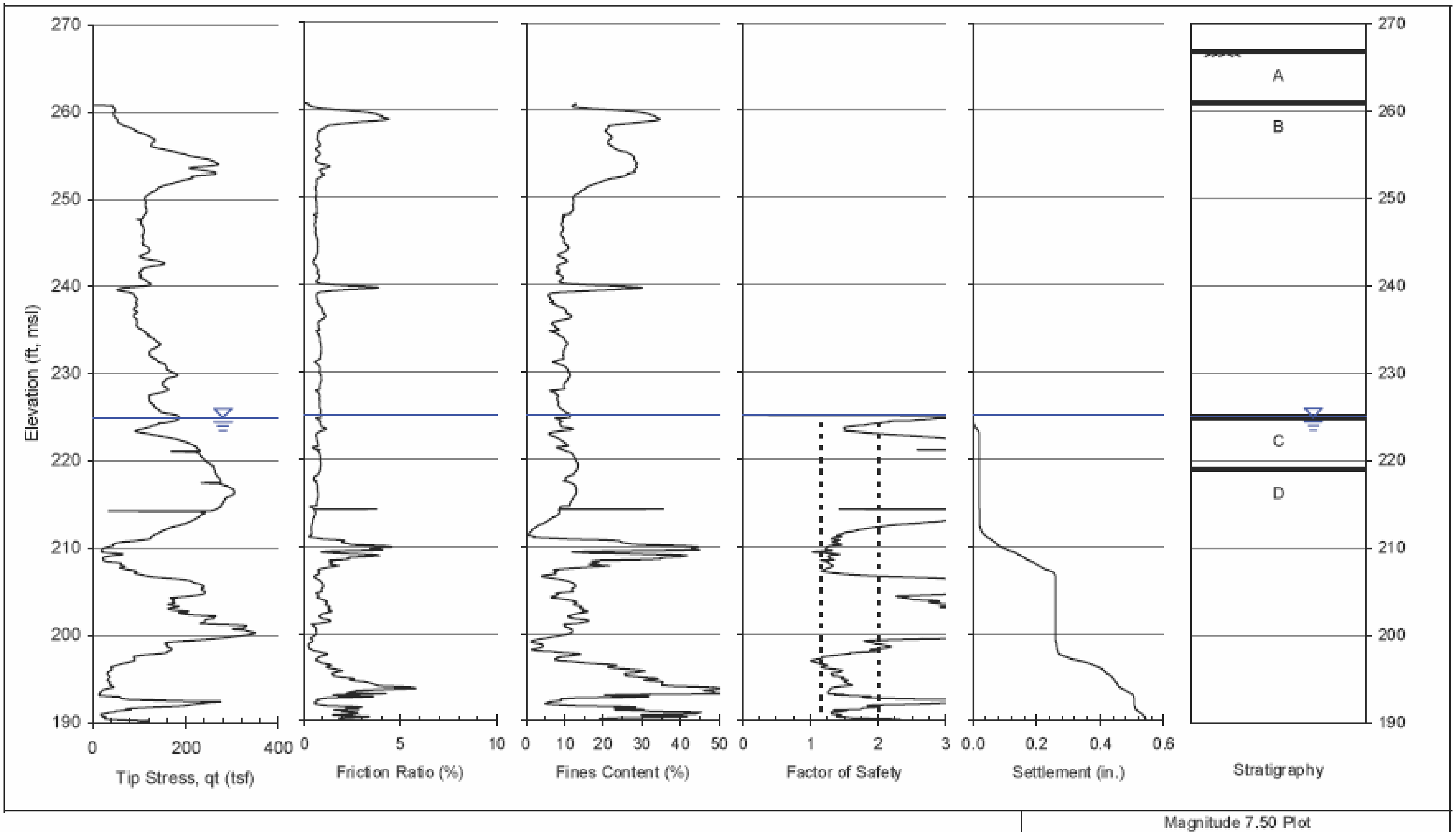
Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	3.11	2.47	2.01	1.56	1.28	0.92
Average Factor of Safety	8.04	6.38	5.20	4.02	3.31	2.36
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.04 in.	0.13 in.	0.70 in.

2,500 Year Weighted Average Settlement	0.34 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C03

Design Basis Earthquake - Volumetric Strain, Old CRR



Magnitude	*4.75*	*5.25*	*5.75*	*6.25*	*6.75*	*7.5*
Minimum Factor of Safety	3.40	2.70	2.20	1.70	1.40	1.00
Average Factor of Safety	11.15	8.85	7.21	5.57	4.59	3.28
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.02 in.	0.10 in.	0.54 in.

2,500 Year Weighted Average Settlement	0.26 in.

Stratigraphy / Layer Description		
A	S1/S2	
B	Bottom of Excavation	
C	C2	
D	S3	
E	S4	

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C04

	DBE					
Magnitudes	4.75	5.25	5.75	6.25	6.75	7.5
Settlement Above Santee	0.00 in.	0.00 in.	0.00 in.	0.00 in.	0.02 in.	0.24 in.

Weighted DBE Settlements

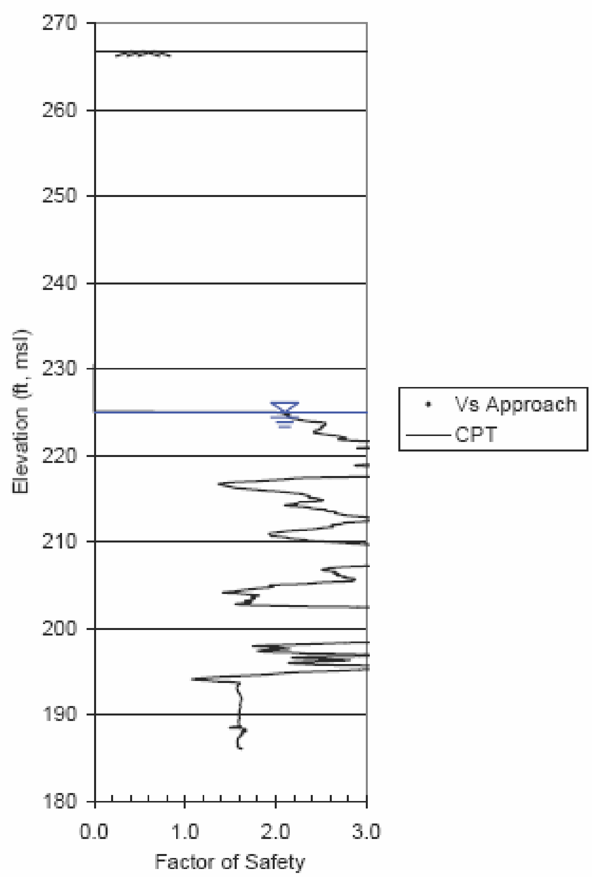
SCPTu ID	2,500 Year Average for all Magnitudes (100 Hz)
Z-V3V5-C04	0.12 in.

DBE Mw =7.5 CPT (tip stress) and Shear Wave Velocity Factor of Safety Comparison

CPT Approach

Min. Factor of Safety
1.07

Average Factor of Safety
2.56



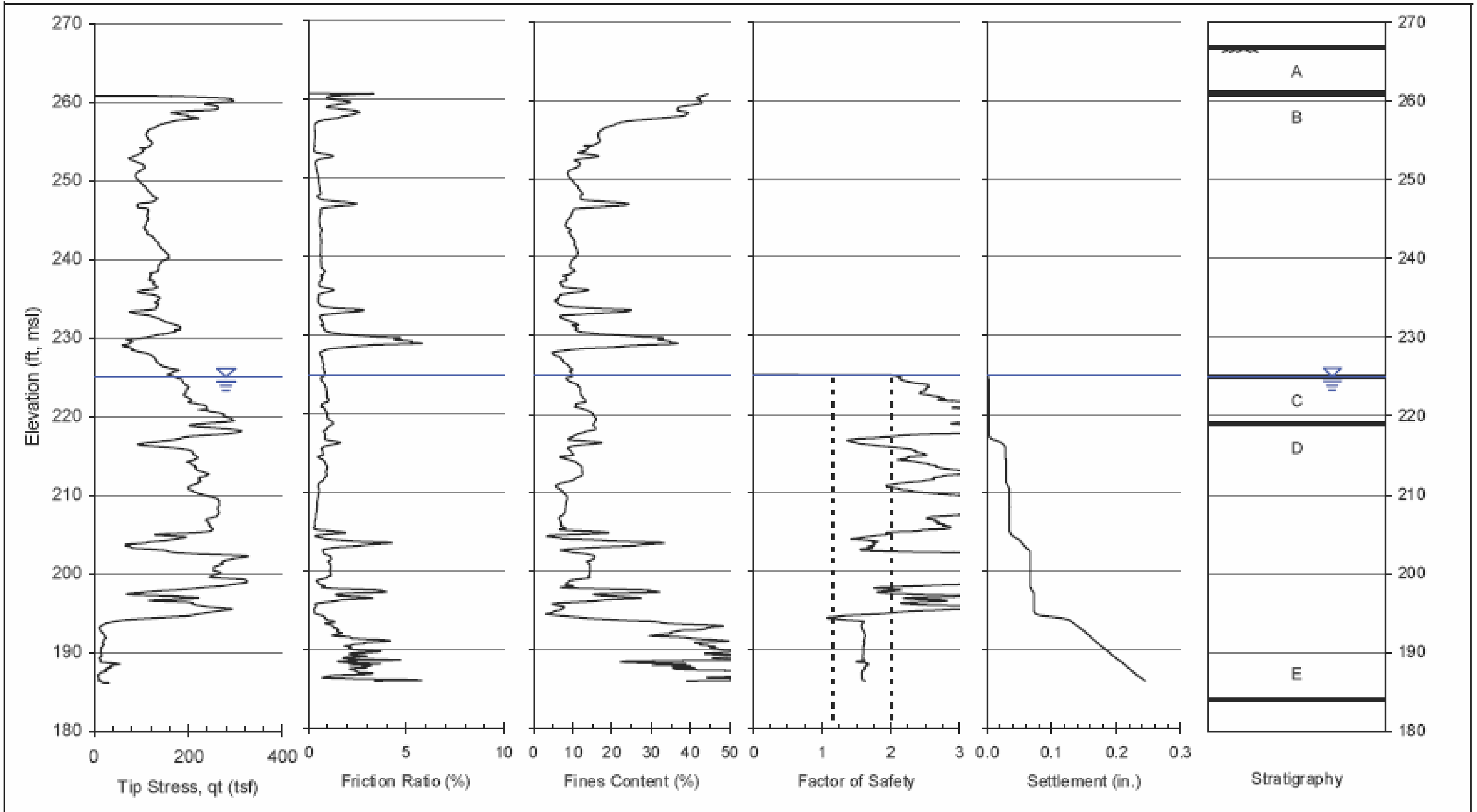
Vs Approach

Min. Factor of Safety
3.12

Average Factor of Safety
4.29

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C04

Design Basis Earthquake - Volumetric Strain



Magnitude 7.50 Plot

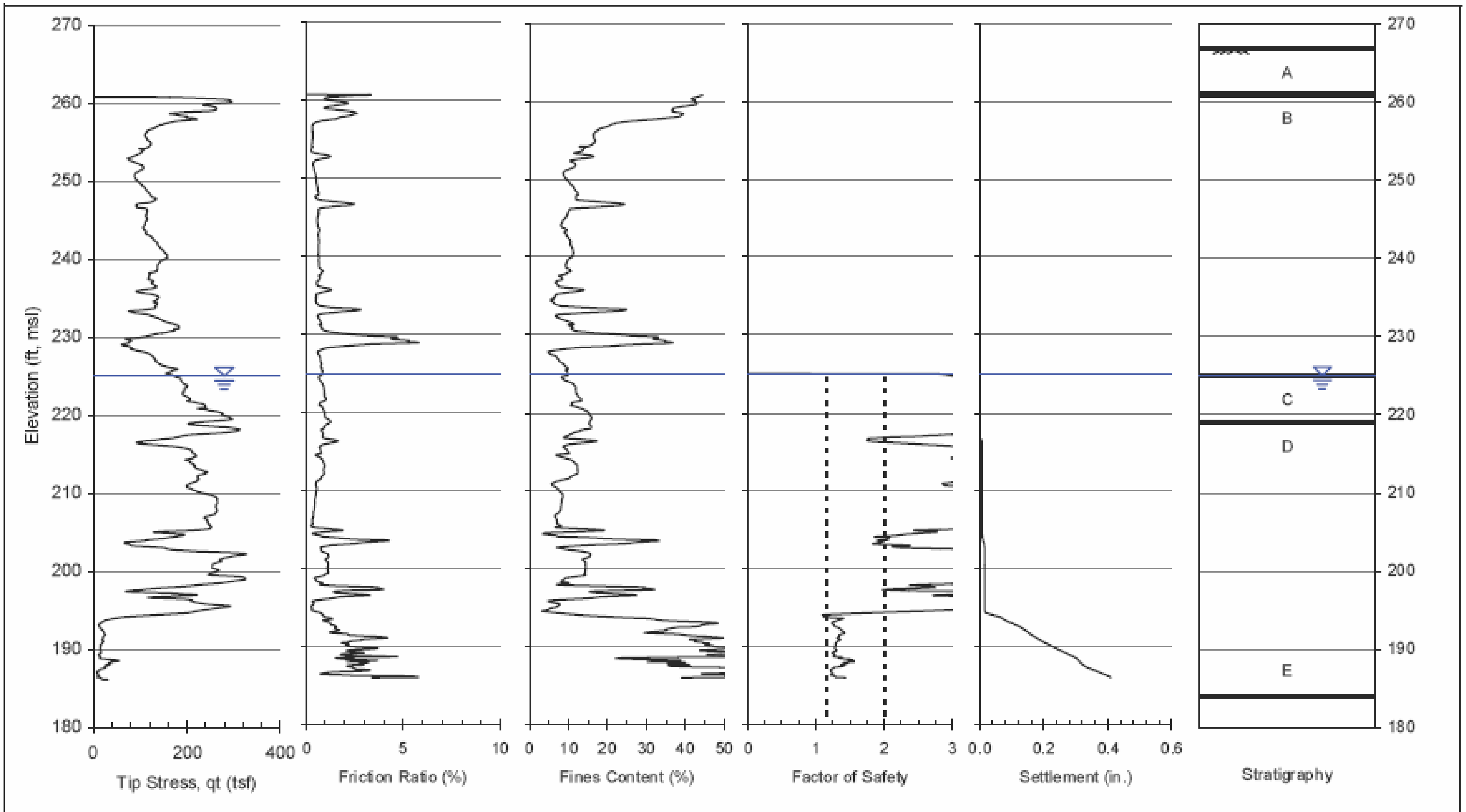
Magnitude	**4.75**	**5.25**	**5.75**	**6.25**	**6.75**	**7.5**
Minimum Factor of Safety	3.65	2.90	2.36	1.83	1.50	1.07
Average Factor of Safety	8.70	6.91	5.63	4.35	3.58	2.56
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.00 in.	0.02 in.	0.24 in.

2,500 Year Weighted Average Settlement	0.12 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C04

Design Basis Earthquake - Volumetric Strain, Old CRR

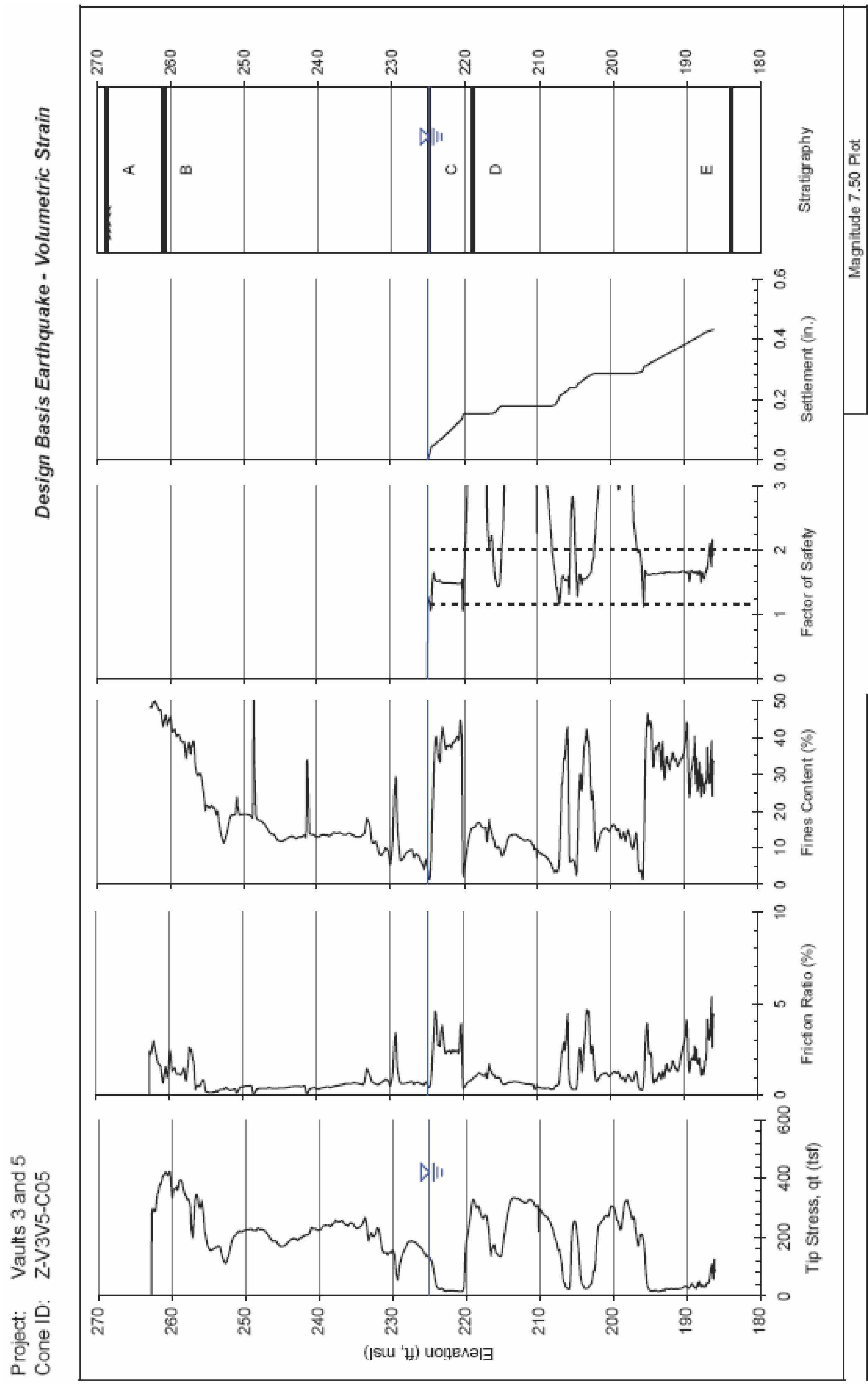


Magnitude 7.50 Plot

Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	3.72	2.95	2.41	1.86	1.53	1.09
Average Factor of Safety	12.36	9.81	8.00	6.18	5.09	3.64
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.02 in.	0.08 in.	0.41 in.

2,500 Year Weighted Average Settlement	0.20 in.

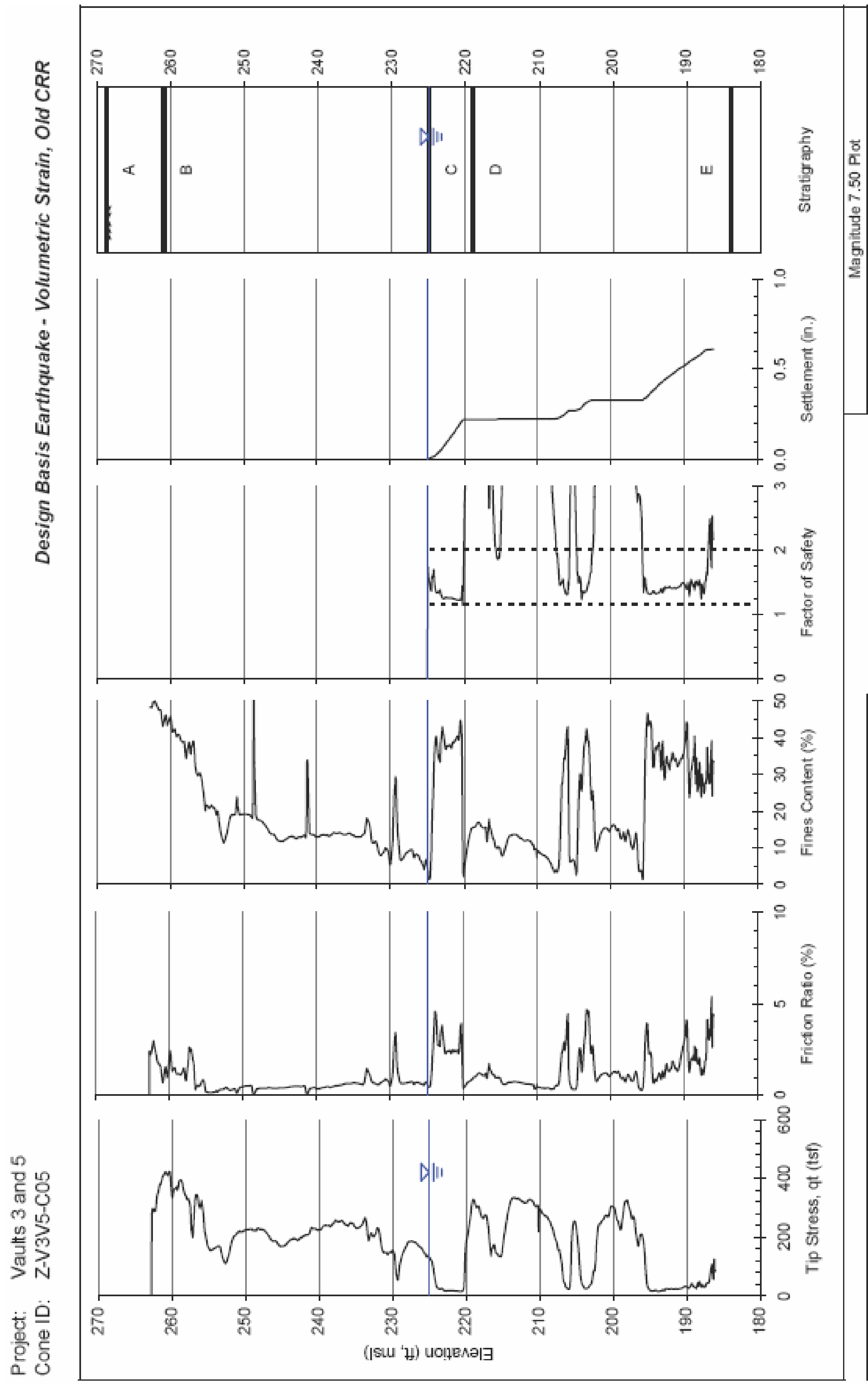
Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4



Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	3.59	2.85	2.32	1.79	1.48	1.06
Average Factor of Safety	8.56	6.80	5.54	4.28	3.53	2.52
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.01 in.	0.05 in.	0.43 in.

2,500 Year Weighted Average Settlement	0.21 in.



Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Magnitude	*4.75*	*5.25*	*5.75*	*6.25*	*6.75*	*7.5*
Minimum Factor of Safety	3.89	3.09	2.51	1.94	1.60	1.14
Average Factor of Safety	11.97	9.51	7.75	5.98	4.93	3.52
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.01 in.	0.11 in.	0.61 in.

2,500 Year Weighted Average Settlement	0.30 in.

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C06

	DBE					
Magnitudes	***4.75***	***5.25***	***5.75***	***6.25***	***6.75***	***7.5***
Settlement Above Santee	0.00 in.	0.00 in.	0.02 in.	0.08 in.	0.29 in.	1.30 in.

Weighted DBE Settlements

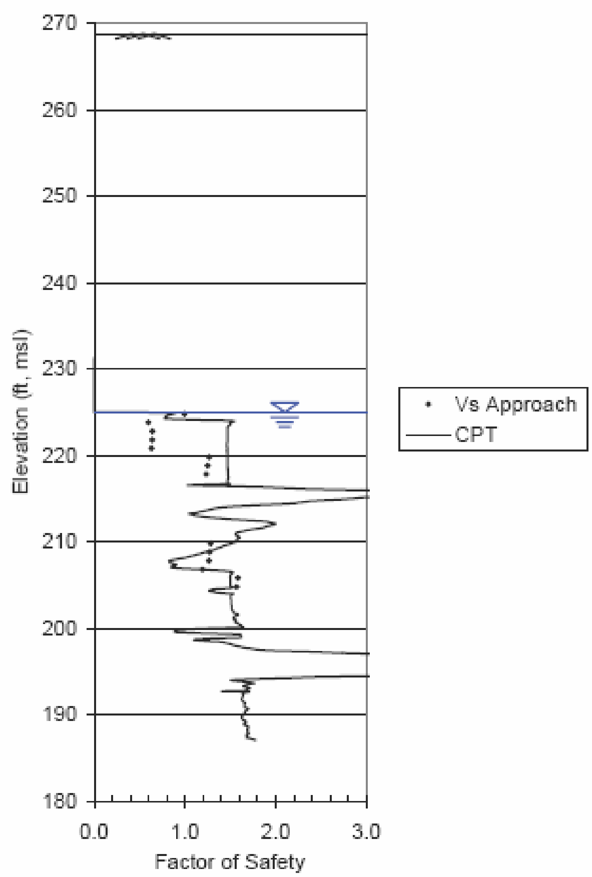
SCPTu ID	**2,500 Year Average for all Magnitudes (100 Hz)**
Z-V3V5-C06	0.64 in.

DBE Mw =7.5 CPT (tip stress) and Shear Wave Velocity Factor of Safety Comparison

CPT Approach

Min. Factor of Safety
0.77

Average Factor of Safety
1.92



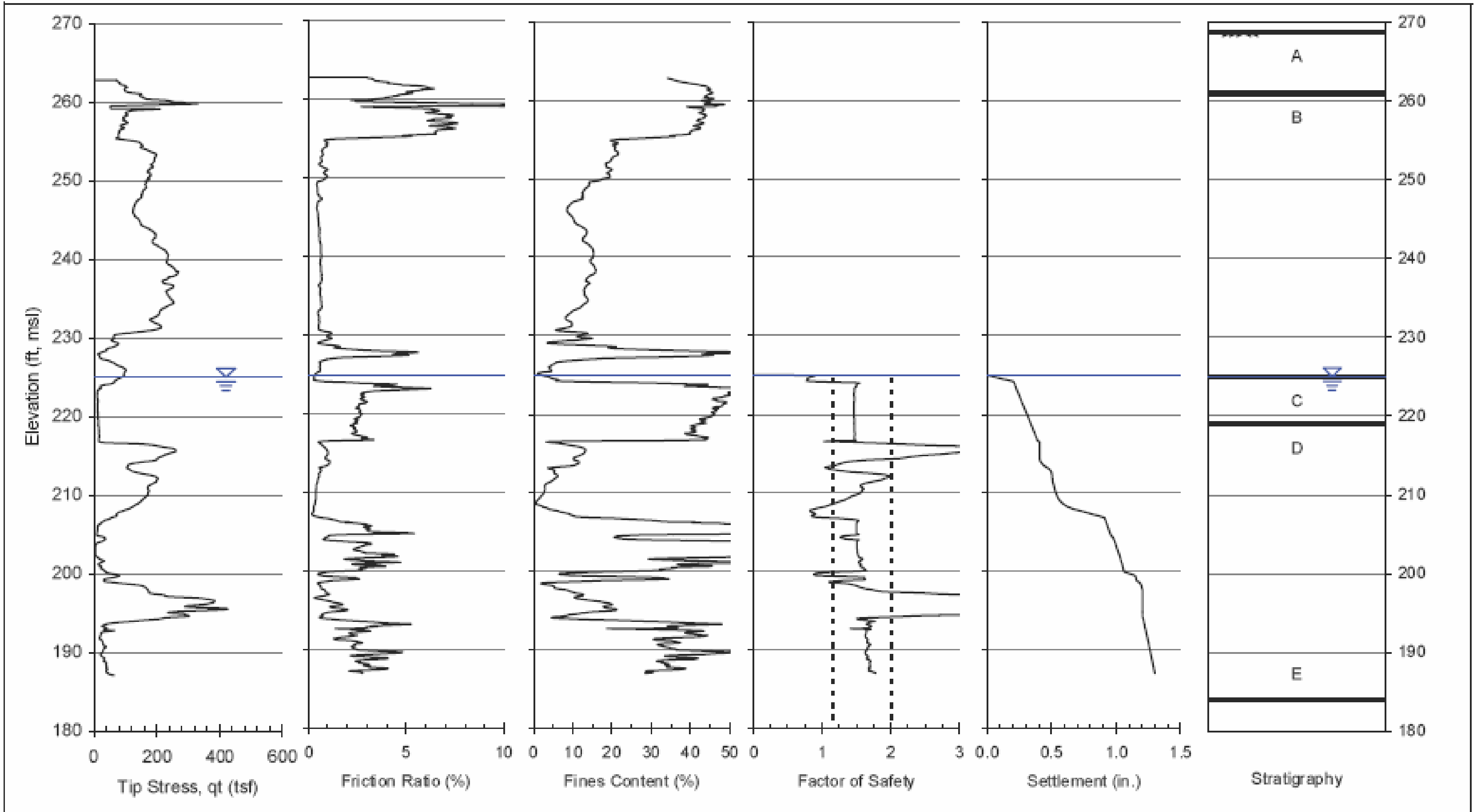
Vs Approach

Min. Factor of Safety
0.60

Average Factor of Safety
3.26

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C06

Design Basis Earthquake - Volumetric Strain



Magnitude 7.50 Plot

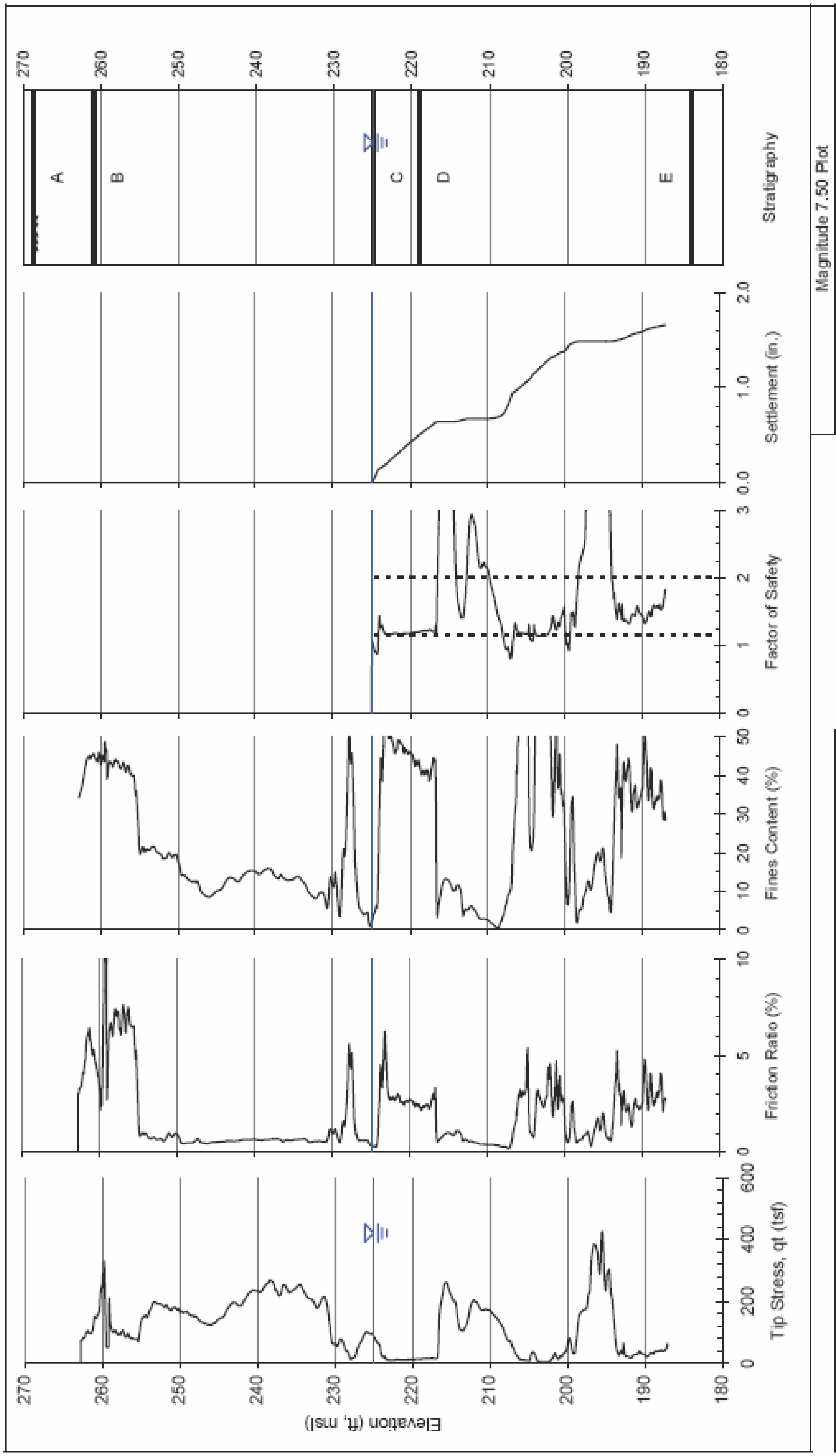
Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	2.62	2.08	1.70	1.31	1.08	0.77
Average Factor of Safety	6.53	5.19	4.23	3.27	2.69	1.92
Maximum Settlement	0.00 in.	0.00 in.	0.02 in.	0.08 in.	0.29 in.	1.30 in.

2,500 Year Weighted Average Settlement	0.64 in.

Stratigraphy / Layer Description		
A	S1/S2	
B	Bottom of Excavation	
C	C2	
D	S3	
E	S4	

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C06

Design Basis Earthquake - Volumetric Strain, Old CRR



Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	2.74	2.18	1.78	1.37	1.13	0.81
Average Factor of Safety	7.07	5.61	4.57	3.53	2.91	2.08
Maximum Settlement	0.00 in.	0.00 in.	0.01 in.	0.11 in.	0.33 in.	1.65 in.

2,500 Year Weighted Average Settlement	0.81 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C07

	DBE					
Magnitudes	4.75	5.25	5.75	6.25	6.75	7.5
Settlement Above Santee	0.00 in.	0.00 in.	0.01 in.	0.03 in.	0.15 in.	0.79 in.

Weighted DBE Settlements

SCPTu ID	2,500 Year Average for all Magnitudes (100 Hz)
Z-V3V5-C07	0.38 in.

DBE Mw =7.5 CPT (tip stress) and Shear Wave Velocity Factor of Safety Comparison

CPT Approach

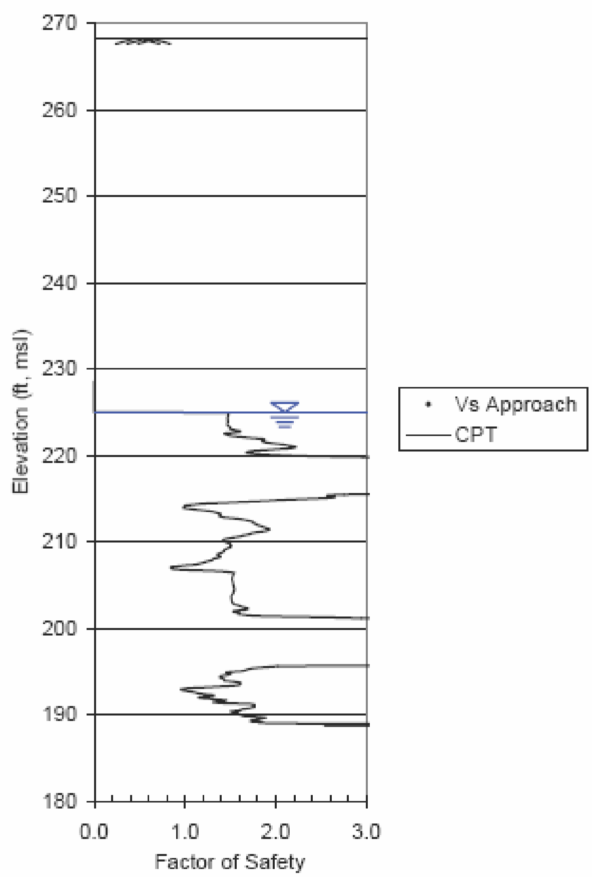
Min. Factor of Safety
0.84

Average Factor of Safety
12.54

Vs Approach

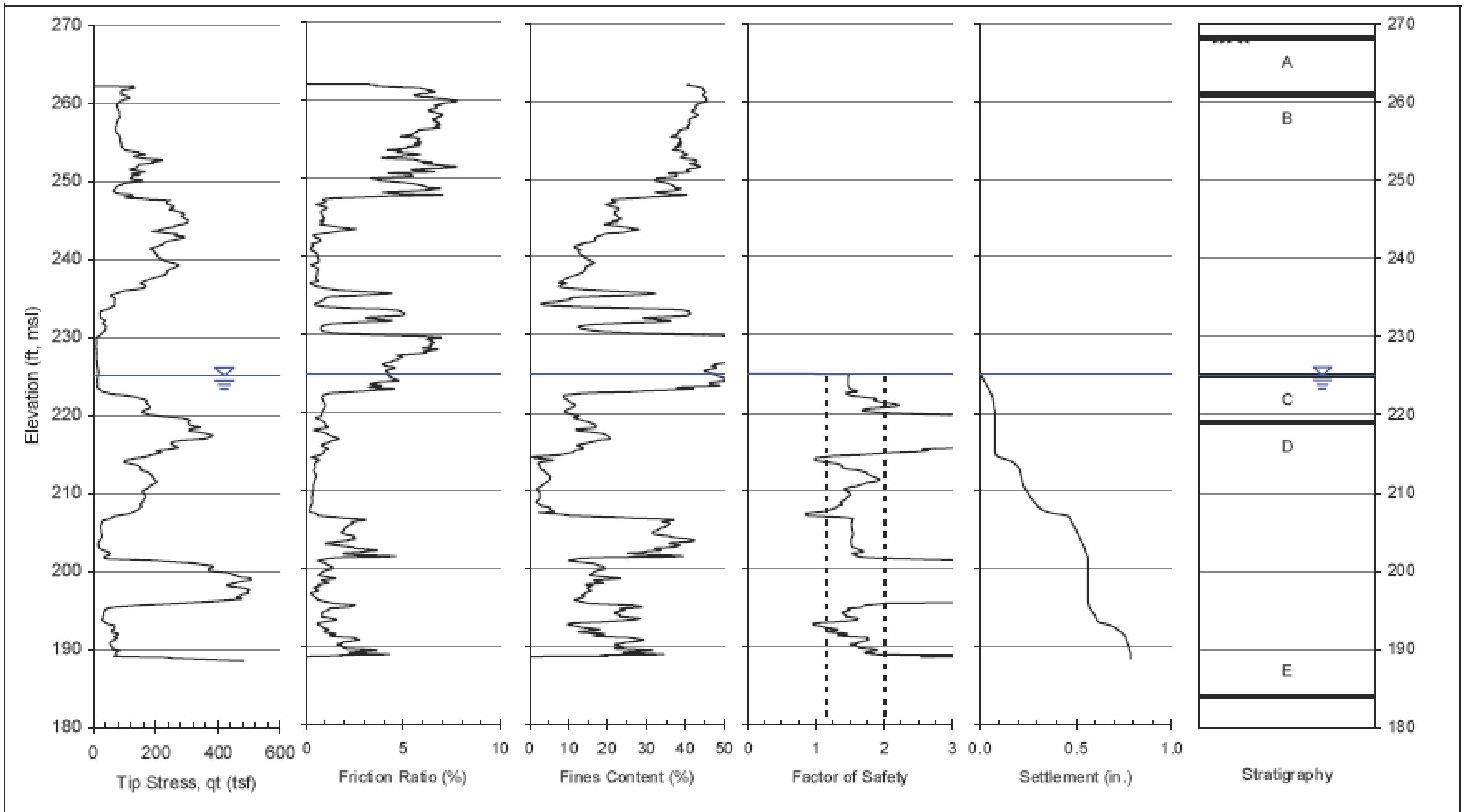
Min. Factor of Safety
4.25

Average Factor of Safety
4.39



Project: Vaults 3 and 5
Cone ID: Z-V3V5-C07

Design Basis Earthquake - Volumetric Strain



Magnitude 7.50 Plot

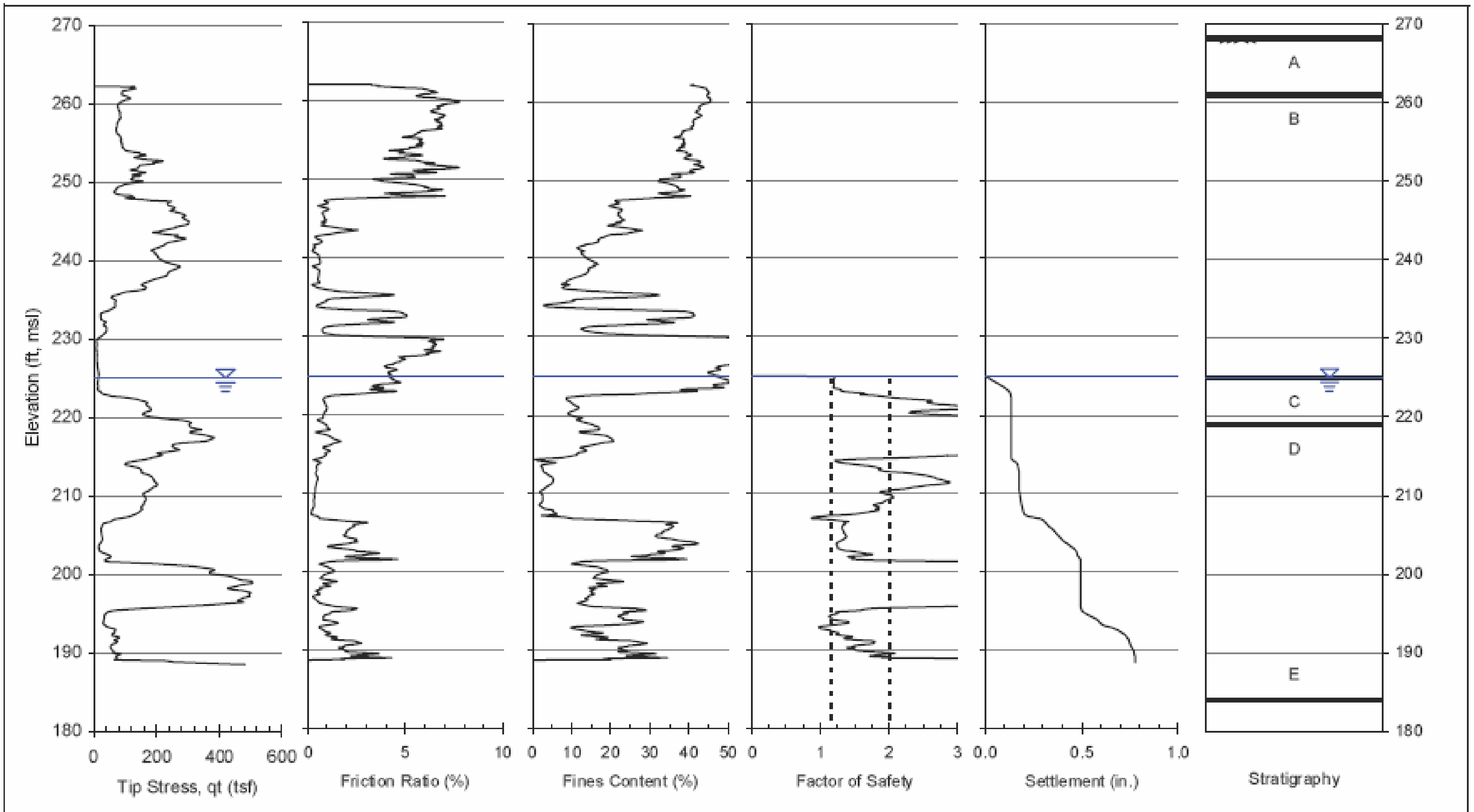
Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	2.87	2.28	1.86	1.44	1.18	0.84
Average Factor of Safety	42.65	33.87	27.60	21.33	17.56	12.54
Maximum Settlement	0.00 in.	0.00 in.	0.01 in.	0.03 in.	0.15 in.	0.79 in.

