Fall 2007

Analysis of soil erosion based on soil properties

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silt, and clay in these three soil types are presented in Table 2.1. The samples were collected in a Shelby tube and the experiments were performed using a rectangular flume. The main objective of this study was to determine the soil erosion rates based on soil type. Analysis of flume experiment results obtained for the same soil types collected from different locations showed similar erosion rates. Soil types 32 and 33 had similar compositions and the results obtained indicated similar erosion rates.

The critical shear stress, the shear stress at which soil erosion begins, obtained for Soils 20B, 32, and 33 were 0.086, 0.069 and 0.072 psf, respectively. Soil 20B showed a higher resistance compared to Soil types 32 and 33 and had the highest critical shear stress value. A higher critical shear stress for 20B was expected because 20B had the highest clay content among the three soil types selected.

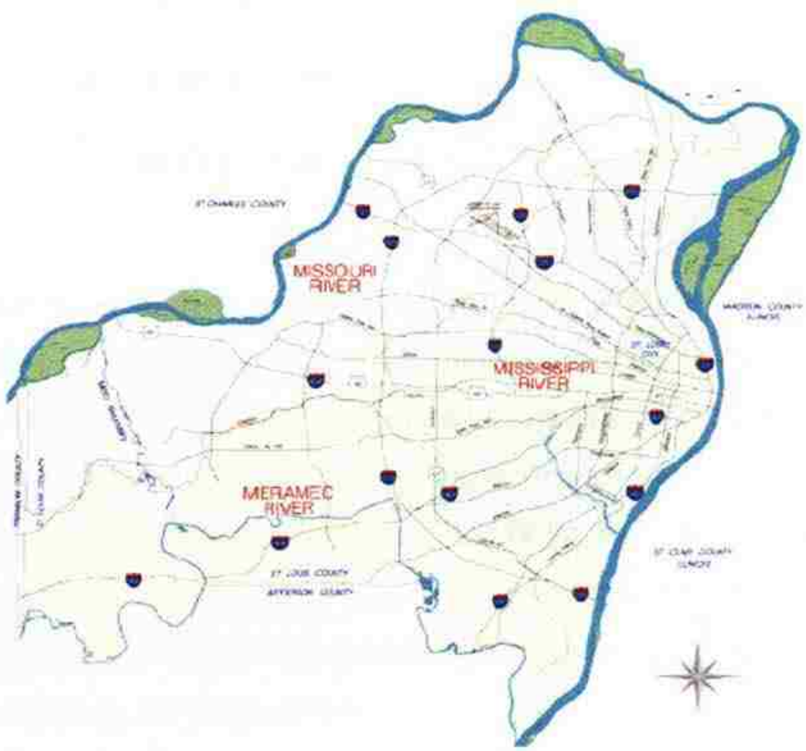


Figure 2.1. Major Watersheds in the Saint Louis Area

these watersheds. All the water from these three watersheds drains in to the Mississippi River. During the previous research, different soil types along tributaries in this watershed from the Missouri Cooperative Soil Survey web site hosted by the Center for Agricultural, Resource, and Environmental Systems were studied and the entire length of each creek was analyzed to find the different soil types present along the streambanks. The three most commonly found soil types were selected for study and were collected from the streambank. The soil types selected, 20B, 32, and 33, were collected from 12 different locations. The soil composition of each of these soil types as given in the NRCS Soil Survey Map are presented in Table 2.1 in Section 2.2.The locations of the soil types were verified by checking the coordinates using a GarminV GPS. The sample collection locations for each of these soil types along with geographic coordinates are given in Appendix A. A detailed explanation of the watersheds can be found in the study by Krishnan (2006). The samples were collected according to the ASTM (D 1587 – 00) standard practice for thin walled tube sampling. The Shelby tube was driven perpendicular to the streambank to the entire tube length (10 in) using the Shelby tube Header shown in Figure 3.1.

Figure 3.1. Shelby Tube Header

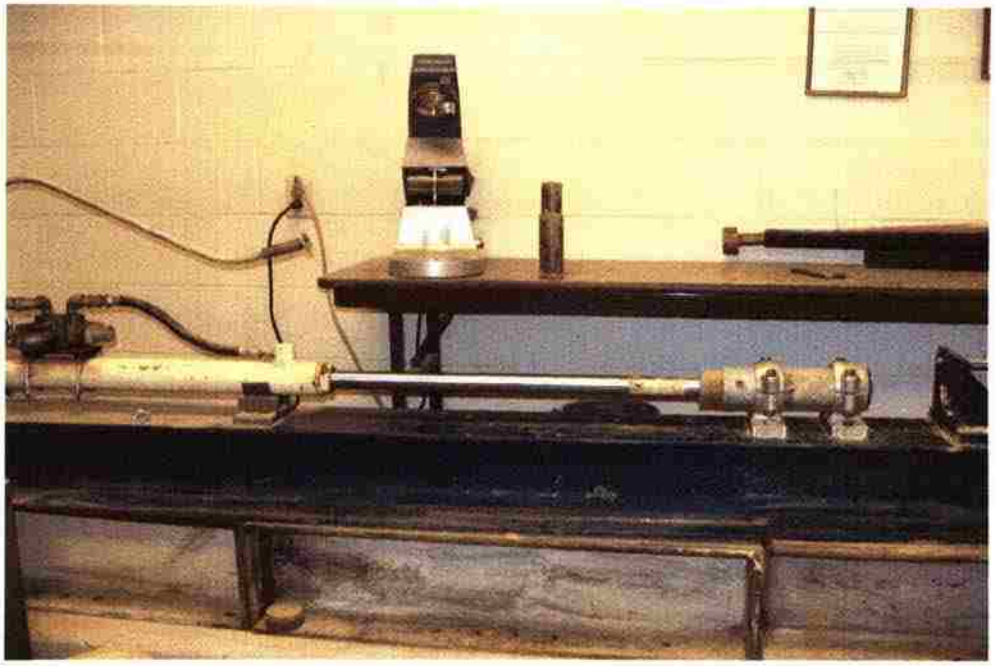


Figure 3.2. Extruding the Sample Using a Hydraulic Press at the UMR Geotechnical Laboratory

To determine the soil's water content, samples were weighed before and after oven drying. Three or four samples of each soil type were tested. The percentage water content determined for each soil type is given by

$$w = \frac{W_w}{W_d} x100 \qquad (3.1)$$

where w is the percentage water content, W_w is the weight of water, and W_d is the weight of the dry soil sample.

3.2.1.3 Unit weight test (ASTM D 4254-91). The unit weights of the natural and prepared specimens were measured by weighing the specimens just before the Direct Shear tests. The specimens used for the Direct Shear tests were of standard size (diameter 63.5 mm and height 32 mm) to determine volume of the specimen. The wet and dry unit weights of the specimens were determined as follows:

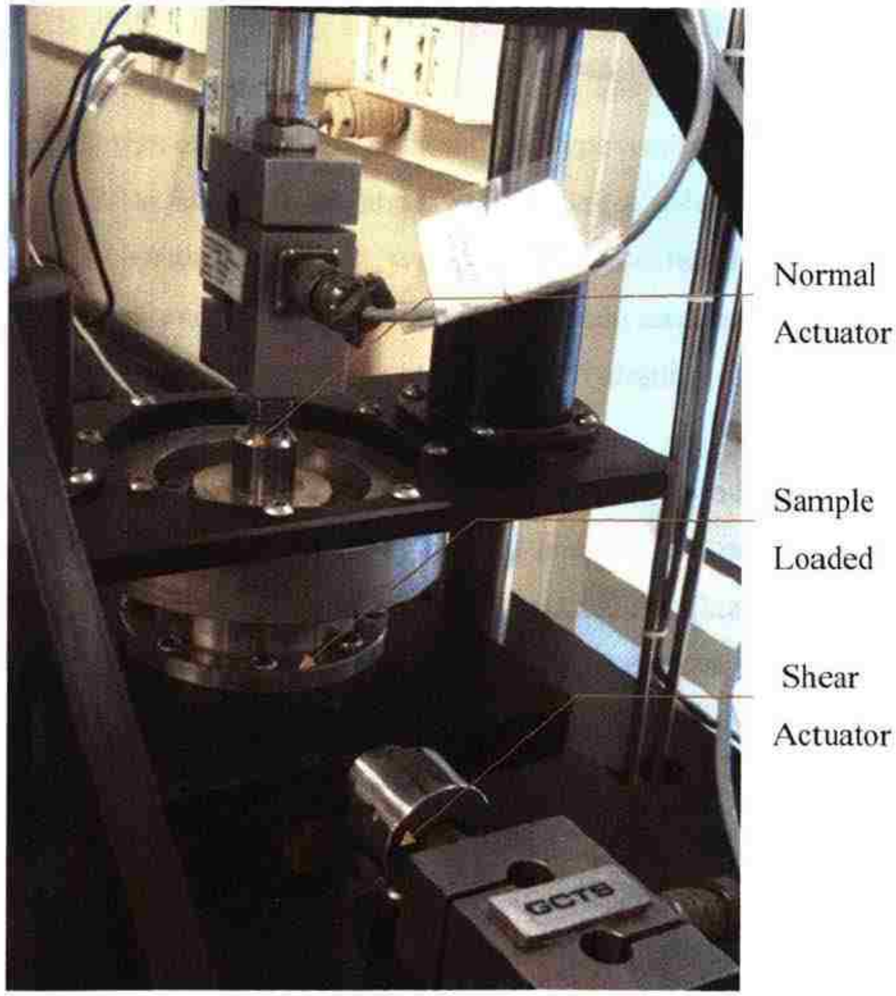


Figure 3.3. The GCTS Direct Shear Apparatus

A graph was plotted with the normal stress applied along the x-axis and shear strength of soil along the y-axis. From a linear fit of the data points plotted, the cohesion of soil specimens was obtained. The linear fit obtained is expressed as:

$$t_{max} = c + \sigma \tan \Phi \tag{3.6}$$

where, t_{max} = Shear Strength (kPa)

c = Cohesion (kPa)

σ = Normal Stress (kPa)

Φ = Friction Angle

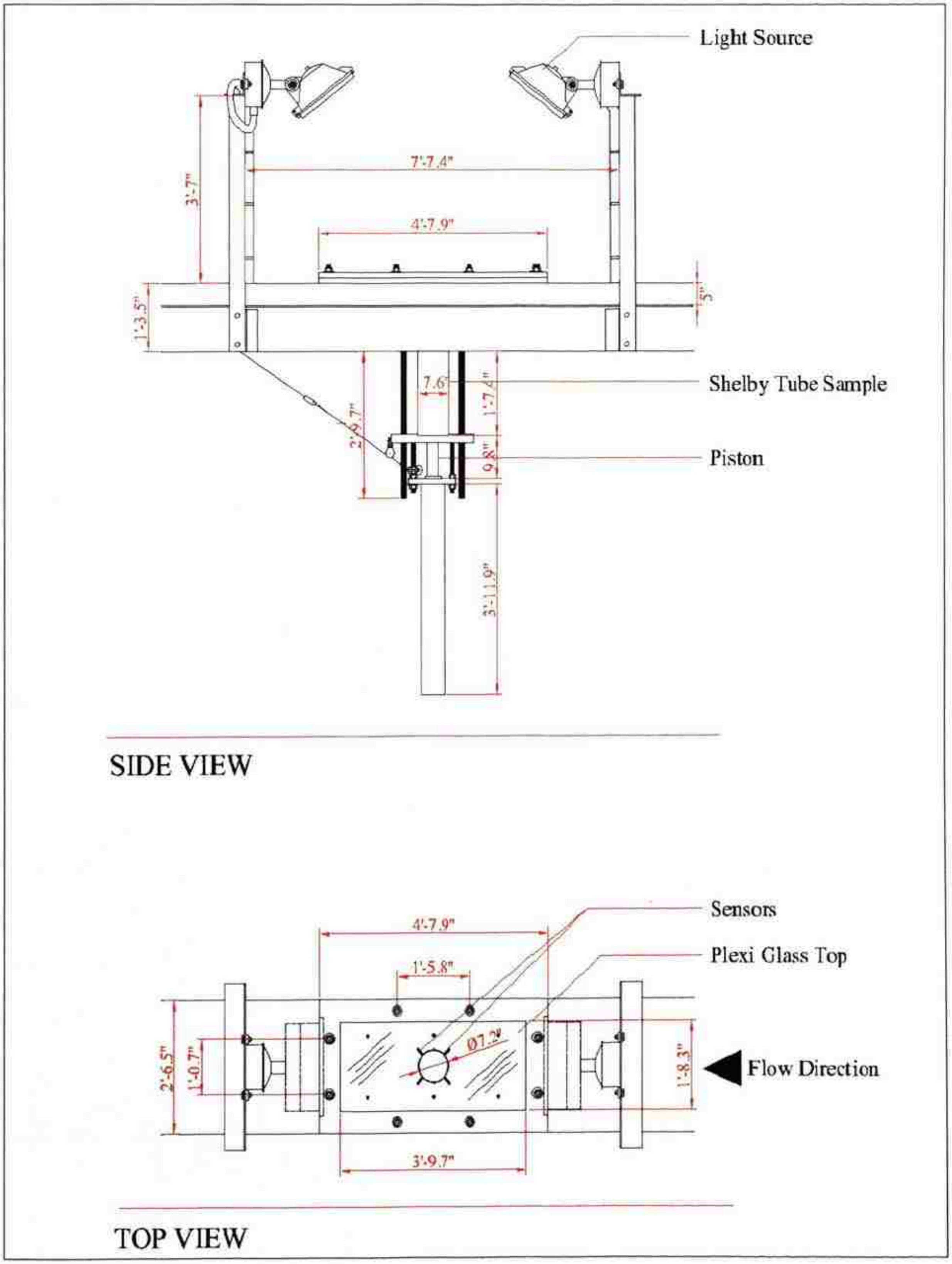


Figure 3.4. Schematic of the Flume at UMR Hydraulics Laboratory (Prepared by William Otero Benitez)

The speed at which the piston pushes the soil sample depends on the rate of erosion. The position of the soil sample, i.e., the position of the piston, was recorded at preset time intervals by the LabView program. An ultrasonic flow meter device, Panametrics, T878 is used to determine the velocity in the pipe. About one inch of soil sample is tested for a particular shear stress. When one inch is eroded, the shear stress applied on the soil sample was changed by changing the flow rate. Whenever the flow rates are changed, flow is allowed to stabilize before recording the measurements. The photograph of the flume shown in Figure 3.5 shows the flume, flume inlet, flow meter and the back pressure valve.

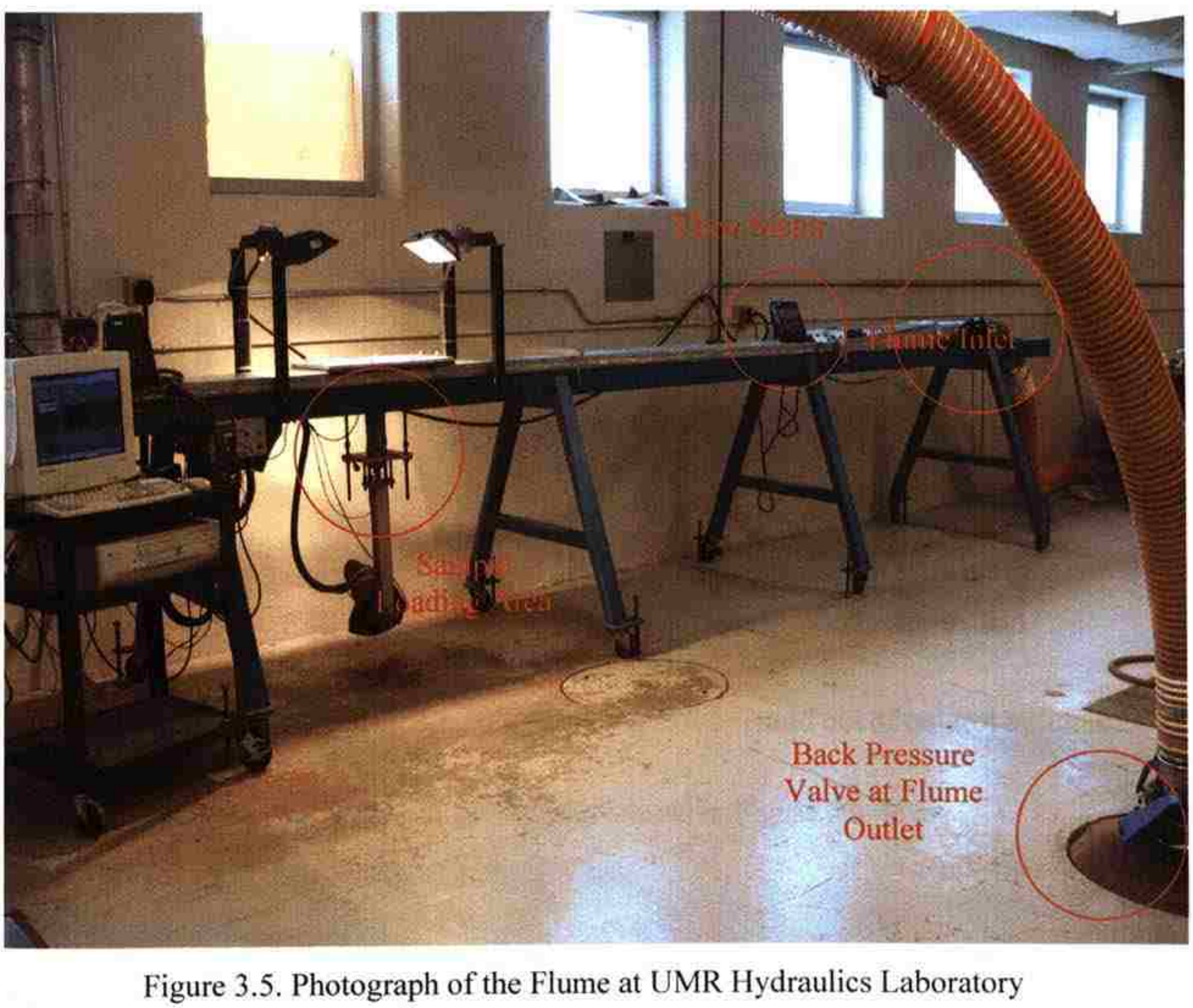


Figure 3.5. Photograph of the Flume at UMR Hydraulics Laboratory

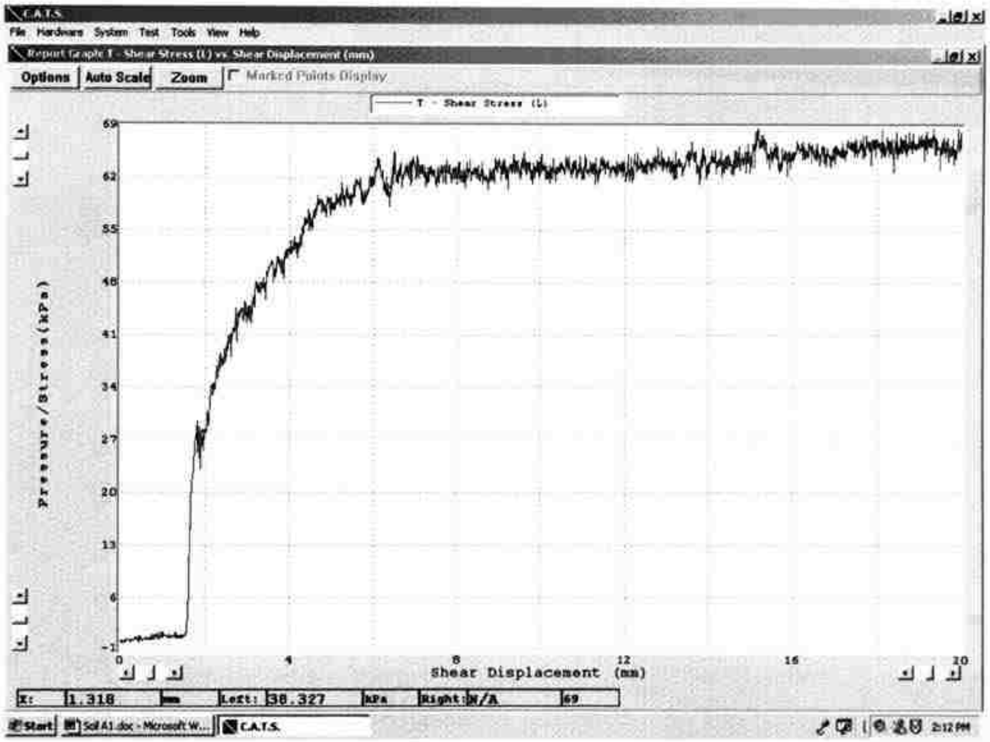


Figure 4.1. Shear Stress vs. Shear Displacement Plot for Soil A1 at 150kPa Normal Stress

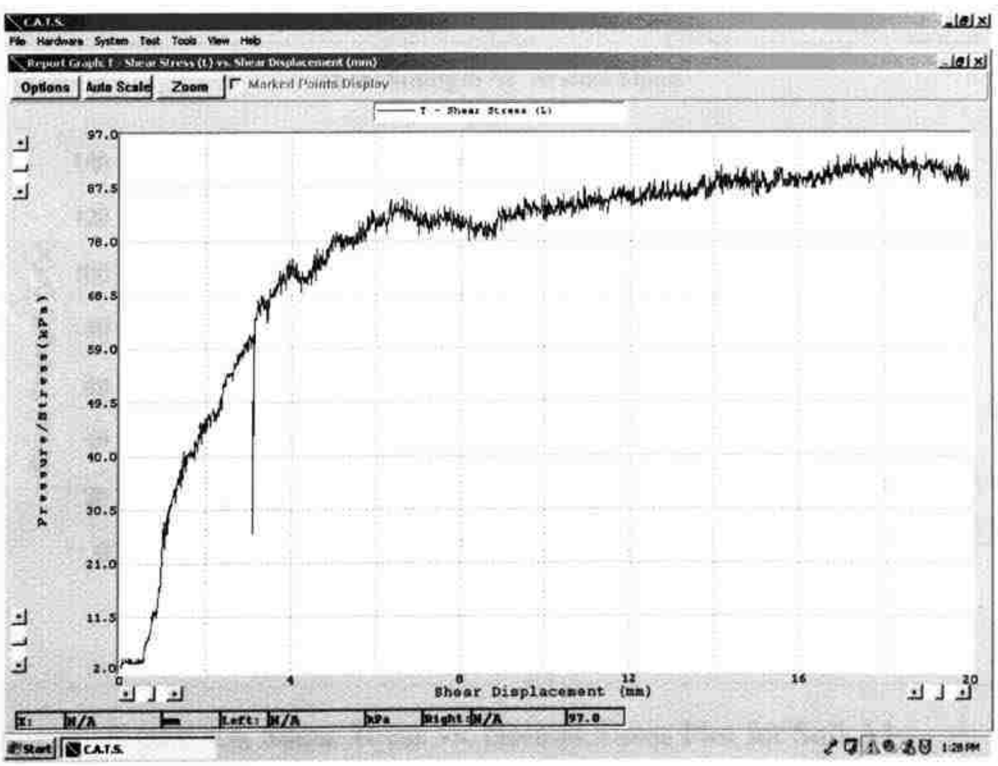


Figure 4.2. Shear Stress vs. Shear Displacement Plot for Soil A1 at 200kPa Normal Stress

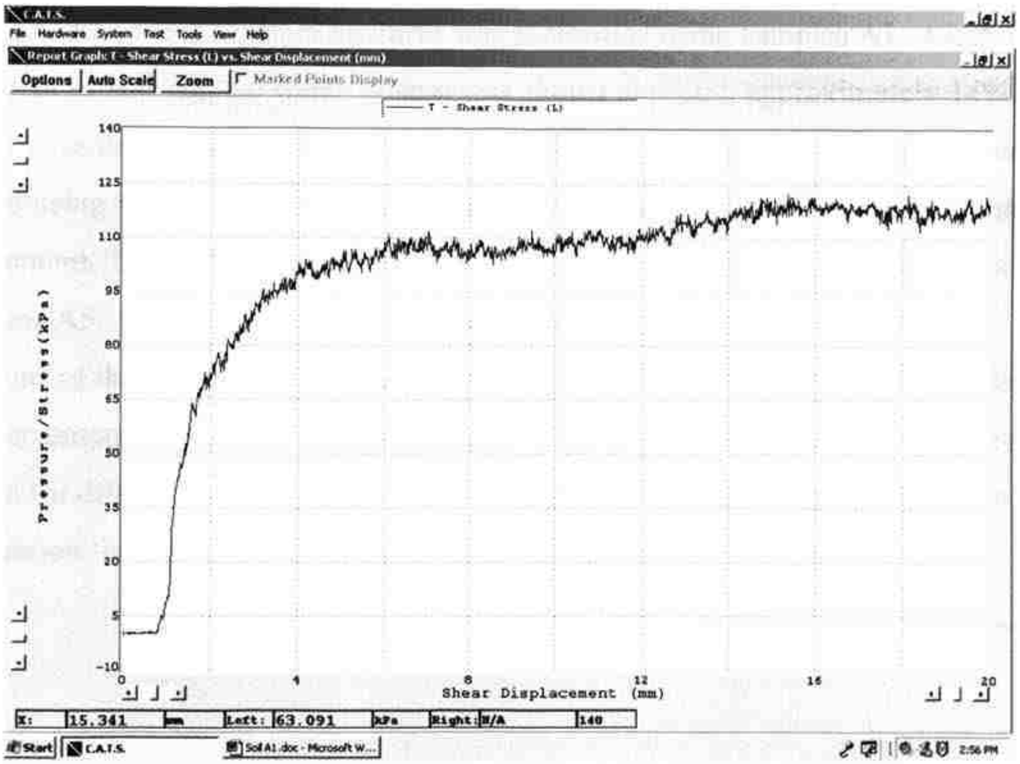


Figure 4.3. Shear Stress vs. Shear Displacement Plot for Soil A1 at 300kPa Normal Stress

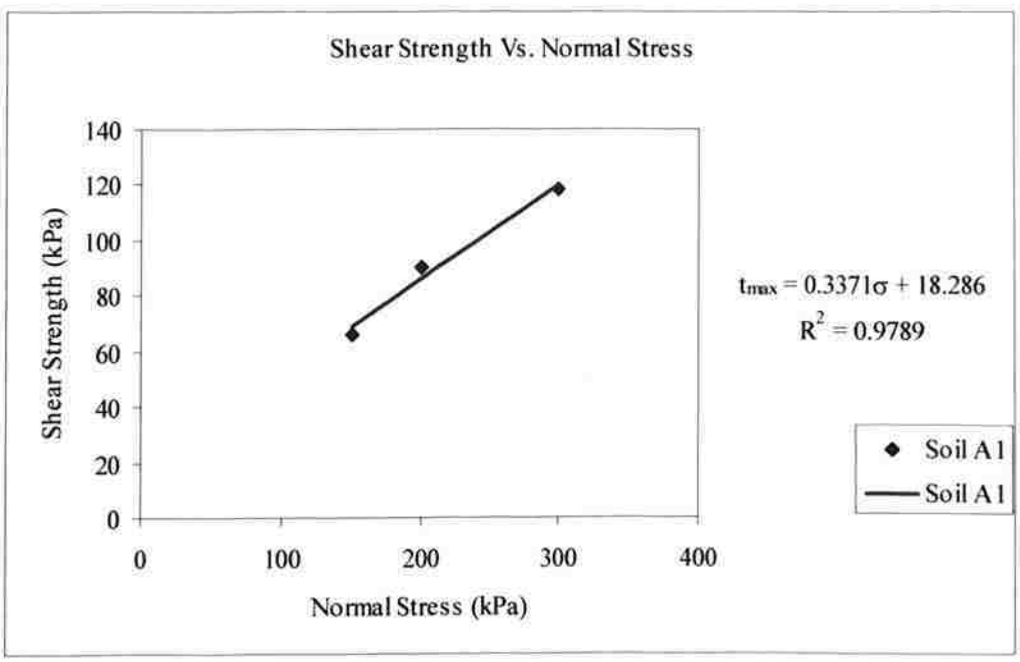


Figure 4.4. Shear Stress vs. Normal Stress Plot for Soil A1

Table 4.5. Shear Stress and Erosion Rate Results for Soil A4 (Cont.)

Soil A4-4#2	2.58	0.04	1.12	1.12	266	0.00
Soil A4-4#3	3.38	0.06	1.12	1.17	301	0.06
Soil A4-4#4	4.20	0.09	1.19	1.50	315	0.36
Soil A4-4#5	4.39	0.10	1.52	2.61	373	1.05
Soil A4-4#6	4.92	0.12	2.79	3.41	184	1.21
Soil A4-4#7	5.67	0.16	3.43	4.23	119	2.42
Soil A4-4#8	6.15	0.18	4.32	4.93	87	2.56

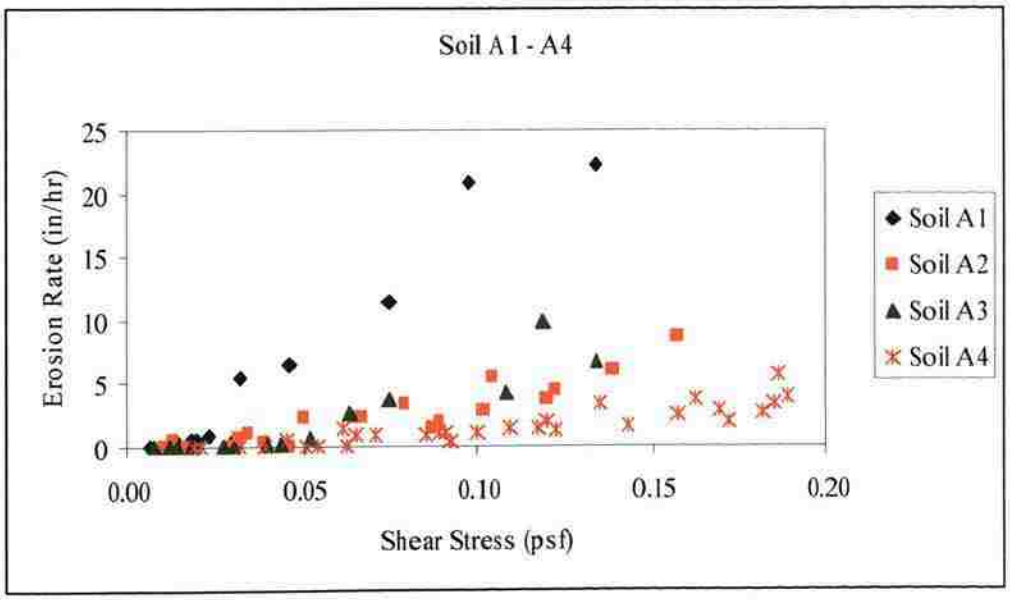


Figure 4.5. Erosion Rate vs. Shear Stress Plot for Soil A1 to A4

Soil types A5 to A8 were prepared by changing the water content while it was attempting to keep the unit weight constant. These samples were also tested in the flume and the results were plotted to see the effect of water content on the erosion rate of soil. Tables 4.6 to 4.9 give the results produced in the flume experiments for Soils A5, A6, A7, and A8.

Soils A5, A6, A7, and A8 were prepared by varying the water content. The variation in water content was difficult to obtain in the compaction process because the samples with high water content tended to stick to the compactor. Hence, it was difficult to achieve a uniform depth for each layer compacted. The water content in these samples varied only from 12% to 16%, which was too small when compared to the variation in natural soils. The natural soils were found to have water contents higher than 30%. Figure 4.6 shows the graph obtained for each of these soil types.

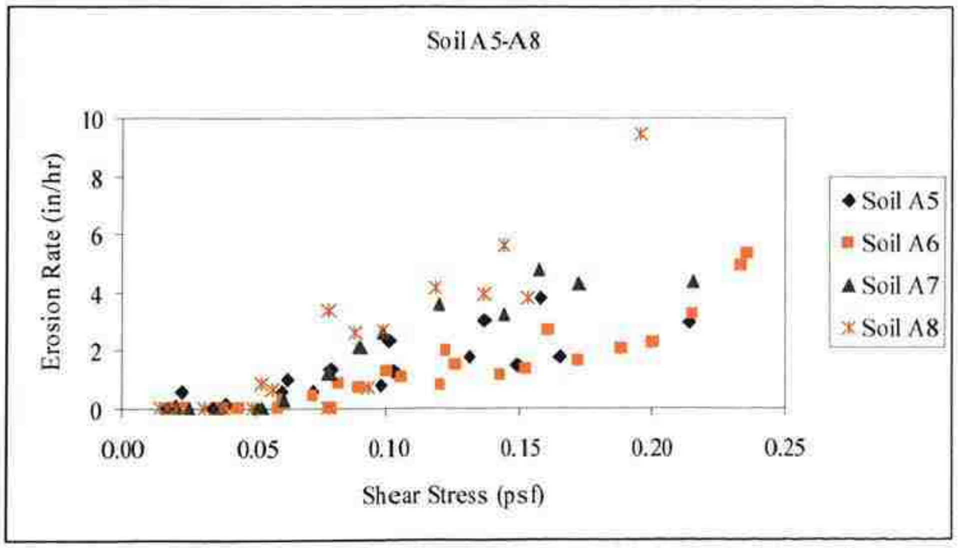


Figure 4.6. Erosion Rate vs. Shear Stress Plot for Soil A5 to A8

4.1.2. Soil Type B. Soil type B had a composition of 45% sand, 35% silt, and 20% clay. This soil was used to prepare four different sets of samples at different compaction levels labeled B1, B2, B3, and B4. A summary of the properties of each set is given in Table 4.10.

Table 4.14. Shear Stress and Erosion Rate Results for Soil B4 (Cont.)

Soil B4-3#1	6.63	0.21	4.20	5.78	322	1.76
Soil B4-3#2	5.77	0.16	5.84	7.42	336	1.70
Soil B4-3#3	3.96	0.08	7.42	7.45	310	0.03
Soil B4-3#4	4.50	0.10	7.45	8.13	506	0.48
Soil B4-3#5	5.32	0.14	8.17	8.70	224	0.86
Soil B4-3#6	6.09	0.18	8.75	9.71	180	1.91
Soil B4-4#1	2.74	0.04	7.44	7.44	389	0.00
Soil B4-4#2	3.17	0.06	7.44	7.44	410	0.00
Soil B4-4#3	3.83	0.08	7.44	7.49	378	0.05
Soil B4-4#4	4.60	0.11	7.49	7.94	291	0.55
Soil B4-4#5	4.92	0.12	8.01	8.83	240	1.22
Soil B4-4#6	5.11	0.13	8.84	9.71	194	1.62

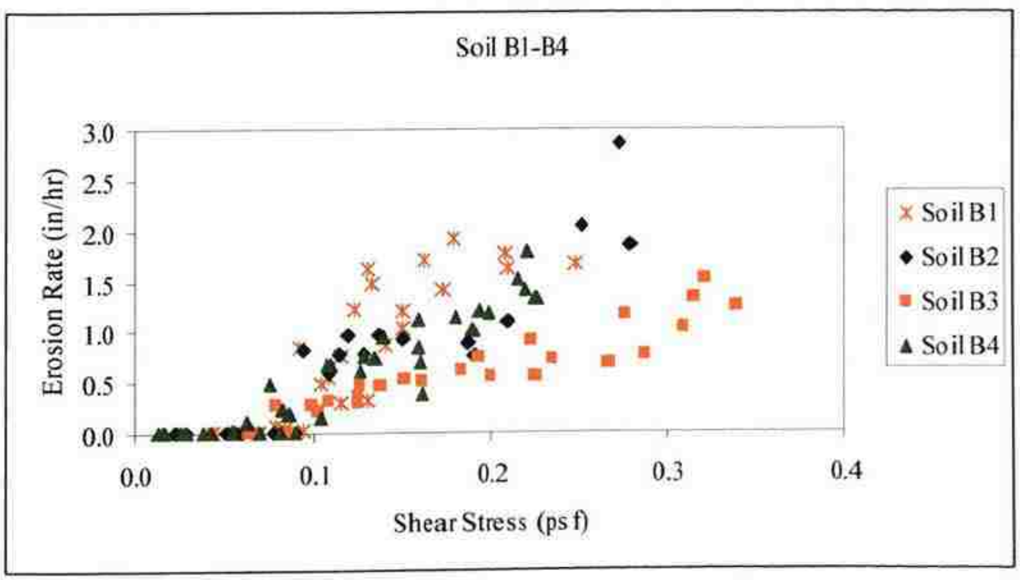


Figure 4.7. Erosion Rate vs. Shear Stress Plot for Soil B1 to B4

4.1.3. Soil Type C. Soil type C had a composition of 35% sand, 35% silt, and 30% clay. This soil was used to prepare four different sets of samples at different compaction levels labeled C1, C2, C3, and C4. The summary of the soil properties of

Table 4.19. Shear Stress and Erosion Rate Results for Soil C4 (Cont.)

