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PROVIDENCE RIVER SEDIMENT EROSION ANALYSIS

Final Report

Sponsor: New England District, Army Corps of Engineers

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Introduction

The U.S. Army Corps of Engineers New England District (NAE) is planning on dredging fine-grained cohesive sediment from a ten-mile stretch of the Providence River. Approximately 5 million cubic yards of material will be removed. Some of this material is contaminated. The district is interested in open-ocean placement of the clean dredged sediments and potential CAD cell placement of contaminated sediments. Sediment samples from the areas to be dredged have indicated that these sediments include a sand fraction, but will behave in a cohesive manner. Such mixed sediments with a significant portion of fines will have erosion rates that are not only a function of grain size, but also of other parameters, including bulk density, mineralogy, grain size distribution, and organic content. Erosion rate equations exist for cohesive sediments, but the parameters required by these equations are site specific, vary significantly with depth, and may change over orders of magnitude between sites.

This report provides experimental results on moisture content profiles, particle size analysis, organic matter content, and erosion tests of Providence River sediments. These experiments were performed on rectangular and cylindrical cores of undisturbed samples taken by Battelle, and rectangular cores of consolidated samples obtained from the Waterways Experiment Station (WES) centrifuge. This information was developed to provide general sediment properties and erosion algorithms for the Providence River sediments to be used in a numerical model of sediment transport due to storm surges at the proposed dredged-material disposal sites.

The undisturbed sediment cores and consolidated sediment cores were provided by the Corps of Engineers. The experimental results were obtained at the Georgia Institute of

Technology using facilities of the School of Civil and Environmental Engineering in the Hydraulics Laboratory, Geotechnical Laboratory and Environmental Engineering Laboratory.

Particle Size Analysis

The specific gravity of the sediment was measured according to ASTM Standard D 854 - 83. The average value of the specific gravity was found to be 2.586. This value was needed for the analysis of particle sizes and for the conversion of saturated moisture content to bulk density.

Particle size analysis of composite bins from the cylindrical cores were conducted using the hydrometer method according to ASTM Standard D 422 - 63. The cylindrical cores were used for the particle size analysis after they had been tested for moisture content. The size distribution analysis required at least 50 grams of sediment so that composite bins from the moisture content tests were analyzed. The results are given in Appendix A. The sediment cores are designated as E99-A, B, and C for Fuller Rock reach; E99-D, E, and F for Sabin Point reach; and E99-G, H, and I for Bullock Point reach.

In general, the size distributions plotted and shown in Appendix A are remarkably similar and show that the "black mud", as described in the Battelle sampling report, is predominately in the silt size range with approximately 20 percent clay. The median size varies from 0.01 to 0.02 mm. The percent retained on the #200 sieve (0.074 mm) varies in general from approximately 1 percent to 16 percent of the total weight with the largest percent of coarse material occurring for the Bullock Point reach (cores H and I). The material retained on the #200 sieve is as much as 60 to 70 percent shell material as noted in Appendix A.

Moisture Content Analysis

Appendix B contains the results of moisture content and permittivity tests of the cylindrical cores as well as a relationship between permittivity and moisture content. The moisture content in percent, w %, is defined herein as

$$w, \% = \frac{W_w}{W_d} x\ 100\% \qquad (1)$$

in which W_w = weight of water = saturated weight minus dry weight; and W_d = dry weight of sediment. The moisture content values are mostly in the range of 175% to 250% with Fuller Rock reach on the higher side and Sabin Point on the lower side of the range. The greatest stratification is exhibited by core E99-H in the Bullock Point reach. In this core, the moisture content falls from approximately 220% at the surface to approximately 100% near the bottom of the sample. This core also has a large percentage of coarse material near the bottom as discussed previously for the particle size results. Most of the other samples are much more uniform in moisture content with respect to depth with a typical change in moisture content from the surface to the bottom of less than 40%. It should be noted that fibers as well as shells were found in some bins of the cylindrical cores.

Erosion Test Procedures

The existing flume setup at Georgia Tech originally was designed for a maximum shear stress of 3.0 Pa at a maximum flow rate of 0.45 cfs for testing homogeneous clay minerals such as kaolinite. A sketch of the flume is shown in Fig. 1. The test sample is 4 in. wide by 12 in.

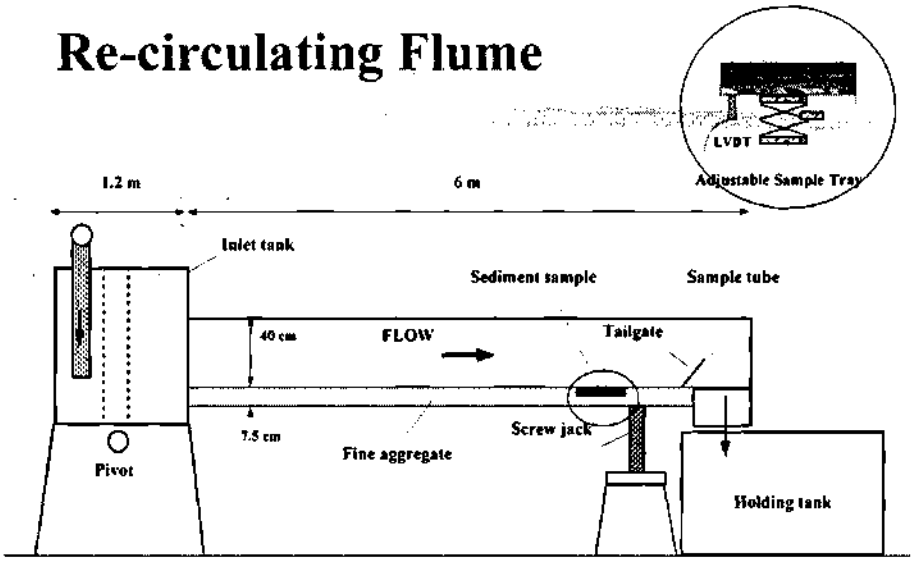


Fig. 1. Definition Sketch of Erosion Flume.

long and it is placed near the downstream end of the flume where the boundary layer is fully developed. The flume bed consists of fixed gravel having a diameter of 3.3 mm so as to establish fully-rough turbulent flow at the test section. A piston extrudes the sediment sample into the flume flow as erosion takes place, and its position can be tracked with an LVDT. The concentration of sediment in the effluent from the flume is measured as a function of time during an erosion test by a continuous-flow particle monitor from which the erosion rate can be determined.

An undisturbed Providence River sample was tested in the existing flume immediately after receiving the undisturbed sediment cores on July 19, 1999, and no erosion at all occurred for a shear stress of 3.0 Pa. This had been anticipated, and an order was placed for a larger capacity slurry pump (2.0 cfs) with a variable-speed motor which was provided by Georgia Tech as project cost-sharing. In the meantime, an existing high-speed water pump with a larger capacity was used temporarily to determine the shear stress range required. The flume inlet was re-designed with a manifold for the higher flow rates needed, and an elliptical-wall transition was constructed in the head box to improve the inlet flow conditions. Detailed velocity distributions were measured at the flume test section with an acoustic Doppler velocimeter to calibrate slope and depth with shear stress. The flows were maintained in the subcritical range with Froude numbers less than 0.7 to minimize surface waves. The maximum shear stress achieved with this arrangement was 6.0 Pa. An undisturbed sample was tested at a shear stress of 6.0 Pa, and only minimal erosion was observed. From this experience, it was determined that the only way to get higher shear stresses in the existing flume was to increase the slope into the supercritical flow range to reduce the depth/width ratio at the higher flow rates of the larger-capacity pump.

The Froude numbers were maintained at a value of less than 2 to avoid roll waves, and several known shear stress conditions were established up to a maximum 12 Pa. It was found that the range of 6 to 12 Pa was sufficient to erode all samples. Subsequently, the new pump arrived and it was installed, and the flow meter was re-calibrated. This arrangement proved satisfactory for the remainder of the erosion testing program.

Because the rectangular sediment cores could not be placed below the flume due to their length, a procedure was developed for cutting samples from the rectangular cores and carefully placing them in the sediment recess in the bottom of the flume and on top of the flume piston, which could then be used to gradually extrude them as erosion occurred. First, a rectangular block was placed at the bottom of the core box to extrude the sediment out the top of the core box into a 2-in. deep plexiglass transfer box with open bottom and top. The core box was slid down over the fixed block at the bottom of the core which extruded the sediment at the top into the transfer box. Next, the sample was cut by a thin wire, and a thin plate was carefully slid under the bottom of the transfer box. The sample was then transferred to the flume by gently extracting it into the sediment cavity of the flume with minimal disturbance. Finally, the movable flume piston in the sediment test cavity was used to position the sediment sample for the erosion tests.

The centrifuged, consolidated cores were received on October 6, 1999, and all but two of them had experienced drying at the surface. The dried surface layer was sliced off and not tested because of cracks that had developed at the surface. The cracks formed weak points which tended to erode in the form of vertical-walled trenches. The remainder of the core was then cut into 2-in. thick bins as before with intervening 0.4-in. bins for determination of moisture-content

profiles because there were no separate cylindrical cores of the consolidated sediment.

Some difficulty with water leaking from the undisturbed rectangular cores was experienced as soon as they arrived. The fabric straps did not provide sufficient compression to seal the top and bottom plates. Within the first few days after the arrival of the cores, long threaded rods were used to connect steel angles and wooden blocks at the top and bottom of the cores so that pressure could be applied to the seals. This was largely successful, but three of the cores still had some surface drying (A, E, and F-duplicate), and they were tested first. In addition, it was noted that a surface skin formed at the sediment surface of the cut test samples that became more resistant to erosion as time passed. For these reasons, the procedure was changed slightly after the first three cores were tested. First, moisture content profiles were taken again for the cores as they were cut for the erosion tests even though moisture content had already been measured for the cylindrical cores at the same location. Second, only one core was cut into bins at a time, and all bins were tested within a few days of cutting. In addition, the surface skin on the cut samples was removed by cutting it with a thin wire immediately prior to an erosion test.

Initially, it was planned to measure the erosion rate by tracking the piston movement with an LVDT as erosion occurred and sampling the concentration in the outlet stream from the flume indirectly with the particle monitor. However, the erosion did not occur as surface erosion but rather as mass erosion in which large chunks were suddenly removed from the sediment surface. These could not be sampled accurately because of their large size and intermittent release. Furthermore, the mass erosion occurred at random locations in the sample leaving an uneven, crater-like surface. Therefore, the erosion was measured by determining the weight of sediment

in the sample cavity before and after erosion over a measured time interval during which erosion was continuous. The dry weight of sediment eroded was determined from the difference in weights and from the moisture content measurements. The erosion time period varied from 15 to 90 min. In some cases, the entire sample was eroded out of the sample cavity without warning, and these tests had to be discarded.

Erosion Results and Analysis

The erosion results are given in the figures in Appendix C. The results of erosion tests on the centrifuged, consolidated samples are shown in Fig. C-1 where they are plotted as erosion rate in $kg/m^2/s$ as a function of shear stress in Pa (1 Pa = 10 dynes/cm^2). Beside each data point is a label that indicates the simulated number of years of consolidation followed by the moisture content in percent. Multiple linear regression analysis was performed for erosion rate as a function of shear stress and moisture content, which were found to be the most significant independent variables. The regression equation had the form given by

$$E = a + b\,\tau_0 + c\,\frac{w,\%}{100} \qquad (2)$$

in which E = erosion rate in $kg/m^2/s$, τ_0 = average bed shear stress in Pa; and w, % = moisture content in percent as defined by Eq. 1. The coefficient of determination for the best-fit lines shown in Fig. C-1 is $r^2 = 0.91$. The erosion rate in the best-fit relationship was then set to zero, and the equation was solved for critical shear stress. This automatically determined a linear relationship for critical shear stress τ_c in Pa as a function of moisture content w, % as shown in Fig. C-2. The erosion rates are re-plotted in Fig. C-3 in terms of $(\tau_0 - \tau_c)$, and the least-squares fitted line is shown along with its equation. The effect of moisture content is entirely reflected in

the value of τ_c since including moisture content in the regression of Fig. C-3 showed only a second-order effect on the coefficient. The r^2 value for the best-fit relationship in Fig. C-3 is 0.83 if the data point at 0.0008 kg/m^2/s is considered an outlier. For the most part, the 15-year consolidation data points have lower moisture contents and higher critical shear stresses so that they plot at the lower end of the best-fit line.

A similar analysis was applied to the undisturbed core samples as shown in Fig. C-4 and Fig. C-5 for Fuller Rock and Sabin Point reaches, respectively. Initially all data points were included in the regression, but statistically significant relationships could not be obtained. A few data points were removed from the regression analysis as indicated by the filled data symbols in Figs. C-4 and C-5. Data points were removed only on the basis of obtaining statistically significant values of the regression coefficients at the 95% level based on the value of the t-statistic, not on maximizing the r^2 value. The r^2 values for the Fuller and Sabin reaches are given in Figs. C-4 and C-5, and they are 0.89 and 0.82, respectively, with standard errors of estimate in the erosion rates of 0.0024 and 0.0032 kg/m^2/s, respectively.

Statistically significant values of the regression coefficients for the Bullock Point reach could not be obtained for any subset of the data points partly because of the shear stresses that were chosen for each erosion test. However, it was noted that the coefficients on shear stress for the Fuller Rock and Sabin Point reaches were nearly identical so this same coefficient was applied to the Bullock Point data. A regression analysis on the remaining variation in the erosion rate data produced a statistically significant value of the coefficient on the moisture content with an r^2 value of 0.56. Only three data points were removed from the regression analysis to achieve this relationship and it is shown in Fig. C-6.

The critical shear stress relationships that resulted from the linear multiple regression analyses are shown in Fig. C-7. They are necessarily straight lines, and they are shown over the range of measured moisture contents to which they apply. The critical shear stresses for all three reaches show a different relationship with moisture content, although the Fuller Rock and Sabin Point reaches have relationships with similar slopes, which are also similar to the slope for the consolidated samples. The Bullock Point relationship is in a similar range of moisture contents, but it has a significantly different slope perhaps because of the higher percentage of coarse material found in these cores as noted previously.

The difference in critical shear stress relationships does not seem to be accounted for by any differences in organic matter content as given in Table C-1. The organic matter content was determined according to ASTM Standard D 2976 - 71. It varied between 10 and 12 percent by weight for all three reaches as well as for the consolidated samples. It is possible that the critical shear stresses are different for the three reaches because of a different microstructure of the sediments at the same moisture content that may be influenced by varying salinities along the estuary, but no definite conclusion can be drawn on this point.

The best-fit relationship with excess shear stress ($\tau_0 - \tau_c$) for all three reaches is shown in Fig. C-8 with an r^2 value of 0.78 and a standard error of estimate in the erosion rate of 0.0028 $kg/m^2/s$. The filled data points that were not included in the multiple regression analyses are also shown in Fig. C-8. They all lie well outside the best-fit line by a factor in excess of twice the standard error of estimate.

It should be noted that bulk density is sometimes used in the literature for erosion measurements instead of moisture content, which was used in this report. However, they are

directly related for saturated sediments by the relationship:

$$\rho_b = \frac{\rho_w SG\,(1 + \frac{w,\%}{100})}{1 + SG\,(\frac{w,\%}{100})} \qquad (3)$$

in which ρ_b = bulk density of sediment; ρ_w = water density; SG = specific gravity of sediment; and w,% = moisture content in percent. For the moisture content range in this study, the bulk density varied from approximately 1.20 to 1.32 g/cm^3.

It is concluded that there is an inherent experimental error in determining average mass erosion rates when the sediment is removed in chunks at random points on the bed where interparticle bonds are weakest. In addition, the effect of particle microstructure on erosion rates is not accounted for completely by bulk density or moisture content alone. Nevertheless, the relationships provided herein should provide reasonable estimates of erosion rates specific to Providence River sediments under storm conditions.

APPENDIX A

Hydrometer Analysis E99-A, Fuller Rock Reach (FRR)
C1-C5 (FRR)

Air Dry Mass Used (grams) =	50.12
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	1.00
Percent of Oven Dried Sample (%) =	2.18

Note: Approximately 50-60% shell material

Hygroscopic Moisture

Weight Air Dry (g) =	11.72
Weight Oven Dry (g)=	10.77
Correction Factor =	0.919
Oven Dry Mass used (grams) =	46.06

Depth (in.)	Weight (g)	Sample
0-2	10.5	C1
2-4	9.96	C2
4-6	9.82	C3
6-8	10.37	C4
8-10	9.47	C5

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	22	100.00	0.00	0.009611	2.00000
				97.82			0.07500
2	2	34.0	22	74.65	10.70	0.009611	0.04996
3	5	30.0	22	65.87	11.40	0.009611	0.03262
4	15	25.0	22	54.89	12.20	0.009611	0.01948
5	30	21.5	22	47.21	12.80	0.009611	0.01411
6	60	16.5	22	36.23	13.60	0.009611	0.01028
7	250	11.5	22	25.25	14.40	0.009611	0.00518
8	1440	10.0	22	21.96	14.70	0.009611	0.00218
9	2970	9.5	22	20.86	14.75	0.009611	0.00152

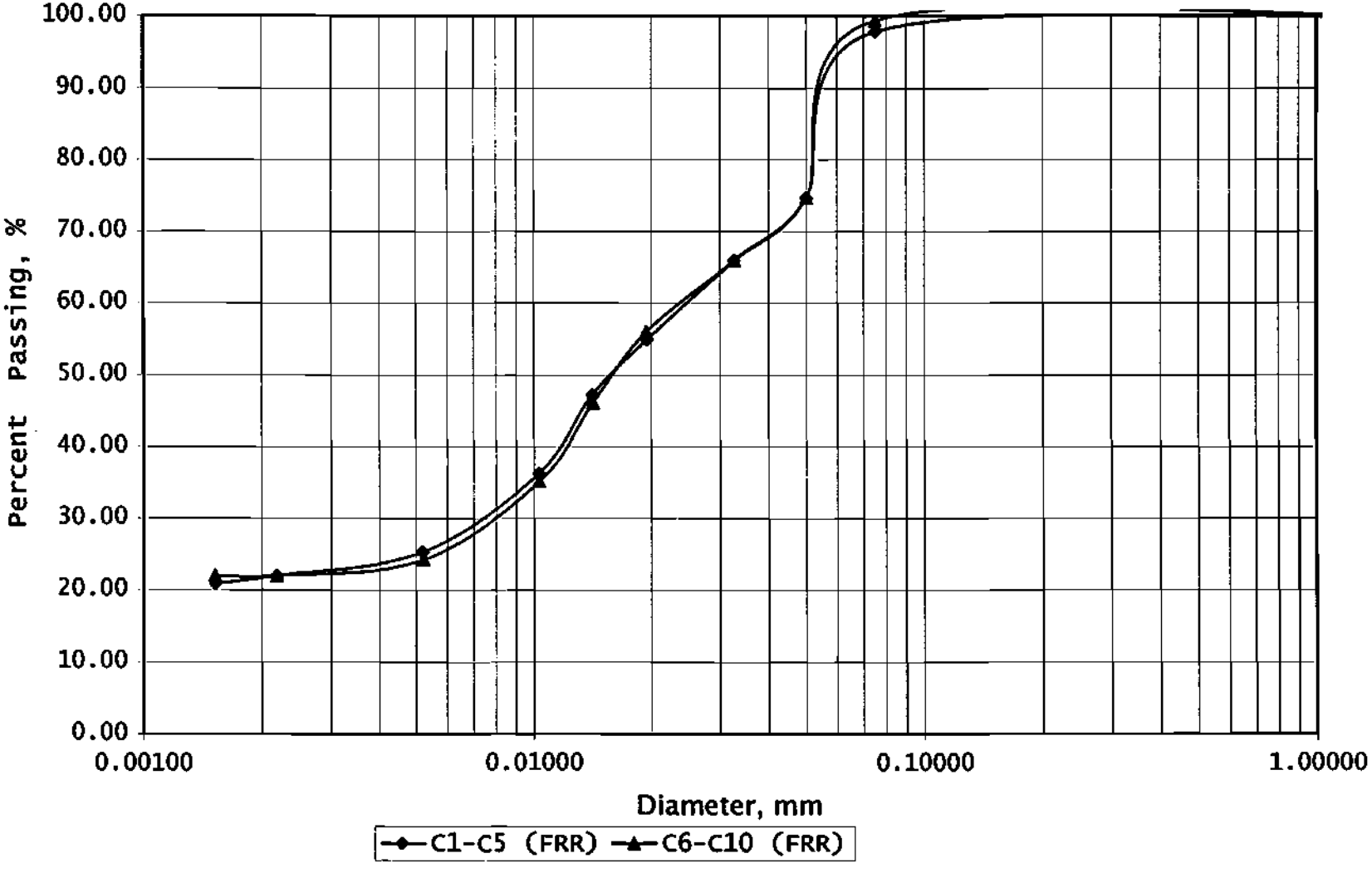
Hydrometer Analysis	E99-A, Fuller Rock Reach (FRR)	
	C6-C10 (FRR)	
Air Dry Mass Used (grams) =	50.96	
Specific Gravity of Soil Particles =	2.586	
Specific Gravity Correction Factor, a =	1.013	
Specific Gravity of Solution =	1.00	
Amount retained on #200 (g) =	0.30	Note: Approximately 0% shell material
Percent of Oven Dried Sample (%) =	0.63	

Hygroscopic Moisture	
Weight Air Dry (g) =	9.72
Weight Oven Dry (g)=	8.94
Correction Factor =	0.920
Oven Dry Mass used (grams) =	46.87

Depth (in.)	Weight (g)	Sample
10-12	10.3	C6
12-14	9.59	C7
14-16	10.6	C8
16-18	10.17	C9
18-20	10.3	C10