2,500 Year Weighted Average Settlement	0.38 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C07

Design Basis Earthquake - Volumetric Strain, Old CRR

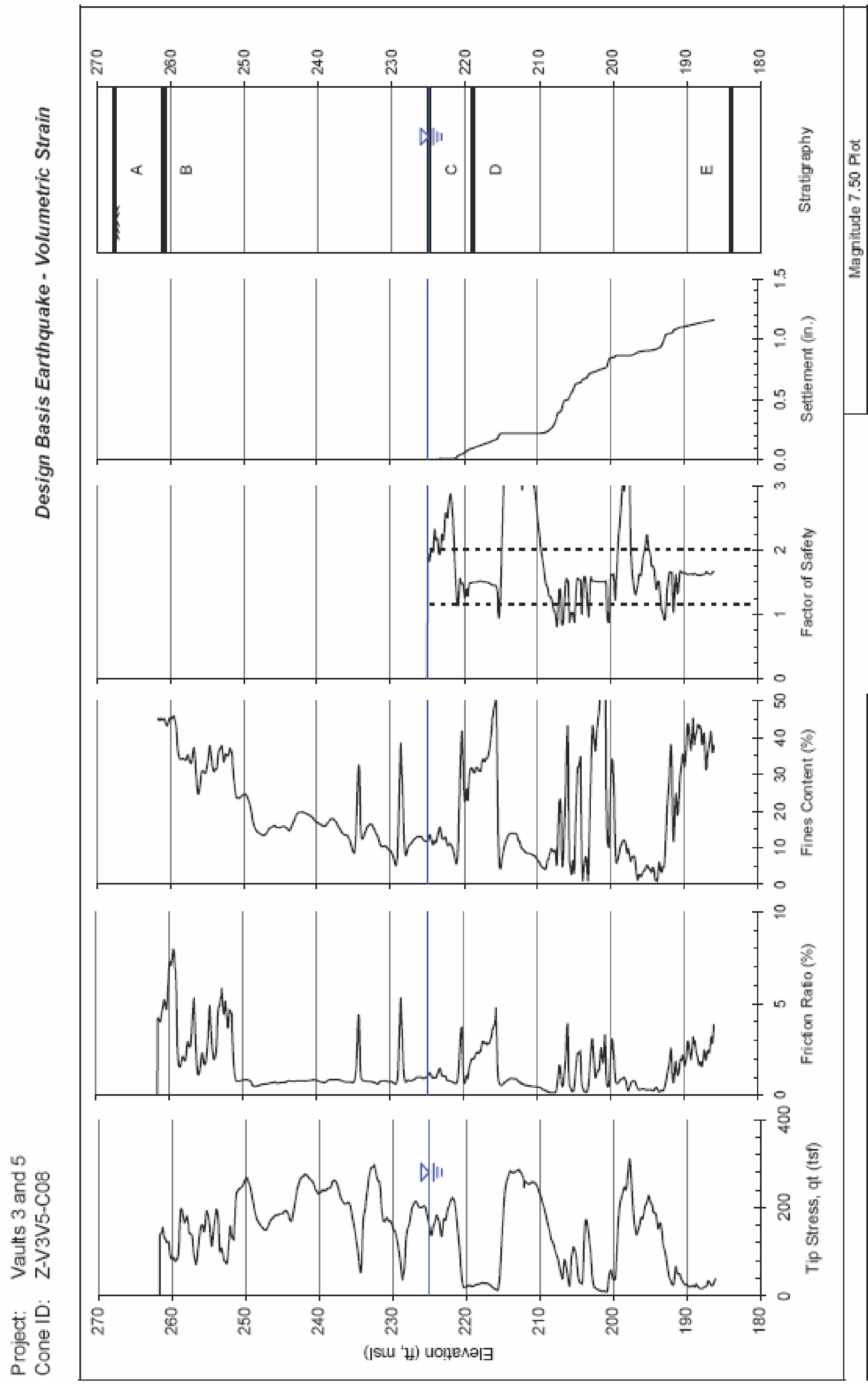


Magnitude 7.50 Plot

Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	2.95	2.35	1.91	1.48	1.22	0.87
Average Factor of Safety	13.20	10.48	8.54	6.60	5.43	3.88
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.04 in.	0.14 in.	0.78 in.

2,500 Year Weighted Average Settlement	0.38 in.

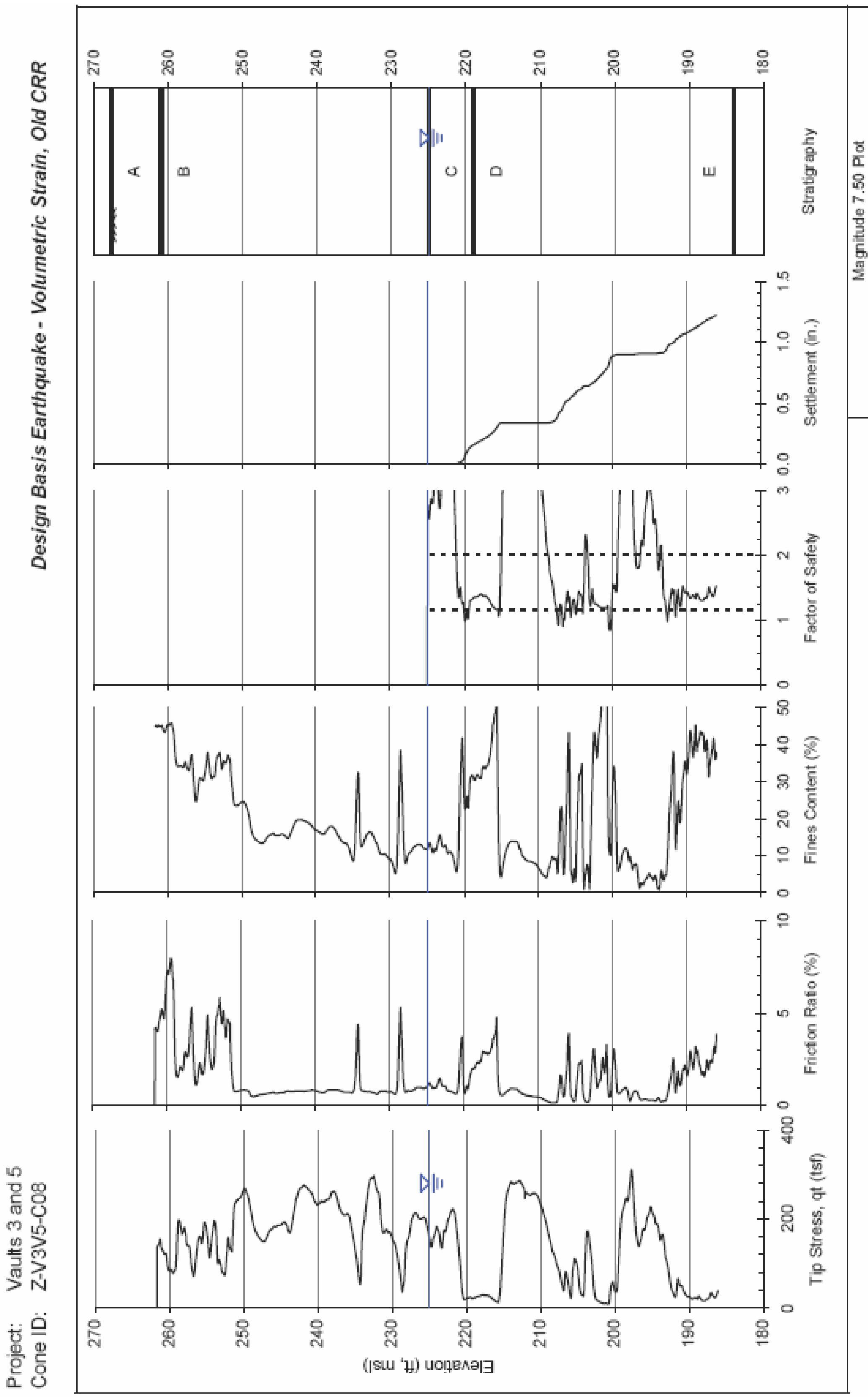
Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4



Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	2.74	2.18	1.77	1.37	1.13	0.81
Average Factor of Safety	6.42	5.10	4.15	3.21	2.64	1.89
Maximum Settlement	0.00 in.	0.00 in.	0.01 in.	0.07 in.	0.24 in.	1.16 in.

2,500 Year Weighted Average Settlement	0.57 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4



Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	2.87	2.28	1.85	1.43	1.18	0.84
Average Factor of Safety	7.82	6.21	5.06	3.91	3.22	2.30
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.06 in.	0.24 in.	1.22 in.

2,500 Year Weighted Average Settlement	0.59 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C09

	DBE					
Magnitudes	4.75	5.25	5.75	6.25	6.75	7.5
Settlement Above Santee	0.00 in.	0.00 in.	0.02 in.	0.11 in.	0.34 in.	1.68 in.

Weighted DBE Settlements

SCPTu ID	2,500 Year Average for all Magnitudes (100 Hz)
Z-V3V5-C09	0.82 in.

DBE Mw =7.5 CPT (tip stress) and Shear Wave Velocity Factor of Safety Comparison

CPT Approach

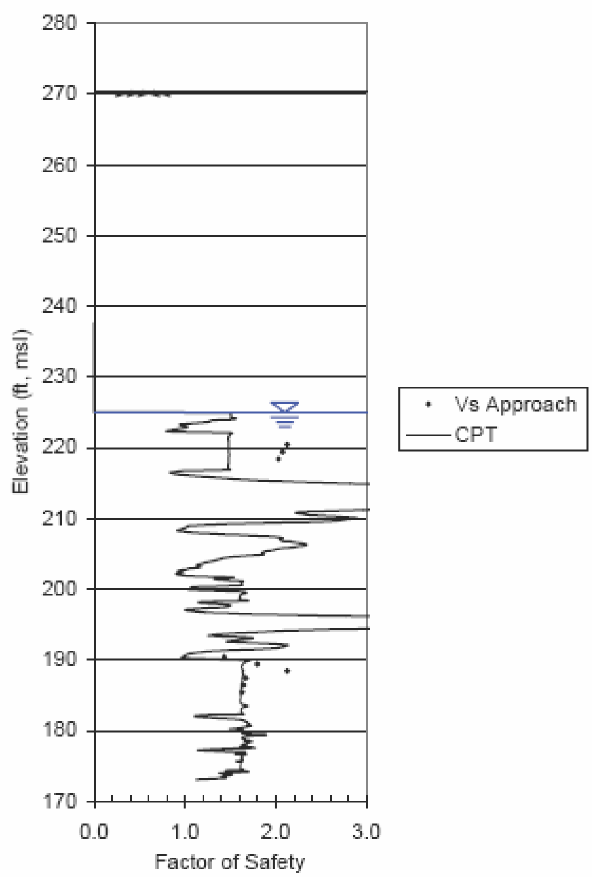
Min. Factor of Safety
0.79

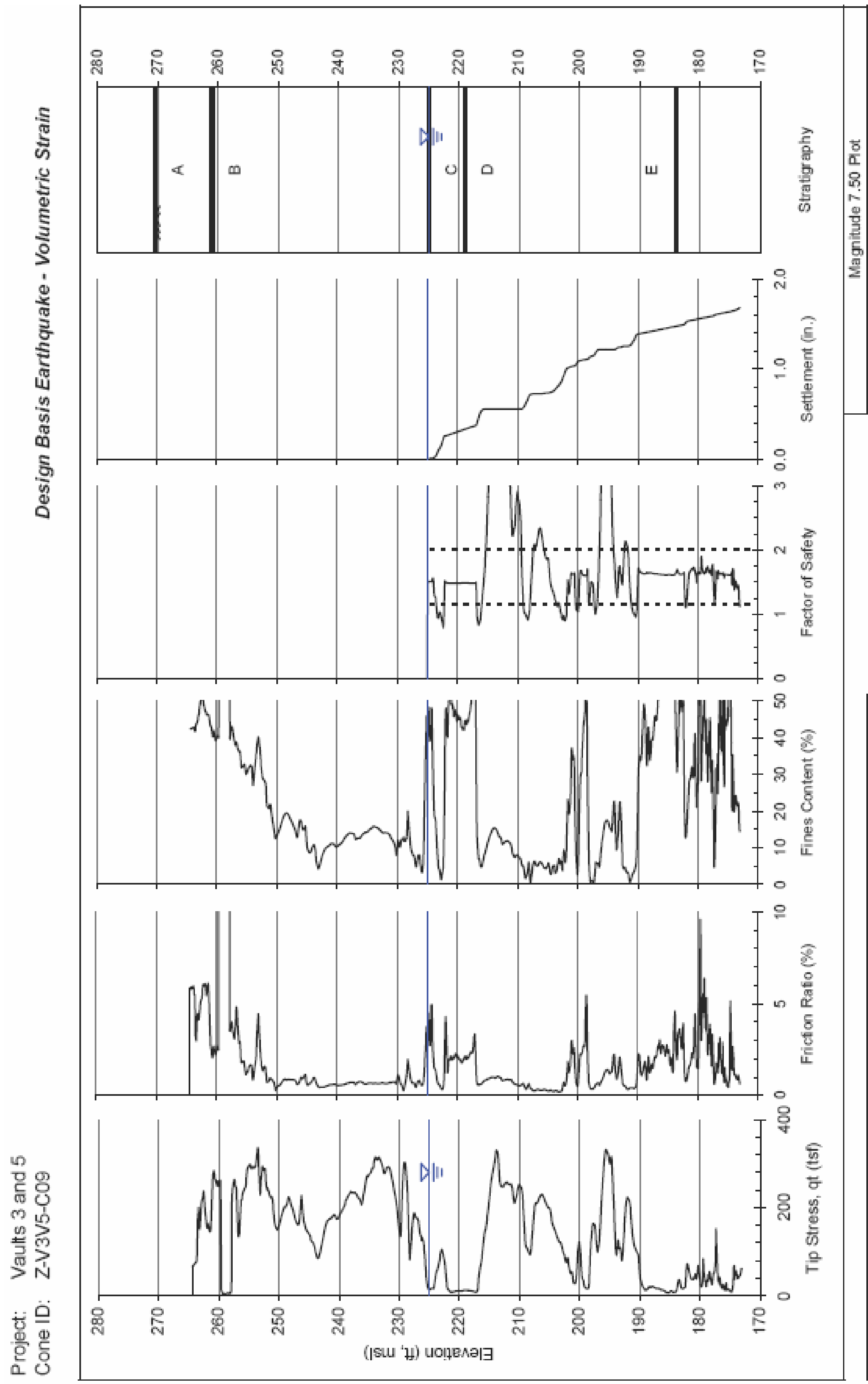
Average Factor of Safety
1.84

Vs Approach

Min. Factor of Safety
1.44

Average Factor of Safety
4.08





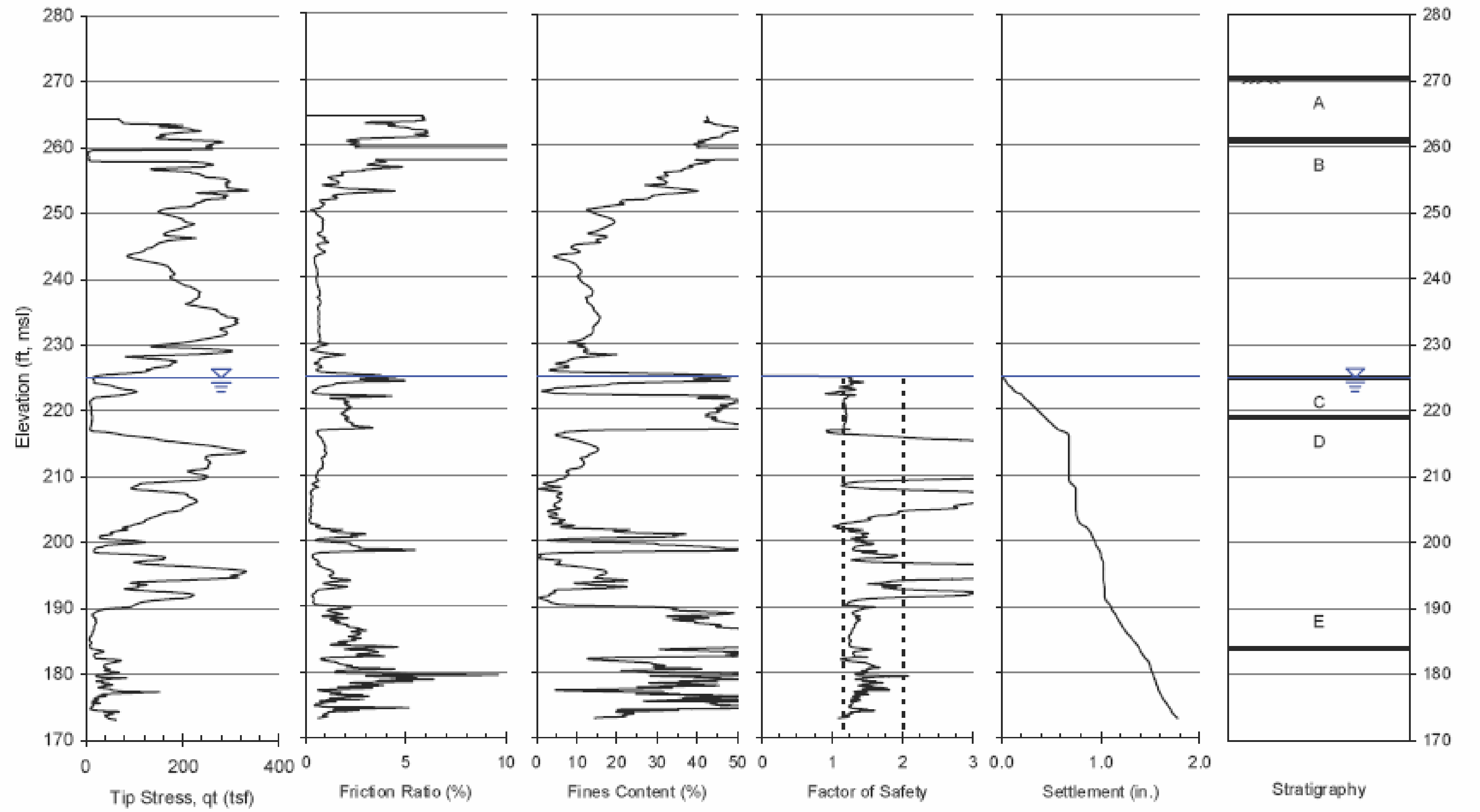
Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	2.68	2.13	1.74	1.34	1.10	0.79
Average Factor of Safety	6.27	4.98	4.05	3.13	2.58	1.84
Maximum Settlement	0.00 in.	0.00 in.	0.02 in.	0.11 in.	0.34 in.	1.68 in.

2,500 Year Weighted Average Settlement	0.82 in.

	Stratigraphy / Layer Description
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C09

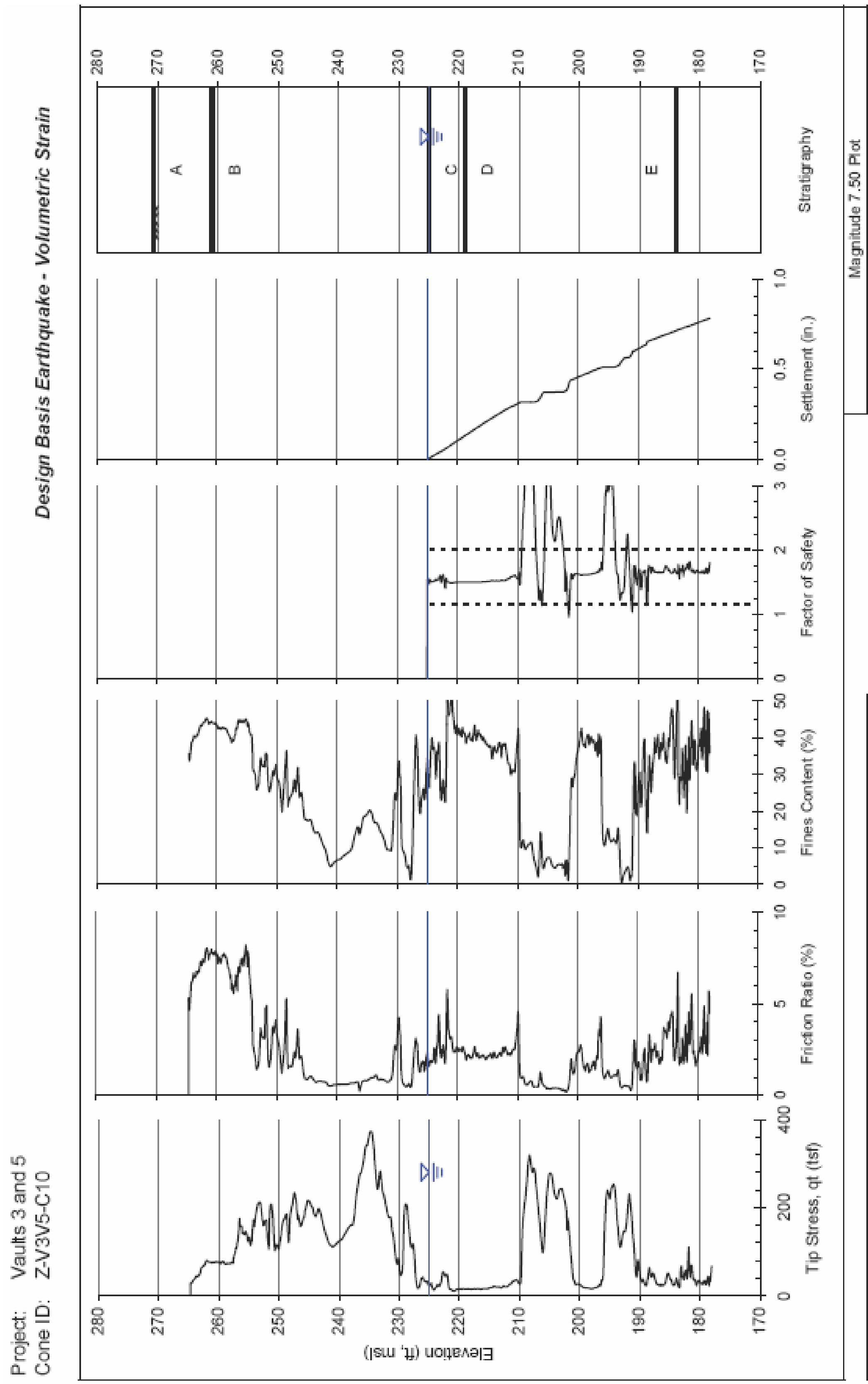
Design Basis Earthquake - Volumetric Strain, Old CRR



Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	3.06	2.43	1.98	1.53	1.26	0.90
Average Factor of Safety	7.19	5.71	4.65	3.60	2.96	2.12
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.09 in.	0.34 in.	1.78 in.

2,500 Year Weighted Average Settlement	0.87 in.

Stratigraphy / Layer Description		
A	S1/S2	
B	Bottom of Excavation	
C	C2	
D	S3	
E	S4	



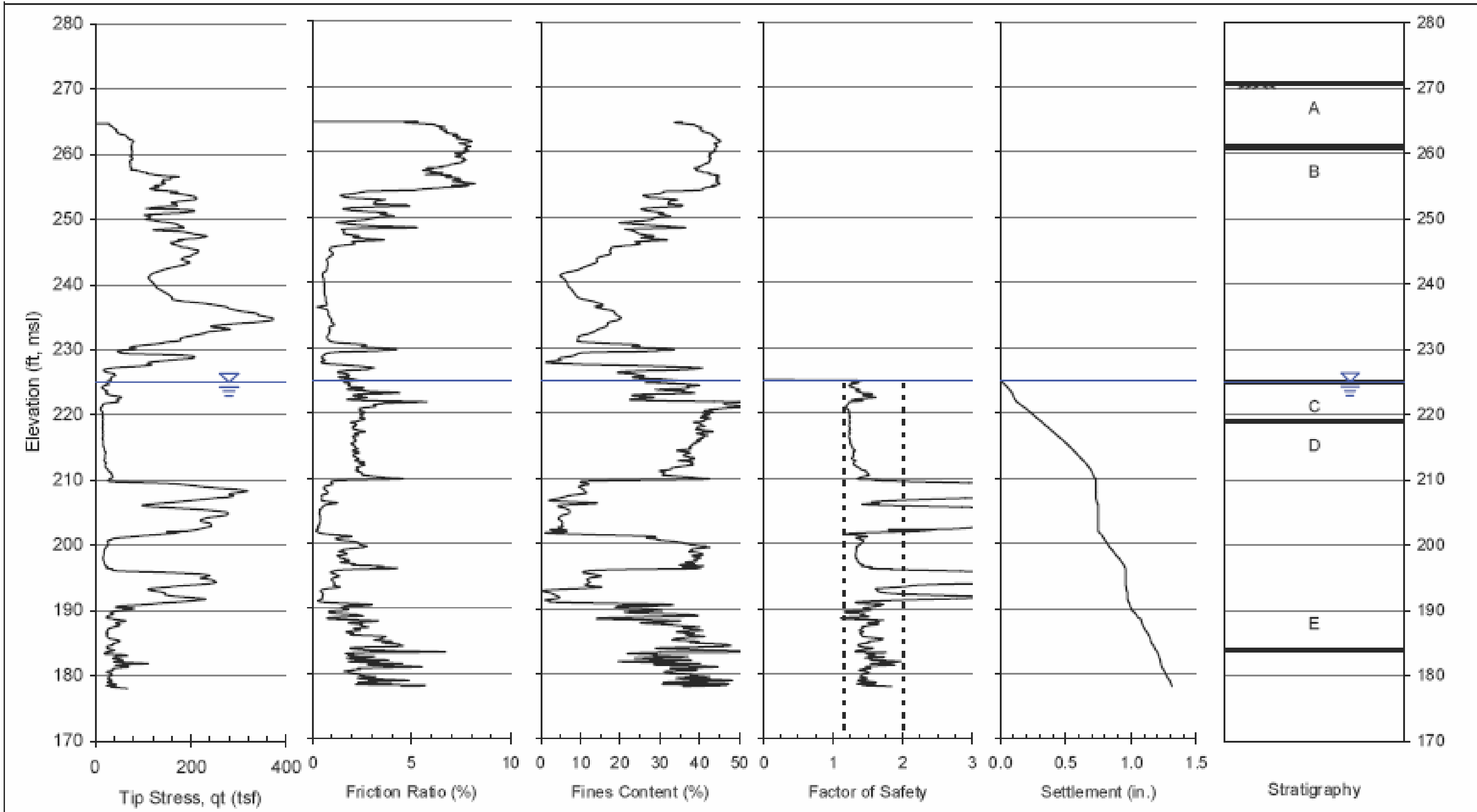
Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	3.26	2.59	2.11	1.63	1.34	0.96
Average Factor of Safety	6.08	4.83	3.93	3.04	2.50	1.79
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.01 in.	0.10 in.	0.78 in.

2,500 Year Weighted Average Settlement	0.38 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C10

Design Basis Earthquake - Volumetric Strain, Old CRR



Magnitude 7.50 Plot

Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	3.77	3.00	2.44	1.89	1.55	1.11
Average Factor of Safety	6.46	5.13	4.18	3.23	2.66	1.90
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.04 in.	0.24 in.	1.31 in.

2,500 Year Weighted Average Settlement	0.64 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C11

	DBE					
Magnitudes	*4.75*	*5.25*	*5.75*	*6.25*	*6.75*	*7.5*
Settlement Above Santee	0.00 in.	0.00 in.	0.00 in.	0.01 in.	0.04 in.	0.38 in.

Weighted DBE Settlements

SCPTu ID	2,500 Year Average for all Magnitudes (100 Hz)
Z-V3V5-C11	0.18 in.

DBE Mw =7.5 CPT (tip stress) and Shear Wave Velocity Factor of Safety Comparison

CPT Approach

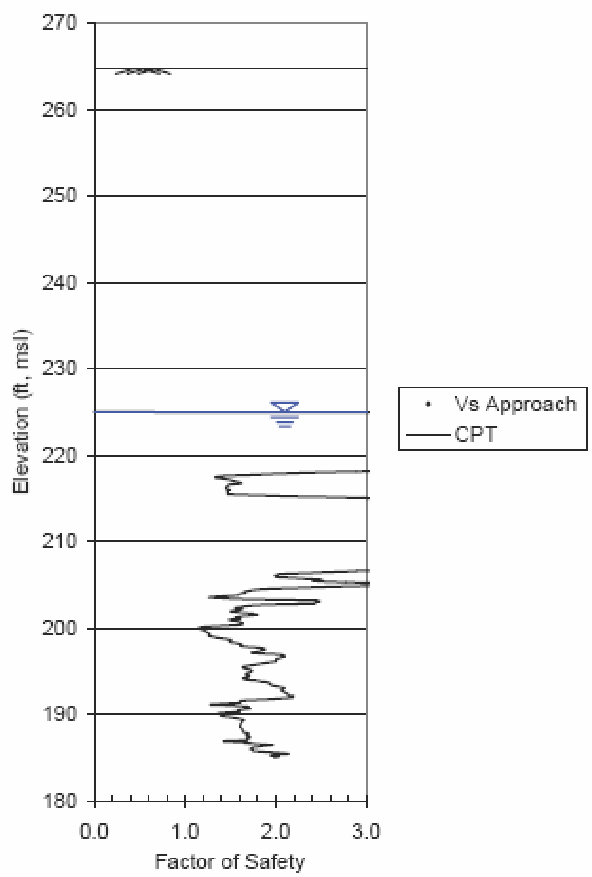
Min. Factor of Safety
1.15

Average Factor of Safety
2.81

Vs Approach

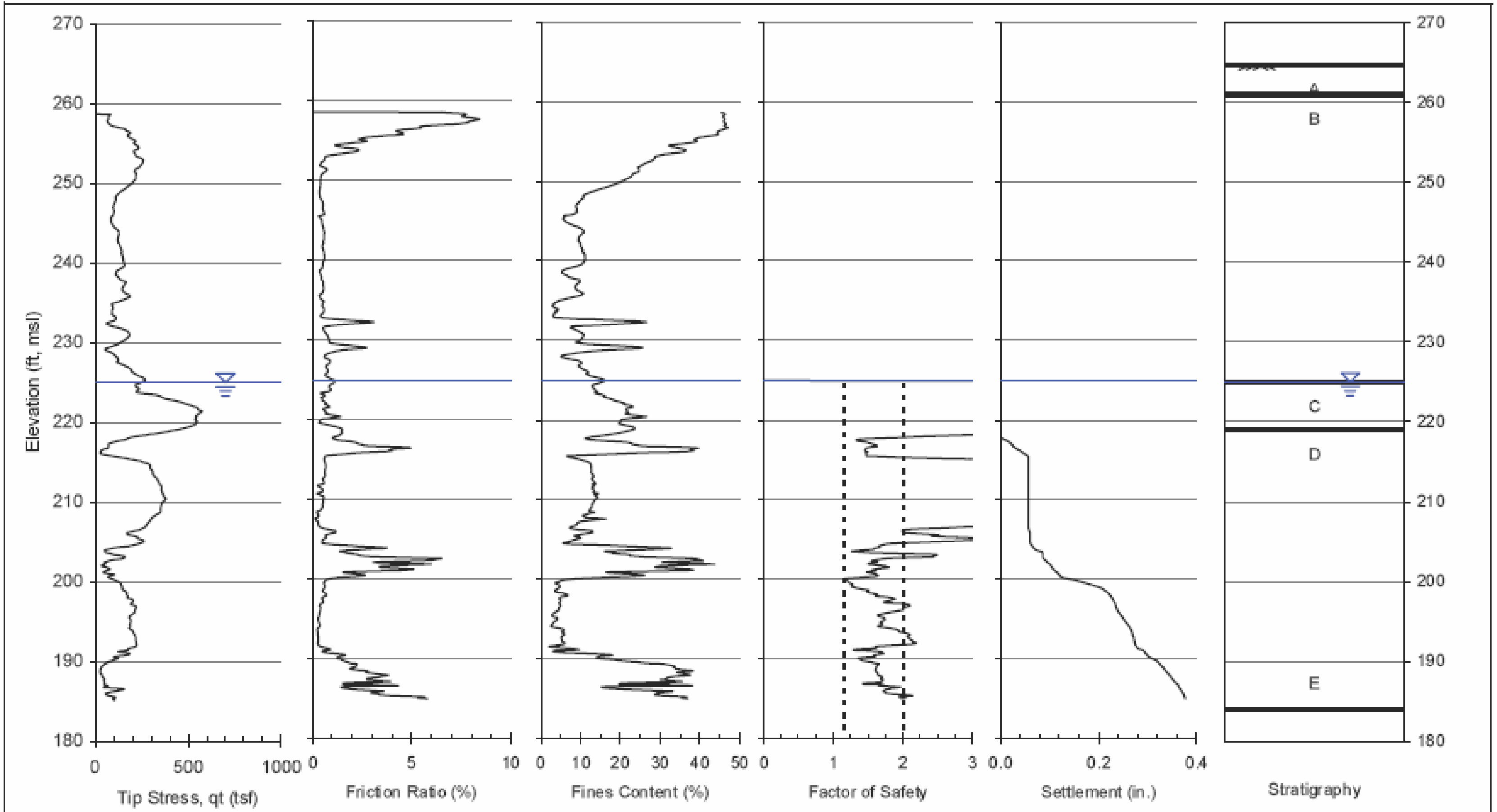
Min. Factor of Safety
4.10

Average Factor of Safety
4.26



Project: Vaults 3 and 5
Cone ID: Z-V3V5-C11

Design Basis Earthquake - Volumetric Strain



Magnitude 7.50 Plot

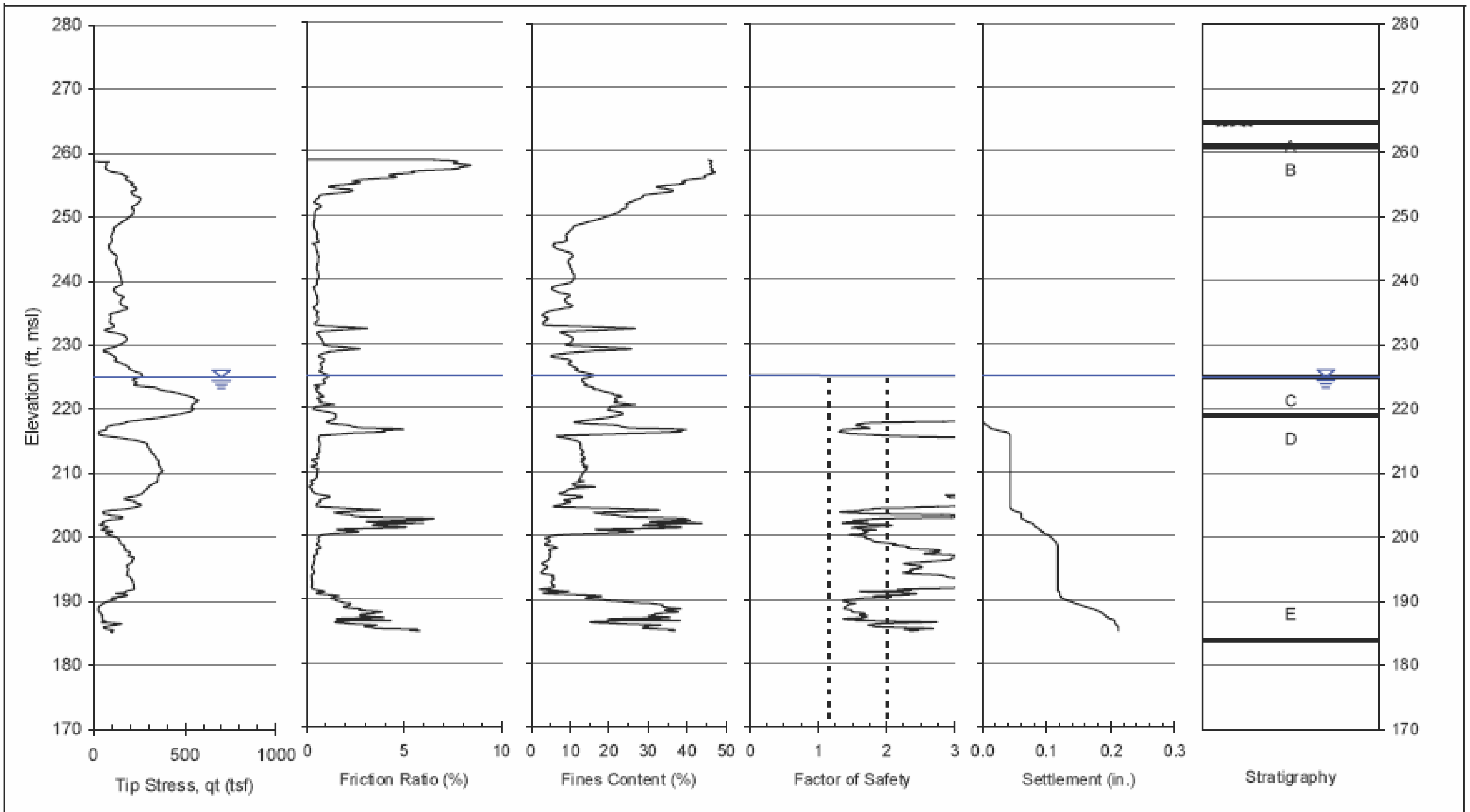
Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	3.90	3.10	2.53	1.95	1.61	1.15
Average Factor of Safety	8.89	7.06	5.75	4.44	3.66	2.61
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.01 in.	0.04 in.	0.38 in.

2,500 Year Weighted Average Settlement	0.18 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C11

Design Basis Earthquake - Volumetric Strain, Old CRR



Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	4.44	3.52	2.87	2.22	1.83	1.30
Average Factor of Safety	19.51	15.50	12.63	9.76	8.04	5.74
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.00 in.	0.03 in.	0.21 in.

2,500 Year Weighted Average Settlement	0.10 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C12

	DBE					
Magnitudes	4.75	5.25	5.75	6.25	6.75	7.5
Settlement Above Santee	0.00 in.	0.00 in.	0.01 in.	0.05 in.	0.19 in.	1.00 in.

Weighted DBE Settlements

SCPTu ID	2,500 Year Average for all Magnitudes (100 Hz)
Z-V3V5-C12	0.49 in.

DBE Mw =7.5 CPT (tip stress) and Shear Wave Velocity Factor of Safety Comparison

CPT Approach

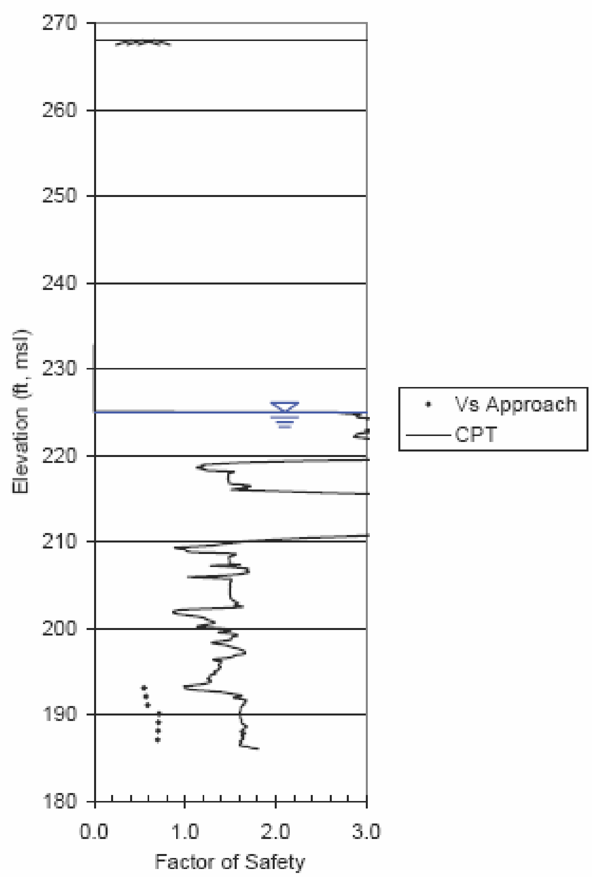
Min. Factor of Safety
0.87

Average Factor of Safety
2.52

Vs Approach

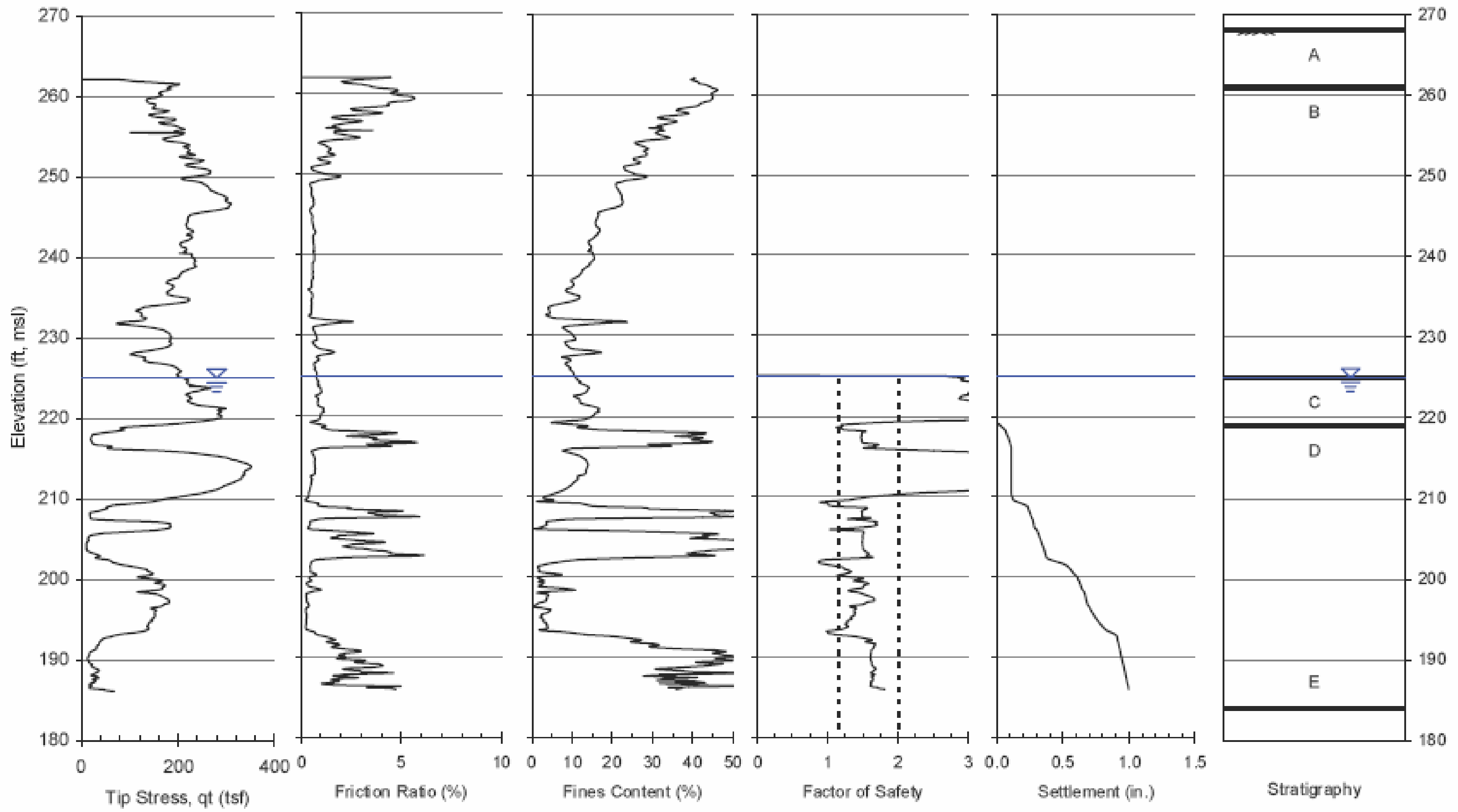
Min. Factor of Safety
0.55

Average Factor of Safety
3.70



Project: Vaults 3 and 5
Cone ID: Z-V3V5-C12

Design Basis Earthquake - Volumetric Strain



Magnitude 7.50 Plot

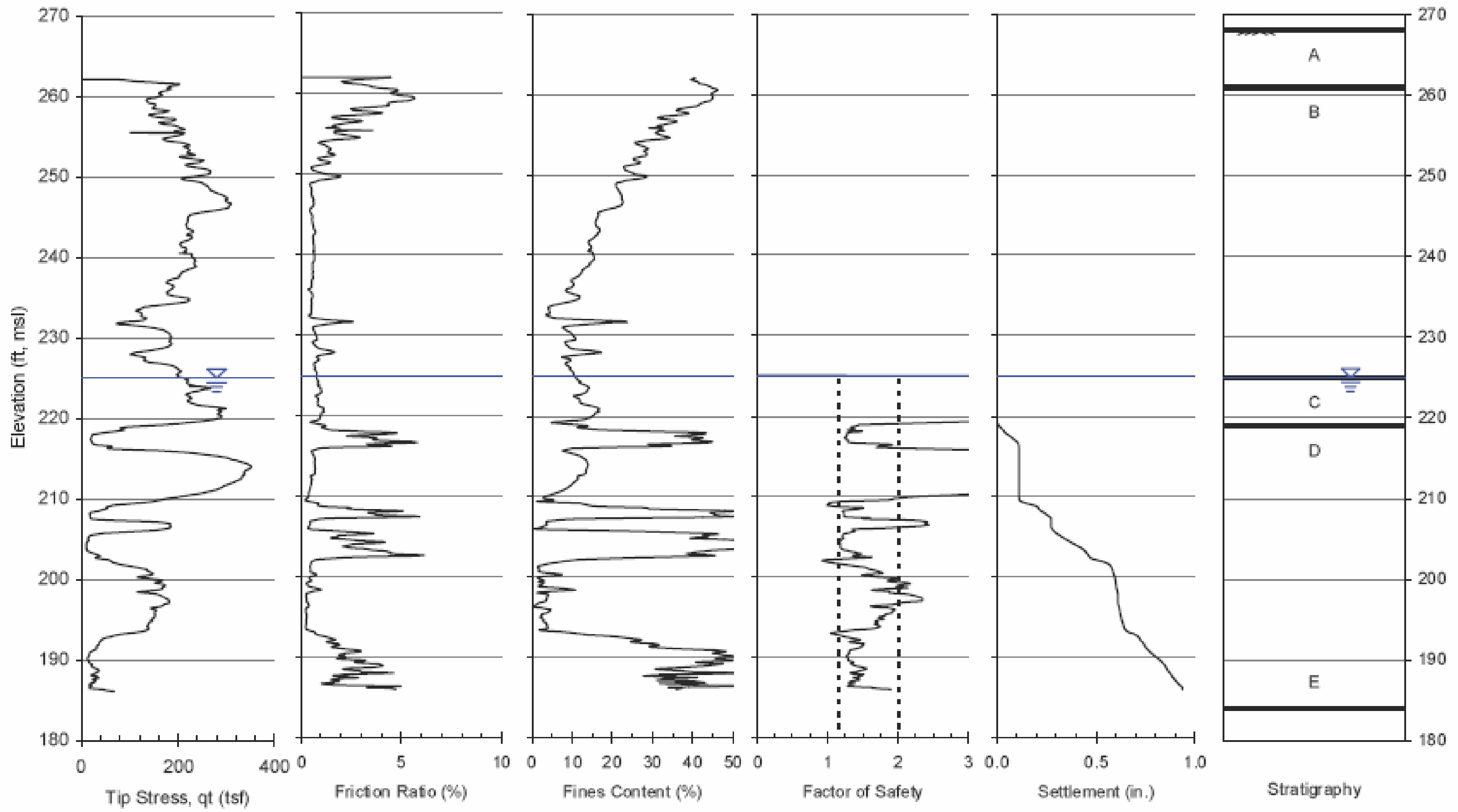
Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	2.96	2.35	1.92	1.48	1.22	0.87
Average Factor of Safety	8.56	6.79	5.54	4.28	3.52	2.52
Maximum Settlement	0.00 in.	0.00 in.	0.01 in.	0.05 in.	0.19 in.	1.00 in.