Soil C4-1#8	10.72	0.49	5.53	5.93	314	0.46
Soil C4-1#9	10.27	0.46	5.93	6.18	364	0.24
Soil C4-1#10	7.69	0.27	6.20	6.32	314	0.14
Soil C4-2#1	7.03	0.23	5.69	5.81	565	0.08
Soil C4-2#2	8.62	0.33	5.81	6.35	783	0.25
Soil C4-2#3	10.75	0.50	6.35	7.19	719	0.42
Soil C4-2#4	9.77	0.42	7.19	8.02	737	0.40
Soil C4-2#5	11.50	0.56	8.03	8.91	709	0.45
Soil C4-3#1	6.04	0.18	5.56	6.38	859	0.34
Soil C4-3#2	4.10	0.09	6.38	6.76	785	0.17
Soil C4-3#3	5.11	0.13	6.76	7.06	635	0.17
Soil C4-3#4	6.17	0.18	7.07	7.49	654	0.23
Soil C4-3#5	7.48	0.26	7.51	8.31	827	0.35
Soil C4-3#6	9.02	0.36	8.40	8.97	556	0.37

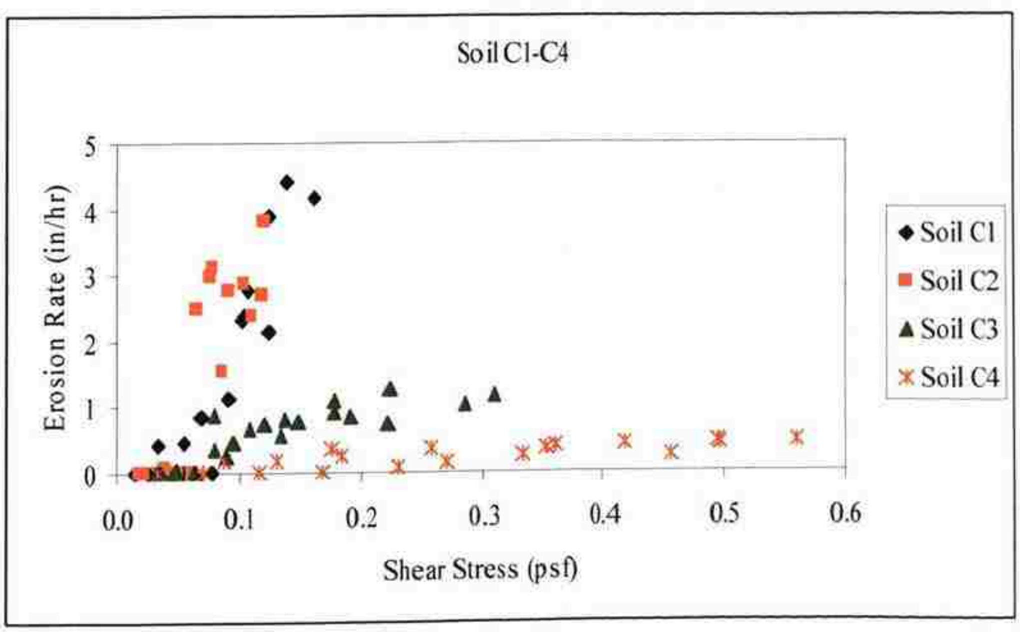


Figure 4.8. Erosion Rate vs. Shear Stress Plot for Soil C1 to C4

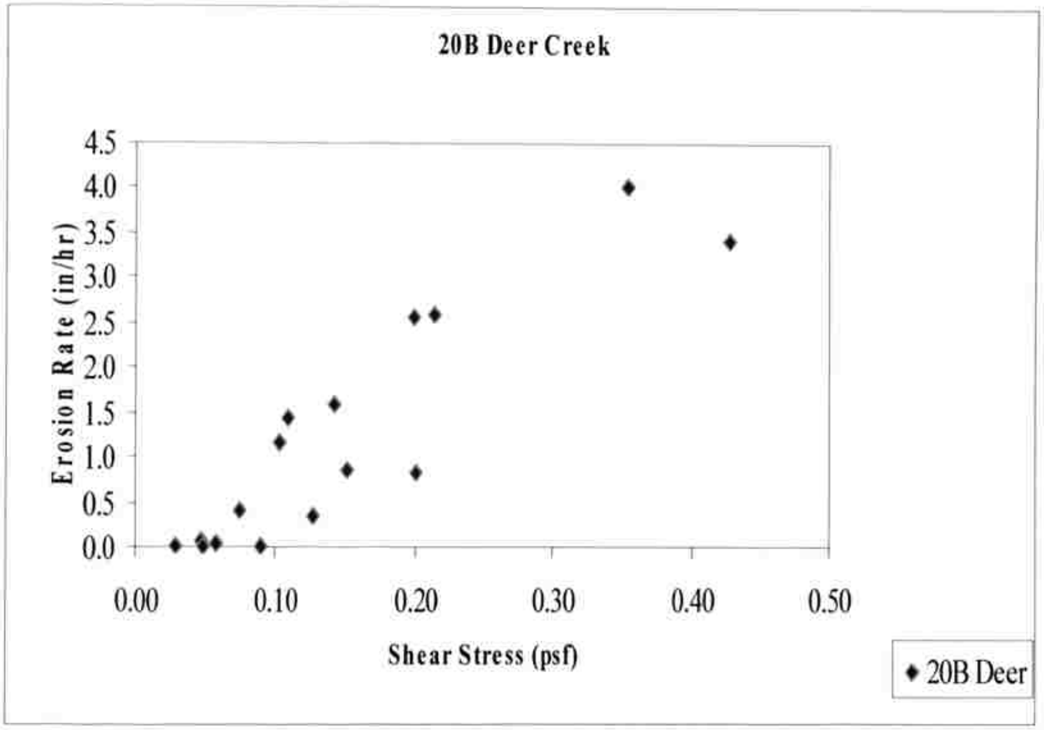


Figure 4.9. Erosion Rate vs. Shear Stress Plot for Soil 20B from Deer Creek

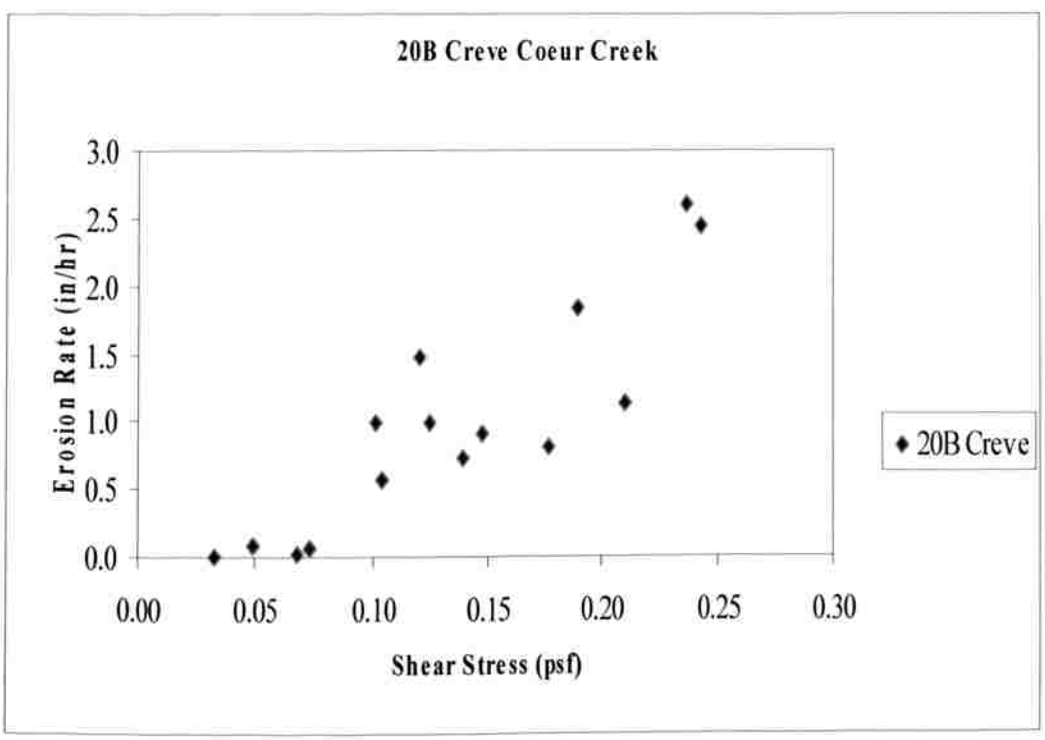


Figure 4.10. Erosion Rate vs. Shear Stress Plot for Soil 20B from Creve Coeur Creek

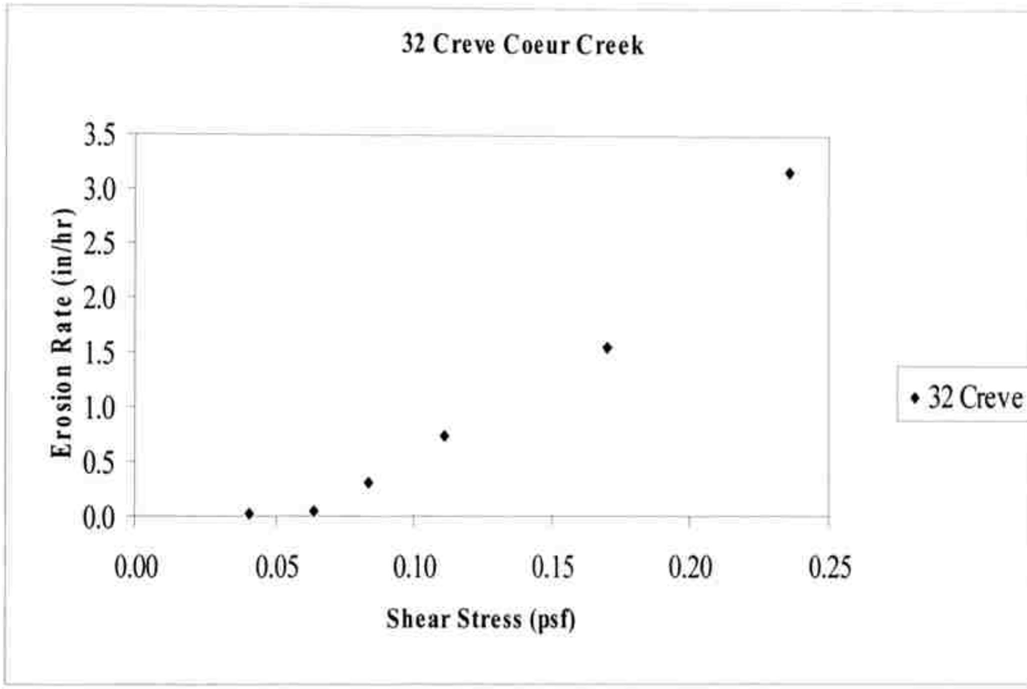


Figure 4.11. Erosion Rate vs. Shear Stress Plot for Soil 32 from Creve Coeur Creek

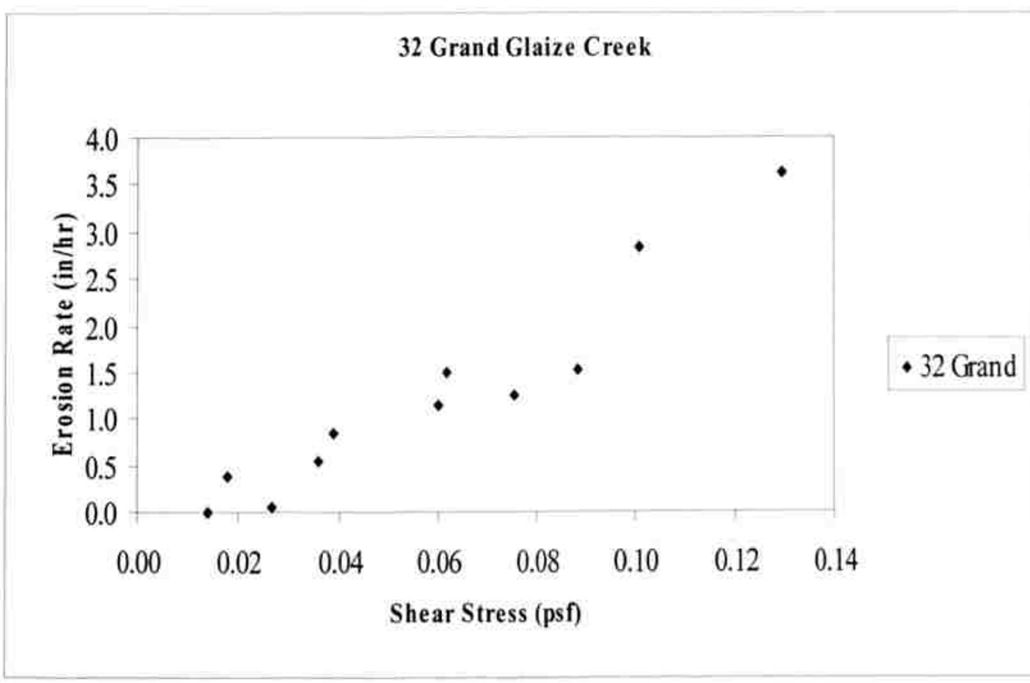


Figure 4.12. Erosion Rate vs. Shear Stress Plot for Soil 32 from Grand Glaize Creek

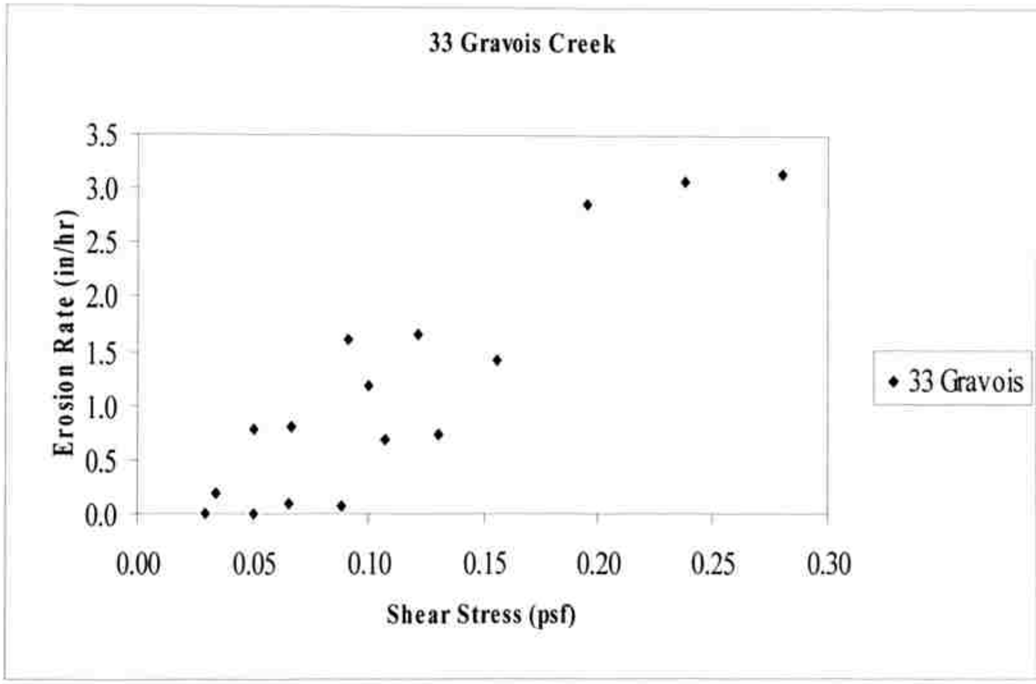


Figure 4.13. Erosion Rate vs. Shear Stress Plot for Soil 33 from Gravois Creek

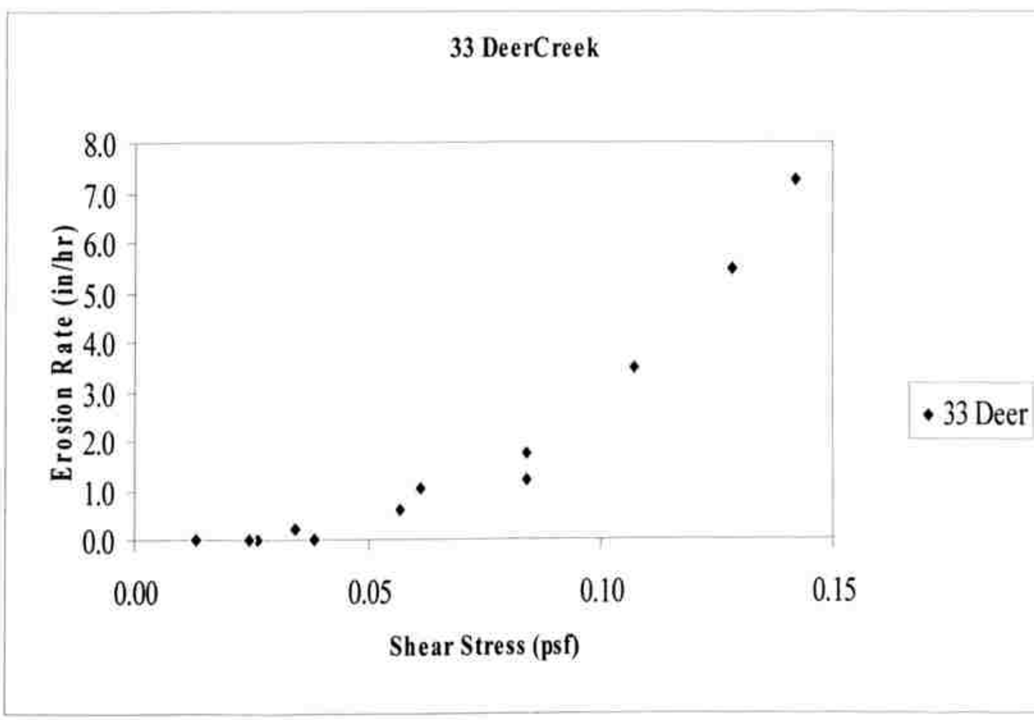


Figure 4.14. Erosion Rate vs. Shear Stress Plot for Soil 33 from Deer Creek

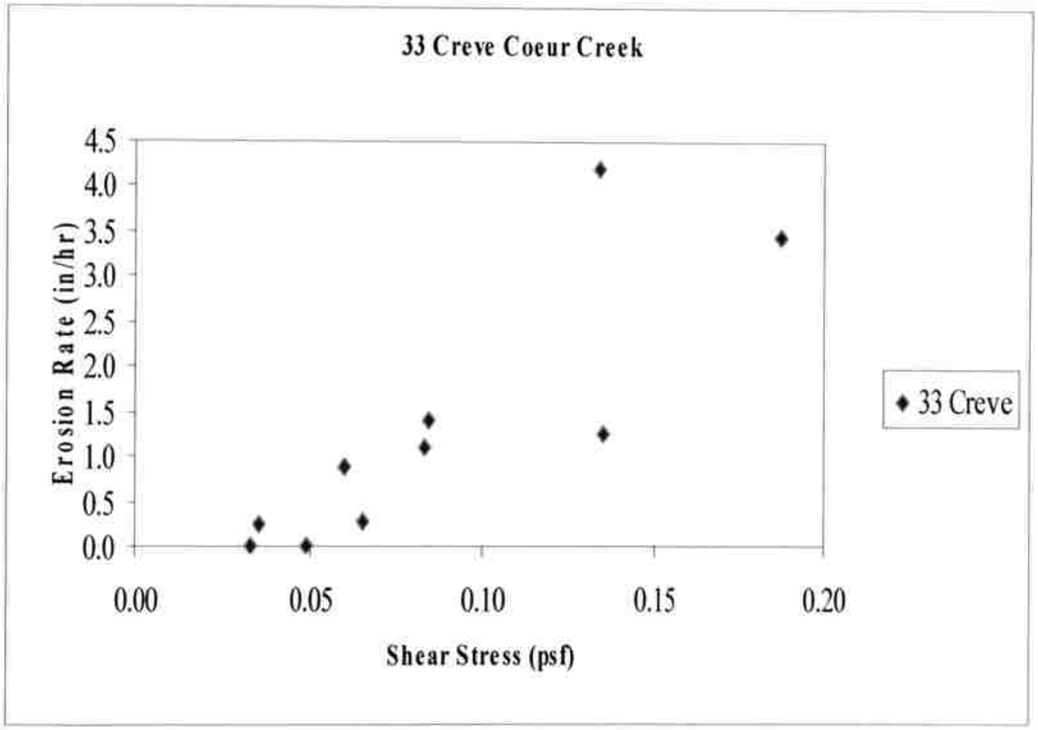


Figure 4.15. Erosion Rate vs. Shear Stress Plot for Soil 33 from Creve Coeur Creek

The detailed soil analysis calculations for the natural samples are provided in Appendices C to H. Most of the natural samples tested were comparatively homogeneous and, hence, the results obtained showed an increase in erosion rate with increased shear stress. Some of the data obtained for certain samples showed a very high variation in the erosion rate compared to the other values in the same dataset due to the presence of rock or roots in the samples. These samples experienced little or no erosion compared to the other samples tested from the same location. The correlation of shear stress to erosion rate was poor and, hence, did not match or come close to the other results. The analysis of soil erosion when roots and rocks are present is beyond the scope of this study, so those results are not presented in this report. Detailed analyses of the results, including statistical analysis, are explained in Section Five.

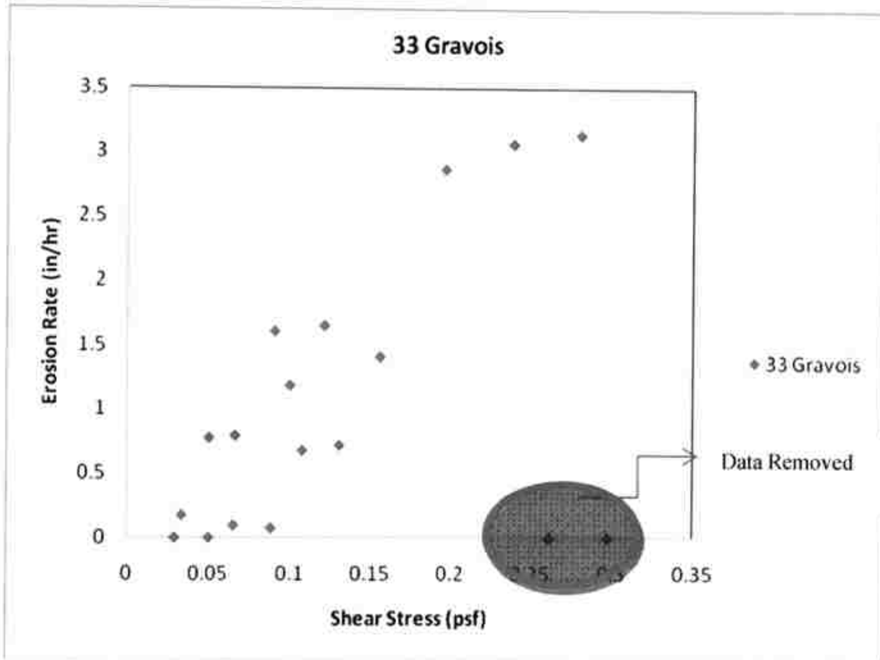


Figure 5.1. The Data Removed for Soil 33 from Gravois Creek

5.2.1. Prepared Soil Regression Analysis. Polynomial and linear fits were tried for the data sets. The linear fit was found to be the best for all data sets. With the exception of Soil C4, the samples prepared in the laboratory had an R-squared value greater than 0.70. For soil C4, the R-squared value obtained was 0.65. Each set of soil from all three prepared soil types was tested for significance using statistical methods. A 95% confidence interval and prediction interval for each set of data were obtained using the MINITAB program. The confidence interval defines the most believable values for a parameter and the prediction interval is the interval within which the response or the outcome is likely to fall. For example, Figure 5.2 shows the best fit obtained for soil A1. The equation of linear fit for soil A1 is given by

$$E = 201.5\tau - 2.819 \tag{5.1}$$

where E is the erosion rate in in/hr and τ is the shear stress applied in psf. The R-squared value obtained was 0.95, which indicates excellent correlation of the data points.

The samples tested for Soil A1 were prepared in the laboratory, hence, the soil was considered homogeneous. That may be the major reason for obtaining such a high correlation of data points. Only two soil samples were tested from this set, so fewer data points were obtained. Due to this high correlation, the 95% confidence interval and the 95% prediction intervals formed a narrow band. All the data points obtained for Soil A1 lies within the 95% prediction interval. The slope of the linear fit is very high, which indicates a higher erosion rate in Soil A1. As compared to the unit weight of other prepared samples the wet unit weight and dry unit weight of Soil A1 was somewhat closer to those of natural samples. Compacting the soil in the Shelby tube at a low unit weight was extremely difficult. The erosion rate of the sample was higher than that of all the other soils tested. A comparison of the slope of linear fit obtained for shear stress to the erosion rate plot gave a better idea of the erodibility of different soil types. The erosion rate of Soil A1, with unit weights similar to the natural samples, was too high as compared to the erosion rate of natural samples, which is shown later in this section.

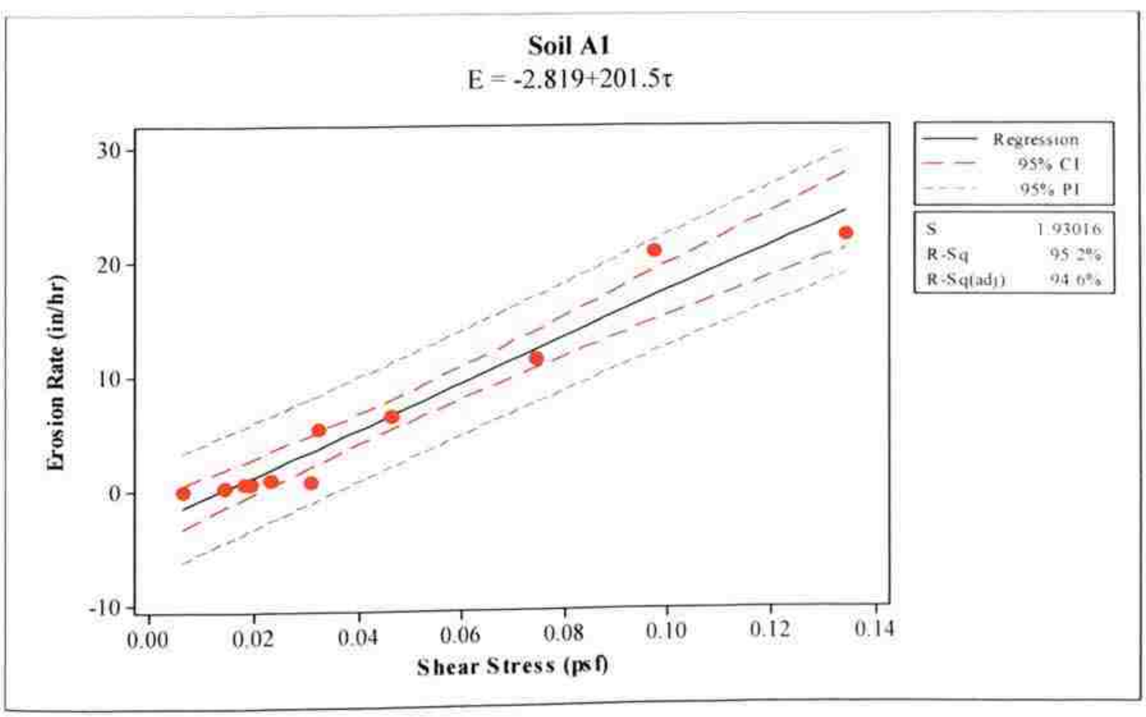


Figure 5.2. 95% Confidence and Prediction Interval for Soil A1

Similarly, the linear fit obtained for Soil A2 is shown in Figure 5.3. Three samples of Soil A2 were tested in the flume and the R-squared value obtained was 0.84. The 95% confidence and prediction intervals were plotted to test the reliability of results. The confidence interval and prediction interval bands were wider than those for Soil A1. Another factor observed in this plot was the slope of the linear fit. The slope of the best fit line for Soil A2 was less than that of Soil A1, which indicated a higher resistance to erosion than in Soil A1. As per the soil analysis, the wet and dry unit weight for Soil A2 is higher than that of Soil A1, which means the Soil A2 is more compacted than Soil A1. The cohesion of Soil A2 was less than that of Soil A1. The higher water content, 17%, of Soil A2 can reduce A2's cohesion. The resistance to erosion was high for lower soil cohesion, which was not an expected trend for the result. Similarly, the linear fit obtained along with the prediction and confidence intervals for different sets of Soil A, were determined and are plotted in Figures 5.4, 5.5, 5.6, 5.7, and 5.8.