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	22	100.00	0.00	0.009611	2.00000
				99.37			0.07500
2	2	34.0	22	74.65	10.70	0.009611	0.04996
3	5	30.0	22	65.87	11.40	0.009611	0.03262
4	15	25.5	22	55.99	12.10	0.009611	0.01940
5	30	21.0	22	46.11	12.90	0.009611	0.01417
6	60	16.0	22	35.13	13.70	0.009611	0.01032
7	250	11.0	22	24.15	14.50	0.009611	0.00520
8	1440	10.0	22	21.96	14.70	0.009611	0.00218
9	2970	10.0	22	21.96	14.70	0.009611	0.00152

Fuller Rock Reach (E99-A)



Hydrometer Analysis	E99-B Fuller Rock Reach (FRR)	
	K1-K3 (FRR)	
Air Dry Mass Used (grams) =	50.04	
Specific Gravity of Soil Particles =	2.586	
Specific Gravity Correction Factor, a =	1.013	
Specific Gravity of Solution =	1.00	
Amount retained on #200 (g) =	0.46	Note: Approximately 70-80% shell material
Percent of Oven Dried Sample (%) =	1.00	

Hygroscopic Moisture	
Weight Air Dry (g) =	9.77
Weight Oven Dry (g)=	8.91
Correction Factor =	0.912
Oven Dry Mass used (grams) =	45.64

Depth (in.)	Weight (g)	Sample
0-4	16.65	K1
4-8	16.73	K2
8-12	16.66	K3

Trial	Time (min)	Hydrometer Reading(152H)	Hydrometer Reading(151H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	Percent of Soil In Suspension (151H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	0	20	100.00	100.00	0.00	0.01002	2.00000
					99.00				0.07500
2	2	36.0	21.0	20	79.05	70.68	10.40	0.01002	0.05030
3	5	31.5	19.0	20	69.16	63.62	11.15	0.01002	0.03294
4	15	25.0	15.5	20	54.89	51.25	12.20	0.01002	0.01989
5	30	22.0	14.0	20	48.31	45.94	12.70	0.01002	0.01435
6	60	18.0	12.0	20	39.52	38.88	13.30	0.01002	0.01038
7	250	13.0	9.5	20	28.54	30.04	14.20	0.01002	0.00526
8	1440	11.0	7.5	20	24.15	22.97	14.50	0.01002	0.00221
9	2970	10.0	7.0	20	21.96	21.21	14.70	0.01002	0.00155

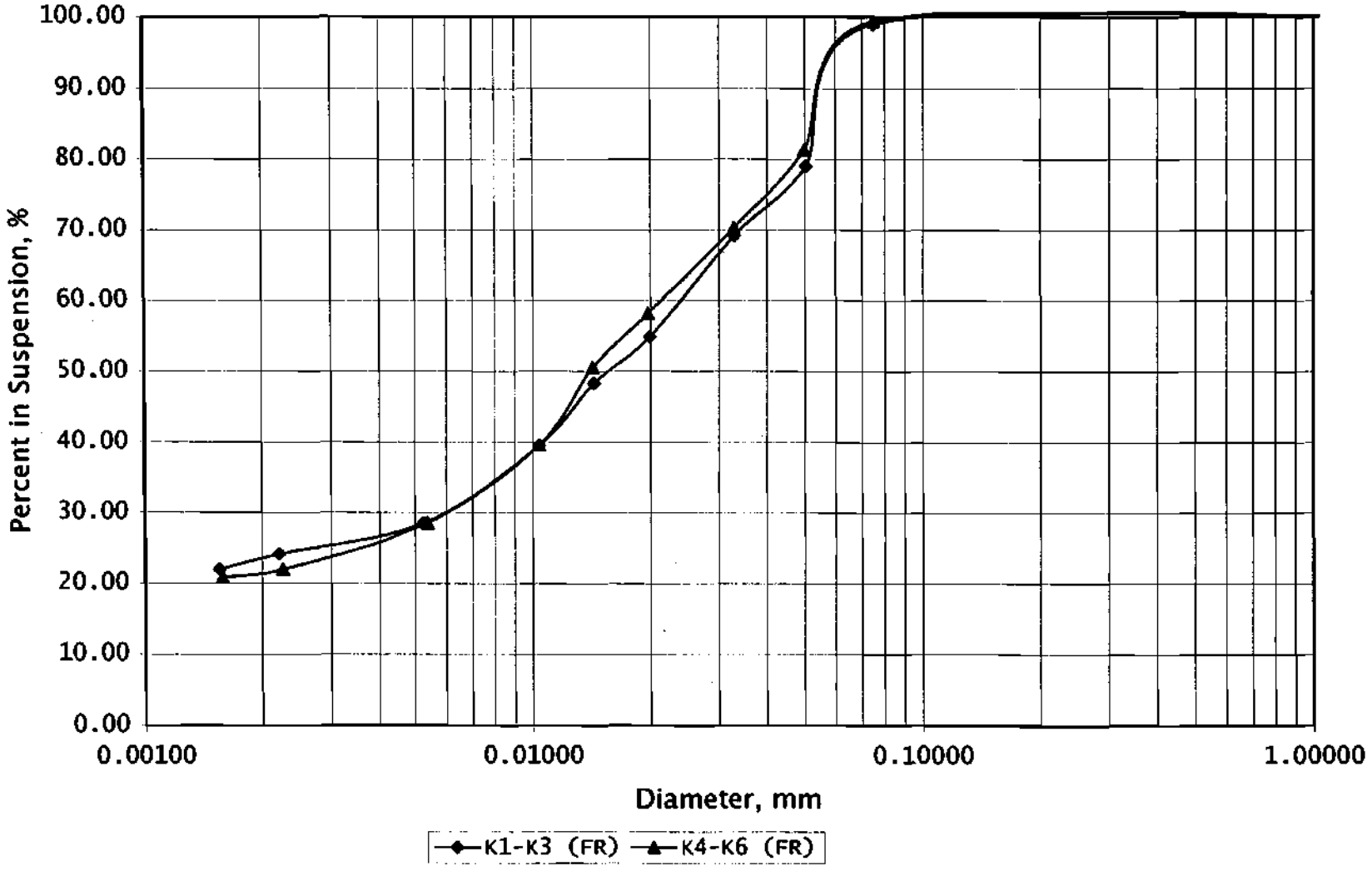
Hydrometer Analysis	E99-B Fuller Rock Reach (FRR)	
	K4-K6 (FRR)	
Air Dry Mass Used (grams) =	49.89	
Specific Gravity of Soil Particles =	2.586	
Specific Gravity Correction Factor, a =	1.013	
Specific Gravity of Solution =	1.00	
Amount retained on #200 (g) =	0.27	Note: Approximately 0% shell material
Percent of Oven Dried Sample (%) =	0.59	

Hygroscopic Moisture	
Weight Air Dry (g) =	9.89
Weight Oven Dry (g)=	9.02
Correction Factor =	0.912
Oven Dry Mass used (grams) =	45.50

Depth (in.)	Weight (g)	Sample
12-16	16.45	K4
16-20	16.68	K5
20-24	16.76	K6

Trial	Time (min)	Hydrometer Reading(152H)	Hydrometer Reading(151H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	Percent of Soil In Suspension (151H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	0	20	100.00	100.00	0.00	0.01002	2.00000
					99.41				0.07500
2	2	37.0	21.0	20	81.24	70.68	10.20	0.01002	0.04981
3	5	32.0	19.0	20	70.26	63.62	11.10	0.01002	0.03286
4	15	26.5	16.0	20	58.19	53.01	11.95	0.01002	0.01969
5	30	23.0	14.5	20	50.50	47.71	12.50	0.01002	0.01424
6	60	18.0	12.0	20	39.52	38.88	13.30	0.01002	0.01038
7	250	13.0	8.0	20	28.54	24.74	14.80	0.01002	0.00537
8	1440	10.0	7.5	20	21.96	22.97	15.10	0.01002	0.00226
9	2970	9.5	7.0	20	20.86	21.21	15.20	0.01002	0.00158

Fuller Rock Reach (E99-B)



Hydrometer Analysis E99-C, Fuller Rock Reach (FRR)
J1-J5 (FRR)

Air Dry Mass Used (grams) =	50.5
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	0.69
Percent of Oven Dried Sample (%) =	1.47

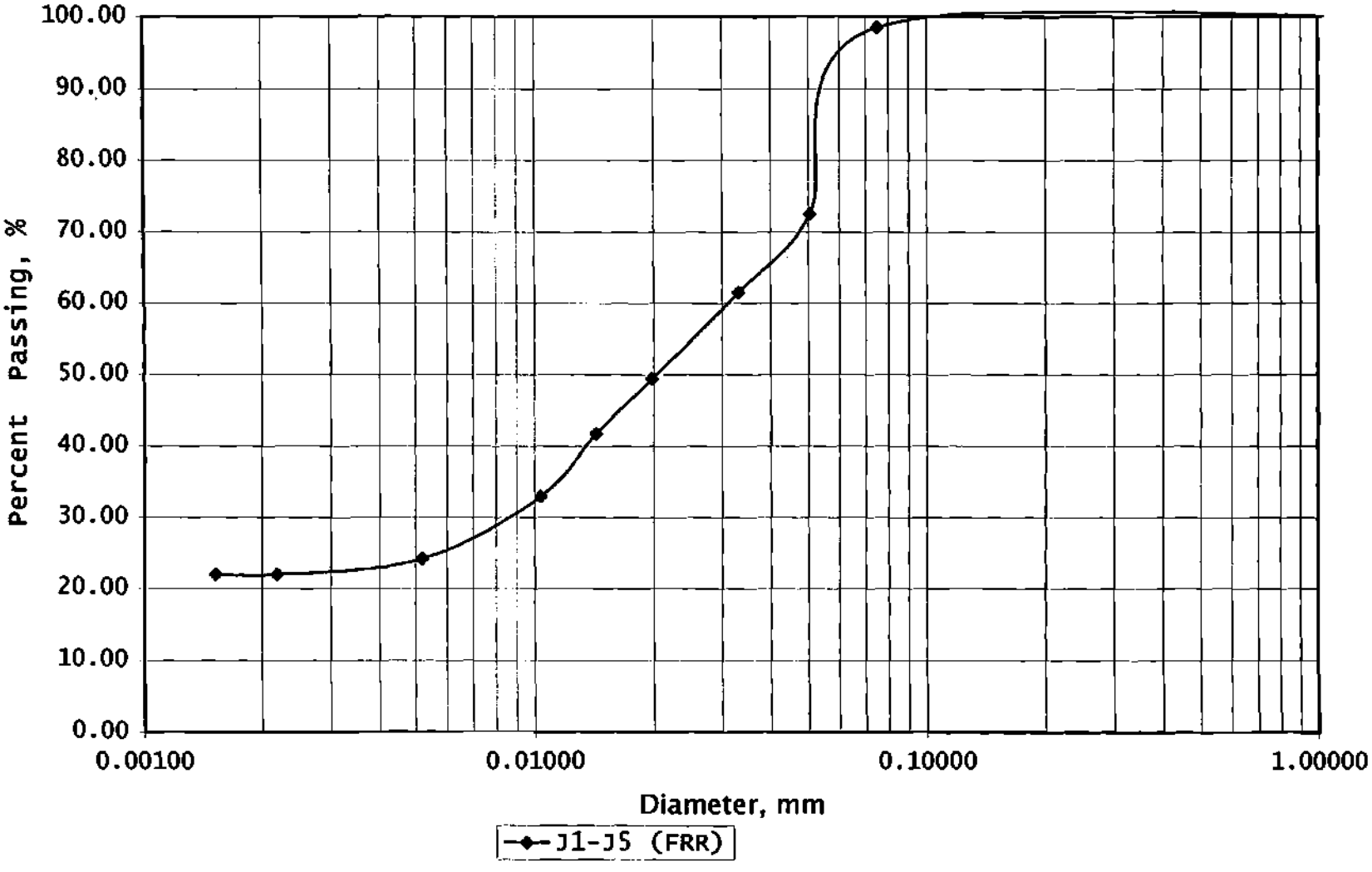
Note: Approximately 0% shell material

Hygroscopic Moisture	
Weight Air Dry (g) =	11.62
Weight Oven Dry (g)=	10.78
Correction Factor =	0.928
Oven Dry Mass used (grams) =	46.85

Depth (in.)	Weight (g)	Sample
0-4	10.26	J1
4-8	10.33	J2
8-12	9.23	J3
12-16	10.08	J4
16-20.75	10.6	J5

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	22	100.00	0.00	0.009611	2.00000
				98.53			0.07500
2	2	33.0	22	72.46	10.90	0.009611	0.05043
3	5	28.0	22	61.48	11.70	0.009611	0.03304
4	15	22.5	22	49.40	12.60	0.009611	0.01980
5	30	19.0	22	41.72	13.20	0.009611	0.01433
6	60	15.0	22	32.94	13.80	0.009611	0.01036
7	250	11.0	22	24.15	14.50	0.009611	0.00520
8	1440	10.0	22	21.96	14.70	0.009611	0.00218
9	2970	10.0	22	21.96	14.70	0.009611	0.00152

Fuller Rock Reach (E99-C)



Hydrometer Analysis E99-D Sabin Point Reach (SPR)
F1-F3 (SPR)

Air Dry Mass Used (grams) =	50.1
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	0.99
Percent of Oven Dried Sample (%) =	2.12

Note: Approximately 40-50% shell material

Hygroscopic Moisture	
Weight Air Dry (g) =	8.12
Weight Oven Dry (g)=	7.539
Correction Factor =	0.928
Oven Dry Mass used (grams) =	46.52

Depth (in.)	Weight (g)	Sample
0-4	16.74	F1
4-8	16.71	F2
8-12	16.65	F3

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	24	100.00	0.00	0.009202	2.00000
				97.88			0.07500
2	2	31.0	24	68.07	11.20	0.009202	0.05002
3	5	27.0	24	59.28	11.90	0.009202	0.03261
4	15	22.0	24	48.31	12.70	0.009202	0.01945
5	30	20.0	24	43.91	13.00	0.009202	0.01391
6	60	15.0	24	32.94	13.80	0.009202	0.01014
7	250	12.0	24	26.35	14.30	0.009202	0.00506
8	1440	10.0	23.5	21.96	14.70	0.009304	0.00215
9	2970	9.0	23	19.76	14.80	0.009407	0.00151

Hydrometer Analysis E99-D Sabin Point Reach (SPR)
F4-F6 (SPR)

Air Dry Mass Used (grams) =	50.12
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	0.67
Percent of Oven Dried Sample (%) =	1.42

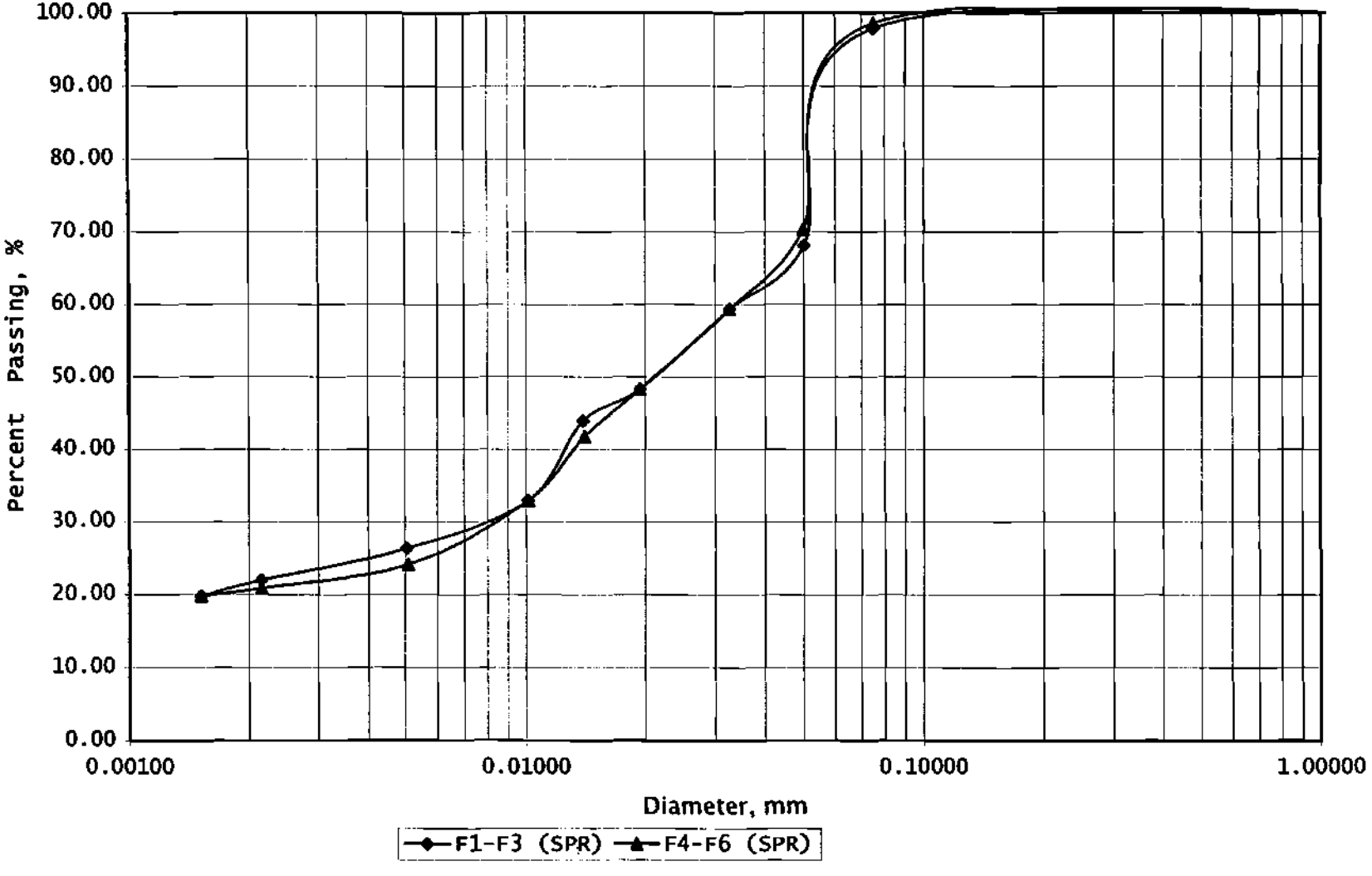
Note: Approximately 10-20% shell material

Hygroscopic Moisture	
Weight Air Dry (g) =	9.637
Weight Oven Dry (g)=	8.994
Correction Factor =	0.933
Oven Dry Mass used (grams) =	46.78

Depth (in.)	Weight (g)	Sample
12-16	16.59	F4
16-20	16.69	F5
20-24	16.84	F6

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	24	100.00	0.00	0.009202	2.00000
				98.58			0.07500
2	2	32.0	24	70.26	11.10	0.009202	0.04980
3	5	27.0	24	59.28	11.90	0.009202	0.03261
4	15	22.0	24	48.31	12.70	0.009202	0.01945
5	30	19.0	24	41.72	13.20	0.009202	0.01402
6	60	15.0	24	32.94	13.80	0.009202	0.01014
7	250	11.0	24	24.15	14.50	0.009202	0.00509
8	1440	9.5	23.5	20.86	14.75	0.009304	0.00215
9	2970	9.0	23	19.76	14.80	0.009407	0.00151

Sabin Point Reach (E99-D)



Hydrometer Analysis E99-E, Sabin Point Reach (SPR)
I1-I3 (SPR)

Air Dry Mass Used (grams) =	49.52
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	2.16
Percent of Oven Dried Sample (%) =	4.68

Note: Approximately 60-70% shell material

Hygroscopic Moisture	
Weight Air Dry (g) =	7.9
Weight Oven Dry (g)=	7.37
Correction Factor =	0.933
Oven Dry Mass used (grams) =	46.20

Depth (in.)	Weight (g)	Sample
0-4	16.41	I1
4-8	16.78	I2
8-12	16.33	I3

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	23	100.00	0.00	0.009407	2.00000
				95.32			0.07500
2	2	32.5	23	71.36	11.00	0.009407	0.05012
3	5	28.0	23	61.48	11.70	0.009407	0.03269
4	15	23.0	23	50.50	12.50	0.009407	0.01951
5	30	18.5	23	40.62	13.25	0.009407	0.01420
6	60	14.0	23	30.74	14.00	0.009407	0.01032
7	250	10.0	23	21.96	14.70	0.009407	0.00518
8	1440	9.0	23	19.76	14.80	0.009407	0.00217
9	2970	9.0	23	19.76	14.80	0.009407	0.00151

Hydrometer Analysis E99-E, Sabin Point Reach (SPR)
I4-I6 (SPR)

Air Dry Mass Used (grams) = 50.04
Specific Gravity of Soil Particles = 2.586
Specific Gravity Correction Factor, a = 1.013
Specific Gravity of Solution = 1.00
Amount retained on #200 (g) = 0.99
Percent of Oven Dried Sample (%) = 2.11