2,500 Year Weighted Average Settlement	0.49 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C12

Design Basis Earthquake - Volumetric Strain, Old CRR



Magnitude 7.50 Plot

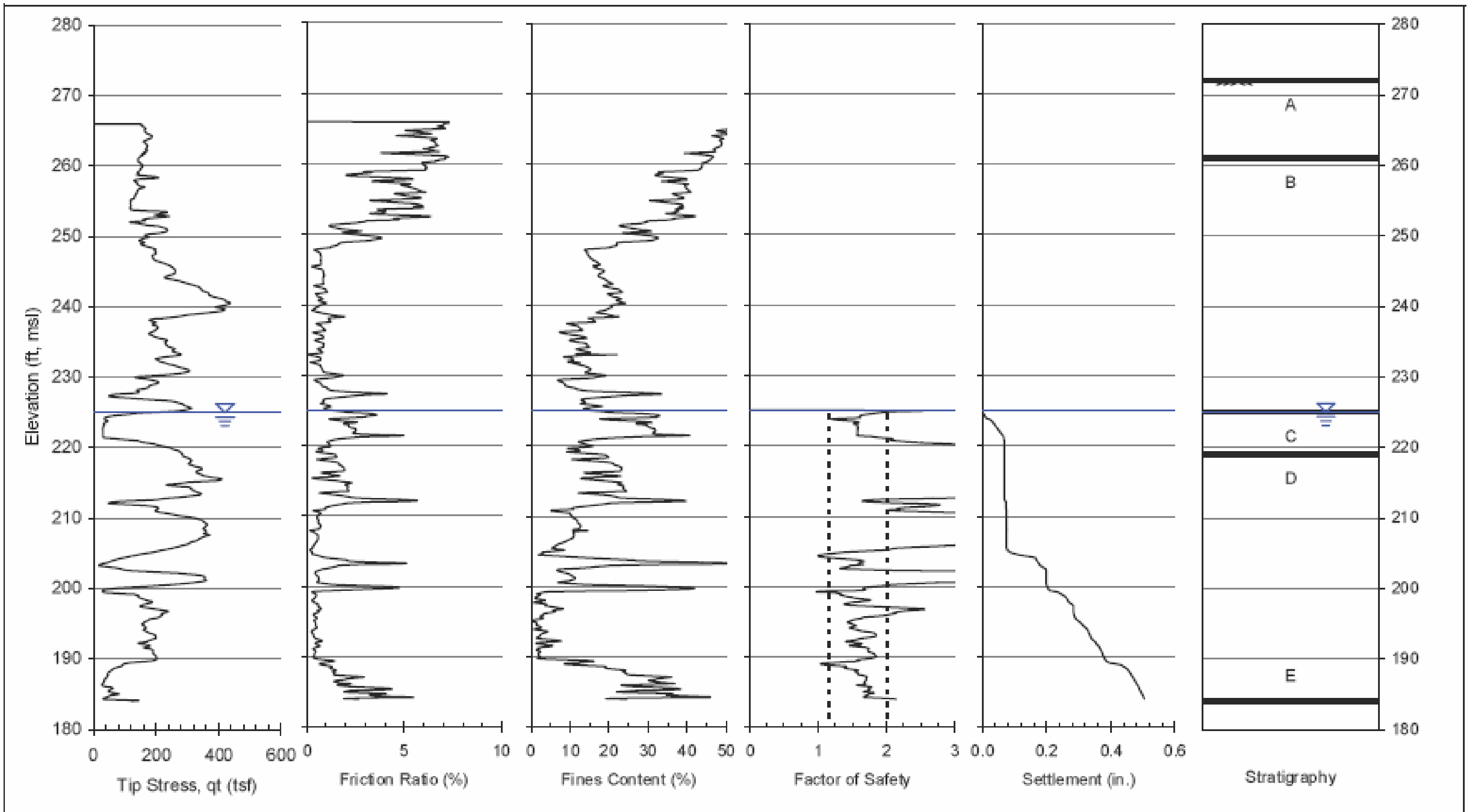
Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	3.13	2.48	2.02	1.56	1.29	0.92
Average Factor of Safety	10.03	7.96	6.49	5.01	4.13	2.95
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.04 in.	0.17 in.	0.94 in.

2,500 Year Weighted Average Settlement	0.45 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C13

Design Basis Earthquake - Volumetric Strain

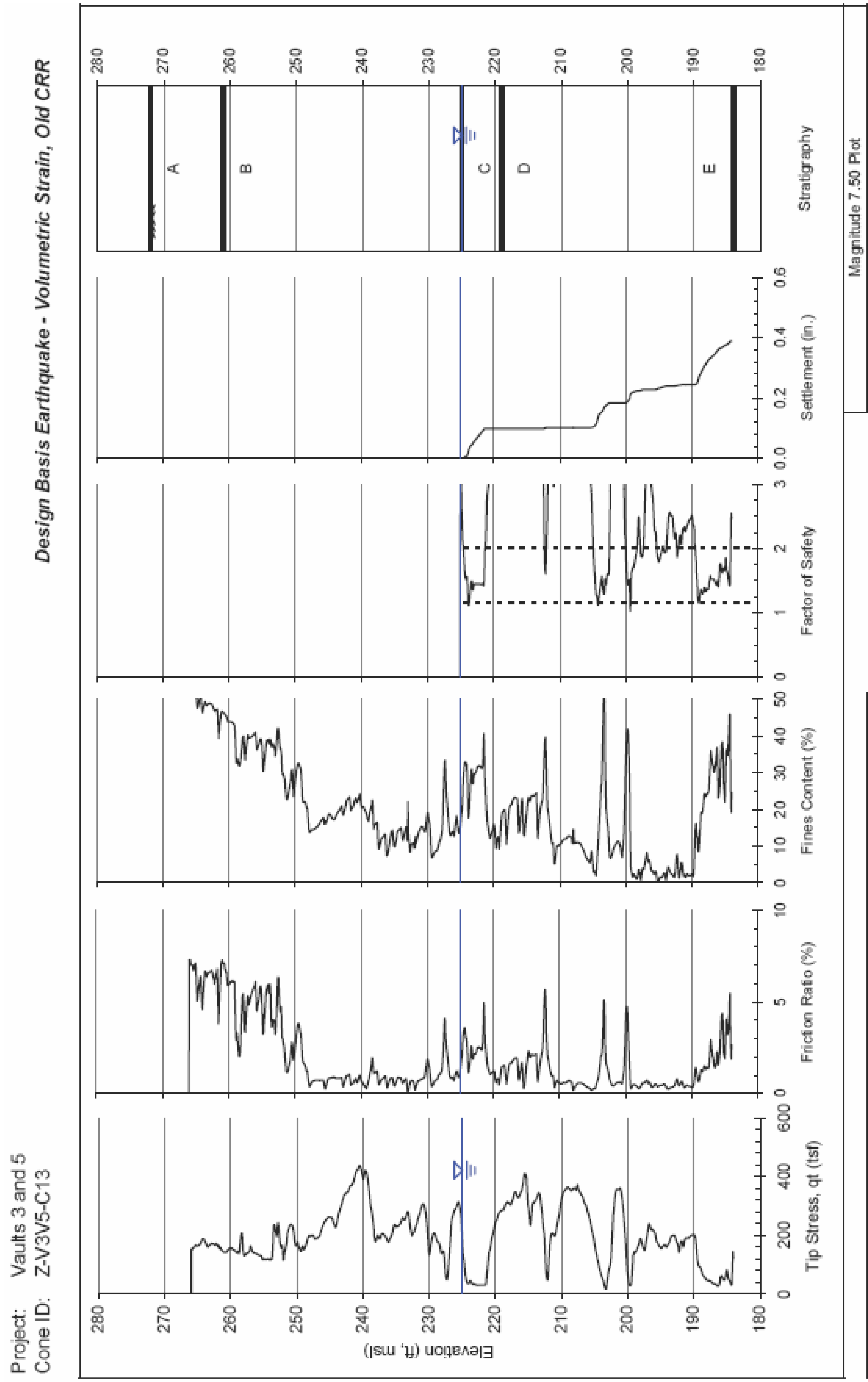


Magnitude 7.50 Plot

Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	3.31	2.63	2.14	1.66	1.36	0.97
Average Factor of Safety	12.08	9.59	7.81	6.04	4.97	3.55
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.01 in.	0.07 in.	0.50 in.

2,500 Year Weighted Average Settlement	0.24 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4



Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	3.47	2.75	2.24	1.73	1.43	1.02
Average Factor of Safety	13.43	10.66	8.69	6.71	5.53	3.95
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.01 in.	0.06 in.	0.39 in.

2,500 Year Weighted Average Settlement	0.19 in.

	Stratigraphy / Layer Description
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C14

	DBE					
Magnitudes	4.75	5.25	5.75	6.25	6.75	7.5
Settlement Above Santee	0.00 in.	0.00 in.	0.00 in.	0.03 in.	0.13 in.	0.88 in.

Weighted DBE Settlements

SCPTu ID	2,500 Year Average for all Magnitudes (100 Hz)
Z-V3V5-C14	0.43 in.

DBE Mw =7.5 CPT (tip stress) and Shear Wave Velocity Factor of Safety Comparison

CPT Approach

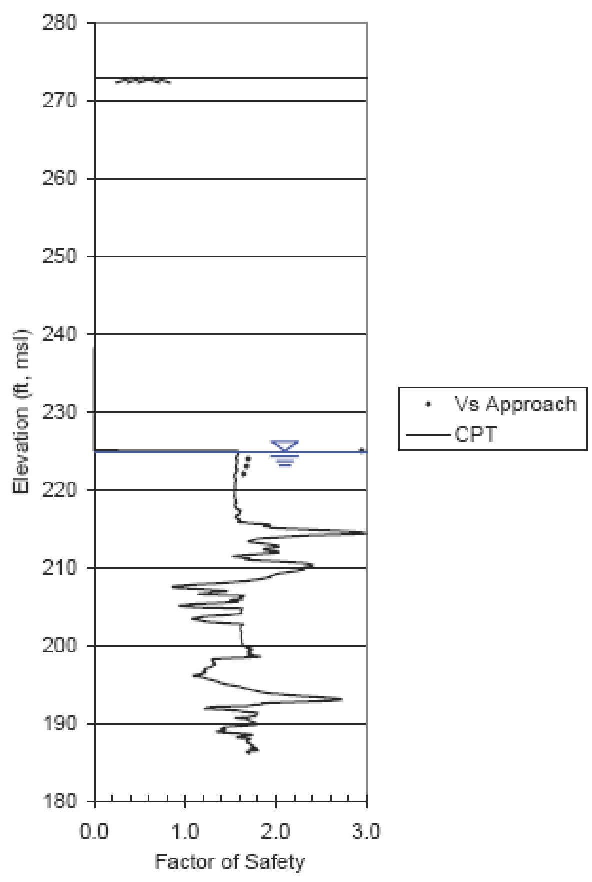
Min. Factor of Safety
0.87

Average Factor of Safety
1.65

Vs Approach

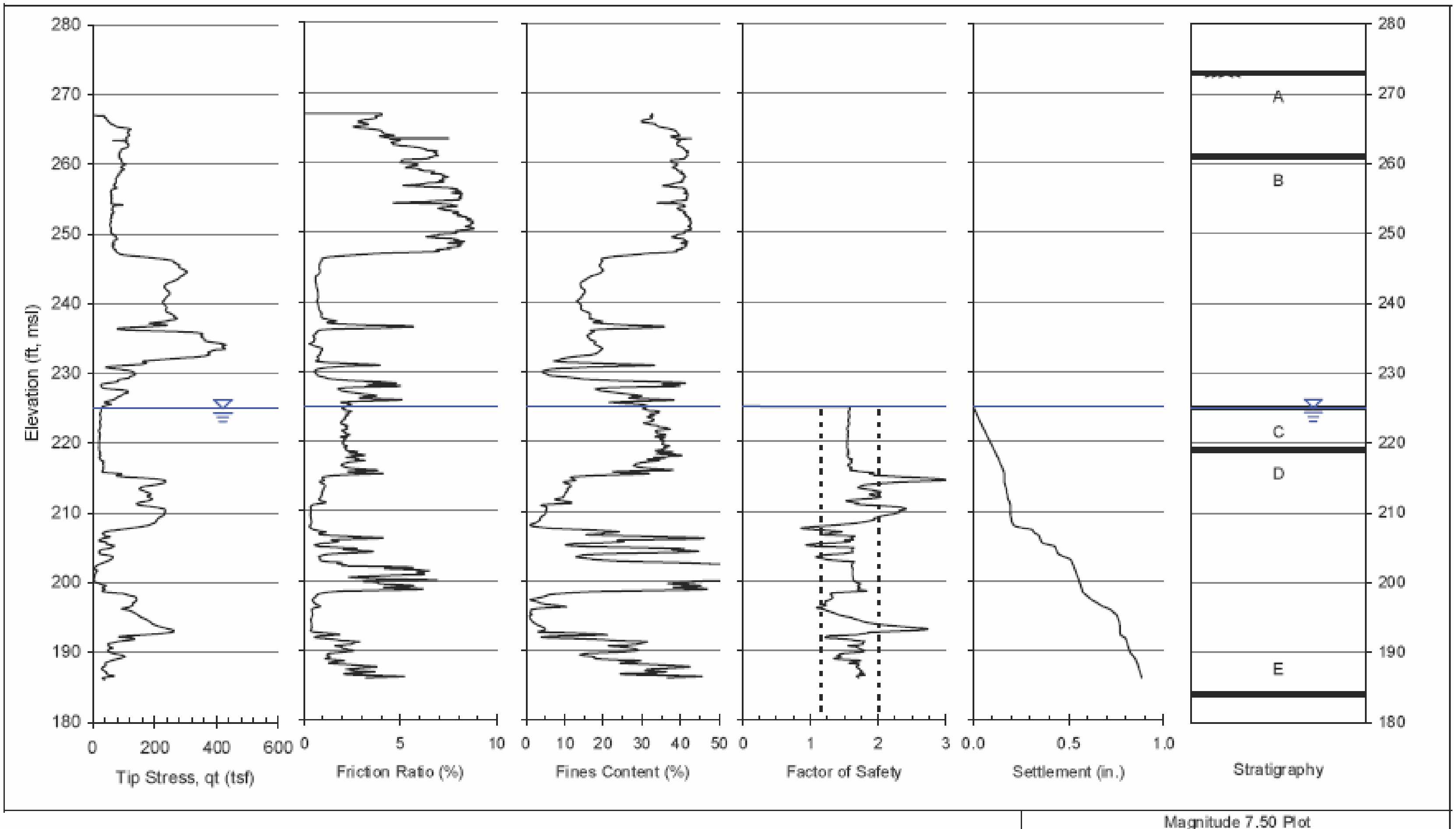
Min. Factor of Safety
1.65

Average Factor of Safety
4.33



Project: Vaults 3 and 5
Cone ID: Z-V3V5-C14

Design Basis Earthquake - Volumetric Strain



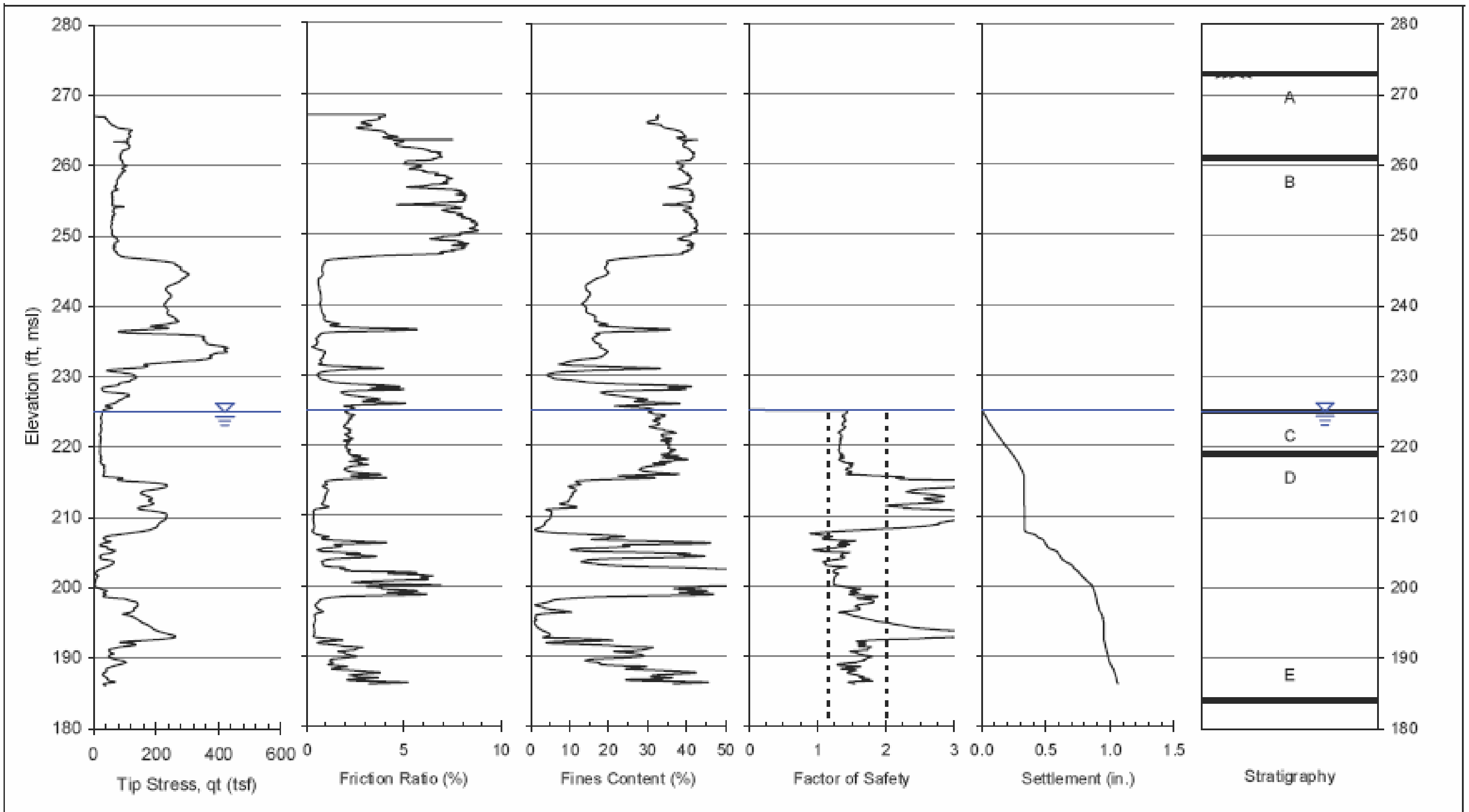
Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	2.94	2.34	1.90	1.47	1.21	0.87
Average Factor of Safety	5.60	4.45	3.62	2.80	2.31	1.65
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.03 in.	0.13 in.	0.88 in.

2,500 Year Weighted Average Settlement	0.43 in.

Stratigraphy / Layer Description		
A	S1/S2	
B	Bottom of Excavation	
C	C2	
D	S3	
E	S4	

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C14

Design Basis Earthquake - Volumetric Strain, Old CRR



Magnitude 7.50 Plot

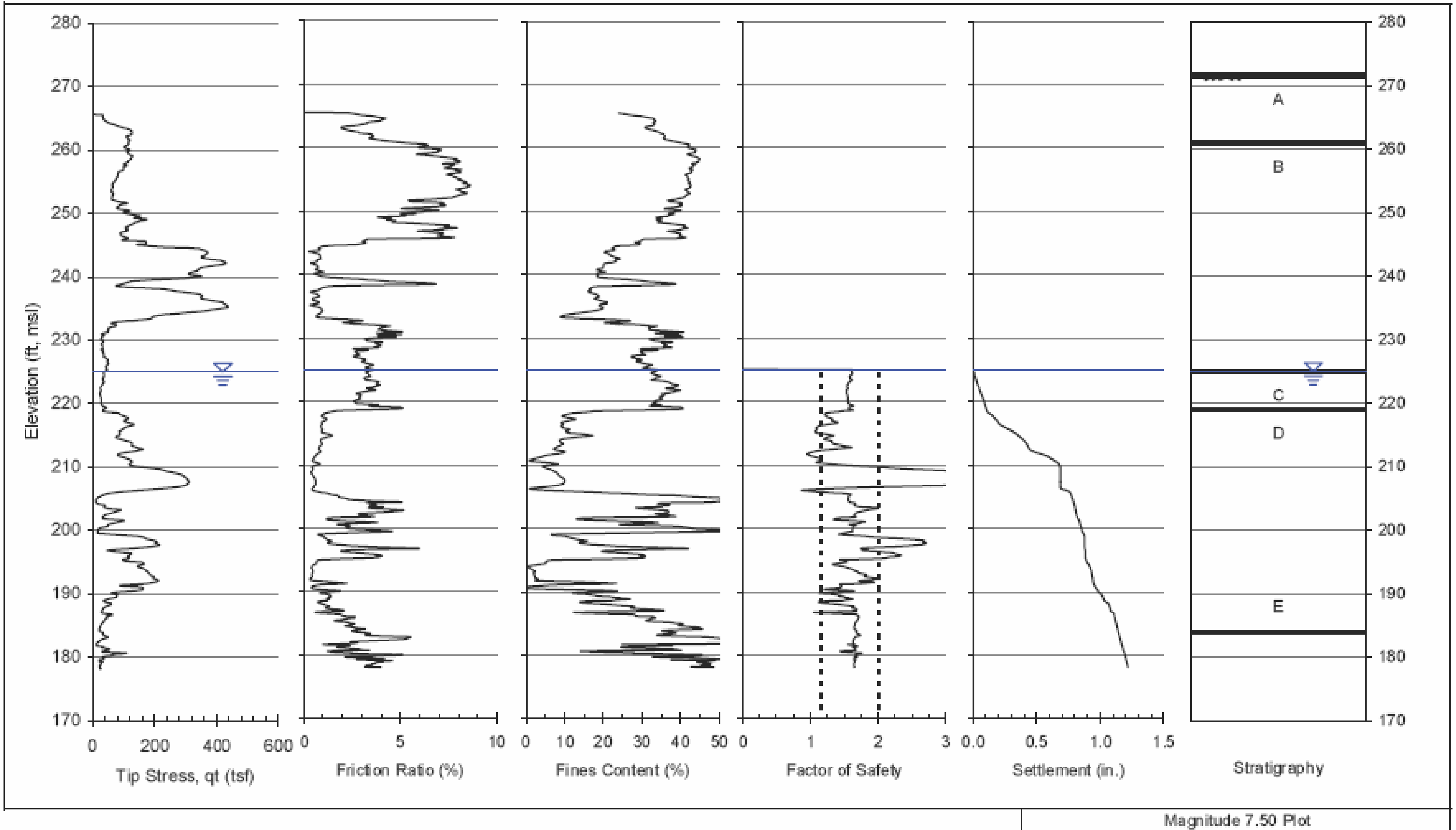
Magnitude	*4.75*	*5.25*	*5.75*	*6.25*	*6.75*	*7.5*
Minimum Factor of Safety	3.01	2.39	1.95	1.50	1.24	0.88
Average Factor of Safety	6.10	4.84	3.95	3.05	2.51	1.79
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.03 in.	0.19 in.	1.06 in.

2,500 Year Weighted Average Settlement	0.51 in.

Stratigraphy / Layer Description		
A	S1/S2	
B	Bottom of Excavation	
C	C2	
D	S3	
E	S4	

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C15

Design Basis Earthquake - Volumetric Strain



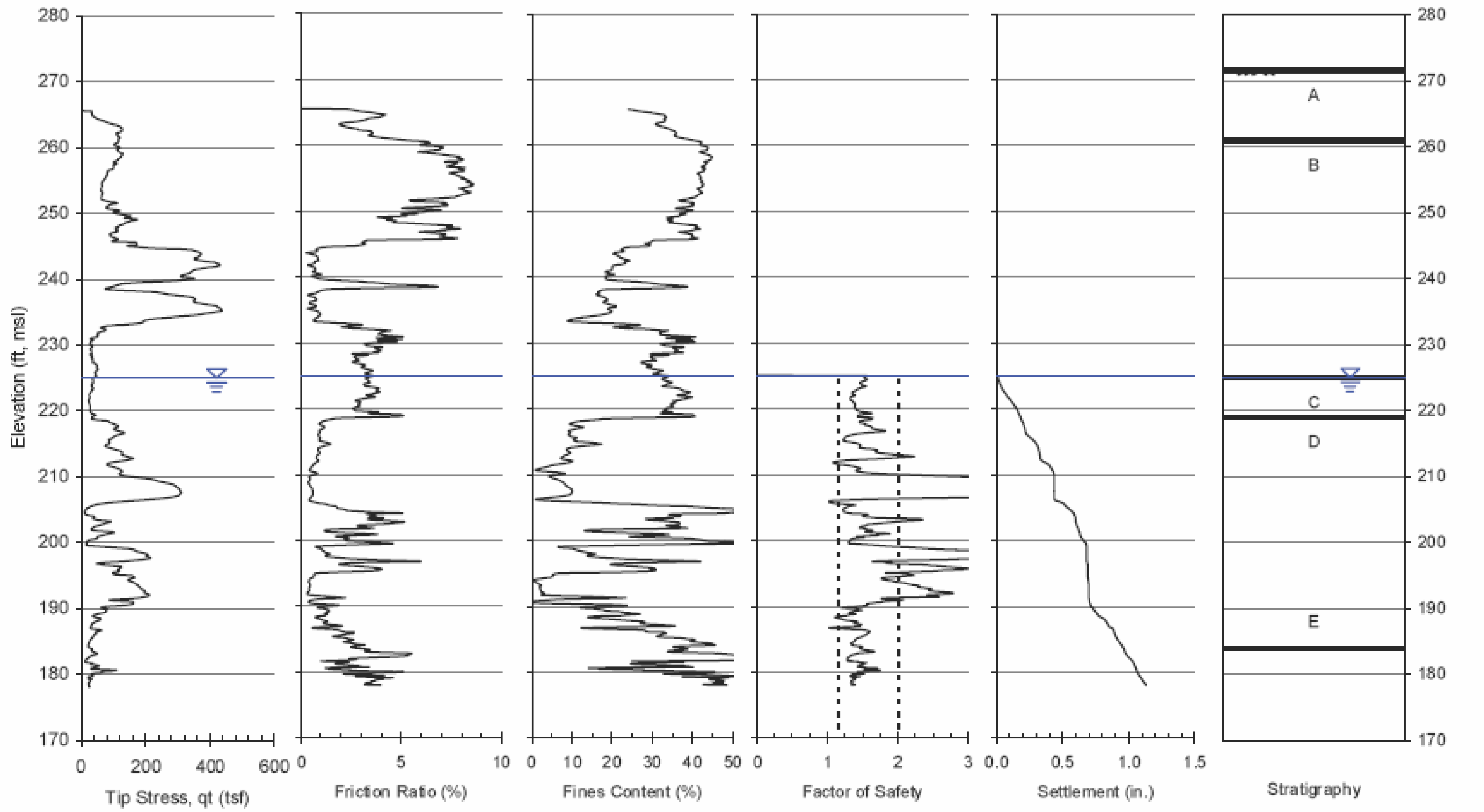
Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	2.95	2.34	1.91	1.47	1.21	0.87
Average Factor of Safety	5.85	4.65	3.79	2.93	2.41	1.72
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.05 in.	0.20 in.	1.22 in.

2,500 Year Weighted Average Settlement	0.59 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C15

Design Basis Earthquake - Volumetric Strain, Old CRR



Magnitude 7.50 Plot

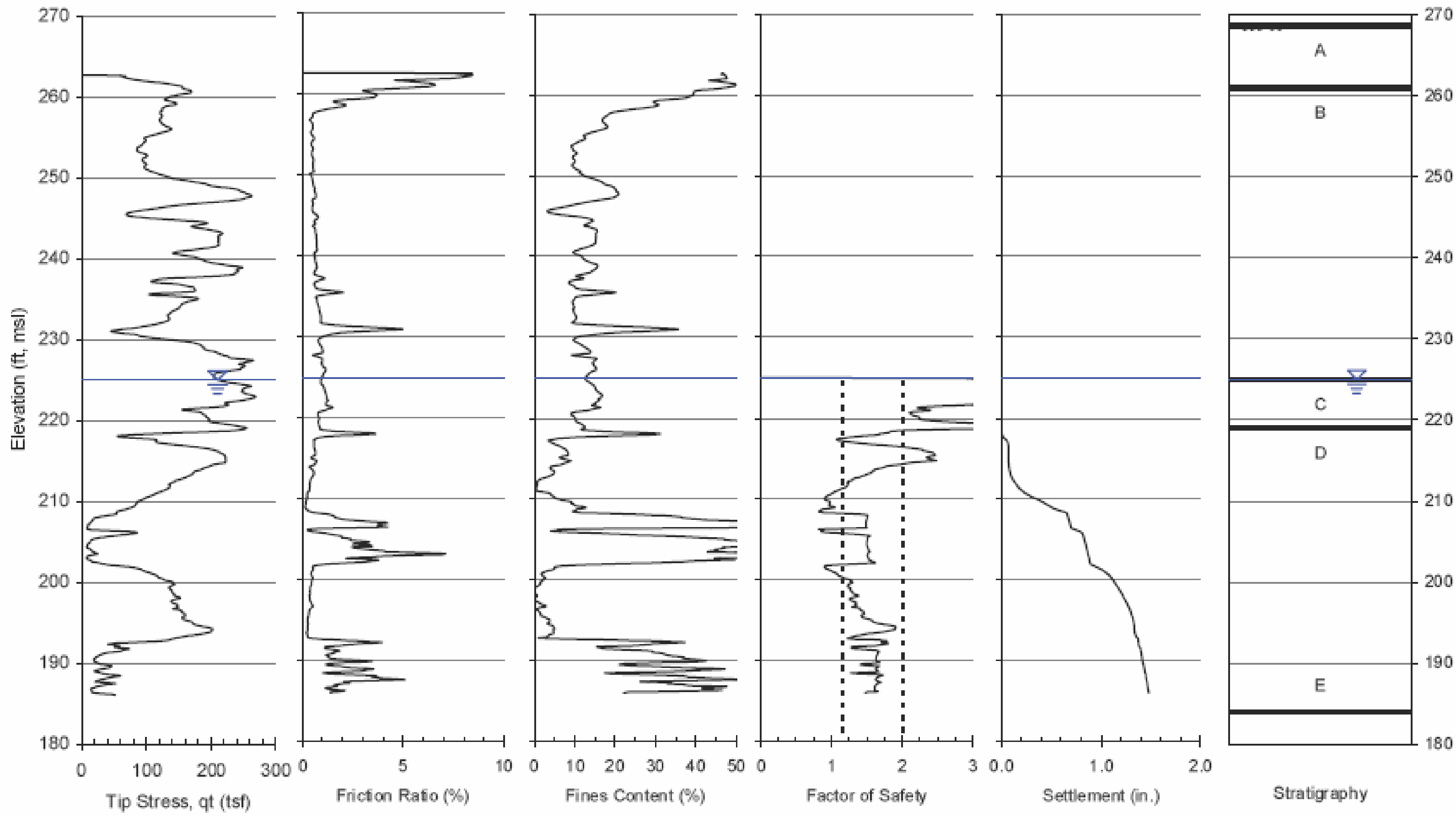
Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	3.49	2.77	2.26	1.74	1.44	1.03
Average Factor of Safety	6.41	5.09	4.15	3.21	2.64	1.89
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.03 in.	0.20 in.	1.13 in.

2,500 Year Weighted Average Settlement	0.55 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C16

Design Basis Earthquake - Volumetric Strain

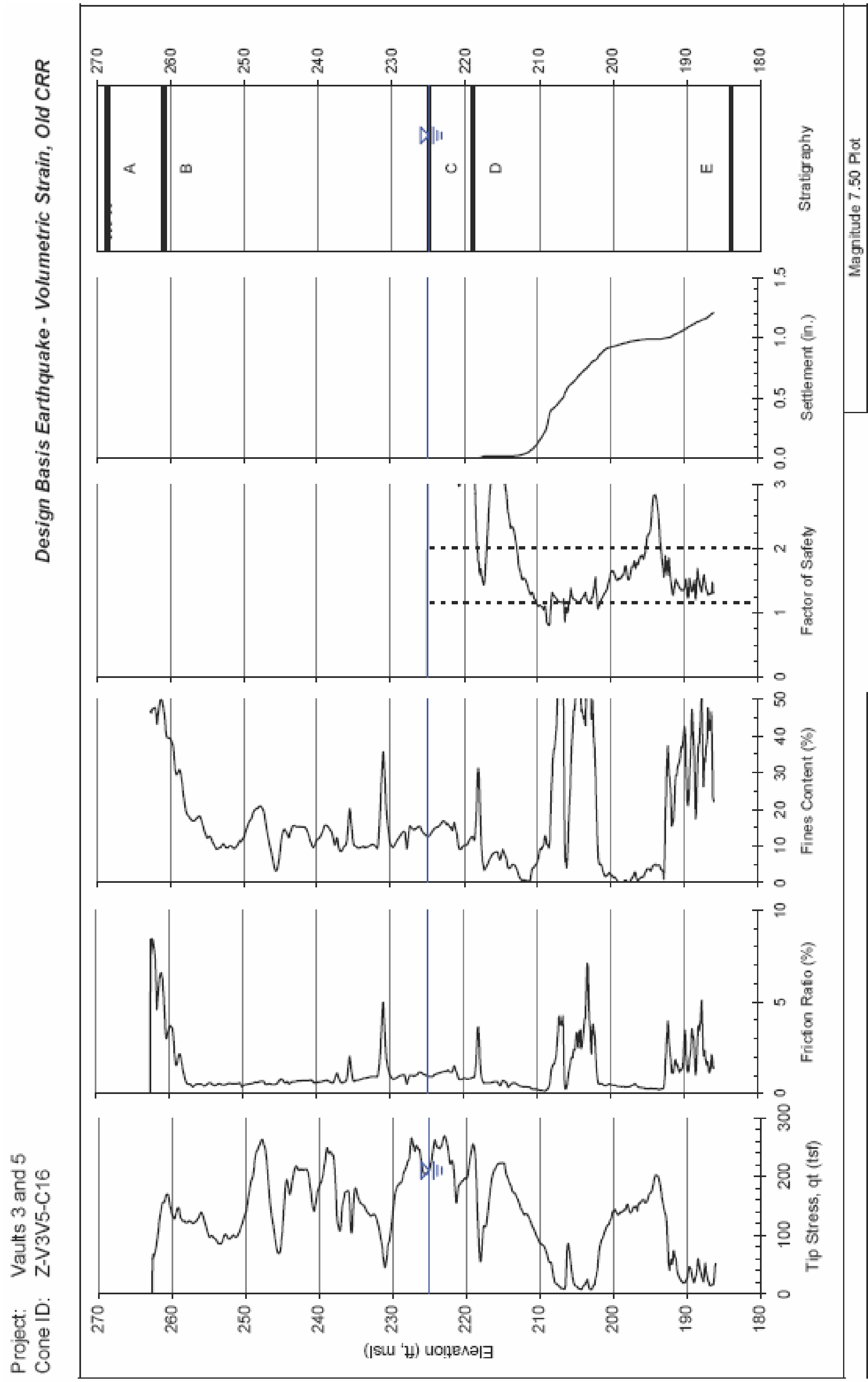


Magnitude 7.50 Plot

Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	2.78	2.20	1.80	1.39	1.14	0.82
Average Factor of Safety	5.98	4.75	3.87	2.99	2.46	1.76
Maximum Settlement	0.00 in.	0.00 in.	0.02 in.	0.10 in.	0.32 in.	1.48 in.

2,500 Year Weighted Average Settlement	0.73 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4



Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	2.72	2.16	1.76	1.36	1.12	0.80
Average Factor of Safety	7.50	5.96	4.85	3.75	3.09	2.21
Maximum Settlement	0.00 in.	0.00 in.	0.01 in.	0.07 in.	0.24 in.	1.21 in.

2,500 Year Weighted Average Settlement	0.59 in.

	Stratigraphy / Layer Description
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C17

	DBE					
Magnitudes	4.75	5.25	5.75	6.25	6.75	7.5
Settlement Above Santee	0.00 in.	0.00 in.	0.01 in.	0.10 in.	0.32 in.	1.64 in.

Weighted DBE Settlements

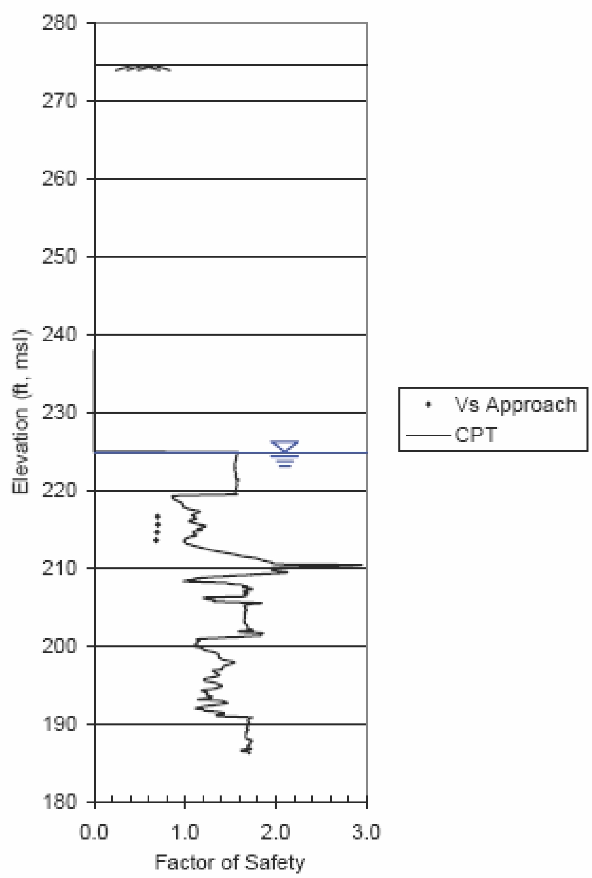
SCPTu ID	2,500 Year Average for all Magnitudes (100 Hz)
Z-V3V5-C17	0.80 in.

DBE Mw =7.5 CPT (tip stress) and Shear Wave Velocity Factor of Safety Comparison

CPT Approach

Min. Factor of Safety
0.86

Average Factor of Safety
1.45



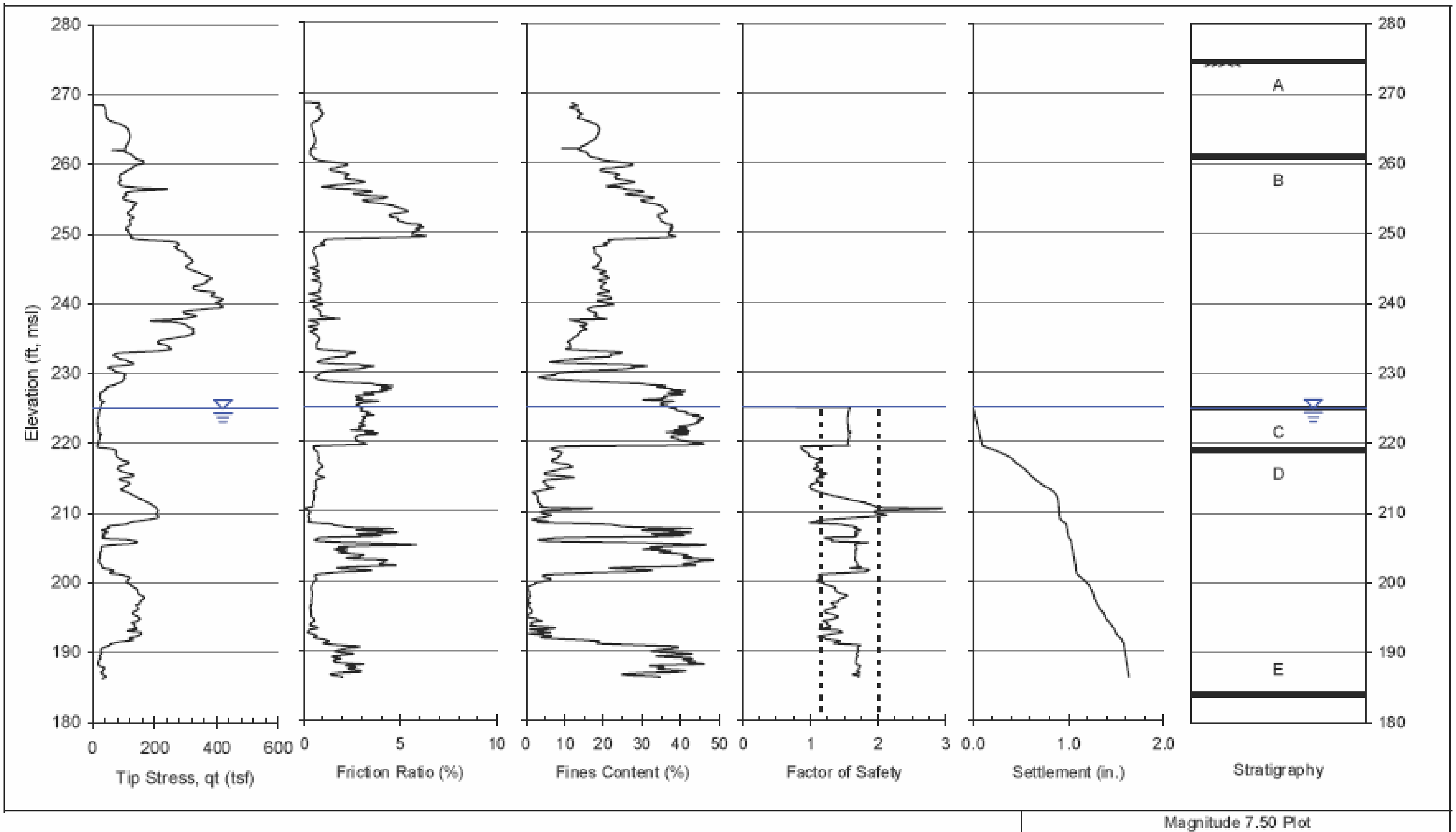
Vs Approach

Min. Factor of Safety
0.69

Average Factor of Safety
4.33

Project: Vaults 3 and 5
Cone ID: Z-V3V5-C17

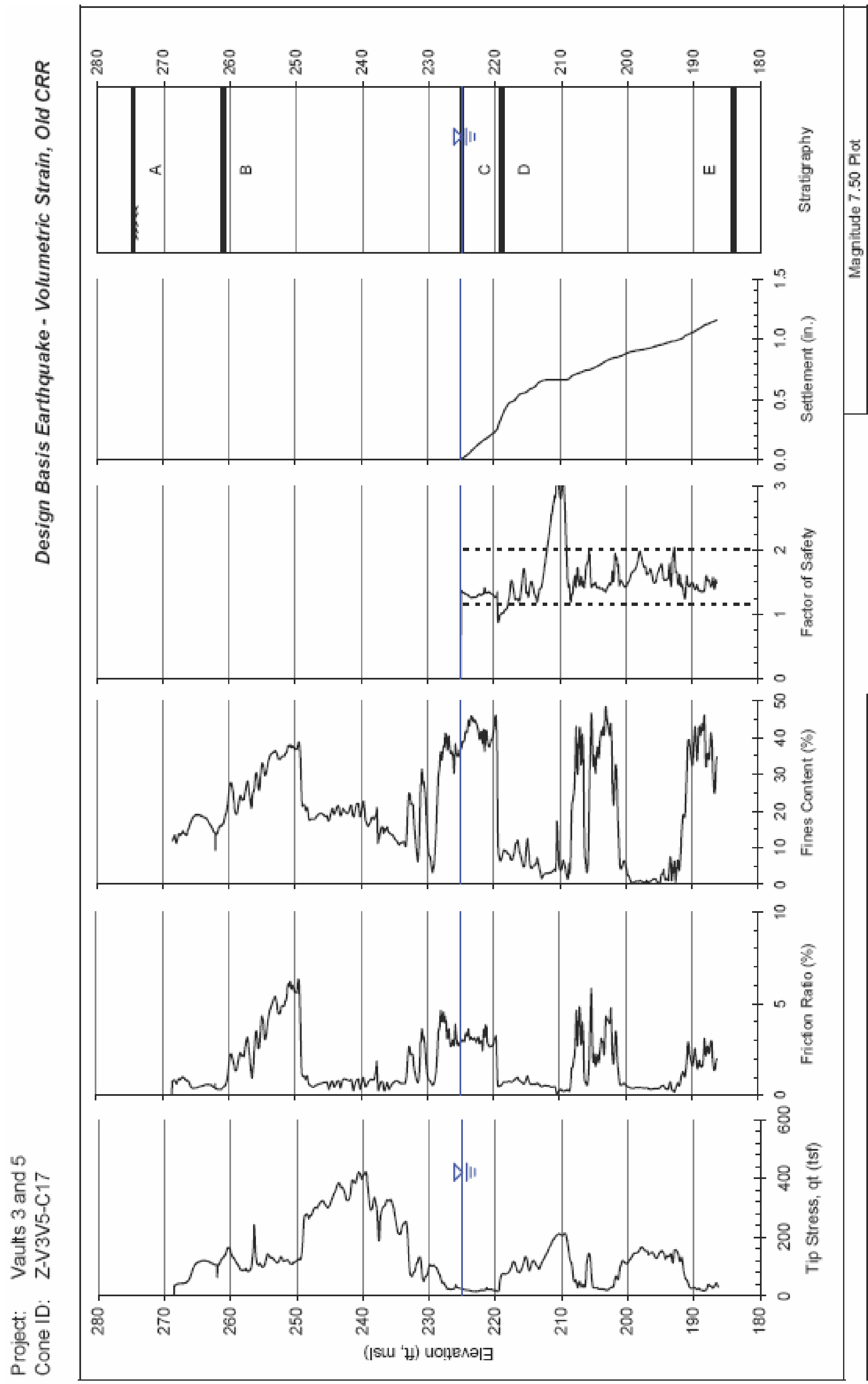
Design Basis Earthquake - Volumetric Strain



Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	2.91	2.31	1.88	1.46	1.20	0.86
Average Factor of Safety	4.94	3.92	3.19	2.47	2.03	1.45
Maximum Settlement	0.00 in.	0.00 in.	0.01 in.	0.10 in.	0.32 in.	1.64 in.