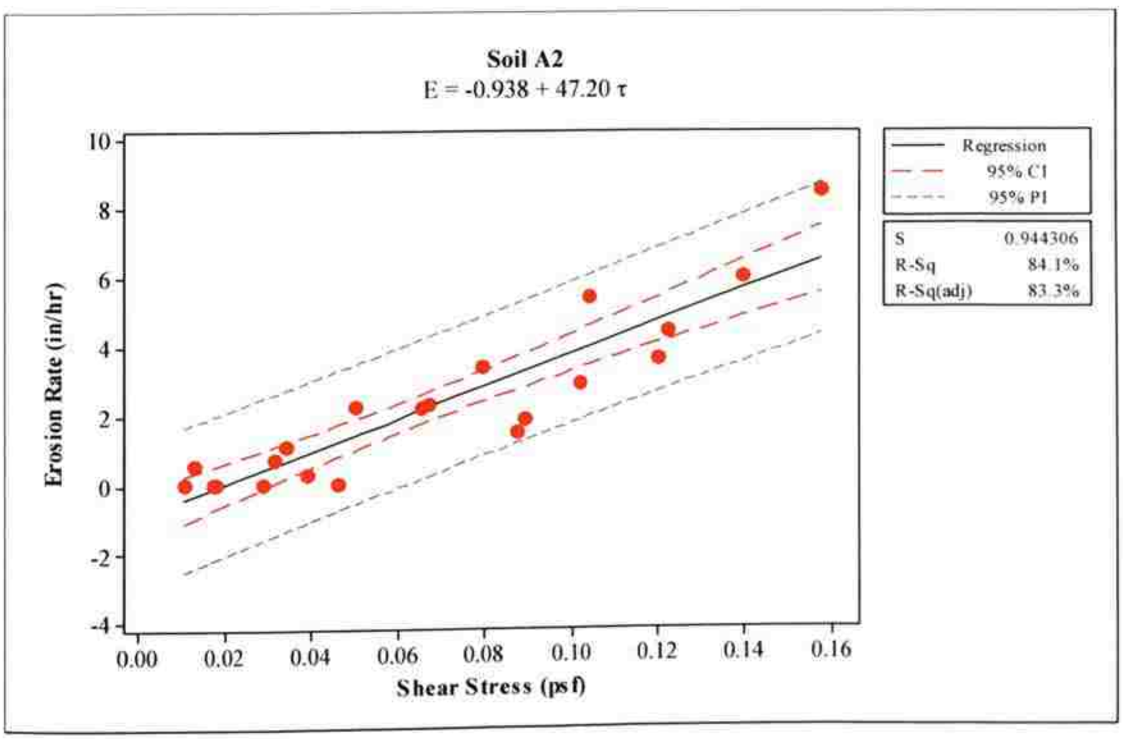


Figure 5.3. 95% Confidence and Prediction Interval for Soil A2

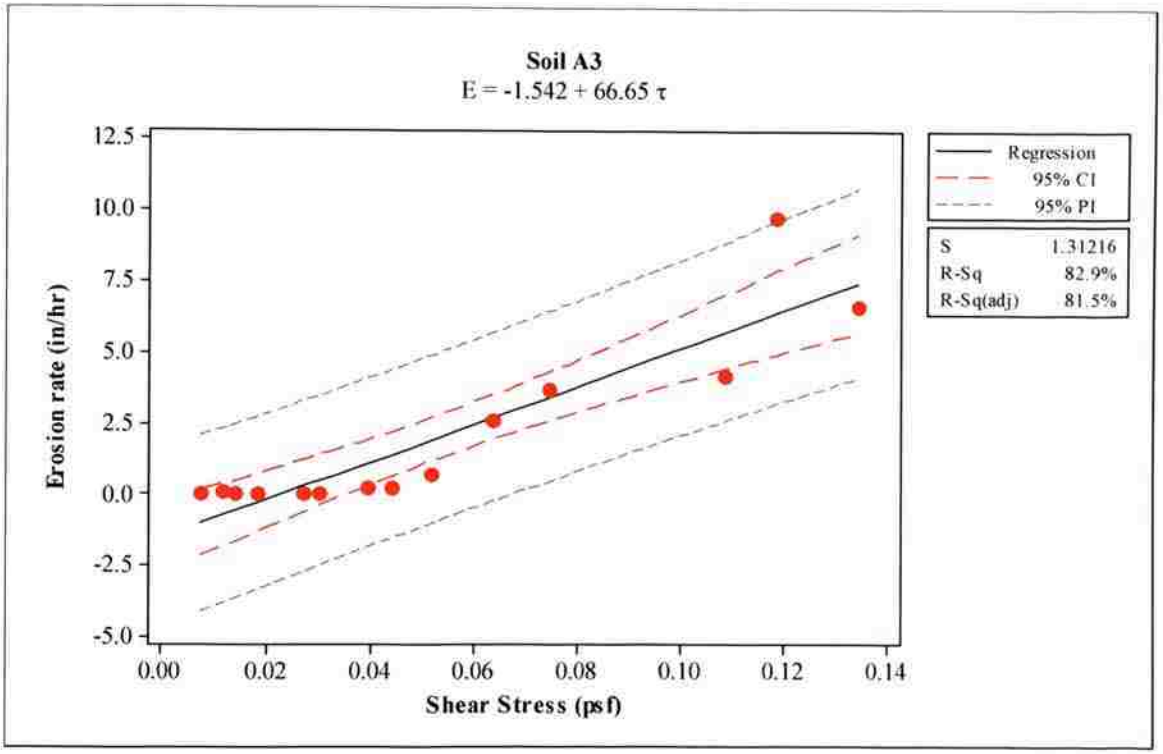


Figure 5.4. 95% Confidence and Prediction Interval for Soil A3

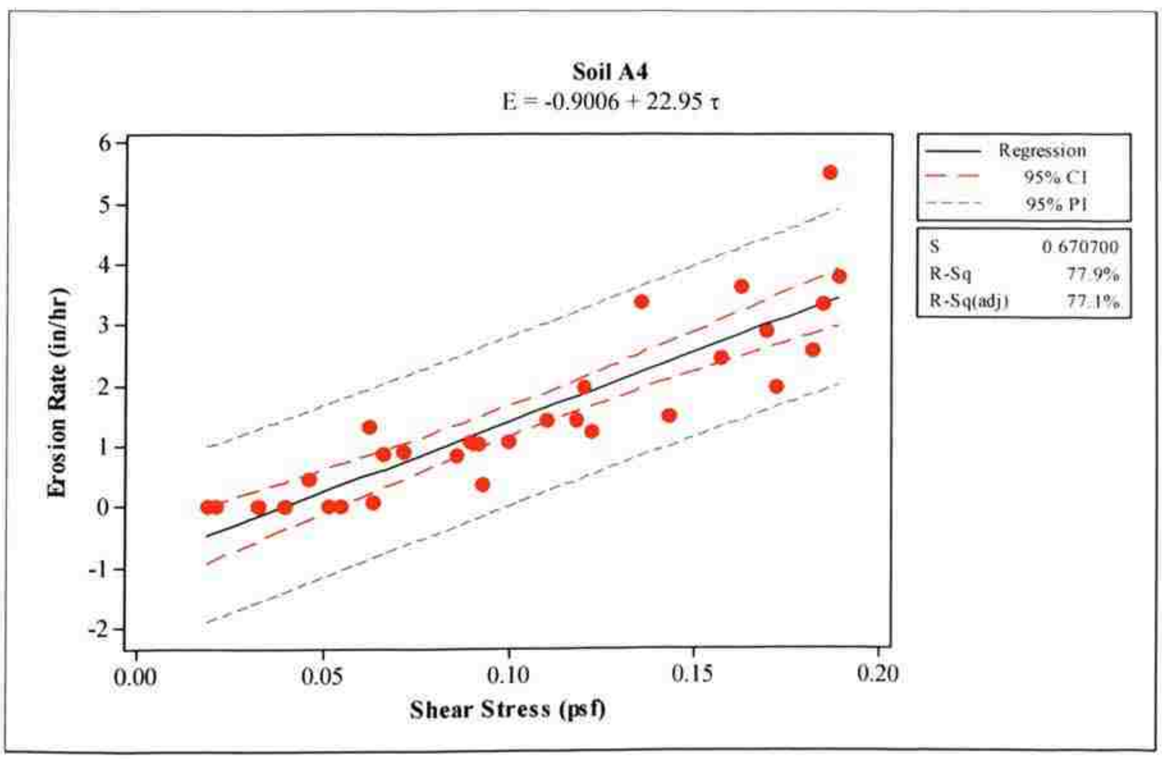


Figure 5.5. 95% Confidence and Prediction Interval for Soil A4

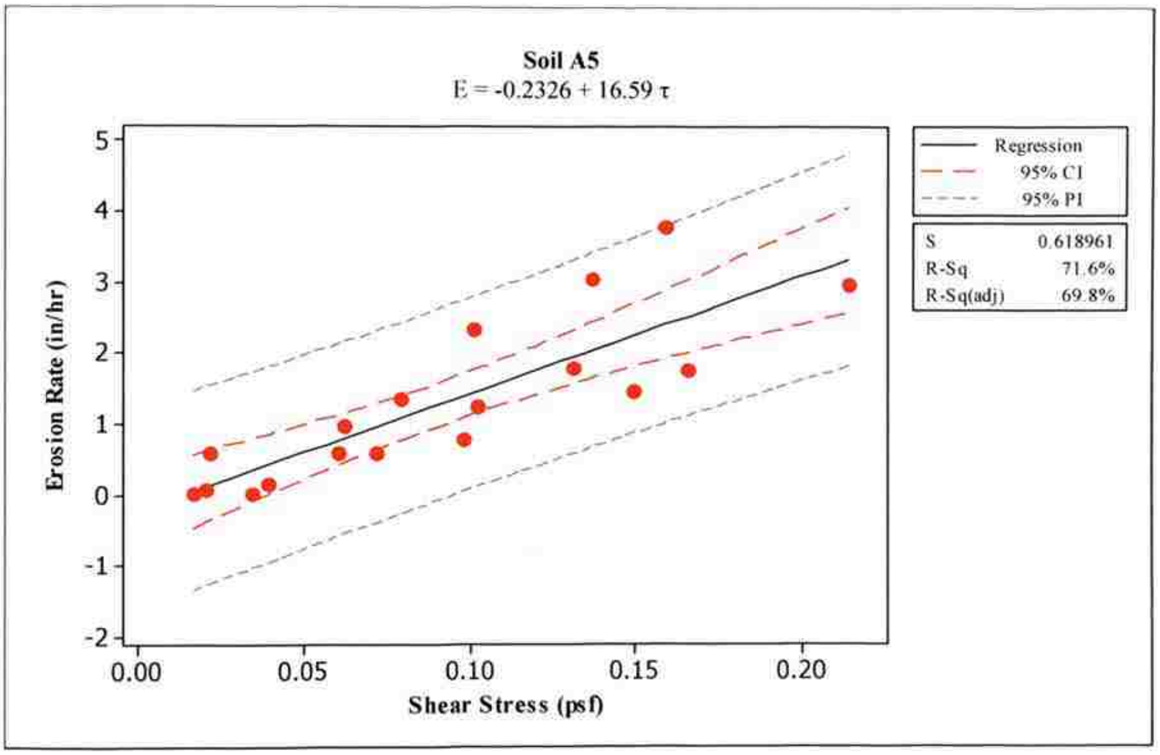


Figure 5.6. 95% Confidence and Prediction Interval for Soil A5

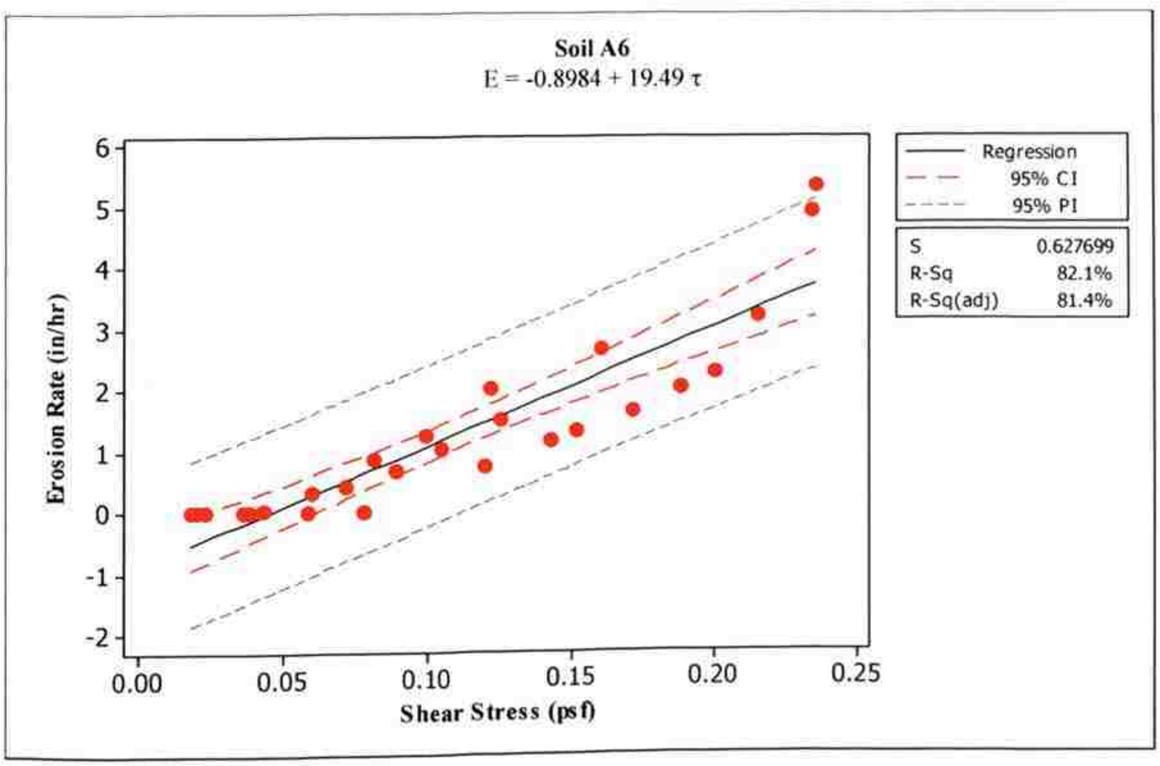


Figure 5.7. 95% Confidence and Prediction Interval for Soil A6

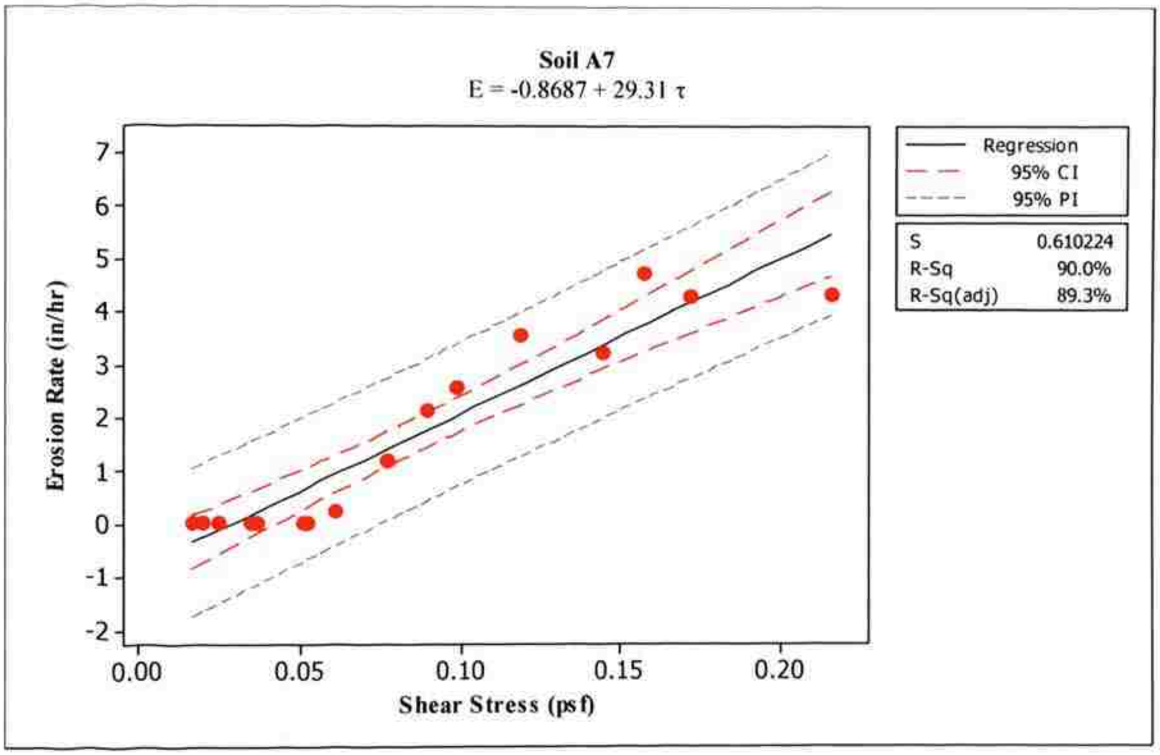


Figure 5.8. 95% Confidence and Prediction Interval for Soil A7

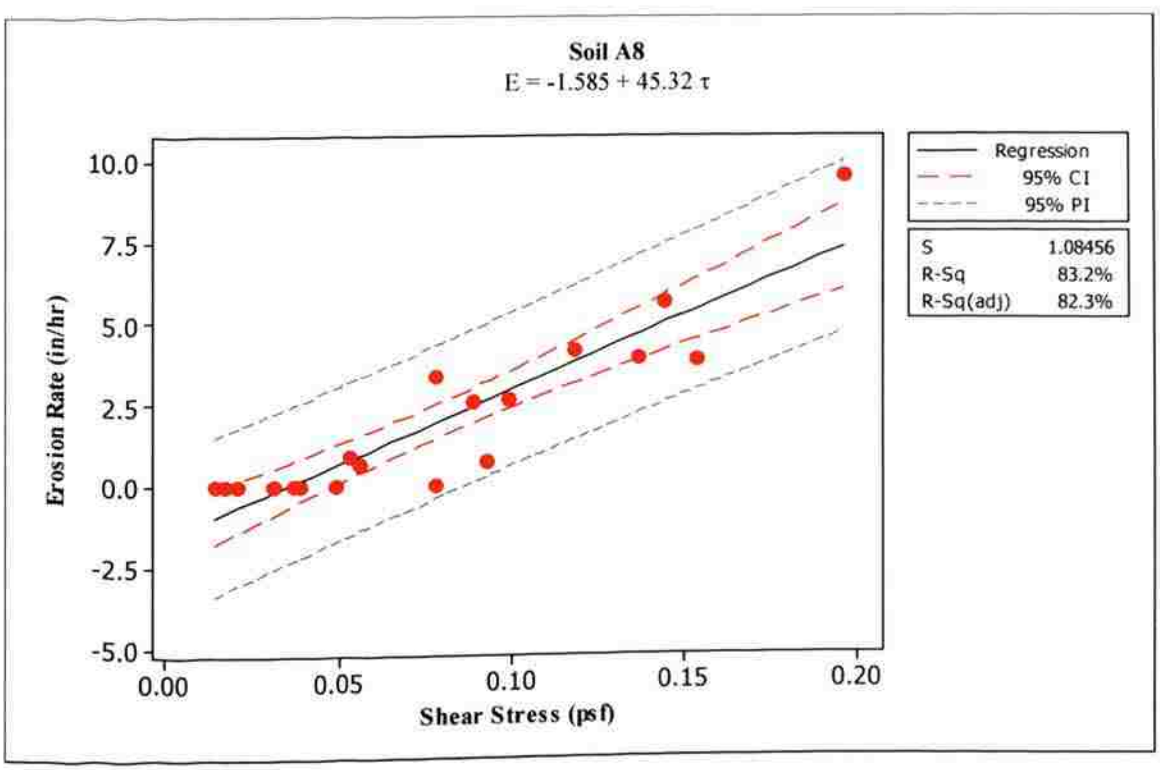


Figure 5.9. 95% Confidence and Prediction Interval for Soil A8

Flume results for Soil B were statistically analyzed to see the significance of the results obtained. The 95% confidence and prediction intervals were plotted for all sets of soil B. The graphs plotted with the linear relationship obtained for Soils B1, B2, B3, and B4, along with the 95% confidence and prediction intervals, are shown in Figures 5.10, 5.11, 5.12 and 5.13, respectively. The R-squared value obtained for Soil B1 was 0.73 while for B2, B3, and B4 it was greater than 0.8. The erosion rate for Soil B1 was the highest and B3 showed the maximum resistance to erosion in this group. Linear fit for Soils B2 and B3 had similar slopes.

Similarly, results obtained for Soils C1 to C4 were analyzed with 95% confidence and prediction intervals. The graphs obtained for these soils are shown in Figures 5.14, 5.15, 5.16, and 5.17. The linear fit obtained for Soils C1 and C2 had similar slopes of 32.78 and 36.13, respectively. The slope of the linear fit for Soil C3 was less than that of Soils C1 and C2 and greater than that of Soil C4. Soil C4 indicated the maximum resistance to erosion among these samples.

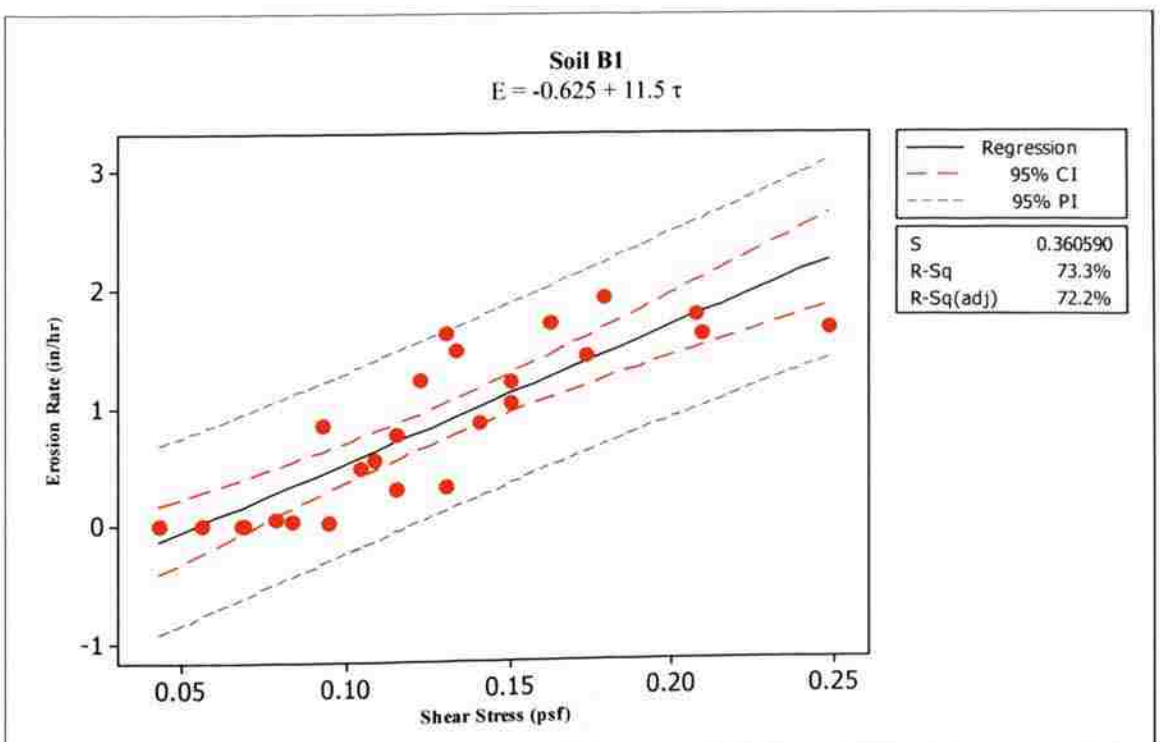


Figure 5.10. 95% Confidence and Prediction Interval for Soil B1

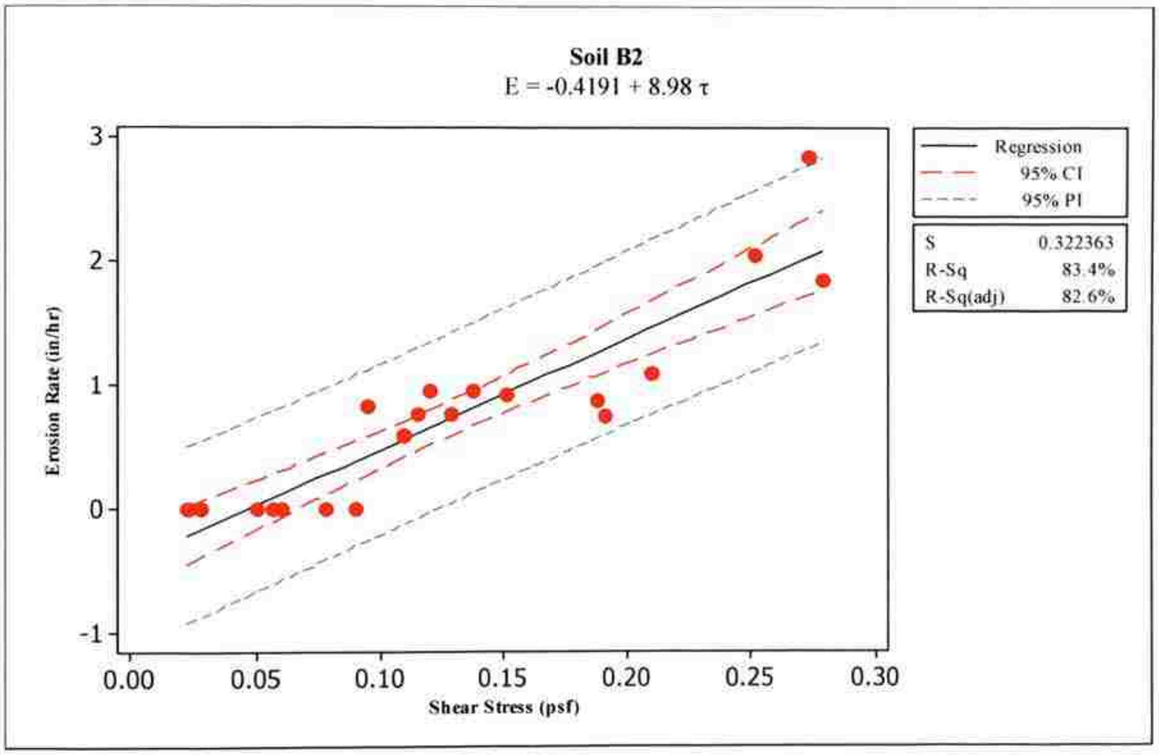


Figure 5.11. 95% Confidence and Prediction Interval for Soil B2

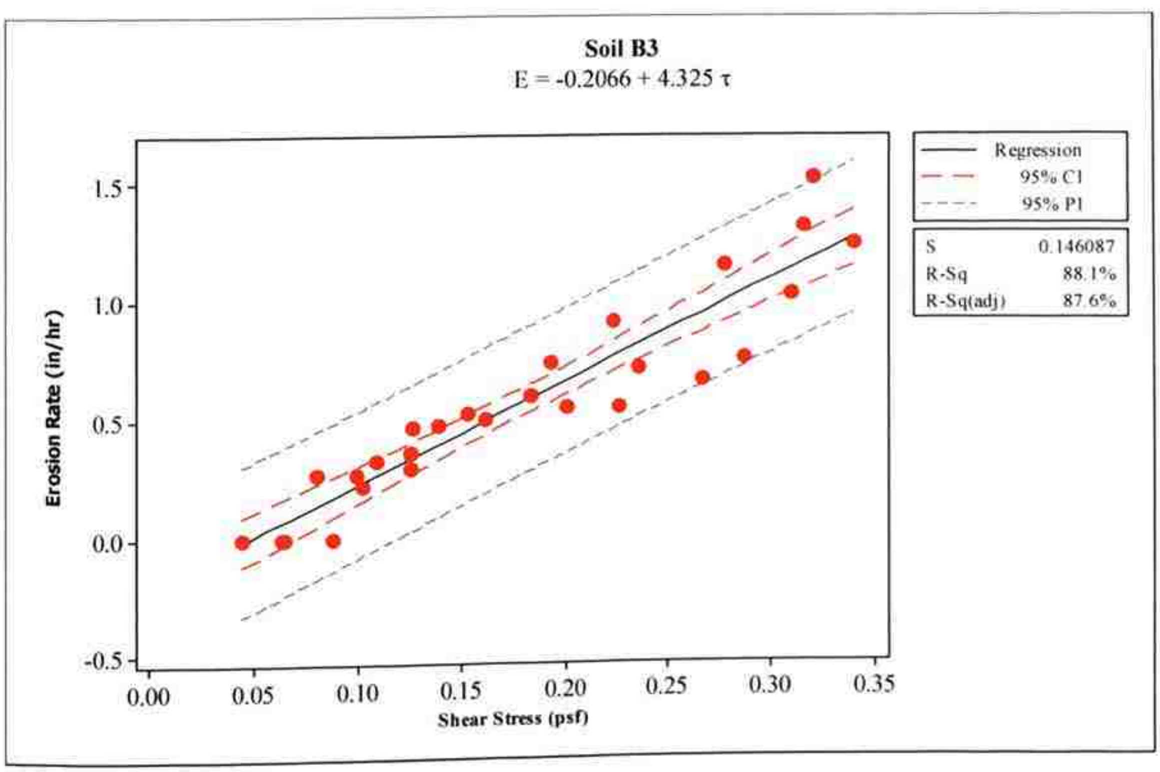


Figure 5.12. 95% Confidence and Prediction Interval for Soil B3

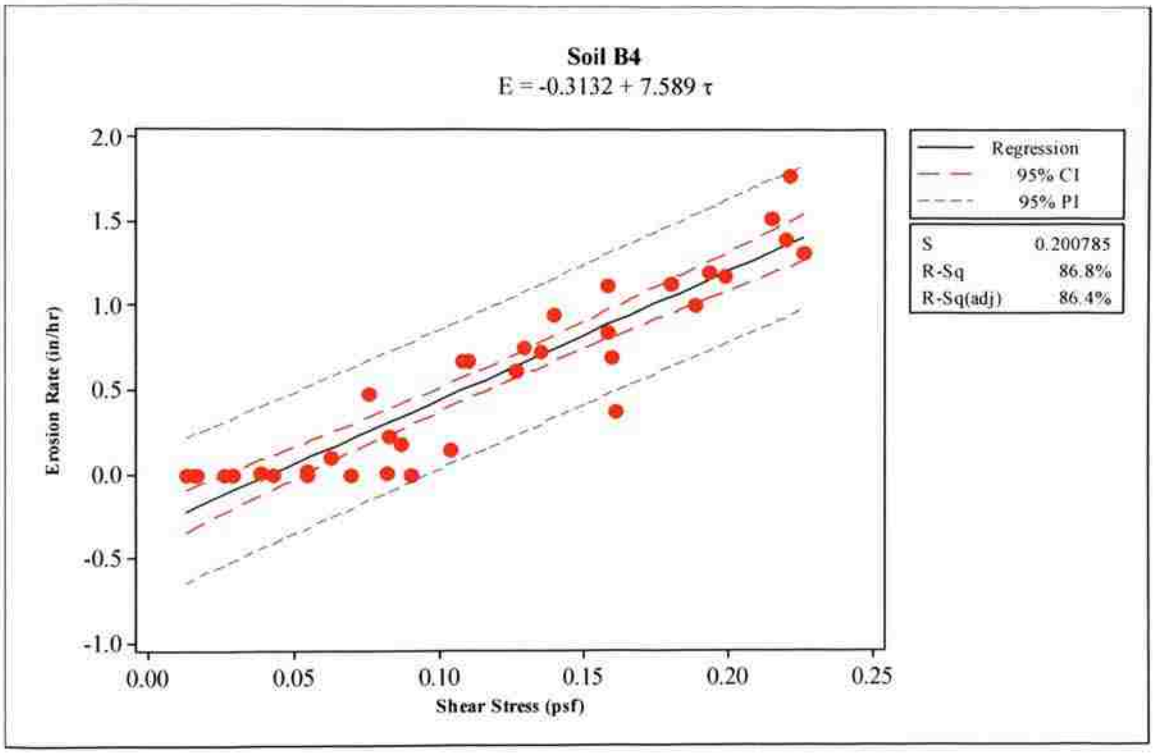


Figure 5.13. 95% Confidence and Prediction Interval for Soil B4

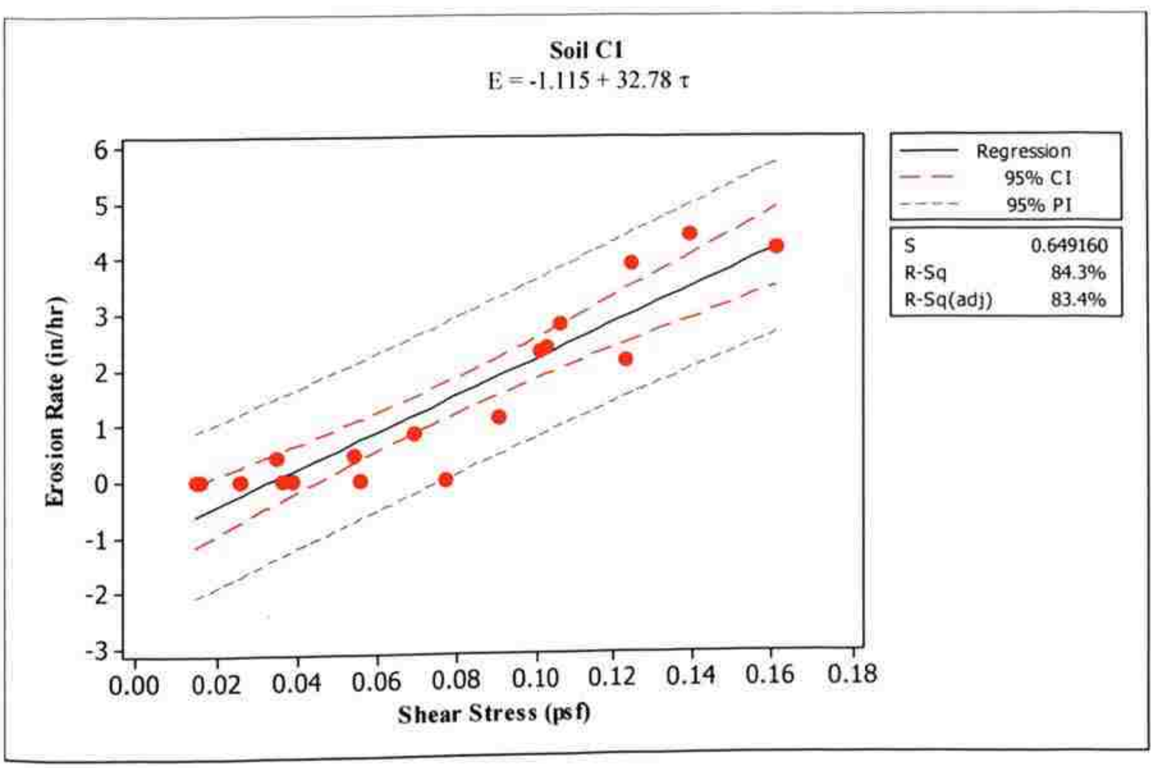


Figure 5.14. 95% Confidence and Prediction Interval for Soil C1

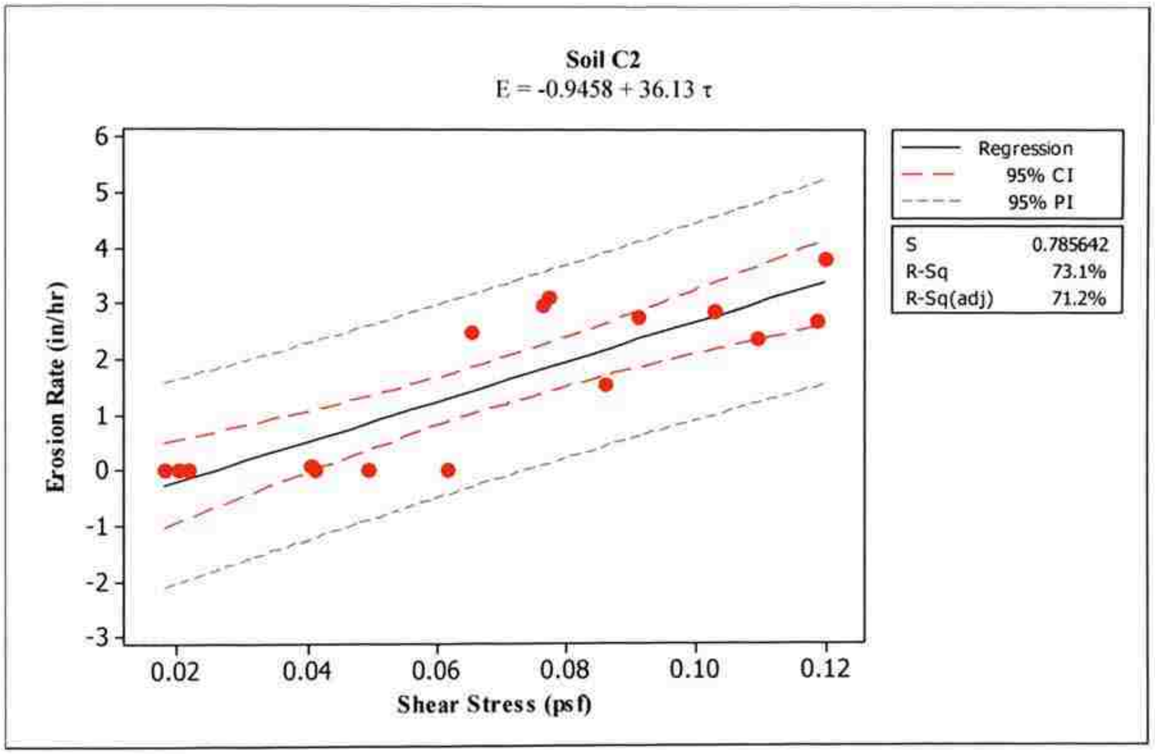


Figure 5.15. 95% Confidence and Prediction Interval for Soil C2

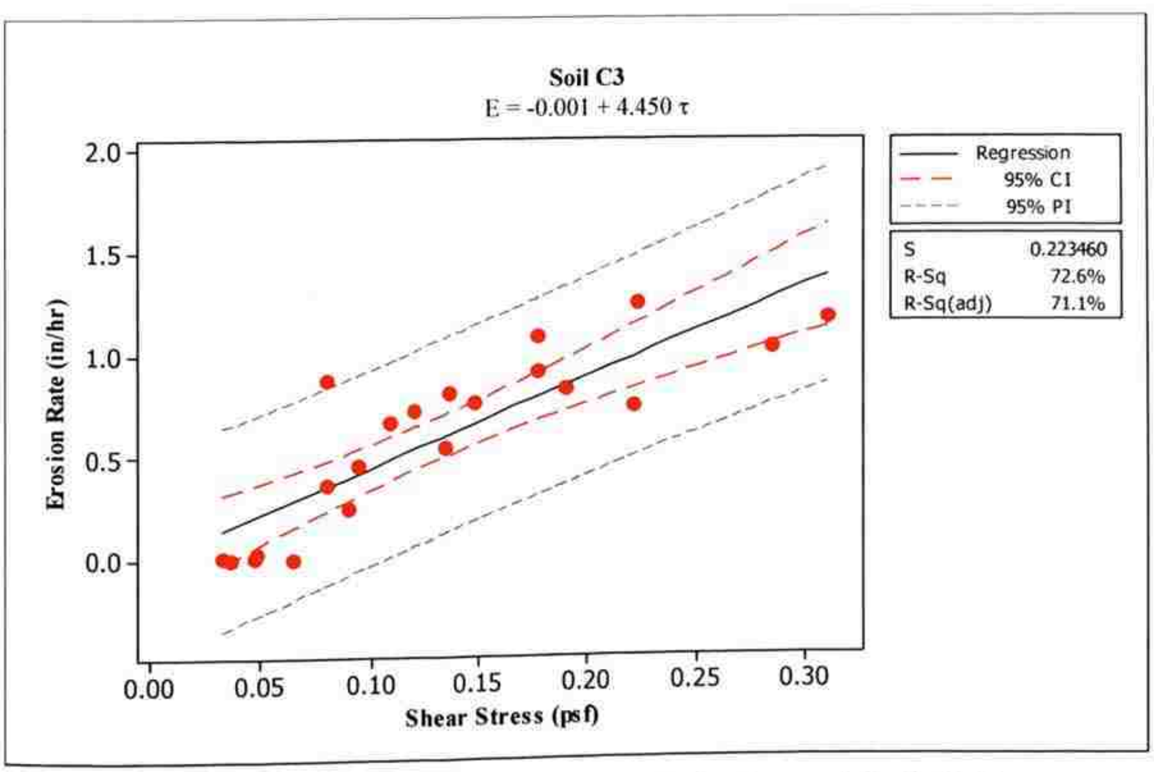


Figure 5.16. 95% Confidence and Prediction Interval for Soil C3

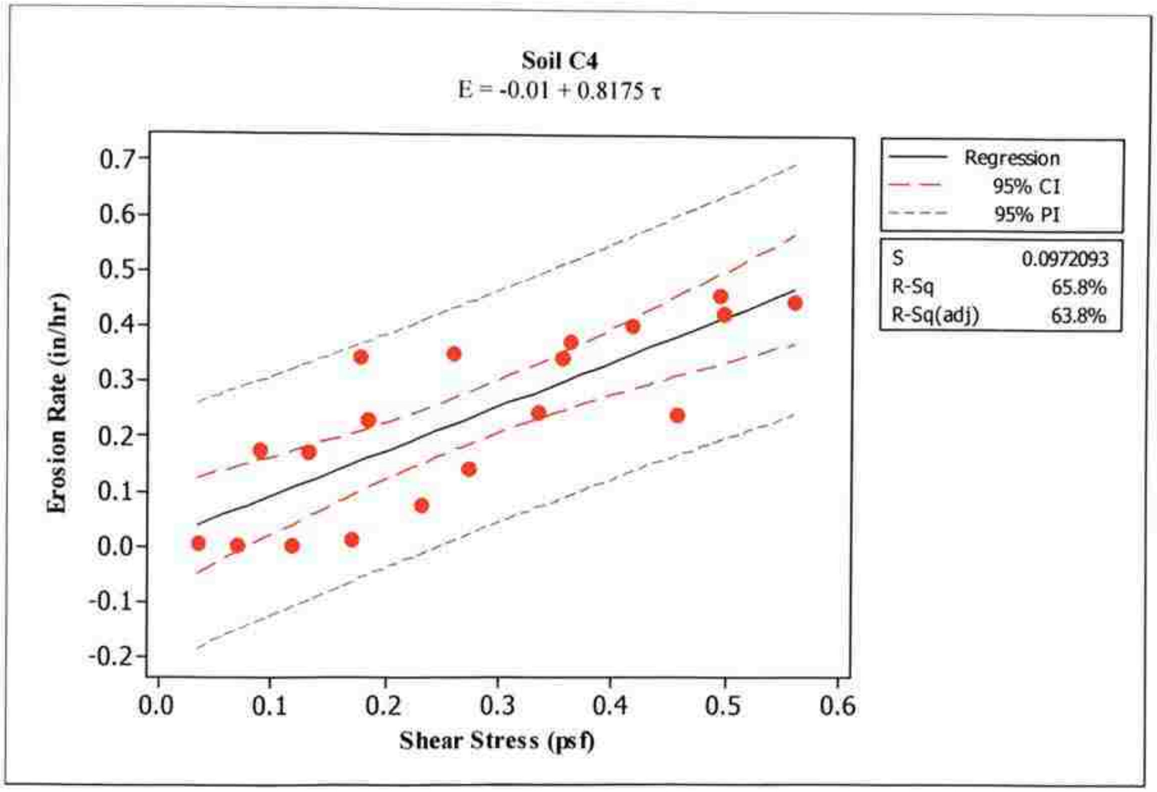


Figure 5.17. 95% Confidence and Prediction Interval for Soil C4

For most of the soil types tested, the erosion rate was zero or slightly greater at low shear stress values. Linear regression analysis was performed including these low erosion data points, but, the linear fit obtained in the low shear stress region indicates higher erosion rate than the actual observed erosion rate. The rate of erosion is higher after the critical shear stress, the shear stress above which mass erosion occurs (Partheniades 1965). Below the critical shear stress value, the erosion rate of soil is very small and time is the major constraint in analyzing erosion below this point. Hence, the linear fit presented for the soil types is not valid in the low shear stress region. If a regression analysis is performed after removing these low erosion data points, it may produce a linear fit with an even higher correlation coefficient. However, the linear fit adopted in this research looks reasonable as the spread of data is almost uniform at higher shear stress values. More detailed analysis is required to predict the rate of erosion at low shear stress values.

5.2.2. Natural Soil Regression Analysis. Before analyzing the natural soil erosion, the soils were classified into different groups based on the USDA Soil Triangle shown in Figure 5.18. The wet sieve analysis and the hydrometer analysis performed on the natural soil samples showed that the soil compositions are not the same as given in NRCS Soil Survey Map, which led to a reclassification of the soils. The USDA soil classifications for the samples collected from different locations are given in Table 5.1. From this table, it is obvious that the classification of a soil such as 20B from the Gravois Creek and Deer Creek by the NRCS Soil Survey Map indicates very different compositions of sand, silt and clay. The composition of Soils 20B, 32, and 33 according to the NRCS Soil Survey Map is given in Table 2.1.