Note: Approximately 5-10% shell material

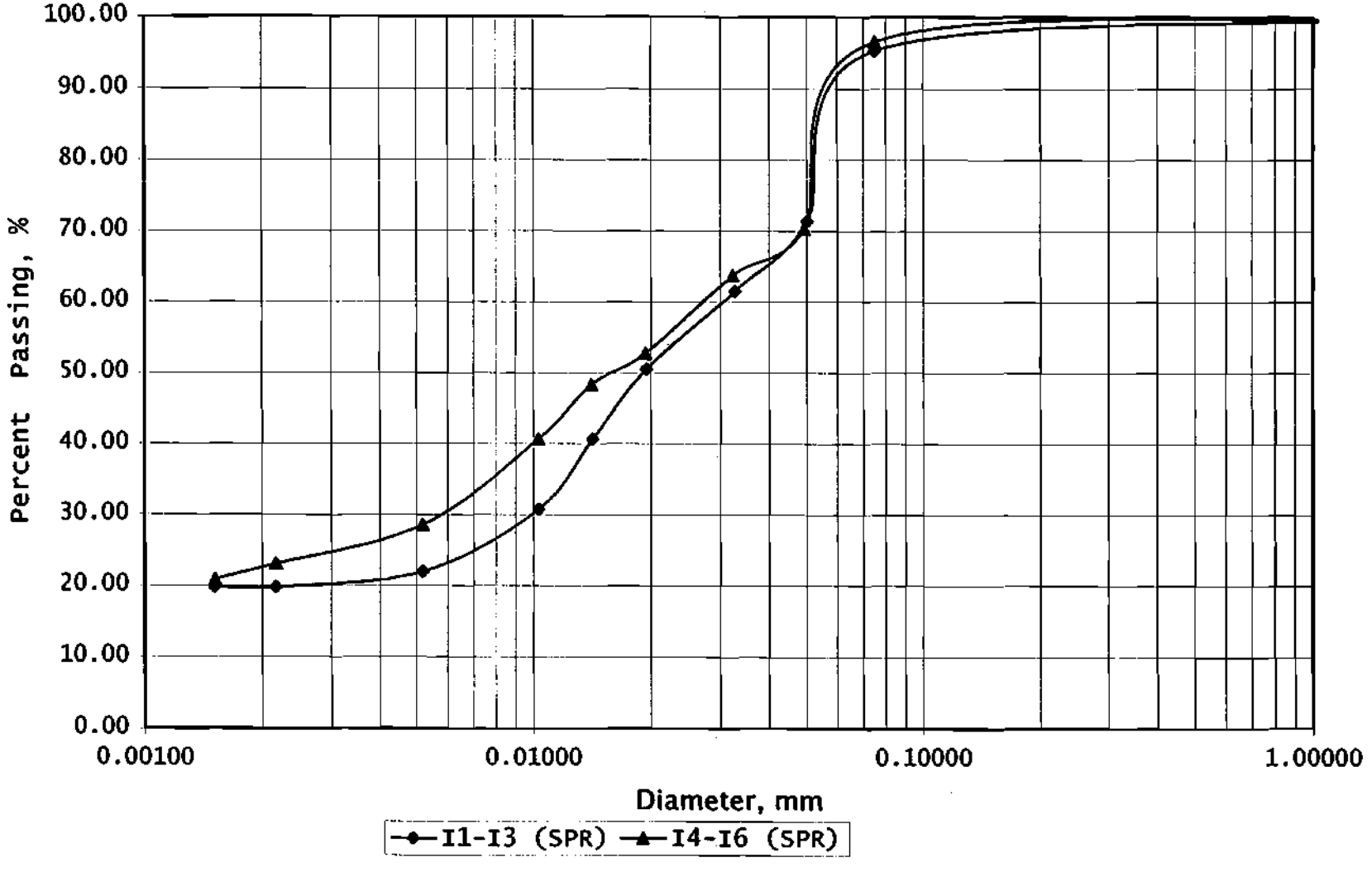
Hygroscopic Moisture

Weight Air Dry (g) = 8.65
Weight Oven Dry (g)= 8.09
Correction Factor = 0.935
Oven Dry Mass used (grams) = 46.80

Depth (in.)	Weight (g)	Sample
12-16	16.49	I4
16-20	16.78	I5
20-24	16.77	I6

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	23	100.00	0.00	0.009407	2.00000
				97.89			0.07500
2	2	35.0	23	76.85	10.60	0.009407	0.04920
3	5	30.0	23	65.87	11.40	0.009407	0.03227
4	15	24.5	23	53.79	12.30	0.009407	0.01935
5	30	19.5	23	42.82	13.10	0.009407	0.01412
6	60	14.5	23	31.84	13.90	0.009407	0.01029
7	250	10.0	23	21.96	14.70	0.009407	0.00518
8	1440	9.0	23	19.76	14.80	0.009407	0.00217
9	2970	8.5	23	18.66	14.90	0.009407	0.00151

Sabin Point Reach (E99-E)



Hydrometer Analysis E99-E Sabin Point Reach (SPR) - Additional Sample
H1-H3 (SPR)

Air Dry Mass Used (grams) =	50.04
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	1.43
Percent of Oven Dried Sample (%) =	3.10

Note: Approximately 50-60% shell material

Hygroscopic Moisture	
Weight Air Dry (g) =	9.74
Weight Oven Dry (g)=	8.98
Correction Factor =	0.922
Oven Dry Mass used (grams) =	46.14

Depth (in.)	Weight (g)	Sample
0-4	16.69	H1
4-8	16.74	H2
8-12	16.61	H3

Trial	Time (min)	Hydrometer Reading(152H)	Hydrometer Reading(151H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	Percent of Soil In Suspension (151H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	0	20	100.00	100.00	0.00	0.01002	2.00000
					96.90				0.07500
2	2	36.5	21.0	20	80.14	70.68	10.30	0.01002	0.05005
3	5	30.0	19.0	20	65.87	63.62	11.40	0.01002	0.03330
4	15	28.0	17.5	20	61.48	58.31	11.70	0.01002	0.01948
5	30	23.0	14.5	20	50.50	47.71	12.50	0.01002	0.01424
6	60	18.0	11.0	20	39.52	35.34	13.30	0.01002	0.01038
7	250	12.0	8.0	20	26.35	24.74	14.30	0.01002	0.00528
8	1440	10.0	7.0	20	21.96	21.21	14.70	0.01002	0.00223
9	2970	9.5	6.5	20	20.86	19.44	14.75	0.01002	0.00155

Hydrometer Analysis E99-E Sabin Point Reach (SPR) - Additional Sample
H4-H6 (SPR)

Air Dry Mass Used (grams) =	50.01
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	0.62
Percent of Oven Dried Sample (%) =	1.35

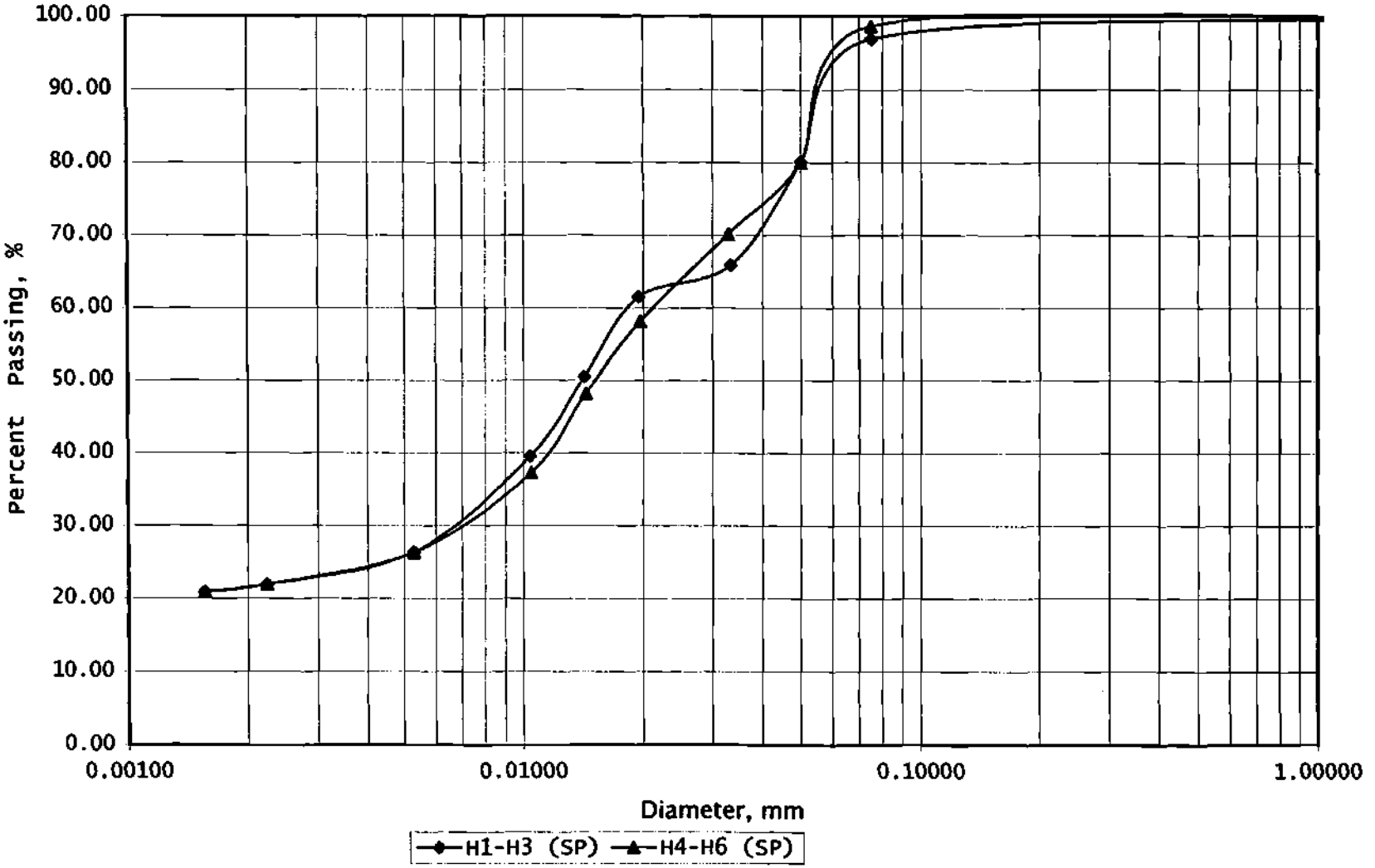
Note: Approximately 0% shell material

Hygroscopic Moisture	
Weight Air Dry (g) =	9.83
Weight Oven Dry (g)=	9.08
Correction Factor =	0.924
Oven Dry Mass used (grams) =	46.19

Depth (in.)	Weight (g)	Sample
12-16	16.65	H4
16-20	16.64	H5
20-23.5	16.72	H6

Trial	Time (min)	Hydrometer Reading(152H)	Hydrometer Reading(151H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	Percent of Soil In Suspension (151H)	L (cm)	n (poise)	Diameter (mm)
1	0	0.00	0.00	20	100	100	0.00	0.01002	2.0000
					98.65				0.07500
2	2	36.50	22.00	20	80.04	74.12	10.30	0.01002	0.05005
3	5	32.00	19.00	20	70.17	63.53	11.10	0.01002	0.03286
4	15	26.50	16.50	20	58.11	54.71	11.95	0.01002	0.01969
5	30	22.00	14.00	20	48.24	45.89	12.70	0.01002	0.01435
6	60	17.00	10.50	20	37.28	33.53	13.50	0.01002	0.01046
7	250	12.00	8.00	20	26.31	24.71	14.30	0.01002	0.00528
8	1440	10.00	7.00	20	21.93	21.18	14.70	0.01002	0.00223
9	2970	9.50	6.50	20	20.83	19.41	14.85	0.01002	0.00156

Sabin Point Reach (E99-E)



Hydrometer Analysis E99-F Sabin Point Reach (SPR)
E1-E3 (SPR)

Air Dry Mass Used (grams) =	49.68
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	0.85
Percent of Oven Dried Sample (%) =	1.85

Note: Approximately 5-10% shell material

Hygroscopic Moisture	
Weight Air Dry (g) =	10.26
Weight Oven Dry (g)=	9.454
Correction Factor =	0.921
Oven Dry Mass used (grams) =	45.78

Depth (in.)	Weight (g)	Sample
0-4	16.65	E1
4-8	16.26	E2
8-12	16.77	E3

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	24	100.00	0.00	0.009202	2.00000
				98.15			0.07500
2	2	33.0	24	72.46	10.90	0.009202	0.04934
3	5	27.0	24	59.28	11.90	0.009202	0.03261
4	15	23.5	24	51.60	12.45	0.009202	0.01926
5	30	20.0	24	43.91	13.00	0.009202	0.01391
6	60	17.0	24	37.33	13.50	0.009202	0.01003
7	250	12.0	24	26.35	14.30	0.009202	0.00506
8	1440	10.5	23.5	23.05	14.60	0.0093043	0.00214
9	2970	9.0	23	19.76	14.80	0.0094065	0.00151

Hydrometer Analysis E99-F Sabin Point Reach (SPR)
E4-E6 (SPR)

Air Dry Mass Used (grams) =	50.2
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	2.86
Percent of Oven Dried Sample (%) =	6.13

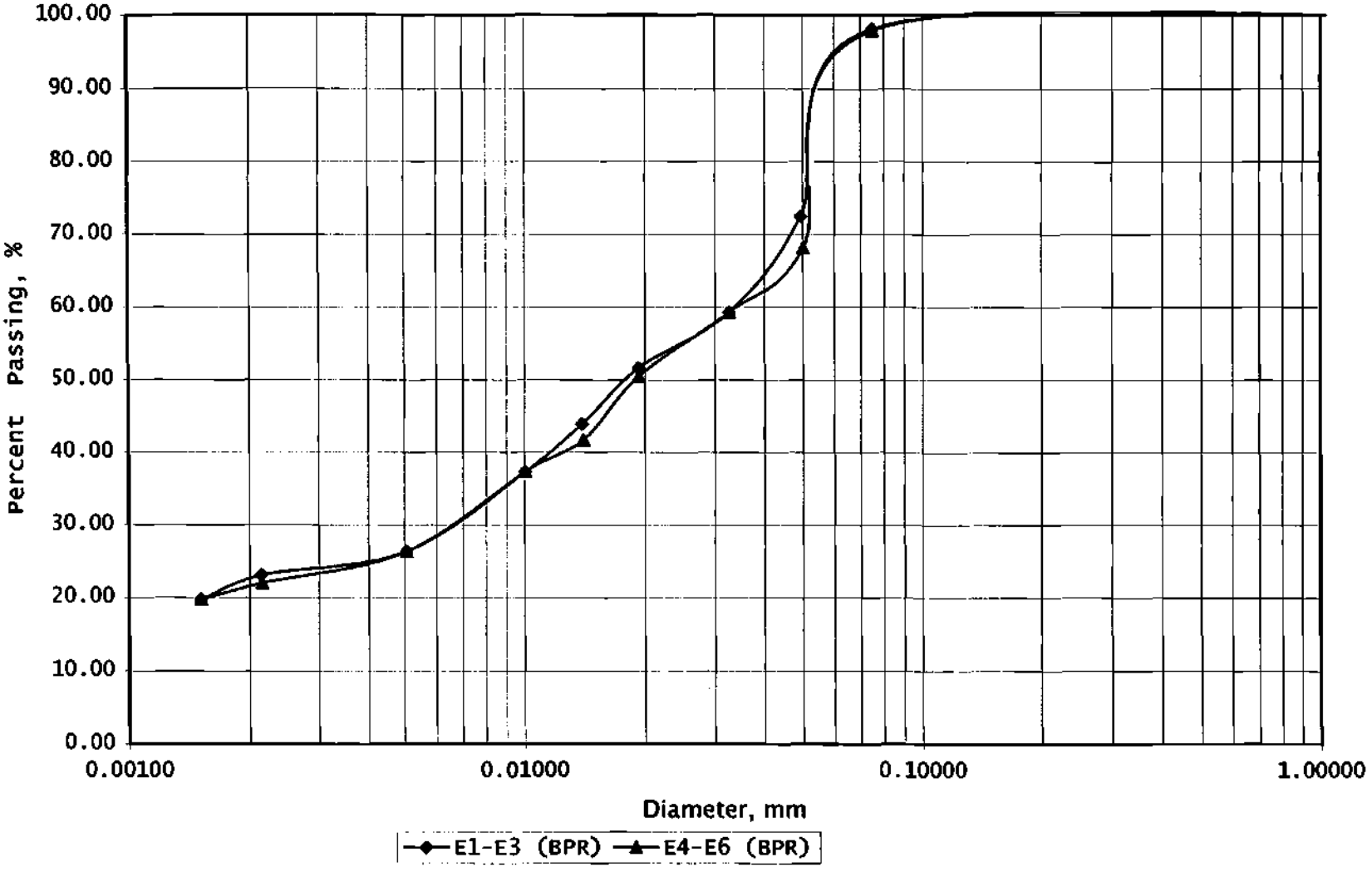
Note: Approximately 20-30% shell material

Hygroscopic Moisture	
Weight Air Dry (g) =	11.15
Weight Oven Dry (g)=	10.37
Correction Factor =	0.930
Oven Dry Mass used (grams) =	46.69

Depth (in.)	Weight (g)	Sample
12-16	16.89	E4
16-20	16.63	E5
20-24.5	16.68	E6

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	24	100.00	0.00	0.009202	2.00000
				93.87			0.07500
2	2	31.0	24	68.07	11.20	0.009202	0.05002
3	5	26.5	24	58.19	12.10	0.009202	0.03288
4	15	22.0	24	48.31	12.70	0.009202	0.01945
5	30	19.0	24	41.72	13.20	0.009202	0.01402
6	60	16.0	24	35.13	13.70	0.009202	0.01010
7	250	11.0	24	24.15	14.50	0.009202	0.00509
8	1440	10.0	23.5	21.96	14.70	0.0093043	0.00215
9	2970	8.5	23	18.66	14.90	0.0094065	0.00151

Sabin Point Reach (E99-F)



Hydrometer Analysis E99-G Bullock Point Reach (BPR)
G1-G4 (BPR)

Air Dry Mass Used (grams) =	50
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	0.40
Percent of Oven Dried Sample (%) =	0.86

Note: Approximately 10- 20% shell material

Hygroscopic Moisture	
Weight Air Dry (g) =	9.781
Weight Oven Dry (g)=	9.074
Correction Factor =	0.928
Oven Dry Mass used (grams) =	46.39

Depth (in.)	Weight (g)	Sample
0-4	12.48	G1
4-8	12.46	G2
8-12	12.53	G3
12-16	12.53	G4

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	24	100.00	0.00	0.009202	2.00000
				99.14			0.07500
2	2	33.0	24	72.46	10.90	0.009202	0.04934
3	5	30.0	24	65.87	11.40	0.009202	0.03192
4	15	25.0	24	54.89	12.20	0.009202	0.01906
5	30	21.0	24	46.11	12.90	0.009202	0.01386
6	60	17.5	24	38.42	13.60	0.009202	0.01006
7	250	12.0	24	26.35	14.30	0.009202	0.00506
8	1440	11.0	23.5	24.15	14.50	0.009304	0.00213
9	2970	10.0	23	21.96	14.70	0.009407	0.00150

Hydrometer Analysis E99-G Bullock Point Reach (BPR)
G5-G8 (BPR)

Air Dry Mass Used (grams) =	50.36
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	0.89
Percent of Oven Dried Sample (%) =	1.91

Note: Approximately 5-10% shell material

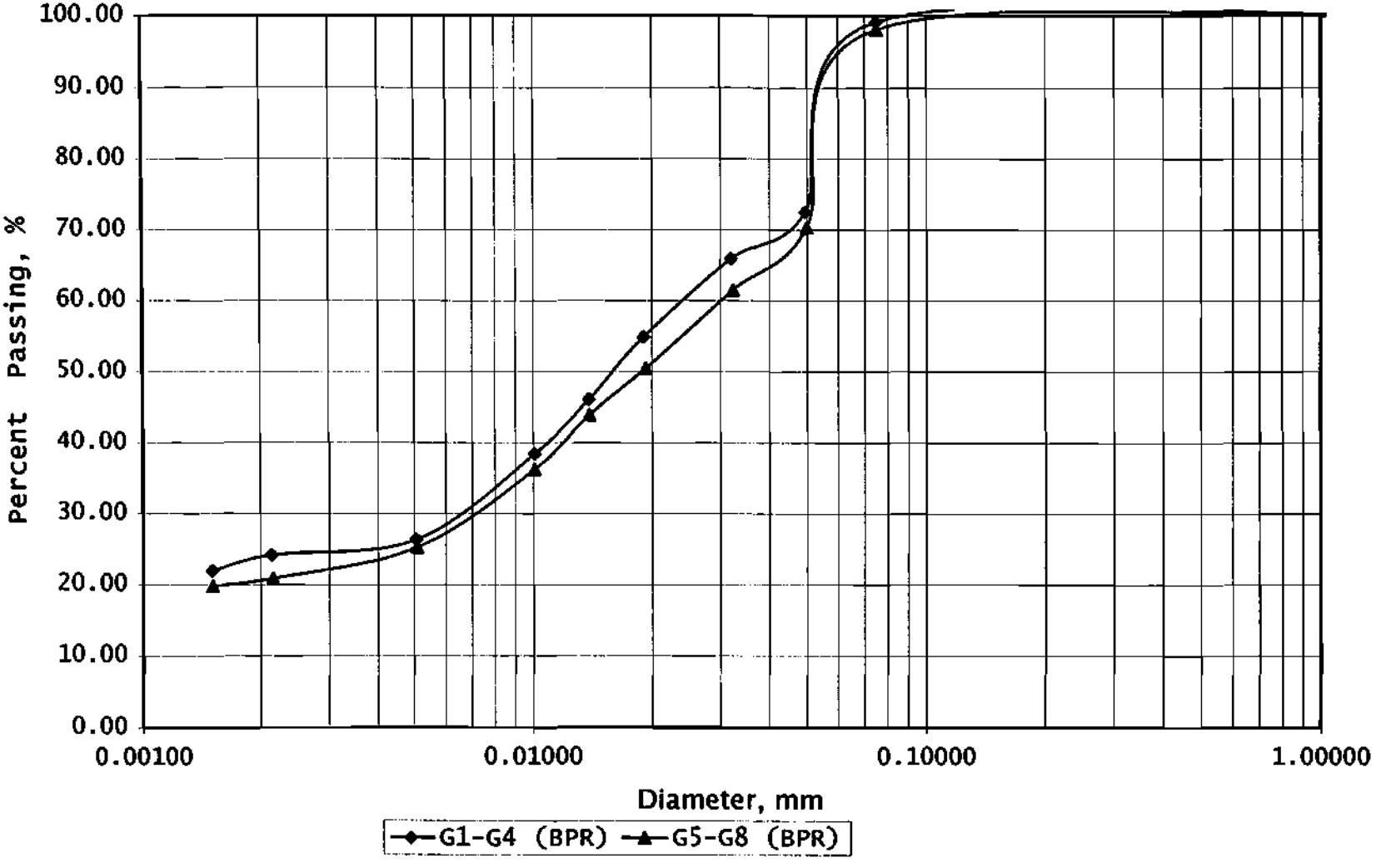
Hygroscopic Moisture

Weight Air Dry (g) =	9.781
Weight Oven Dry (g)=	9.074
Correction Factor =	0.928
Oven Dry Mass used (grams) =	46.72