2,500 Year Weighted Average Settlement	0.80 in.

Stratigraphy / Layer Description	
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4



	Stratigraphy / Layer Description
A	S1/S2
B	Bottom of Excavation
C	C2
D	S3
E	S4

Magnitude	4.75	5.25	5.75	6.25	6.75	7.5
Minimum Factor of Safety	2.97	2.36	1.92	1.49	1.22	0.87
Average Factor of Safety	5.33	4.23	3.45	2.66	2.19	1.57
Maximum Settlement	0.00 in.	0.00 in.	0.00 in.	0.03 in.	0.21 in.	1.16 in.

2,500 Year Weighted Average Settlement	0.56 in.

Appendix E – Electronic Files

The following files are included with this calculation

Folder: CPT Data		
Z-V3V5-C01.ecp	Z-V3V5-C07.ecp	Z-V3V5-C13.ecp
Z-V3V5-C02.ecp	Z-V3V5-C08.ecp	Z-V3V5-C14.ecp
Z-V3V5-C03.ecp	Z-V3V5-C09.ecp	Z-V3V5-C15.ecp
Z-V3V5-C04.ecp	Z-V3V5-C10.ecp	Z-V3V5-C16.ecp
Z-V3V5-C05.ecp	Z-V3V5-C11.ecp	Z-V3V5-C17.ecp
Z-V3V5-C06.ecp	Z-V3V5-C12.ecp	
Z-V3V5-C01.vel	Z-V3V5-C07.vel	Z-V3V5-C12.vel
Z-V3V5-C04.vel	Z-V3V5-C09.vel	Z-V3V5-C14.vel
Z-V3V5-C06.vel	Z-V3V5-C11.vel	Z-V3V5-C17.vel
Folder: Current CRR		
ZVZV3V5C01-old CRR.xls	ZVZV3V5C07-old CRR.xls	ZVZV3V5C13-old CRR.xls
ZVZV3V5C02-old CRR.xls	ZVZV3V5C08-old CRR.xls	ZVZV3V5C14-old CRR.xls
ZVZV3V5C03-old CRR.xls	ZVZV3V5C09-old CRR.xls	ZVZV3V5C15-old CRR.xls
ZVZV3V5C04-old CRR.xls	ZVZV3V5C10-old CRR.xls	ZVZV3V5C16-old CRR.xls
ZVZV3V5C05-old CRR.xls	ZVZV3V5C11-old CRR.xls	ZVZV3V5C17-old CRR.xls
ZVZV3V5C06-old CRR.xls	ZVZV3V5C12-old CRR.xls	
Folder: Current CRR		
ZVZV3V5C01-current CRR.xls	ZVZV3V5C07-current CRR.xls	ZVZV3V5C13-current CRR.xls
ZVZV3V5C02-current CRR.xls	ZVZV3V5C08-current CRR.xls	ZVZV3V5C14-current CRR.xls
ZVZV3V5C03-current CRR.xls	ZVZV3V5C09-current CRR.xls	ZVZV3V5C15-current CRR.xls
ZVZV3V5C04-current CRR.xls	ZVZV3V5C10-current CRR.xls	ZVZV3V5C16-current CRR.xls
ZVZV3V5C05-current CRR.xls	ZVZV3V5C11-current CRR.xls	ZVZV3V5C17-current CRR.xls
ZVZV3V5C06-current CRR.xls	ZVZV3V5C12-current CRR.xls	

Appendix E – Soft Zone Analysis

K-CLC-Z-00016, Rev. 0

June 2009

Soft Zone Induced Settlements for Saltstone Disposal Cells 3 and 5

(16 pages)

CALCULATION COVER SHEET

Project	Calculation No.	Project Number
Saltstone Disposal Cells No. 3 and 5	K-CLC-Z-00016	Y546
Title	**Functional Classification**	**Sheet 1 of 15**
Soft Zone Induced Settlements for Saltstone Disposal Cells 3 and 5	PS	
	Discipline	
	Geotechnical	
Calc Level ☒ Type 1 ☐ Type 2	**Type 1 Calc Status** ☐ Preliminary ☒ Confirmed	
Computer Program No. ☒ N/A	**Version / Release No.** N/A	
Purpose and Objective	**DC/RO**	
The purpose of this calculation is to provide an estimate of the settlement resulting from the compression of soft zones for Saltstone Disposal Cells 3 and 5.	UNCLASSIFIED DOES NOT CONTAIN UNCLASSIFIED CONTROLLED NUCLEAR INFORMATION ADC & Reviewing Official [signature] A.A. Siddall (Name) Date: 7/23/2009	

Summary of Conclusion

See the Results and Conclusions Section.

Revision

Rev. No.	Revision Description
0	Original

Sign Off

Rev. No.	Originator (Print) Sign / Date	Verification / Checking Method	Verifier / Checker (Print) Sign / Date	Manager (Print) Sign / Date
0	Rucker J. Williams	Document Review	Bruce Nothdurft, PE	William T. Li
	[signature] 6/24-09		[signature] 6/24/09	[signature] 6-25-09

Additional Reviewer (Print)	Signature	Date
N/A		
Design Authority (Print)	**Signature**	**Date**
N/A		
Release to Outside Agency (Print)	**Signature**	**Date**
N/A		

Security Classification of the Calculation
Unclassified

TABLE OF CONTENTS

1. Introduction

The purpose of this calculation is to provide an estimate of the settlement resulting from the compression of soft for Saltstone Disposal Cells No. 3 and 5.

2. Input

2.1 Soft Zone Input

Seventeen (17) CPTs and and SCPTs were pushed for the Disposal Cells 3 and 5 site, see Figure 1. Stratigraphic interpretations of the CPT and SCPTs are summarized below (Ref. 1). These 17 CPTs and SCPTs were evaluated for the presence of soft zones.

				Elevation Top Pick (ft, msl)			
CPT ID	**CPT Type**	**SRS Northing**	**SRS Easting**	**Elevation ft, msl**	**C2 Layer**	**S3 Layer**	**S4 Layer**
ZV3V5C1	SCPT	78429	66907	264.9	NP	224	185
ZV3V5C2	CPT	78267	66960	268.6	221	215	184
ZV3V5C3	CPT	78477	66813	263.9	NP	219	190
ZV3V5C4	SCPT	78405	66836	266.8	NP	221	186
ZV3V5C5	CPT	78325	66863	268.8	226	221	186
ZV3V5C6	SCPT	78244	66889	268.8	229	217	187
ZV3V5C7	SCPT	78173	66913	268.2	233	223	NDE
ZV3V5C8	CPT	78374	66741	267.7	220	216	186
ZV3V5C9	SCPT	78293	66768	270.4	225	216	173
ZV3V5C10	CPT	78213	66794	270.7	227	211	178
ZV3V5C11	SCPT	78414	66623	264.7	218	215	185
ZV3V5C12	SCPT	78343	66646	268.1	219	216	186
ZV3V5C13	CPT	78262	66673	272.0	225	221	184
ZV3V5C14	SCPT	78181	66699	273.0	228	216	186
ZV3V5C15	CPT	78110	66723	271.6	231	220	178
ZV3V5C16	CPT	78319	66575	268.7	NP	228	186
ZV3V5C17	SCPT	78158	66628	274.6	228	219	186

NDE=Not Deep Enough
NP = Not Present

Four (4) borings were also performed for this investigation. The borings are listed in the table below.

Boring ID	**SRS Northin g**	**SRS Eastin g**	**Elevatio n ft, msl**	**Adjacent CPT**
ZV3V5B1	78395	66839	266.9	ZV3V5C4
ZV3V5B2	78235	66894	269.9	ZV3V5C6
ZV3V5B3	78333	66649	268.3	ZV3V5C1 2
ZV3V5B4	78171	66702	272.8	ZV3V5C1 4

3. Computation

Soft zones are layers of underconsolidated soils within the Santee Formation (S4 layer) which are identified by a corrected tip stress value less than or equal to 15 tsf. Layers of soft zone soils (corrected tip stress less than or equal to 15 tsf) are considered to behave as a single soft zone if the interval of harder material (corrected tip stress greater than 15 tsf) between the soft zone soils is less than or equal to 2 feet in thickness. The thickness of the soft zone is the summation of the less than 15 tsf material. The top elevation of the soft zone is the top of the first layer of soil with a corrected tip stress less than 15 tsf within the Santee Formation Santee Formation (S4 layer).

If the interval of harder soil (corrected tip stress greater than 15 tsf) between soft zone soils is greater than 2 feet, the layers of soft zones soils are considered to behave as two separate soft zones (See Figure 3).

Soft zones may also be identified by N value less than or equal to 5 blows per foot (including weight of rod and weight of hammer events) within the Santee Formation (S4 layer).

The only soft zone encountered in this investigation was in Z-V3V5-C06 at an elevation of 172 ft, msl. This soft zone is less than ¼ foot thick. No soft zones were identified within the 2 SPT boreholes.

3.1 Soft Zone Settlement

As no significant soft zones were identified beneath Cells No. 3 and 5, the soft zone configuration from Saltstone Vault No. 2 will be used to provide a conservative estimate of surface settlement due to any soft zones that maybe present at Cells No. 3 and 5.

The following properties are considered for the soft zone geometry and properties for Disposal Cells 3 and 5 (Ref. 2).

Thickness	14 ft
Compression Index, C_c	0.196
Initial Void Ratio, e_0	0.72
Overconsolidation Ratio, OCR	0.9
Compression Ratio, $C_c/(1+e_0)$	0.114

The bottom of the excavation will be 261 ft, msl at Disposal Cells 3 and 5. The average top of the S4 layer (Santee Formation) at Disposal Cells 3 and 5 is 184 ft, msl. For conservatism, it will be assumed that the top of the soft zone is located at the top of the S4 layer.

The compression of the soft zone s_S at depth is estimated assuming full overburden pressure:

$$s_S = H \{C_c/(1 + e_o)\} \log \{(P_o + \Delta P)/P_o\}$$

Where s_S is the compression of the soft zone and H is the thickness of the soft zone. C_c and e_0 were described in the previous section. When the arch above the soft zone is weakened the $P_o + \Delta P$ term is equal to the overburden pressure and the P_o term in the denominator is the soft zone preconsolidation pressure. In this instance the equation becomes:

$s_S = H \{C_c/(1 + e_o)\} \log (1/OCR)$

where OCR is the overconsolidation ratio of the soft zone.

Using the soft zone properties from Vault 2, the compression of the soft zone is:

$s_S = H \{C_c/(1 + e_o)\} \log (1/OCR) = 14 \times 0.196/(1 + 0.72) \times \log (1/0.9) = 0.0730$ feet

or $s_S = 0.876$ inches.

3.2 Methodology for Computing Surface Settlement

A vertical slice of subsurface with unit thickness or perpendicular to the longitudinal direction of the soft zone was considered. Ground settlement, which is propagated from the subsurface deformation, was computed considering the surface settlement profile resembles the shape of an inverted normal distribution curve (Ref. 3). The surface settlement s(x) at any point x is:

$s(x) = s(0)\ \mathrm{Exp.}\{-x^2/(2i^2)\}$ (Eq. 1)

Where i is the distance from the center of the normal probability curve to the point of inflection:

$i = W/(2\pi)^{1/2}$ (Eq. 2)

and W is the half width of the normal probability curve and may be estimated as (Ref. 3):

$W = z \tan \beta + W_{SZ}/2.$ (Eq. 3)

where:

z is the soft zone depth and

β is based on soil type

The volume lost at-depth due to compression of soft zone can be computed as:

$V_L = s_S W_{SZ.}$ (Eq. 4)

Where s_S is the compression of the soft zone computed in the previous section and W_{SZ} is the width of the soft zone.

As the soft zone collapses, the volume of the soil above the soft zone will be increased as a result of dilation and loosening as the soil stresses redistribute. For granular soils, appreciable volume changes can occur in the soil as a result of disturbances and displacement (Ref. 3).

The volume of the surface settlement is:

$V_S = R_{S/L} V_L$ (Eq. 5)

where $R_{S/L}$ is the ratio of the volume of the surface settlement to the volume lost at-depth due to compression of the soft zone. Substituting Equation (4) into Equation (5):

$V_S = R_{S/L}\ s_S\ W_{SZ.}$ (Eq. 6)

Surface settlement at the center of the normal probably curve is:

$s(0) = V_S/W$ (Eq. 7)

Substituting Equation (6) into Equation (7)

$s(0) = R_{S/L}\ s_S\ W_{SZ}/W$ (Eq. 8)

Substituting Equation (8) into Equation (1), settlement at any point x can then be expressed as

$s(x) = R_{S/L}\ s_S\ W_{SZ}/W\ \mathrm{Exp}[-x^2/(2i^2)]$ (Eq. 9)

Figure 3 illustrates the properties of a normal probability curve settlement trough.

3.3 Surface Settlement due to the Compression of a Narrow Soft Zone

The assumption of normal probability is for underground disturbance over a short width. Assume the width of the soft zone is:

W_{SZ} = 5 feet

For the project site, at elevation of the foundation, 258 feet, MSL, the distance to the average depth of the soft zone is:

z = 261 – 184 = 77 feet

For SRS soil conditions β falls between 33 and 50 degrees. For sands below groundwater level, β is generally greater than 50 degrees. A smaller β will provide conservative values of maximum slope and maximum change of slope (Ref. 3) at the project site, consider β = 33 degrees:

$W = z \tan\beta + W_{SZ}/2 = 77 \tan(33^{o}) + 5/2 = 52.504$ feet

$i = W/(2\pi)^{1/2} = 52.504 / (2\pi)^{1/2} = 20.946$ feet

The volume of the surface settlement is generally one third to two thirds less than the volume of lost ground (Ref. 1). In this calculation, $R_{S/L}$ is considered to be 2/3.

$s(0) = R_{S/L}\, s_S\, W_{SZ} /W = (2/3) \times 0.876 \times 5/52.504 = 0.0556$ inches

Equation 1 becomes:

$s(x) = 0.0556 \text{ Exp } \{-x^2/(2 \times 20.946^2)\}$ inches

or $s(x) = 0.0556 \text{ Exp}(-x^2/877.49)$ inches

3.4 Surface Settlement

Wide soft zones maybe represented as a series of adjacent narrower soft zones. Surface settlements due to the wide soft zone are computed by superimposing the settlement troughs for each of the narrow soft zones. For this calculation, a series of 5 foot wide soft zones were utilized to represent soft zones ranging in width from 25 feet to 150 feet.

Maximum differential settlement is assumed to be equal to the total soft zone induced settlement. Maximum slope is the rate of change of settlement along the settlement trough, while curvature is the rate of change of the slope along the settlement trough.

Figure 4 presents the surface settlement profiles for each of the soft zone widths considered. Figures 5 – 7 illustrate the maximum surface settlement, maximum slope, and maximum curvature as functions of soft zone width. The values for these parameters are summarized in the table below. The maximum curvature summarized in the maximum absolute value of the concave up and concave down curves. The ratio of the surface settlement to the compression of the soft zone at depth is also given in the table below.

Soft Zone Width (ft)	Maximum Settlement (in)	Maximum Differential Settlement (in)	Maximum Slope (ft/ft)	Maximum Curvature (ft/ft per ft)	Ratio of Maximum Settlement (S_0) to Soft Zone Compression at Depth
25	-0.263	0.263	0.00060	0.00004	30%
50	-0.447	0.447	0.00087	0.00005	51%
75	-0.542	0.542	0.00093	0.00003	62%
100	-0.574	0.574	0.00093	0.00003	65%
125	-0.582	0.582	0.00093	0.00003	66%
150	-0.584	0.584	0.00093	0.00003	67%
Maximum	-0.584	0.584	0.00093	0.00005	67%

3.5 Reaction Under a Rigid Foundation

Foundations can be designed as either flexible foundations or as rigid foundations. For a flexible foundation, the foundation is considered to deform in the same shape and magnitude as the settlement profile provided in this calculation.

For a rigid foundation, the soil beneath the lab under the slab will settle uniformly, but the reaction on the foundation will not be uniform. Based on a recommended subgrade modulus of 35 pci (Ref. 4), and a differential settlement of 0.53, the reaction at the center of the trough could be less than the reaction away from the center by an amount of

$$p = k \times y = 35 \text{ pci} \times 0.53 \text{ inches} = 18.55 \text{ psi} \approx 2{,}700 \text{ psf.}$$

4. Results and Conclusions

Considering the maximum values presented in Section 3.4, the following values are recommended for design of soft zone induced settlements.

Parameter	Recommended Value
Maximum soft zone settlement:	½ inch
Maximum soft zone differential settlement:	½ inch
Maximum Slope:	0.0010 ft/ft
Maximum Curvature:	0.00005

5. References

1. K-CLC-Z-00012, Rev. 0, Stratigraphy for Saltstone Disposal Cells 3 and 5, May 2009.
2. K-CLC-Z-00009, Rev. 0, Settlement due to Compression of Soft Zone, March 2006.
3. Cording, E.J., et al., “Displacements Around Tunnels in Soils,” Report No. 76T-22, U.S. Department of Transportation, Washington D.C.
4. K-CLC-Z-00014, Rev. 0, Generic Geotechnical Calculations for Saltstone Disposal Cells 3 and 5, June 2009.

Figures

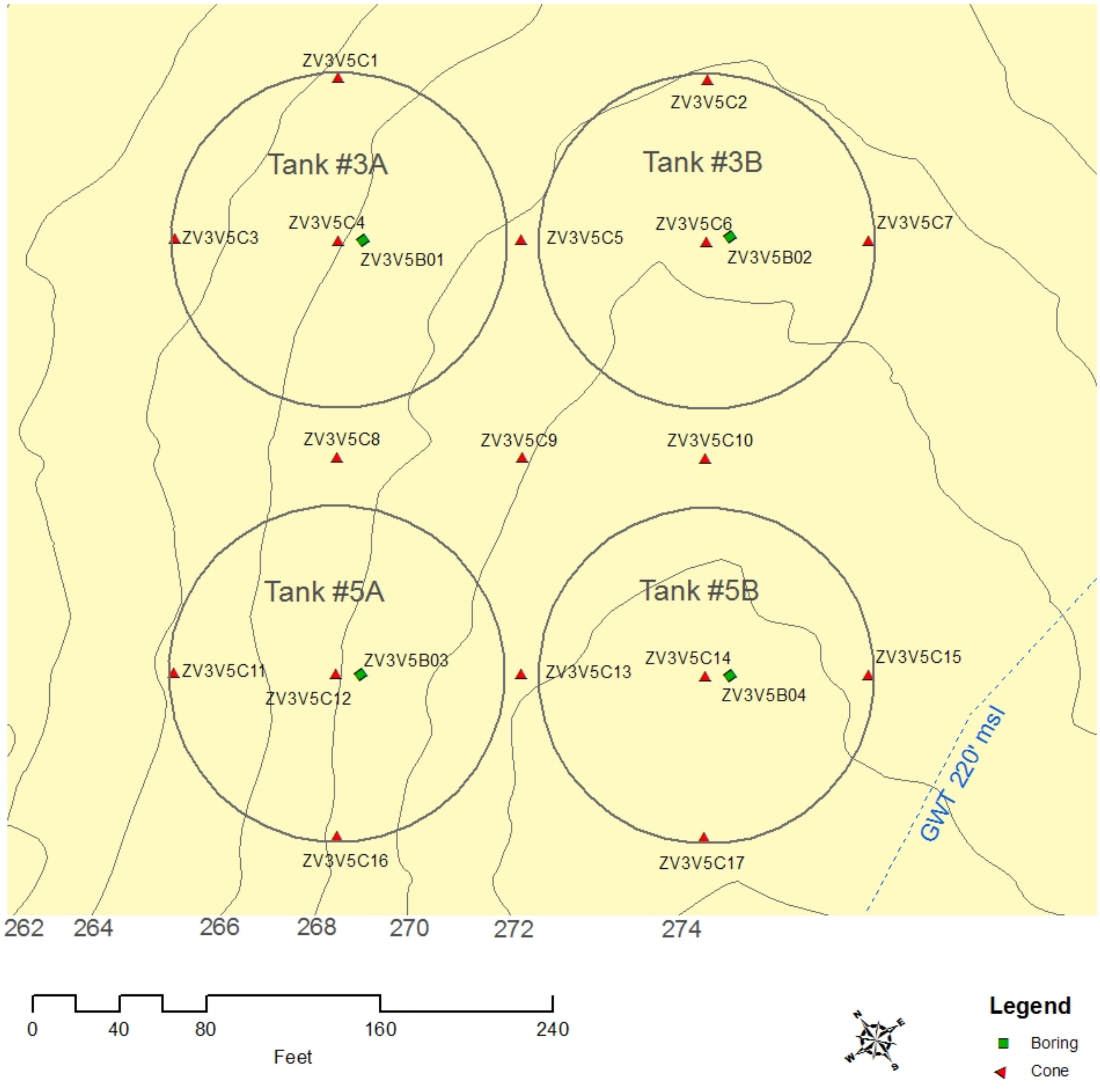


Figure 1: Location of Geotechnical Investigations

Thickness		Depth
1.5 feet thick	q_t = 15 tsf	100.0 ft 101.5 ft
0.5 feet thick	q_t > 15 tsf	
1.0 feet thick	q_t = 15 tsf	102.0 ft 103.0 ft

One Soft Zone
- 2.5 feet thick
  Top depth - 100 feet

1.5 feet thick	q_t = 15 tsf	100.0 ft 101.5 ft
2.5 feet thick	q_t > 15 tsf	
1.0 feet thick	q_t = 15 tsf	104.0 ft 105.0 ft

Two Soft Zones
- 1.5 feet thick
  Top depth - 100 feet
- 1.0 foot thick
  Top depth - 104 feet

Figure 2: Graphical Depiction of Soft Zone Determination

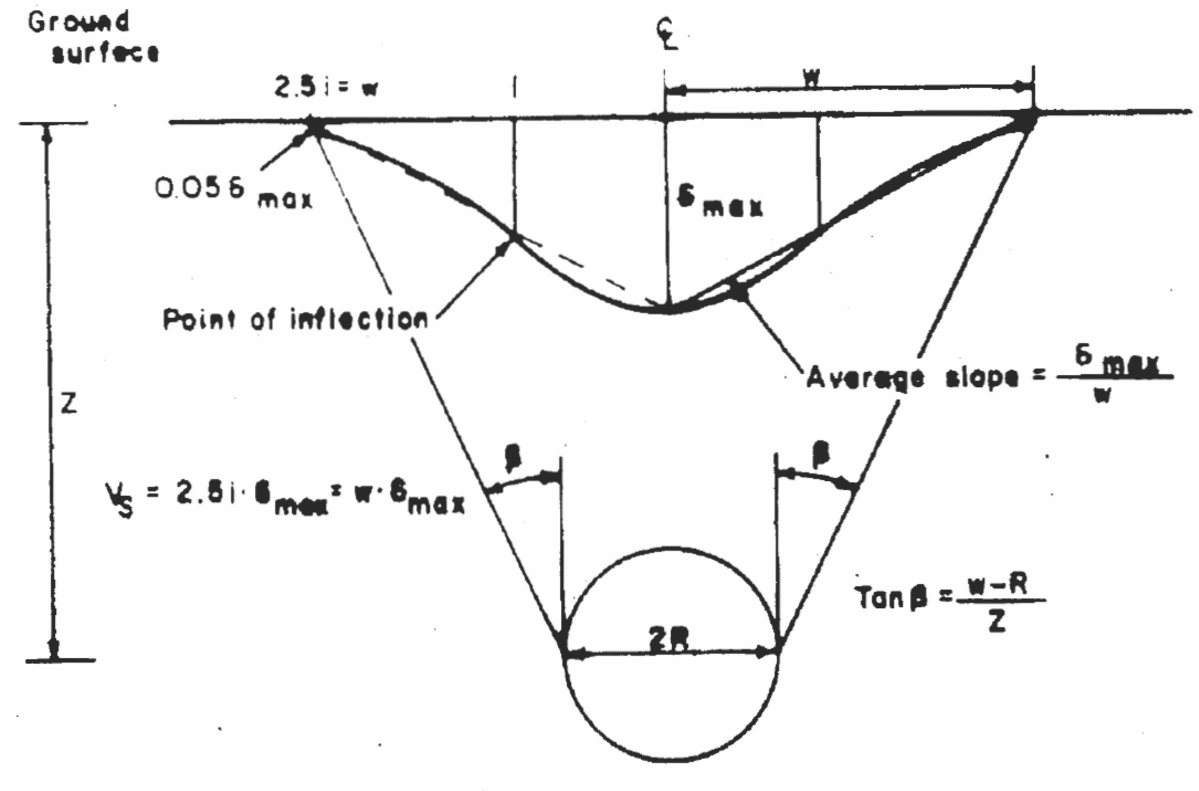


Figure 3: Geometry of Surface Settlement Trough

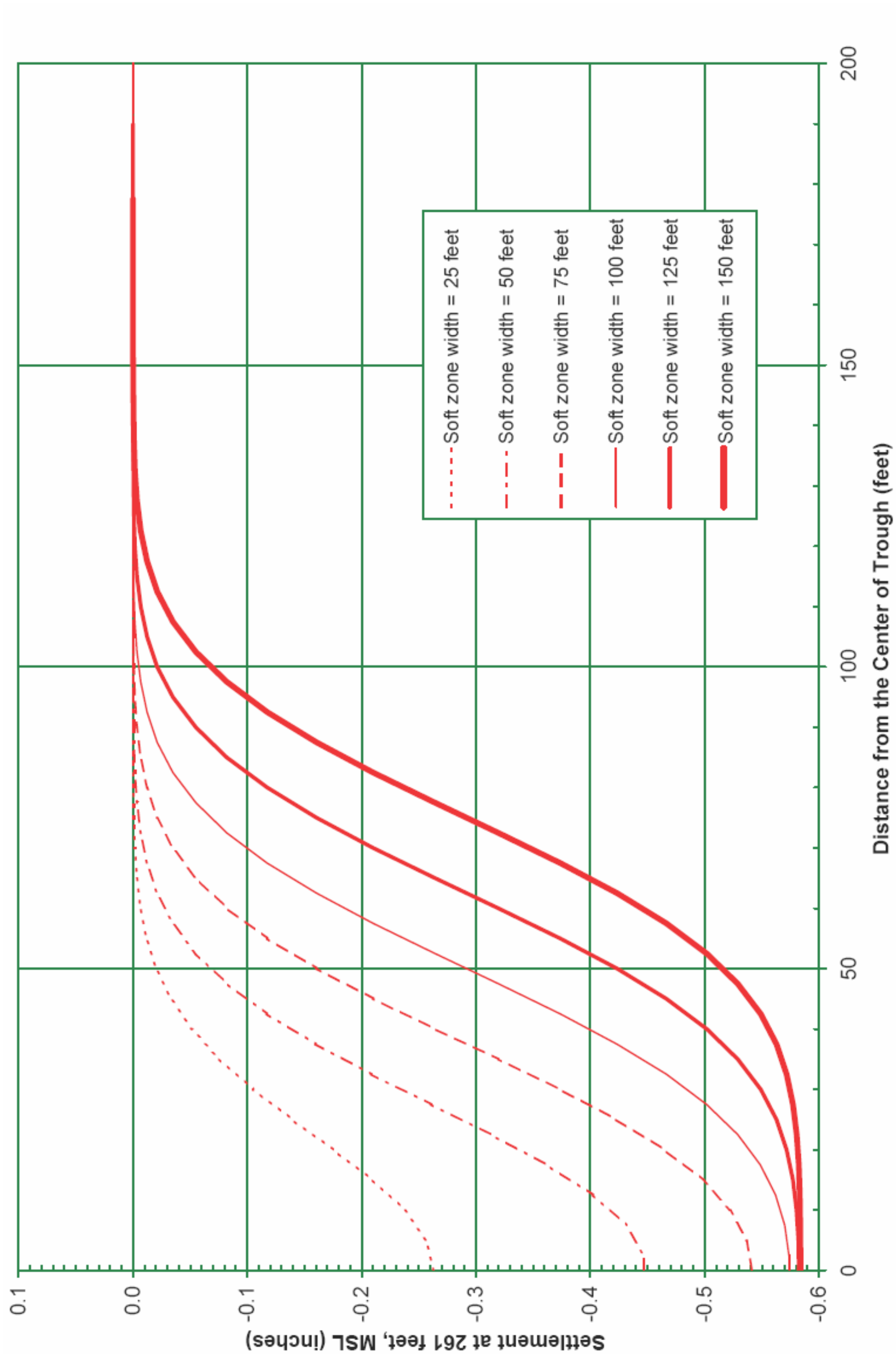


Figure 4: Surface Settlement Profile for Soft Zones of Various Widths

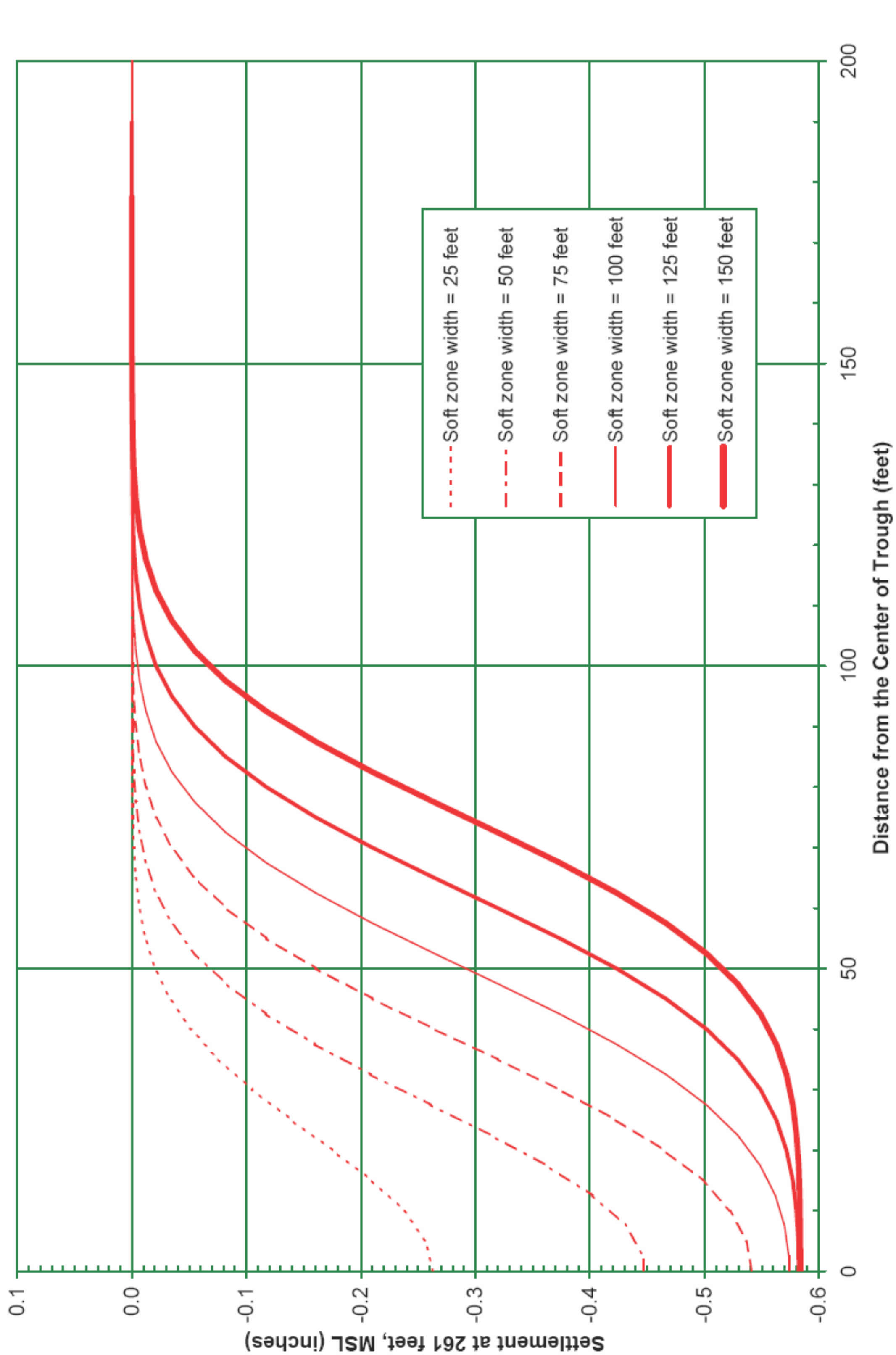


Figure 5: Maximum Surface Settlement for Soft Zones of Various Widths

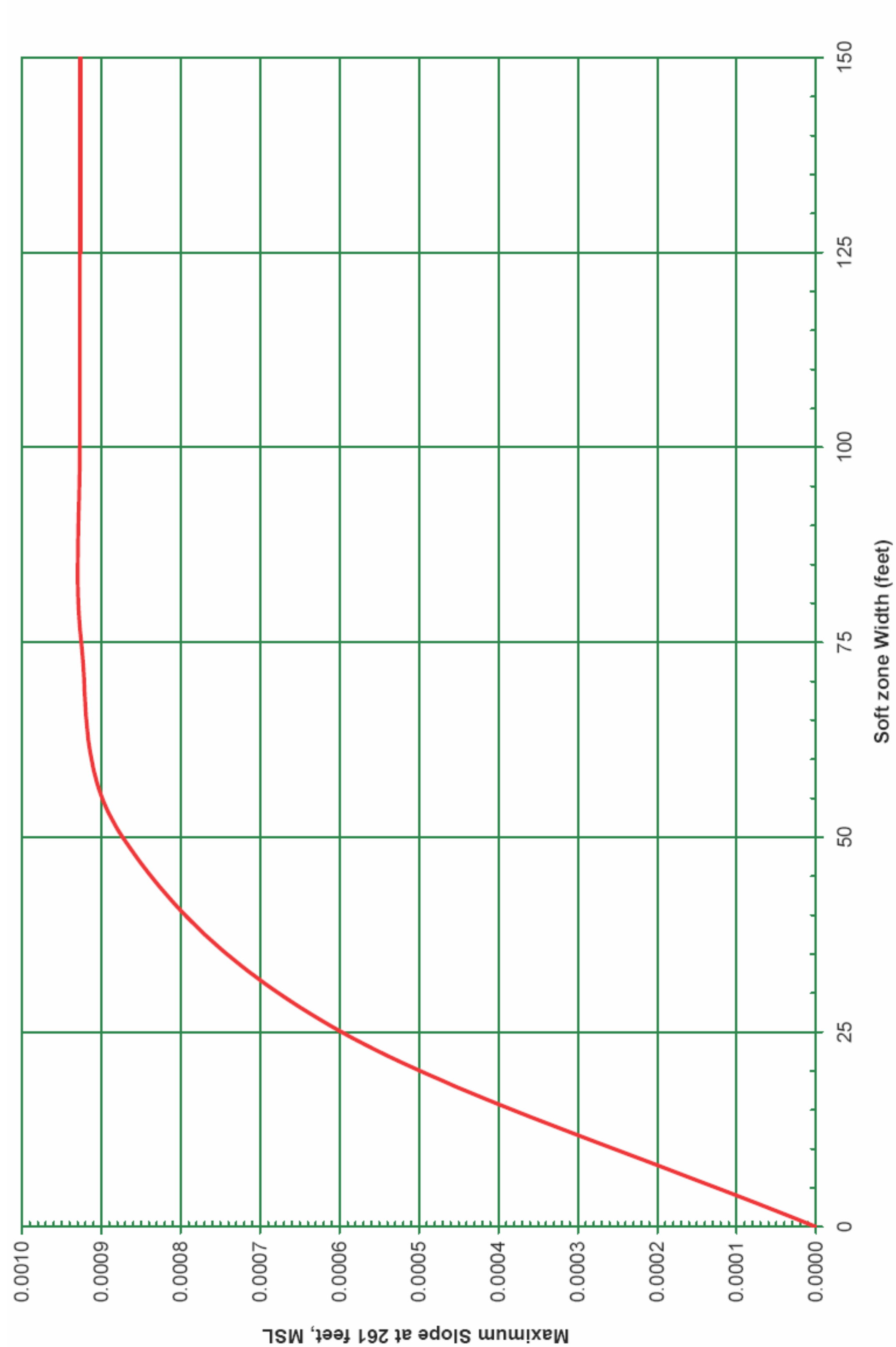


Figure 6: Maximum Surface Slope for Soft Zones of Various Widths

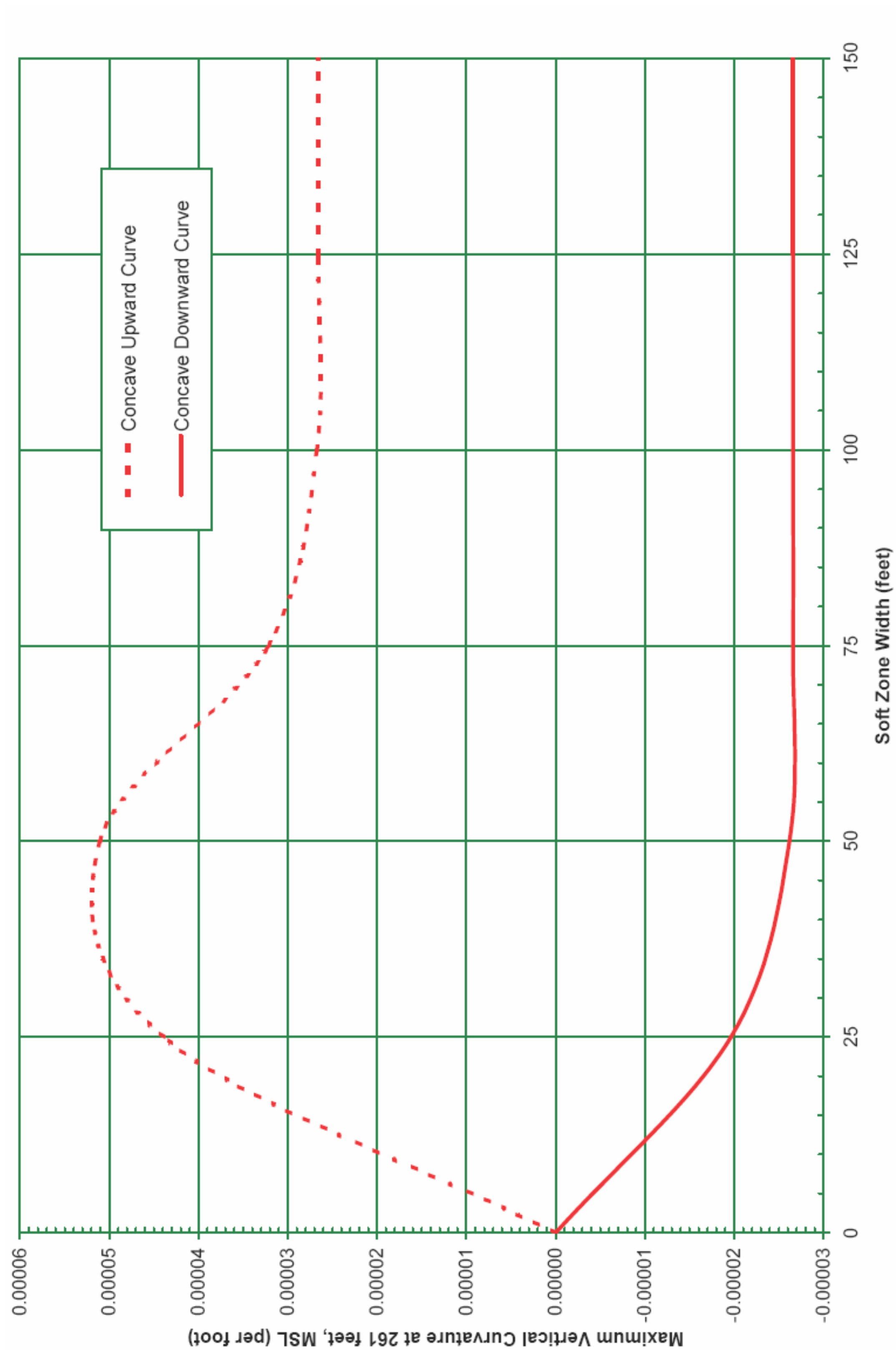


Figure 7: Maximum Surface Settlement Curvature for Soft Zones of Various Widths

Appendix F – Slope Stability Analysis

K-CLC-Z-00002, Rev. 1

September 2003

Slope Stability for the Saltstone Disposal Facility (U)

(57 pages)

Calculation Cover Sheet

Project	Calculation No.	Project Number
N.A.	K-CLC-Z-00002	N.A. MDM 3/24/03
Title Slope Stability for the Saltstone Disposal Facility (U)	**Functional Classification** GS **Discipline** Geotechnical	Sheet 1 of ~~47~~ 56 (one disk containing computer files)

☐ Preliminary ☒ Confirmed

Computer Program No.	Version / Release No.
☐ SLOPW/W	4.24

Purpose and Objective

The purpose of this calculation is to determine global slope stability safety factors for the soil cover over the Saltstone Disposal Facility for static and seismic loading cases.

Summary of Conclusion

See Summary and Conclusions Section on Sheet 7.

FOR REVISION 1 SEE SHEET 7 & 7A.

UNCLASSIFIED
DOES NOT CONTAIN
UNCLASSIFIED CONTROLLED
NUCLEAR INFORMATION
ADC & Reviewing Official [signature]
(Name and Title)
Date: 3/24/03

Revision

Rev. No.	Revision Description
0	Original
1	ADDITIONAL SLOPE STABILITY RUNS USING TOTAL STRESS SHEAR STRENGTHS AND HIGHER PEAK GROUND ACCELERATIONS.

Sign Off

Rev. No.	Originator (Print) Sign / Date	Verification / Checking Method	Verifier / Checker (Print) Sign / Date	Manager (Print) Sign / Date
0	Michael D. McHood [signature]	Document Review	William T. Li [signature]	Michael R. Lewis [signature] 8/21/02
1	MICHAEL D. MCHOOD [signature] 3/24/03	Document Review	William T. Li [signature]	[signature] 4/3/03

Release to Outside Agency – Design Authority (Print)	Signature	Date
NA	NA	NA

Security Classification of the Calculation

Unclassified

slope-calc.doc

ENGINEERING DOC. CONTROL-SRS
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TABLE OF CONTENTS

1.0 PURPOSE

The purpose of this calculation is to determine global slope stability safety factors for the soil cover over the Saltstone Disposal Facility for static and seismic loading cases.