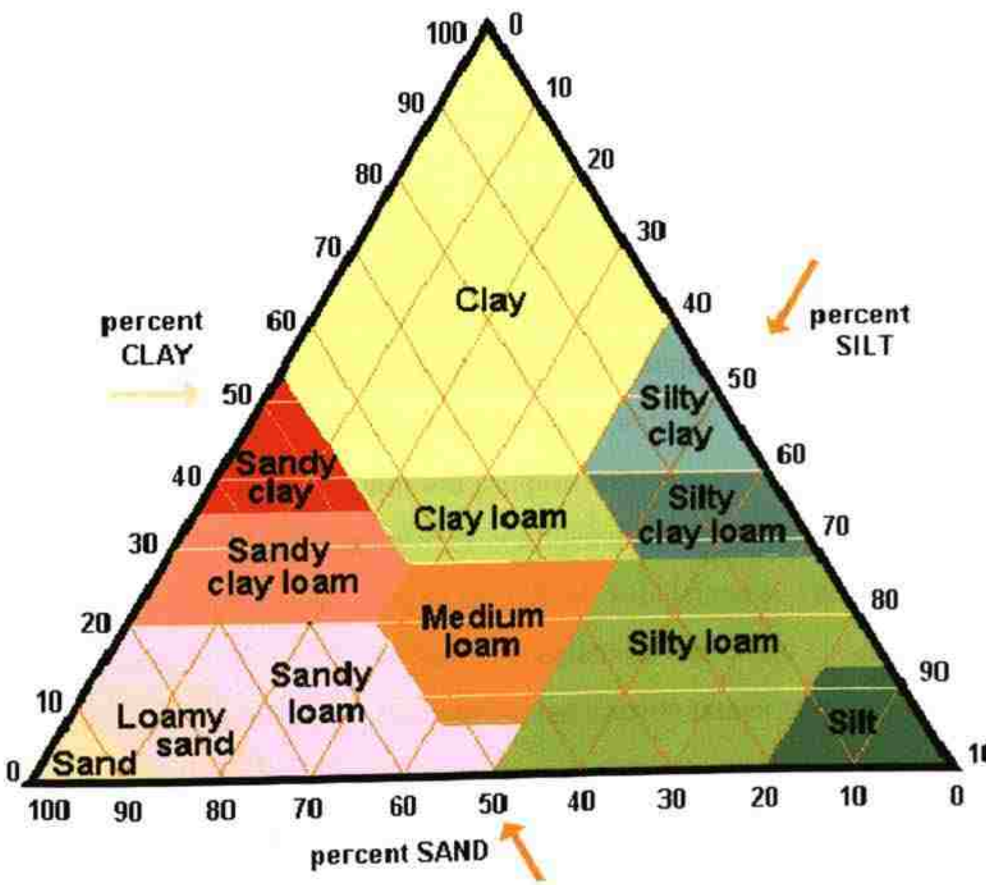


Figure 5.18. USDA Soil Textural Triangle

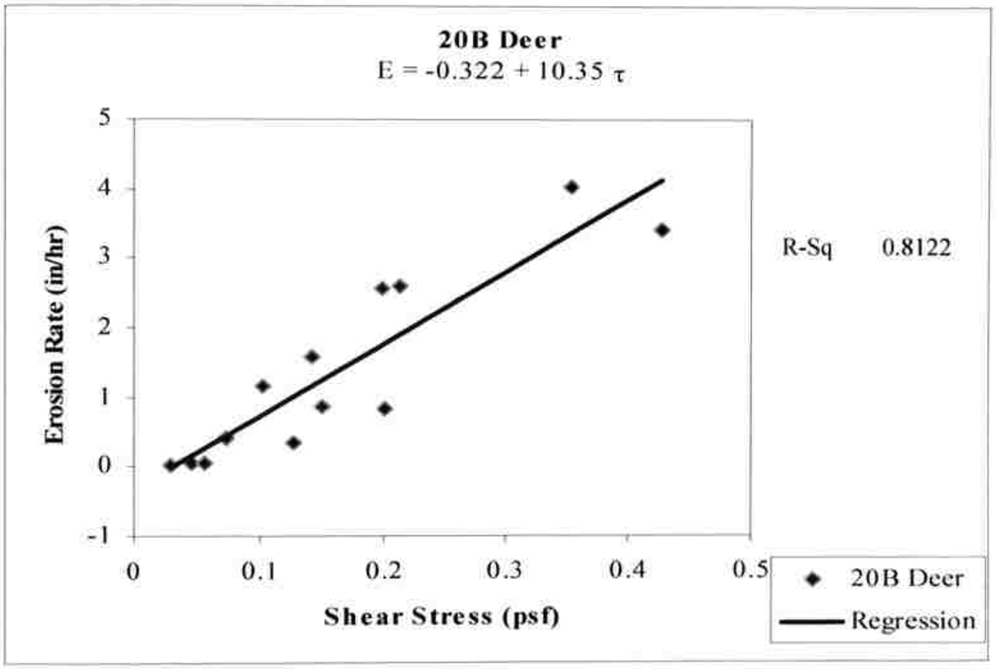


Figure 5.19. Linear Fit for Soil 20B from Deer Creek

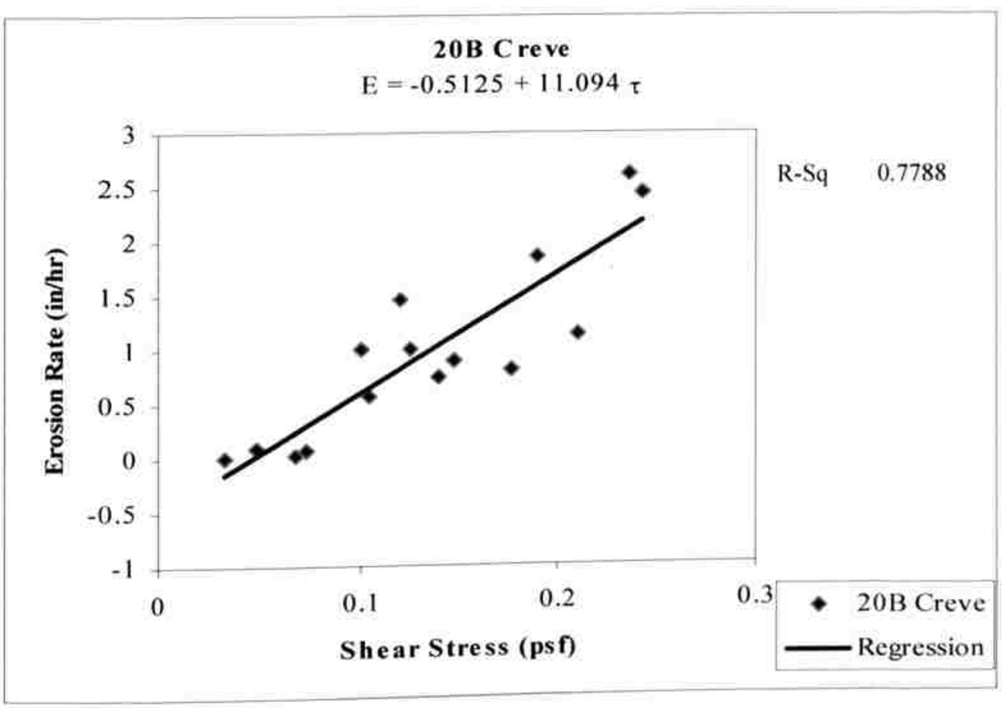


Figure 5.20. Linear Fit for Soil 20B from Creve Coeur Creek

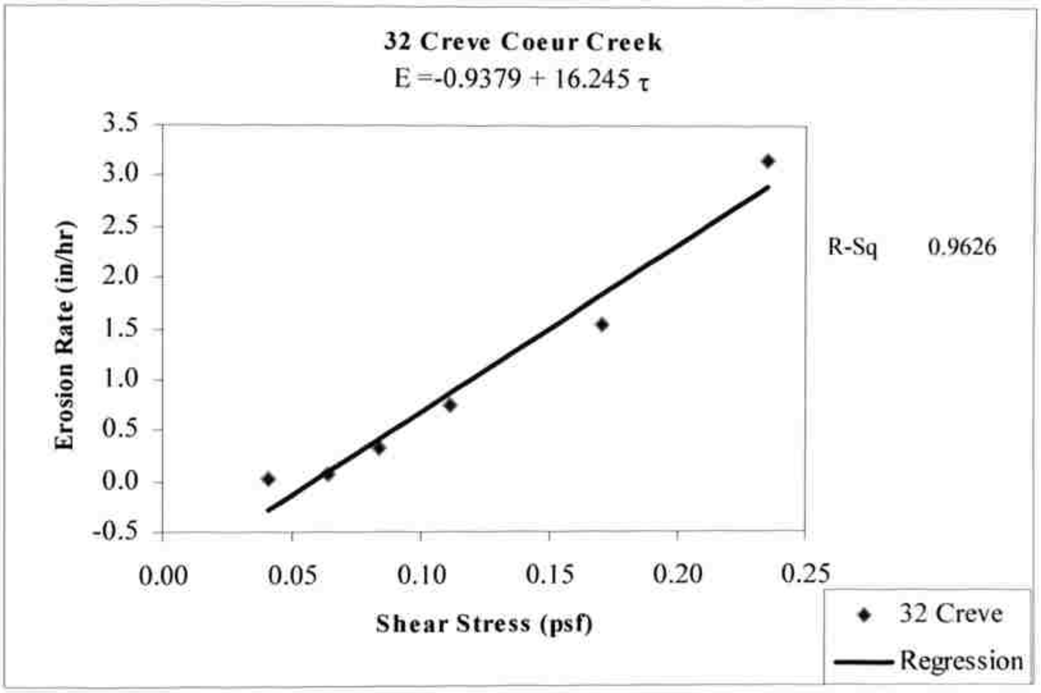


Figure 5.21. Linear Fit for Soil 32 from Creve Coeur Creek

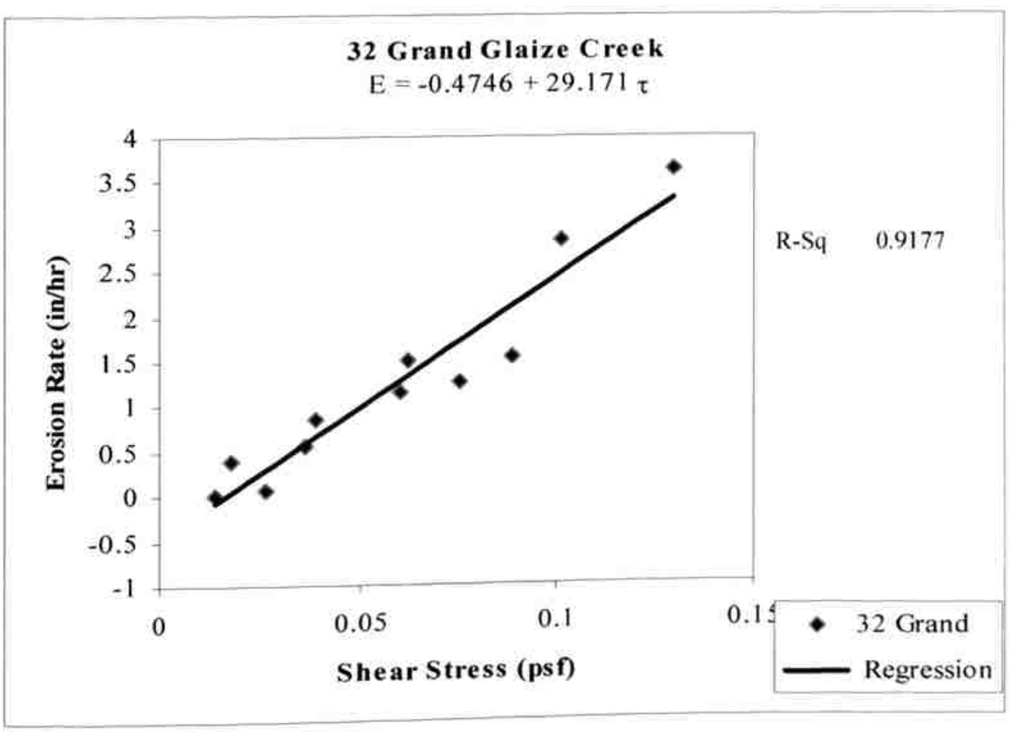


Figure 5.22. Linear Fit for Soil 32 from Grand Glaize Creek

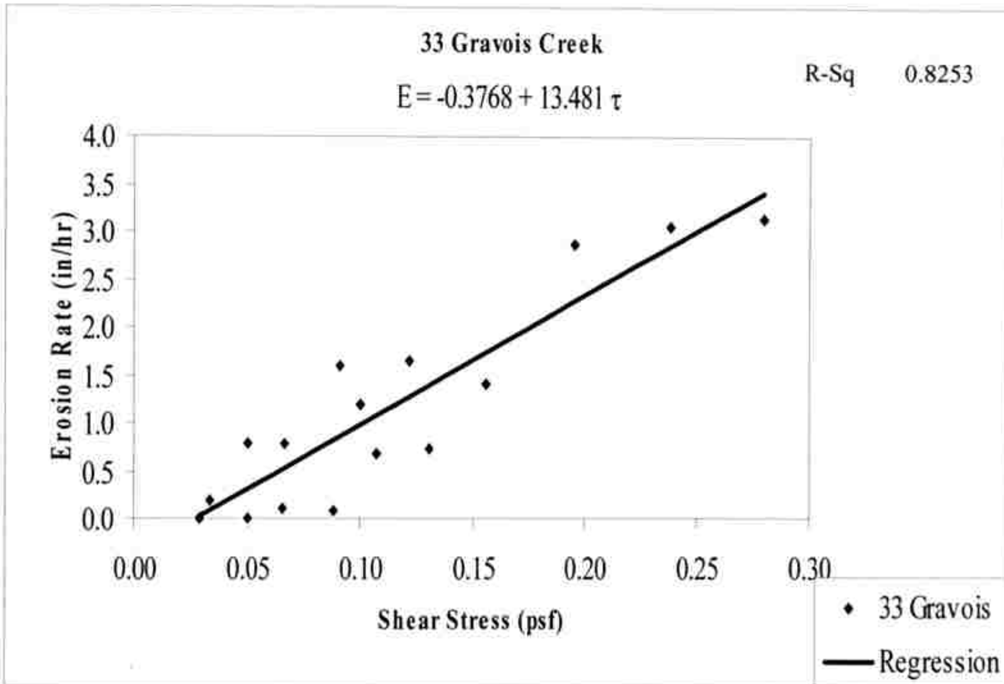


Figure 5.23. Linear Fit for Soil 33 from Gravois Creek

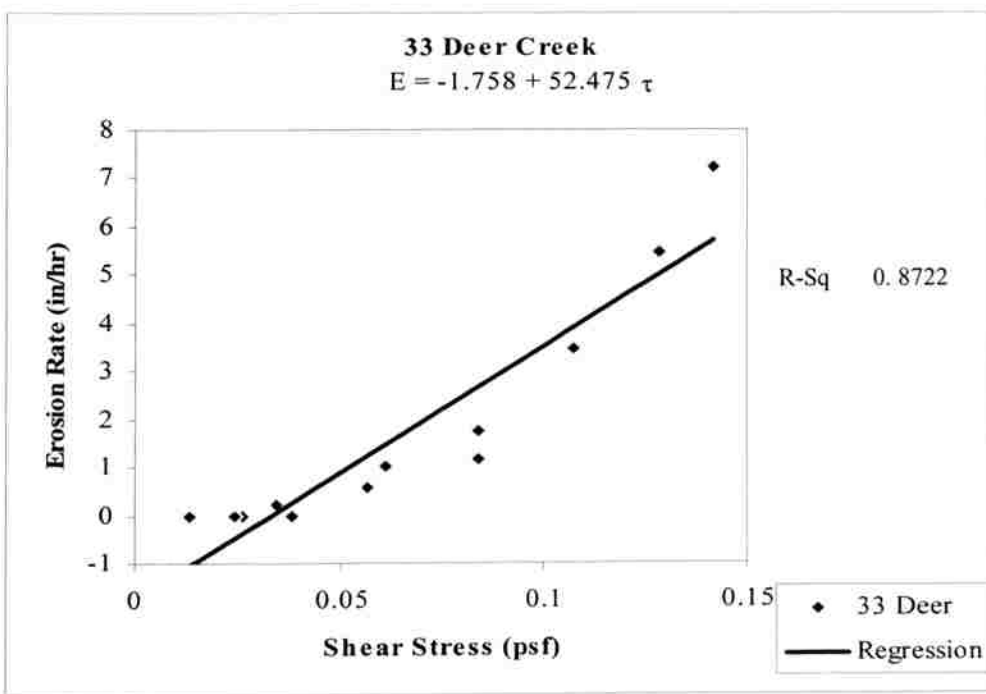


Figure 5.24. Linear Fit for Soil 33 from Deer Creek

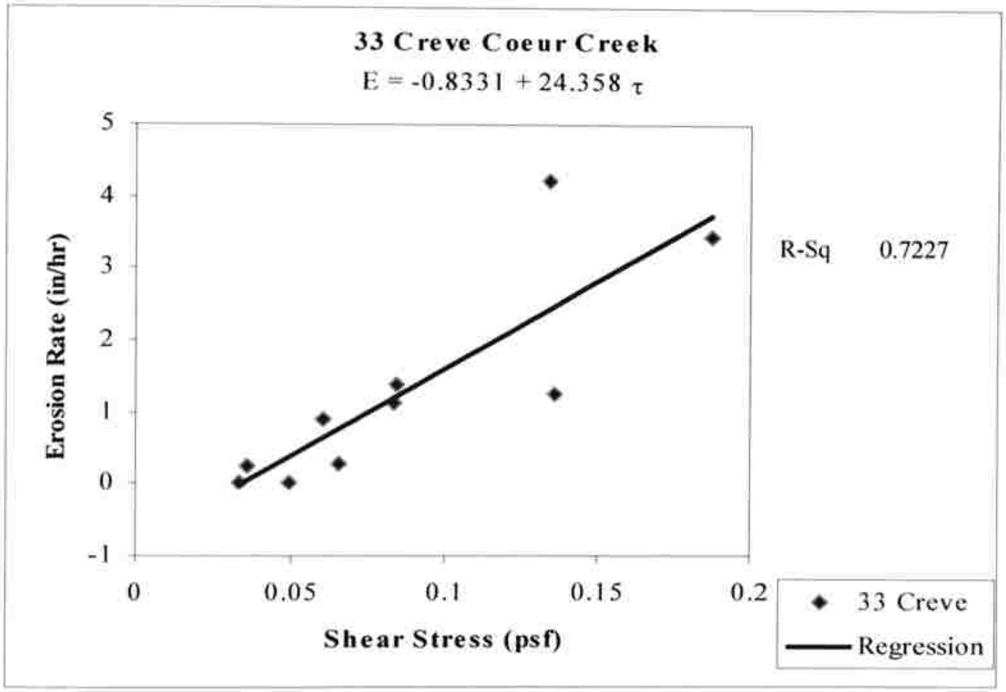


Figure 5.25. Linear Fit for Soil 33 from Creve Coeur Creek

The test of significance was performed for these natural soils after grouping the soils based on the USDA classification given in Table 5.1. The results obtained for Soil types 20B Deer Creek, 20B Creve Coeur Creek, 32 Creve Coeur Creek, and 33 Creve Coeur Creek were grouped together as Silty Loam and a combined data plot was obtained.

A combined data plot obtained for eight Silty Loam samples from four different locations is shown in Figure 5.26. The linear fit obtained for the combined Silty Loam soil plot is given by

$$E = 11.14\ \tau - 0.2944 \tag{5.3}$$

The R-squared value obtained for the combined data was 0.645 . The 95% confidence interval and prediction interval obtained for the Silty Loam is also shown in Figure 5.26. Similarly, the results obtained for Soils 33 from Deer Creek and 32 from Grand Glaize Creek were grouped together to perform the statistical analysis.

The linear fit and the 95% confidence and prediction intervals for this Sandy Loam group is given in Figure 5.27. The numbers of samples in other soil types were not large enough to form a new group to establish a relationship between the shear stress and erosion rates. In the Loamy Sand group, there was not enough sample of 20B from Gravois Creek. Hence, the only sample tested was Soil 32 from Gravois Creek. Also, there was only one soil for the Loam group, so no grouping analysis was performed for that.

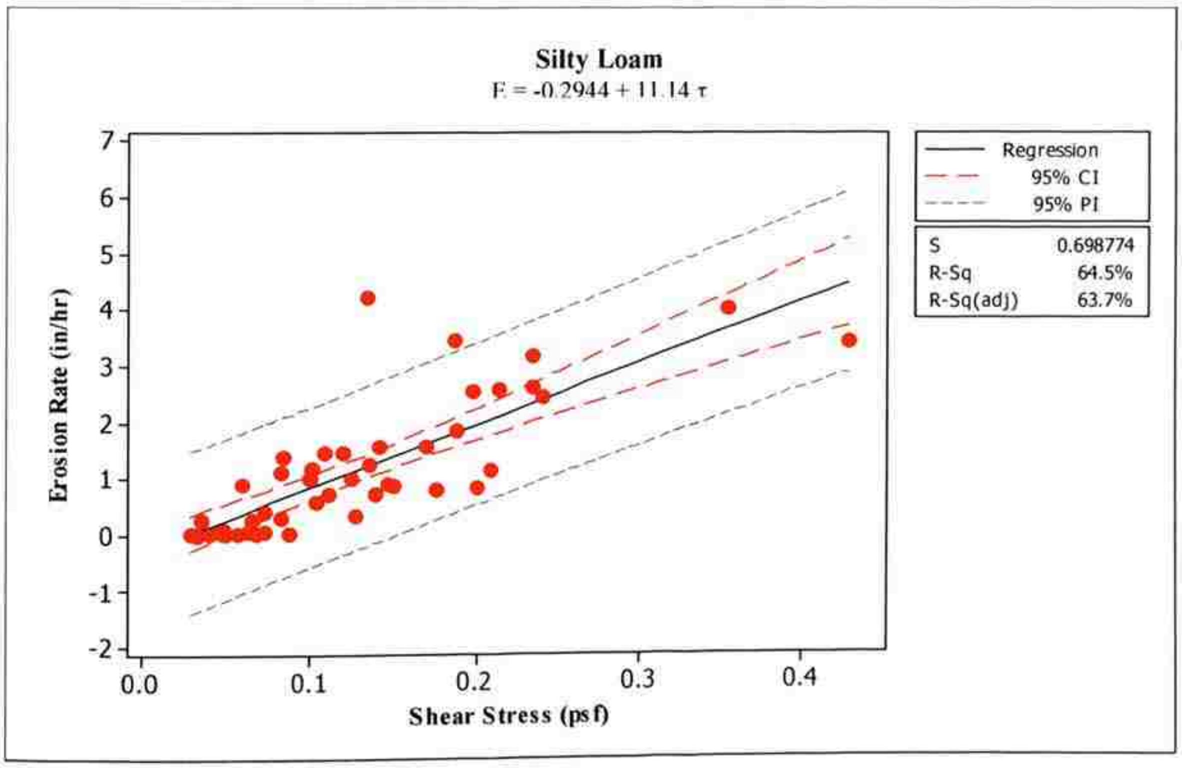


Figure 5.26. Combined Data Plot for Silty Loam

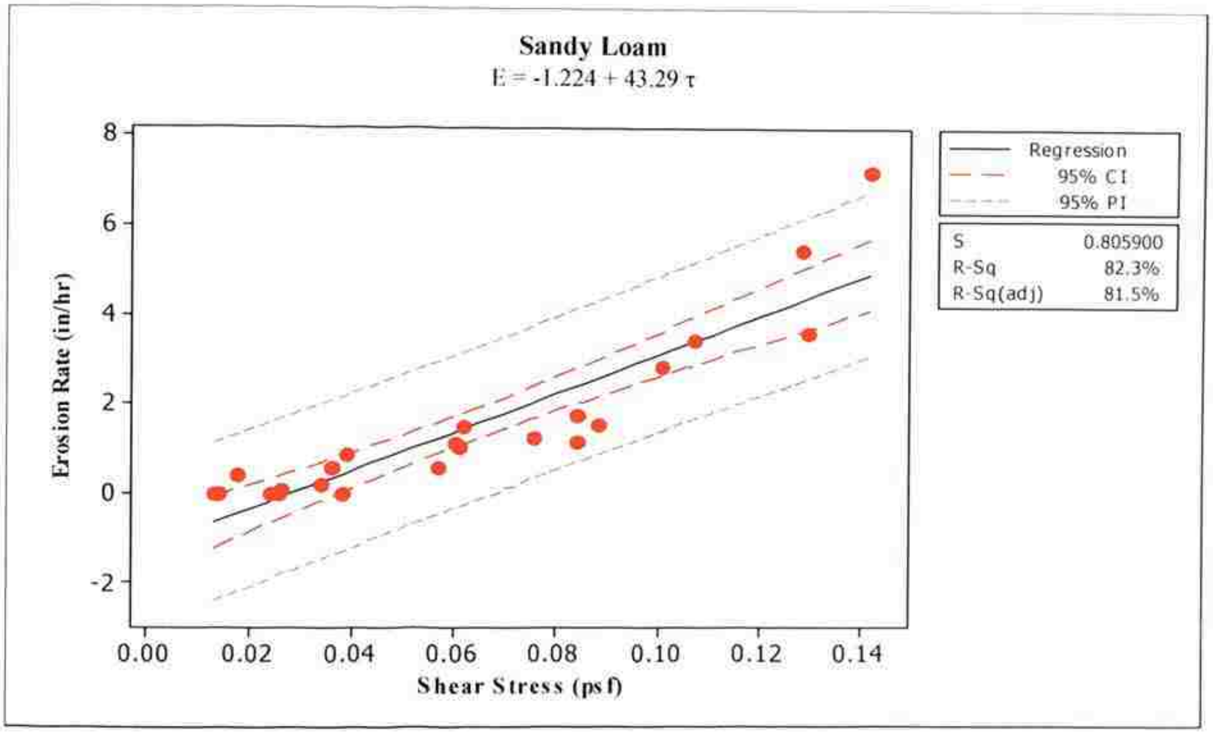


Figure 5.27. Combined Data Plot for Sandy Loam

The best fit line obtained for the Sandy Loam group is given by

$$E = 43.29\ \tau - 1.224 \qquad (5.4)$$

Soil samples collected from two different creeks were tested in the Sandy Loam group. The R-squared value obtained for the Sandy Loam soil group is .823.

The slope of linear fit obtained for the Silty Loam group is 11.14 while the slope of the Sandy Loam group is 43.29. The greater slope of the Sandy Loam group indicates a higher erosion rate for Sandy Loam soils than for Silty Loam soils.

5.3. ANALYSIS OF PREPARED SAMPLE WITH SOIL PROPERTIES

5.3.1. Comparison of Similar Soil Types. The linear fits obtained for the prepared samples were used for the comparison of erosion rate of similar soil types first. A combined data plot used to establish the relationship between the erosion rate and any of the soil properties for Soil A is shown in Figure 5.28. The slope of the linear fit is a good indicator of soil erosion rate. In Figure 5.28, Soil A1 has the highest slope for the linear fit, indicating the highest erosion rate for Soil A1 as compared to other soils in Soil A. Hence, the slope of linear fit obtained for each soil type was analyzed with the soil properties analyzed for Soil A. Most of the soil types in Soil A showed a relationship to the dry unit weight of the soil. Soil A1, with least dry unit weight, had highest slope for the linear fit, while all the other soils had dry unit weight greater than 1.7 and showed a higher resistance to erosion when compared to Soil A1. Soil A4, A5, A6, and A7 had dry unit weights higher than 1.8 g/cm^3 and all of them showed higher resistance to erosion.

All the three soil types had a similar trend when their erosion rates were compared with the dry unit weight of the soil. The slope of the linear fit obtained for each soil type was found to increase with an increase in the dry unit weight of the soil. The combined data plot obtained for Soils B and C are shown in Figures 5.29 and 5.30, respectively. The dry unit weight of each soil is listed in the graph.

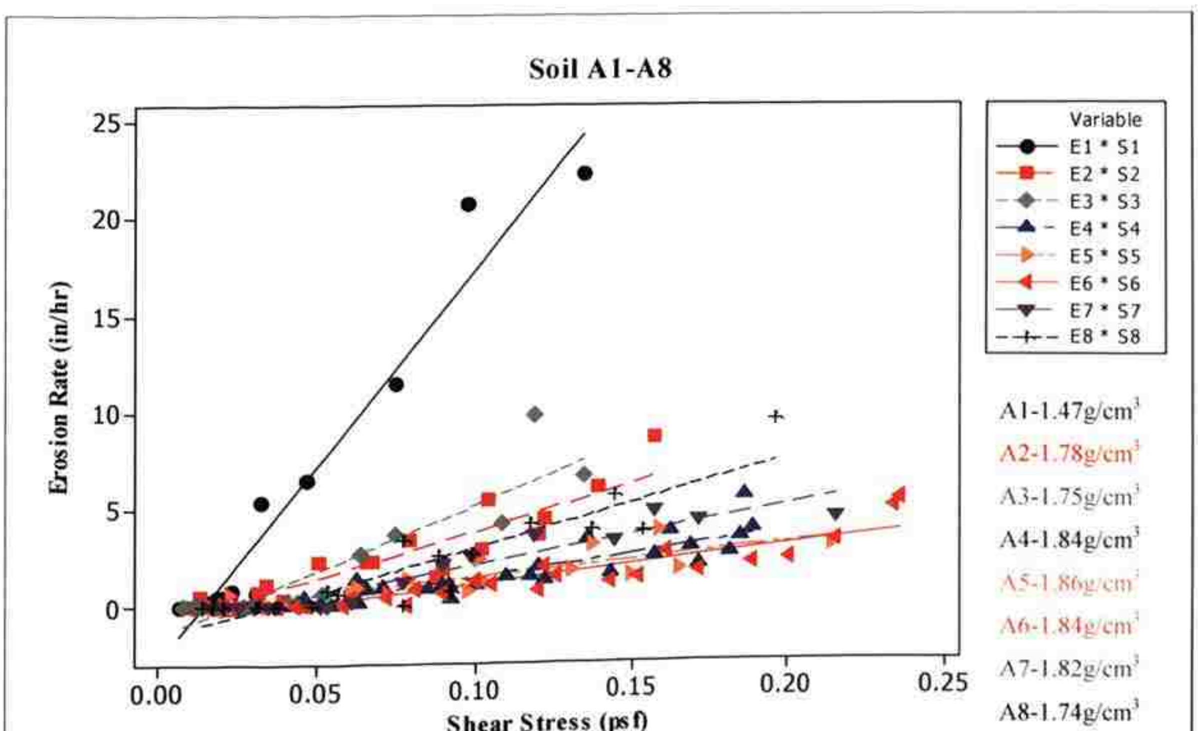


Figure 5.28. Combined Data Plot Along with Linear Fit for Soil A1 to A8

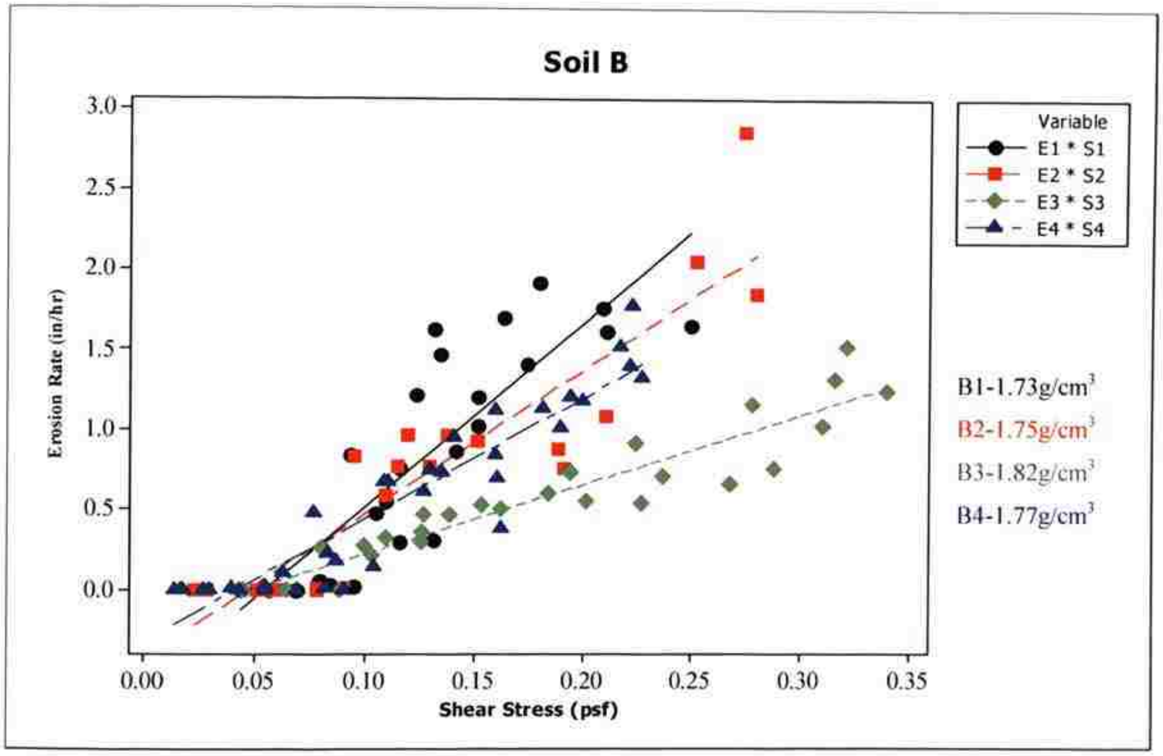


Figure 5.29. Combined Data Plot Along with Linear Fit for Soil B1 to B4

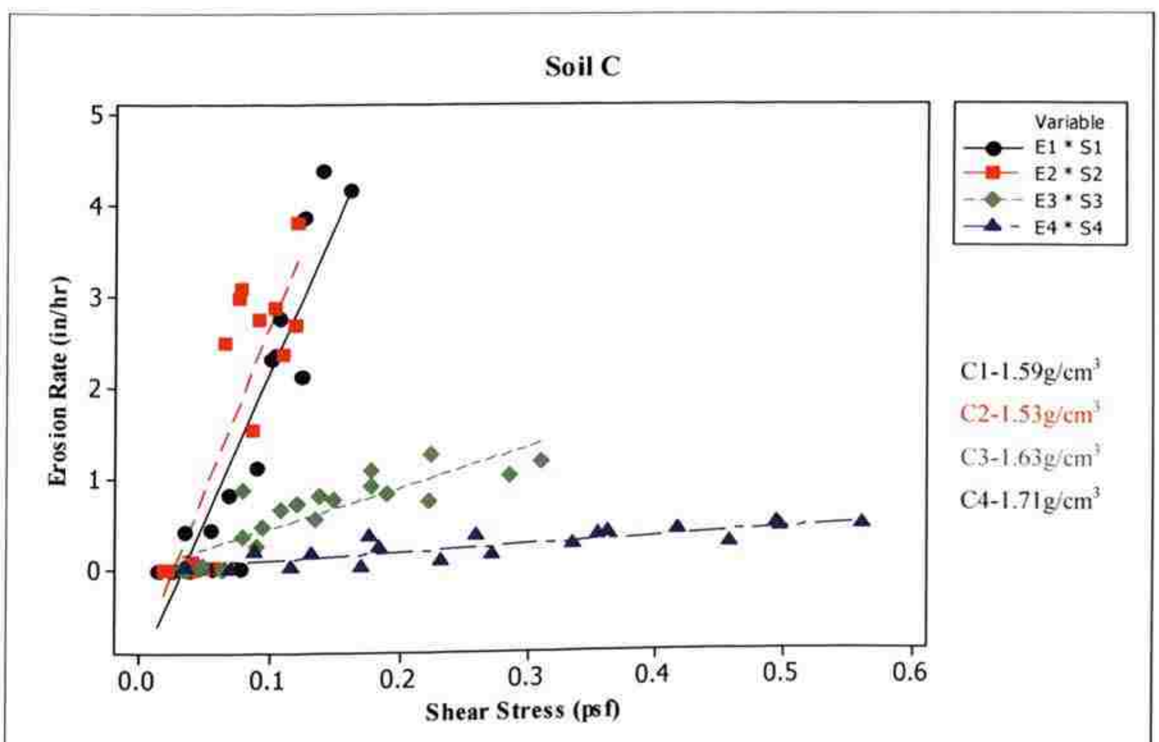


Figure 5.30. Combined Data Plot Along with Linear Fit for Soil C1 to C4

Among the Soil B group, Soils B1, B2, and B4 had similar dry unit weight and similar erosion rates, while Soil B3 had a higher dry unit weight and a lower erosion rate as compared to the other three soils. Soil C also showed a similar trend.

5.3.2. Comparison of Similar Soil Types with Similar Dry Unit Weights. From Soil A, the samples with similar dry unit weight were plotted together and the linear fit obtained showed a high correlation of data points with an R-squared value of about 0.75. Soils A2, A3, and A8, with an average dry unit weight of 1.76 g/cm^3, were plotted together and are shown in Figure 5.31. Similarly, Soils A4, A5, A6, and A7, with an average dry unit weight of 1.84 g/cm^3, are plotted in Figure 5.32. The slopes of the two plots were 49.23 and 22.24, respectively, which indicates higher erosion rate for lower dry unit weight.

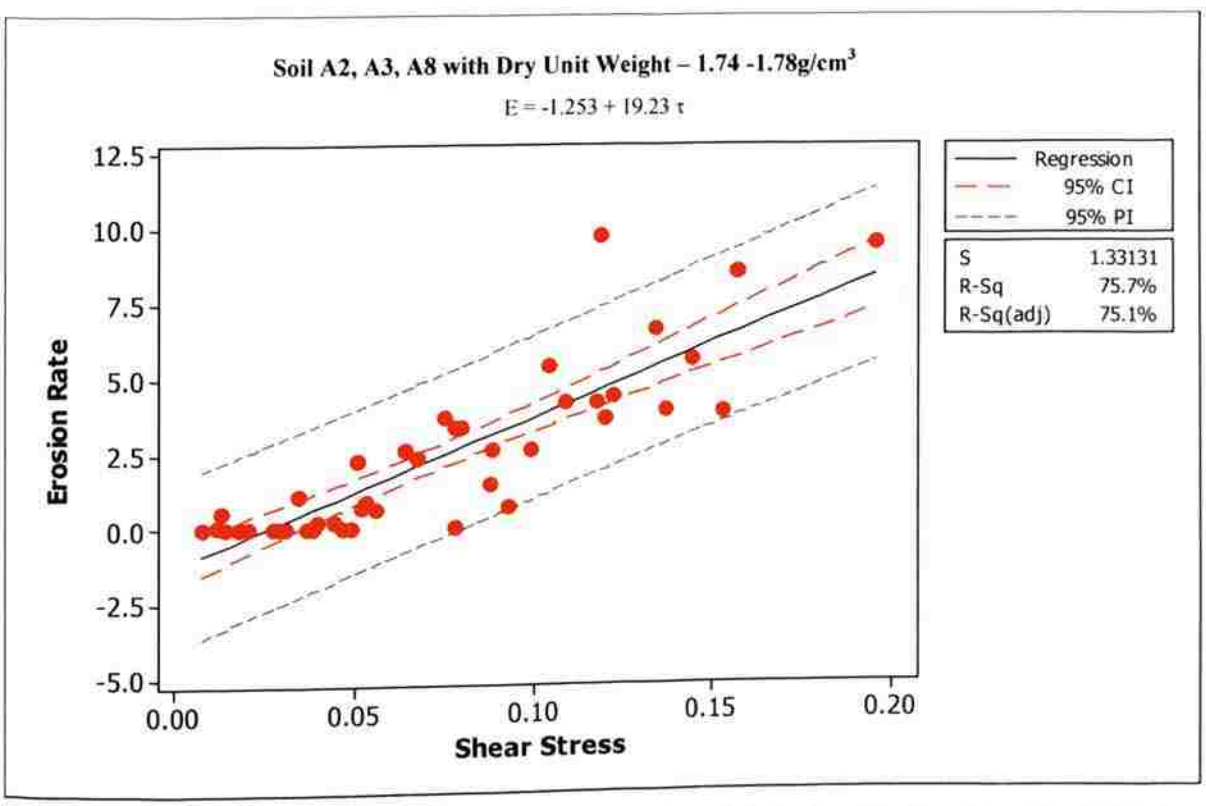


Figure 5.31. Combined Data Plot for Soil A2, A3 and A8 with Similar Dry Unit Weight

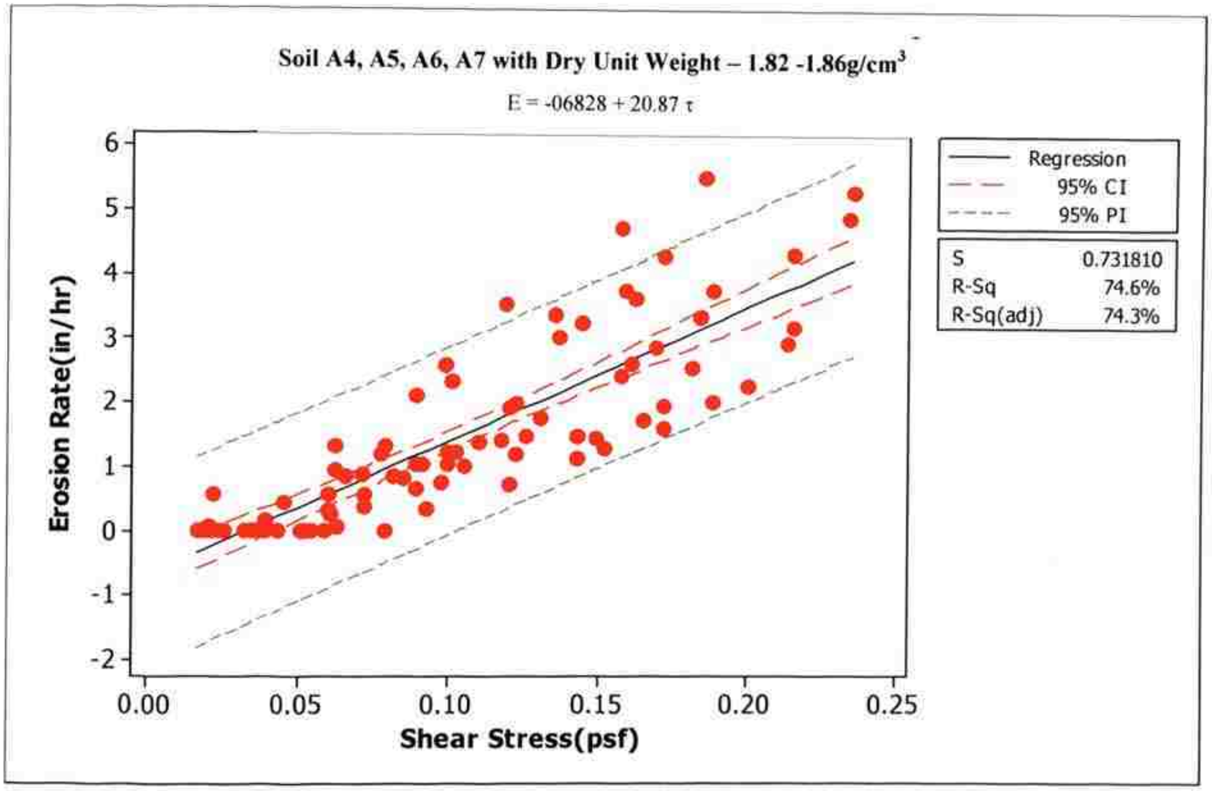


Figure 5.32. Combined Data Plot for Soil A4, A5, A6 and A7 with Similar Dry Unit Weight

5.3.3. Comparison of Different Soil Types with Similar Unit Weights. The comparison of flume experiment results for the same soil types in Sections 5.3.2 and 5.3.3 showed a relationship between the erosion rate and the dry unit weight of the soil. The samples of the three different Soils A, B, and C were compared to analyze the effect of any other soil parameter that affected the erosion rate of soil. Samples with similar dry unit weights were selected for this analysis to minimize the effect of dry unit weight. The soil types selected were Soils A8, B4, and C4, with dry unit weights of 1.74, 1.77, and 1.71 g/cm^3, respectively. Figure 5.31 shows the linear fit obtained for these three soil types. The only difference in the three soil types was in the percentage clay content. Soil A8 had minimal clay content and showed the highest erosion rate. Soil B4 had 10% more clay content than Soil A8 and 10% less than Soil C4. Soil C4, with highest clay content, has the lowest erosion rate. Thus, the analysis performed on three different prepared soil types indicated the effect of percentage clay in the erosion rate of soil.