Depth (in.)	Weight (g)	Sample
16-20	12.58	G5
20-24	12.53	G6
24-28	12.55	G7
28-31.75	12.7	G8

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	24	100.00	0.00	0.009202	2.00000
				98.09			0.07500
2	2	32.0	24	70.26	11.10	0.009202	0.04980
3	5	28.0	24	61.48	11.70	0.009202	0.03233
4	15	23.0	24	50.50	12.50	0.009202	0.01930
5	30	20.0	24	43.91	13.00	0.009202	0.01391
6	60	16.5	24	36.23	13.60	0.009202	0.01006
7	250	11.5	24	25.25	14.40	0.009202	0.00507
8	1440	9.5	23.5	20.86	14.75	0.009304	0.00215
9	2970	9.0	23	19.76	14.80	0.009407	0.00151

Bullock Point Reach (E99-G)



Hydrometer Analysis E99-H, Bullock Point Reach (BPR)
A1-A4 (BPR)

Air Dry Mass Used (grams) =	49.82
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	1.57
Percent of Oven Dried Sample (%) =	3.44

Note: Approximately 60-70% shell material

Hygroscopic Moisture	
Weight Air Dry (g) =	10.83
Weight Oven Dry (g)=	9.92
Correction Factor =	0.916
Oven Dry Mass used (grams) =	45.63

Depth (in.)	Weight (g)	Sample
0-2	11.33	A1
2-4	12.68	A2
4-6	12.95	A3
6-8	12.86	A4

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	23	100.00	0.00	0.009407	2.00000
				96.56			0.07500
2	2	32.0	23	70.26	11.10	0.009407	0.05035
3	5	29.0	23	63.68	11.50	0.009407	0.03241
4	15	24.0	23	52.70	12.40	0.009407	0.01943
5	30	22.0	23	48.31	12.70	0.009407	0.01390
6	60	18.5	23	40.62	13.25	0.009407	0.01004
7	250	13.0	23	28.54	14.20	0.009407	0.00509
8	1440	10.5	23	23.05	14.60	0.009407	0.00215
9	2970	9.5	23	20.86	14.75	0.009407	0.00151

Hydrometer Analysis E99-H, Bullock Point Reach (BPR)
A5-A8 (BPR)

Air Dry Mass Used (grams) =	49.89
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	4.77
Percent of Oven Dried Sample (%) =	10.28

Note: Approximately 70-80% shell material

Hygroscopic Moisture	
Weight Air Dry (g) =	11.28
Weight Oven Dry (g)=	10.49
Correction Factor =	0.930
Oven Dry Mass used (grams) =	46.40

Depth (in.)	Weight (g)	Sample
8-10	12.53	A5
10-12	12.54	A6
12-14	12.49	A7
14-16	12.33	A8

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	23	100.00	0.00	0.009407	2.00000
				89.72			0.07500
2	2	31.0	23	68.07	11.20	0.009407	0.05057
3	5	27.0	23	59.28	11.90	0.009407	0.03297
4	15	22.0	23	48.31	12.70	0.009407	0.01966
5	30	18.0	23	39.52	13.30	0.009407	0.01423
6	60	15.5	23	34.03	13.75	0.009407	0.01023
7	250	11.5	23	25.25	14.40	0.009407	0.00513
8	1440	9.5	23	20.86	14.75	0.009407	0.00216
9	2970	8.5	23	18.66	14.90	0.009407	0.00151

Hydrometer Analysis E99-H, Bullock Point Reach (BPR)
A9-A11 (BPR)

Air Dry Mass Used (grams) =	49.99
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	7.51
Percent of Oven Dried Sample (%) =	15.92

Note: Approximately 50-60% shell material

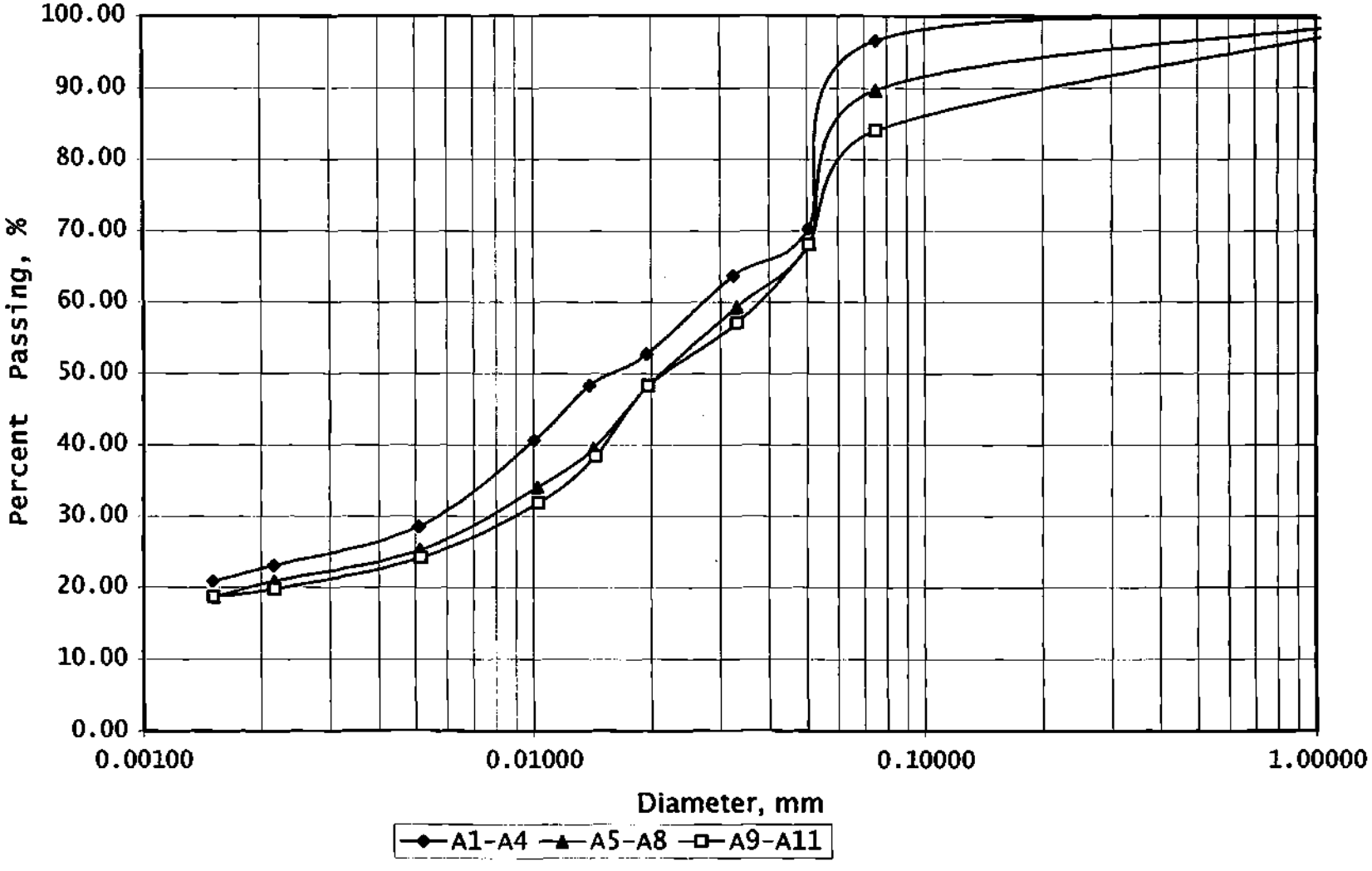
Hygroscopic Moisture

Weight Air Dry (g) =	9.55
Weight Oven Dry (g)=	9.01
Correction Factor =	0.943
Oven Dry Mass used (grams) =	47.16

Depth (in.)	Weight (g)	Sample
16-18	16.75	A9
18-20	16.66	A10
20-22.5	16.58	A11

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	23	100.00	0.00	0.009407	2.00000
				84.08			0.07500
2	2	31.0	23	68.07	11.20	0.009407	0.05057
3	5	26.0	23	57.09	12.00	0.009407	0.03311
4	15	22.0	23	48.31	12.70	0.009407	0.01966
5	30	17.5	23	38.42	13.60	0.009407	0.01439
6	60	14.5	23	31.84	13.90	0.009407	0.01029
7	250	11.0	23	24.15	14.50	0.009407	0.00515
8	1440	9.0	23	19.76	14.80	0.009407	0.00217
9	2970	8.5	23	18.66	14.90	0.009407	0.00151

Bullock Point Reach (E99-H)



Hydrometer Analysis	E99-I, Bullock Point Reach (BPR) B1-B5 (BPR)	
Air Dry Mass Used (grams) =	49.41	
Specific Gravity of Soil Particles =	2.586	
Specific Gravity Correction Factor, a =	1.013	
Specific Gravity of Solution =	1.00	
Amount retained on #200 (g) =	1.81	Note: Approximately 60-70% shell material
Percent of Oven Dried Sample (%) =	3.95	

Hygroscopic Moisture	
Weight Air Dry (g) =	9.02
Weight Oven Dry (g)=	8.36
Correction Factor =	0.927
Oven Dry Mass used (grams) =	45.79

Depth (in.)	Weight (g)	Sample
0-2	10.08	B1
2-4	10.24	B2
4-6	9.57	B3
6-8	9.61	B4
8-10	9.91	B5

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	22	100.00	0.00	0.009611	2.00000
				96.05			0.07500
2	2	32.0	22	70.26	11.10	0.009611	0.05089
3	5	28.0	22	61.48	11.70	0.009611	0.03304
4	15	23.5	22	51.60	12.50	0.009611	0.01972
5	30	20.0	22	43.91	13.00	0.009611	0.01422
6	60	17.0	22	37.33	13.50	0.009611	0.01025
7	250	12.0	22	26.35	14.30	0.009611	0.00517
8	1440	10.0	22	21.96	14.70	0.009611	0.00218
9	2970	9.5	22	20.86	14.75	0.009611	0.00152

Hydrometer Analysis E99-I, Bullock Point Reach (BPR)
B6-B10 (BPR)

Air Dry Mass Used (grams) =	50.76
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	0.93
Percent of Oven Dried Sample (%) =	1.98

Note: Approximately 20-30% shell material

Hygroscopic Moisture	
Weight Air Dry (g) =	11.62
Weight Oven Dry (g)=	10.78
Correction Factor =	0.928
Oven Dry Mass used (grams) =	47.09

Depth (in.)	Weight (g)	Sample
10-12	10.34	B6
12-14	10.09	B7
14-16	9.99	B8
16-18	10.15	B9
18-20	10.19	B10

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	22	100.00	0.00	0.009611	2.00000
				98.02			0.07500
2	2	32.0	22	70.26	11.10	0.009611	0.05089
3	5	28.0	22	61.48	11.70	0.009611	0.03304
4	15	24.0	22	52.70	12.40	0.009611	0.01964
5	30	21.0	22	46.11	12.90	0.009611	0.01417
6	60	17.0	22	37.33	13.50	0.009611	0.01025
7	250	11.5	22	25.25	14.40	0.009611	0.00518
8	1440	10.0	22	21.96	14.70	0.009611	0.00218
9	2970	9.5	22	20.86	14.75	0.009611	0.00152

Hydrometer Analysis E99-I, Bullock Point Reach (BPR)
B11-B14 (BPR)

Air Dry Mass Used (grams) =	50.05
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	0.54
Percent of Oven Dried Sample (%) =	1.15

Note: Approximately 0% shell material

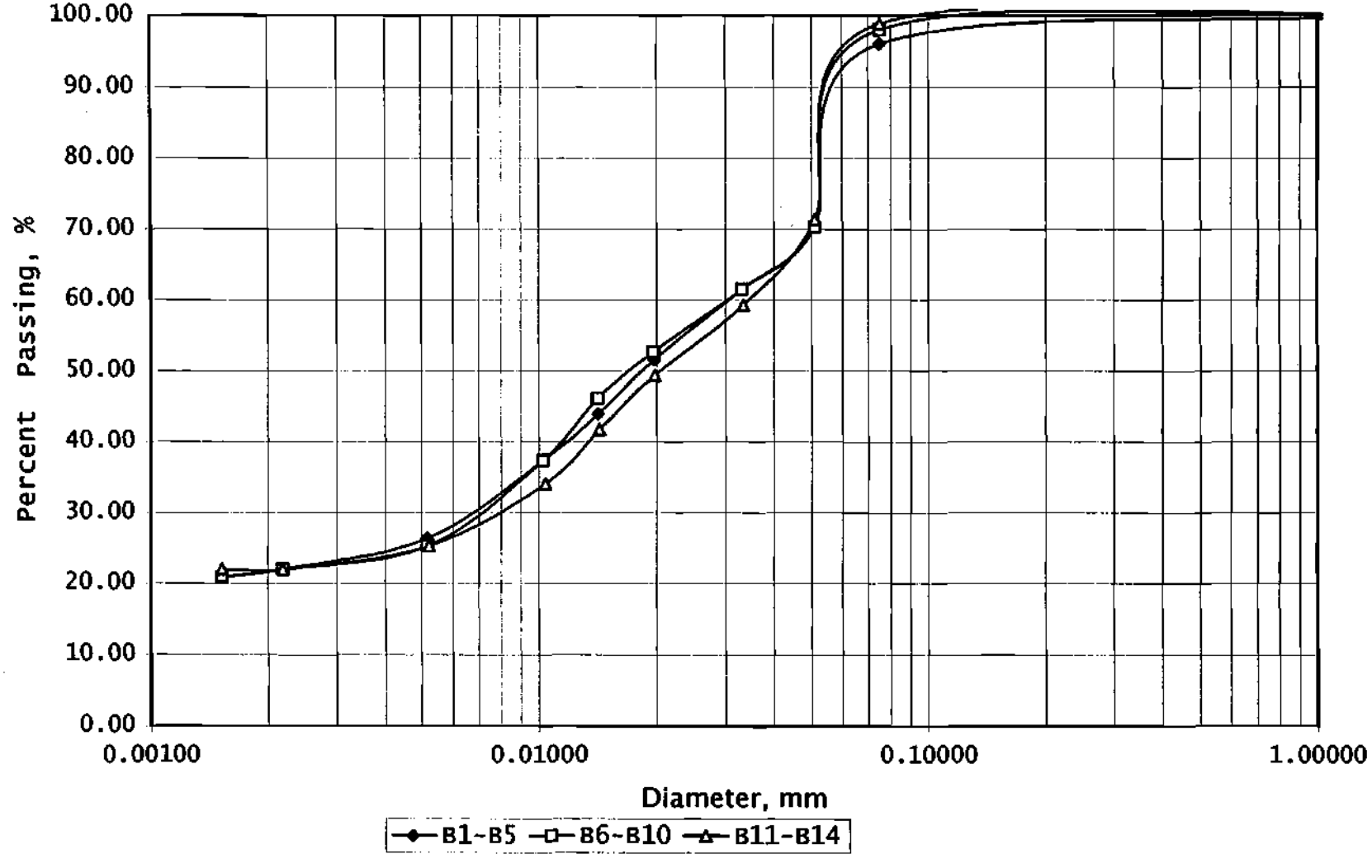
Hygroscopic Moisture

Weight Air Dry (g) =	7.75
Weight Oven Dry (g)=	7.27
Correction Factor =	0.938
Oven Dry Mass used (grams) =	46.95

Depth (in.)	Weight (g)	Sample
20-22	11.19	B11
22-24	14.56	B12
24-26	12.04	B13
26-28	12.26	B14

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	22	100.00	0.00	0.009611	2.00000
				98.85			0.07500
2	2	32.5	22	71.36	11.15	0.009611	0.05100
3	5	27.0	22	59.28	11.90	0.009611	0.03333
4	15	22.5	22	49.40	12.60	0.009611	0.01980
5	30	19.0	22	41.72	13.20	0.009611	0.01433
6	60	15.5	22	34.03	13.90	0.009611	0.01040
7	250	11.5	22	25.25	14.60	0.009611	0.00522
8	1440	10.0	22	21.96	14.70	0.009611	0.00218
9	2970	10.0	22	21.96	14.70	0.009611	0.00152

Bullock Point Reach (E99-I)



Hydrometer Analysis	E99-I Bullock Point Reach (BPR) D1-D3 (BPR)		
Air Dry Mass Used (grams) =	50.14		
Specific Gravity of Soil Particles =	2.586		
Specific Gravity Correction Factor, a =	1.013		
Specific Gravity of Solution =	1.00		
Amount retained on #200 (g) =	0.99	Note: Approximately 60-70% shell material	
Percent of Oven Dried Sample (%) =	2.14		

Hygroscopic Moisture	
Weight Air Dry (g) =	8.233
Weight Oven Dry (g)=	7.584
Correction Factor =	0.921
Oven Dry Mass used (grams) =	46.19

Depth (in.)	Weight (g)	Sample
0-4	16.59	D1
4-8	16.86	D2
8-12	16.69	D3

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	24	100.00	0.00	0.009202	2.00000
				97.86			0.07500
2	2	31.0	24	68.07	11.20	0.009202	0.05002
3	5	27.0	24	59.28	11.90	0.009202	0.03261
4	15	23.0	24	50.50	12.50	0.009202	0.01930
5	30	19.0	24	41.72	13.20	0.009202	0.01402
6	60	17.0	24	37.33	13.50	0.009202	0.01003
7	250	12.0	24	26.35	14.30	0.009202	0.00506
8	1440	10.0	23.5	21.96	14.70	0.0093043	0.00215
9	2970	9.0	23	19.76	14.80	0.0094065	0.00151

Hydrometer Analysis E99-I Bullock Point Reach (BPR)
D4-D6 (BPR)

Air Dry Mass Used (grams) =	49.82
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	0.61
Percent of Oven Dried Sample (%) =	1.33

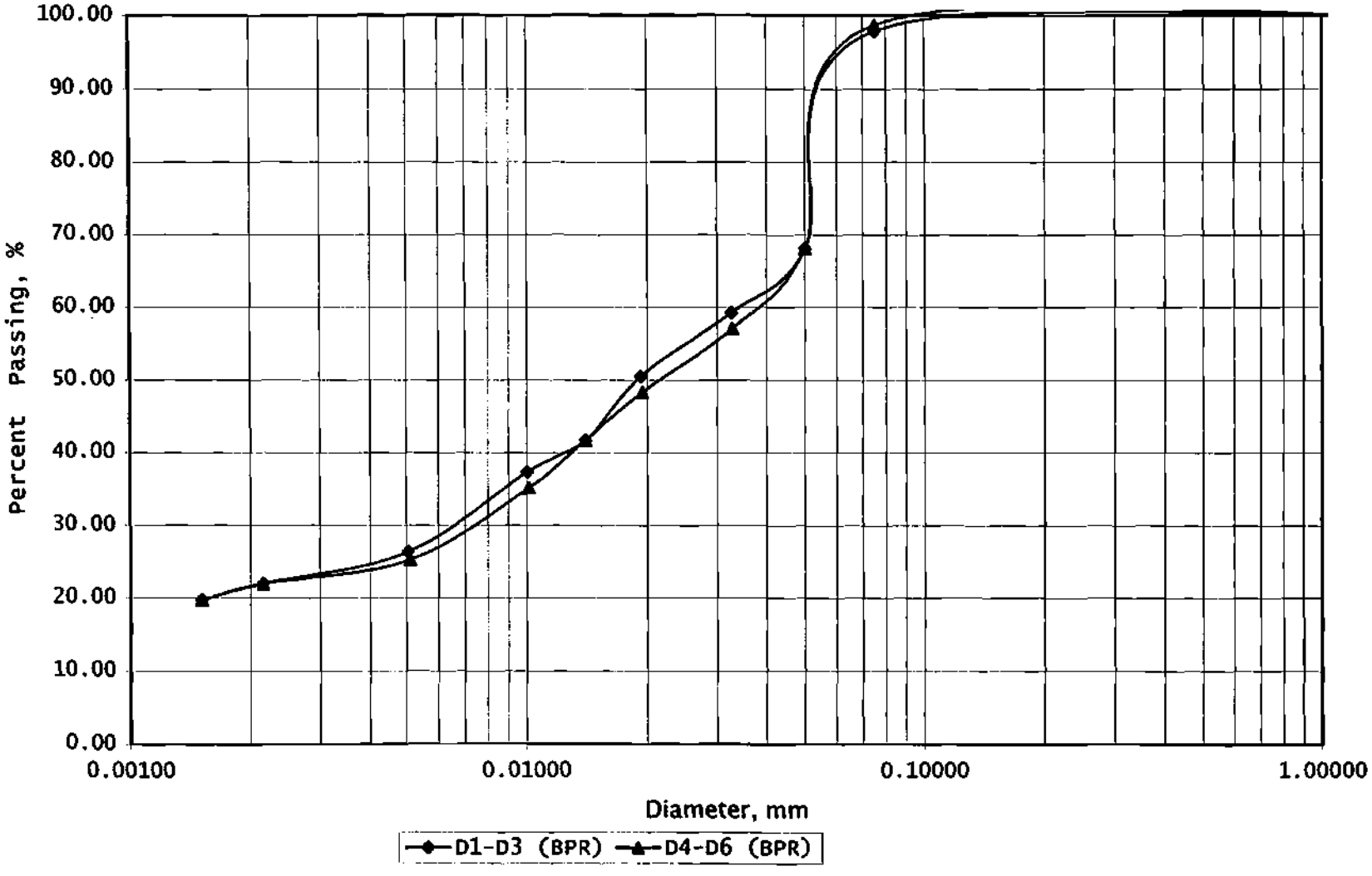
Note: Approximately20-30% shell material

Hygroscopic Moisture	
Weight Air Dry (g) =	9.503
Weight Oven Dry (g)=	8.758
Correction Factor =	0.922
Oven Dry Mass used (grams) =	45.91

Depth (in.)	Weight (g)	Sample
12-16	16.81	D4
16-20	16.43	D5
20-24	16.58	D6

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	24	100.00	0.00	0.009202	2.00000
				98.67			0.07500
2	2	31.0	24	68.07	11.20	0.009202	0.05002
3	5	26.0	24	57.09	12.00	0.009202	0.03275
4	15	22.0	24	48.31	12.70	0.009202	0.01945
5	30	19.0	24	41.72	13.20	0.009202	0.01402
6	60	16.0	24	35.13	13.70	0.009202	0.01010
7	250	11.5	24	25.25	14.60	0.009202	0.00511
8	1440	10.0	23.5	21.96	14.70	0.0093043	0.00215
9	2970	9.0	23	19.76	14.80	0.0094065	0.00151

Bullock Point Reach (E99-I)



Hydrometer Analysis Fuller Rock Reach 15 yr

Depth = 1.5 - 2.0 in.