2.0 INPUT DATA

2.1 SLOPE / VAULT GEOMETRY AND DESIGN

This calculation is based on the following design information:

- Vault Dimensions and slope geometry were taken from SRS drawings C-CC-Z-0013 (SRS, 1998), W828992 (SRS, 1989), W780527 (SRS, 1986a), and W780529 (SRS, 1986b) (see Attachment 1).
- For this calculation the concrete vault and contents was modeled as a monolith with a conservatively assumed unit weight of 140 pcf.
- By specification the grout used to fill the Saltstone Vaults has a minimum compressive strength of 200 psi (WSRC, 1992). Actual compressive strength of the grout may be higher. For this calculation the conservative 200 psi value was used to model the disposal vault. No addition strength was attributed to the vault due to the reinforced concrete walls.

It is important to note that several conceptual designs have been considered for closure of the Saltstone Vaults. Both 4H:1V and 8H:1V slopes have been considered in conceptual designs for the final cover system. This calculation assumes the steeper 4H:1V slope. The post closure slope crest was set at 20 feet above the top of the vault. Other conceptual closure designs have much less fill placed over the top of the vault, reducing the slope height. The geometry of the vault and closure cover slope model is shown in Figure 1.

It is also important to note that some of the conceptual designs include geosynthetics and/or designed soil layers (i.e., low permeability capping soil or high permeability drainage layers). This calculation only considers global slope stability. Stability of the interface between geosynthetics and designed soil layers needs to be evaluated and designed for during final design of the cover system.

2.2 GROUNDWATER

The water table in the vicinity of Vault No. 4, based on Well ZBG-2, varies between 213 and 228 ft-msl (see Figure 2 and 3). However, the groundwater elevation used for the slope stability analysis is conservatively placed at 245 feet mean sea level. This conservative assumption is based on water levels observed in boreholes during drilling, (MRCE, 1986a) historical readings (Cook, 1983) and reports of perched water in Z-Area (MRCE, 1986b and Cook, 1986).

2.3 SEISMIC LOADING

Based on the USGS seismic hazard maps (Frankel et al., 1996, see Figure 4) and the International Building Code (ICC, 2000) a PGA of 0.21g would be selected for Z-Area. However, the International Building Code allows a reduction of up to 20% in cases where site specific studies have been performed. Extensive ground response modeling has been performed for the SRS (Lee et. al, 1997; Lee, 1998). Based on the results of ground response modeling at SRS the reduction is warranted and a PGA of 0.17g (i.e., 0.21 x 0.8) is applicable. This PGA is very conservative when compared with the PGA of 0.11g determined for Performance Category 1 structures at SRS (Lee, 1998), which is the performance category of the Saltstone Vaults.

For this calculation a horizontal seismic coefficient (k_h) of 0.17 and vertical seismic coefficients (k_v) of ±0.17 were used. Engineering practice allows seismic coefficients as low as ½ of the PGA and therefore these seismic coefficients are very conservative (Abramson et al., 1996). Combined horizontal and vertical loading cases were run with one component at 100 % and the second concurrent component at 40%, consistent with ASCE Standard 4-98 (ASCE, 1998). Seismic loading cases are summarized below.

- $k_h = 0.17$ and $k_v = 0$
- $k_h = 0$ and $k_v = \pm 0.17$ (+ is down and – is up)
- $k_h = 0.17$ and $k_v = \pm 0.07$ (+ is down and – is up)
- $k_h = 0.07$ and $k_v = \pm 0.17$ (+ is down and – is up)

2.4 SOILS AND VAULT STRENGTH

This calculation considers long-term stability of the soil slopes after closure of the saltstone vaults. Long-term soil shear strength properties are based on effective friction angle (ϕ'). Samples from borings ZB-2, ZB-8, Z-1, Z-2 and Z-4 (see Figure 3) were tested to determine ϕ'. Saturated CU and CIU triaxial shear tests yield ϕ' values between 28° and 34° (BSRI, 1992; Woodward-Clyde, 1985). Selection of the ϕ' values of 28° for the natural soil and 33° for the engineered fill is conservative and allows for some strength loss during seismic loading. Laboratory tests results are presented in Attachment 2. The following effective stress shear strengths were used for the slope stability calculations:

	Effective Stress Properties	
Engineered Fill	$\phi' =$ 33°	$c' =$ 20 psf
Natural Soil (above water table)	$\phi' =$ 28°	$c' =$ 100 psf
Natural Soil (below water table)	$\phi' =$ 28°	$c' =$ 0 psf
Vault Strength *	$\phi' =$ 0°	$c' =$ 4,000 psf

* For this calculation the concrete vault and grout were modeled as a soil having $\phi' = 0$ and $c' = 4{,}000$ psf i.e., constant shear strength corresponding of compressive strength of 200 psi as defined by the American Concrete Institute (shear strength = $2\sqrt{fc'}$ where fc' is compressive strength [ACI, 2002]), which is about a third of the shear strength as defined by Mohr-Coulomb failure criteria (shear strength = ½qu where qu is unconfined compression strength).

Engineered fill will be placed around and over the Saltstone vaults. The final design for the Saltstone Disposal Facility has not been performed and engineered fill will not be placed until some future date. The engineered fill must meet the requirements of existing site standards (WSRC, 2001) and be compacted to a minimum density of 95% of maximum dry density, determined in accordance with ASTM D-1557. The shear strength for the engineered fill is based on experience with SRS fill soils and engineering judgement. A soil unit weight of 120 pcf was assumed for this calculation.

For conservatism, a tension crack was assumed for all models (both static and seismic cases). The tension crack is two feet deep along the top of the slope up to the crest, tapering to zero feet at the toe of the slope. The tension crack was filled with water as may occur after rain.

3.0 CALCULATIONS

Slope stability calculations were completed using SLOPE/W version 4.24 software (GEO-SLOPE, 1998). SLOPE/W is commercially available software similar to PC STABL and other slope stability analysis software. Safety factors were calculated using Ordinary, Bishop's, Janbu's, and Spencer's Methods. Results reported in this calculation are from Spencer's method, which considers both moment and force equilibrium. Static and seismic slope stability calculations were completed for a closure concept having a 4H:1V slopes extending to the base of the vault. Several seismic loading cases were run having different vertical and horizontal loading. The results for both static and seismic cases are summarized in Table 1. Computer files are contained on the accompanying compact disk.

The models run allowed slip surfaces to pass through the disposal vault. Failure through the vault was never the critical case (i.e., didn't have the lowest factor of safety). At the request of the South Carolina Department of Health and Environmental Control, (SCDHEC) an additional stability case was run where slip surfaces were forced through the disposal vault to determine factor of safety against a combined vault and slope failure. Factor of safety for "vault failure" case is also summarized in Table 1.

As advised by the consultant, Dr. Marcuson, additional runs were performed where total stress shear strength was used. Total stress shear strength is lower than the effective stress accounting for pore pressure and strength loss due to loading and provides additional conservatism. For the additional runs the natural soil above the water table was given a conservative friction angle of 23° with cohesion of 650 psf. The natural soil below the water table was modeled two ways 1) with a friction angle of 8° and cohesion of 900 psf and 2) with a friction angle of zero and cohesion of 1,600 psf. Attachment 2 discusses the shear strength tests. In addition, the vault strength is the same as the engineered fill, assuming a failure through the engineered fill along the edge of the vault. For the total stress runs the seismic coefficients are $k_h = 0.17$ and $k_v = -0.07$ (i.e., the lowest factor of safety case using effective stress shear strength). Factor of safety for the "total stress" cases are summarized in Table 1.

Table 1. Summary of Slope Stability Safety Factors Computed Using Slope/W and Effective Stress Shear Strengths

	Horizontal Seismic Coefficient (k_h)	Vertical Seismic Coefficient (k_v)	Factor of Safety	Minimum Acceptable Factor of Safety
Case 1 static	0	0	2.6	1.2 to 1.5
Case 2	0.17	0	1.5	1.0 to 1.2
Case 3	0	0.17	2.6	1.0 to 1.2
Case 4	0	-0.17	2.7	1.0 to 1.2
Case 5	0.17	0.07	1.6	1.0 to 1.2
Case 6	0.17	-0.07	1.5	1.0 to 1.2
Case 7	0.07	0.17	2.1	1.0 to 1.2
Case 8	0.07	-0.17	2.0	1.0 to 1.2
Case 9 vault failure	0.17	-0.07	1.8	1.0 to 1.2
Case 10 total stress	0.17	-0.07	1.2	1.0 to 1.2
Case 11 total stress	0.17	-0.07	1.2	1.0 to 1.2

Note: For Cases 1 through 8 effective stress shear strength was used, see Section 2.4.
For Case 9 the failure surface was forced through the vault with k_h and k_v same as Case 6 (i.e., lowest factor of safety case).
For Case 10 and 11 total stress shear strength was used. Natural soil above the water table was given a friction angle of 23° with cohesion of 650 psf. Natural soil below the water table was two ways 1) with a friction angle of 8° with cohesion of 900 psf (Case 10) and 2) with a friction angle of zero with cohesion of 1,600 psf (Case11). See Attachment 2 for shear strength tests.

3.1 ACCEPTABLE SAFETY FACTORS

3.1.1 STATIC

Generally, the recommended safety factor for static slope stability is around 1.5. However, safety factors as low as 1.2 have been recommended. The range of acceptable safety factors is due to many reasons including the consequence of failure, the extent of the subsurface characterization, whether or not site specific strength testing was performed, and the natural variability of the soils.

3.1.2 SEISMIC

For seismic slope stability, generally accepted safety factors range from 1.0 to 1.2 (USACE, 1970; Abramson et al., 1996; Huang, 1983). As with static slope stability, the range of acceptable safety factors is due to many reasons including the consequence of failure, the extent of the subsurface characterization, whether or not site specific strength testing was performed, and the natural variability of the soils.

4.0 RESULTS

A summary of the safety factors computed using SLOPE/W for static and seismic loading cases is contained in Table 1. Figures 5 through 15 contain the plots of the individual SLOPE/W stability runs. In all cases the static and seismic safety factors are much greater than required. Additional details of the analysis can be obtained from computer files listed in Attachment 3 and copied on the accompanying disk.

Figures 16 through 18 show variations of the case 6 seismic loading with a limited number of radius focal points and larger radii. These runs were performed to show other failure surfaces and their factor of safety. These failure surfaces extend down through the natural soil and past the toe of the slope. Factors of safety are greater for these deeper failure surfaces.

5.0 SUMMARY AND CONCLUSIONS

A slope of 4 horizontal to 1 vertical provides factors of safety above the range of acceptable factors of safety (see Table 1). However, for long term stability the following recommendations should be implemented.

- Engineered fill must meet the requirements of existing site standards (WSRC, 2001) and be compacted to a minimum density of 95% of maximum dry density, determined in accordance with ASTM D-1557, to achieve acceptable shear strength.
- Drainage ditches shall be provided so water is conveyed away from the disposal vaults.
- Erosion control on the slopes is required

It is also important to note that final design for cover system has not been performed. Final design may include geosynthetics and/or designed soil layers (i.e., low permeability capping soil or high permeability drainage layers). This calculation only considers global slope stability. Stability of the interface between geosynthetics and designed soil layers needs to be evaluated during final design of the cover system. However, for the range of slopes being considered (4H:1V and 8H:1V), incorporation of geosynthetics and/or designed soil layers is not expected to be an issue.

6.0 PURPOSE AND RESULTS FOR REVISION 1

At the request of SCDHEC additional slope stability analysis was performed for a horizontal PGA of 0.20g and 0.21g. Horizontal seismic coefficients (K_h) of 0.20 and 0.21 were used (i.e., the full PGA). No vertical seismic coefficients (K_v) were used for the additional work.

At the request of SCDHEC, the soil model was extended to include the soil beyond the vault allowing a failure beneath and past the vault structure. For the additional work the "total stress" cases (i.e., case 10 and 11 from the Revision 0 work) were re-evaluated because they result in the lowest Factor of Safety. The "total stress" or "undrained"

condition is conservative and assumes significant generation of pore pressure and associated strength loss during seismic loading. Figures 19 and 20 show the case 10 and case 11 soil models used for the previous work. Figures 21 and 22 show the extended models used for the additional work. Note that for the extended soil models (Figures 21 and 22) soil strengths are aligned with the soil stratum as opposed to assigning all soil beneath the water table one strength. Also note that the soil strength for deeper soils has been increased representing average strength as opposed to conservative lower bound strength. Strength test data are presented in Attachment 2. Sheet 42 shows strength data for the C2 stratum and the reinterpreted strength used for the C2 stratum. The strength of the engineered fill for both the effective stress cases and the total stress cases is $\phi = 33°$ & $c = 20$ psf. This strength is conservative and allows for some strength loss during seismic loading. By design the engineered fill will need to meet this strength requirement.

Results of the additional analyses are presented in Table 2. Figures 23 through 26 contain the plots of the additional slope stability runs. In all cases the static and seismic safety factors are acceptable. Additional details of the analysis can be obtained from computer files listed in Attachment 3 and copied on the accompanying disk.

Table 2. Additional Slope Stability Safety Factors Computed Using Slope/W and Total Stress Shear Strengths

	Soil Strength Condition	Soil Strength 1	Vault Strength 2	Horizontal Seismic Coefficient (k_h)	Vertical Seismic Coefficient (k_v)	Factor of Safety
Case 10 a	total stress	Figure 21	$\phi = 33°$ & c = 20 psf	0.20	0	1.3
Case 10 b	total stress	Figure 21	$\phi = 33°$ & c = 20 psf	0.21	0	1.3
Case 11 a	total stress	Figure 22	$\phi = 0°$ & c = 4000 psf	0.20	0	1.2
Case 11 b	total stress	Figure 22	$\phi = 0°$ & c = 4000 psf	0.21	0	1.2

1 Shear strengths of the soil layers are shown on the referenced Figure.

2 Shear strength of the vault was modeled both as a weak grout ($\phi = 0°$ & c = 4000 psf) and as engineered fill ($\phi = 33°$ & c = 20 psf). Results reported here are those that produced the lowest factor of safety.

6.0 REFERENCES

Abramson, Lee W., Lee, Thomas S., Sunil, Sharma and Glenn M. Boyce (1996). *Slope Stability and Stabilization Methods*, John Wiley and Sons, Inc., p. 410

American Concrete Institute (ACI) (2002). *Building Code Requirements for Structural Concrete (ACI 318-02) and Commentary (ACI 318R-02)*, Farmington Hills, Michigan, January 2002.

American Society of Civil Engineers (ASCE), 1998. *Seismic Analysis of Safety-Related Nuclear Structures and Commentary*, ASCE Standard 4-98, Reston Virginia, 1998.

Bechtel Savannah River, Inc. (BSRI), 1992. *Savannah River Site Z-Area Vault No. 2 Geotechnical Investigations Report (U)*, Report No. C-ESR-Z-00001, Rev. 0, July 1992.

Cook, James R., 1983. *Estimation of High Water Table Levels at the Saltstone Disposal Site (Z-Area)*, Letter Report from James R. Cook to E. L. Albenesius, Correspondence No. DPST-83-607, June 27, 1983.

Cook, James R., 1986. *Hydrogeologic Data from Z Area*, Letter Report from James R. Cook to E. L. Albenesius, Correspondence No. DPST-86-320, March 27, 1986.

Frankel, A., Mueller, C., Barnhard, T., Perkins, D., Leyendecker, E. V., Dickman, N., Hanson, S., and M. Hopper, 1996. *National Seismic-Hazard Maps: Documentation*, USGS Open File Report 96-532, USGS Earthquake Hazard Program – National Seismic Hazard Mapping Project web site http://geohazards.cr.usgs.gov/eq/, Denver, CO, June 1996.

GEO-SLOPE (1998). *User's Guide SLOPE/W for Slope Stability Analysis, Version 4*, GEO-SLOPE International Ltd., Calgary, Alberta, Canada.

Huang, Yang H. (1983). *Stability Analysis for Earth Slopes*, Vas Nostrand Reinhold Company, p. 25.

International Code Council, Inc. (ICC), 2000. *International Building Code 2000*, Building Officials and Code Administrators International, Inc., Country Club Hills, IL; International Conference of Building Officials, Whittier, CA; and Southern Building Code Congress International, Inc., Birmingham, AL, March 2000.

Lee, R. C., Maryak, M. E., and M. D. McHood, 1997. *SRS Seismic Response Analysis and Design Basis Guidelines*, WSRC-TR-97-0085, Rev. 0, March 31, 1997.

Lee, R. C., 1998. *Soil Surface Seismic Hazard and Design Basis Guidelines for Performance Category 1 & 2 SRS Facilities*, WSRC-TR-98-00263, Rev. 0, September 30, 1998.

Mueser Rutledge Consulting Engineers (MRCE), 1986a. *Saltstone Disposal Z-Area Savannah River Plant*, #6329, SGS File No. Z-SDF-2, New York, NY, October 14, 1986.

Mueser Rutledge Consulting Engineers (MRCE), 1986b. *Shallow Soils Investigation Z-Area Savannah River Plant*, #6465, SGS File No. Z-SDF-4, New York, NY, October 15, 1986.

SRS (1986a). *Saltstone Disposal Site Final Closure Grading Plan SHT 1 of 2*, SRS Drawing No. W780527, Rev. 0, October 9, 1986.

SRS (1986b). *Saltstone Disposal Site Final Closure Grading Sections*, SRS Drawing No. W780529, Rev. 0, October 9, 1986.

SRS (1989). *Saltstone Vaults 6 & 7 Plan, Sections and Details Concrete*, SRS Drawing No. W828992, Rev. B1, March 10, 1989.

SRS (1998). *Saltstone Vault No. 4 Permanent Roof Concrete Sections and Details Sheet No. 1 (U)*, SRS Drawing No. C-CC-Z-0013, Rev. 3, July 7, 1998.

Unites States Army Corps of Engineers (USACE) (1970). *Engineering and Design Stability of Earth Fill and Rock Dams*, United States Army Corp. of Engineers, EM 1110-2-1902.

Woodward-Clyde Consultants (1985). *Investigations of Slope Stability Savannah River Plant Aiken, South Carolina*, SGS Document No. G-SRS-17, Plymouth Meeting, PA, July 9, 1985.

Westinghouse Savannah River Co. (WSRC) (1992). *Radiological Performance Assessment for the Z-Area Saltstone Disposal Facility*, WSRC-RP-92-1360, Rev. 0, December 18, 1992.

Westinghouse Savannah River Co. (WSRC) (2001). *Excavation, Backfill, Placement of Low Permeability Soil and Grading (U)*, WSRC-IM-95-58, Guide No. 02224-G, Rev. 1, July 25, 2001.

FIGURES

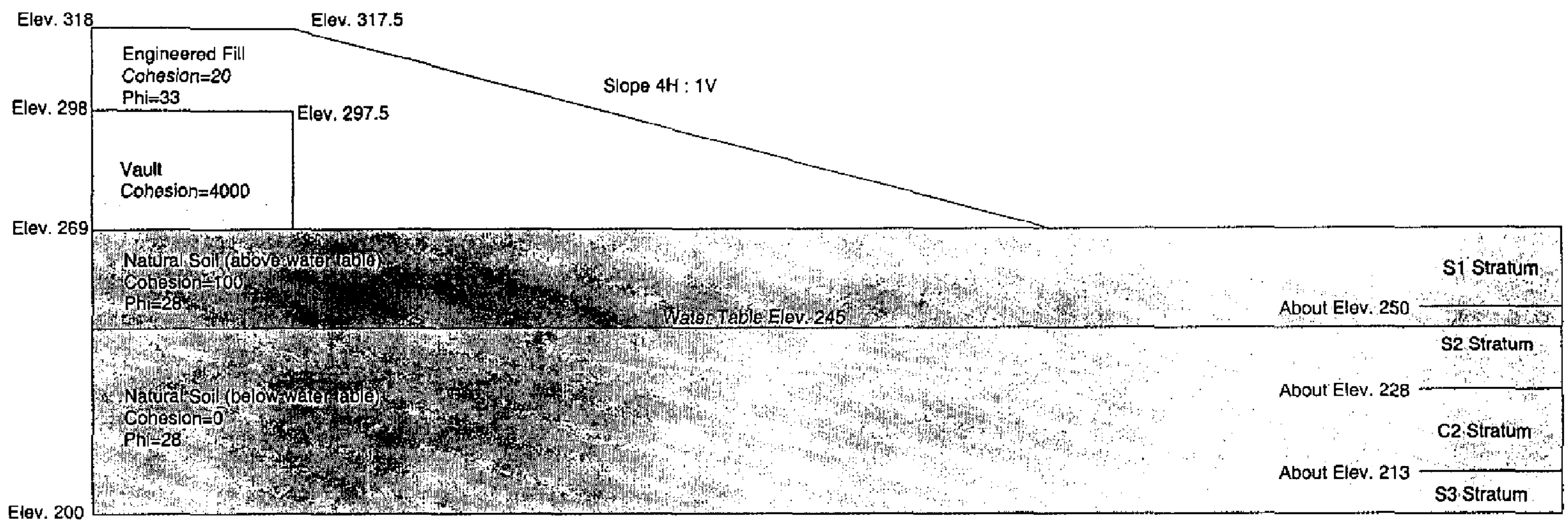

Figure 1. Vault and Closure Cover Slope Geometry Used to Calculate Slope Stability

Calculation No.	Sheet No.	Rev.
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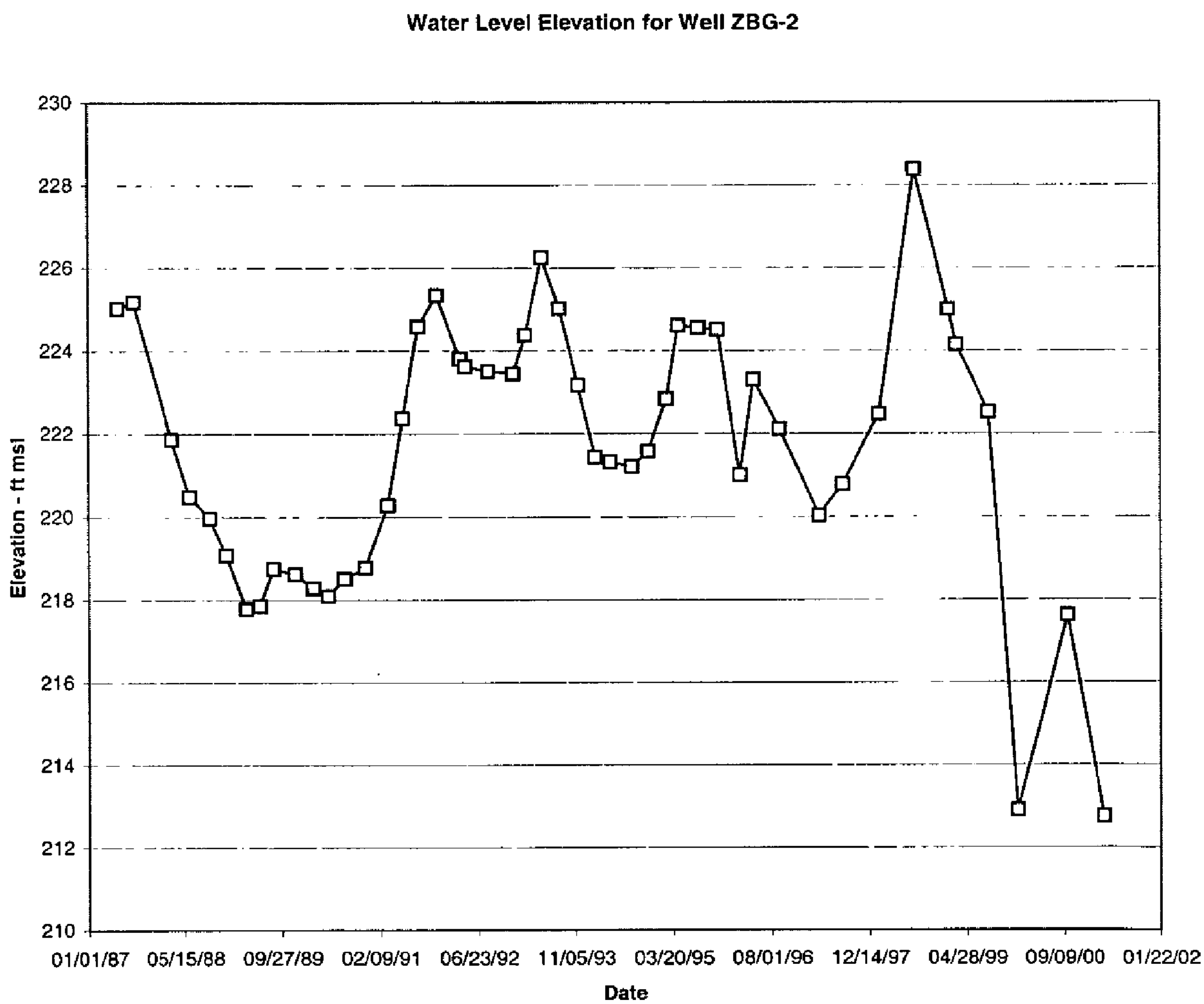

well-zbg-2.xls

Figure 2 - Water Table Elevation Measured in Well ZBG-2
(SRS Groundwater Information Management System)

Calculation No. K-CLC-Z-00002
Sheet No. 13
Rev. 0

Z-Area Vault No. 4

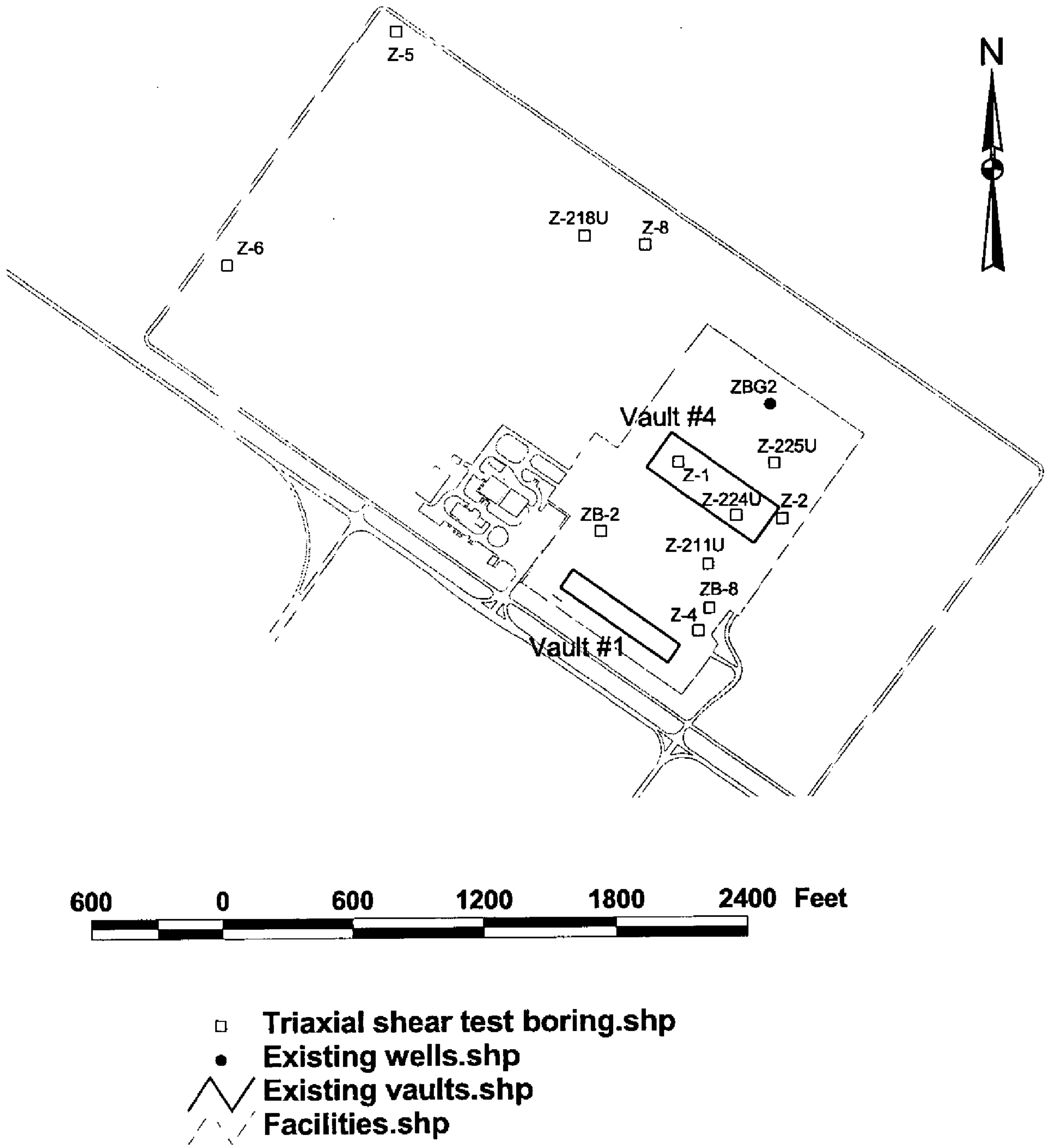

Figure 3 - Location of Vault No. 4, Triaxial Shear Test Borings and Well ZBG-2

Calculation No. K-CLC-Z-00002
Sheet No. 14
Rev. 0

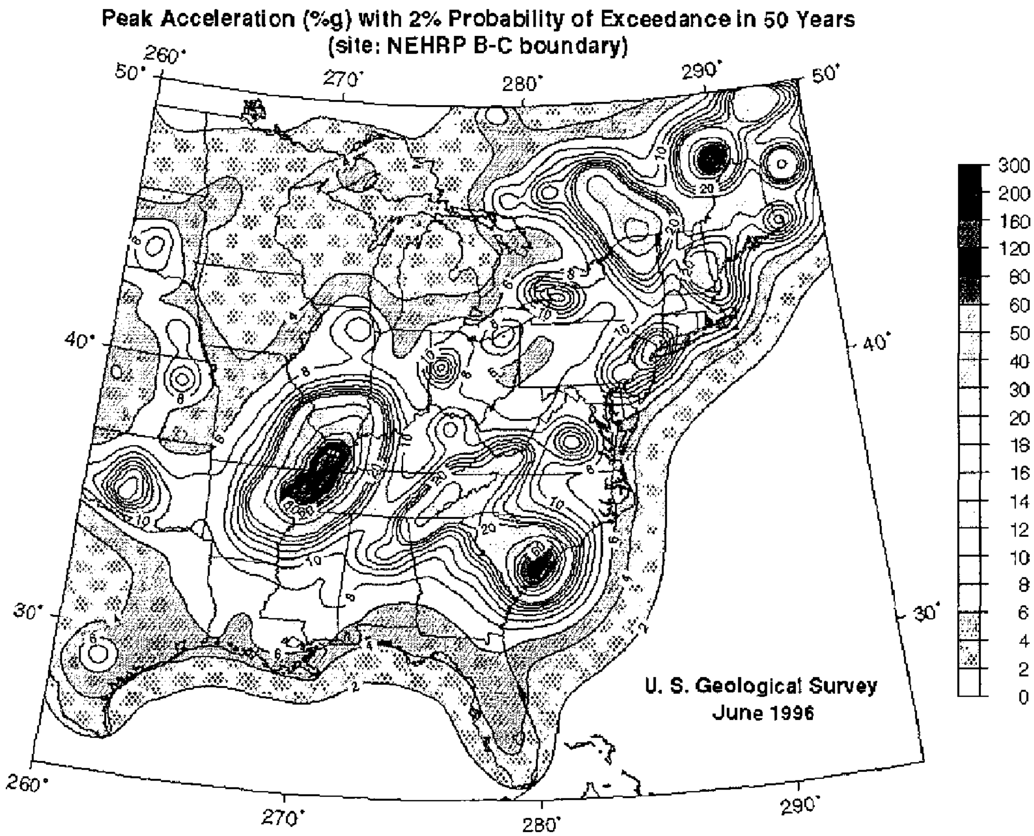

Figure 4 - USGS Hazard Map for Peak Ground Acceleration
2% Probability of Exccedance in 50 Years
(Frankel et al., 1996)

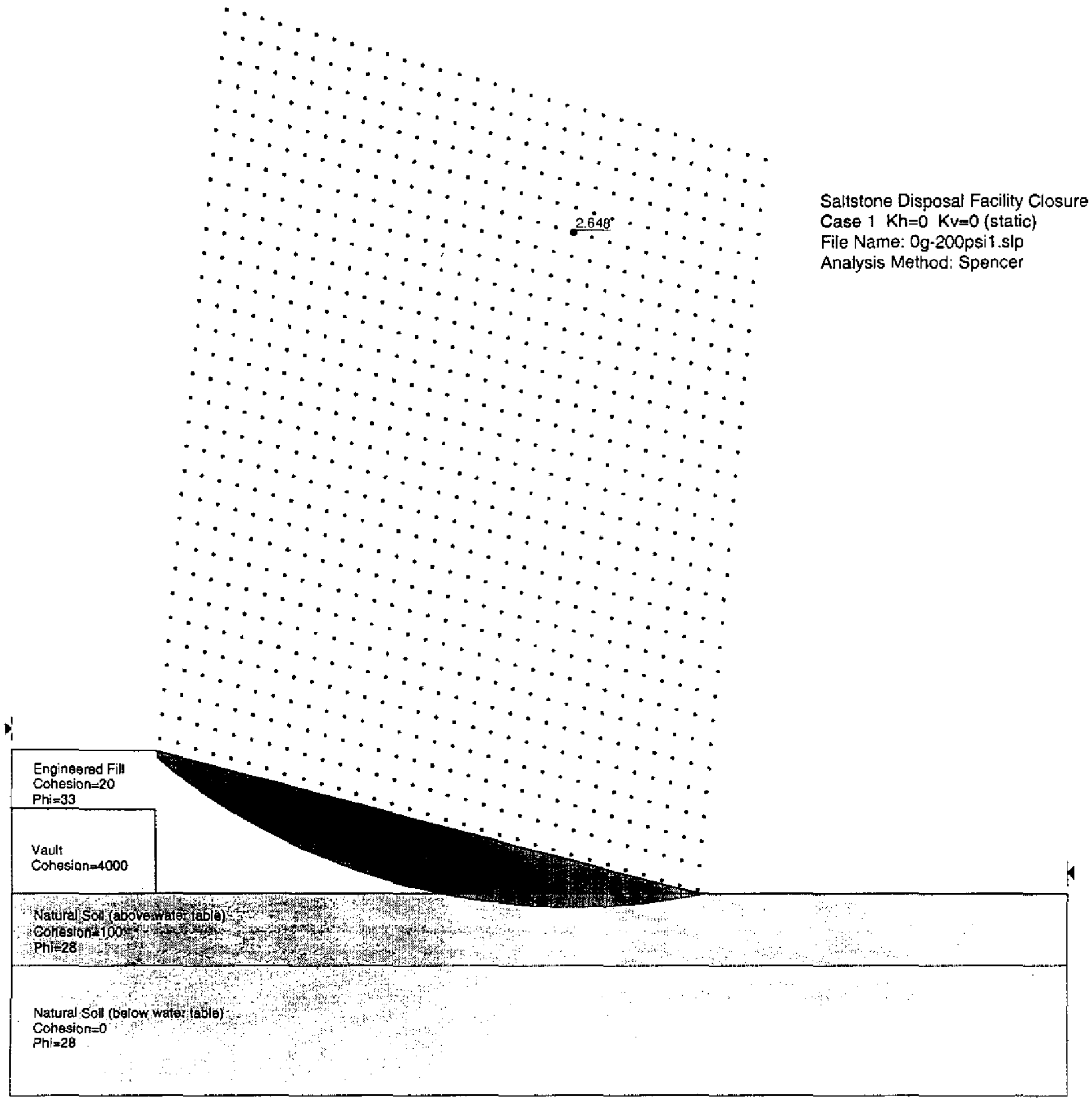

Figure 5. Safety Factor Calculated Using Slope/W for Case 1 (Static Case k_h=0 and k_v=0)

Calculation No.	Sheet No.	Rev.
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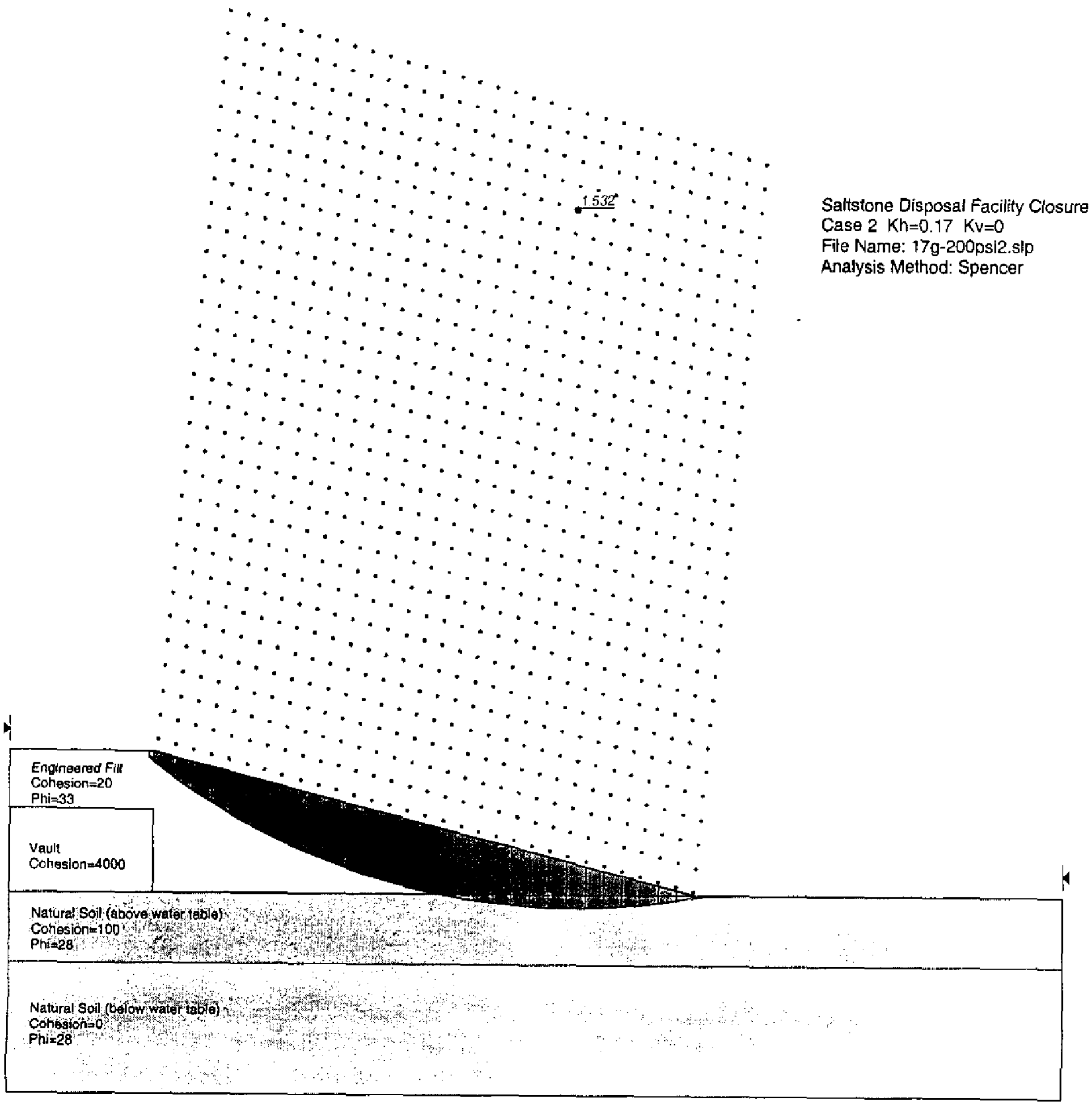

Figure 6. Safety Factor Calculated Using Slope/W for Case 2 (k_h=0.17 and k_v=0)

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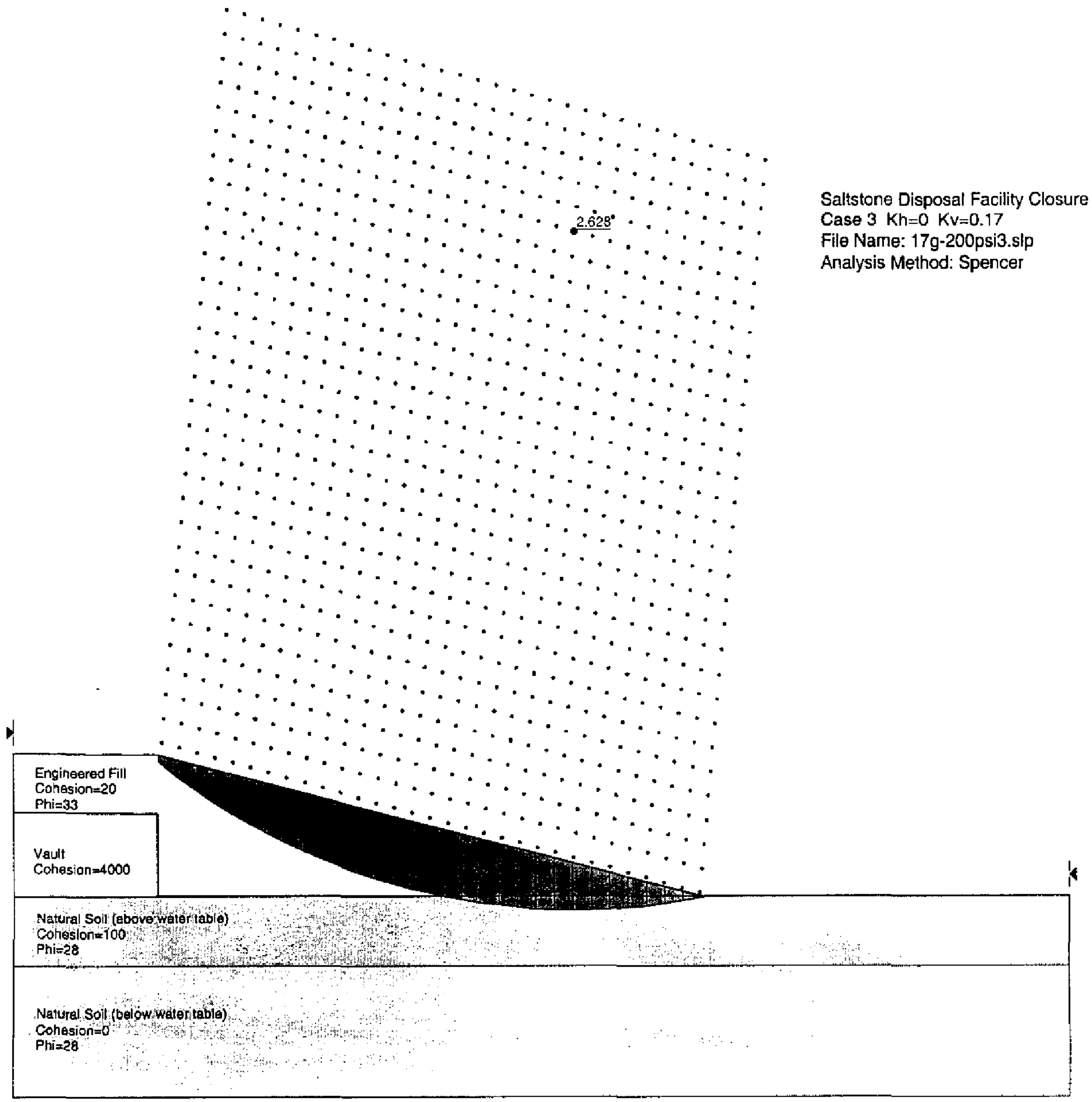

Figure 7. Safety Factor Calculated Using Slope/W for Case 3 (k_h=0 and k_v=0.17)