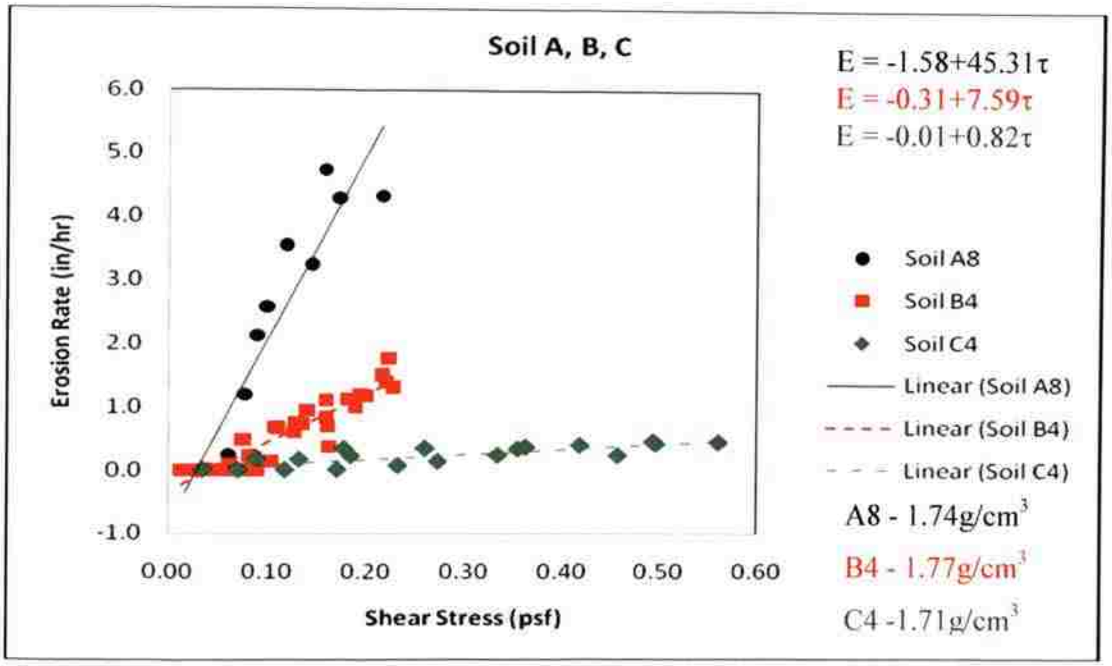


Figure 5.33. Comparison of Soil A8, B4 and C4

5.4. MULTIPLE REGRESSION ANALYSIS

In the prepared soil analysis, it was found that the dry unit weight of the soil and the percentage clay were the two major soil parameters affecting soil erosion rate. Hence, a multiple regression analysis was performed on the results obtained for natural soils to predict erosion rates based these two soil parameters. As the erosion rate varies with increases in the shear stress values, the slope (*S*) and the erosion rate axis intercept (*Y*) of the linear fit obtained were used to perform the multiple regression analysis. The linear fit obtained was in the form given below:

$$E = S\tau - Y \tag{5.5}$$

where, E = erosion rate (in/hr)

S = Slope (ft/ft)

τ = Shear Stress (psf)

Y = Erosion Rate Axis Intercept (in/hr)

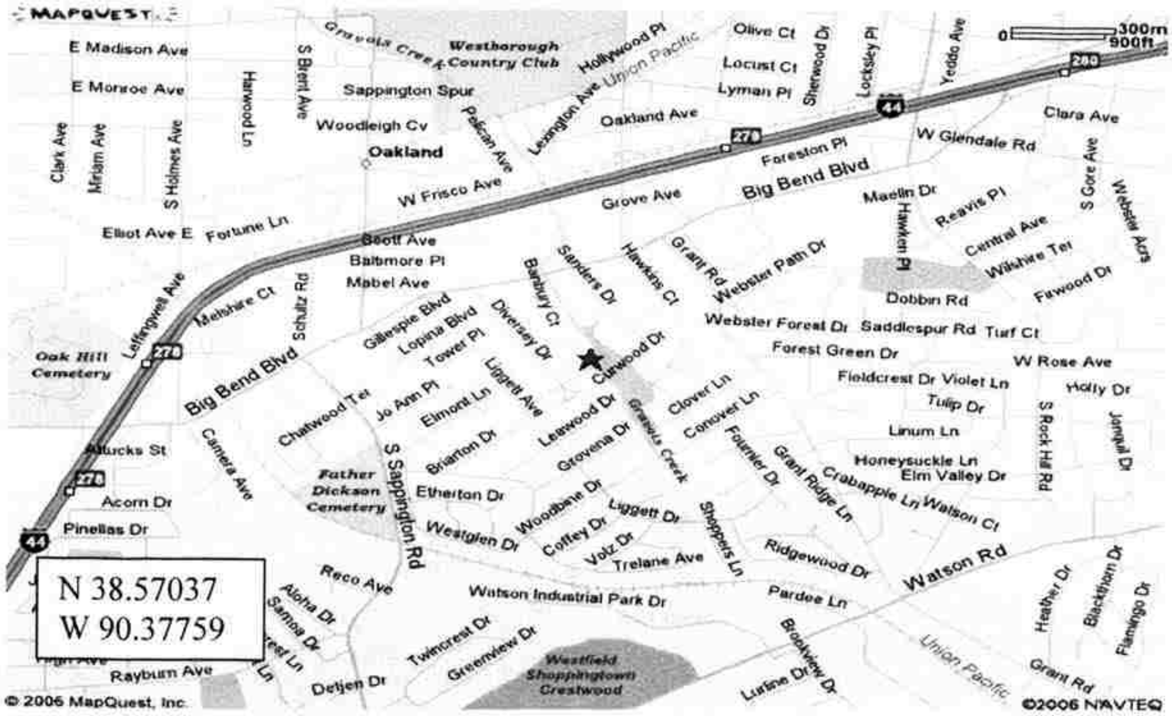


Figure D.1. Sampling Location of Soil Type 20B at Gravois Creek

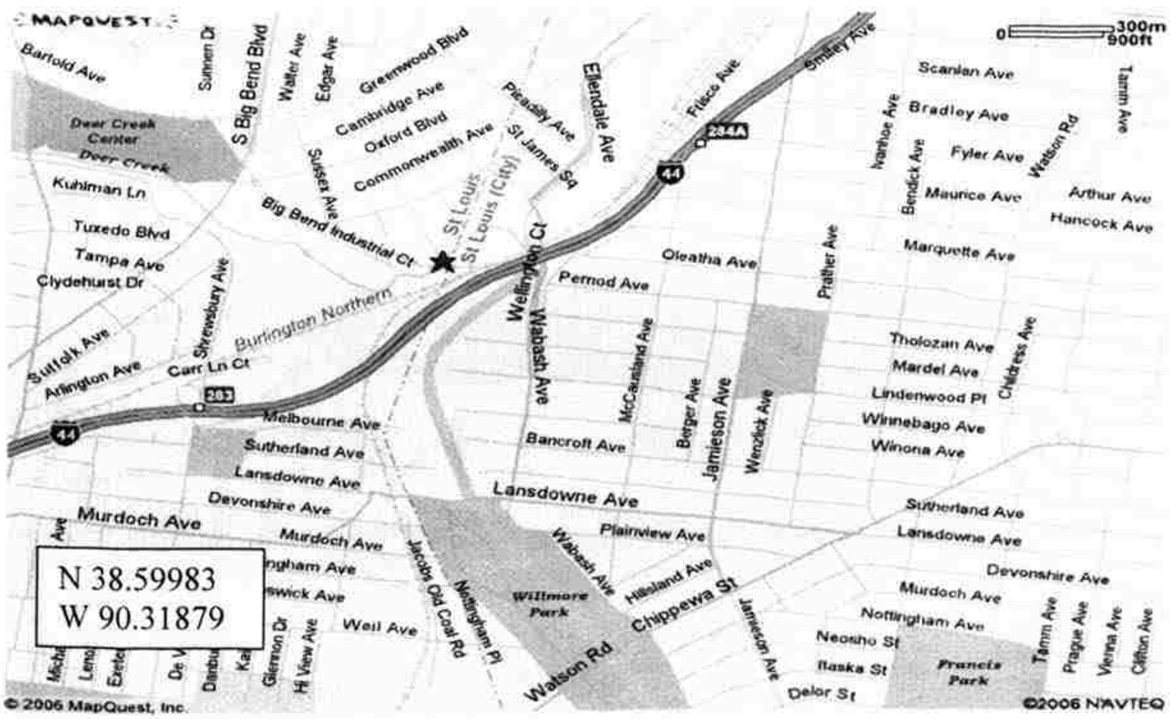


Figure D.2. Sampling Location of Soil Type 20B at Deer Creek

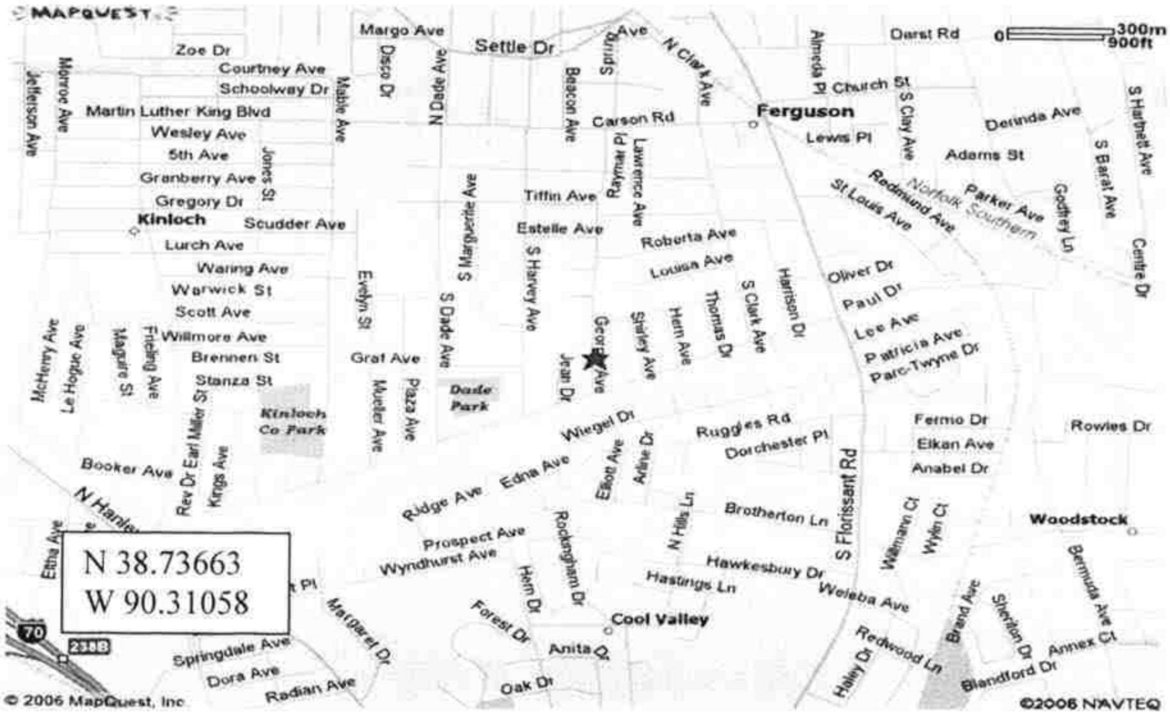


Figure D.3. Sampling Location of Soil Type 20B at Creve Coeur Creek

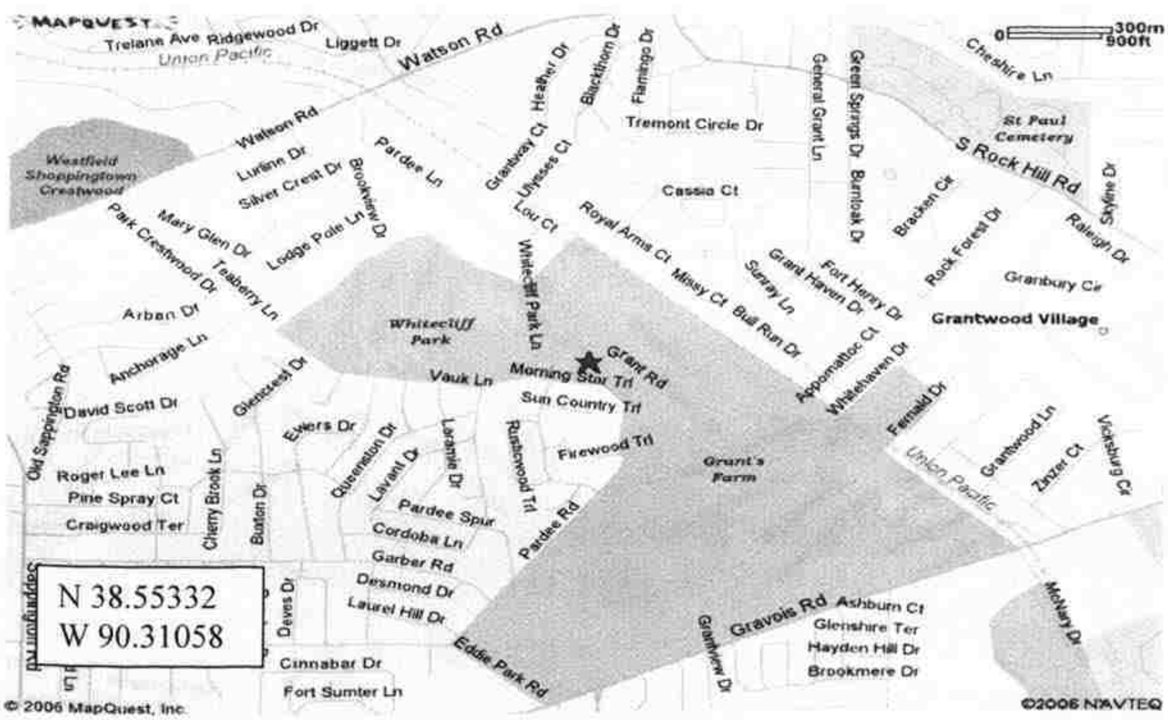


Figure D.4. Sampling Location of Soil Type 32 at Gravois Creek

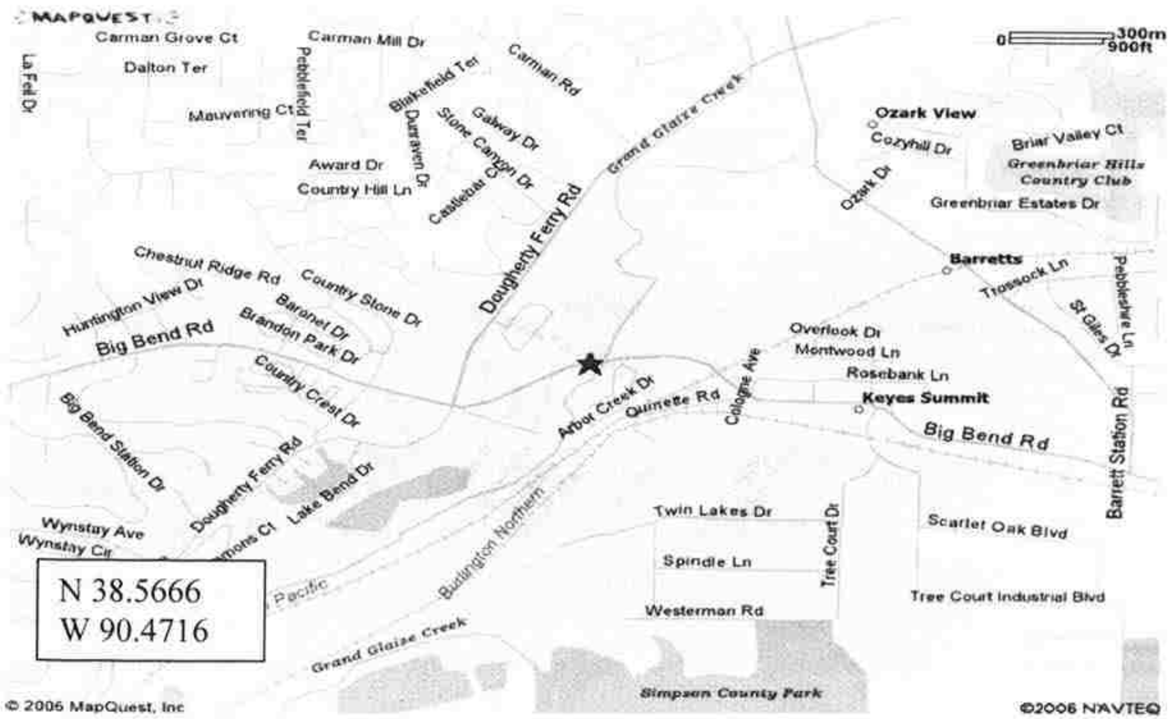


Figure D.5. Sampling Location of Soil Type 32 at Grand Glaize Creek

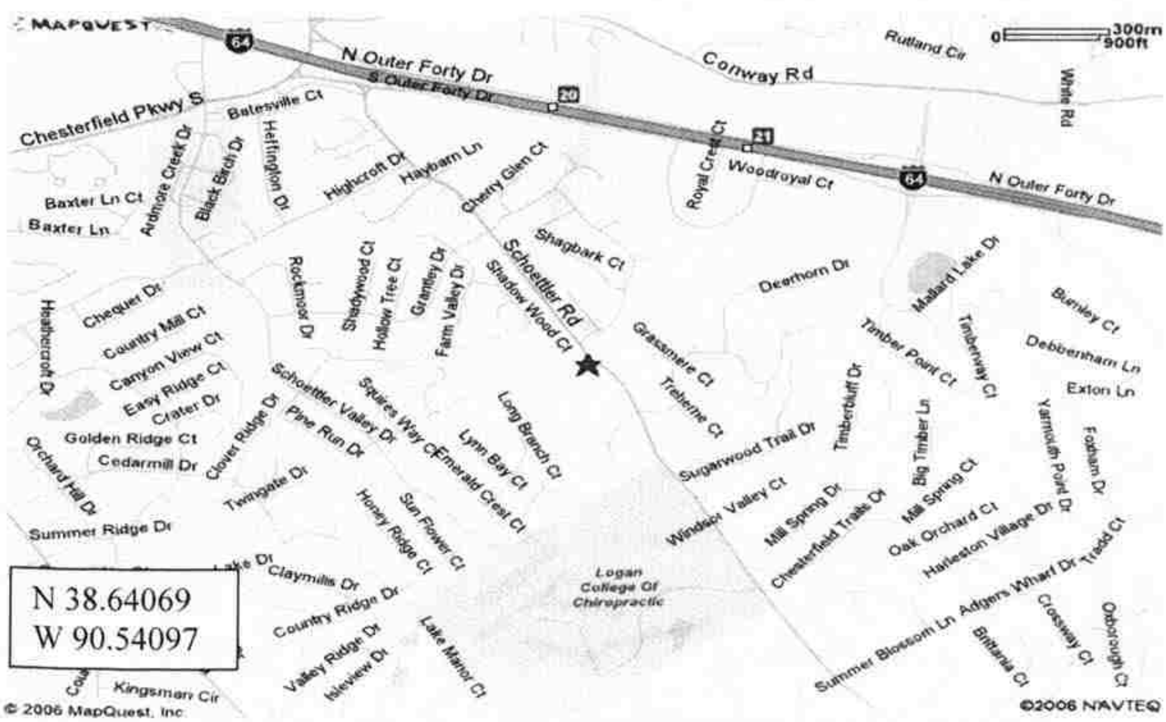


Figure D.6. Sampling Location of Soil Type 32 at Creve Coeur Creek

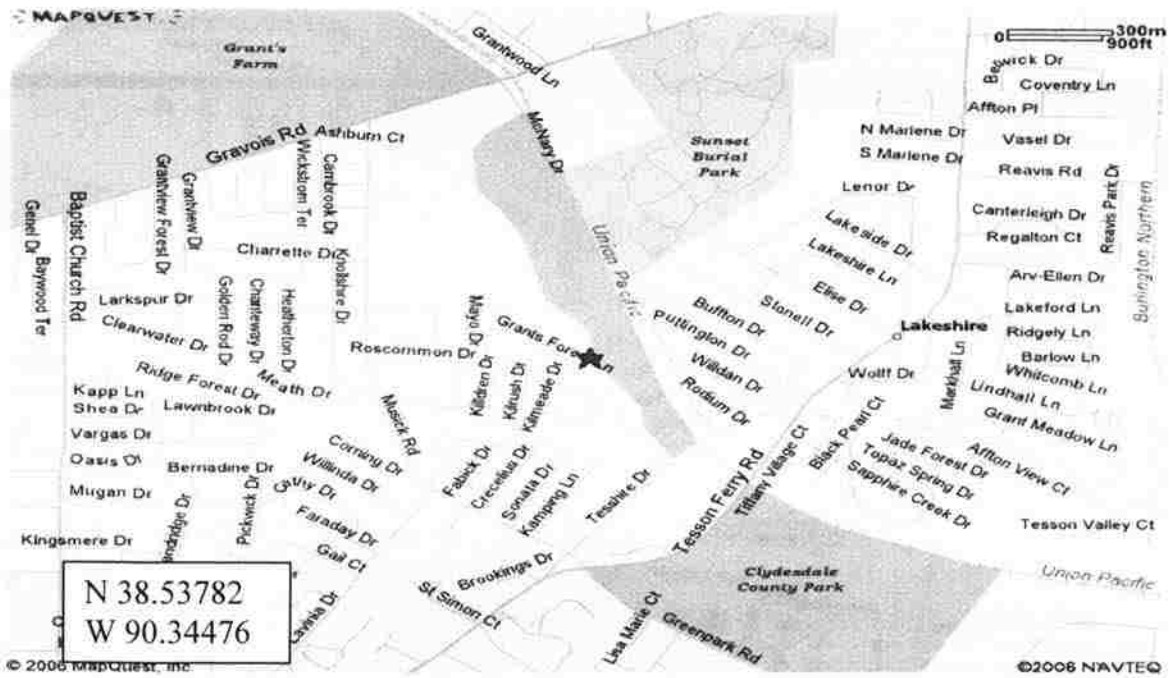


Figure D.9. Sampling Location of Soil Type 33 at Gravois Creek

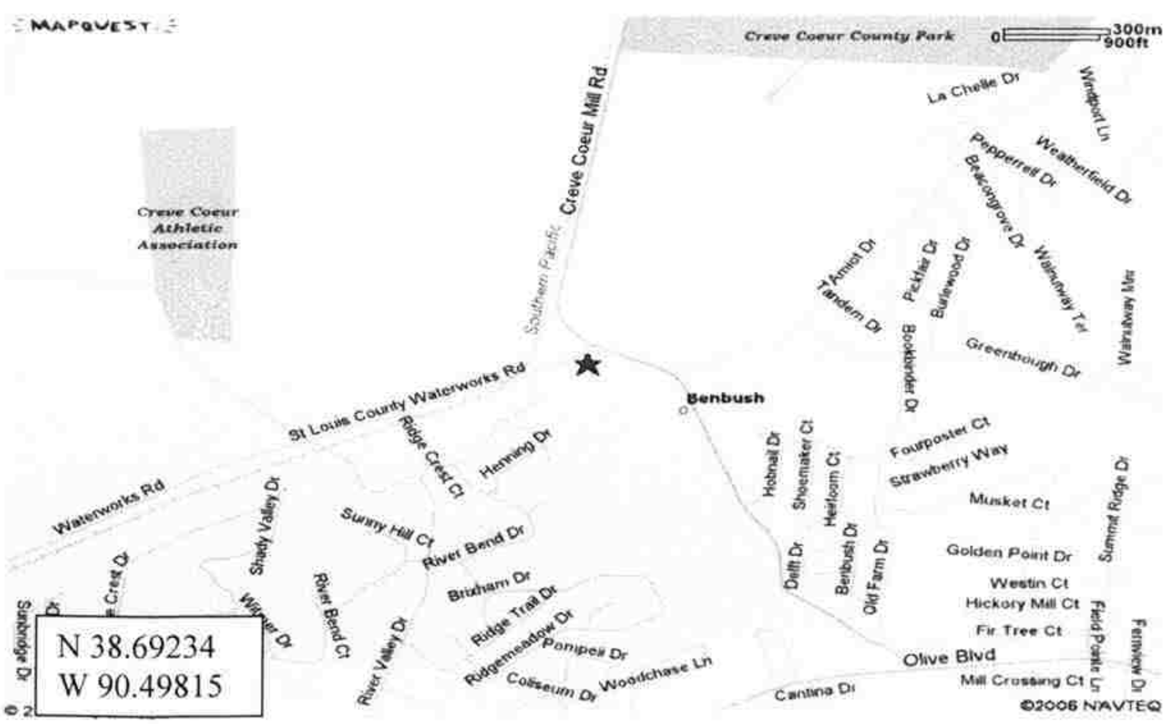


Figure D.10. Sampling Location of Soil Type 33 at Creve Coeur Creek

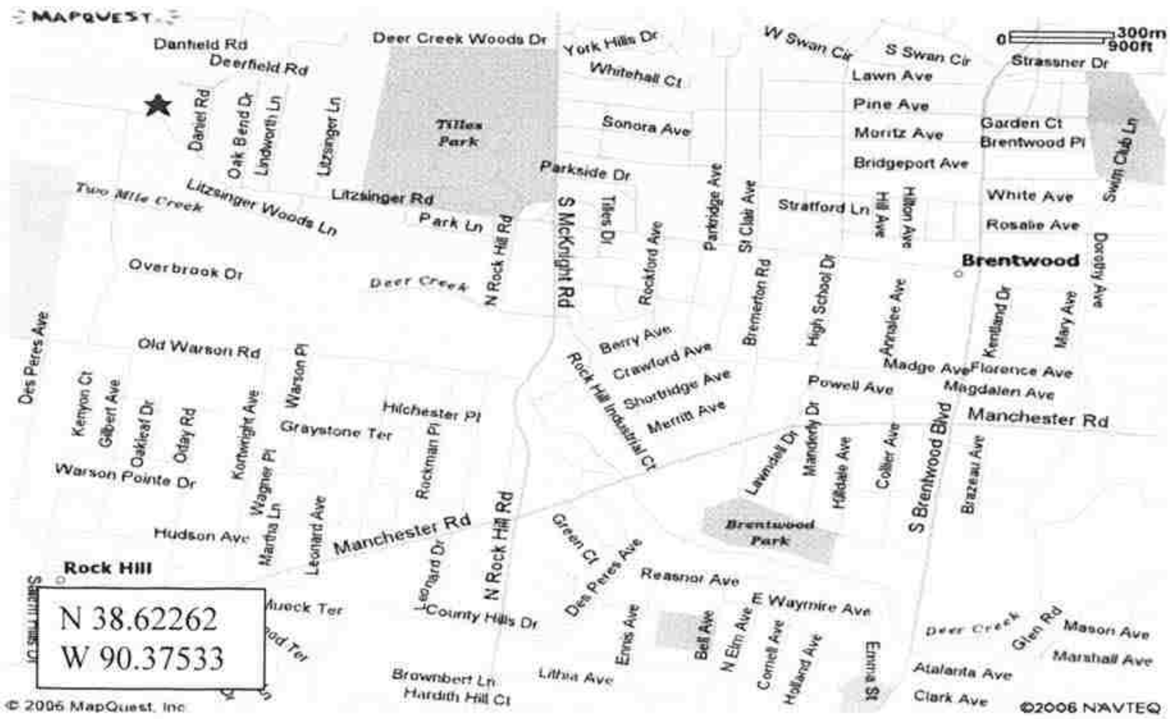


Figure D.11. Sampling Location of Soil Type 33 at Deer Creek

Hydrometer analysis

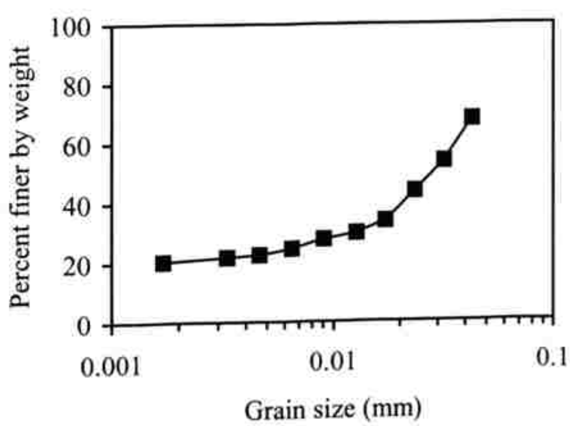
Analyst name: *Preetha Veeraraghavan*
Test date: *7/27/2006*
Sample description: *20B Deer Creek - Sample #1*

Mass in suspension W_0 = *50.00* g
Specific unit weight G_s = *2.65*
Dispersing agent correction C_d = *4.00* g/L
Menicus correction C_m = *0.50* g/L
Cylinder diameter d_c = *6.00* cm
Hydrometer bulb volume V_b = *60* cm^3

Graduation mark on hydrometer stem (g/L) R_s	Distance to bulb center (cm) H_s
0	17.8
10	16.1
20	14.5
30	12.9
40	11.4
50	9.8
60	8.1

Time (min) t	Hydrometer reading (g/L) Rt	Temperature (°C) Te	Corrected distance of fall (cm) HR	Grain size (mm) D	Percent finer by weight p
1	37	22	10.36	0.0430	67.8
2	30	22	11.55	0.0321	53.8
4	25	22	12.40	0.0235	43.8
8	20	22	13.25	0.0172	33.8
15	18	22	13.59	0.0127	29.8
30	17	22	13.76	0.0090	27.8
60	15.5	21.5	14.02	0.0065	24.6
120	14.5	21.5	14.19	0.0046	22.6
240	14.2	21	14.24	0.0033	21.8
900	13.5	21	14.36	0.0017	20.4

Clay fraction (%) = 20.6



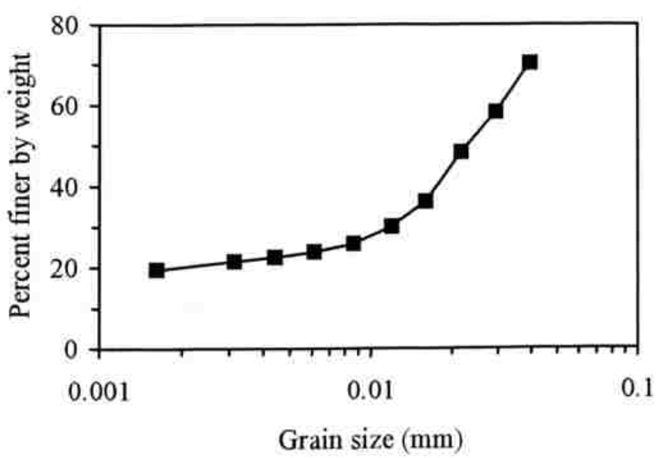
Hydrometer analysis

Analyst name: *Preetha Veeraraghavan*
Test date: *8/12/2006*
Sample description: 20B Deer Creek Sample #2

Mass in suspension =	*50.00*	g
Specific unit weight =	*2.65*	
Dispersing agent correction =	*4.00*	g/L
Menicus correction =	*0.50*	g/L
Cylinder diameter =	*5.95*	cm
Hydrometer number =	*1*	

Time (min)	Hydrometer reading (g/L)	Temperature (°C)	Corrected distance of fall (cm)	Grain size (mm)	Percent finer by weight
t	Rt	Te	HR	D	p
1	*38*	*23*	*9.15*	*0.0399*	*70.2*
2	*32*	*23*	*10.11*	*0.0297*	*58.2*
4	*27*	*23*	*10.91*	*0.0218*	*48.2*
8	*21*	*23*	*11.87*	*0.0161*	*36.2*
15	*18*	*22.75*	*12.35*	*0.0120*	*30.1*
30	*16*	*22.25*	*12.67*	*0.0087*	*25.9*
60	*15*	*22.25*	*12.83*	*0.0062*	*23.9*
120	*14.5*	*21.5*	*12.91*	*0.0044*	*22.6*
240	*14*	*21.25*	*12.99*	*0.0031*	*21.5*
900	*13*	*21.5*	*13.15*	*0.0016*	*19.6*

Clay fraction (%) = 20.0



Hydrometer analysis

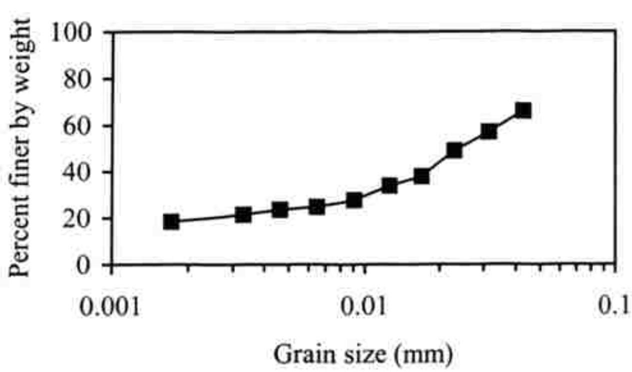
Analyst name: *Preetha Veeraraghavan*
Test date: *7/29/2006*
Sample description: *20B Gravois Creek Sample #1*

Mass in suspension W_0 =	*50.00*	g
Specific unit weight G_s =	*2.65*	
Dispersing agent correction C_d =	*4.00*	g/L
Menicus correction C_m =	*0.50*	g/L
Cylinder diameter d_c =	*6.00*	cm
Hydrometer bulb volume V_b =	*60*	cm^3

Graduation mark on hydrometer stem (g/L) R_s	Distance to bulb center (cm) H_s
0	18
10	16.2
20	14.5
30	12.9
40	11.2
50	9.5
60	7.9

Time (min) t	Hydrometer reading (g/L) Rt	Temperature (°C) Te	Corrected distance of fall (cm) HR	Grain size (mm) D	Percent finer by weight p
1	36	22.5	10.37	0.0428	66.0
2	31.5	22.5	11.18	0.0314	57.0
4	27.5	22.5	11.90	0.0229	49.0
8	22	22.5	12.89	0.0169	38.0
15	20	22.25	13.25	0.0125	33.9
30	17	22	13.79	0.0091	27.8
60	15.5	22	14.06	0.0065	24.8
120	15	21.5	14.15	0.0046	23.6
240	14	21.25	14.33	0.0033	21.5
900	12.5	21	14.60	0.0017	18.4

Clay fraction (%) = 18.9



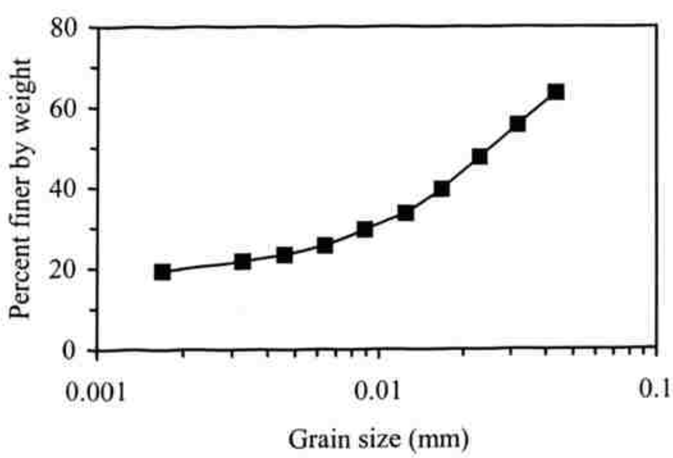
Hydrometer analysis

Analyst name: *Preetha Veeraraghavan*
Test date: *8/15/2006*
Sample description: 20B Gravois Creek Sample #2