Air Dry Mass Used (grams) =	45.838
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	0.695
Percent of Oven Dried Sample (%) =	1.62

Hygroscopic Moisture

Weight Air Dry (g) =	10.51
Weight Oven Dry (g)=	9.84
Correction Factor =	0.936
Oven Dry Mass used (grams) =	42.92

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	24	100.00	0.00	0.009202	2.00000
			24	98.38			0.07500
2	2	36.0	24	79.05	10.40	0.009202	0.04820
3	5	32.5	24	71.36	11.00	0.009202	0.03135
4	15	25.0	24	54.89	12.20	0.009202	0.01906
5	30	17.0	24	37.33	13.50	0.009202	0.01418
6	60	12.5	23	27.45	14.25	0.009407	0.01041
7	250	10.0	24	21.96	14.70	0.009202	0.00513
8	1440	9.5	24	20.86	14.75	0.009202	0.00214

Hydrometer Analysis Fuller Rock Reach 5 yr

Depth = 4.5 - 6.0 in.

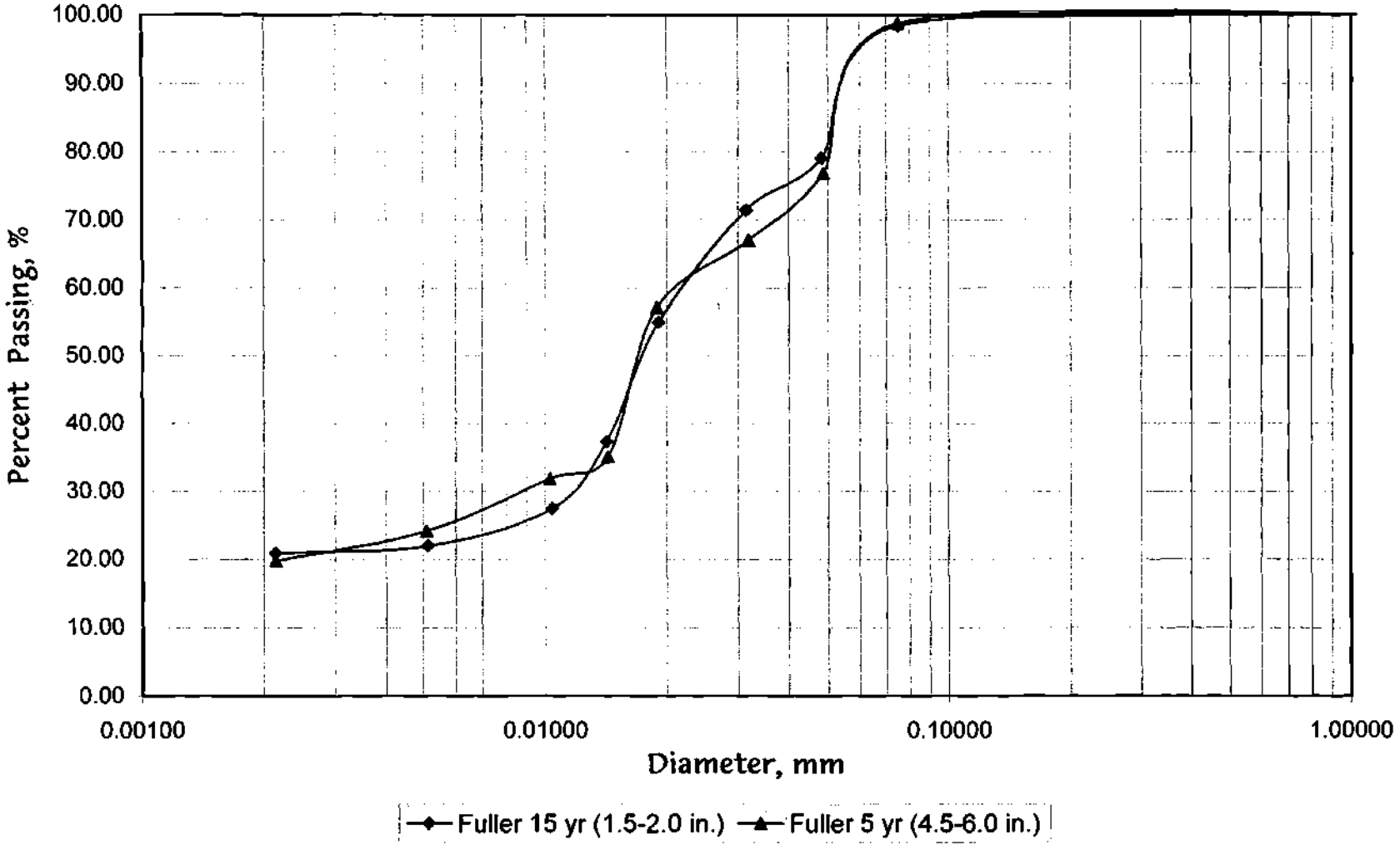
Air Dry Mass Used (grams) =	47.635
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	0.5496
Percent of Oven Dried Sample (%) =	1.23

Hygroscopic Moisture

Weight Air Dry (g) =	12.98
Weight Oven Dry (g)=	12.16
Correction Factor =	0.937
Oven Dry Mass used (grams) =	44.63

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	24	100.00	0.00	0.009202	2.00000
			24	98.77			0.07500
2	2	35.0	24	76.85	10.60	0.009202	0.04866
3	5	30.5	24	66.97	11.30	0.009202	0.03178
4	15	26.0	24	57.09	12.00	0.009202	0.01891
5	30	16.0	24	35.13	13.70	0.009202	0.01428
6	60	14.5	23	31.84	13.90	0.009407	0.01029
7	250	11.0	24	24.15	14.50	0.009202	0.00509
8	1440	9.0	24	19.76	14.80	0.009202	0.00214

Fuller Rock Reach 15/5 yr



Hydrometer Analysis Sabin Point Reach 15 yr

Depth = 2 - 2.5 in.

Air Dry Mass Used (grams) =	49.81
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	1.9294
Percent of Oven Dried Sample (%) =	4.20

Hygroscopic Moisture

Weight Air Dry (g) =	9.65
Weight Oven Dry (g)=	8.91
Correction Factor =	0.923
Oven Dry Mass used (grams) =	45.99

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	24	100.00	0.00	0.009202	2.00000
			24	95.80			0.07500
2	2	35.0	24	76.85	10.60	0.009202	0.04866
3	5	30.0	24	65.87	11.40	0.009202	0.03192
4	15	24.0	24	52.70	12.40	0.009202	0.01922
5	30	15.0	24	32.94	13.80	0.009202	0.01434
6	60	11.0	23	24.15	14.50	0.009407	0.01051
7	250	9.0	24	19.76	14.80	0.009202	0.00514
8	1440	7.5	24	16.47	15.25	0.009202	0.00218

Hydrometer Analysis Sabin Point Reach 15 yr

Depth = 4 - 4.5 in.

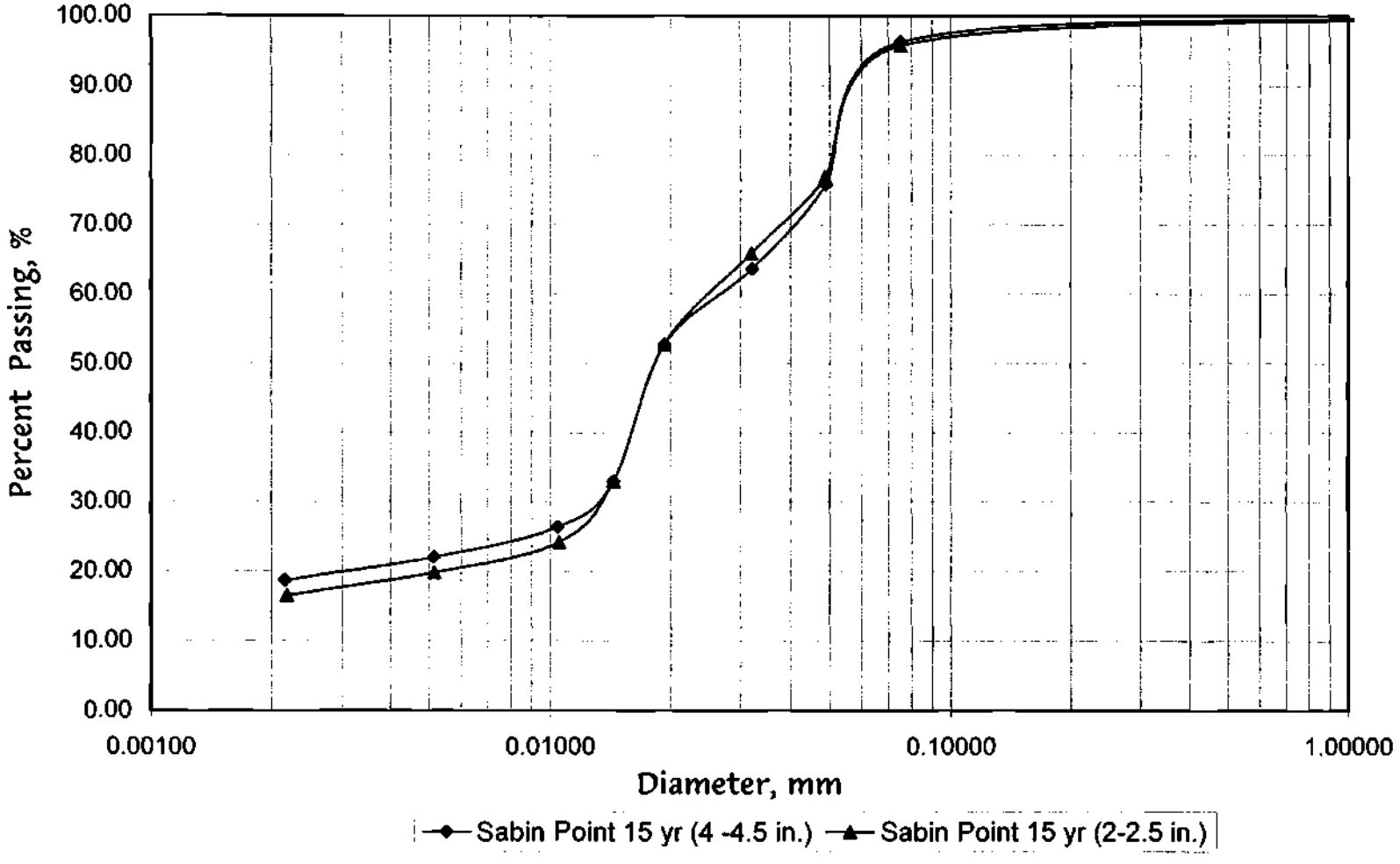
Air Dry Mass Used (grams) =	48.582
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	1.6549
Percent of Oven Dried Sample (%) =	3.69

Hygroscopic Moisture

Weight Air Dry (g) =	11.54
Weight Oven Dry (g)=	10.64
Correction Factor =	0.922
Oven Dry Mass used (grams) =	44.79

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	24	100.00	0.00	0.009202	2.00000
			24	96.31			0.07500
2	2	34.5	24	75.75	10.65	0.009202	0.04878
3	5	29.0	24	63.68	11.50	0.009202	0.03206
4	15	24.0	24	52.70	12.40	0.009202	0.01922
5	30	15.0	24	32.94	13.80	0.009202	0.01434
6	60	12.0	23	26.35	14.30	0.009407	0.01043
7	250	10.0	24	21.96	14.70	0.009202	0.00513
8	1440	8.5	24	18.66	14.90	0.009202	0.00215

Sabin Point Reach 15 yr



Hydrometer Analysis Bullock Point Reach 15 yr

Depth = 0 - 2.5 in.

Air Dry Mass Used (grams) =	46.433
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	1.1461
Percent of Oven Dried Sample (%) =	2.62

Hygroscopic Moisture

Weight Air Dry (g) =	12.44
Weight Oven Dry (g)=	11.73
Correction Factor =	0.943
Oven Dry Mass used (grams) =	43.78

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	24	100.00	0.00	0.009202	2.00000
			24	97.38			0.07500
2	2	34.0	24	74.65	10.70	0.009202	0.04889
3	5	28.0	24	61.48	11.70	0.009202	0.03233
4	15	23.0	24	50.50	12.50	0.009202	0.01930
5	30	17.0	24	37.33	13.50	0.009202	0.01418
6	60	12.5	23	27.45	14.25	0.009407	0.01041
7	250	10.0	24	21.96	14.70	0.009202	0.00513
8	1440	7.0	24	15.37	15.20	0.009202	0.00217

Hydrometer Analysis Bullock Point Reach 15 yr

Depth = 5.5 - 6.0 in.

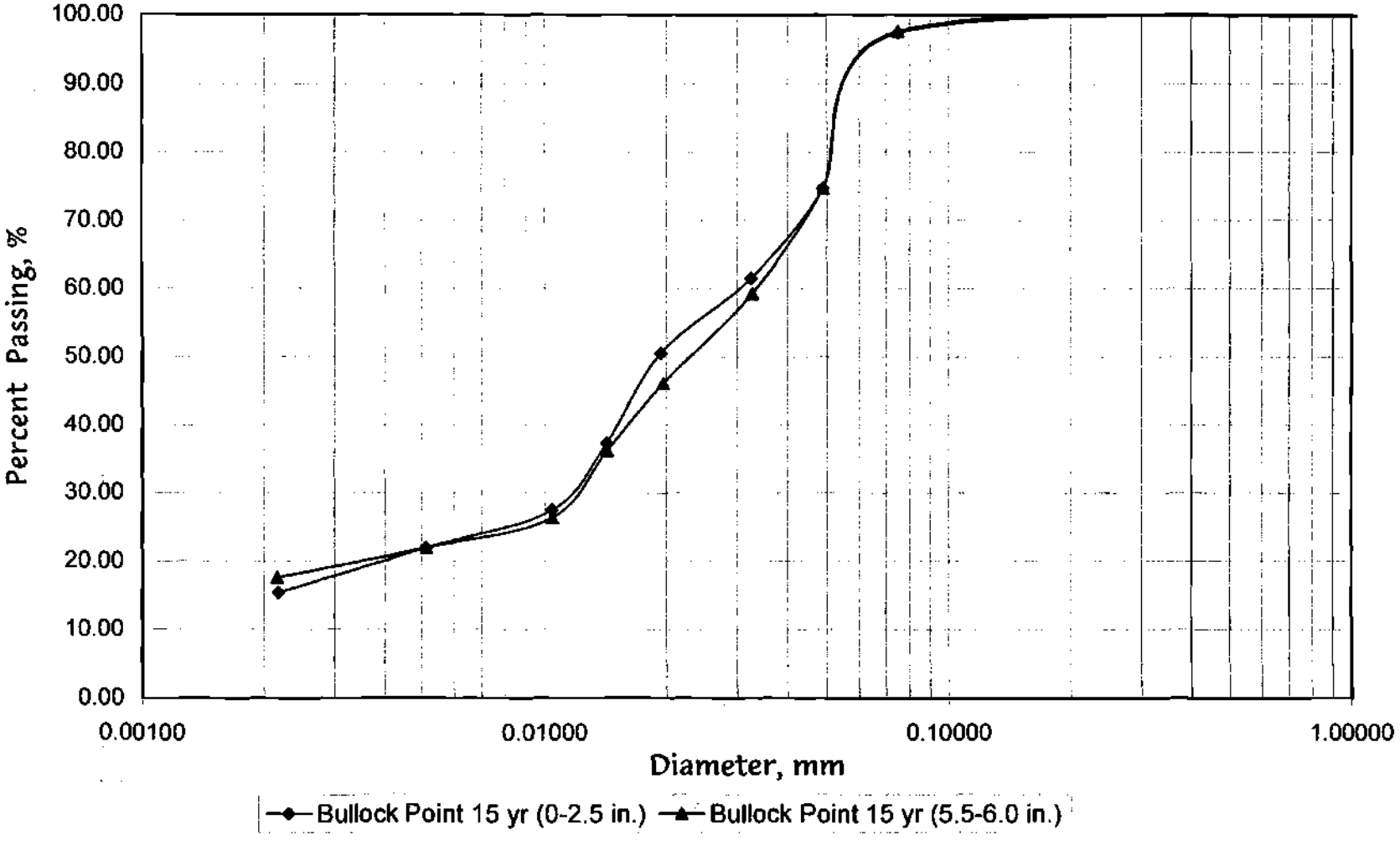
Air Dry Mass Used (grams) =	39.942
Specific Gravity of Soil Particles =	2.586
Specific Gravity Correction Factor, a =	1.013
Specific Gravity of Solution =	1.00
Amount retained on #200 (g) =	0.865
Percent of Oven Dried Sample (%) =	2.36

Hygroscopic Moisture

Weight Air Dry (g) =	8.64
Weight Oven Dry (g)=	7.94
Correction Factor =	0.919
Oven Dry Mass used (grams) =	36.71

Trial	Time (min)	Hydrometer Reading(152H)	Temperature (Celsius)	Percent of Soil In Suspension (152H)	L (cm)	n (poise)	Diameter (mm)
1	0	0	24	100.00	0.00	0.009202	2.00000
			24	97.64			0.07500
2	2	34.0	24	74.65	10.70	0.009202	0.04889
3	5	27.0	24	59.28	11.90	0.009202	0.03261
4	15	21.0	24	46.11	12.90	0.009202	0.01960
5	30	16.5	24	36.23	13.60	0.009202	0.01423
6	60	12.0	23	26.35	14.30	0.009407	0.01043
7	250	10.0	24	21.96	14.70	0.009202	0.00513
8	1440	8.0	24	17.57	15.00	0.009202	0.00216

Bullock Point Reach 15 yr



APPENDIX B

SAMPLE PREPARATION

- Soil specimens came in 4" plastic tubes, generally with 3"-6" inches of water on top.
- The water from the top of the sample is removed by siphoning.
- The specimen is displaced from the tube onto a pan, by means of a full cross section piston which is used to slowly push the soil out.
- Once the sample is extruded, it is divided into 2" or 4" long specimens. A small sample is taken from each section for permittivity and moisture content measurements. The rest is placed into a flask for shear-wave velocity and viscosity measurements.

SHEAR WAVE MEASUREMENTS

Experimental Setup

- Bender elements are mounted on mechanically uncoupled rigid supports to prevent wave transmission through the support system.
- The tip of bender elements is separated about 2 cm. Lateral windows in the frame promote the scape of P-waves generated on side lobes.
- Bender elements are coated with water sealing resin (e.g. Polyurethane) to avoid short circuit within the conductive slurry.
- A shield coating paint is applied above (e.g. EMI-RFI Shield). The shield around both bender elements is connected to a common ground to avoid electrical cross talk.

Testing Procedure

- The combination of Sampling Rate/Frequency of the Source is selected so that every measurement coincides with a full cycle of the source, without the presence of late arrivals. This facilitates stacking, or signal averaging for noise reduction.
- A square wave with 20 Hz frequency was used, and the sampling rate was kept at 20 kHz.
- Before running the test, the samples are mixed to homogenize the water content (remolded condition, i.e., cancellation of diagenetic effects).

COMPLEX PERMITTIVITY ("Point" measurement)

- A HP 8752A network analyzer with coaxial termination probe was used. It was calibrated with air, water and short. Spectral measurements were conducted between 0.02 GHz and 1.3 GHz.
- This measurement determines a local value corresponding to ~0.3 cm^3 of the specimen
- The effective conductivity σ_{eff} is computed from the imaginary part of the relative permittivity ε" as

  $$\sigma_{eff} = 2\pi f \cdot \varepsilon'' \cdot \varepsilon_0$$

  where f is the frequency, and ε_0 is the permittivity of free space.

MOISTURE CONTENT ("Layer-wide" measurement)

- The same specimen used to determine the permittivity is used to measure the moisture content
- The measured volume is about 6 cm^3.

VISCOSITY

- A Brookfield DV-E viscometer is used
- The spindle number is S06 and the rotational speed is 0.3 rpm. All measurements are conducted with the guard-leg.
- The equilibrium time for the viscosity measurement is about 6 minutes.