Calculation No.	Sheet No.	Rev.
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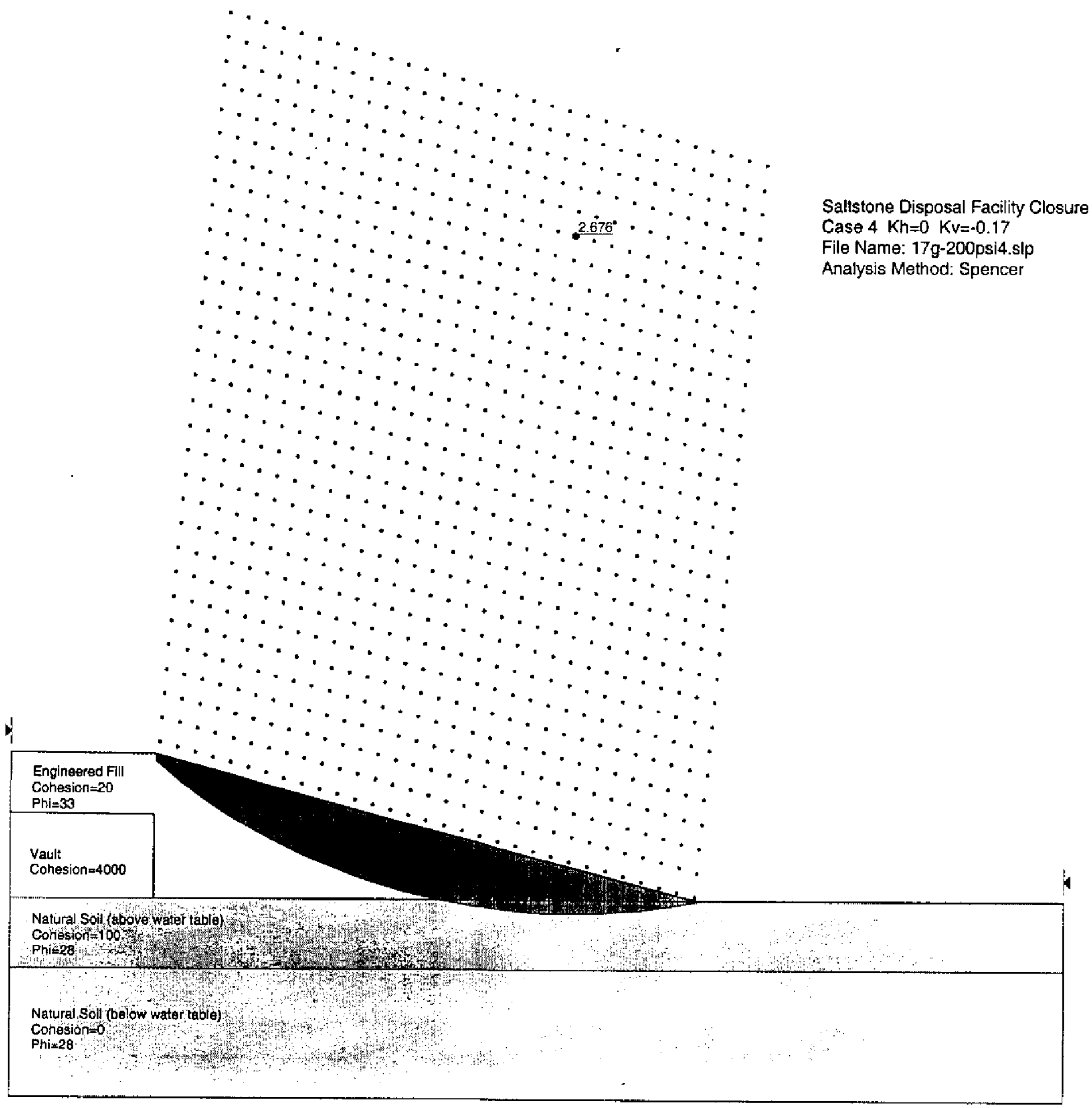

Figure 8. Safety Factor Calculated Using Slope/W for Case 4 (k_h=0 and k_v=-0.17)

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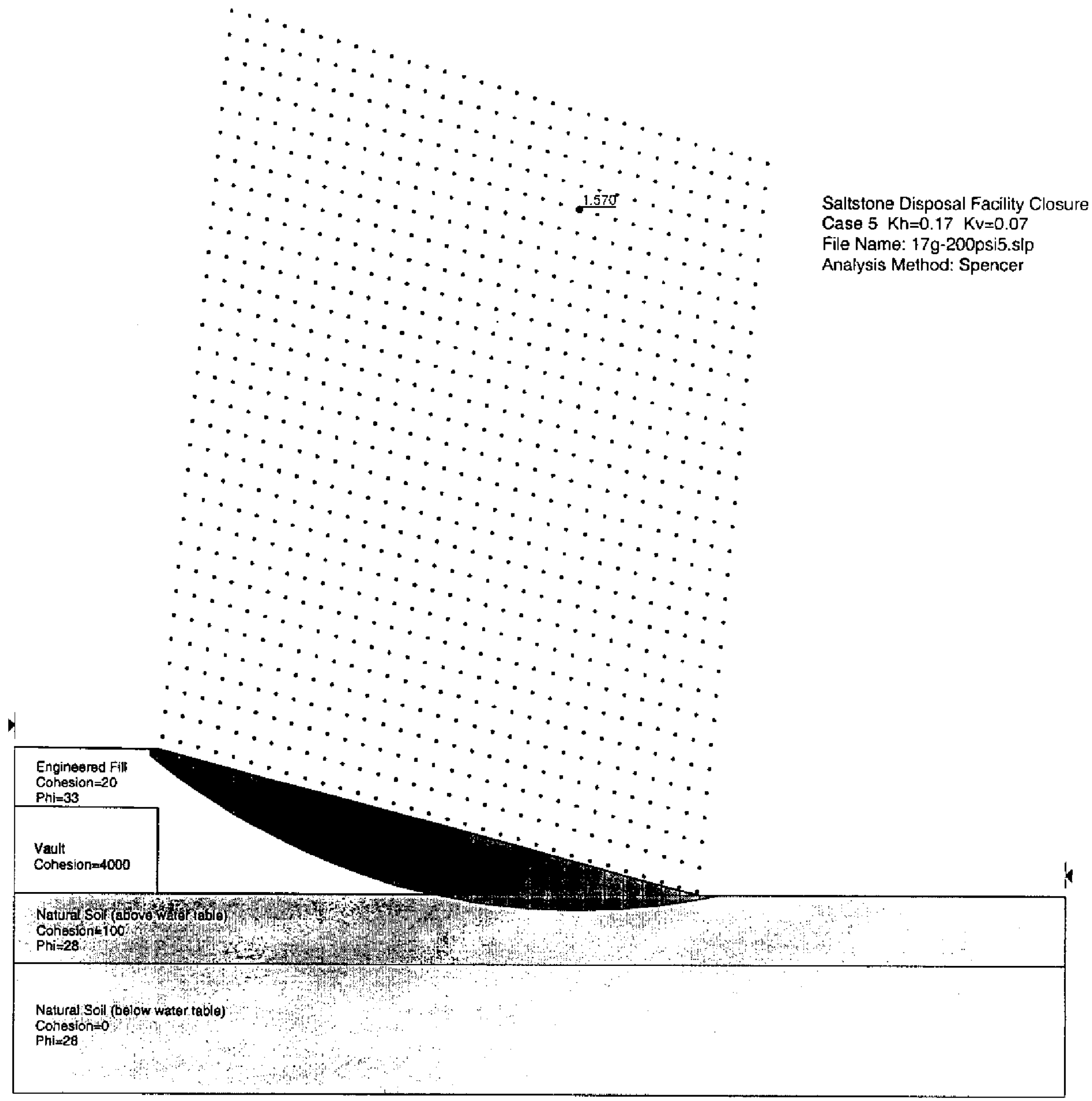

Figure 9. Safety Factor Calculated Using Slope/W for Case 5 (k_h=0.17 and k_v=0.07)

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K-CLC-Z-00002	19	0

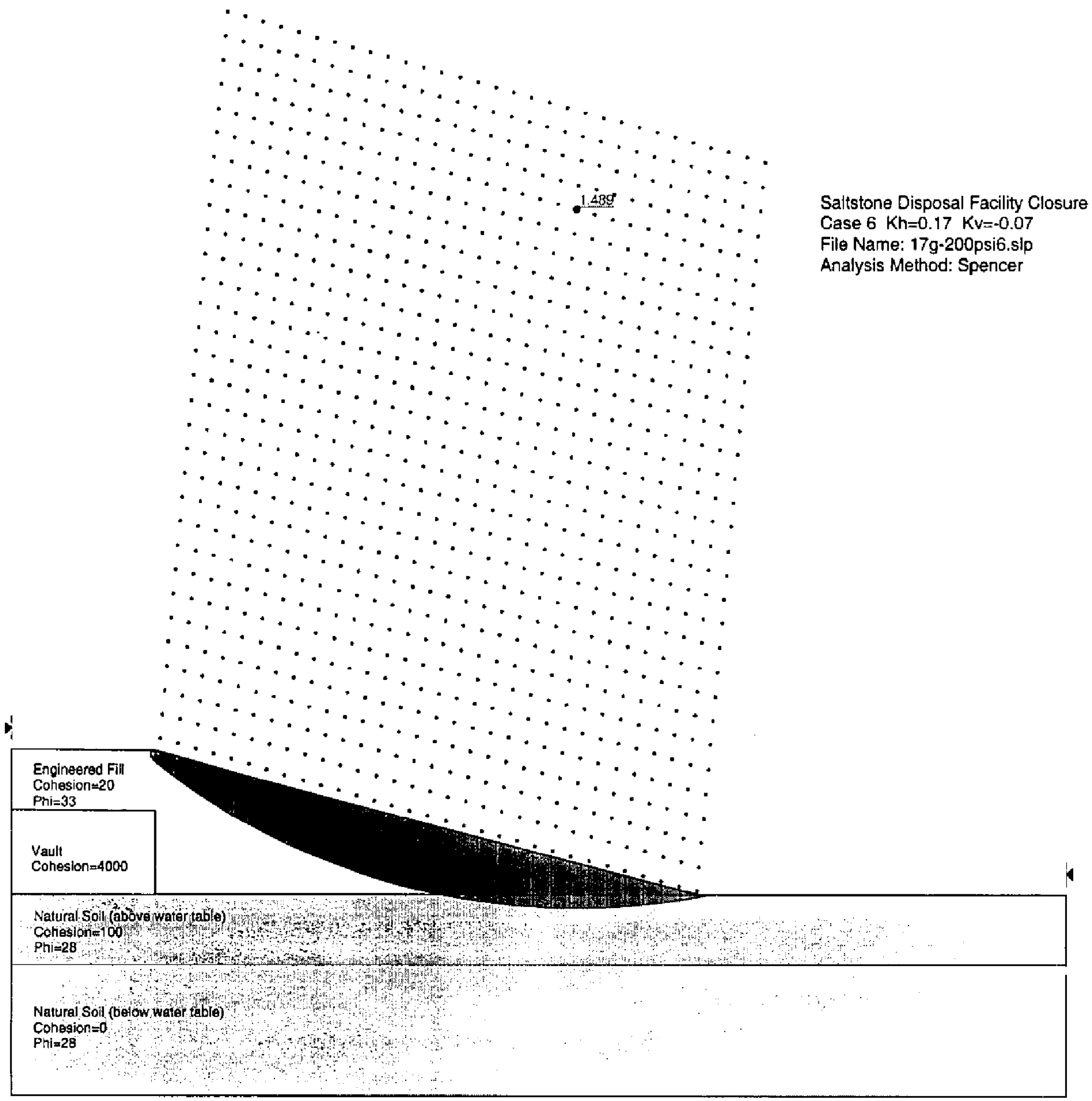


Figure 10. Safety Factor Calculated Using Slope/W for Case 6 (k_h=0.17 and k_v=-0.07)

Calculation No.	Sheet No.	Rev.
K-CLC-Z-00002	20	0

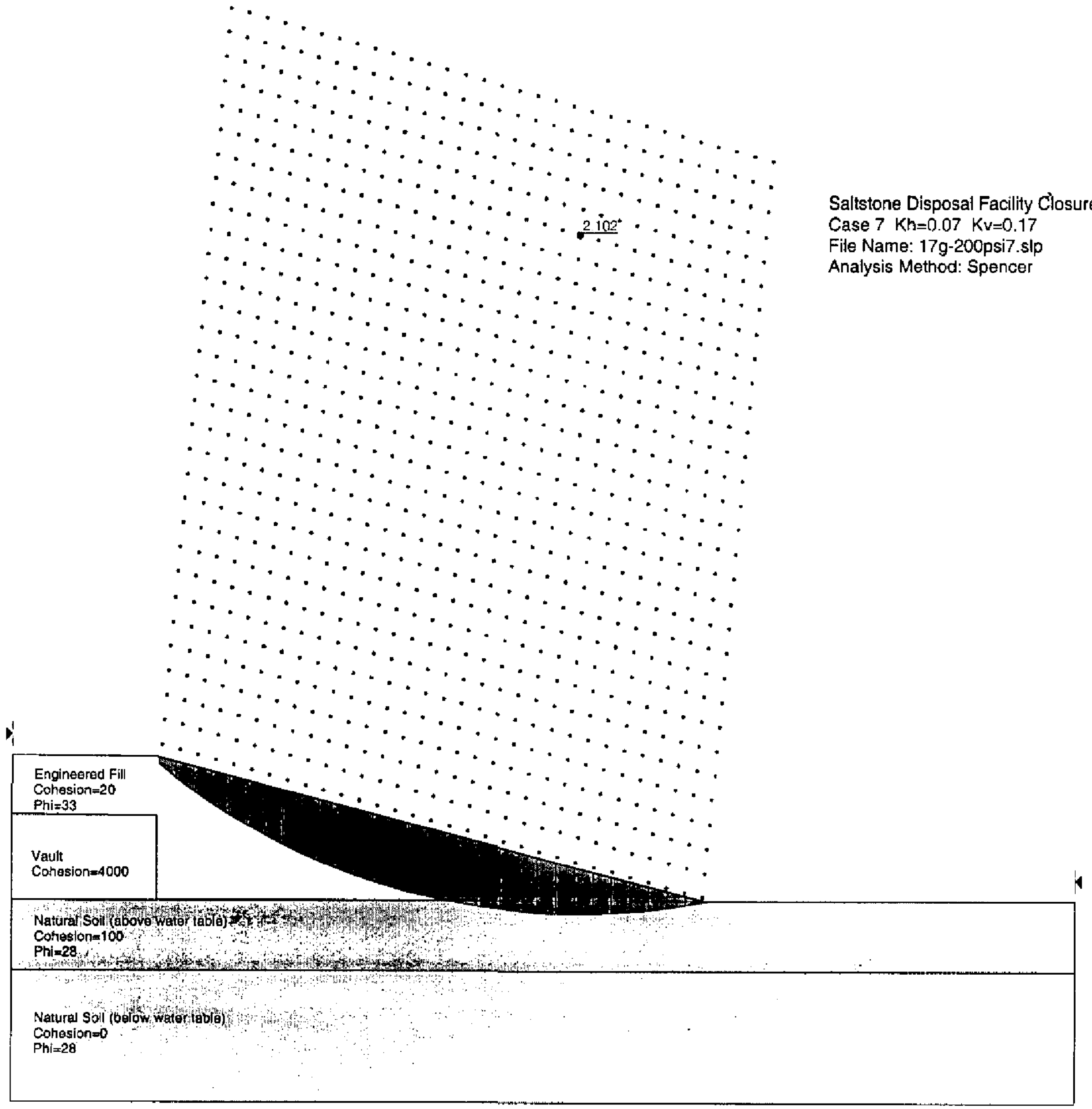


Figure 11. Safety Factor Calculated Using Slope/W for Case 7 (k_h=0.07 and k_v=0.17)

Calculation No.	Sheet No.	Rev.
K-CLC-Z-00002	21	0

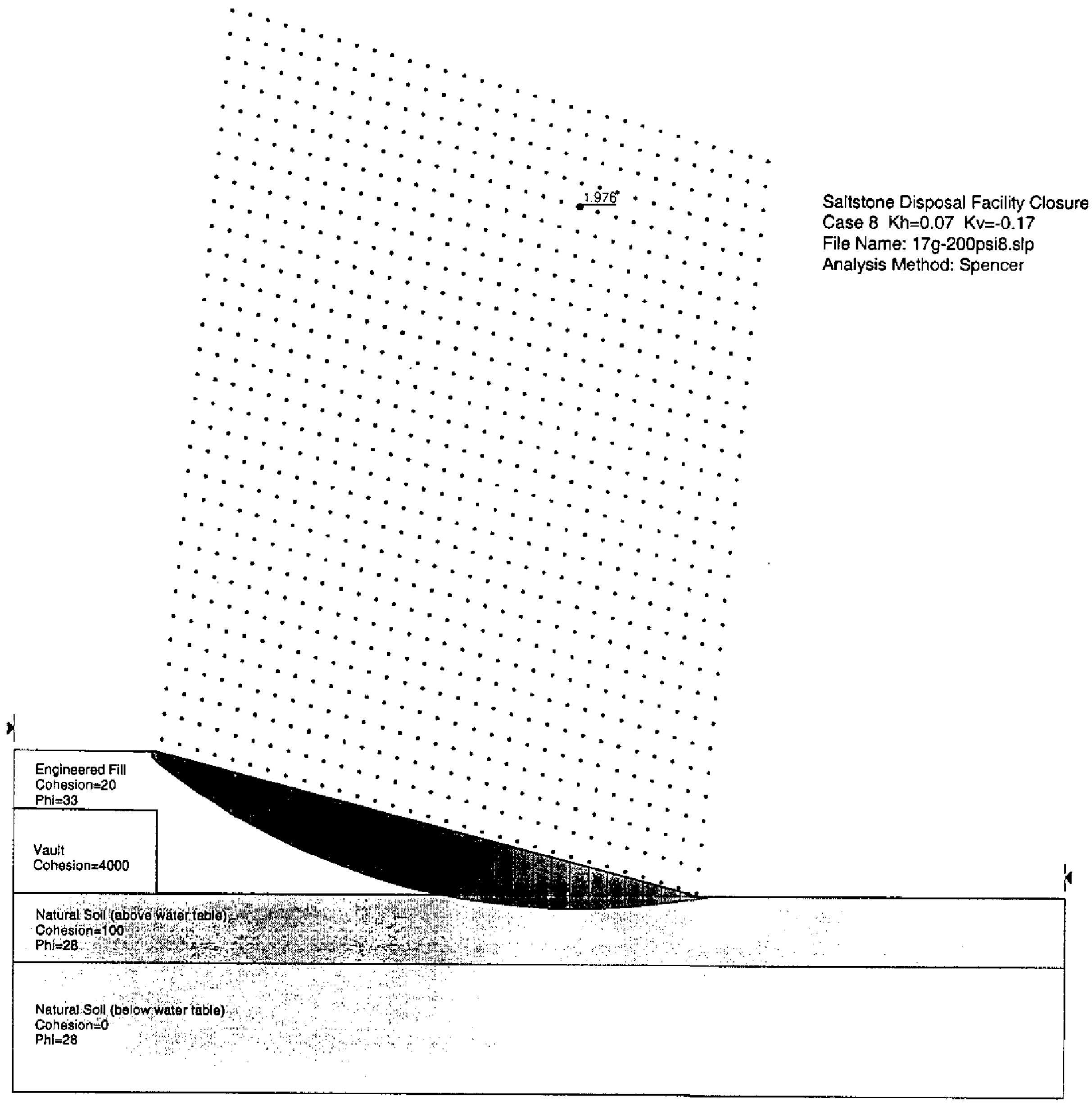


Figure 12. Safety Factor Calculated Using Slope/W for Case 8 (k_h=0.07 and k_v=-0.17)

Calculation No.	Sheet No.	Rev.
K-CLC-Z-00002	22	0

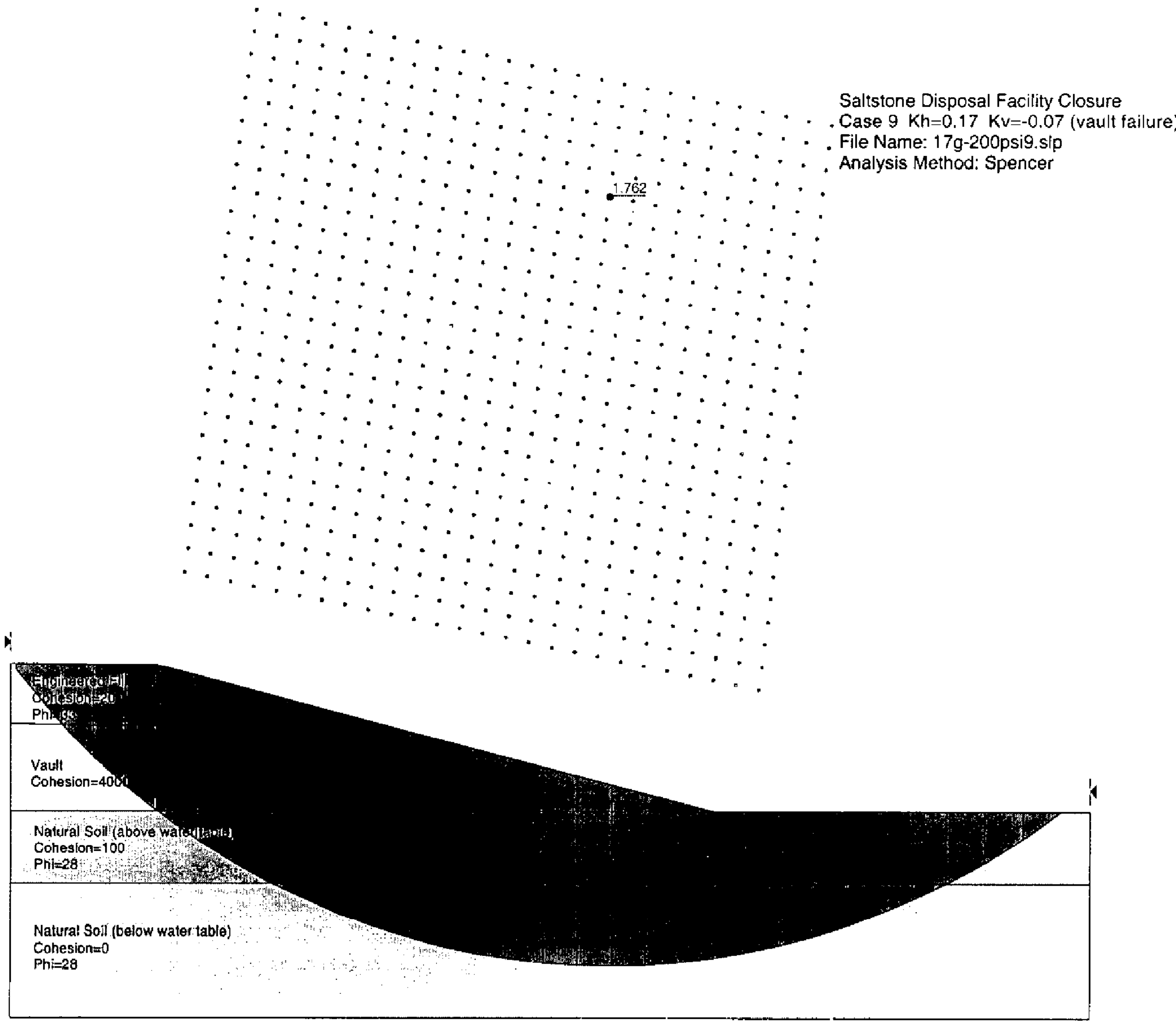


Figure 13. Safety Factor Calculated Using Slope/W for Case 9 (Vault Failure – corner k_h=0.17 and k_v=-0.07)

Calculation No.	Sheet No.	Rev.
K-CLC-Z-00002	23	0

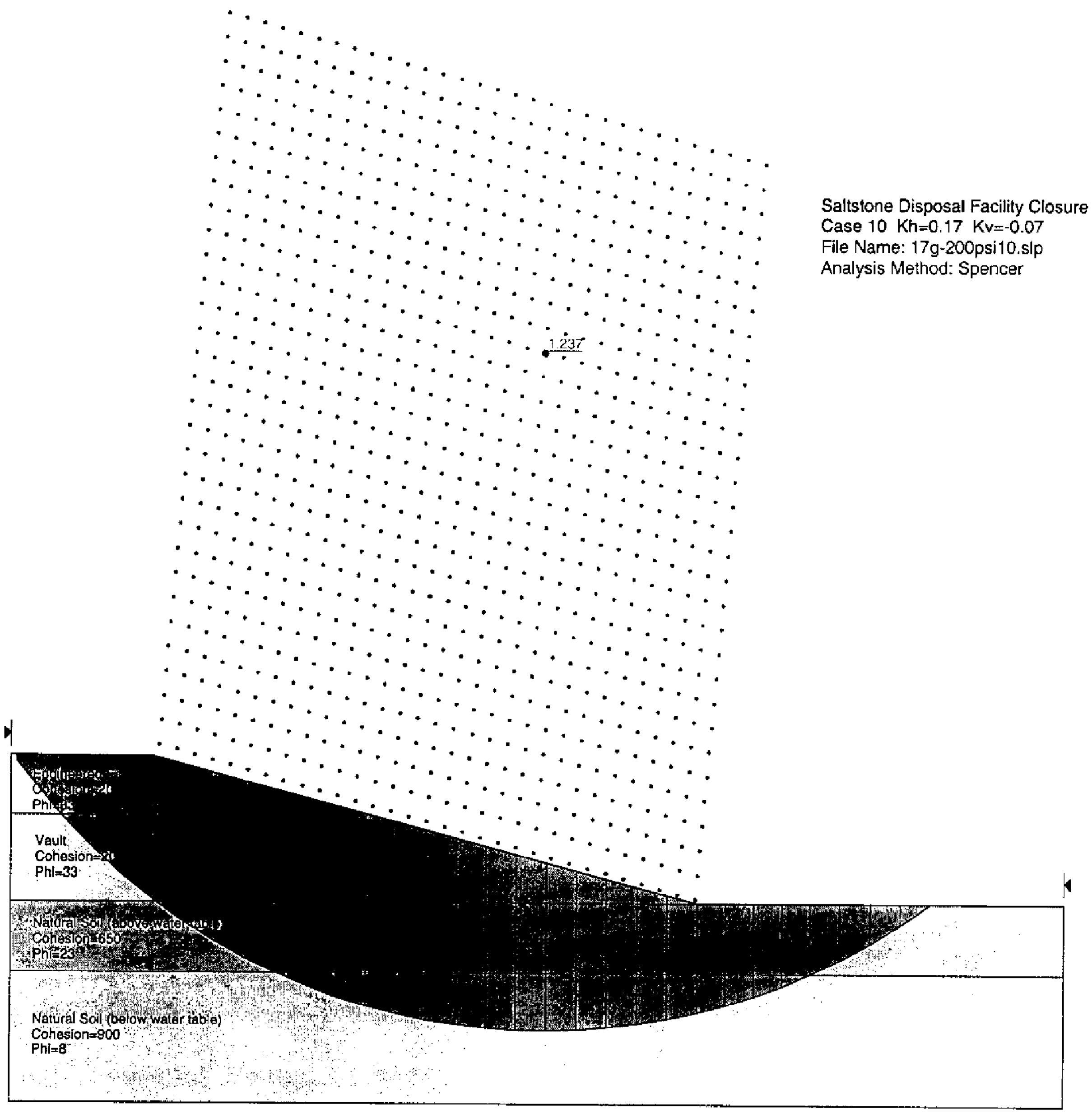


Figure 14. Safety-Factor Calculated Using Slope/W for Case 10 (total stress k_h=0.17 and k_v=-0.07)

Calculation No.	Sheet No.	Rev.
K-CLC-Z-00002	24	0

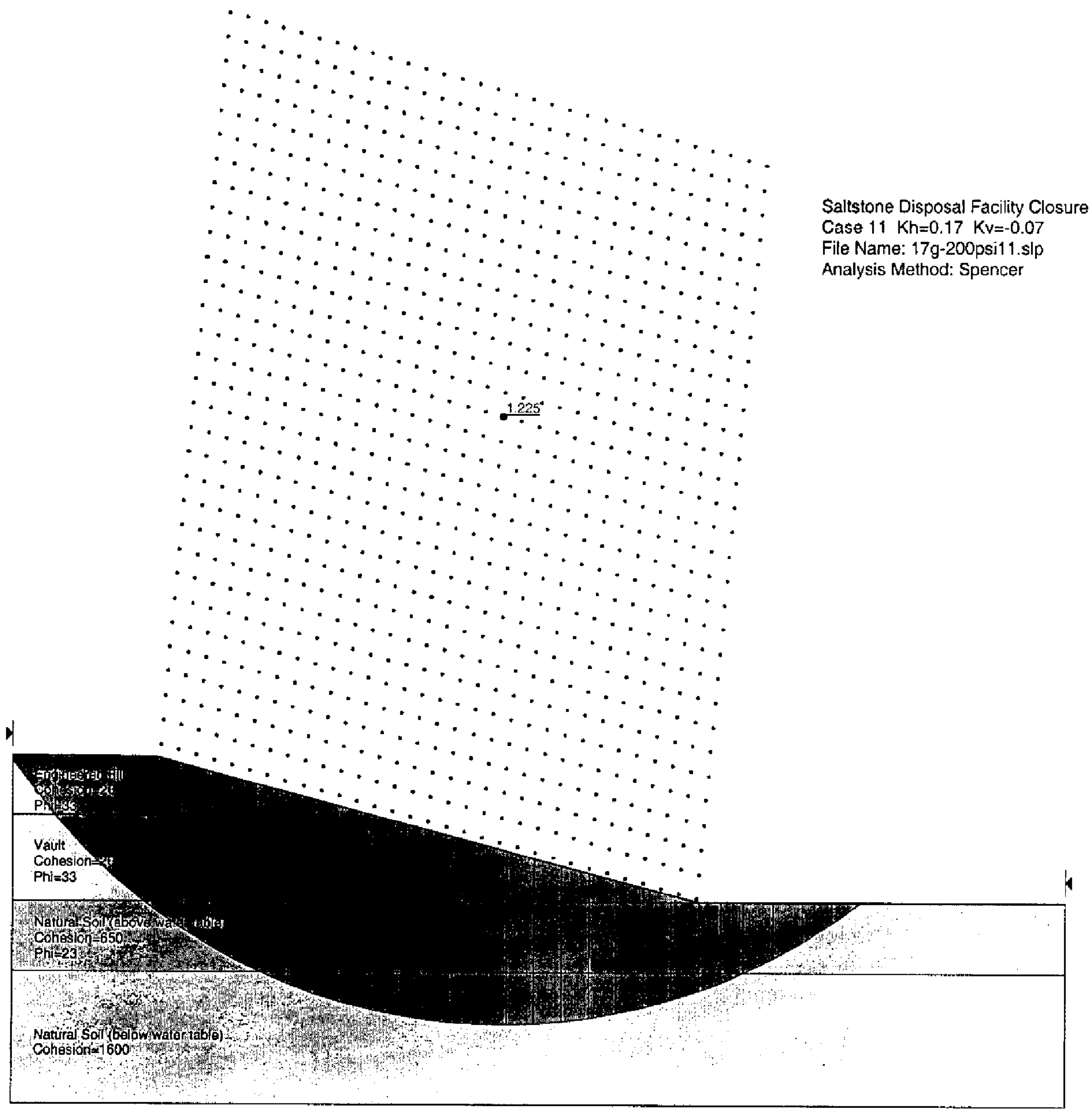


Figure 15. Safety Factor Calculated Using Slope/W for Case 11 (total stress k_h=0.17 and k_v=-0.07)

Calculation No.	Sheet No.	Rev.
K-CLC-Z-00002	25	0

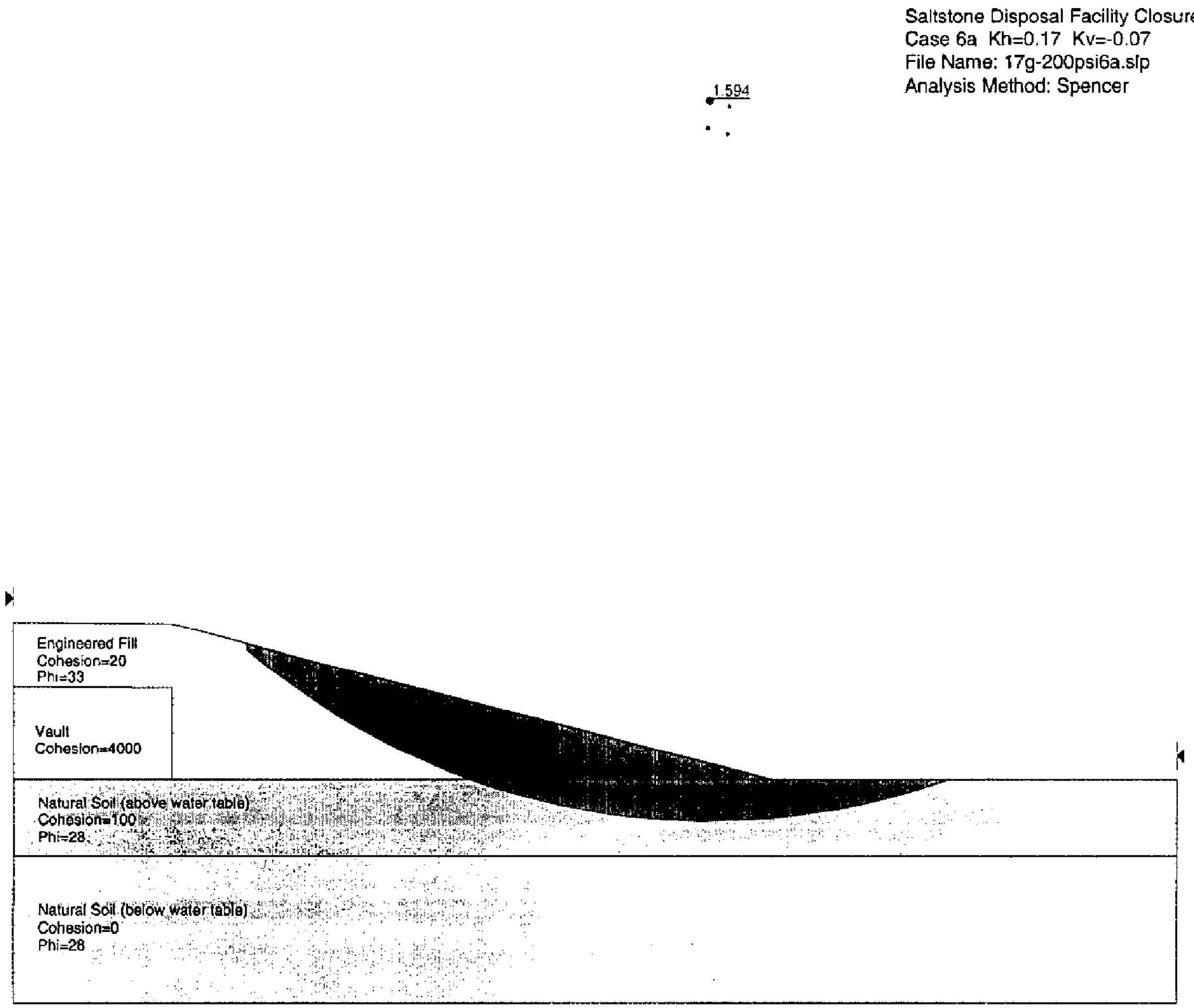


Figure 16. Safety Factor Calculated Using Slope/W for Case 6a (k_h=0.17 and k_v=-0.07)
(limited number of radius focal points and larger radii)

Calculation No.	Sheet No.	Rev.
K-CLC-Z-00002	26	0

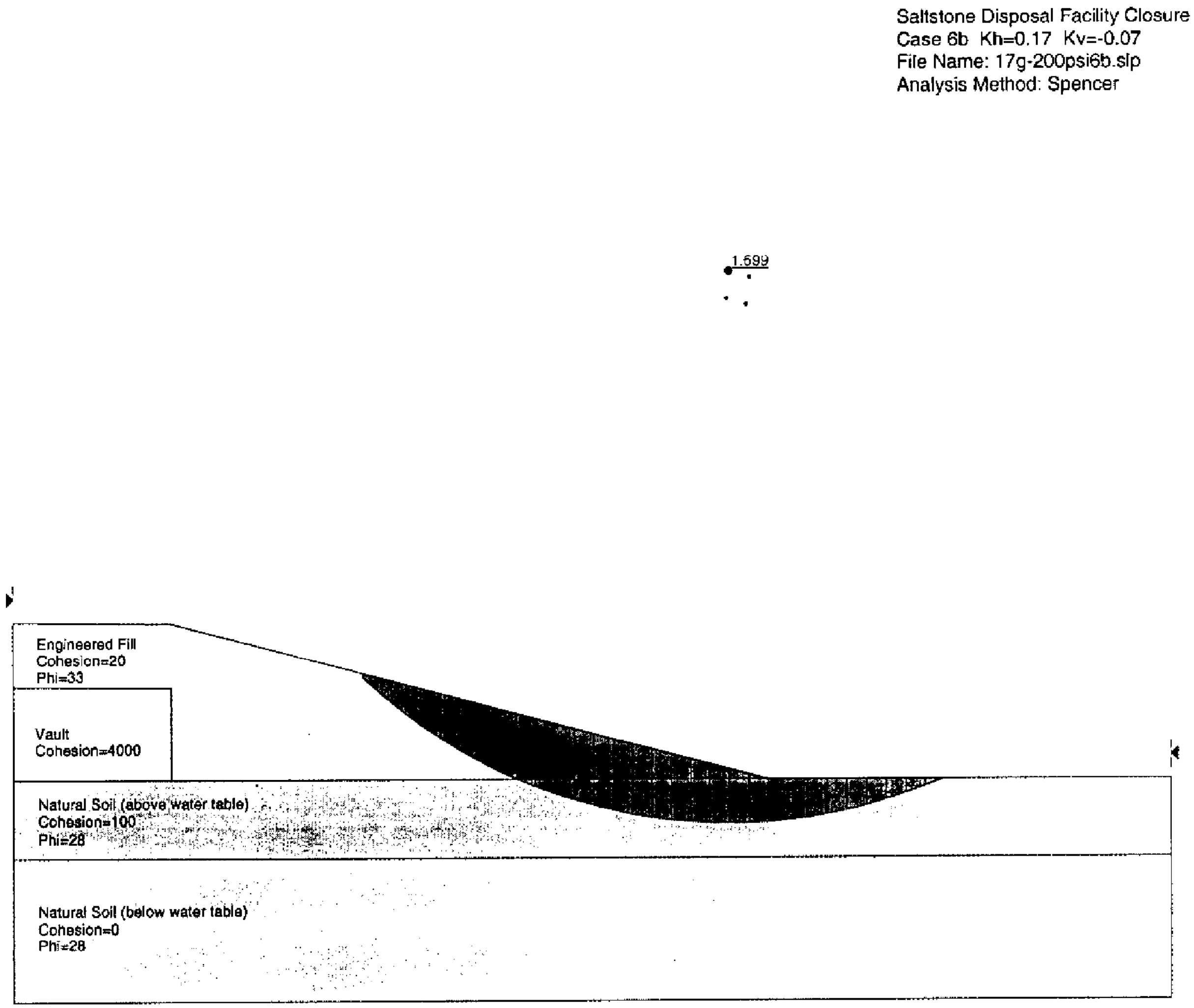


Figure 17. Safety Factor Calculated Using Slope/W for Case 6b (k_h=0.17 and k_v=-0.07)
(limited number of radius focal points and larger radii)

Calculation No.	Sheet No.	Rev.
K-CLC-Z-00002	27	0

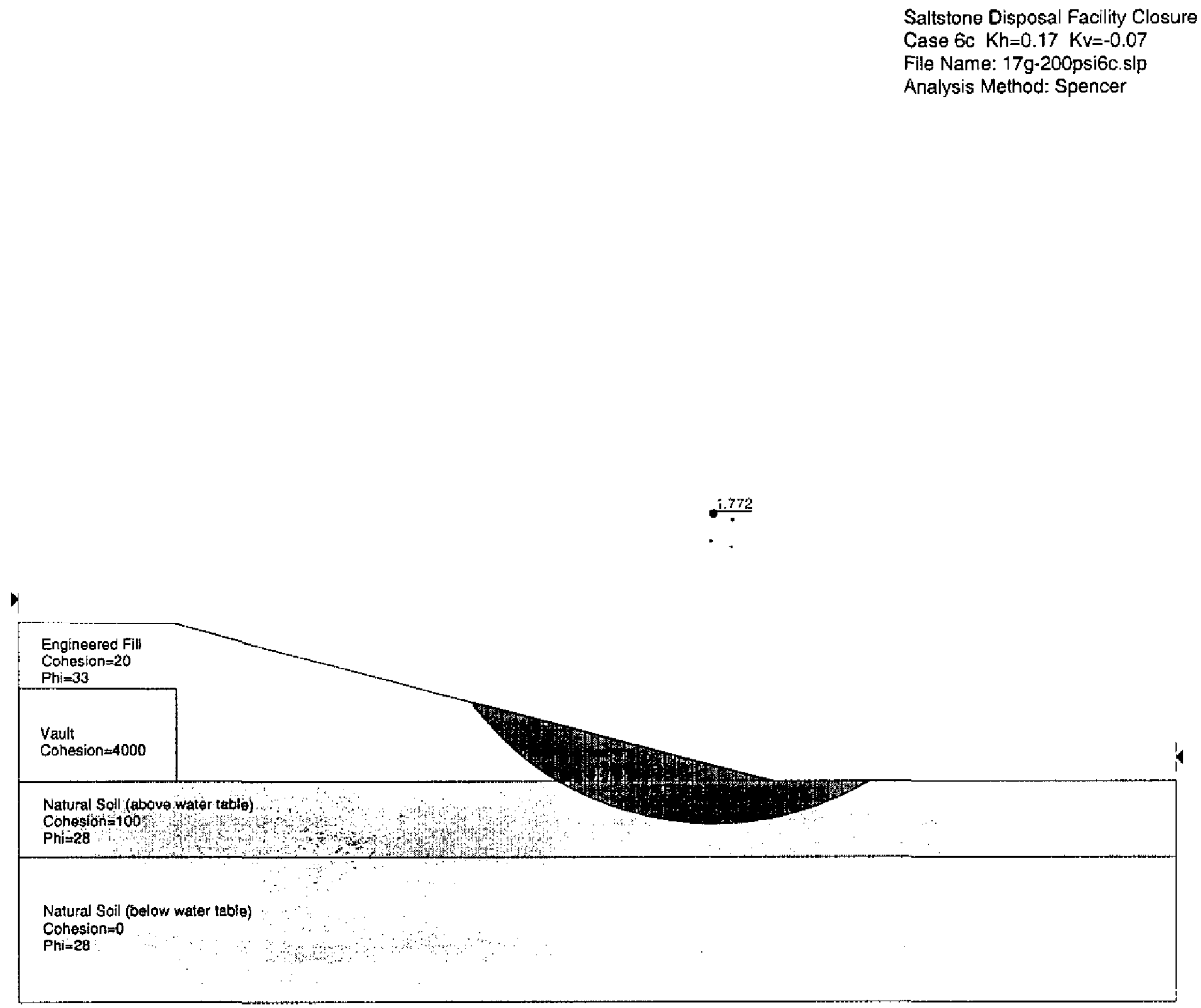


Figure 18. Safety Factor Calculated Using Slope/W for Case 6c (k_h=0.17 and k_v=-0.07)
(limited number of radius focal points and larger radii)