Mass in suspension = *50.00* g
Specific unit weight = *2.65*
Dispersing agent correction = *4.00* g/L
Menicus correction = *0.50* g/L
Cylinder diameter = *6.00* cm
Hydrometer number = *2*

Time (min)	Hydrometer reading (g/L)	Temperature (°C)	Corrected distance of fall (cm)	Grain size (mm)	Percent finer by weight
t	Rt	Te	HR	D	p
1	35	21.5	10.51	0.0436	63.6
2	31	21.5	11.15	0.0317	55.6
4	27	21.5	11.80	0.0231	47.6
8	23	21.5	12.45	0.0168	39.6
15	20	21.5	12.93	0.0125	33.6
30	18	21.5	13.25	0.0089	29.6
60	16	21.5	13.58	0.0064	25.6
120	15	21	13.74	0.0046	23.4
240	14.25	20.75	13.86	0.0033	21.8
900	13	21	14.06	0.0017	19.4

Clay fraction (%) = 19.8



Hydrometer analysis

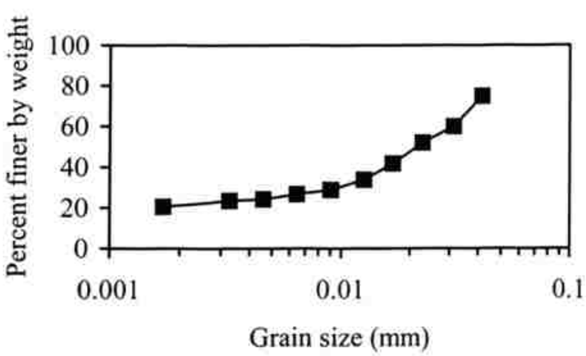
Analyst name: *Preetha Veeraraghavan*
Test date: *7/28/2006*
Sample description: *20B Creve Coeur Creek Sample # 1*

Mass in suspension W_0 =	50.00	g
Specific unit weight G_s =	2.65	
Dispersing agent correction C_d =	4.00	g/L
Menicus correction C_m =	0.50	g/L
Cylinder diameter d_c =	6.00	cm
Hydrometer bulb volume V_b =	60	cm^3

Graduation mark on hydrometer stem (g/L) R_s	Distance to bulb center (cm) H_s
0	17.8
10	16.1
20	14.5
30	12.9
40	11.4
50	9.8
60	8.1

Time (min) t	Hydrometer reading (g/L) Rt	Temperature (°C) Te	Corrected distance of fall (cm) HR	Grain size (mm) D	Percent finer by weight p
1	40.5	22.5	9.77	0.0415	75.0
2	33	22.5	11.04	0.0312	60.0
4	29	22.5	11.72	0.0227	52.0
8	24	22	12.57	0.0167	41.8
15	20	22	13.25	0.0126	33.8
30	17.5	22	13.68	0.0090	28.8
60	16.5	21.75	13.85	0.0064	26.7
120	15.25	21.75	14.06	0.0046	24.2
240	15	21.25	14.10	0.0033	23.5
900	13.5	21.25	14.36	0.0017	20.5

Clay fraction (%) = 21.0



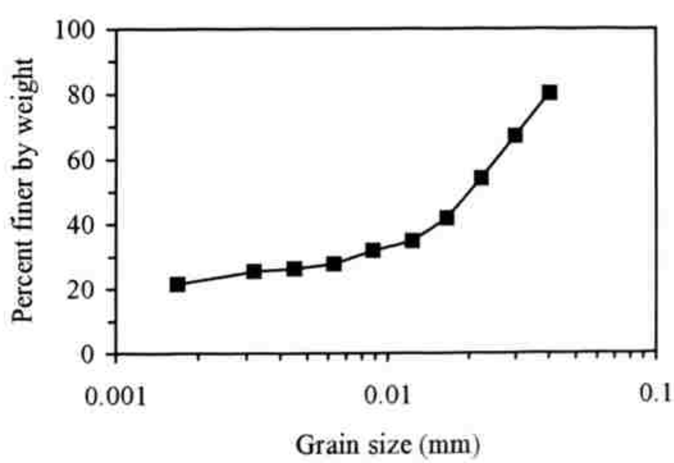
Hydrometer analysis

Analyst name: *Preetha Veeraraghavan*
Test date: *8/12/2006*
Sample description: 20B Creve Coeur Sample #2

Mass in suspension = *50.00* g
Specific unit weight = *2.65*
Dispersing agent correction = *4.00* g/L
Menicus correction = *0.50* g/L
Cylinder diameter = *5.95* cm
Hydrometer number = *2*

Time (min) t	Hydrometer reading (g/L) Rt	Temperature (°C) Te	Corrected distance of fall (cm) HR	Grain size (mm) D	Percent finer by weight p
1	43	22.5	9.20	0.0403	80.0
2	36.5	22.5	10.25	0.0301	67.0
4	30	22.5	11.30	0.0223	54.0
8	24	22	12.27	0.0165	41.8
15	20.5	22	12.83	0.0124	34.8
30	19	22	13.07	0.0088	31.8
60	17	21.75	13.40	0.0063	27.7
120	16.25	21.75	13.52	0.0045	26.2
240	16	21.25	13.56	0.0032	25.5
900	14	21.25	13.88	0.0017	21.5

Clay fraction (%) = 22.3



Hydrometer analysis

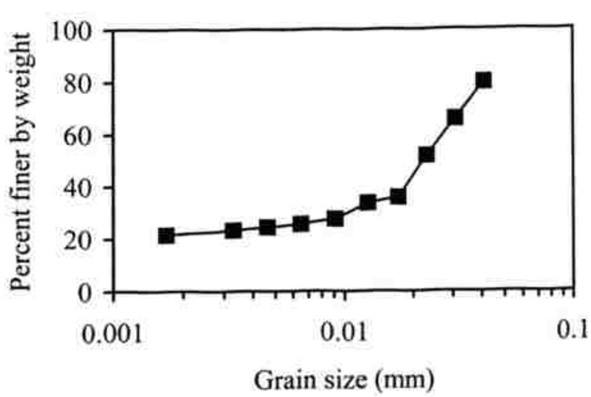
Analyst name: *Preetha Veeraraghavan*
Test date: *8/16/2006*
Sample description: *32 Creve Coeur Creek Sample # 1*

Mass in suspension W_0 = *50.00* g
Specific unit weight G_s = *2.65*
Dispersing agent correction C_d = *4.00* g/L
Menicus correction C_m = *0.50* g/L
Cylinder diameter d_c = *6.00* cm
Hydrometer bulb volume V_b = *60* cm^3

Graduation mark on hydrometer stem (g/L) R_s	Distance to bulb center (cm) H_s
0	17.8
10	16.1
20	14.5
30	12.9
40	11.4
50	9.8
60	8.1

Time (min) t	Hydrometer reading (g/L) Rt	Temperature (°C) Te	Corrected distance of fall (cm) HR	Grain size (mm) D	Percent finer by weight p
1	43	22	9.34	0.0408	79.7
2	36	22	10.53	0.0307	65.8
4	29	22	11.72	0.0229	51.8
8	21	22	13.08	0.0171	35.8
15	20	21.75	13.25	0.0126	33.7
30	17	21.5	13.76	0.0091	27.6
60	16	21.5	13.93	0.0065	25.6
120	15.5	21	14.02	0.0046	24.4
240	15	20.75	14.10	0.0033	23.3
900	14	21.25	14.27	0.0017	21.5

Clay fraction (%) = *21.8*



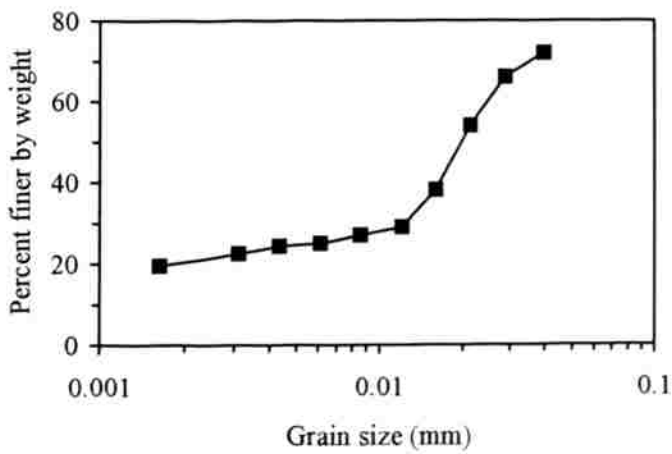
Hydrometer analysis

Analyst name: *Preetha Veeraraghavan*
Test date: *8/19/2006*
Sample description: 32 Creve Coeur Creek Sample #2

Mass in suspension =	*50.00*	g
Specific unit weight =	*2.65*	
Dispersing agent correction =	*4.00*	g/L
Menicus correction =	*0.50*	g/L
Cylinder diameter =	*6.00*	cm
Hydrometer number =	*1*	

Time (min) t	Hydrometer reading (g/L) Rt	Temperature (°C) Te	Corrected distance of fall (cm) HR	Grain size (mm) D	Percent finer by weight p
1	39	22.5	*9.00*	*0.0399*	*72.0*
2	36	22.5	*9.48*	*0.0289*	*66.0*
4	30	22.5	*10.44*	*0.0215*	*54.0*
8	22	22.5	*11.72*	*0.0161*	*38.0*
15	17.5	22.5	*12.44*	*0.0121*	*29.0*
30	16.5	22.5	*12.60*	*0.0086*	*27.0*
60	15.5	22.5	*12.76*	*0.0061*	*25.0*
120	15.25	22.25	*12.80*	*0.0044*	*24.4*
240	14.5	21.5	*12.92*	*0.0031*	*22.6*
900	13	21.5	*13.16*	*0.0016*	*19.6*

Clay fraction (%) = 20.3



Hydrometer analysis

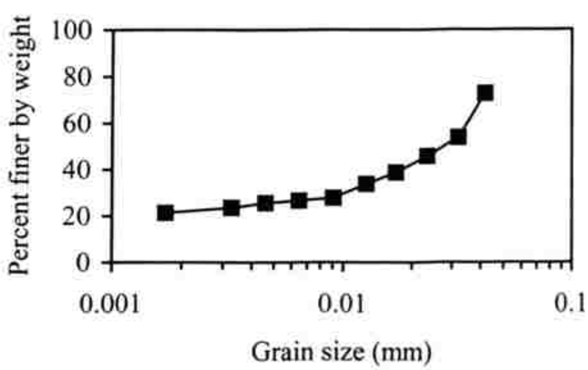
Analyst name: *Preetha Veeraraghavan*
Test date: *8/11/2006*
Sample description: *32 Grand Glaize Creek Sample # 1*

Mass in suspension W_0 =	*50.00*	g
Specific unit weight G_s =	*2.65*	
Dispersing agent correction C_d =	*4.00*	g/L
Menicus correction C_m =	*0.50*	g/L
Cylinder diameter d_c =	*6.00*	cm
Hydrometer bulb volume V_b =	*60*	cm^3

Graduation mark on hydrometer stem (g/L) R_s	Distance to bulb center (cm) H_s
0	18
10	16.2
20	14.5
30	12.9
40	11.2
50	9.5
60	7.9

Time (min) t	Hydrometer reading (g/L) Rt	Temperature (°C) Te	Corrected distance of fall (cm) HR	Grain size (mm) D	Percent finer by weight p
1	39.5	22	*9.74*	*0.0417*	*72.8*
2	30	22	*11.45*	*0.0320*	*53.8*
4	26	22	*12.17*	*0.0233*	*45.8*
8	22.5	22	*12.80*	*0.0169*	*38.8*
15	20	22	*13.25*	*0.0126*	*33.8*
30	17	22	*13.79*	*0.0091*	*27.8*
60	16.5	21.75	*13.88*	*0.0064*	*26.7*
120	16	21.5	*13.97*	*0.0046*	*25.6*
240	15	21.5	*14.15*	*0.0033*	*23.6*
900	14	21	*14.33*	*0.0017*	*21.4*

Clay fraction (%) = *21.8*



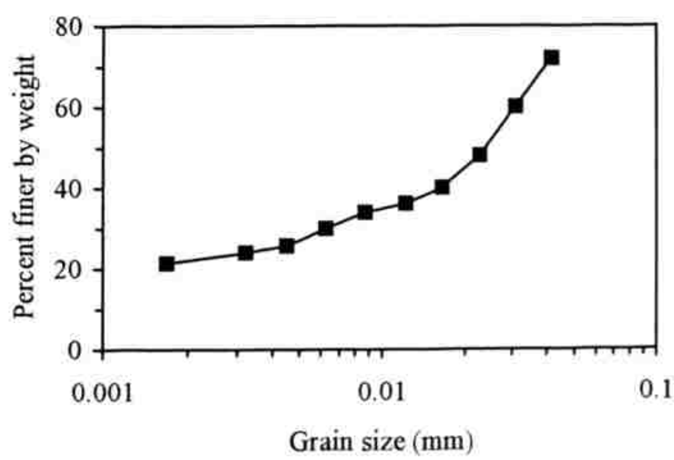
Hydrometer analysis

Analyst name: *Preetha Veeraraghavan*
Test date: *8/17/2006*
Sample description: 32 Grand Glaize Creek Sample #2

Mass in suspension =	*50.00*	g
Specific unit weight =	*2.65*	
Dispersing agent correction =	*4.00*	g/L
Menicus correction =	*0.50*	g/L
Cylinder diameter =	*6.00*	cm
Hydrometer number =	*2*	

Time (min)	Hydrometer reading (g/L)	Temperature (°C)	Corrected distance of fall (cm)	Grain size (mm)	Percent finer by weight
t	Rt	Te	HR	D	p
1	39	22.5	*9.86*	*0.0417*	*72.0*
2	33	22.5	*10.83*	*0.0309*	*60.0*
4	27	22.5	*11.80*	*0.0228*	*48.0*
8	23	22.5	*12.45*	*0.0166*	*40.0*
15	21	22.5	*12.77*	*0.0123*	*36.0*
30	20	22.25	*12.93*	*0.0087*	*33.9*
60	18	22.25	*13.25*	*0.0063*	*29.9*
120	16	21.6	*13.58*	*0.0045*	*25.6*
240	15.25	21.25	*13.70*	*0.0032*	*24.0*
900	14	21	*13.90*	*0.0017*	*21.4*

Clay fraction (%) = 21.9



Hydrometer analysis

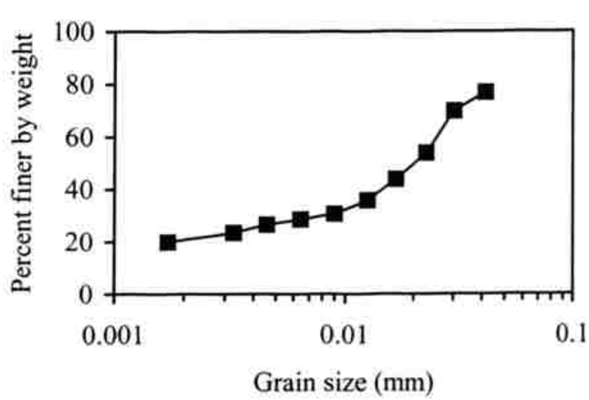
Analyst name: *Preetha Veeraraghavan*
Test date: *8/11/2006*
Sample description: *32 Gravois Creek Sample # 1*

Mass in suspension W_0 =	50.00	g
Specific unit weight G_s =	2.65	
Dispersing agent correction C_d =	4.00	g/L
Menicus correction C_m =	0.50	g/L
Cylinder diameter d_c =	6.00	cm
Hydrometer bulb volume V_b =	60	cm^3

Graduation mark on hydrometer stem (g/L) R_s	Distance to bulb center (cm) H_s
0	17.8
10	16.1
20	14.5
30	12.9
40	11.4
50	9.8
60	8.1

Time (min) t	Hydrometer reading (g/L) Rt	Temperature (°C) Te	Corrected distance of fall (cm) HR	Grain size (mm) D	Percent finer by weight p
1	41.5	22	9.60	0.0414	76.7
2	38	22	10.19	0.0302	69.8
4	30	22	11.55	0.0227	53.8
8	25	22	12.40	0.0166	43.8
15	21	22	13.08	0.0125	35.8
30	18.5	21.75	13.51	0.0090	30.7
60	17.5	21.5	13.68	0.0064	28.6
120	16.5	21.5	13.85	0.0046	26.6
240	15	21.25	14.10	0.0033	23.5
900	13.25	21	14.40	0.0017	19.9

Clay fraction (%) = 20.5



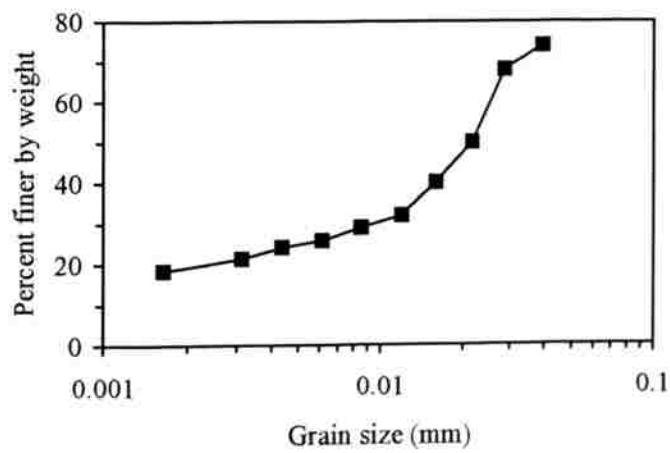
Hydrometer analysis

Analyst name: *Preetha Veeraraghavan*
Test date: *8/15/2006*
Sample description: 32 Gravois Creek Sample #2

Mass in suspension = *50.00* g
Specific unit weight = *2.65*
Dispersing agent correction = *4.00* g/L
Menicus correction = *0.50* g/L
Cylinder diameter = *5.95* cm
Hydrometer number = *1*

Time (min) t	Hydrometer reading (g/L) Rt	Temperature (°C) Te	Corrected distance of fall (cm) HR	Grain size (mm) D	Percent finer by weight p
1	40	22.5	8.83	0.0395	74.0
2	37	22.5	9.31	0.0287	68.0
4	28	22.5	10.75	0.0218	50.0
8	23	22.5	11.55	0.0160	40.0
15	19	22.5	12.19	0.0120	32.0
30	17.5	22.4	12.43	0.0086	28.9
60	16	22	12.67	0.0061	25.8
120	15.25	21.5	12.79	0.0044	24.1
240	14	21	12.99	0.0031	21.4
900	12.5	21	13.23	0.0016	18.4

Clay fraction (%) = 19.0



Hydrometer analysis

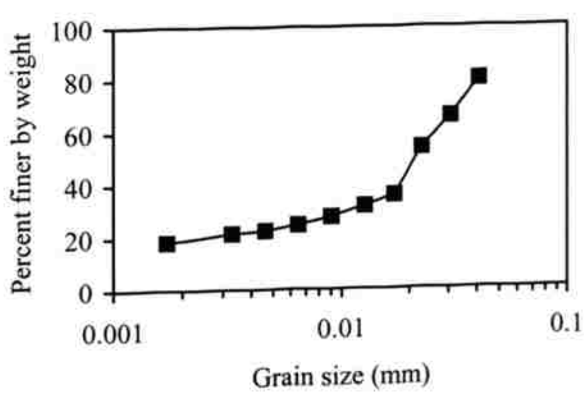
Analyst name: *Preetha Veeraraghavan*
Test date: *8/17/2006*
Sample description: *33 Creve Coeur Creek Sample # 1*

Mass in suspension W_0 =	50.00	g
Specific unit weight G_s =	2.65	
Dispersing agent correction C_d =	4.00	g/L
Menicus correction C_m =	0.50	g/L
Cylinder diameter d_c =	6.00	cm
Hydrometer bulb volume V_b =	60	cm^3

Graduation mark on hydrometer stem (g/L) R_s	Distance to bulb center (cm) H_s
0	17.8
10	16.1
20	14.5
30	12.9
40	11.4
50	9.8
60	8.1

Time (min) t	Hydrometer reading (g/L) Rt	Temperature (°C) Te	Corrected distance of fall (cm) HR	Grain size (mm) D	Percent finer by weight p
1	43	22	9.34	0.0408	79.7
2	36	22	10.53	0.0307	65.8
4	30	22	11.55	0.0227	53.8
8	21	22	13.08	0.0171	35.8
15	19	22	13.42	0.0126	31.8
30	17	22	13.76	0.0090	27.8
60	15.5	21.75	14.02	0.0065	24.7
120	14.5	21.5	14.19	0.0046	22.6
240	14	21.25	14.27	0.0033	21.5
900	12.5	21	14.53	0.0017	18.4

Clay fraction (%) = *18.9*



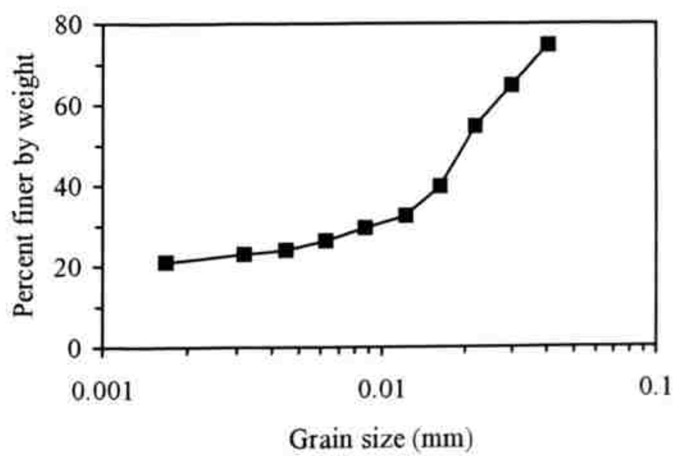
Hydrometer analysis

Analyst name: *Preetha Veeraraghavan*
Test date: *8/20/2006*
Sample description: 33 Creve Coeur Creek Sample #2

Mass in suspension =	*50.00*	g
Specific unit weight =	*2.65*	
Dispersing agent correction =	*4.00*	g/L
Menicus correction =	*0.50*	g/L
Cylinder diameter =	*6.00*	cm
Hydrometer number =	*2*	

Time (min)	Hydrometer reading (g/L)	Temperature (°C)	Corrected distance of fall (cm)	Grain size (mm)	Percent finer by weight
t	Rt	Te	HR	D	p
1	40	24	*9.70*	*0.0407*	*74.6*
2	35	24	*10.51*	*0.0299*	*64.6*
4	30	24	*11.32*	*0.0220*	*54.6*
8	22.5	24	*12.53*	*0.0163*	*39.6*
15	19	23.5	*13.09*	*0.0123*	*32.4*
30	17.5	23.5	*13.33*	*0.0088*	*29.4*
60	16	23.25	*13.58*	*0.0063*	*26.3*
120	15	22.5	*13.74*	*0.0045*	*24.0*
240	14.5	22.5	*13.82*	*0.0032*	*23.0*
900	13.75	21.5	*13.94*	*0.0017*	*21.1*

Clay fraction (%) = 21.5



Hydrometer analysis

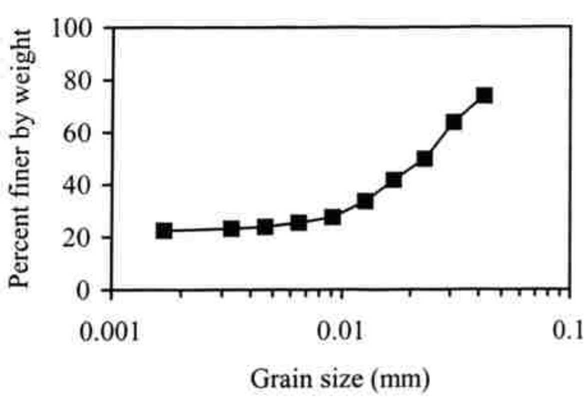
Analyst name: *Preetha Veeraraghavan*
Test date: *8/16/2006*
Sample description: *33 Deer Creek Sample # 1*

Mass in suspension W_0 =	*50.00*	g
Specific unit weight G_s =	*2.65*	
Dispersing agent correction C_d =	*4.00*	g/L
Menicus correction C_m =	*0.50*	g/L
Cylinder diameter d_c =	*6.00*	cm
Hydrometer bulb volume V_b =	*60*	cm^3

Graduation mark on hydrometer stem (g/L) R_s	Distance to bulb center (cm) H_s
0	17.8
10	16.1
20	14.5
30	12.9
40	11.4
50	9.8
60	8.1

Time (min) t	Hydrometer reading (g/L) Rt	Temperature (°C) Te	Corrected distance of fall (cm) HR	Grain size (mm) D	Percent finer by weight p
1	40	22	*9.85*	*0.0419*	*73.8*
2	35	22	*10.70*	*0.0309*	*63.8*
4	28	22	*11.89*	*0.0230*	*49.8*
8	24	22	*12.57*	*0.0167*	*41.8*
15	20	21.75	*13.25*	*0.0126*	*33.7*
30	17	21.5	*13.76*	*0.0091*	*27.6*
60	16	21.25	*13.93*	*0.0065*	*25.5*
120	15.25	21	*14.06*	*0.0046*	*23.9*
240	15	20.75	*14.10*	*0.0033*	*23.3*
900	14.5	21.25	*14.19*	*0.0017*	*22.5*

Clay fraction (%) = *22.6*



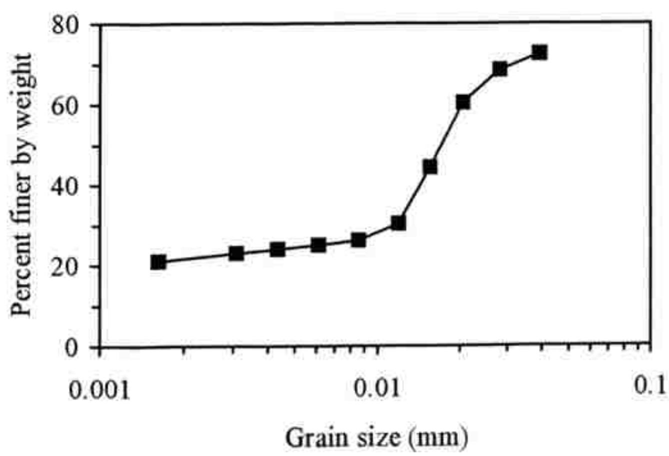
Hydrometer analysis

Analyst name: *Preetha Veeraraghavan*
Test date: *8/20/2006*
Sample description: 33 Deer Creek Sample #2

Mass in suspension =	*50.00*	g
Specific unit weight =	*2.65*	
Dispersing agent correction =	*4.00*	g/L
Menicus correction =	*0.50*	g/L
Cylinder diameter =	*6.00*	cm
Hydrometer number =	*1*	

Time (min) t	Hydrometer reading (g/L) Rt	Temperature (°C) Te	Corrected distance of fall (cm) HR	Grain size (mm) D	Percent finer by weight p
1	39	23.5	9.00	0.0394	72.4
2	37	23.5	9.32	0.0284	68.4
4	33	23.5	9.96	0.0207	60.4
8	25	23.5	11.24	0.0156	44.4
15	18	23	12.36	0.0120	30.2
30	16	23	12.68	0.0086	26.2
60	15.5	22.5	12.76	0.0061	25.0
120	15	22.5	12.84	0.0043	24.0
240	14.5	22.5	12.92	0.0031	23.0
900	13.75	21.5	13.04	0.0016	21.1

Clay fraction (%) = 21.5



Hydrometer analysis

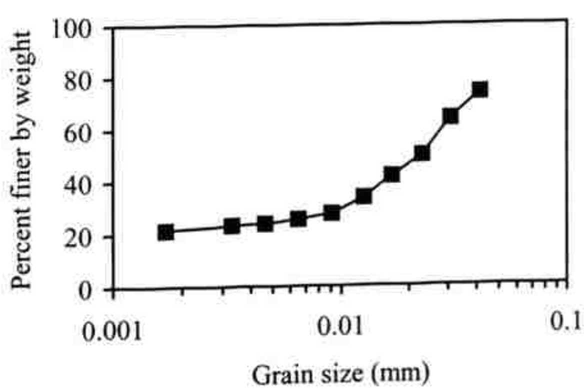
Analyst name: *Preetha Veeraraghavan*
Test date: *8/16/2006*
Sample description: *33 Gravois Creek Sample # 1*

Mass in suspension W_0 =	50.00	g
Specific unit weight G_s =	2.65	
Dispersing agent correction C_d =	4.00	g/L
Menicus correction C_m =	0.50	g/L
Cylinder diameter d_c =	6.00	cm
Hydrometer bulb volume V_b =	60	cm^3

Graduation mark on hydrometer stem (g/L) R_s	Distance to bulb center (cm) H_s
0	18
10	16.2
20	14.5
30	12.9
40	11.2
50	9.5
60	7.9

Time (min) t	Hydrometer reading (g/L) Rt	Temperature (°C) Te	Corrected distance of fall (cm) HR	Grain size (mm) D	Percent finer by weight p
1	40	22	9.65	0.0415	73.8
2	35	22	10.55	0.0307	63.8
4	28	22	11.81	0.0230	49.8
8	24	22	12.53	0.0167	41.8
15	20	21.75	13.25	0.0126	33.7
30	17	21.5	13.79	0.0091	27.6
60	16	21.25	13.97	0.0065	25.5
120	15.25	21	14.10	0.0046	23.9
240	15	20.75	14.15	0.0033	23.3
900	14	21.25	14.33	0.0017	21.5

Clay fraction (%) = *21.8*



Hydrometer analysis

Analyst name: *Preetha Veeraraghavan*
Test date: *8/17/2006*
Sample description: 33 Gravois Creek Sample #2

Mass in suspension =	*50.00*	g
Specific unit weight =	*2.65*	
Dispersing agent correction =	*4.00*	g/L
Menicus correction =	*0.50*	g/L
Cylinder diameter =	*6.00*	cm
Hydrometer number =	*2*	

Time (min) t	Hydrometer reading (g/L) Rt	Temperature (°C) Te	Corrected distance of fall (cm) HR	Grain size (mm) D	Percent finer by weight p
1	38	23	10.02	0.0418	70.2
2	33	23	10.83	0.0307	60.2
4	25	23	12.12	0.0230	44.2
8	22	23	12.61	0.0166	38.2
15	19	22.9	13.09	0.0124	32.1
30	18	22.5	13.25	0.0088	30.0
60	17	22.25	13.41	0.0063	27.9
120	16.5	22.25	13.49	0.0045	26.9
240	15.75	21.5	13.62	0.0032	25.1
900	14.5	21.75	13.82	0.0017	22.7

Clay fraction (%) = 23.2

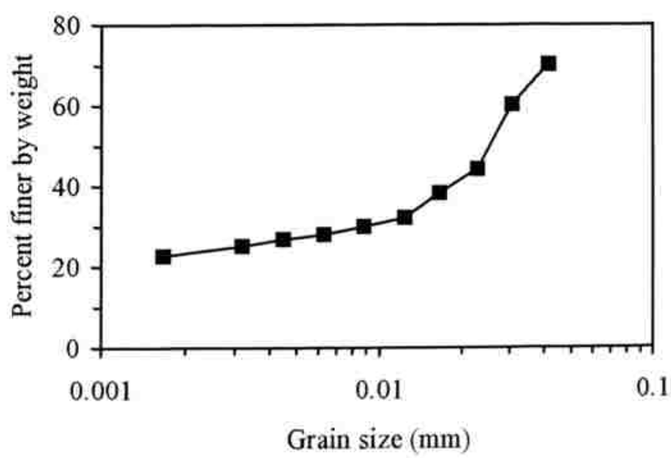
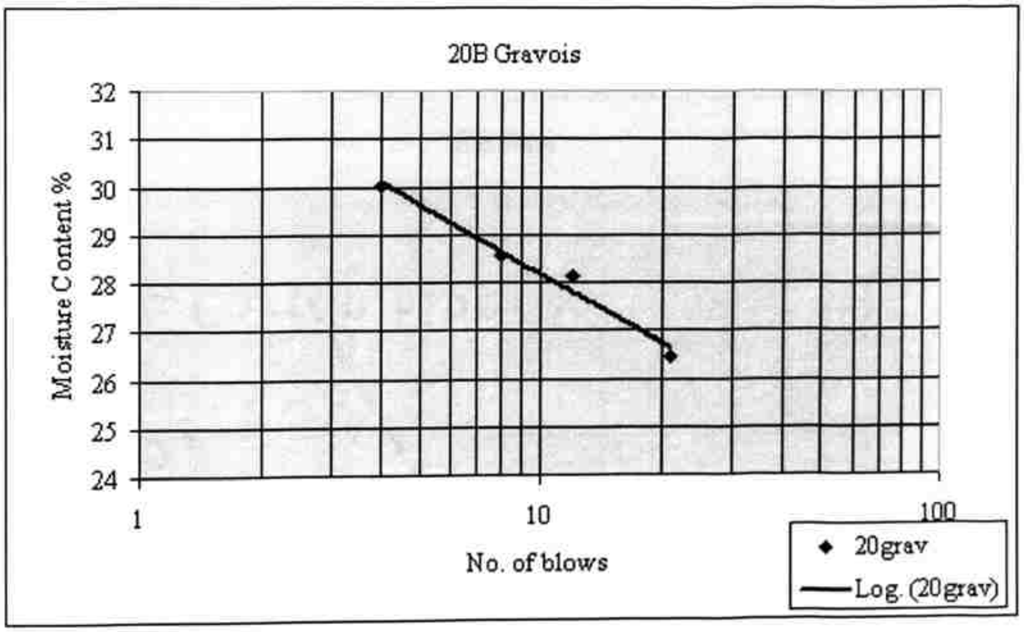


Table E1. Atterberg Limit Test Results for Soil 20B from Gravois Creek

Liquid Limit Test

Sample#	No.of Blows	$W_s + W_c$ (g)	W_d + Wc (g)	W_s(g)	W_d (g)	Moisture Content
LL1	21	35.3	30.3	23.9	18.9	26.46
LL2	12	51.9	43.1	40.1	31.3	28.12
LL3	8	47.8	39.8	36	28	28.57
LL4	4	53	43.3	42	32.3	30.03



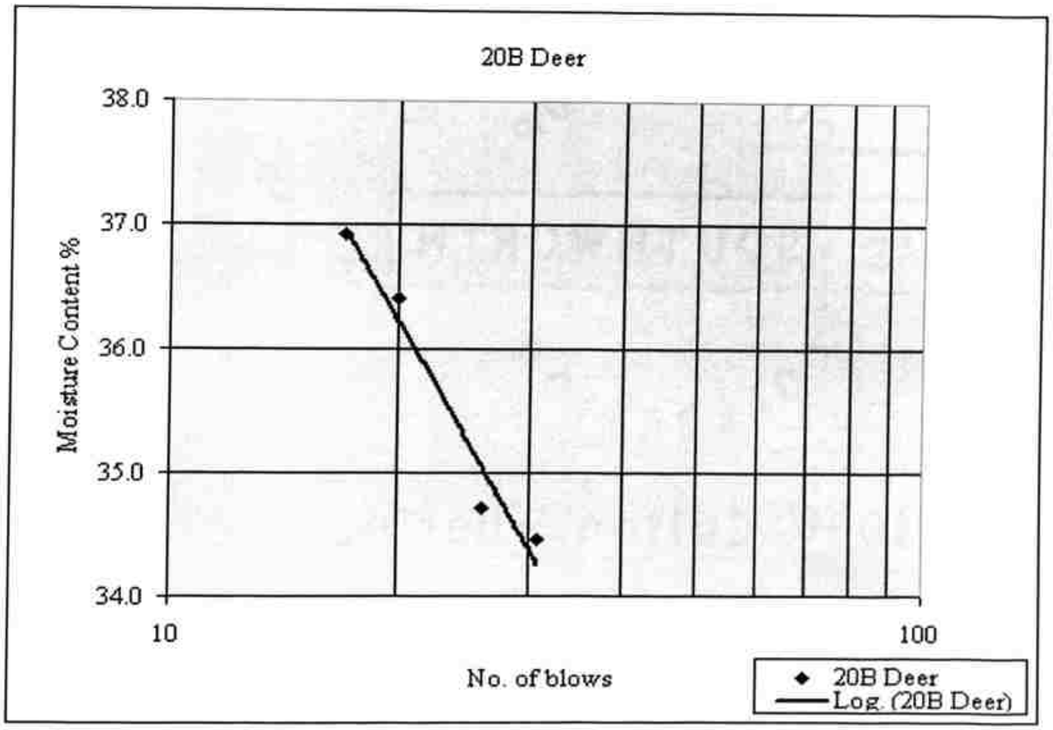
Plastic Limit Test

Sample#	W_c (g)	$W_s + W_c$ (g)	W_d + Wc (g)	W_s (g)	W_d (g)	Moisture Contnent
PL1	10.8	22.8	20.7	12	9.9	21.21

Table E2. Atterberg Limit Test Results for Soil 20B from Deer Creek

Liquid Limits

Sample#	No.of Blows	$W_s + W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s (g)	W_d (g)	Moisture Content
LL1	31	43.8	35.6	11.8	32	23.8	34.45
LL2	26	43.3	34.9	10.7	32.6	24.2	34.71
LL3	20	43.3	34.6	10.7	32.6	23.9	36.40
LL4	17	43.6	34.7	10.6	33	24.1	36.93