DATA SUMMARY

Tube number & description: E99-A, Fuller Rock Reach **Sediment depth:** 22.5 inches

Depth	Material	Weight (g)			Dieletric Properties @1 GHz			V_s	η	Note
(in)	*Water, Mud*	W_{wet}	W_{dry}	*w%*	*File name*	ε'	σ_{eff} *(S/cm)*	*(cm/s)*	*(mPa·s)*	
0~2	M	42.88	12.23	250.61	C1	60.77	0.032			
2~4	M	49.09	14.42	240.43	C2	60.61	0.032			
4~6	M	57.93	17.44	232.17	C3	59.31	0.030			
6~8	M	64.96	19.82	227.75	C4	58.73	0.030			
8~12	M	68.66	21.27	222.80	C5	58.90	0.031			
10~12	M	58.18	18.45	215.34	C6	58.58	0.030			
12~14	M	65.77	18.43	256.86	C7	62.52	0.033			
14~16	M	66.77	20.09	232.35	C8	60.69	0.032			
16~18	M	66.82	19.22	247.66	C9	60.93	0.032			
18~20	M	65.68	19.31	240.13	C10	60.08	0.032			

Note: very homogeneous core

Tube number & description: E99-A, Fuller Rock Reach **Sediment depth:** 22.5 inches

Depth	Material	Weight (g)			Dielectric Properties @1 GHz			V_s	η	Note
(in)	*Water, Mud*	W_{sat}	W_{dry}	*w%*	*File name*	ε'	σ_{eff} *(S/cm)*	*(cm/s)*	*(mPa·s)*	
20~22.5	M	54.88	17.83	207.80	C11	60.20	0.032			

Note: very homogeneous core

Tube number & description: E99-B, Fuller Rock Reach **Sediment depth:** 23.5 inches

Depth	Material	Weight (g)			Dieletric Properties @1 GHz			V_s	η	Note
(in)	*Water, Mud*	W_{sat}	W_{dry}	*w%*	*File name*	ε'	σ_{eff} *(S/cm)*	*(cm/s)*	*(mPa·s)*	
0~4	M	68.36	20.92	226.77	K1	60.89	0.032			
4~8	M	69.11	20.99	229.25	K2	58.06	0.03			Large amount of fibers
8~12	M	66.79	21.24	214.45	K3	61.06	0.032			
12~16	M	65.53	20.67	217.03	K4	58.73	0.031			
16~20	M	65.03	22.43	189.92	K5	57.46	0.030			
20~23.5	M	69.63	23.01	202.61	K6	59.60	0.031			

Note: The soil is not very cohesive

Tube number & description: E99-C, Fuller Rock Reach **Sediment depth:** 20.75 inches

Depth	Material	Weight (g)			Dieletric Properties @1 GHz			V_s	η	Note
(in)	*Water, Mud*	W_{sat}	W_{dry}	*w%*	*File name*	ε'	σ_{eff} *(S/cm)*	*(cm/s)*	*(mPa·s)*	
0~4	M	62.11	18.11	242.96	J1	62.35	0.033			
4~8	M	70.05	20.83	236.29	J2	61.16	0.032			
8~12	M	63.91	20.07	218.44	J3	60.57	0.032			
12~16	M	63.51	19.66	223.04	J4	60.14	0.032			
16~20.75	M	67.55	19.53	245.88	J5	61.07	0.032			

Tube number & description: E99-D, Sabin Point Reach **Sediment depth:** 29 inches

Depth	Material	Weight (g)			Dieletric Properties @1 GHz			V_s	η	Note
(in)	*Water, Mud*	W_{sat}	W_{dry}	*w%*	*File name*	*ε'*	σ_{eff} *(S/cm)*	*(cm/s)*	*(mPa·s)*	
0~4	M	66.82	22.66	194.88	F1	59.36	0.031			
4~8	M	60.02	19.35	210.18	F2	58.75	0.030			
8~12	M	71.2	23.96	197.16	F3	55.03	0.029			Fibers
12~16	M	68.76	21.25	223.58	F4	55.86	0.029			Fibers
16~20	M	70.45	22.75	209.67	F5	53.67	0.028			Fibers, Shells
20~24	M	70.35	25.72	173.52	F6	53.53	0.027			Shells, Sandy material
24~29	M	71.88	25.58	181.00	F7	56.71	0.030			

Tube number & description: E99-E, Sabin Point Reach, Additional sample **Sediment depth:** 23.25 inches

Depth	Material	Weight (g)			Dieletric Properties @1 GHz			V_s	η	Note
(in)	*Water, Mud*	W_{wet}	W_{dry}	*w%*	*File name*	*ε'*	σ_{eff} *(S/cm)*	*(cm/s)*	*(mPa·s)*	
0~4	M	76.72	26.37	190.94	H1	58.30	0.030			Fibers
4~8	M	66.77	24.5	172.53	H2	60.49	0.032			Fibers
8~12	M	65.28	23.05	183.21	H3	57.97	0.030			A little green color is visible
12~16	M	74.31	25.73	188.81	H4	57.85	0.030			
16~20	M	62.37	22.15	181.58	H5	60.25	0.032			
20~23.25	M	64.26	22.39	187.00	H6	56.93	0.030			

Tube number & description: E99-E, Sabin Point Reach **Sediment depth:** 24 inches

Depth	Material	Weight (g)			Dieletric Properties @1 GHz			V_s	η	Note
(in)	*Water, Mud*	W_{sat}	W_{dry}	*w%*	*File name*	ε'	σ_{eff} *(S/cm)*	*(cm/s)*	*(mPa·s)*	
0~4	M	67.17	23.49	185.95	I1	58.36	0.030			
4~8	M	63.42	23.2	173.36	I2	57.16	0.029			
8~12	M	55.56	18.43	201.47	I3	56.46	0.029			
12~16	M	61.59	21.64	184.61	I4	56.80	0.029			
16~20	M	54.27	19.36	180.32	I5	55.36	0.028			
20~24	M	59.14	21.62	173.54	I6	55.48	0.028			

Tube number & description: E99-F, Sabin Point Reach **Sediment depth:** 24.25 inches

Depth	Material	Weight (g)			Dieletric Properties @1 GHz			V_s	η	Note
(in)	*Water, Mud*	W_{sat}	W_{dry}	*w%*	*File name*	ε'	σ_{eff} *(S/cm)*	*(cm/s)*	*(mPa·s)*	
0~4	M	69.12	20.31	240.32	E1	61.68	0.033			
4~8	M	74.68	23.78	214.05	E2	58.92	0.031			
8~12	M	77.1	24.81	210.76	E3	59.63	0.031			
12~16	M	78.35	25.25	210.30	E4	56.63	0.029			Fibers
16~20	M	70.76	26.03	171.84	E5	53.55	0.028			Fibers
20~24.25	M	77.73	27.19	185.88	E6	54.65	0.028			

Tube number & description: E99-G, Bullocks Point Reach **Sediment depth:** 31.75 inches

Depth	Material	Weight (g)			Dieletric Properties @1 GHz			V_s	η	Note
(in)	*Water, Mud*	W_{sat}	W_{dry}	*w%*	*File name*	ε'	σ_{eff} *(S/cm)*	*(cm/s)*	*(mPa·s)*	
0~4	M	73.48	22.96	220.03	G1	60.10	0.032			A lot of Fibers; Shells
4~8	M	71.69	23.84	200.71	G2	60.11	0.032			Fibers
8~12	M	68.13	22.07	208.70	G3	57.22	0.030			
12~16	M	64.14	20.53	212.42	G4	56.37	0.029			
16~20	M	69.69	23.27	199.48	G5	57.44	0.030			
20~24	M	63.79	21.79	192.75	G6	58.78	0.031			
24~28	M	73.48	26.26	179.82	G7	56.5				
28~31.75	M	63.17	21.56	193.00	G8	54.13	0.028			

Tube number & description: E99-H **Sediment depth:** 22.5 inches

Depth	Material	Weight (g)			Dieletric Properties @1 GHz			V_s	η	Note
(in)	*Water, Mud*	W_{sat}	W_{dry}	*w%*	*File name*	ε'	σ_{eff} *(S/cm)*	*(cm/s)*	*(mPa·s)*	
	W				AW	74.96	0.044			
0~2	M	44.3	13.79	221.25	A1	61.79	0.034	*(0"~6")*		
2~4	M	50.28	15.35	227.56	A2	60.61	0.032	339	397000	
4~6	M	50.03	15.17	229.80	A3	60.65	0.032			
6~8	M	59.28	19.79	199.55	A4	56.65	0.030	*(6"~9")*334	447000	
8~10	M	55.52	18.76	195.95	A5	54.12	0.028			
10~12	M	58.34	19.1	205.45	A6	58.78	0.031	*(9"~12")*382	1057000	
12~14	M	62.9	20.67	204.31	A7	58.76	0.031	436		Below depth 14" soils become sandy
14~16	M	50.69	25.3	100.36	A8	53.84	0.028	*(14"~18")*		
16~18	M	73.21	34.36	113.07	A9	51.64	0.026	882		Some gray clay and organic information

[*Shear wave*]: Frequency 20 Hz [*Viscosity*]: Spindle number: S06 Speed: 0.3 rpm Guardleg: Yes .

Tube number & description: E99-H

Sediment depth: 22.5 inches

Depth	Material	Weight (g)			Dieletric Properties @1 GHz			V_s	η	Note
(in)	*Water, Mud*	W_{sat}	W_{dry}	*w%*	*File name*	ε'	σ_{eff} *(S/cm)*	*(cm/s)*	*(mPa·s)*	
18~20	M	44.31	21.53	105.81	A10	53.99	0.027	*(18"~22")*		
20~22.5	M	53.98	23.29	131.77	A11	51.10	0.026	875	3247000	Plenty of shells around depth 20"

[*Shear wave*]: Frequency 20 Hz [*Viscosity*]: Spindle number: S06 Speed: 0.3 rpm Guardleg: Yes .

Tube number & description: E99-I, Bullocks Point Reach **Sediment depth:** 28.75 inches

Depth	Material	Weight (g)			Dieletric Properties @1 GHz			V_s	η	Note
(in)	*Water, Mud*	W_{sat}	W_{dry}	*w%*	*File name*	ε'	σ_{eff} *(S/cm)*	*(cm/s)*	*(mPa·s)*	
0~4	M	59.1	21.16	179.30	D1	57.46	0.030			Fibers
4~8	M	58.5	19.18	205.01	D2	58.24	0.030			Fibers
8~12	M	70.43	21.88	221.89	D3	60.17	0.032			
12~16	M	70.53	23.2	204.01	D4	56.78	0.029			
16~20	M	66.78	21.69	207.88	D5	58.75	0.031			
20~24	M	67.16	22.76	195.08	D6	57.60	0.030			
24~28.75	M	72.59	25.48	184.89	D7	57.17	0.030			

Note: very homogeneous core

Tube number & description: E99-I

Sediment depth: 28 inches

Depth	Material	Weight (g)			Dieletric Properties @1 GHz			V_s	η	Note
(in)	*Water, Mud*	W_{sat}	W_{dry}	*w%*	*File name*	*ε'*	σ_{eff} *(S/cm)*	*(cm/s)*	*(mPa·s)*	
	W				BW	74.41	0.043			
0~2	M	45.95	15.4	198.38	B1	58.09	0.031	*(0"~4")*		
2~4	M	48.73	16.78	190.41	B2	59.17	0.031	367	1130000	
4~6	M	53.35	18.42	189.63	B3	59.43	0.031	*(4"~8")*		
6~8	M	44.21	14.61	202.60	B4	56.96	0.030	465	1977000	
8~12	M	54.14	18.82	187.67	B5	58.71	0.031	*(8"~12")*		
10~12	M	55.34	17.22	221.37	B6	59.10	0.031	390	1167000	
12~14	M	55.8	19.15	191.38	B7	58.89	0.031	*(12"~16")*		
14~16	M	47.36	15.17	212.20	B8	58.42	0.031	471	2770000	
16~18	M	53.05	17	212.06	B9	58.65	0.031	*(16"~20")*		

[*Shear wave*]: Frequency_____ [*Viscosity*]: Spindle number: S06 Speed: 0.3 rpm Guardleg: Yes .

Tube number & description: E99-I

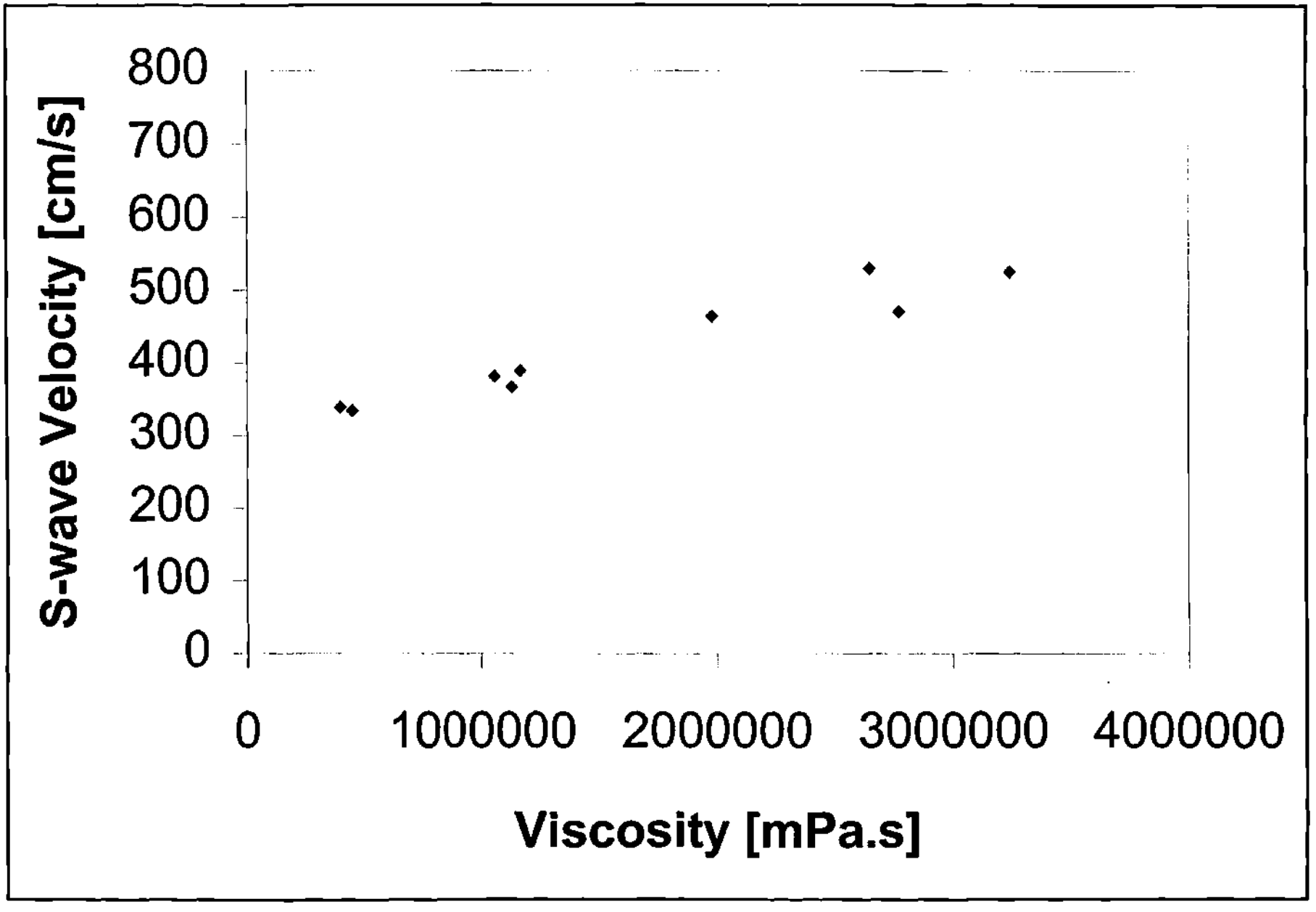
Sediment depth: 28 inches

Depth	Material	Weight (g)			Dieletric Properties @1 GHz			V_s	η	Note
(in)	*Water, Mud*	W_{sat}	W_{dry}	*w%*	*File name*	*ε'*	σ_{eff} *(S/cm)*	*(cm/s)*	*(mPa·s)*	
18~20	M	53.06	18.74	183.14	B10	59.17	0.031	526	3240000	
20~22	M	36.65	12.73	187.90	B11	57.63	0.030	*(20"~24")*		
22~24	M	58.08	21.28	172.93	B12	56.58	0.029	582		
24~26	M	41.89	14.57	187.51	B13	56.53	0.030	*(24"~28")*		
26~28	M	47.67	18.51	157.54	B14	58.29	0.031	530	2647000	

[*Shear wave*]: Frequency_____ [*Viscosity*]: Spindle number: S06 Speed: 0.3 rpm Guardleg: Yes

SHEAR WAVE VELOCITY
AND
VISCOSITY

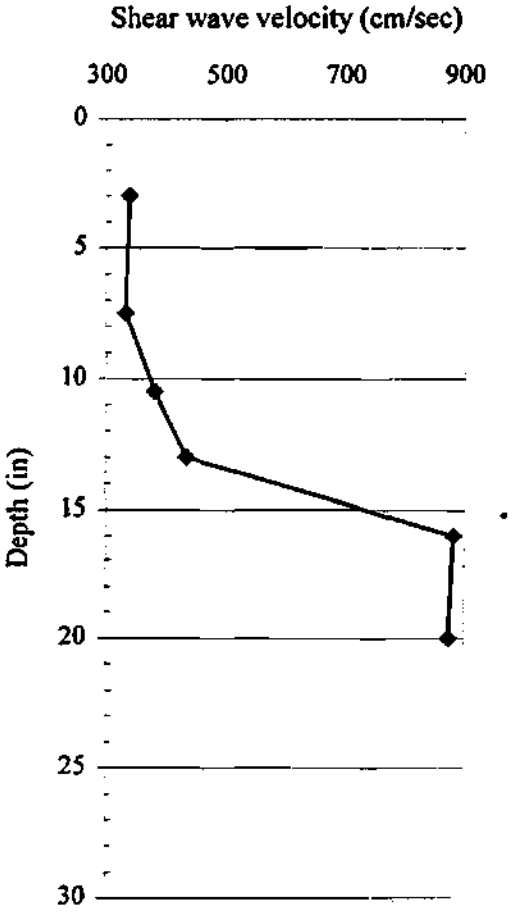
(Note: a correlated behavior is observed)

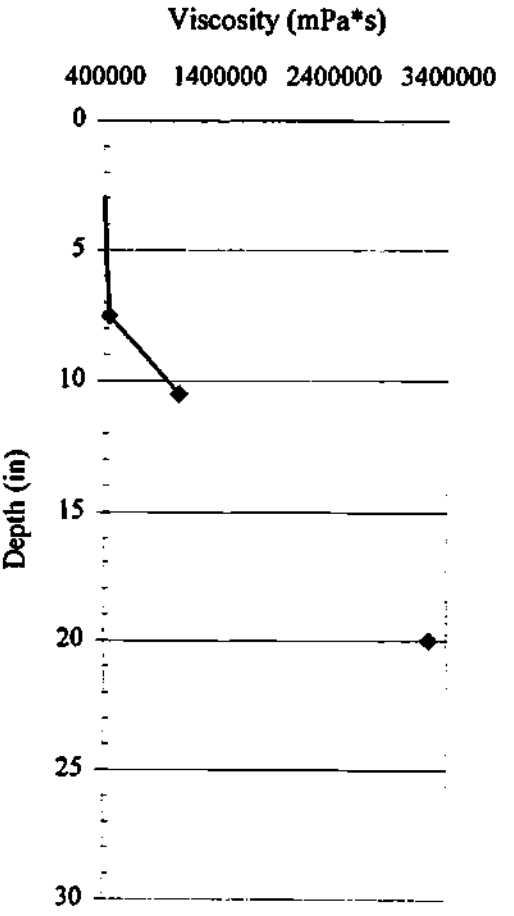

S-wave Velocity [cm/s]
800
700
600
500
400
300
200
100
0
0
1000000
2000000
3000000
4000000
Viscosity [mPa.s]

Viscosity and Shear wave velocity

Tube A (E99-H)

Depth (in)	Viscosity(mPa*s)	Vs (cm/sec)
3	397000	339
7.5	447000	334
10.5	1057000	382
13		436
16		882
20	3247000	875