Calculation No.	Sheet No.	Rev.
K-CLC-Z-00002	28	0

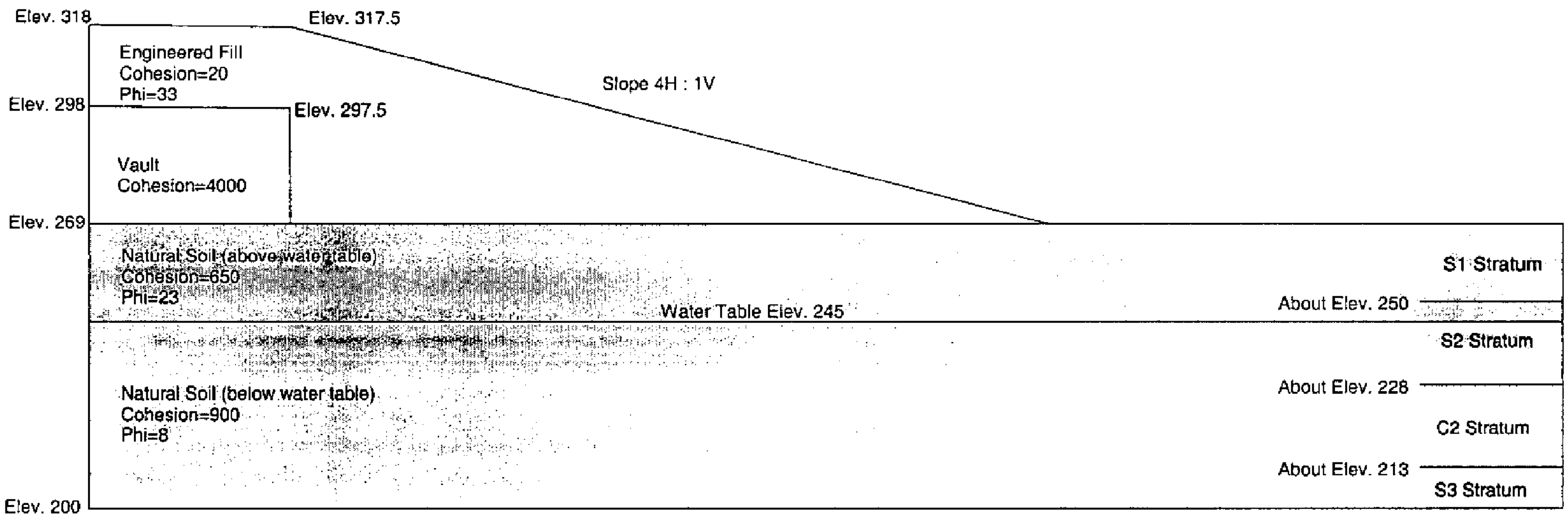


Figure 19. Vault and Closure Cover Soil Model Used for Revision 0 Case 10

Calculation No.	Sheet No.	Rev.
K-CLC-Z-00002	28A	1

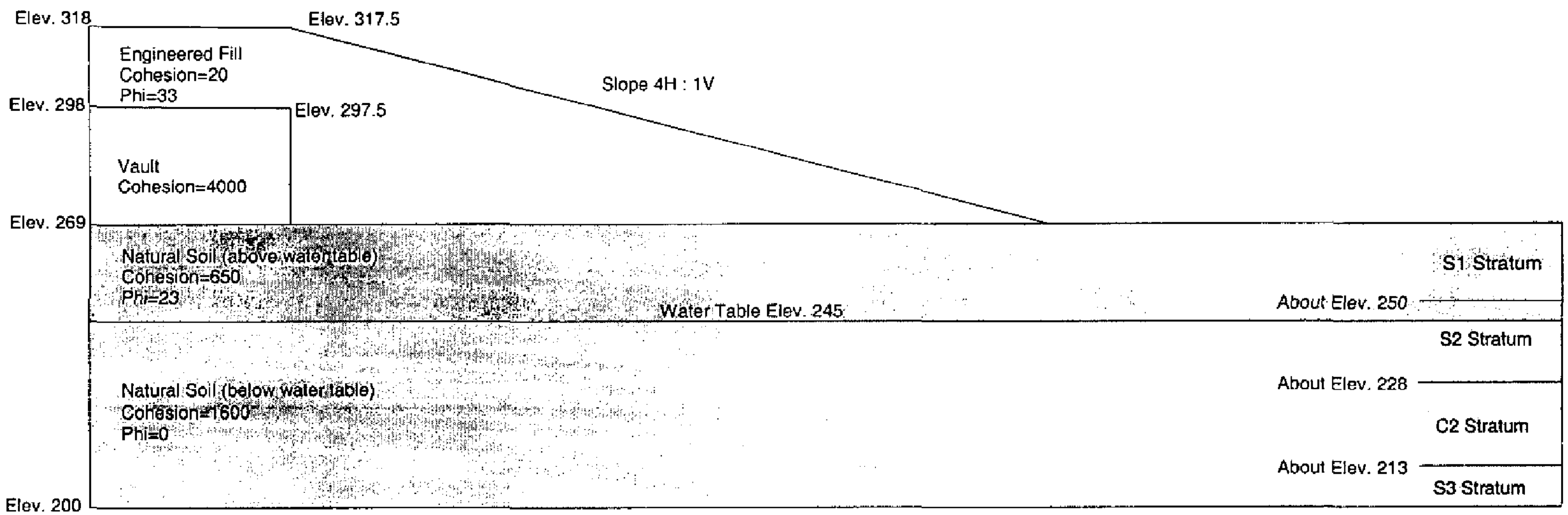


Figure 20. Vault and Closure Cover Soil Model Used for Revision 0 Case 11

Calculation No.	Sheet No.	Rev.
K-CLC-Z-00002	28B	1

Engineered Fill
Cohesion=20
Phi=33

Vault
Cohesion=20
Phi=33

S1 Stratum
Cohesion=650
Phi=23

S2 Stratum
Cohesion=650
Phi=23

C2 Stratum
Cohesion=500
Phi=15

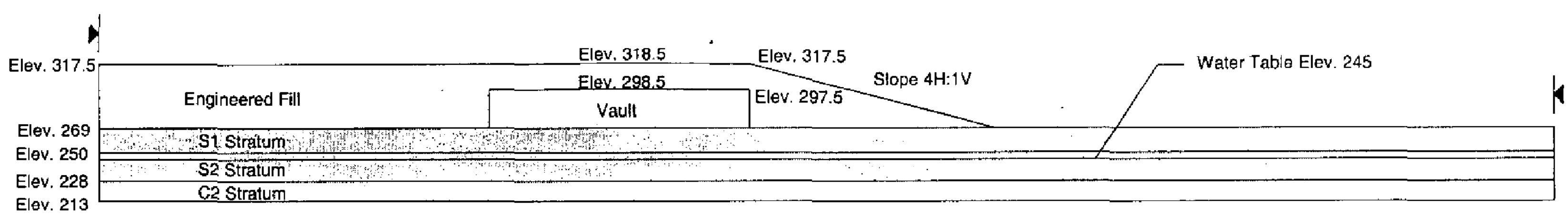


Figure 21. Vault and Closure Cover Soil Model Used for Case 10 Extended (Revision 1)

Calculation No.	Sheet No.	Rev.
K-CLC-Z-00002	28C	1

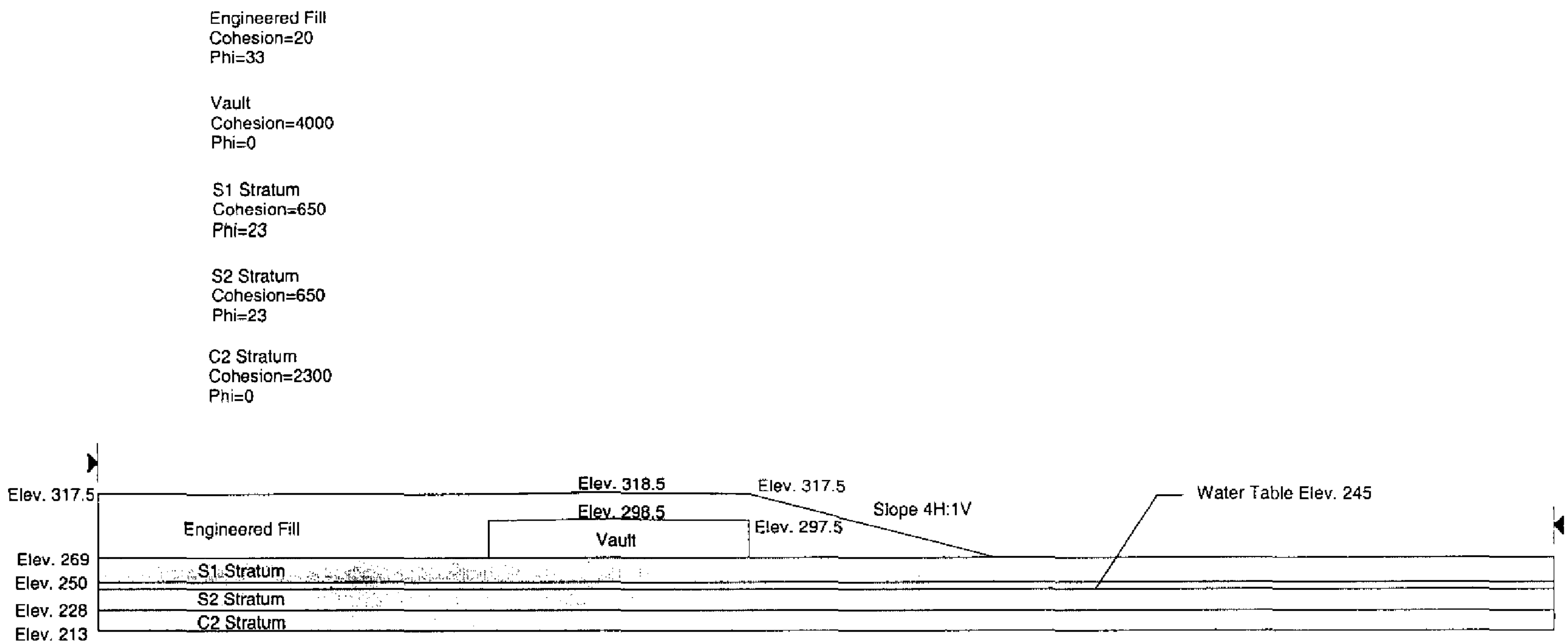


Figure 22. Vault and Closure Cover Soil Model Used for Case 11 Extended (Revision 1)

Calculation No.	Sheet No.	Rev.
K-CLC-Z-00002	28D	1

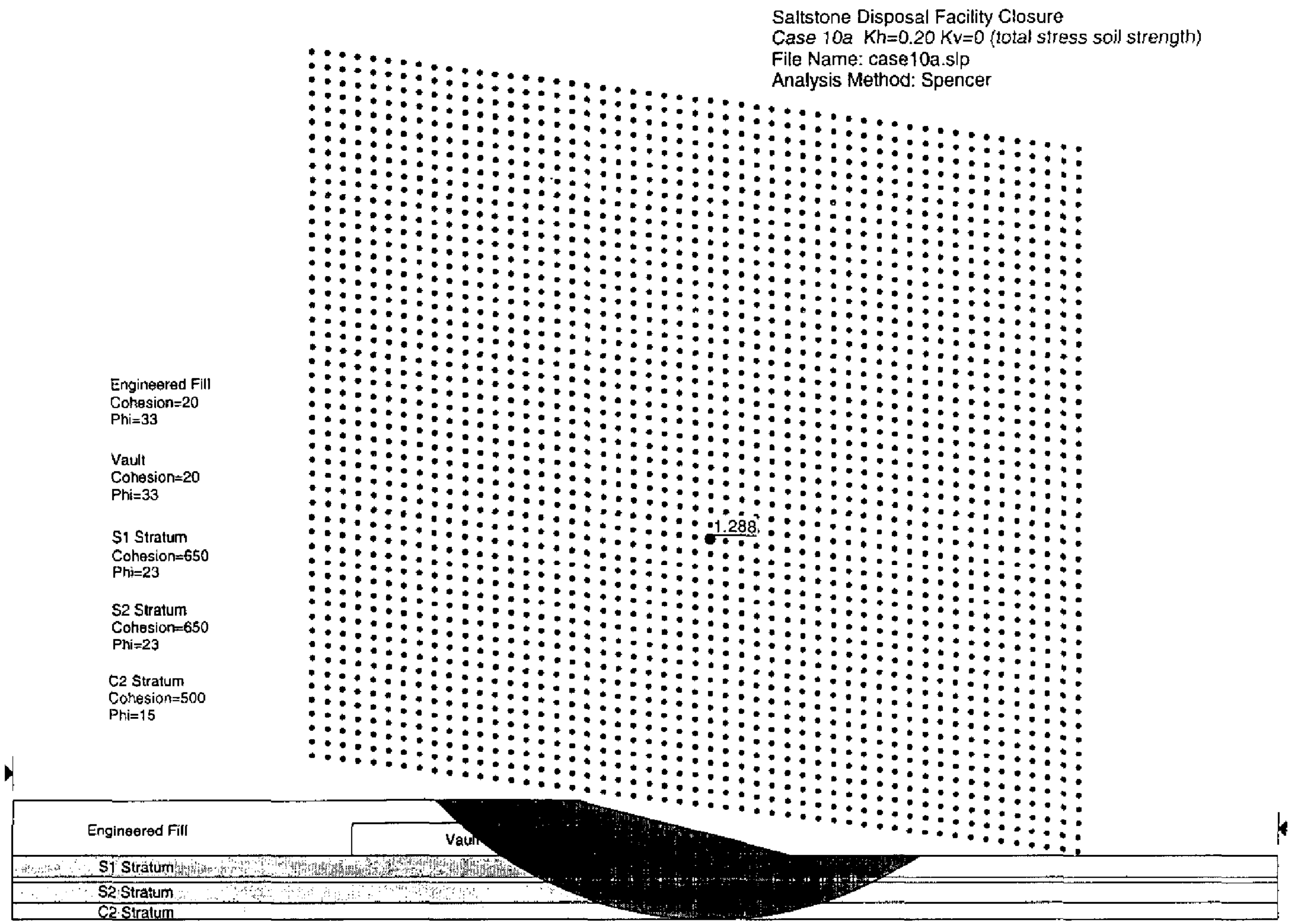


Figure 23. Safety Factor Calculated Using Slope/W for Case 10a Extended (total stress k_h=0.20 and k_v=0)

Calculation No.	Sheet No.	Rev.
K-CLC-Z-00002	28E	1

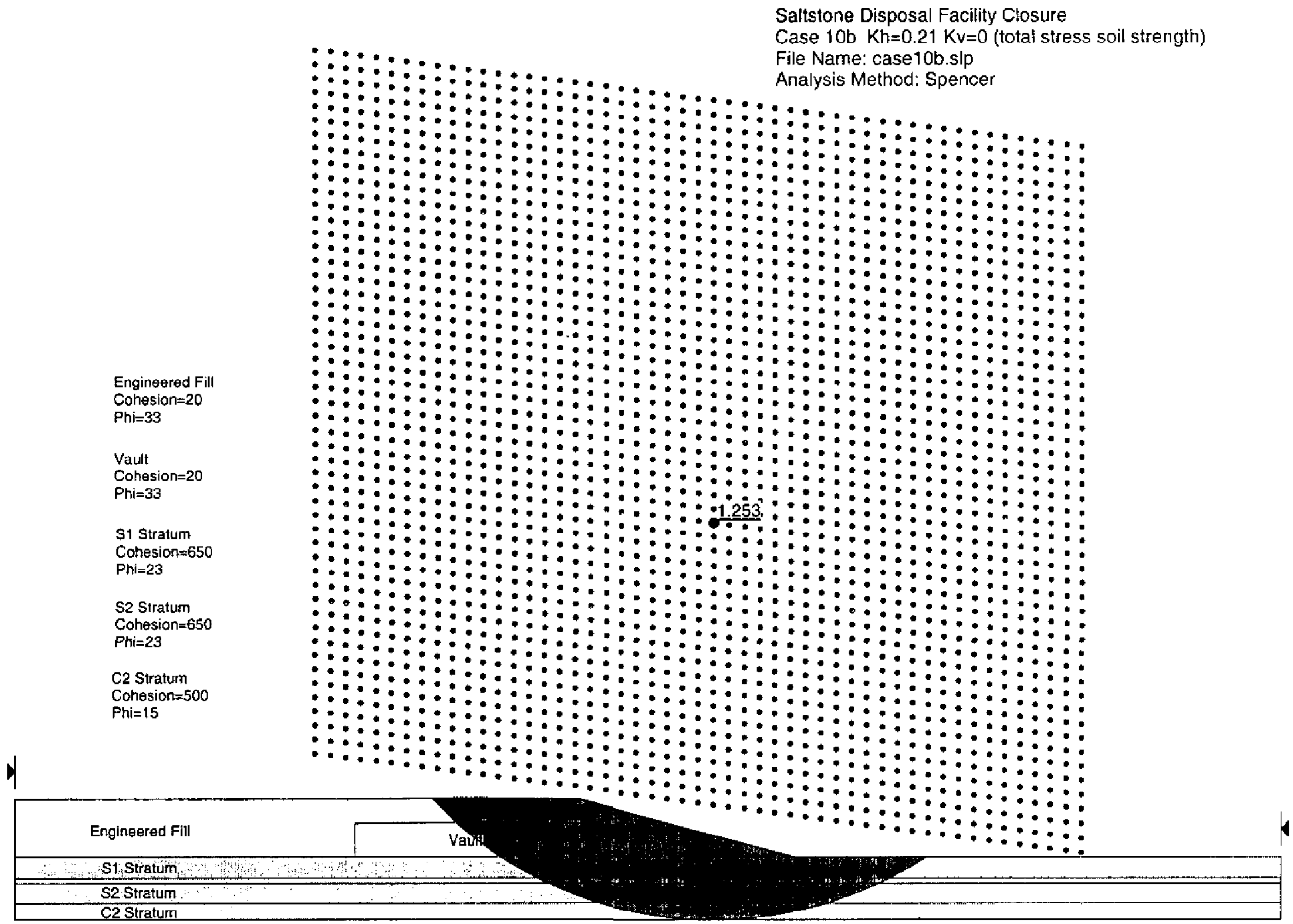


Figure 24. Safety Factor Calculated Using Slope/W for Case 10b Extended (total stress k_h=0.21 and k_v=0)

Calculation No.	Sheet No.	Rev.
K-CLC-Z-00002	28F	1

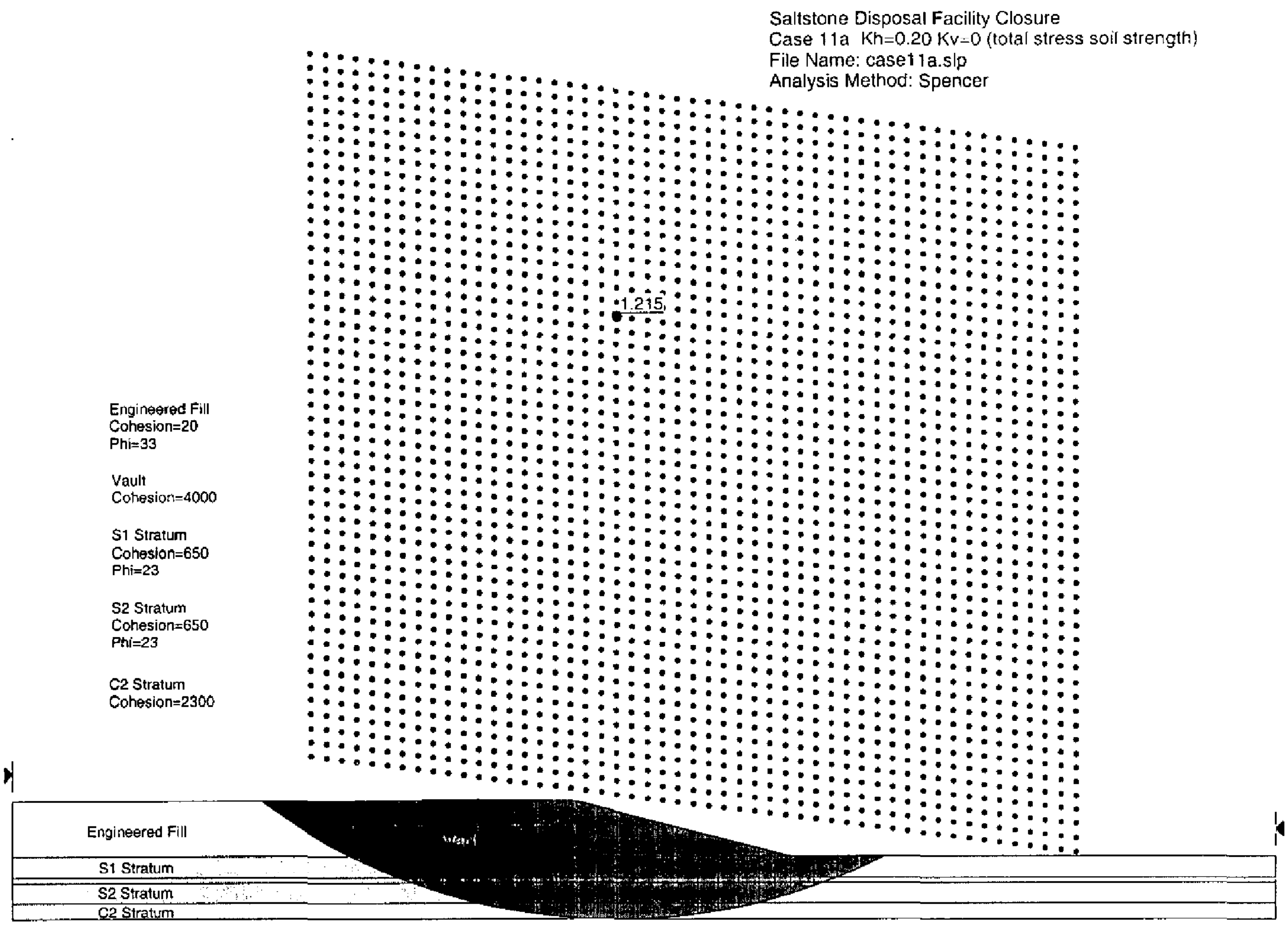


Figure 25. Safety Factor Calculated Using Slope/W for Case 11a Extended (total stress k_h=0.20 and k_v=0)

Calculation No.	Sheet No.	Rev.
K-CLC-Z-00002	28G	1

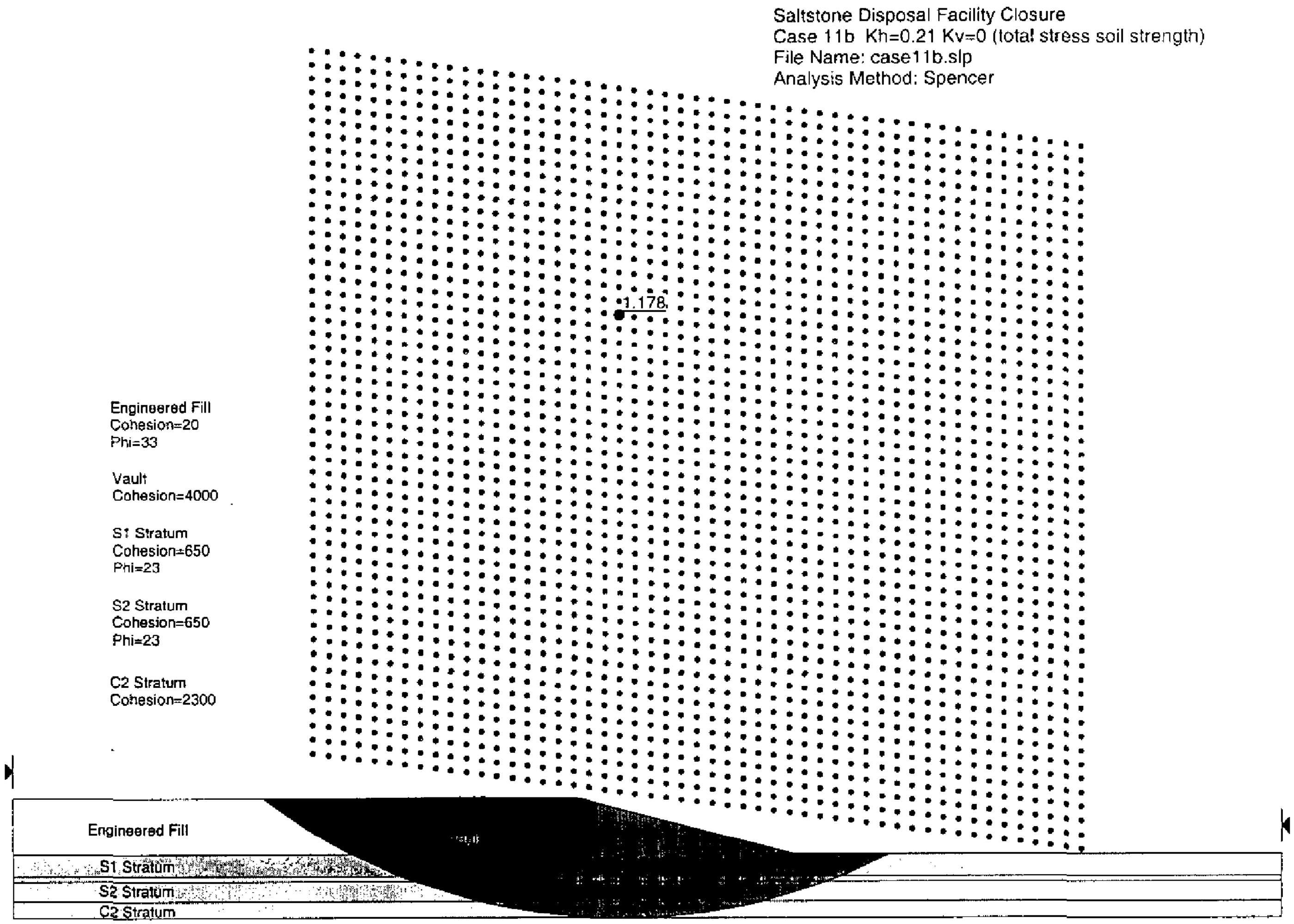
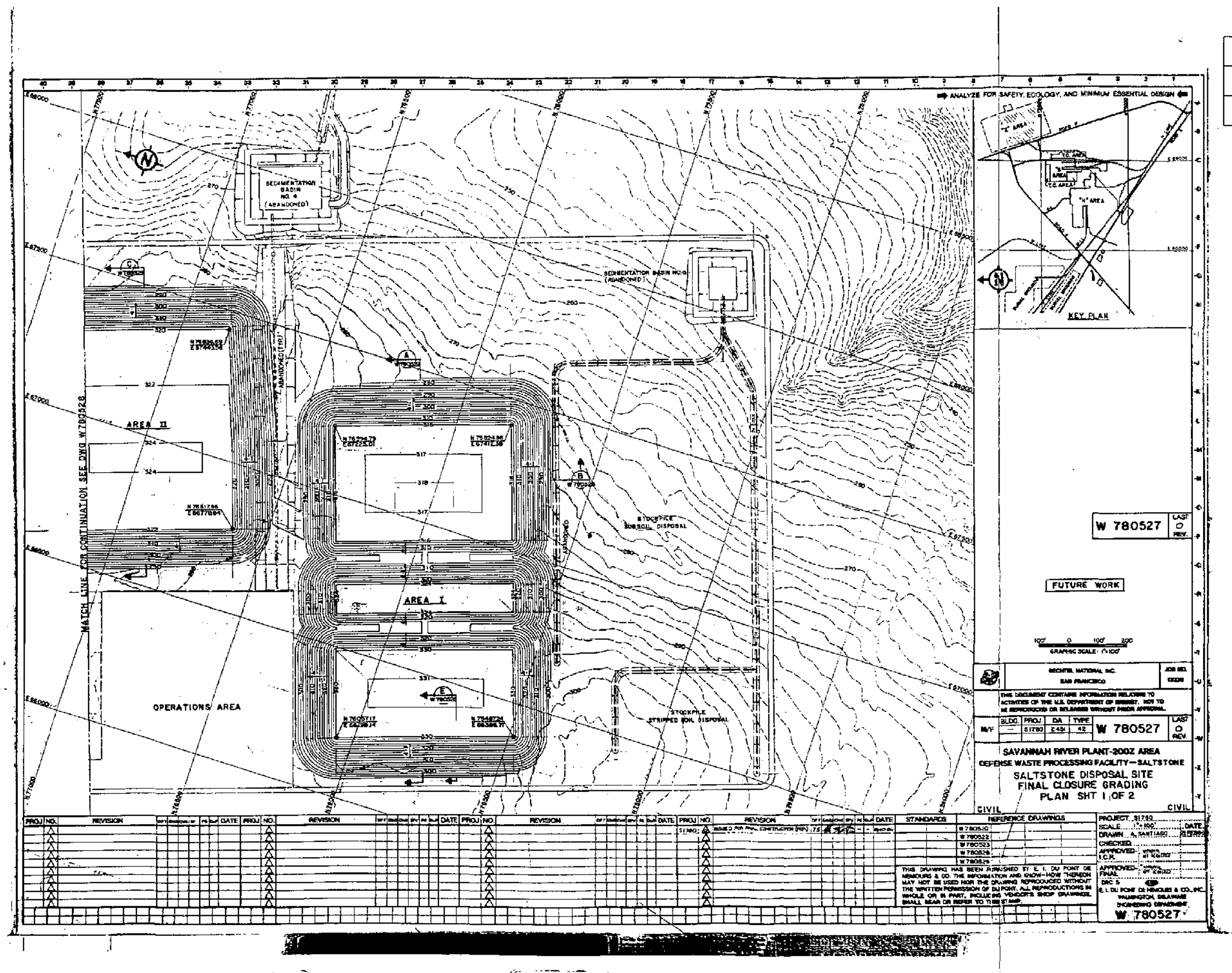


Figure 26. Safety Factor Calculated Using Slope/W for Case 11b Extended (total stress k_h=0.21 and k_v=0)

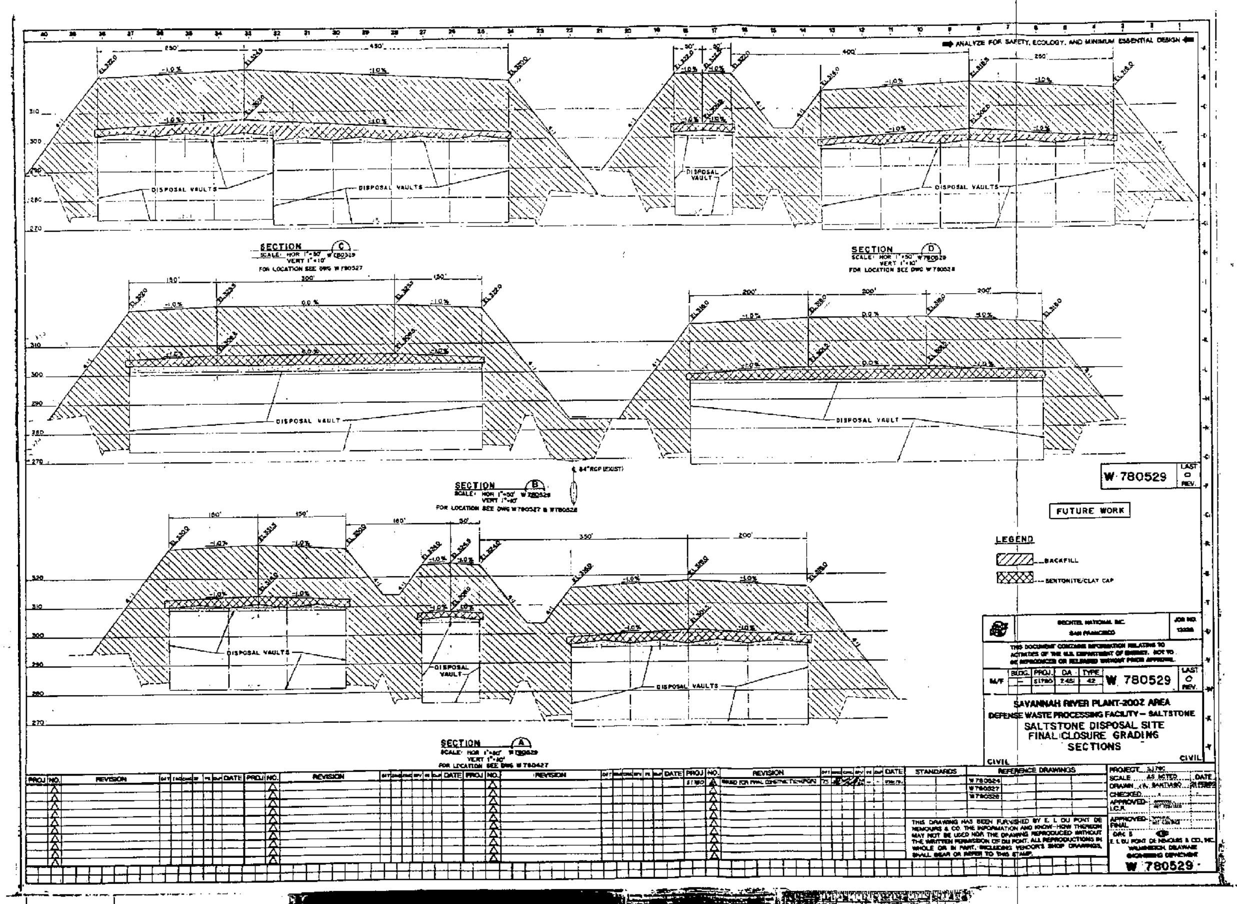
Calculation No.	Sheet No.	Rev.
K-CLC-Z-00002	28H	1

ATTACHMENT 1: DRAWINGS

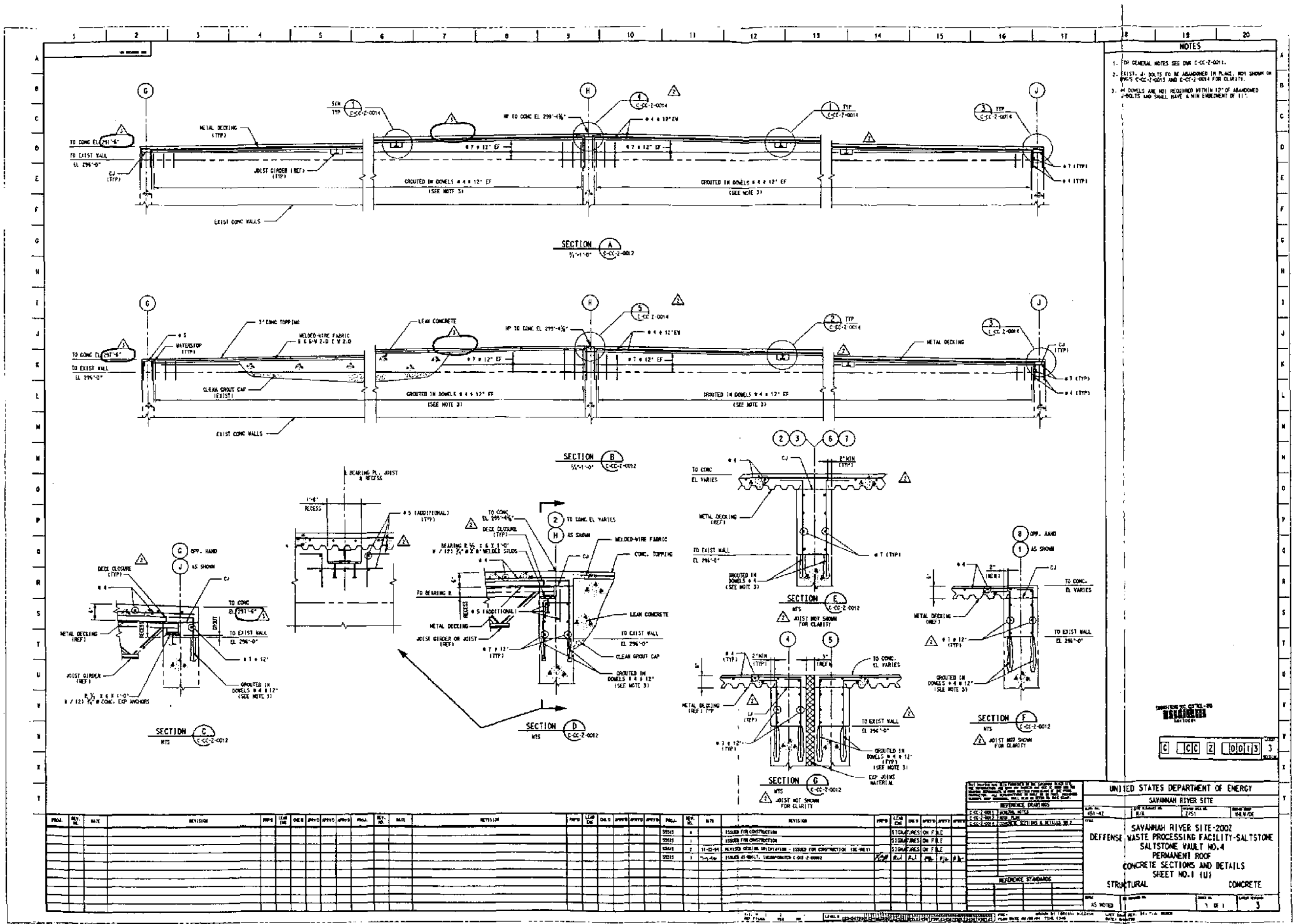
Calculation No. K-CLC-Z-00002
Sheet No. 30
Rev. 0



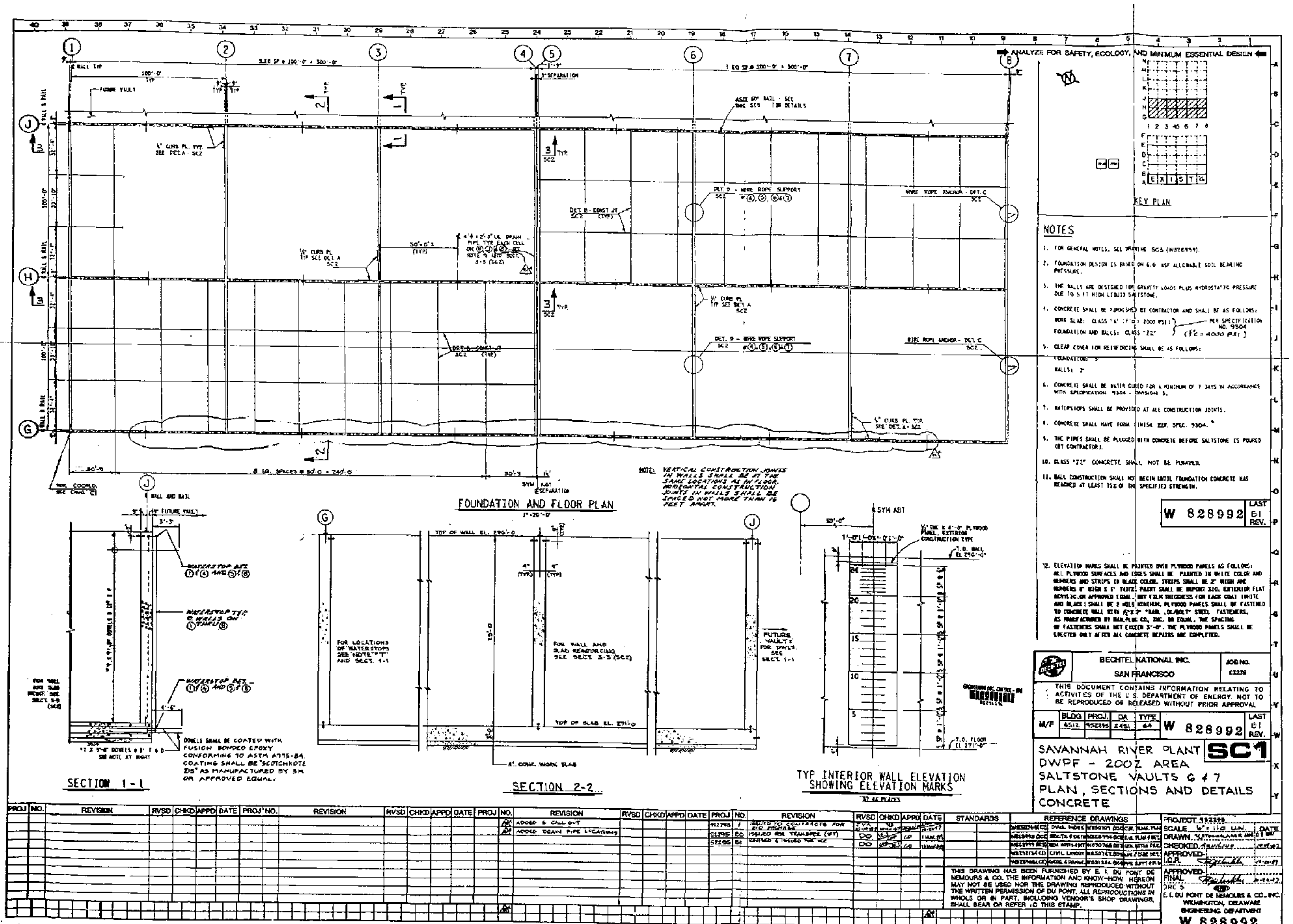
Calculation No. K-CLC-Z-00002
Sheet No. 31
Rev. 0



Calculation No. K-CLC-Z-00002
Sheet No. 32
Rev. 0



Calculation No. K-CLC-Z-00002
Sheet No. 33
Rev. 0



ATTACHMENT 2: SOIL SHEAR STRENGTH DATA

This attachment contains effective and total stress shear strength test results performed in the vicinity of the Saltstone Vaults. More detail regarding the testing can be obtained from *Investigations of Slope Stability Savannah River Plant Aiken, South Carolina*, by Woodward-Clyde Consultants (1985), *Stability of Trenches 200 Z Area Saltstone Landfill Savannah River Plant Aiken, South Carolina*, by Woodward-Clyde Consultants (1986), *Savannah River Site Z-Area Vault No. 2 Geotechnical Investigations Report (U)*, by Bechtel Savannah River, Inc. (1992), and *Saltstone Disposal Z-Area Savannah River Plant*, by Mueser Rutledge Consulting Engineers (1986).

Figure 1, on sheet 11 of this calculation, shows approximate elevations for the various soil strata beneath Vault No. 4. Detailed descriptions of the strata are provided in, *Saltstone Disposal Z-Area Savannah River Plant*, by Mueser Rutledge Consulting Engineers (1986). The majority of the strength tests are above the water table in the S1 stratum (see sheet 35). The S2 and S3 strata have very limited data. The S2 stratum is believed to behave like the S1 stratum when above the water table. Cone Penetrometer and Standard Penetration tests indicate that the S2 stratum is as strong or stronger than the S1 stratum. Assuming that the S2 stratum behaves as the S1 stratum is conservative. Five tests are available for the C2 stratum below the water table. The S3 stratum is interspersed and underlies the C2 stratum and is stronger than the C2 stratum. Assuming that the S3 stratum behaves as the C2 stratum is conservative. Boring ID, type of test, test moisture, and stratum for the triaxial shear tests are provided on sheet 35.

Effective stress results show sandy behavior with little cohesion for both saturated and unsaturated tests. Total stress results from unsaturated samples also tend to behave as sandy soils with little cohesion. However, total stress results from saturated samples exhibit strength due to cohesion and behave somewhat like clayey soils.

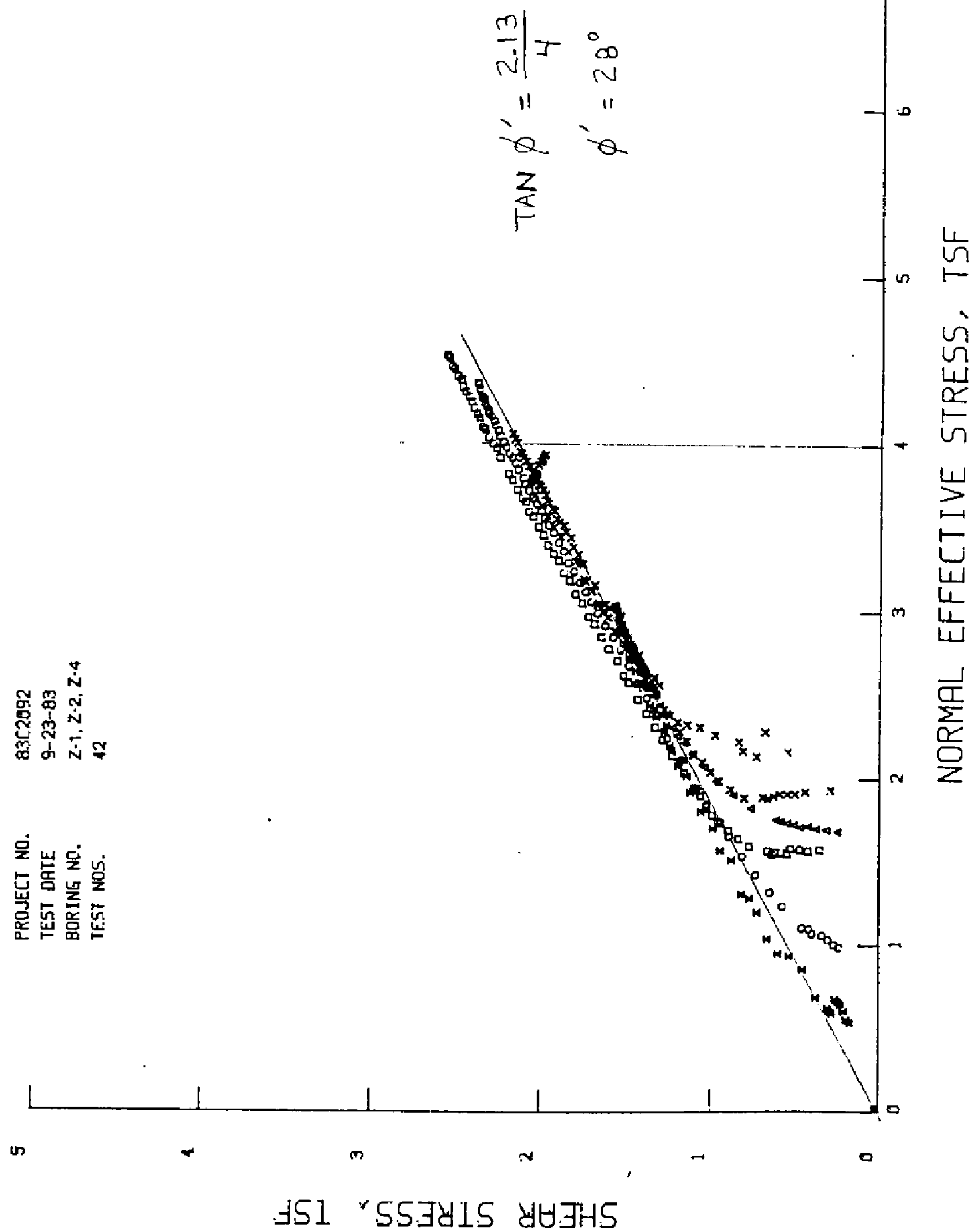
For "effective stress" cases the S1, S2, C2 and S3 soils above and below the water table were modeled as with a conservative friction angle 28° and cohesion of 100 psf above the water and no cohesion below the water table (see sheets 36 through 40 for supporting data).

For the "total stress" cases the S1 and S2 soils above the water table were modeled with a conservative friction angle of 23° with cohesion of 650 psf as interpreted by Woodward-Clyde Consultants (1986) (see sheet 41 for plot of data). The S2, C2 and S3 soils below the water table were modeled two ways to insure the most conservative interpretation. The soils below the water table were modeled with 1) a friction angle of 8° and cohesion of 900 psf and 2) a friction angle of zero and cohesion of 1,600 psf (see sheet 42 for plot of saturated total stress data).