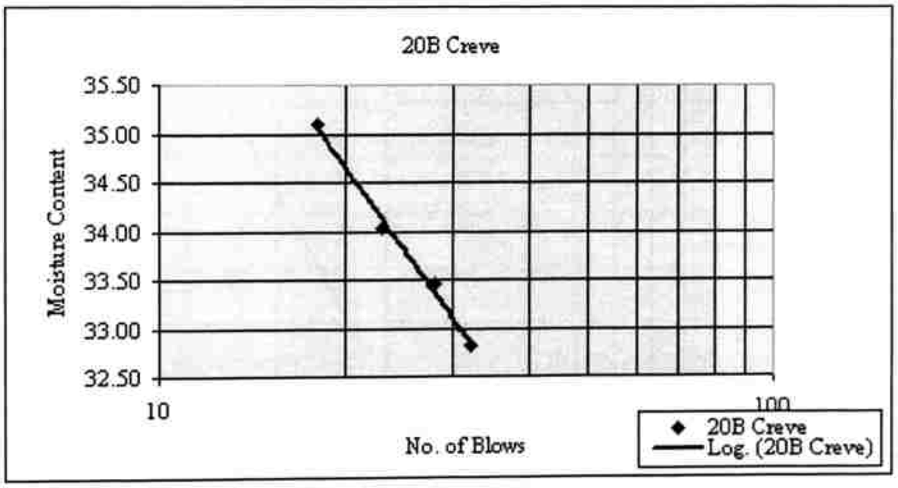
Plastic Limit

Sample#	$W_s + W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s (g)	W_d (g)	Moisture Contnent
PL1	26.2	23.4	11.8	14.4	11.6	24.14

Table E3. Atterberg Limit Test Results for Soil 20B from Creve Coeur Creek

Liquid Limit

Sample#	No.of Blows	$W_{s+}W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s(g)	W_d (g)	Moisture Contnent
LL1	32	38.2	31.7	11.9	26.3	19.8	32.83
LL2	28	41.9	34.1	10.78	31.12	23.32	33.45
LL3	23	48.8	39.3	11.39	37.41	27.91	34.04
LL4	18	50.2	40.2	11.7	38.5	28.5	35.09



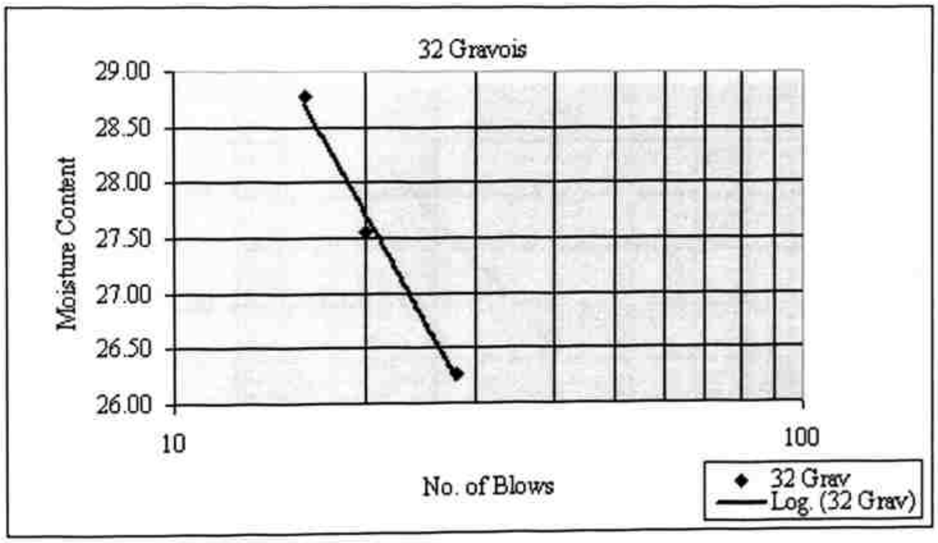
Plastic Limit

Sample#	$W_{s+}W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s(g)	W_d (g)	Moisture Contnent
PL1	17.1	16.2	11.22	5.88	4.98	18.07
PL2	20.3	18.8	11.77	8.53	7.03	21.34

Table E4. Atterberg Limit Test Results for Soil 32 from Gravois Creek

Liquid Limit

Sample#	No.of Blows	$W_s + W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s (g)	W_d (g)	Moisture Contnent
LL1	28	37.5	32	11.06	26.44	20.94	26.27
LL2	20	32.3	27.7	11.01	21.29	16.69	27.56
LL3	16	31.8	27.1	10.77	21.03	16.33	28.78



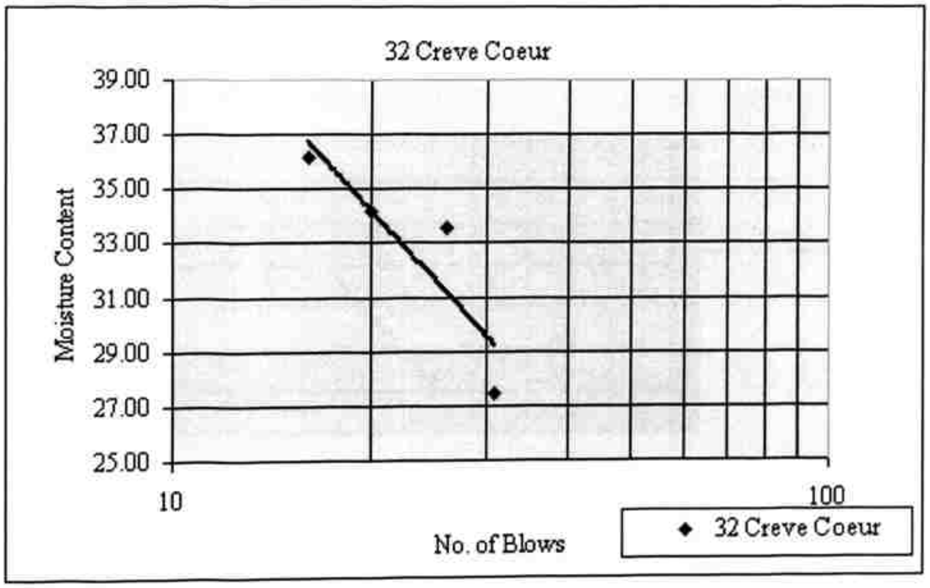
Plastic Limit

Sample#	$W_s + W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s (g)	W_d (g)	Moisture Contnent
PL1	22.8	21	11.63	11.17	9.37	19.21

Table E5. Atterberg Limit Test Results for Soil 32 from Creve Coeur Creek

Liquid Limit

Sample#	No.of Blows	$W_{s+}W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s (g)	W_d (g)	Moisture Contnent
LL1	31	38.9	32.9	11.06	27.84	21.84	27.47
LL2	26	38.6	31.6	10.77	27.83	20.83	33.61
LL3	20	38.1	31.4	11.8	26.3	19.6	34.18
LL4	16	38.8	31.6	11.68	27.12	19.92	36.14



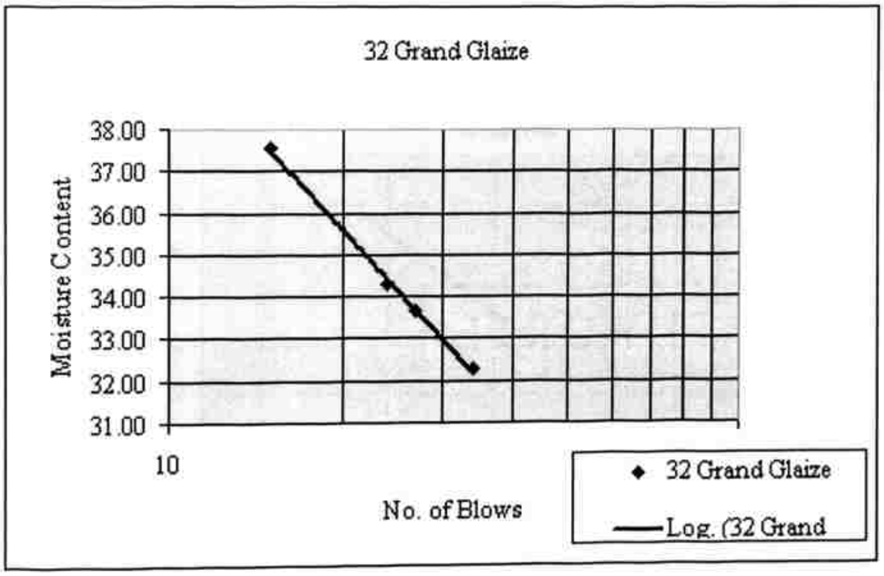
Plastic Limit

Sample#	$W_{s+}W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s (g)	W_d (g)	Moisture Contnent
PL1	26.5	23.5	11.13	15.37	12.37	24.25
PL2	31.3	27.5	11.01	20.29	16.49	23.04

Table E6. Atterberg Limit Test Results for Soil 32 from Grand Glaize Creek

Liquid Limits

Sample#	No.of Blows	$W_{s+}W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s(g)	W_d (g)	Moisture Contnent
LL1	34	38.9	32.1	11.02	27.88	21.08	32.26
LL2	27	39.2	32.3	11.79	27.41	20.51	33.64
LL3	24	39.6	32.5	11.79	27.81	20.71	34.28
LL4	15	47.7	37.9	11.79	35.91	26.11	37.53



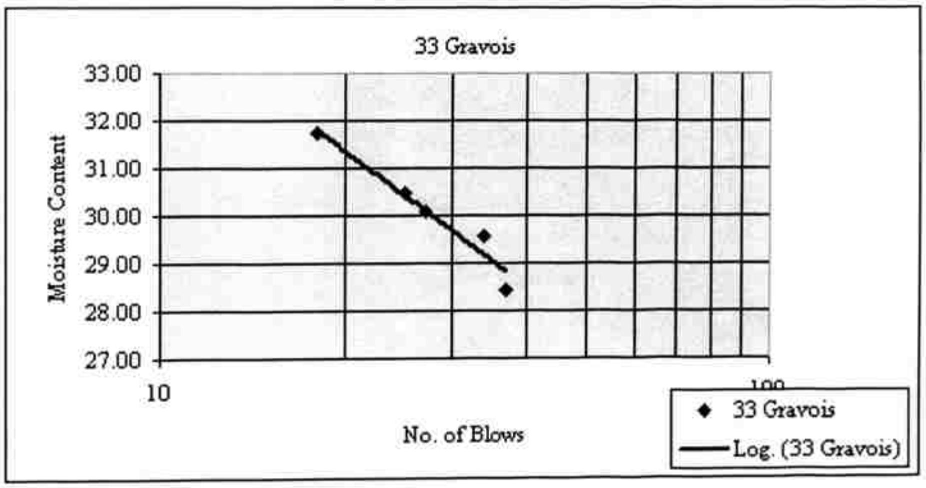
Plastic Limit

Sample#	$W_{s+}W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s(g)	W_d (g)	Moisture Contnent
PL1	20.5	18.5	10.98	9.52	7.52	26.60
PL2	21.1	19.1	11.45	9.65	7.65	26.14

Table E7. Atterberg Limit Test Results for Soil 33 from Gravois Creek

Liquid Limit

Sample#	No.of Blows	$W_{s+}W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s (g)	W_d (g)	Moisture Contnent
LL1	37	39.9	33.7	11.9	28	21.8	28.44
LL2	34	46.7	38.6	11.22	35.48	27.38	29.58
LL3	27	50.7	41.7	11.77	38.93	29.93	30.07
LL4	25	51.5	42.2	11.7	39.8	30.5	30.49
LL5	18	49.4	40.3	11.63	37.77	28.67	31.74



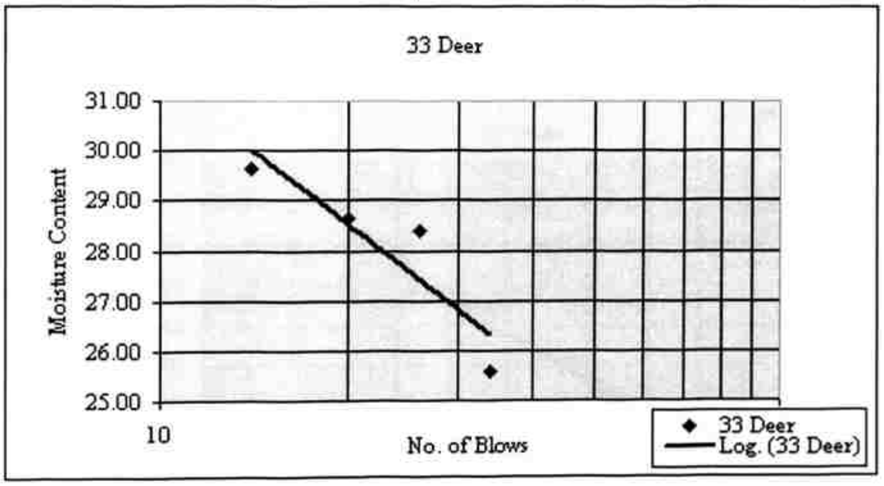
Plastic Limit

Sample#	$W_{s+}W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s (g)	W_d (g)	Moisture Contnent
PL1	27.9	24.8	10.78	17.12	14.02	22.11
PL2	29.6	26.4	11.39	18.21	15.01	21.32

Table E8. Atterberg Limit Test Results for Soil 33 from Deer Creek

Liquid Limit

Sample#	No.of Blows	$W_{s+}W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s (g)	W_d (g)	Moisture Contnent
LL1	34	38.9	33.2	10.91	27.99	22.29	25.57
LL2	26	40.1	33.7	11.17	28.93	22.53	28.41
LL3	20	41.1	34.6	11.92	29.18	22.68	28.66
LL4	14	38.5	32.4	11.82	26.68	20.58	29.64



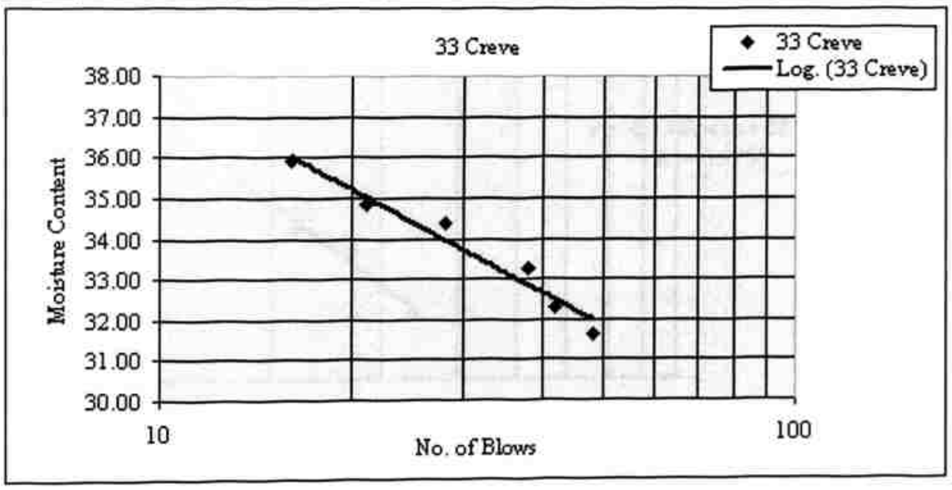
Plastic Limit

Sample#	$W_{s+}W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s (g)	W_d (g)	Moisture Contnent
PL1	33.2	29.6	11.78	21.42	17.82	20.20
PL2	28.8	25.8	11.05	17.75	14.75	20.34

Table E9. Atterberg Limit Test Results for Soil 33 from Creve Coeur Creek

Liquid Limit

Sample#	No.of Blows	$W_s + W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s (g)	W_d (g)	Moisture Contnent
LL1	48	42	34.7	11.63	30.37	23.07	31.64
LL2	42	40.1	33	11.01	29.09	21.99	32.29
LL3	38	38.8	31.8	10.77	28.03	21.03	33.29
LL4	28	35	28.8	10.78	24.22	18.02	34.41
LL5	21	45.1	36.5	11.8	33.3	24.7	34.82
LL6	16	52.6	41.6	10.98	41.62	30.62	35.92



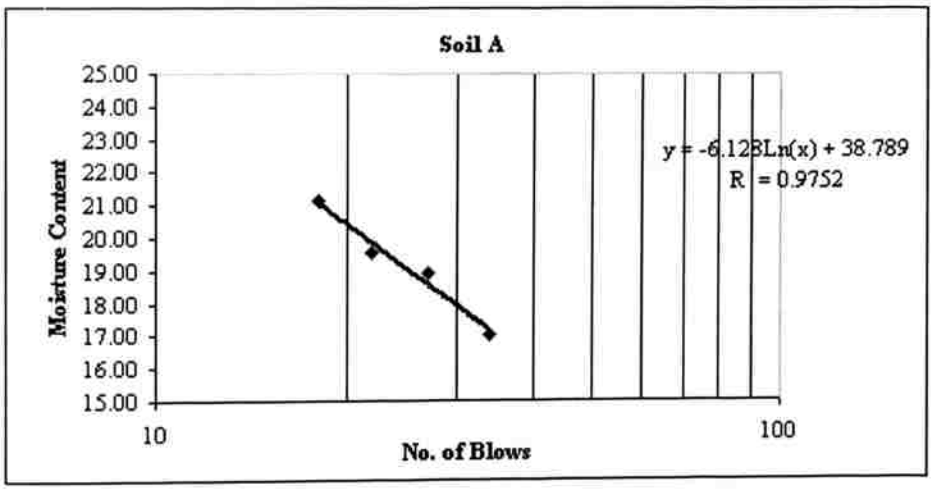
Plastic Limit

Sample#	$W_s + W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s (g)	W_d (g)	Moisture Contnent
PL1	33	29.2	11.77	21.23	17.43	21.80
PL2	30	26.9	11.22	18.78	15.68	19.77

Table E10. Atterberg Limit Test Results for Soil A

Liquid Limit

Sample#	No.of Blows	$W_{s+}W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s (g)	W_d (g)	Moisture Content
LL1	34	51.7	45.8	11.17	40.53	34.63	17.04
LL2	27	44.1	38.9	11.45	32.65	27.45	18.94
LL3	22	47.1	41.2	11.08	36.02	30.12	19.59
LL4	18	46.2	40.2	11.8	34.4	28.4	21.13



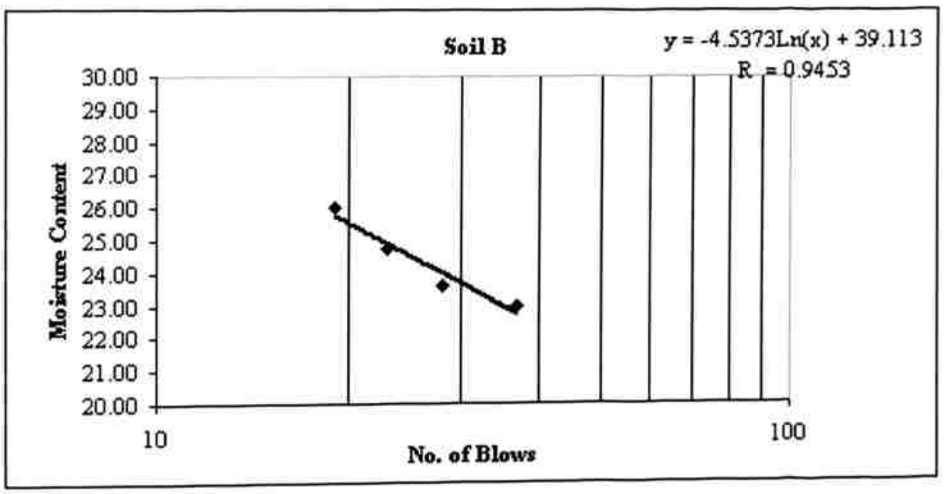
Plastic Limit

Sample#	$W_{s+}W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s (g)	W_d (g)	Moisture Content
PL1	26.5	24.9	11.9	14.6	13	12.31
PL2	21.5	20.2	10.77	10.73	9.43	13.79
						13.05

Table E11. Atterberg Limit Test Results for Soil B

Liquid Limit

Sample#	No.of Blows	$W_{s+}W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s(g)	W_d (g)	Moisture Contnent
LL1	37	46.7	40.2	11.92	34.78	28.28	22.98
LL2	23	55.9	47	11.01	44.89	35.99	24.73
LL3	28	61.5	52	11.8	49.7	40.2	23.63
LL4	19	58.3	48.7	11.8	46.5	36.9	26.02



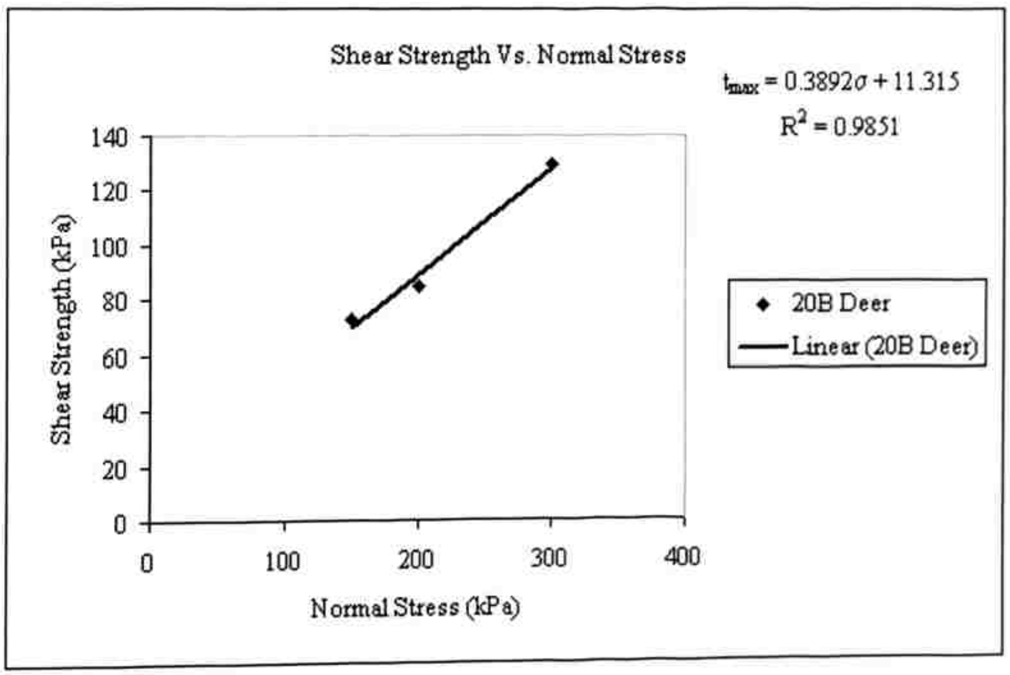
Plastic Limit

Sample#	$W_{s+}W_c$ (g)	W_d + Wc (g)	W_c (g)	W_s(g)	W_d (g)	Moisture Contnent
PL1	24.6	23.1	10.8	13.8	12.3	12.20
PL2	24.8	23.5	11.7	13.1	11.8	11.02
						11.61

Deer Creek - Soil Type 20B

Soil Type 20B - Deer Creek - Sand - 32%, Silt - 54%, Clay - 14%

TRIAL	Max Shear Stress	Normal Stress Applied
	kPa	kPa
1	72.456	150
2	85.003	200
3	129.45	300



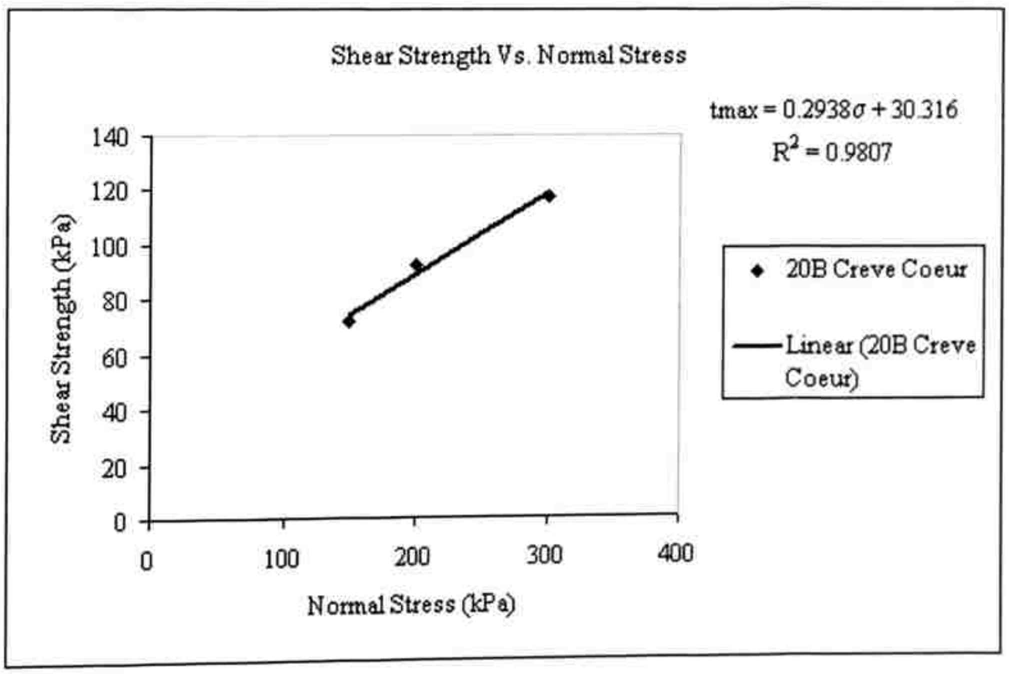
$t_{max} = 0.3892\sigma + 11.315$

Cohesion, c = 11.315kPa

Creve Coeur Creek - Soil Type 20B

Soil Type 20B - Creve Coeur Creek - Sand - 9%, Silt - 72%, Clay - 19%

TRIAL	Max Shear Stress	Normal Stress Applied
	kPa	kPa
1	72	150
2	92.64	200
3	117.255	300



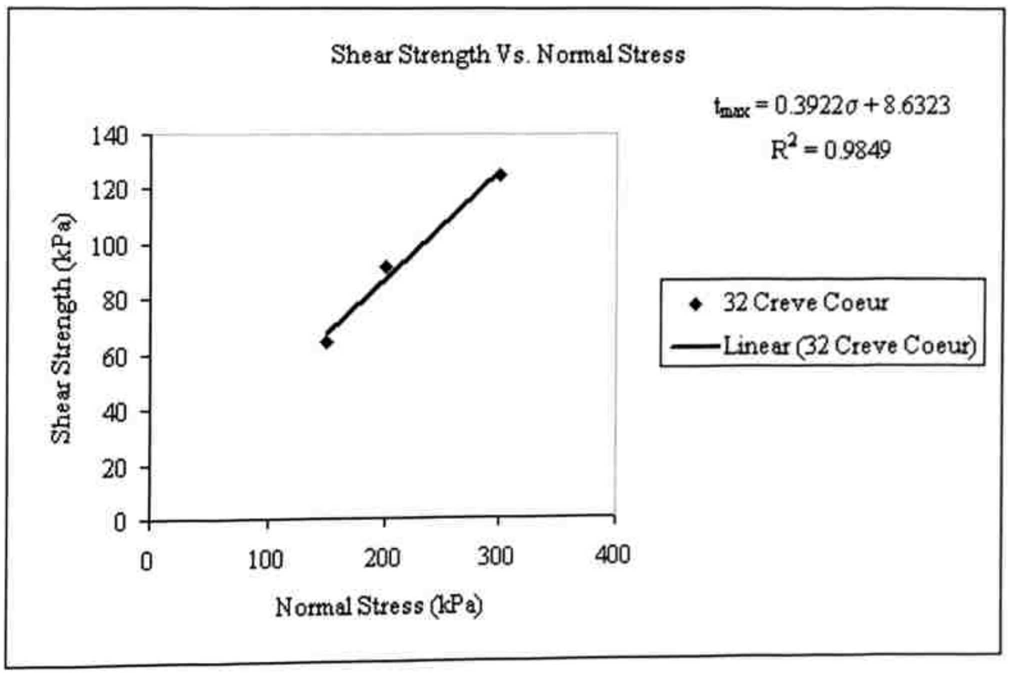
$t_{max} = 0.2938\sigma + 30.32$

Cohesion, c = 30.32 kPa

Creve Coeur Creek - Soil Type 32

Soil Type 32 - Creve Coeur Creek - Sand - 22%, Silt - 61%, Clay - 17%

TRIAL	Max Shear Stress	Normal Stress Applied
	kPa	kPa
1	64.667	150
2	91.2791	200
3	124.902	300



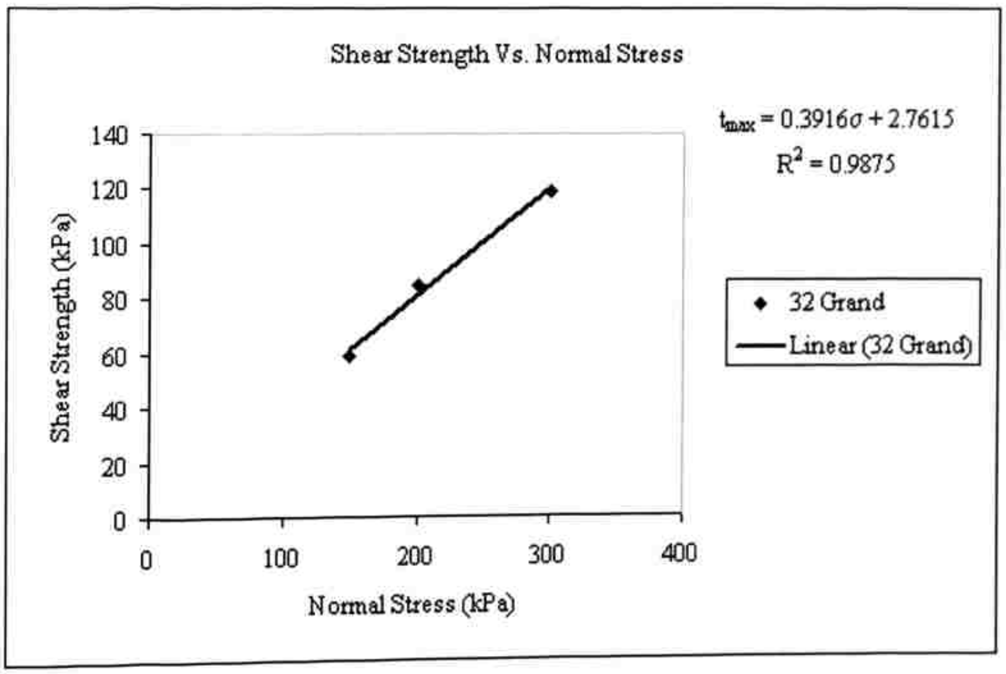
$t_{max} = 0.3922\sigma + 8.6323$

Cohesion, c = 8.6323 kPa

Grand Glaize Creek - Soil Type 32

Soil Type 32 - Grand Glaize Creek - Sand - 53.6%, Silt - 36.25%, Clay - 10.13%

TRIAL	Max Shear Stress	Normal Stress Applied
	kPa	kPa
1	58.9618	150
2	84.8973	200
3	118.975	300



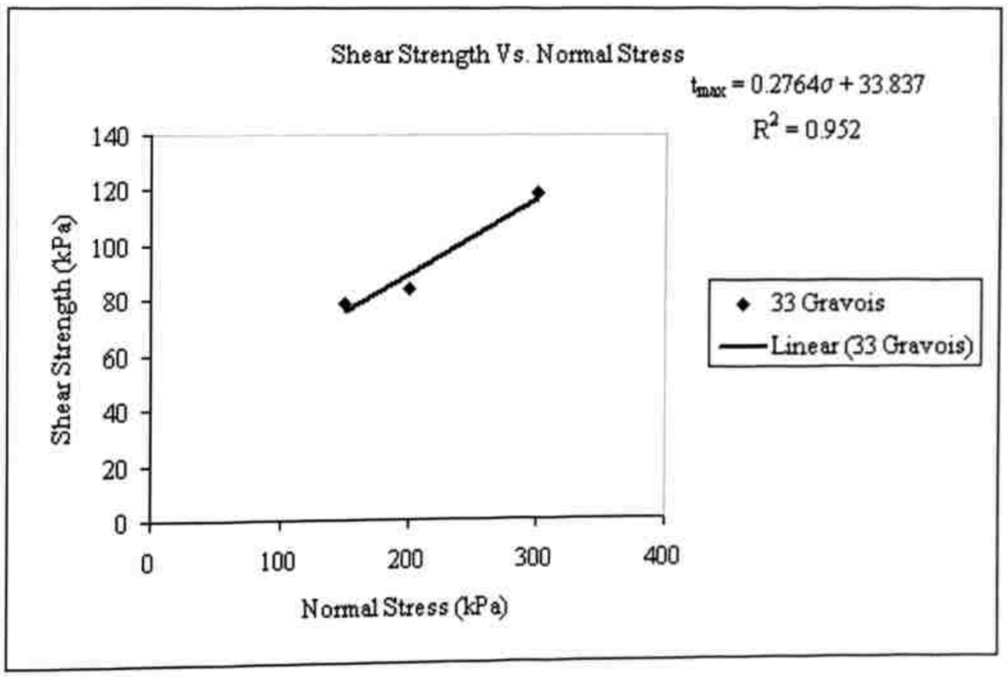
$t_{max} = 0.3916\sigma + 2.7615$

Cohesion, c = 2.7615 kPa

Gravois Creek - Soil Tye 33

Soil Type 33 - Gravois Creek - Sand - 40%, Silt - 46%, Clay - 14%

TRIAL	Max Shear Stress	Normal Stress Applied
	kPa	kPa
1	78.8857	150
2	83.7439	200
3	118.557	300



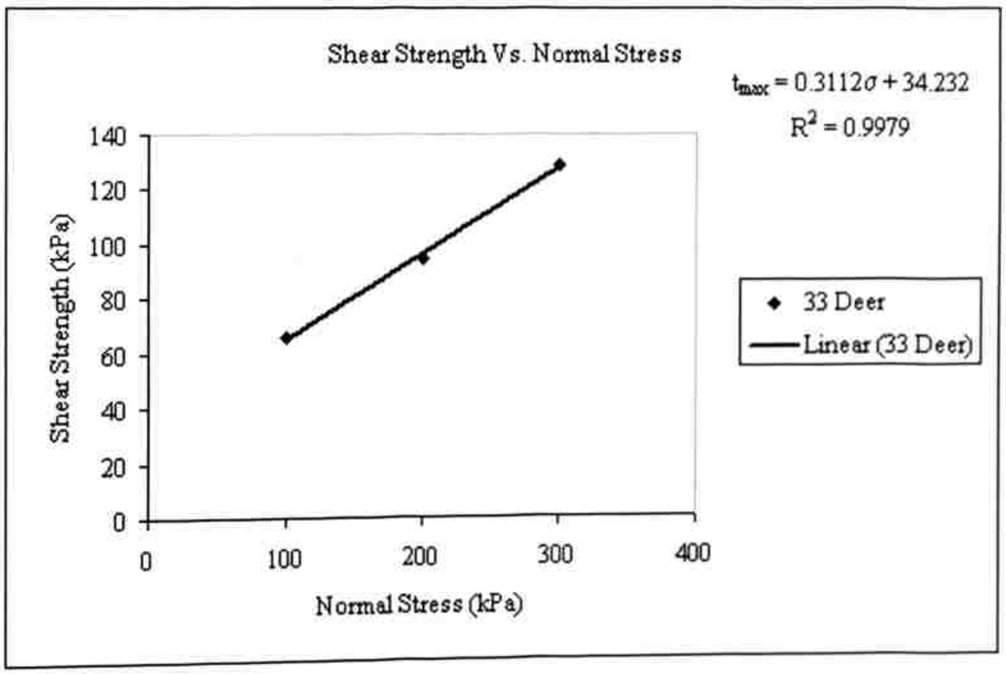
$t_{max} = 0.2764\sigma + 33.84$

Cohesion, c = 33.84 kPa

Deer Creek - Soil Type 33

Soil Type 33 - Deer Creek - Sand - 59%, Silt - 32%, Clay - 9%

TRIAL	Max Shear Stress	Normal Stress Applied
	kPa	kPa
1	66.1768	100
2	94.83	200
3	128.421	300



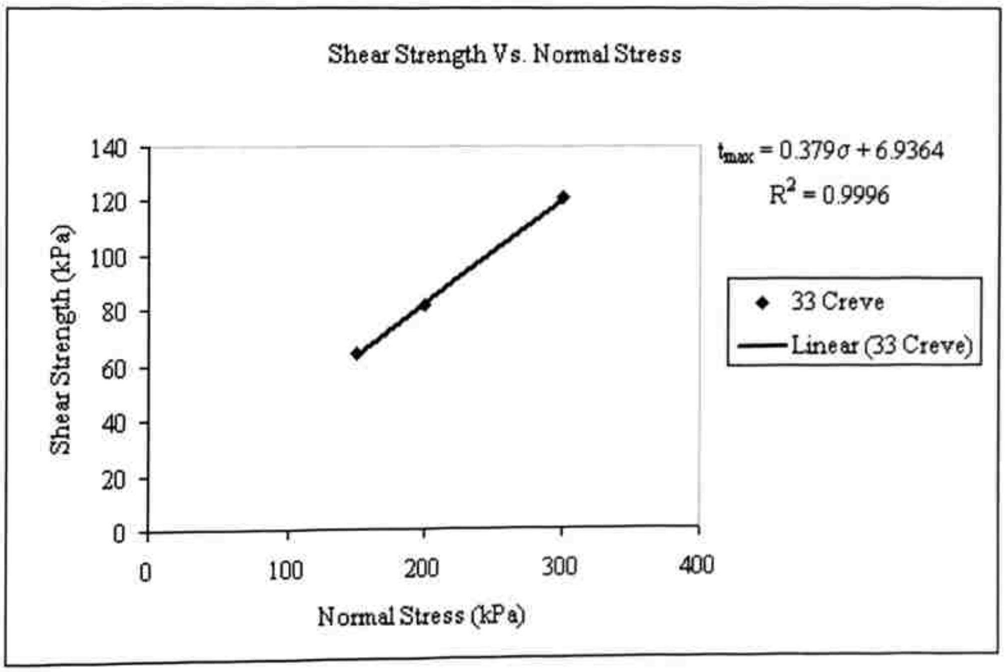
$t_{max} = 0.3112\sigma + 34.232$

Cohesion, c = 34.232 kPa

Creve Coeur Creek- Soil Type 33

Soil Type 33 - Creve Coeur Creek - Sand - 11%, Silt - 71%, Clay - 18%

TRIAL	Max Shear Stress	Normal Stress Applied
	kPa	kPa
3	64.24	150
1	82.05	200
2	120.86	300