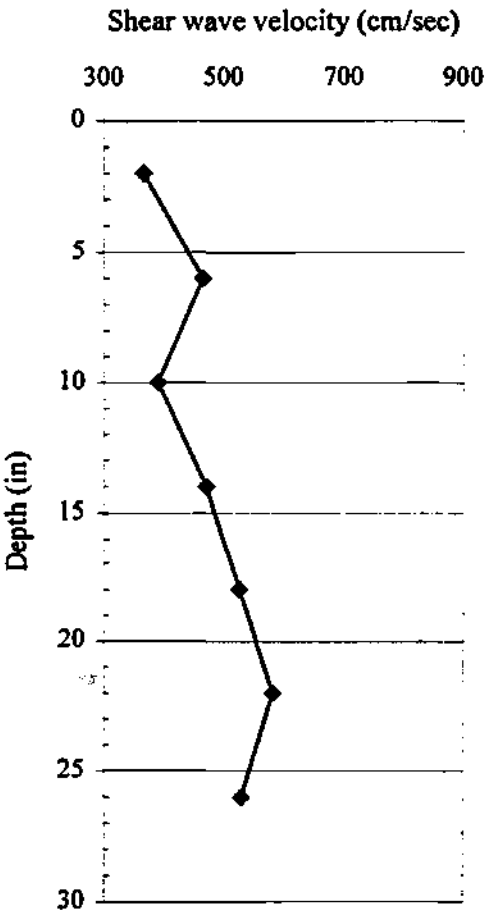


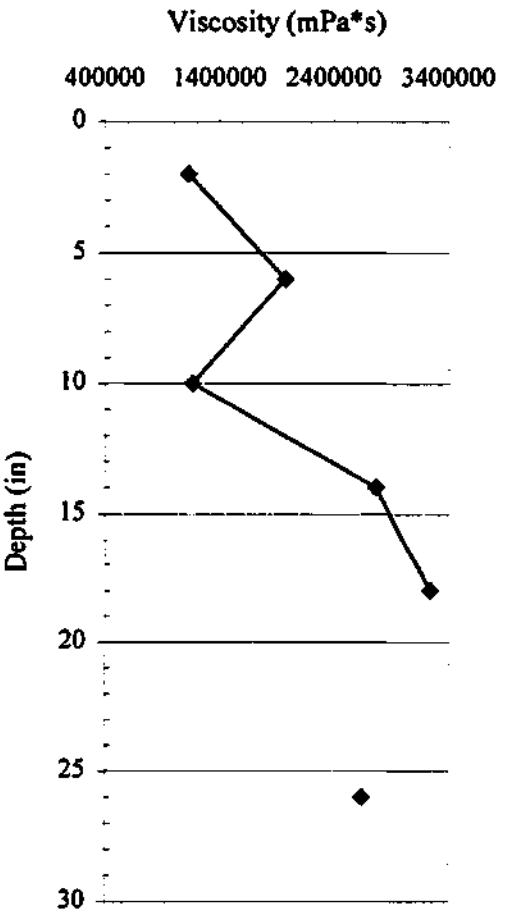


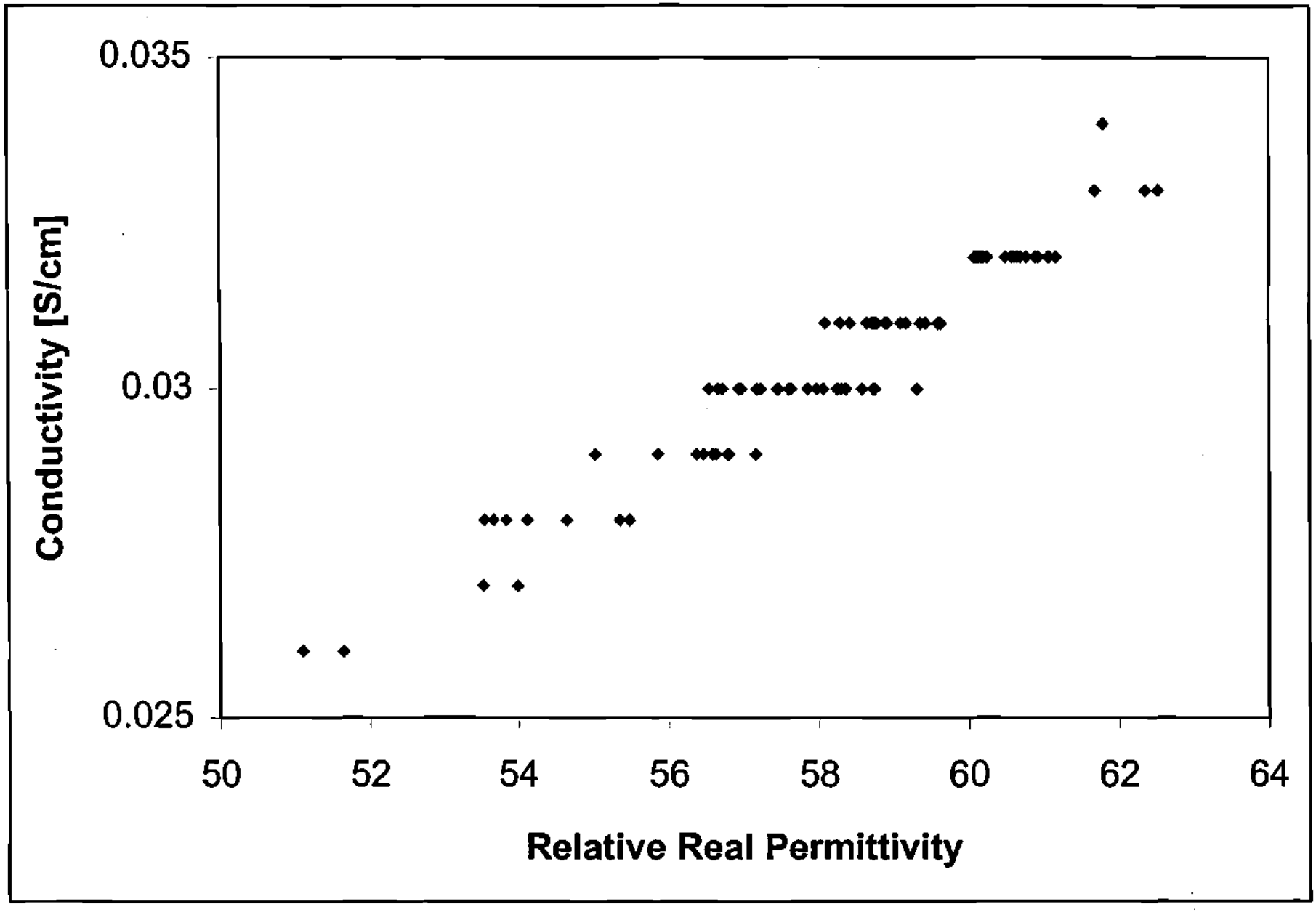
Viscosity and Shear wave velocity

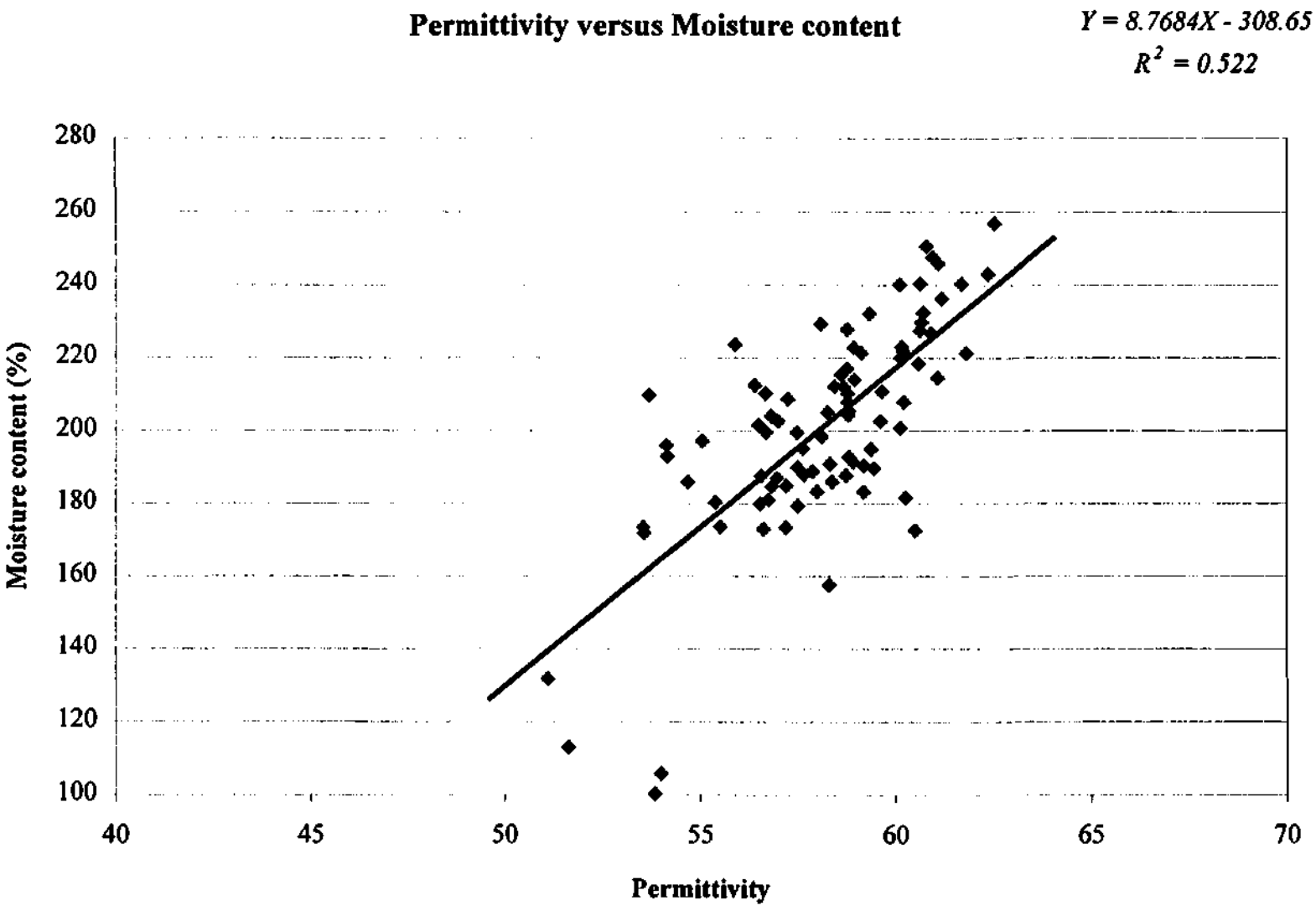
Tube B (E99-I)

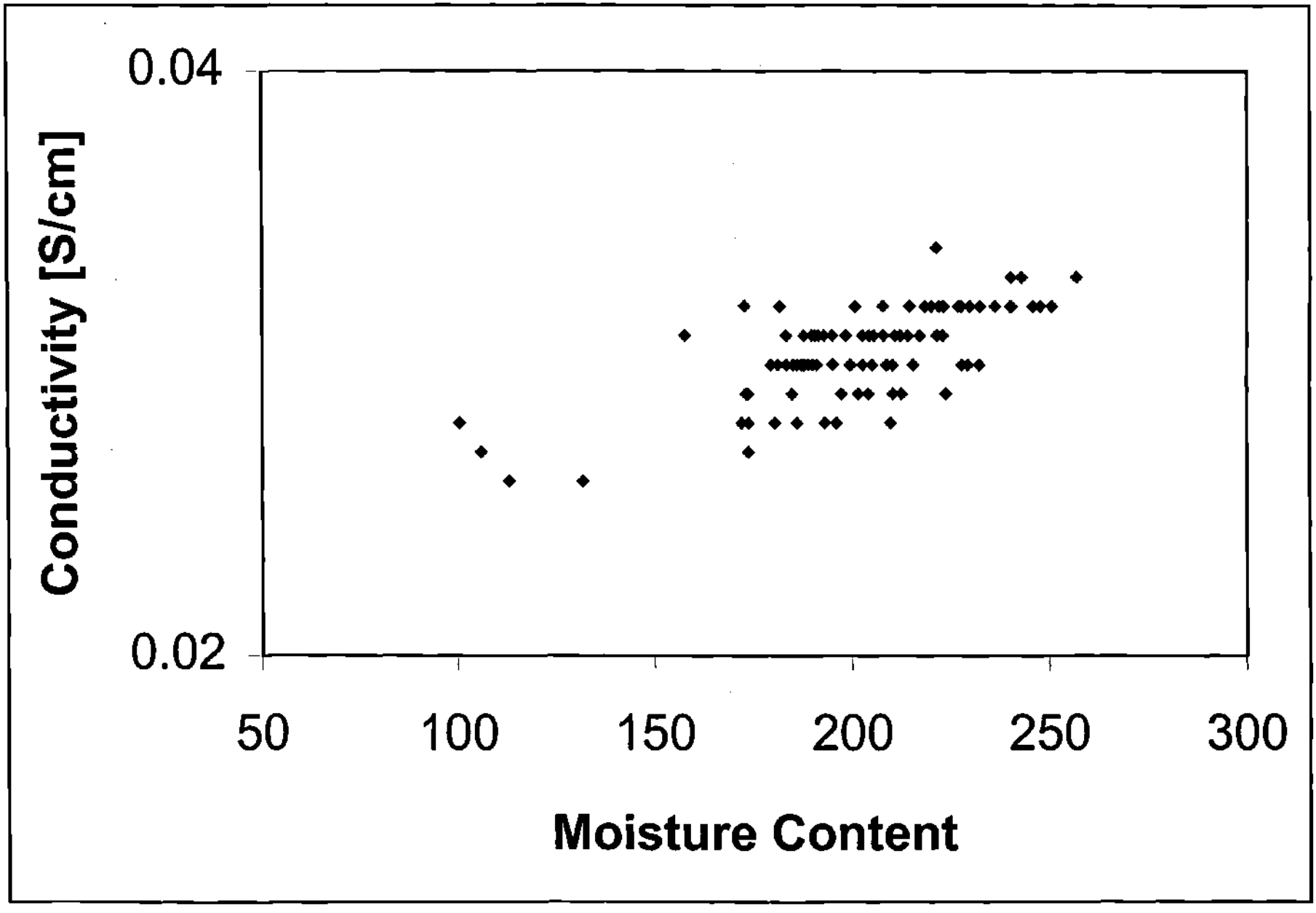
Depth (in)	Viscosity(mPa*s)	Vs (cm/sec)
2	1130000	367
6	1977000	465
10	1167000	390
14	2770000	471
18	3240000	526
22		582
26	2647000	530






0.035
0.03
0.025
Conductivity [S/cm]
50
52
54
56
58
60
62
64
Relative Real Permittivity

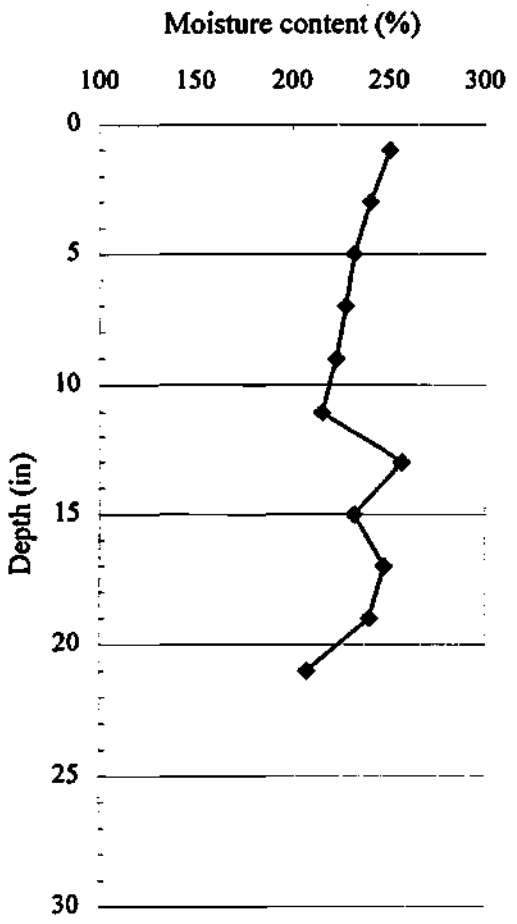

Permittivity versus Moisture content
Y = 8.7684X - 308.65
R2 = 0.522
Moisture content (%)
280
260
240
220
200
180
160
140
120
100
40
45
50
55
60
65
70
Permittivity

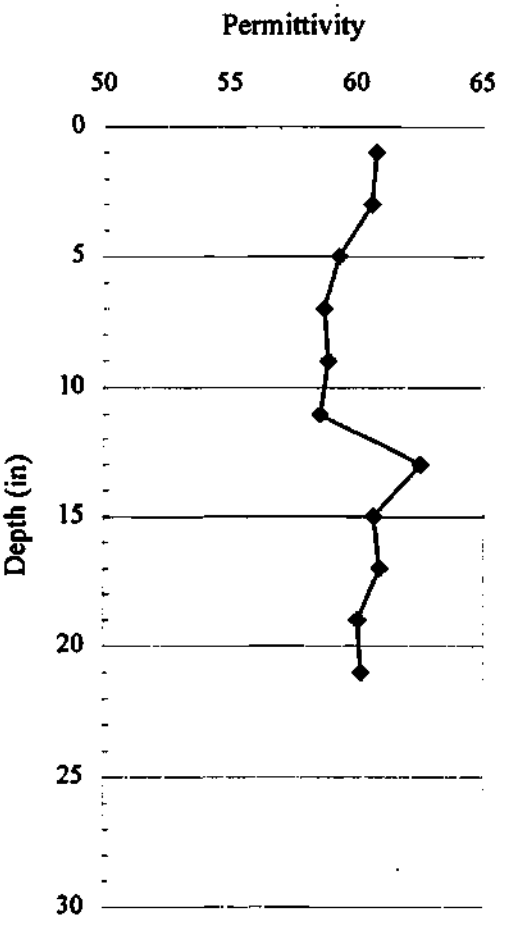

0.04
0.02
Conductivity [S/cm]
50
100
150
200
250
300
Moisture Content

Tube number & description: E99-A, Fuller Rock Reach

File code: C

Depth	*w%*	*Permittivity*
1	250.61	60.77
3	240.43	60.61
5	232.17	59.31
7	227.75	58.73
9	222.80	58.9
11	215.34	58.58
13	256.86	62.52
15	232.35	60.69
17	247.66	60.93
19	240.13	60.08
21	207.80	60.2

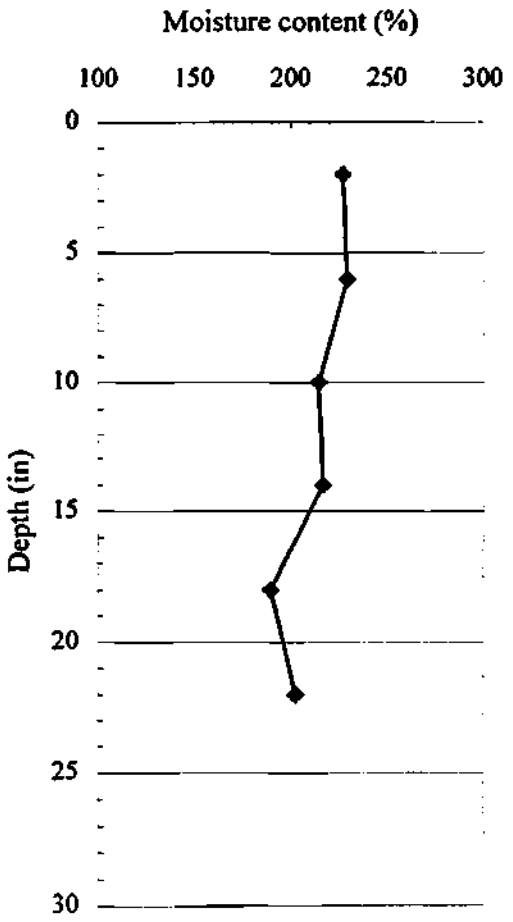


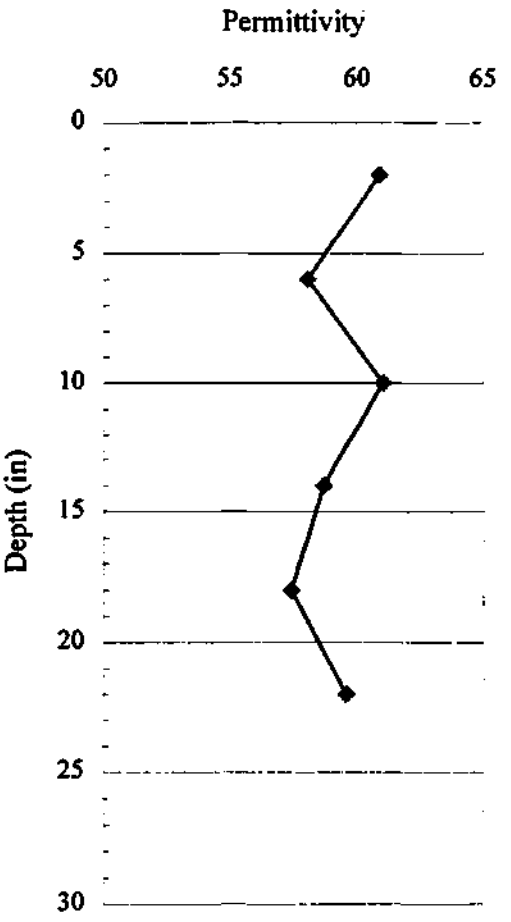


Tube number & description: E99-B, Fuller Rock Reach

File code: K

Depth	*w%*	*Permittivity*
2	226.77	60.89
6	229.25	58.06
10	214.45	61.06
14	217.03	58.73
18	189.92	57.46
22	202.61	59.6