SGS File No.	Boring ID	SRS Northing	SRS Easting	Type of Test	Test Moisture	Stratum	Mid. Elev. (ft-msl)	Sheet No.
Z-SDF-9	ZB-2	76156	66598	CU	saturated	S1	261.0	37, 38, 42
Z-SDF-9	ZB-8	75575	66689	CU	saturated	S1	270.8	39, 40, 42
G-SRS-17 and Z-SDF-8	Z-1	76200	66975	CIU	natural	S1	270.9	41
G-SRS-17 and Z-SDF-8	Z-1	76200	66975	CIU	saturated	S1	270.4	36
G-SRS-17 and Z-SDF-8	Z-1	76200	66975	CIU	natural	S1	260.9	41
G-SRS-17 and Z-SDF-8	Z-1	76200	66975	CIU	saturated	S1	260.4	36
G-SRS-17 and Z-SDF-8	Z-2	75710	67200	CIU	saturated	S1	271.2	36
G-SRS-17 and Z-SDF-8	Z-2	75710	67200	CIU	natural	S1	270.7	41
G-SRS-17 and Z-SDF-8	Z-2	75710	67200	CIU	saturated	S1	256.7	36
G-SRS-17 and Z-SDF-8	Z-2	75710	67200	CIU	natural	S1	256.2	41
G-SRS-17 and Z-SDF-8	Z-4	75520	66585	CIU	natural	S1	273.3	41
G-SRS-17 and Z-SDF-8	Z-4	75520	66585	CIU	saturated	S1	272.8	36
G-SRS-17 and Z-SDF-8	Z-4	75520	66585	CIU	natural	S1	263.25	41
G-SRS-17 and Z-SDF-8	Z-4	75520	66585	CIU	saturated	S1	262.8	36
G-SRS-17 and Z-SDF-8	Z-1	76200	66975	UU	natural	S1	250.6	41
G-SRS-17 and Z-SDF-8	Z-1	76200	66975	UU	natural	S2	240.9	41
G-SRS-17 and Z-SDF-8	Z-5	78560	67120	UU	natural	S2	240.3	41
G-SRS-17 and Z-SDF-8	Z-6	78150	65850	UU	natural	S1	260.1	41
G-SRS-17 and Z-SDF-8	Z-8	77100	67450	UU	natural	S1	259.6	41
Z-SDF-2	Z-211U	75741	66805	CU	natural	S3	192	42, 43, 44
Z-SDF-2	Z-218U	77297	67251	CU	natural	C2	214.9	42, 43, 44
Z-SDF-2	Z-224U	75847	67041	CU	natural	C2	221.2	42, 43, 44
Z-SDF-2	Z-224U	75847	67041	CU	natural	C2	217.7	42, 43, 44
Z-SDF-2	Z-225U	75939	67325	CU	natural	C2	216	42, 43, 44
Z-SDF-2	Z-225U	75939	67325	CU	natural	C2	216	42, 43, 44

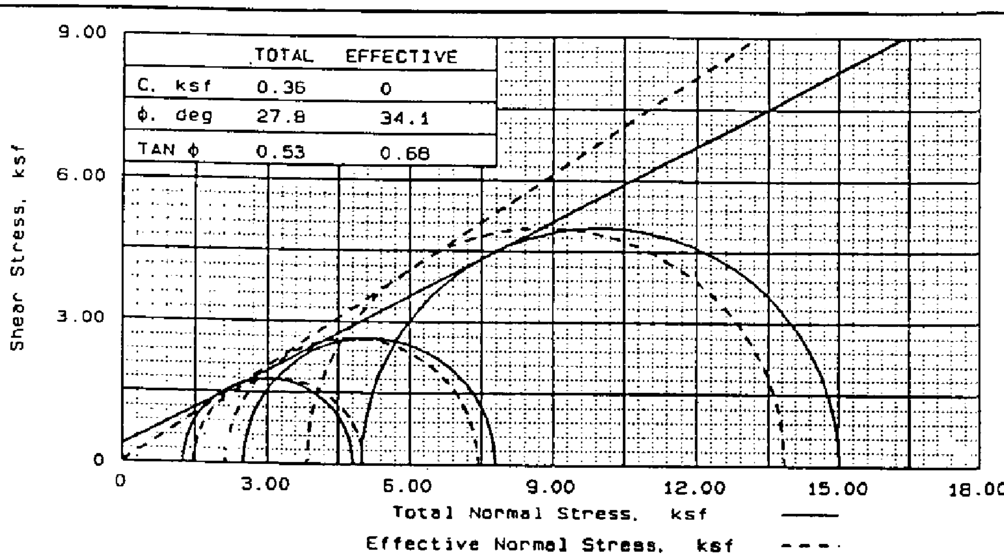
CU – Consolidated Undrained
CIU – Isotropically Consolidated Undrained
UU – Unconsolidated Undrained

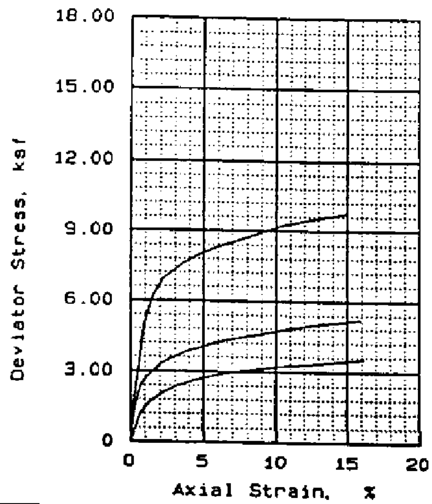
Calculation No. K-CLC-Z-00002
Sheet No. 36
Rev. 0



Calculation No.	K-CLC-Z-00002
Sheet No.	37
Rev.	0

	TOTAL	EFFECTIVE
C, ksf	0.36	0
ϕ, deg	27.8	34.1
TAN ϕ	0.53	0.68





SAMPLE NO.		1	2	3
INITIAL	WATER CONTENT, %	14.5	12.8	12.9
	DRY DENSITY, pcf	109.3	107.3	105.8
	SATURATION, %	72.2	60.4	58.6
	VOID RATIO	0.543	0.571	0.593
	DIAMETER, in	2.87	2.87	2.86
	HEIGHT, in	5.60	5.60	5.60
AT TEST	WATER CONTENT, %	17.4	19.8	21.2
	DRY DENSITY, pcf	114.7	109.8	107.2
	SATURATION, %	100.0	100.0	100.0
	VOID RATIO	0.470	0.536	0.572
	DIAMETER, in	2.81	2.84	2.85
	HEIGHT, in	5.54	5.56	5.58
BACK PRESSURE, ksf		2.75	2.68	2.00
CELL PRESSURE, ksf		7.75	5.18	3.25
FAILURE STRESS, ksf		10.01	5.30	3.56
PORE PRESSURE, ksf		3.90	3.04	1.79
STRAIN RATE, %/min.		0.100	0.100	0.100
ULTIMATE STRESS, ksf				
PORE PRESSURE, ksf				
$\bar{\sigma}_1$ FAILURE, ksf		13.86	7.44	5.02
$\bar{\sigma}_3$ FAILURE, ksf		3.85	2.14	1.47

TYPE OF TEST:
CU with pore pressures

SAMPLE TYPE: UNDISTURBED

DESCRIPTION: RED BROWN & PURPLE CLAYEY SILTY MED. TO FN. SAND

LL= PL= PI=

SPECIFIC GRAVITY= 2.70

REMARKS: TESTED BY

REVIEWED BY

FIG. NO. 1

CLIENT: BECHTEL SAVANNAH RIVER, INC.

PROJECT: Z-AREA TASK ORDER 4

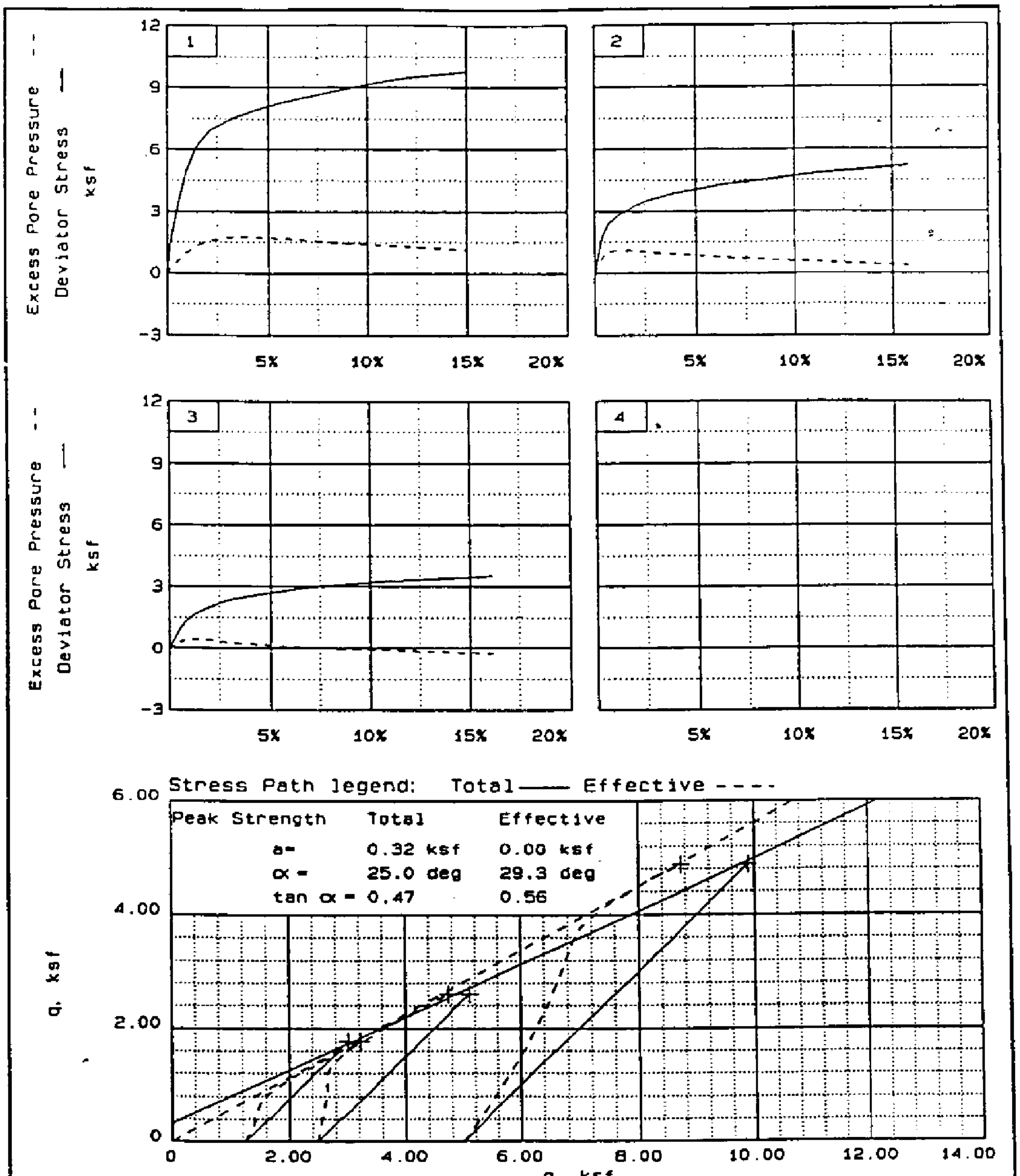
SAMPLE LOCATION: B-2 UD @ 20-22 FT.

PROJ. NO.: 1461010594 DATE: JUNE 12, 1992

TRIAXIAL COMPRESSION TEST

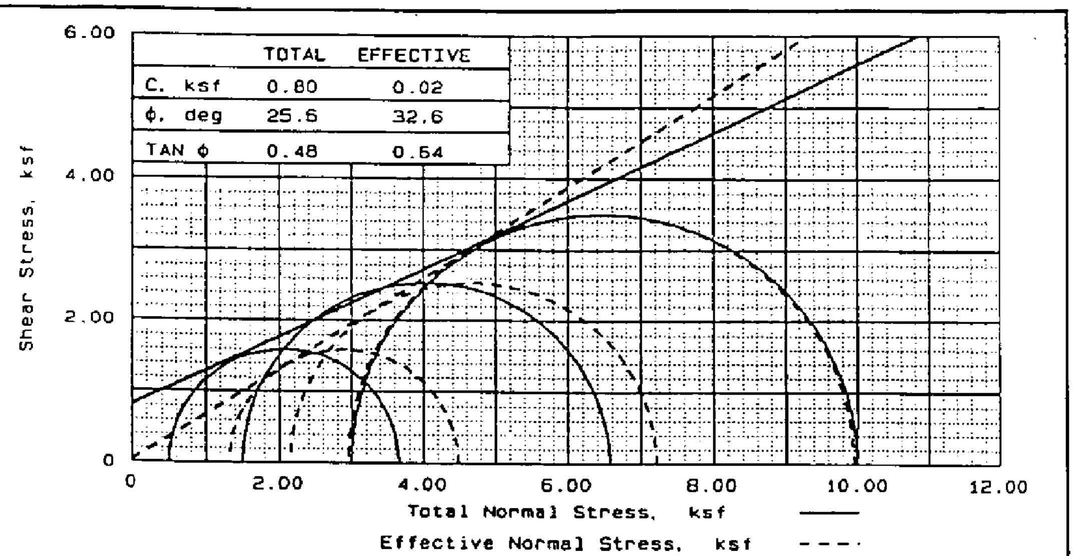
LAW ENGINEERING, INC.

Calculation No. K-CLC-Z-00002
Sheet No. 38
Rev. 0

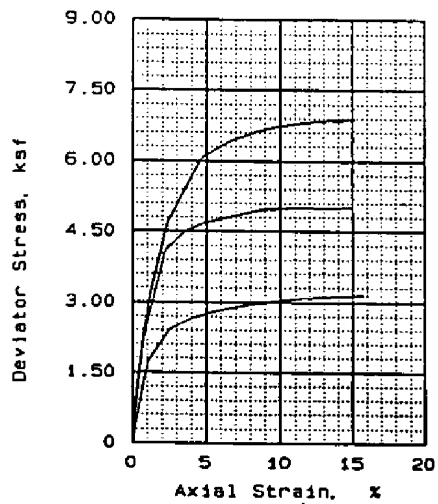


Client: BECHTEL SAVANNAH RIVER, INC.
Project: Z-AREA TASK ORDER 4
Location: B-2 UD @ 20-22 FT.
File: 61010594 Project No.: 1461010594 Page 2/2 Fig. No. 1

Calculation No. K-CLC-Z-00002
Sheet No. 39
Rev. 0



	TOTAL	EFFECTIVE
C, ksf	0.80	0.02
ϕ, deg	25.6	32.6
TAN ϕ	0.48	0.64



SAMPLE NO.		1	2	3
INITIAL	WATER CONTENT, %	15.7	16.6	15.0
	DRY DENSITY, pcf	109.5	109.5	119.5
	SATURATION, %	78.5	83.2	98.9
	VOID RATIO	0.539	0.540	0.410
	DIAMETER, in	2.86	2.86	2.87
	HEIGHT, in	5.60	5.60	5.60
AT TEST	WATER CONTENT, %	19.5	19.2	13.8
	DRY DENSITY, pcf	110.4	110.9	122.8
	SATURATION, %	100.0	100.0	100.0
	VOID RATIO	0.527	0.519	0.373
	DIAMETER, in	2.85	2.85	2.84
	HEIGHT, in	5.59	5.58	5.56
BACK PRESSURE, ksf		2.85	2.82	2.81
CELL PRESSURE, ksf		3.35	4.32	5.81
FAILURE STRESS, ksf		3.16	5.07	6.99
PORE PRESSURE, ksf		2.03	2.17	2.85
STRAIN RATE, %/min.		0.100	0.100	0.100
ULTIMATE STRESS, ksf				
PORE PRESSURE, ksf				
$\bar{\sigma}_1$ FAILURE, ksf		4.48	7.22	9.94
$\bar{\sigma}_3$ FAILURE, ksf		1.32	2.15	2.96

TYPE OF TEST:
CU with pore pressures

SAMPLE TYPE: UNDISTURBED

DESCRIPTION: PURPLE BROWN CLAYEY SILTY MED. TO FN SAND

LL= PL= PI=

SPECIFIC GRAVITY= 2.70

REMARKS: TESTED BY

REVIEWED BY

FIG. NO. 2

CLIENT: BECHTEL SAVANNAH RIVER, INC.

PROJECT: Z-AREA TASK ORDER 4

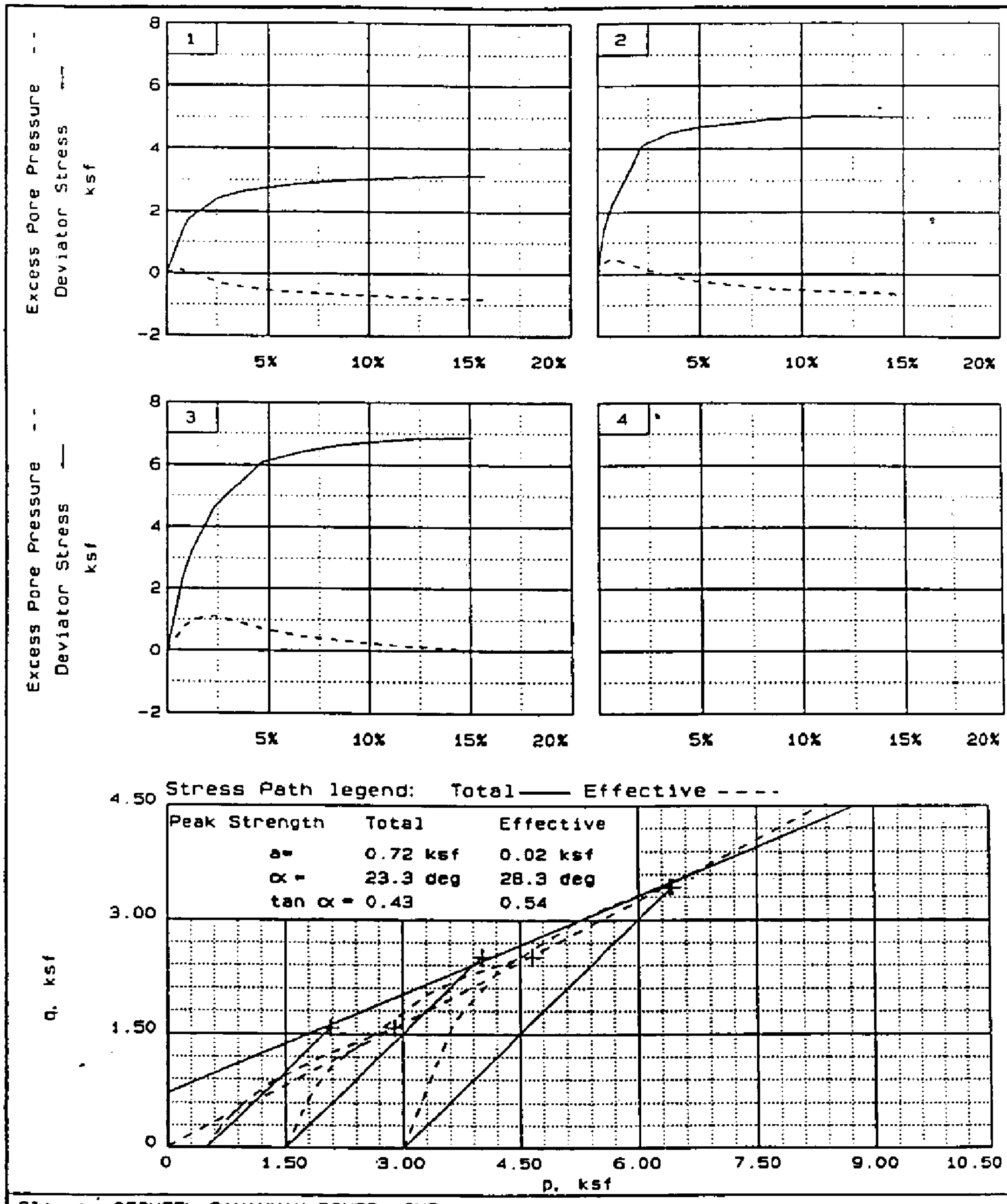
SAMPLE LOCATION: B-8 UD @ 10-12.5 FT.

PROJ. NO.: 1461010594 DATE: JUNE 12, 1992

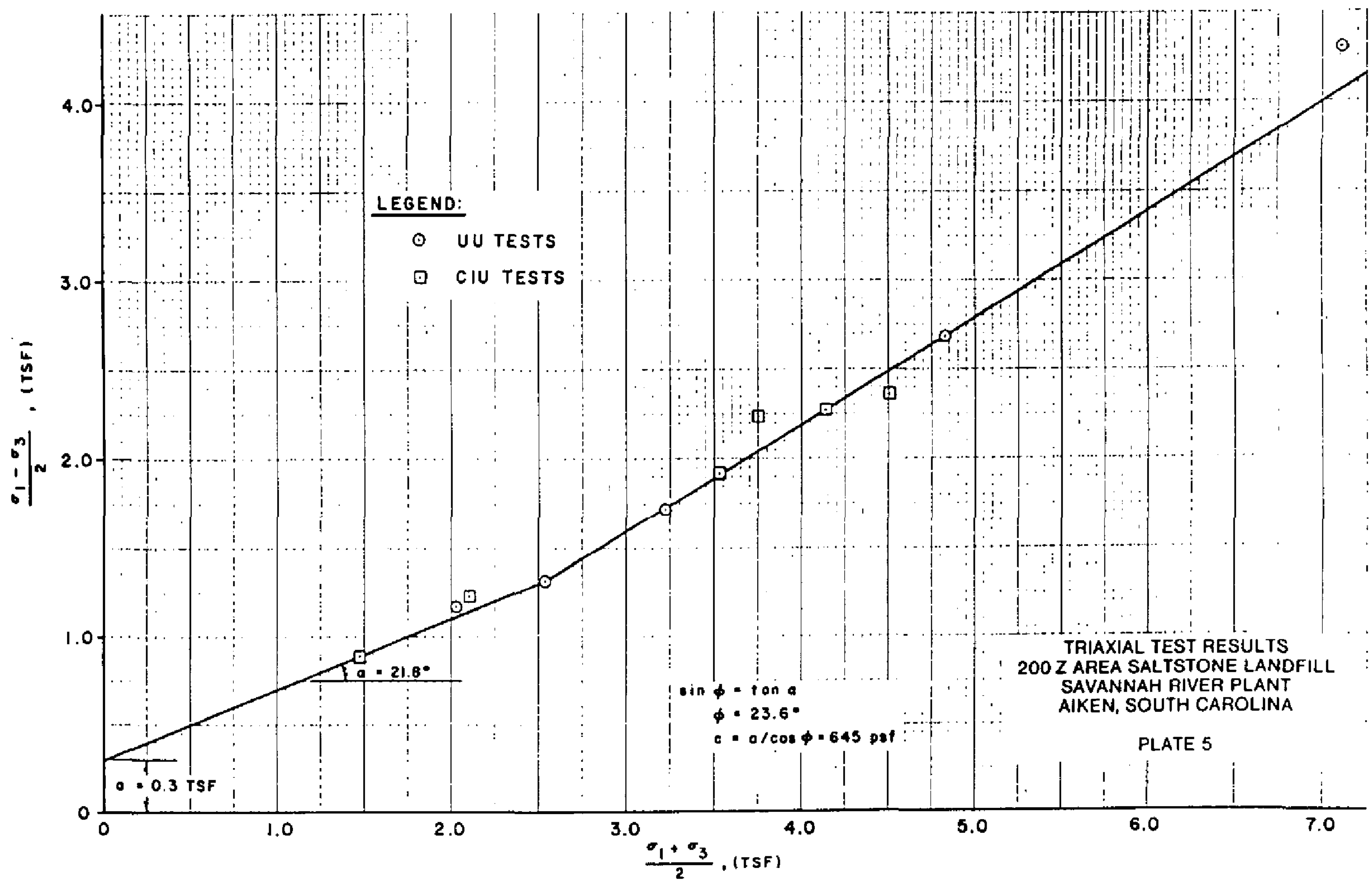
TRIAXIAL COMPRESSION TEST

LAW ENGINEERING, INC.

Calculation No. K-CLC-Z-00002
Sheet No. 40
Rev. 0

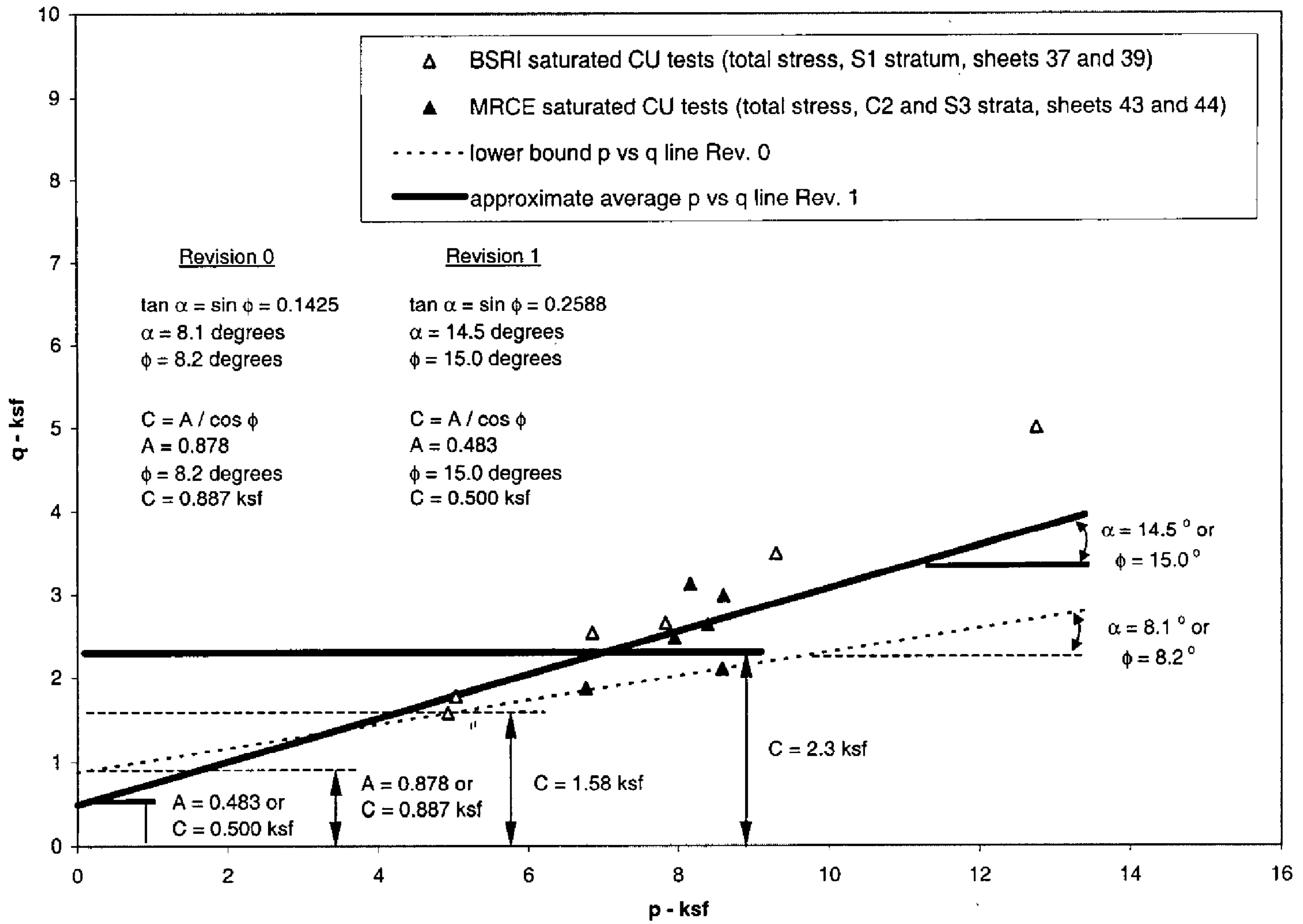


Client: BECHTEL SAVANNAH RIVER INC.
Project: Z-AREA TASK ORDER 4
Location: B-8 UD @ 10-12.5 FT.
File: 1010594A Project No.: 1461010594 Page 2/2 Fig. No. 2



Calculation No.	Sheet No.	Rev.
K-CLC-Z-00002	41	0

p vs q plot for Saturated Total Stress Tests



Calculation No. K-CLC-Z-00002	Sheet No. 42	Rev. 1

TABLE NO. 1

SUMMARY OF LABORATORY TEST DATA

Calculation No. K-CLC-Z-00002
Sheet No. 43
Rev. 0

SAMPLE IDENTIFICATION / CLASSIFICATION PROPERTIES

Boring Number	Sample Number	Elevation, Ft.	Stratum Designation	Soil Type	Average Natural Water Content, w_n, %	Liquid Limit, w_L, %	Plasticity Index, I_p, %	Natural Water Content of Limit Sample, w_n, %	Specific Gravity of Solids, G_s	Unified Soil Classification System: Group Symbol	% Sand (<#4 >#200 Sieve)	% Fines (<#200 Sieve)
Z-201U	18S	220.3	C2		31	42	17	29		SC	73	27
										SC	82	18
PZ-202U	1UD	263.8	S1		19	49	26	19		SC&CL	69	31
	2UD	258.8	S1		16	44	21	17		SC	68	32
	3UD	253.8	S1		16	42	15	16		SC	82	18
PZ-210U	1UD	270.6	S1		17	45	24	18		SC	72	28
	2UD	265.6	S1		17	35	12	17		SC	77	23
	3U	258.6	S1		15	49	26	15		SC	74	26
Z-211U	25S	192.0	S3a		53	60	36	47	2.77	SC		
PZ-216U	1U	275.0	S1		13	51	24	14		SC	79	21
	2U	270.5	S1		21	31	7	21		SC	68	32
	3UD	265.2	S1		17	38	14	17		SC	55	45
Z-218U	18U	215.1	C2		69	136	35	108		MH		98
			S3a		46					SC	68	32
Z-219U	19U	218.0	C2		30	62	43	28	2.75	SC&CH		
					30					SC	67	33
	22U	211.5	C2		33	68	47	38		SC	87	13
	23S	209.5	S3a		28	66	44	28		SC	88	12
Z-220U	17U	219.3	S3b		27					SP-SC	91	9
	18U	217.8	S3b		30					SP-SC	90	10
						127	98	104		CH		

PHYSICAL PROPERTIES

Boring Number	Sample Number	Strength: Type of Test	Compressive Strength $(\sigma_1-\sigma_3)$, TSF	Confining Pressure σ_3, TSF	Strain at Failure, %	Natural Water Content, w_n, %	Water Content at End of Test, w_f, %	Consolidation: Natural Water Content, w_n, %	Initial Void Ratio, e_o	Existing Overburden Stress, P_o, TSF	Estimated Preconsolidation Stress, P_c, TSF	Compression Index, C_c	Swelling Index, C_s	Void Ratio at Start of Swell, e_r
Z-211U	25S	CU	2.10	3.24	3.0	52.9	46.9	56.3	1.616	4.8	2.7	0.800	0.060	0.909
Z-218U	18U	CU	2.63	2.88	3.1	68.5	67.6							
Z-219U	19U							34.3	1.017	4.6	5.3	0.429	0.063	0.516

SOIL DESCRIPTION

(S1) RED-BROWN AND GRAY CLAYEY FINE TO MEDIUM SAND; TO FINE TO MEDIUM SAND, SOME CLAY OCCASIONALLY INTERLAYERED WITH SANDY CLAY.

(C2) YELLOW-BROWN AND LIGHT GREEN CLAYEY FINE SAND:TO FINE TO MEDIUM SAND, SOME CLAY, INTERLAYERED WITH STIFF YELLOW-BROWN SILTY CLAY, TRACE LIGNITE, OCCASIONAL LAYERS OF LIGHT GRAY-GREEN CALCAREOUS FINE TO MEDIUM SAND, SOME CLAY, CLAY LAYERS, TRACE SHELLS.

(S3a) LIGHT BROWN TO GRAY FINE TO MEDIUM SAND, SOME CLAY, TRACE LIGNITE, OCCASIONAL SANDY CLAY LAYERS.

(S3b) LIGHT BROWN, AND YELLOW-BROWN FINE TO MEDIUM SAND, TRACE CLAY.

NOTES

1. All tests summarized were performed in the soils laboratory of Mueser Rutledge Consulting Engineers.
2. The sample elevation is the average of the sampling interval.
3. GROUND SURFACE ELEVATIONS AT BORINGS ARE:

Boring No.	Elevation Ft.	Boring No.	Elevation Ft.
Z-201U	279.3	Z-218U	278.9
PZ-202U	278.3	Z-219U	290.5
PZ-210U	288.1	Z-220U	286.3
Z-211U	289.5	Z-224U	281.2
PZ-216U	294.5	Z-225U	277.0

4. "Average natural water content" is a weighted average of all material types recovered.
5. Compression tests performed were: CU - Consolidated Undrained Triaxial Compression.
6. Strength tests were performed on samples approximately 2.8 inches in diameter with a height-to-diameter ratio of 2.
7. Compression Index, C_c = the slope of the virgin curve (straight line portion of the consolidation test e-log p plot).

$$e_2 = e_1 - C_c \times \log (P_2/P_1)$$

8. Swelling Index, C_s = the slope of the rebound curve of the consolidation test...

$$e_2 = e_1 + C_s \times \log (P_1/P_2)$$

MUESER RUTLEDGE CONSULTING ENGINEERS

708 THIRD AVENUE, NEW YORK, N.Y. 10017

SALTSTONE DISPOSAL
SAVANNAH RIVER PLANT - Z AREA
E.I. DUPONT DE NEMOURS & CO., INC.

DATE: 7-14-86 FILE NO. 6329 SHEET 1 OF 2 TABLE NO. 1

Calculation No. K-CLC-Z-00002
Sheet No. 44
Rev. 0

TABLE NO. 1

SUMMARY OF LABORATORY TEST DATA

SAMPLE IDENTIFICATION					CLASSIFICATION PROPERTIES								PHYSICAL PROPERTIES												
										UNIFIED SOIL CLASSIFICATION SYSTEM			STRENGTH						CONSOLIDATION						
BORING NUMBER	SAMPLE NUMBER	ELEVATION, FT.	STRATUM DESIGNATION	SOIL TYPE	AVERAGE NATURAL WATER CONTENT, w_n, %	LIQUID LIMIT, w_L, %	PLASTICITY INDEX, I_p, %	NATURAL WATER CONTENT OF LIMIT SAMPLE, w_n, %	SPECIFIC GRAVITY OF SOLIDS, G_s	GROUP SYMBOL	% SAND (<#4 >#200 SIEVE)	% FINES (<#200 SIEVE)	TYPE OF TEST	COMPRESSIVE STRENGTH $(\sigma_1-\sigma_3)$, TSF	CONFINING PRESSURE σ_3, TSF	STRAIN AT FAILURE, %	NATURAL WATER CONTENT, w_n, %	WATER CONTENT AT END OF TEST, w_f, %	NATURAL WATER CONTENT, w_n, %	INITIAL VOID RATIO, e_o	EXISTING OVERBURDEN STRESS, P_o, TSF	ESTIMATED PRECONSOLIDATION STRESS, P_c, TSF	COMPRESSION INDEX, C_c	SWELLING INDEX, C_s	VOID RATIO AT START OF SWELL, e_r
Z-224U	6U	224.7	C2		22					SC	81	19													
					40	84	38	43	2.86	SC	62	38							36.7	1.213	3.6	7.5	0.476	0.032	0.678
	8U	221.3	C2		58	114	84	58		CH	34	66	CU	1.87	2.45	4.3	54.8	54.8							
	10U	218.2	C2		80	134	83	63		CH		81	CU	3.12	2.52	2.6	78.8	77.9							
	13U	213.2	C2			62	36	35		CH		54													
					31					*SC	65	35													
	15U	210.5	C2		31	104	83	31		SC	86	14													
Z-225U	4U	219.5	S3a		31	56	36	29		SC	74	26													
	6U	216.0	C2		61	131	100	58	2.79	CH		77	CU	2.47	2.74	2.9	62.3	62.6	58.9	1.675	3.8	6.6	1.118	0.214	0.700
	7U	214.0	C2			94	72	54		CH		59													
					49					SC	56	44	CU	2.98	2.81	4.1	43.9	43.8							

SOIL DESCRIPTION

(S1) RED-BROWN AND GRAY CLAYEY FINE TO MEDIUM SAND: TO FINE TO MEDIUM SAND, SOME CLAY OCCASIONALLY INTERLAYERED WITH SANDY CLAY.

(C2) YELLOW-BROWN AND LIGHT GREEN CLAYEY FINE SAND:TO FINE TO MEDIUM SAND, SOME CLAY, INTERLAYERED WITH STIFF YELLOW-BROWN SILTY CLAY, TRACE LIGNITE, OCCASIONAL LAYERS OF LIGHT GRAY-GREEN CALCAREOUS FINE TO MEDIUM SAND, SOME CLAY, CLAY LAYERS, TRACE SHELLS.

(S3a) LIGHT BROWN TO GRAY FINE TO MEDIUM SAND, SOME CLAY, TRACE LIGNITE, OCCASIONAL SANDY CLAY LAYERS.

(S3b) LIGHT BROWN, AND YELLOW-BROWN FINE TO MEDIUM SAND, TRACE CLAY.

NOTES

1. All tests summarized were performed in the soils laboratory of Mueser Rutledge Consulting Engineers.
2. The sample elevation is the average of the sampling interval.
3. GROUND SURFACE ELEVATIONS AT BORINGS ARE:

Boring No.	Elevation Ft.	Boring No.	Elevation Ft.
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Z-211U	289.5	Z-224U	281.2
PZ-216U	294.5	Z-225U	277.0

4. "Average natural water content" is a weighted average of all material types recovered.
5. Compression tests performed were: CU - Consolidated Undrained Triaxial Compression.
6. Strength tests were performed on samples approximately 2.8 inches in diameter with a height-to-diameter ratio of 2.
7. Compression Index, C_c = the slope of the virgin curve (straight line portion of the consolidation test e-log p plot).

$$e_2 = e_1 - C_c \times \log (P_2/P_1)$$

8. Swelling Index, C_s = the slope of the rebound curve of the consolidation test...

$$e_2 = e_1 + C_s \times \log (P_1/P_2)$$

9. * - Sample showed a positive reaction with HCL.

MUESER RUTLEDGE CONSULTING ENGINEERS
708 THIRD AVENUE, NEW YORK, N.Y. 10017

SALTSTONE DISPOSAL
SAVANNAH RIVER PLANT - Z AREA
E.I. DUPONT DE NEMOURS & CO., INC.

ATTACHMENT 3: SLOPE/W FILES

The five types of files were created and used by SLOPE/W for this calculation.
The **SLP** file contains the data required for the factor of safety calculations (slope dimensions, soil layering, loads, etc.). The **SL2** file contains information relating to the graphical layout or presentation of the problem (e.g. page size and units, engineering units and scale, sketch lines and text). The **FAC** or factor of safety file contains the computed factors of safety for each slip surface. The **FRC** or slice forces file stores the slice forces for the critical slip surface. The **SL3** file contains the current graphical layout information for the contour drawing information.

The file names provide some information about the problem. The first part of the name indicates the seismic force, 17g indicate the peak ground acceleration of 0.17g and 0g indicates no seismic force or the static case (see Section 2.3 Seismic Loading for horizontal and vertical loading combinations). The 200psi indicates compressive strength of the vault grout (see Section 2.1 Slope /Vault Geometry and Design). The last number (1 through 11) is the seismic loading case (see Table 1). The files created for this calculation are listed on sheets 46 and 47. The attached CD contains a copy of the computer files.

SLOPE/W File Listing

Date	Time	File Size	File Name
7/29/02	04:44p	3,658,435	0g-200psi1.fac
7/29/02	04:44p	23,694	0g-200psi1.frc
7/29/02	04:43p	2,157	0g-200psi1.sl2
7/29/02	04:51p	2,116	0g-200psi1.sl3
7/29/02	04:43p	4,650	0g-200psi1.slp
7/29/02	04:52p	3,658,435	17g-200psi2.fac
7/29/02	04:52p	23,694	17g-200psi2.frc
7/29/02	05:18p	2,157	17g-200psi2.sl2
7/29/02	05:18p	2,116	17g-200psi2.sl3
7/29/02	05:18p	4,650	17g-200psi2.slp
7/29/02	05:20p	3,658,435	17g-200psi3.fac
7/29/02	05:20p	23,694	17g-200psi3.frc
7/29/02	05:20p	2,157	17g-200psi3.sl2
7/29/02	05:22p	2,116	17g-200psi3.sl3
7/29/02	05:20p	4,650	17g-200psi3.slp
7/29/02	05:24p	3,658,435	17g-200psi4.fac
7/29/02	05:24p	23,694	17g-200psi4.frc
7/29/02	05:24p	2,157	17g-200psi4.sl2
7/29/02	05:26p	2,116	17g-200psi4.sl3
7/29/02	05:24p	4,650	17g-200psi4.slp
7/29/02	05:27p	3,658,435	17g-200psi5.fac
7/29/02	05:27p	23,694	17g-200psi5.frc
7/29/02	05:27p	2,157	17g-200psi5.sl2
7/29/02	05:32p	2,116	17g-200psi5.sl3
7/29/02	05:27p	4,650	17g-200psi5.slp
7/29/02	05:33p	3,658,435	17g-200psi6.fac
7/29/02	05:33p	23,694	17g-200psi6.frc
7/29/02	05:33p	2,157	17g-200psi6.sl2
7/29/02	05:35p	2,116	17g-200psi6.sl3
7/29/02	05:33p	4,650	17g-200psi6.slp
7/30/02	01:12p	16,164	17g-200psi6a.fac
7/30/02	01:12p	23,694	17g-200psi6a.frc
7/30/02	01:12p	2,157	17g-200psi6a.sl2
7/30/02	01:13p	2,116	17g-200psi6a.sl3
7/30/02	01:12p	4,650	17g-200psi6a.slp
7/30/02	01:16p	16,164	17g-200psi6b.fac
7/30/02	01:16p	22,995	17g-200psi6b.frc
7/30/02	01:15p	2,157	17g-200psi6b.sl2
7/30/02	11:57a	2,116	17g-200psi6b.sl3
7/30/02	01:15p	4,650	17g-200psi6b.slp
7/30/02	01:19p	16,164	17g-200psi6c.fac
7/30/02	01:19p	22,296	17g-200psi6c.frc
7/30/02	01:19p	2,157	17g-200psi6c.sl2
7/30/02	01:20p	2,116	17g-200psi6c.sl3
7/30/02	01:19p	4,650	17g-200psi6c.slp

Calculation No. K-CLC-Z-00002
Sheet No. 47
Rev. 1

Date	Time	File Size	File Name
7/29/02	05:36p	3,658,435	17g-200psi7.fac
7/29/02	05:36p	23,694	17g-200psi7.frc
7/29/02	05:36p	2,157	17g-200psi7.sl2
7/29/02	05:48p	2,116	17g-200psi7.sl3
7/29/02	05:36p	4,650	17g-200psi7.slp
7/29/02	05:50p	3,658,435	17g-200psi8.fac
7/29/02	05:50p	23,694	17g-200psi8.frc
7/29/02	05:50p	2,157	17g-200psi8.sl2
7/29/02	05:52p	2,116	17g-200psi8.sl3
7/29/02	05:50p	4,650	17g-200psi8.slp
7/30/02	08:51a	478,827	17g-200psi9.fac
7/30/02	08:51a	23,694	17g-200psi9.frc
7/30/02	08:50a	2,157	17g-200psi9.sl2
7/30/02	08:56a	2,116	17g-200psi9.sl3
7/30/02	08:50a	4,684	17g-200psi9.slp
8/6/02	04:34p	3,658,435	17g-200psi10.fac
8/6/02	04:34p	23,694	17g-200psi10.frc
8/6/02	04:34p	2,157	17g-200psi10.sl2
8/6/02	04:36p	2,116	17g-200psi10.sl3
8/6/02	04:34p	4,650	17g-200psi10.slp
8/6/02	04:38p	3,658,435	17g-200psi11.fac
8/6/02	04:38p	23,694	17g-200psi11.frc
8/6/02	04:38p	2,157	17g-200psi11.sl2
8/6/02	04:39p	2,116	17g-200psi11.sl3
8/6/02	04:38p	4,650	17g-200psi11.slp

Additional SLOPE/W File Listing for Revision 1

Date	Time	File Size	File Name
3/21/2003	01:53p	7,459,075	case10a.fac
3/21/2003	01:53p	22,995	case10a.frc
3/21/2003	01:55p	3,071	case10a.sl2
3/21/2003	01:55p	3,030	case10a.sl3
3/21/2003	01:55p	5,380	case10a.slp
3/21/2003	01:56p	7,459,075	case10b.fac
3/21/2003	01:56p	22,995	case10b.frc
3/21/2003	01:58p	3,071	case10b.sl2
3/21/2003	01:58p	3,030	case10b.sl3
3/21/2003	01:58p	5,380	case10b.slp
3/21/2003	01:33p	7,459,075	case11a.fac
3/21/2003	01:33p	23,694	case11a.frc
3/21/2003	01:35p	3,071	case11a.sl2
3/21/2003	01:34p	3,030	case11a.sl3
3/21/2003	01:35p	5,380	case11a.slp
3/21/2003	01:29p	7,459,075	case11b.fac
3/21/2003	01:29p	23,694	case11b.frc
3/21/2003	01:31p	3,071	case11b.sl2
3/21/2003	01:31p	3,030	case11b.sl3
3/21/2003	01:31p	5,380	case11b.slp