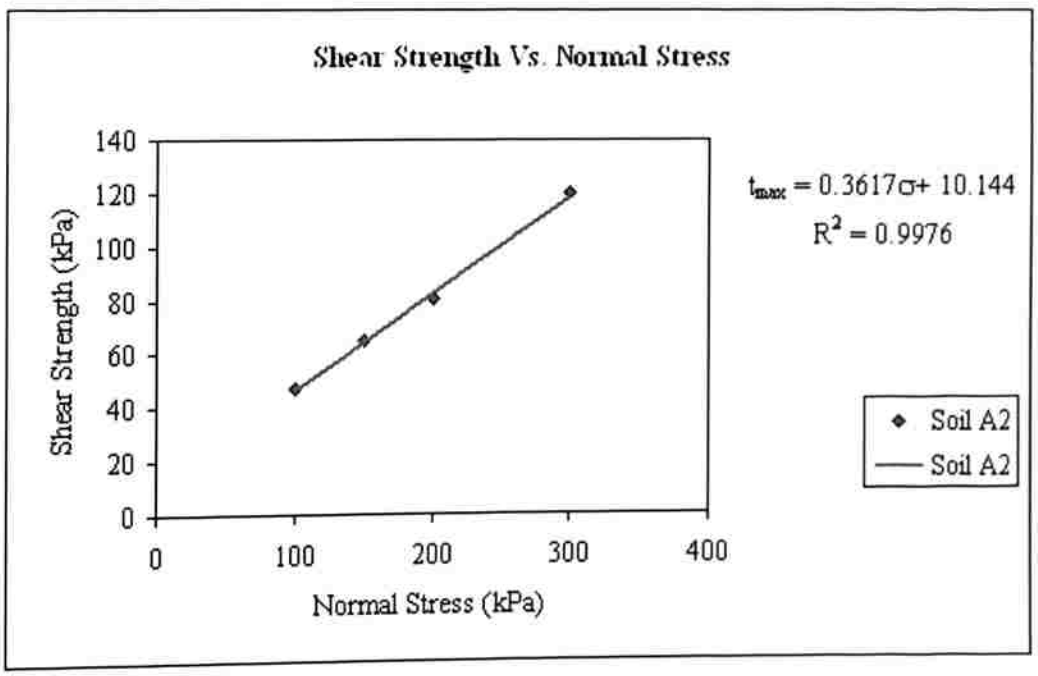


$t_{max} = 0.379\sigma + 6.9364$

Cohesion, c = 6.9364 kPa

Soil Type A2
Sand - 58%, Silt - 32%, Clay - 9%

Run #	Max Shear Stress (kPa)	Normal Stress Applied (kPa)
1	46.94	100
2	65.069	150
3	80.2	200
4	119.61	300

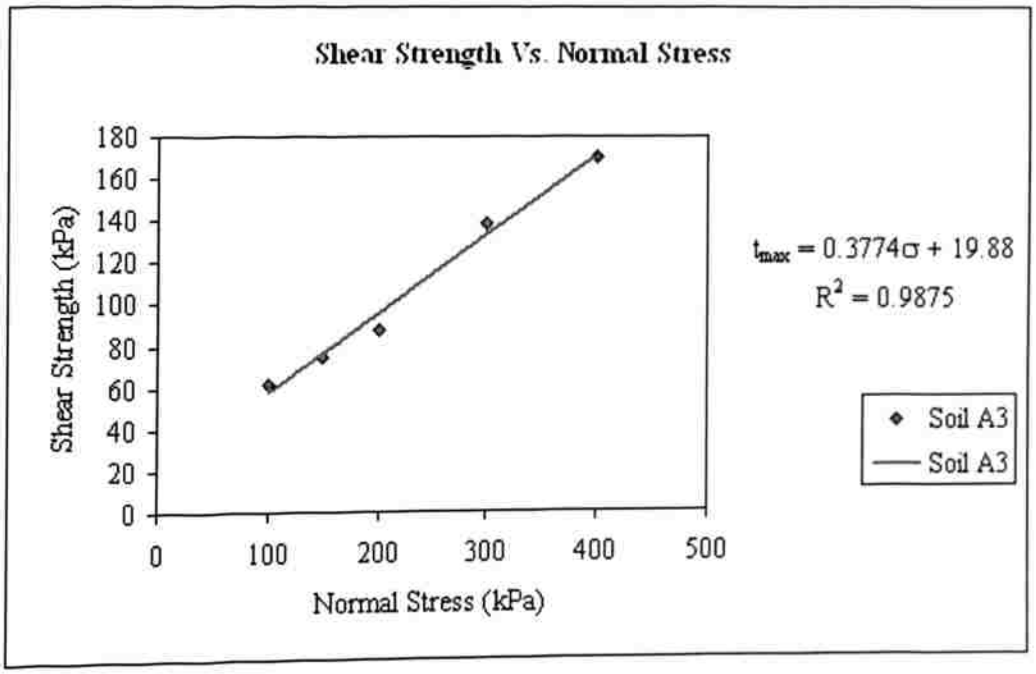


$t_{max} = 0.3617\sigma + 10.144$

Cohesion, c = 10.144 kPa

Soil Type A3
Sand - 58%, Silt - 32%, Clay - 9%

Run #	Max Shear Stress (kPa)	Normal Stress Applied (kPa)
1	62	100
2	75	150
3	88	200
4	138.44	300
5	170	400



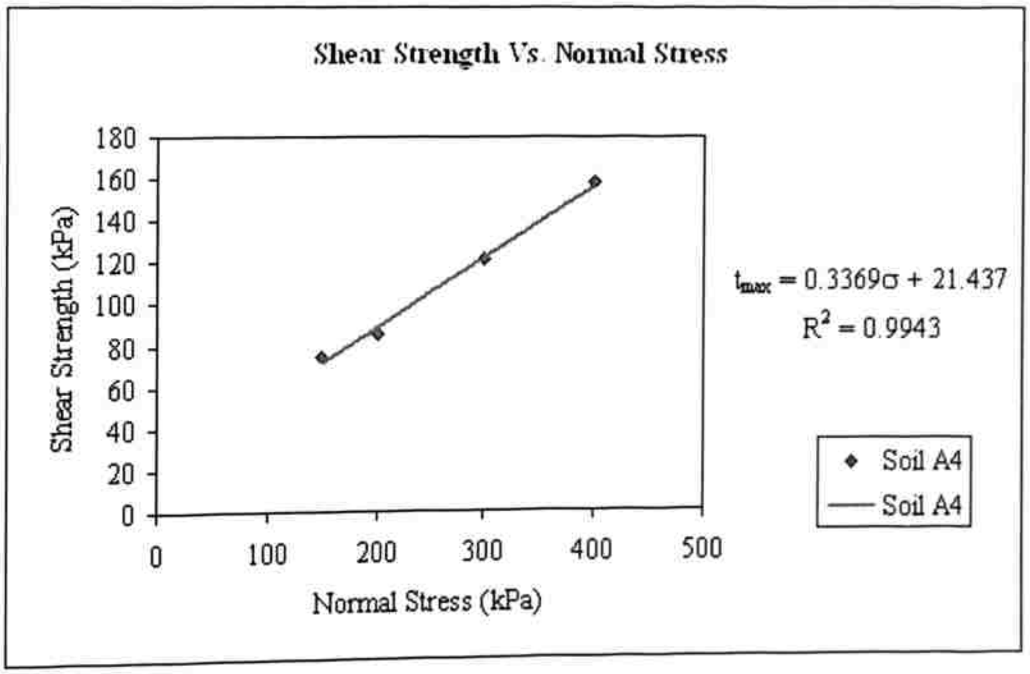
$t_{max} = 0.3774\sigma + 19.88$

Cohesion, c = 19.88 kPa

Soil Type A4

Sand - 58%, Silt - 32%, Clay - 10%;

Run #	Max Shear Stress (kPa)	Normal Stress Applied (kPa)
1	75.0631	150
2	85.64	200
3	121.089	300
4	157.657	400



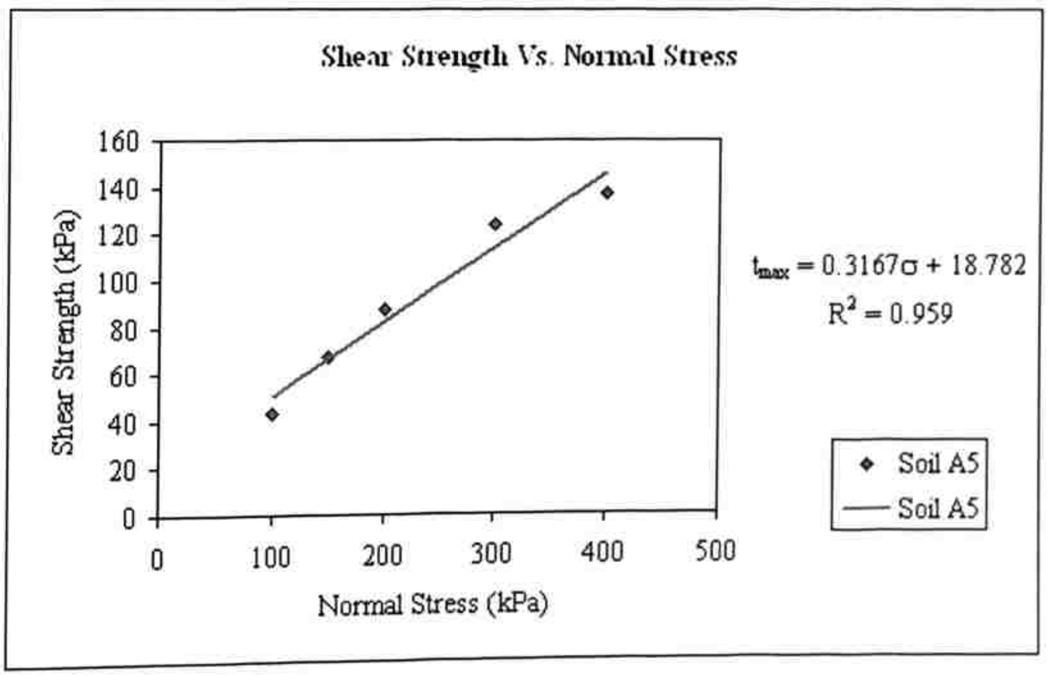
$\tau_{max} = 0.3369\sigma + 21.437$

Cohesion, c = 21.437 kPa

Soil Type A5

Sand - 58%, Silt - 32%, Clay - 10%

Run #	Max Shear Stress (kPa)	Normal Stress Applied (kPa)
1	43	100
2	67.181	150
3	87.272	200
4	123.55	300
5	137.06	400



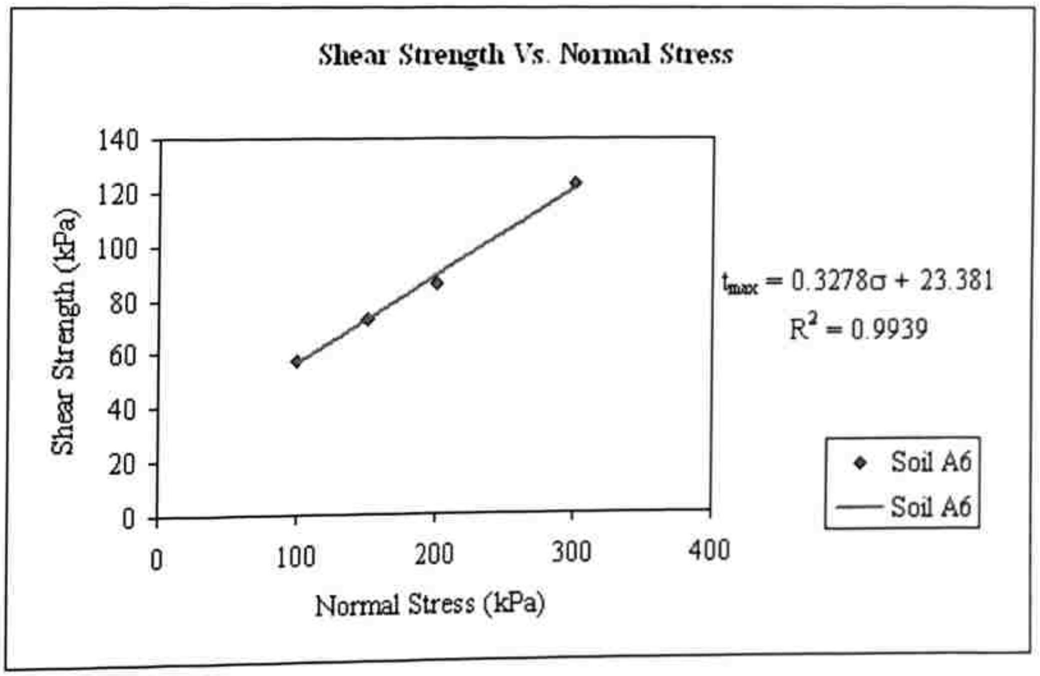
$t_{max} = 0.3167\sigma + 18.782$

Cohesion, c = 18.782 kPa

Soil Type A6

Sand - 58%, Silt - 32%, Clay - 10%

Run #	Max Shear Stress (kPa)	Normal Stress Applied (kPa)
1	57.5	100
2	72.896	150
3	85.733	200
4	123.23	300



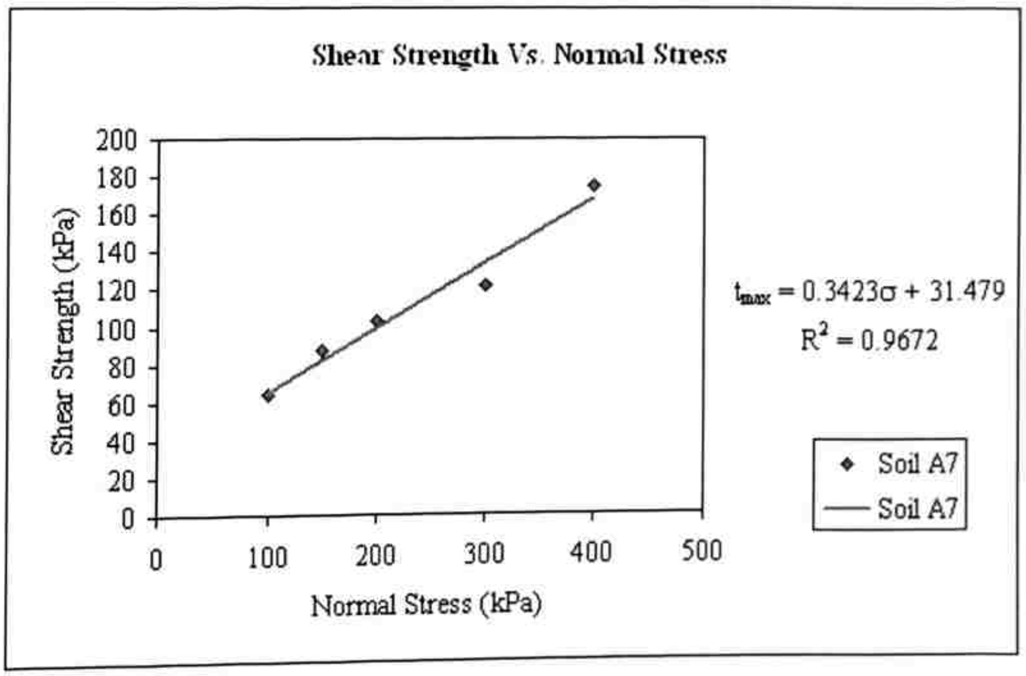
$t_{max} = 0.3278\sigma + 23.381$

Cohesion, c = 23.381 kPa

Soil Type A7

Sand - 58%, Silt - 32%, Clay - 10%

Run #	Max Shear Stress (kPa)	Normal Stress Applied (kPa)
1	64	100
2	87.817	150
3	102.48	200
4	121.8	300
5	175	400



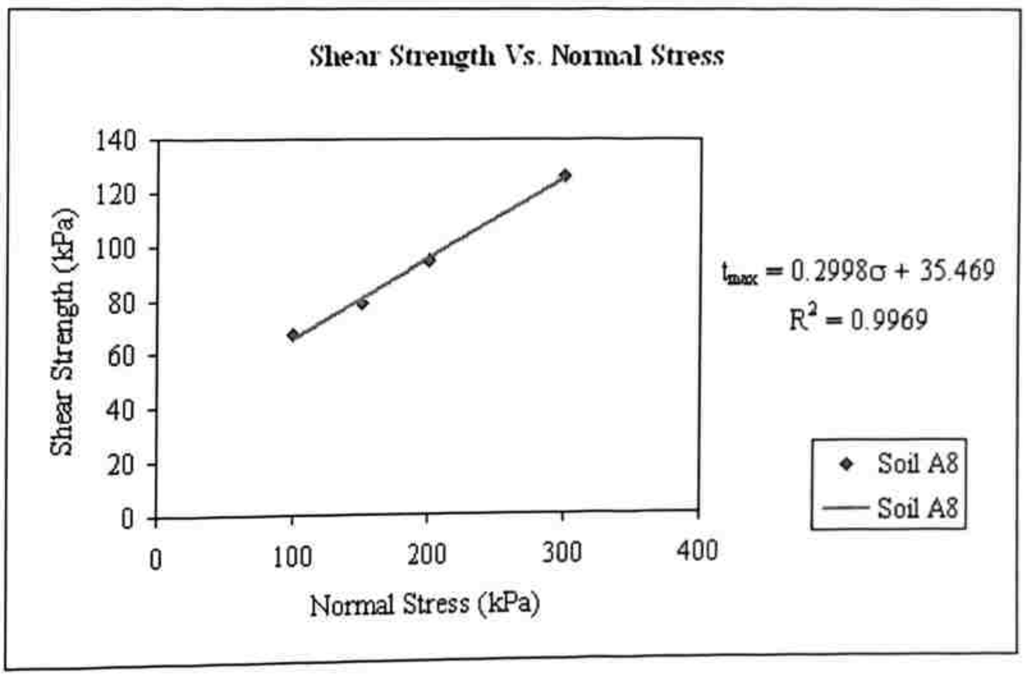
$t_{max} = 0.3423\sigma + 31.479$

Cohesion, c = 31.479 kPa

Soil Type A8

Sand - 58%, Silt - 32%, Clay - 10%

Run #	Max Shear Stress (kPa)	Normal Stress Applied (kPa)
1	67	100
2	79.004	150
3	94.469	200
4	126.24	300



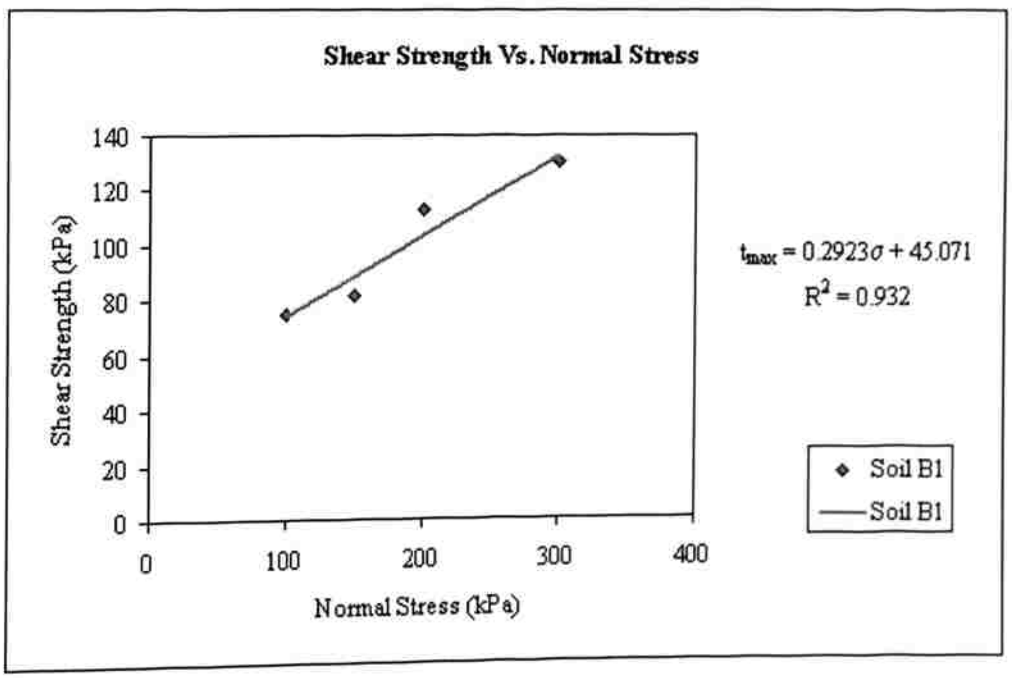
$t_{max} = 0.2998\sigma + 35.469$

Cohesion, c = 35.469 kPa

Soil Type B1

Sand - 45%, Silt - 35%, Clay - 20%

Run #	Max Shear Stress (kPa)	Normal Stress Applied (kPa)
1	75	100
	82	150
2	112.5	200
3	130	300



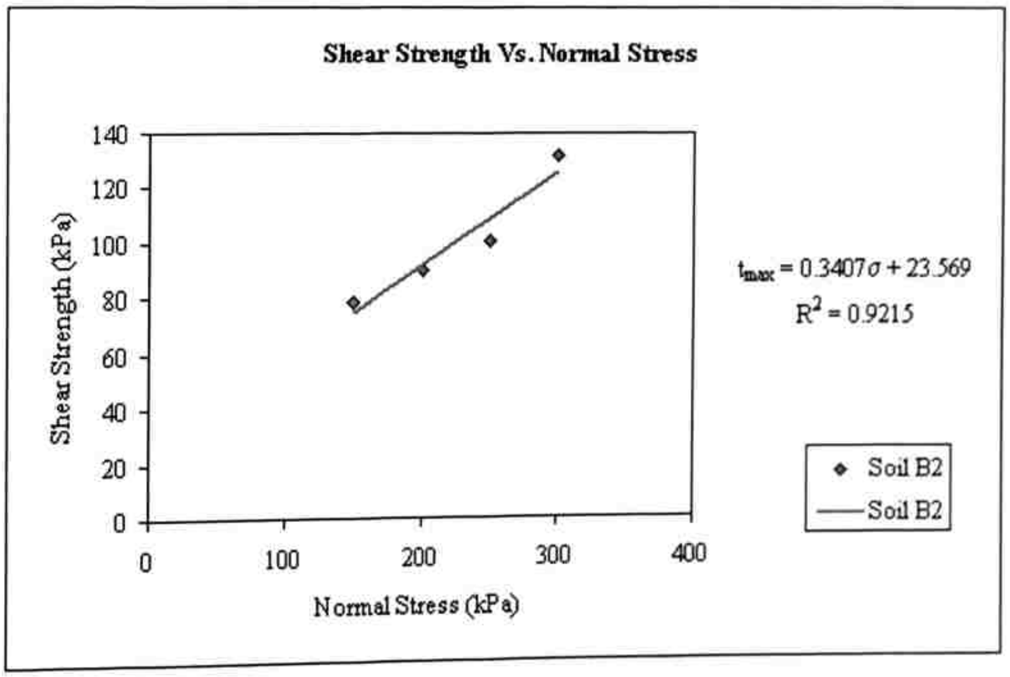
$t_{max} = 0.2923\sigma + 45.071$

Cohesion, c = 45.071 kPa

Soil Type B2

Sand - 45%, Silt - 35%, Clay - 20%

Run #	Max Shear Stress (kPa)	Normal Stress Applied (kPa)
1	78.715	150
2	89.72	200
3	100.61	250
4	131.87	300



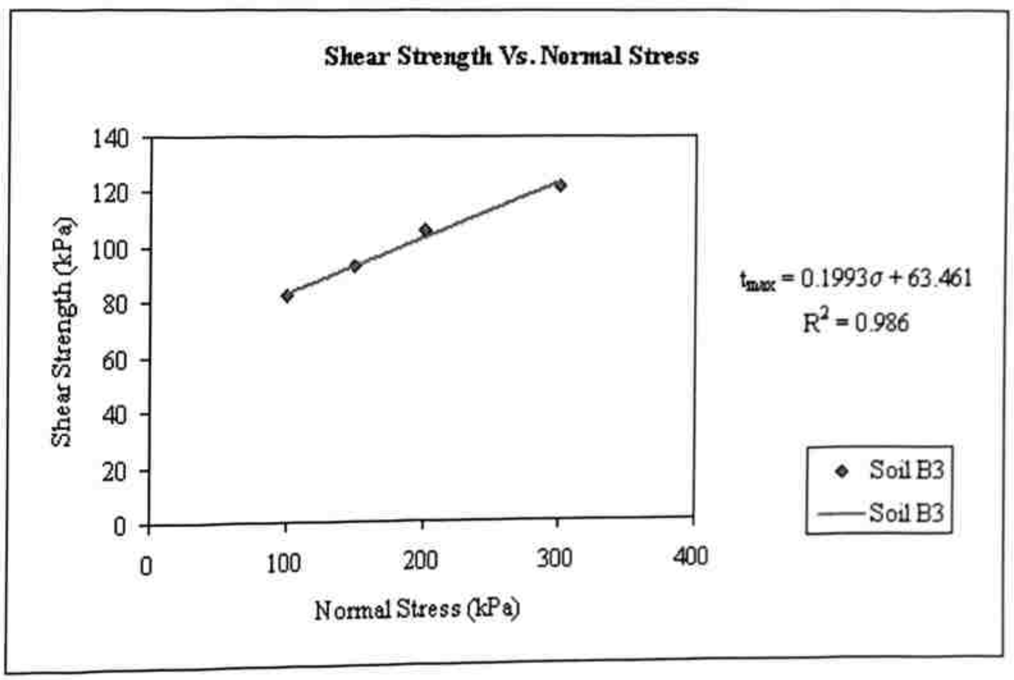
$t_{max} = 0.3407\sigma + 23.569$

Cohesion, c = 23.569 kPa

Soil Type B3

Sand -45%, Silt - 35%, Clay - 20%

Run #	Max Shear Stress (kPa)	Normal Stress Applied (kPa)
1	82.2	100
2	92.969	150
3	106.3	200
4	121.87	300

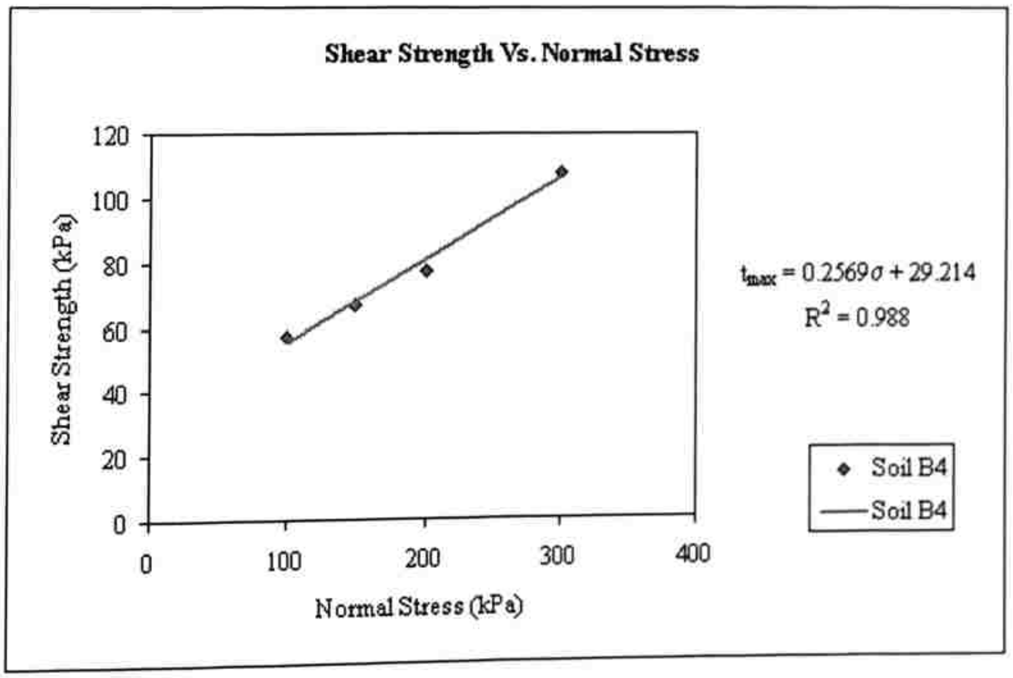


$t_{max} = 0.1993\sigma + 63.461$

Cohesion, c = 63.46 kPa

Soil Type B4
Sand -45%, Silt - 35%, Clay - 20%

Run #	Max Shear Stress (kPa)	Normal Stress Applied (kPa)
1	57	100
2	67	150
3	77.5	200
4	108	300

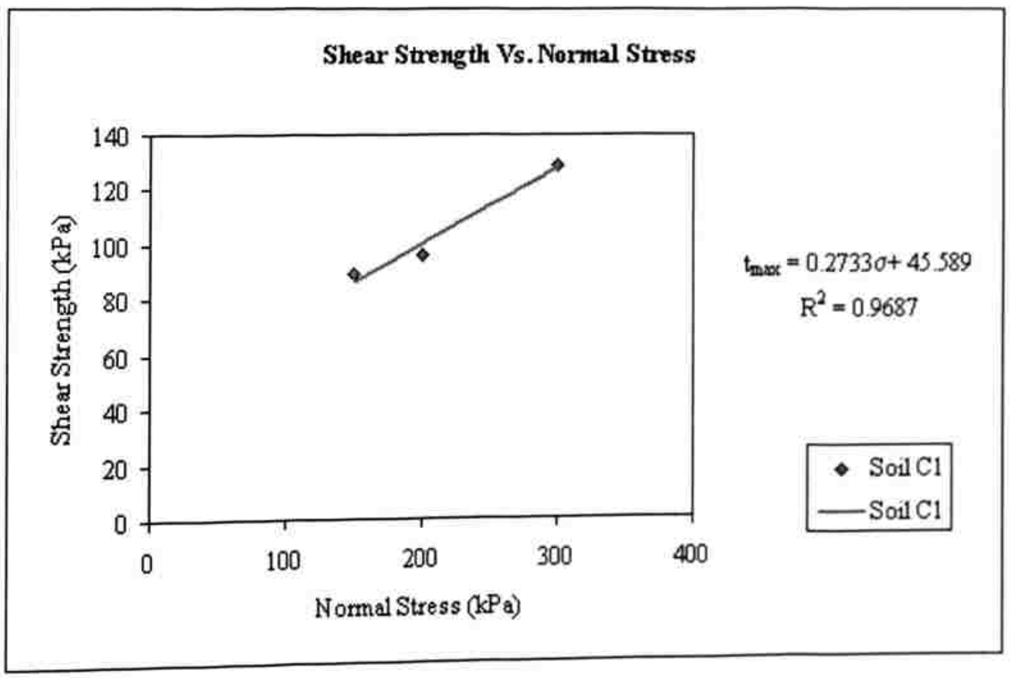


$t_{max} = 0.2569\sigma + 29.214$

Cohesion, c = 29.214 kPa

Soil Type C1
Sand - 35%, Silt - 35%, Clay - 30%

Run #	Max Shear Stress (kPa)	Normal Stress Applied (kPa)
	89.42	150
2	96	200
3	129	300

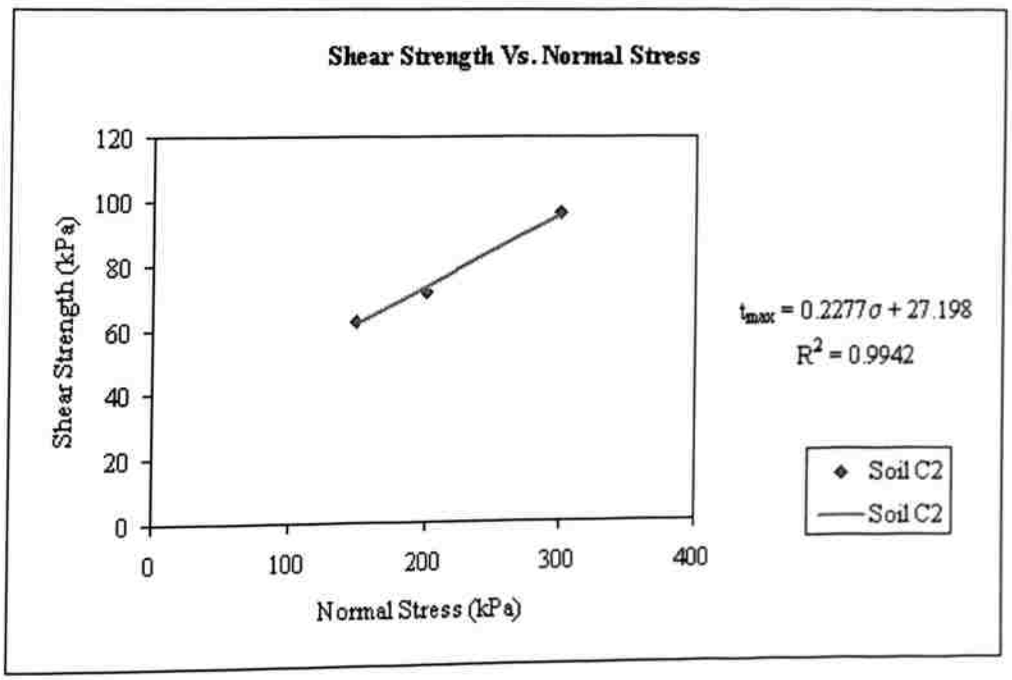


$t_{max} = 0.2773\sigma + 45.589$

Cohesion, c = 45.589 kPa

Soil Type C2
Sand -35%, Silt - 35%, Clay - 30%

Run #	Max Shear Stress (kPa)	Normal Stress Applied (kPa)
1	62.35	150
2	71.23	200
3	96	300

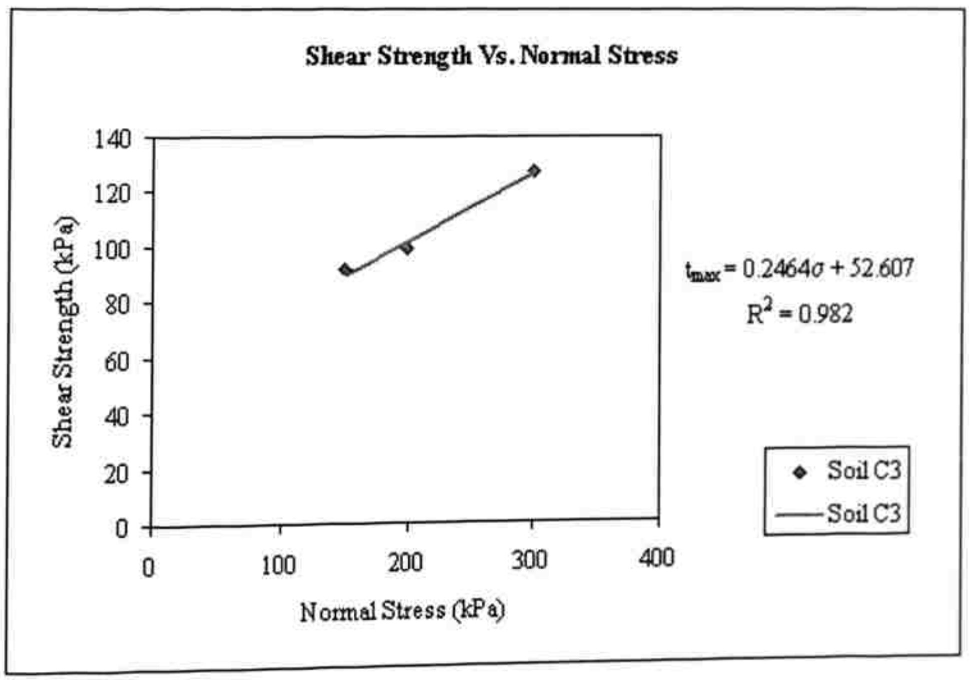


$$t_{max} = 0.2277\sigma + 27.189$$

Cohesion, c = 27.189 kPa

Soil Type C3
Sand -35%, Silt - 35%, Clay - 30%

Run #	Max Shear Stress (kPa)	Normal Stress Applied (kPa)
1	91.5	150
2	99	200
3	127.5	300



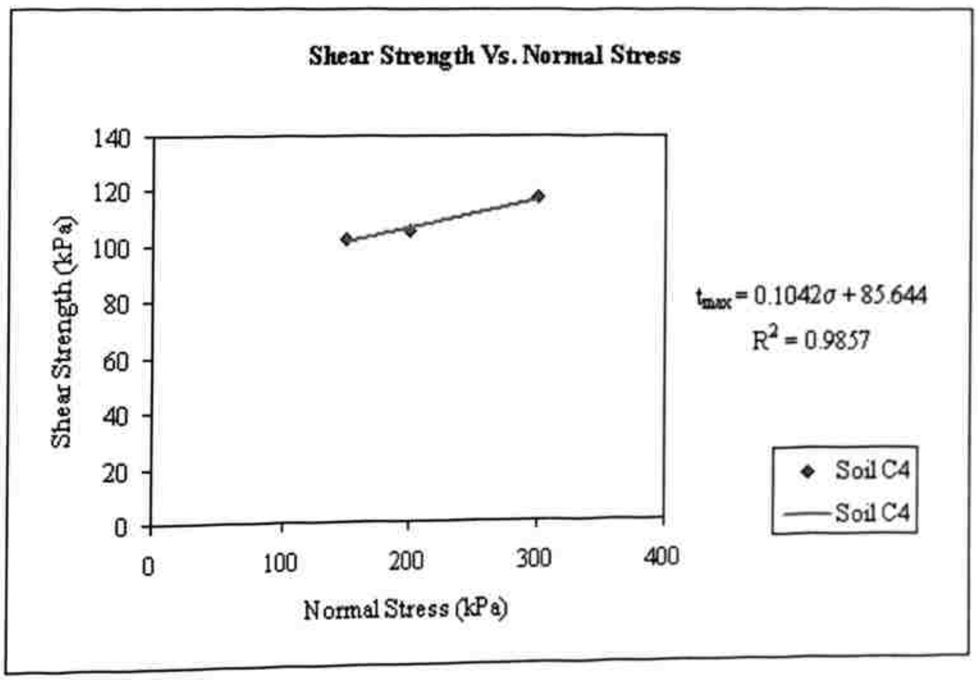
$t_{max} = 0.2464\sigma + 52.607$

Cohesion, c = 52.607 kPa

Soil Type C4

Sand -35%, Silt - 35%, Clay - 30%

Run #	Max Shear Stress (kPa)	Normal Stress Applied (kPa)
1	102	150
2	105.4	200
3	117.27	300



$t_{max} = 0.1042\sigma + 85.644$

Cohesion, c = 85.644 kPa