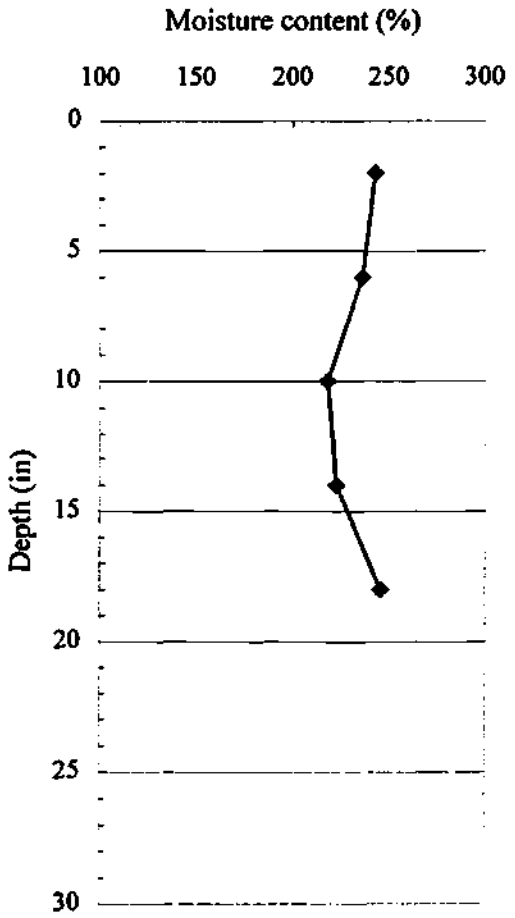


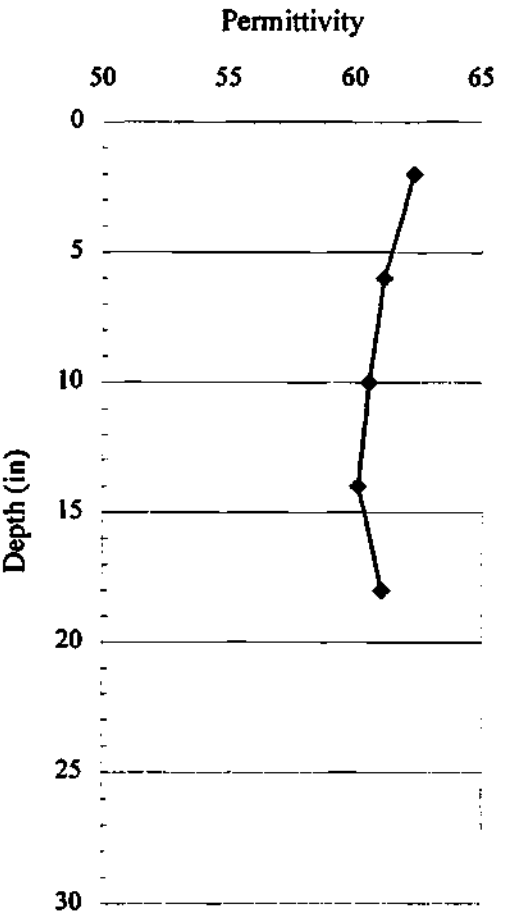


Tube number & description: E99-C, Fuller Rock Reach

File code: J

Depth	*w%*	*Permittivity*
2	242.96	62.35
6	236.29	61.16
10	218.44	60.57
14	223.04	60.14
18	245.88	61.07

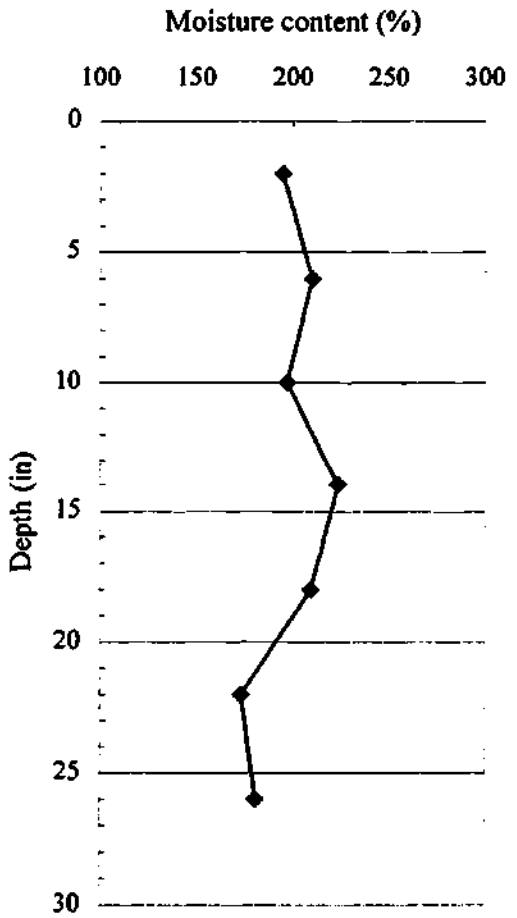


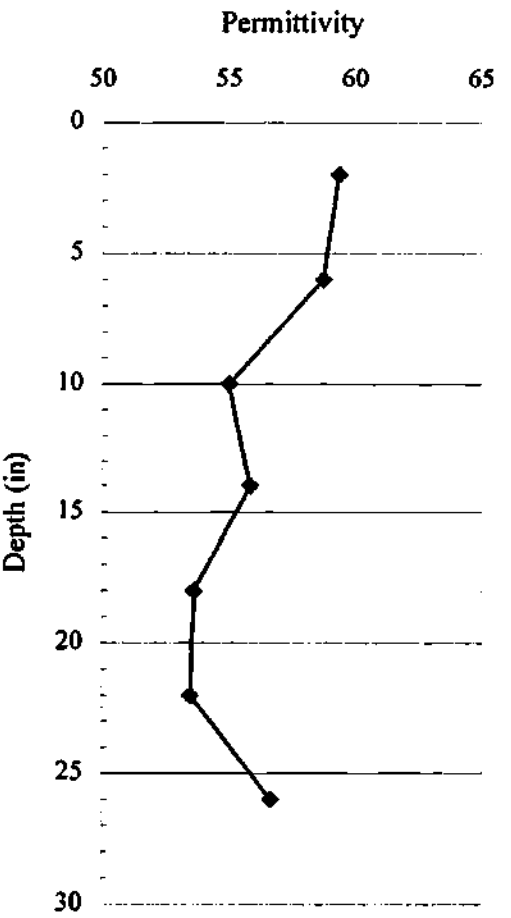


Tube number & description: E99-D, Sabin Point Reach

File code: F

Depth	*w%*	*Permittivity*
2	194.88	59.36
6	210.18	58.75
10	197.16	55.03
14	223.58	55.86
18	209.67	53.67
22	173.52	53.53
26	181.00	56.71

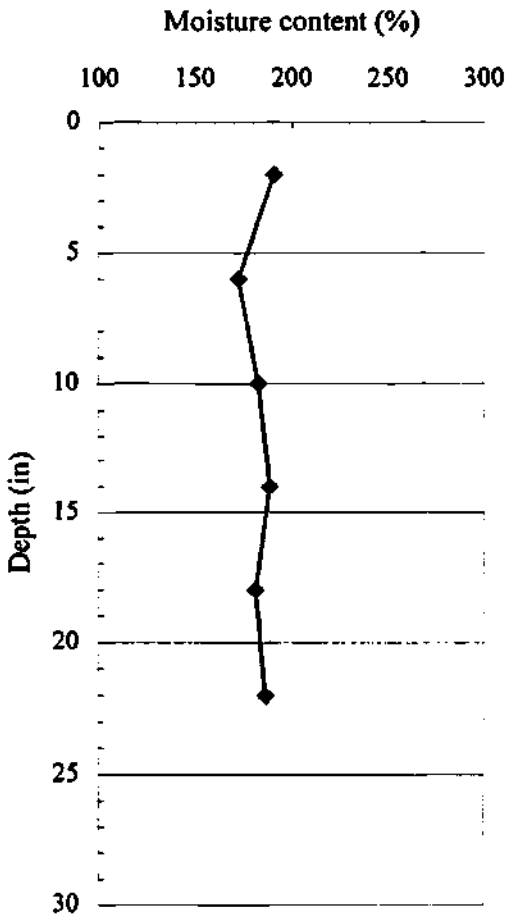


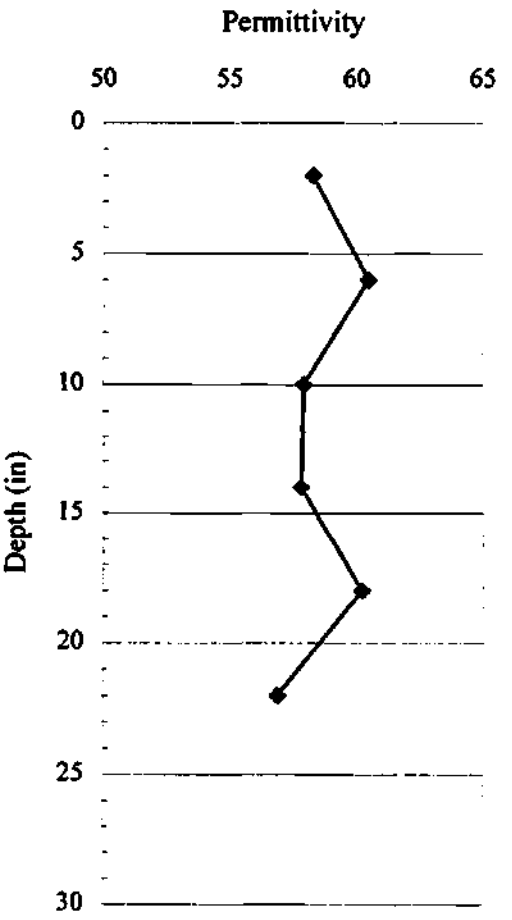


Tube number & description: E99-E, Sabin Point Reach, Additional sample

File code: H

Depth	*w%*	*Permittivity*
2	190.94	58.3
6	172.53	60.49
10	183.21	57.97
14	188.81	57.85
18	181.58	60.25
22	187.00	56.93

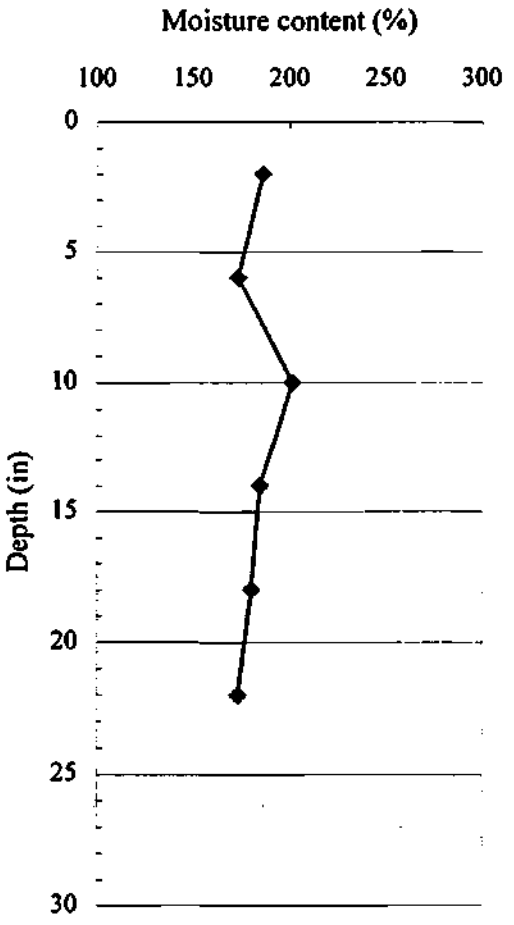


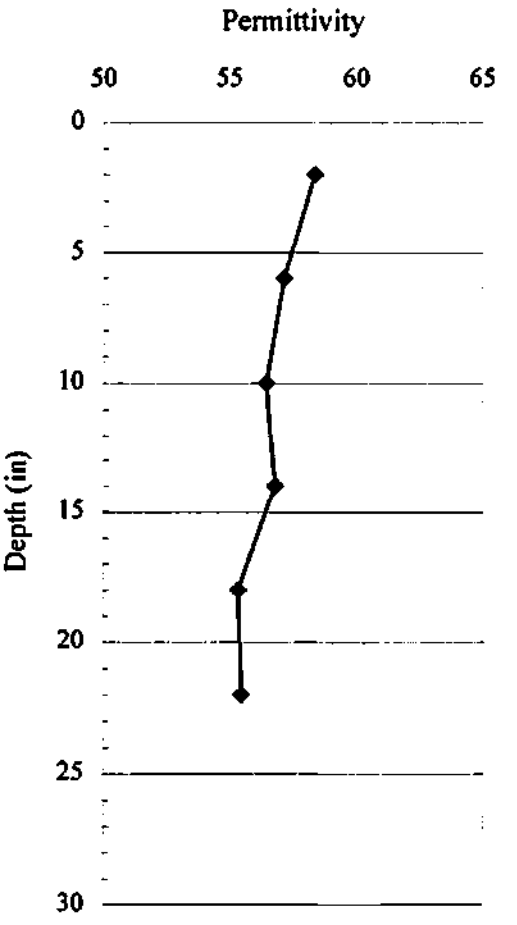


Tube number & description: E99-E, Sabin Point Reach

File code: I

Depth	*w%*	*Permittivity*
2	185.95	58.36
6	173.36	57.16
10	201.47	56.46
14	184.61	56.8
18	180.32	55.36
22	173.54	55.48

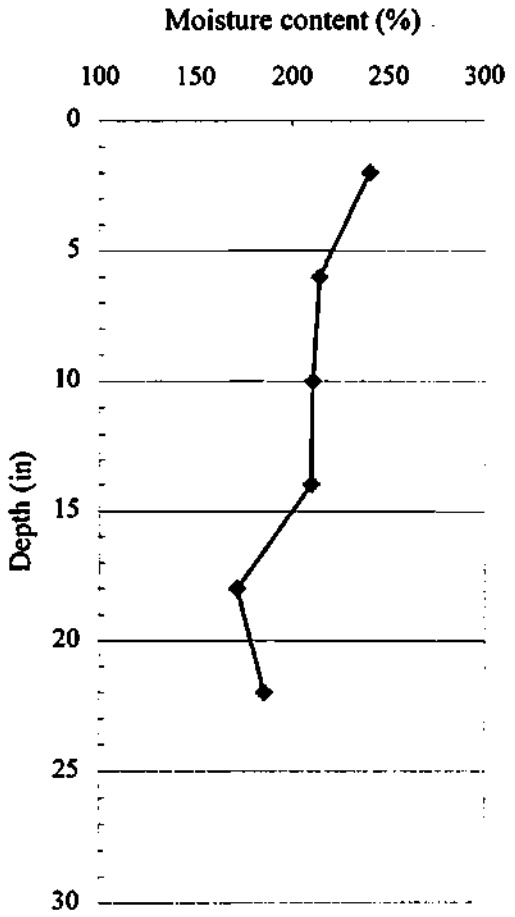


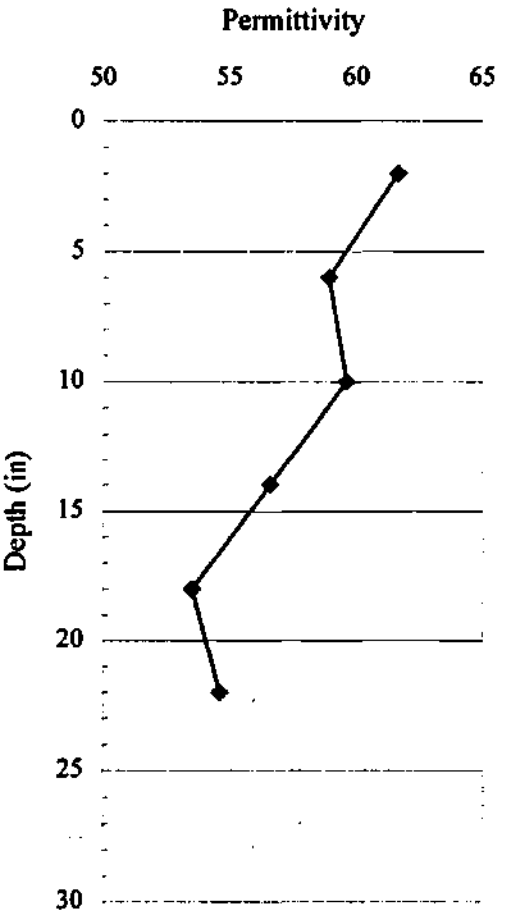


Tube number & description: E99-F, Sabin Point Reach

File code: E

Depth	*w%*	*Permittivity*
2	240.32	61.68
6	214.05	58.92
10	210.76	59.63
14	210.30	56.63
18	171.84	53.55
22	185.88	54.65

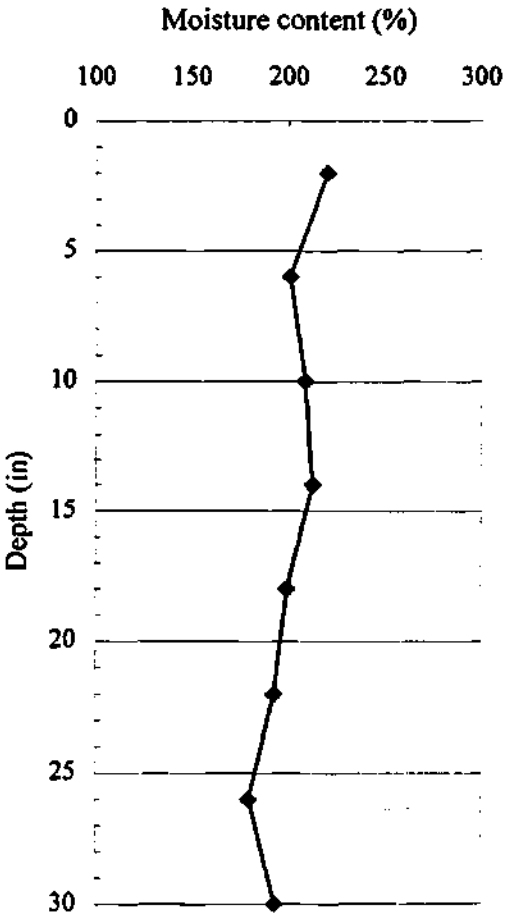


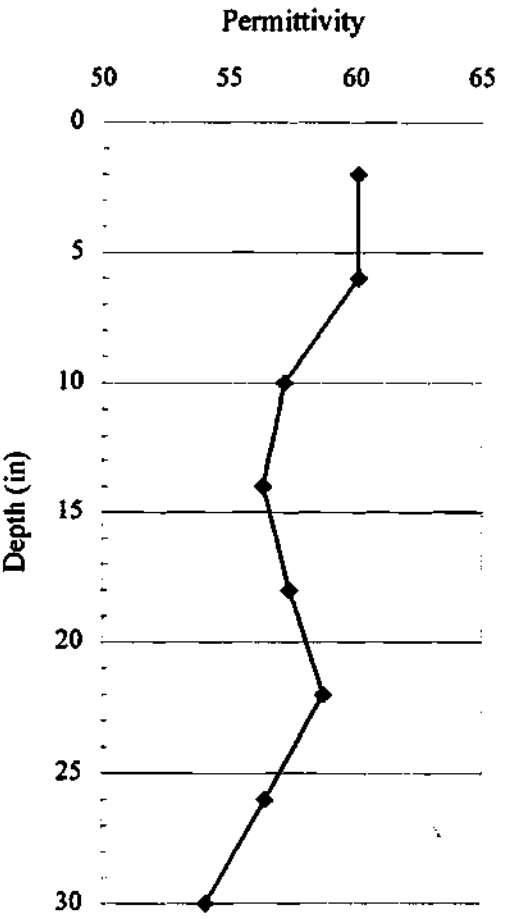


Tube number & description: E99-G, Bullocks Point Reach

File code: G

Depth	*w%*	*Permittivity*
2	220.03	60.1
6	200.71	60.11
10	208.70	57.22
14	212.42	56.37
18	199.48	57.44
22	192.75	58.78
26	179.82	56.5
30	193.00	54.13

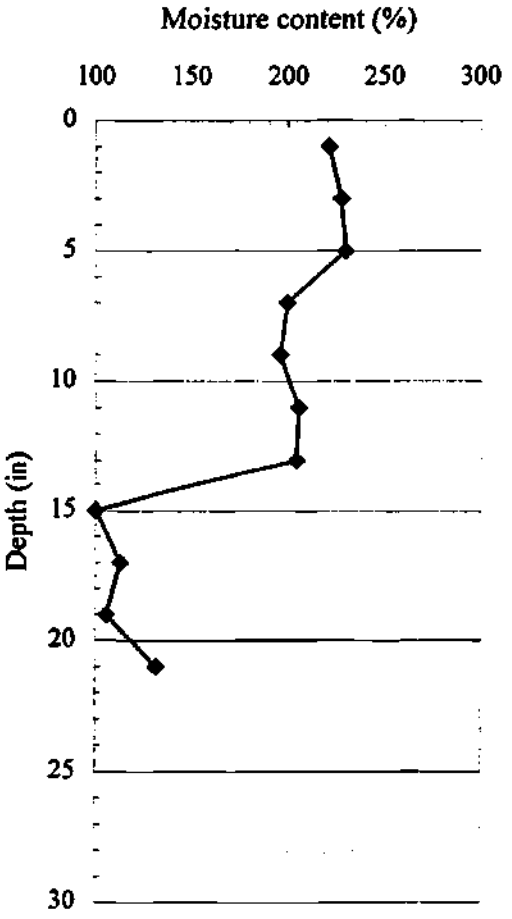


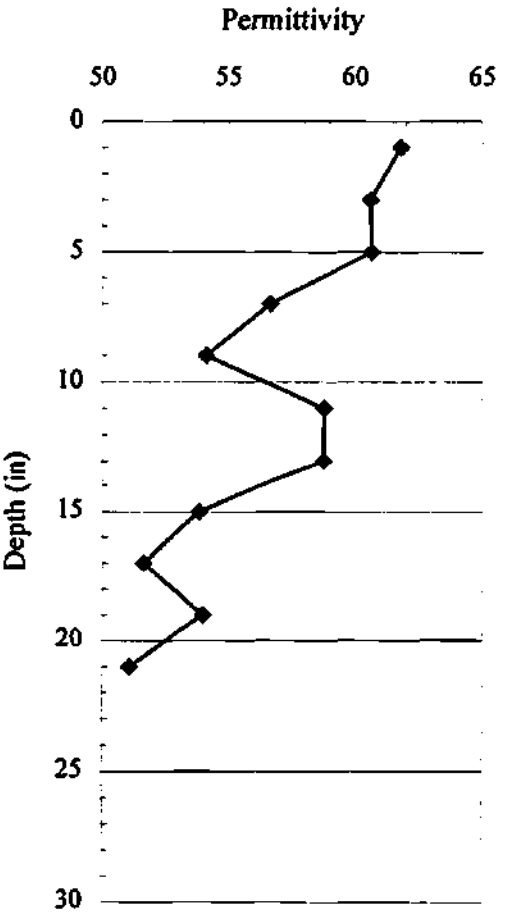


Tube number & description: E99-H

File code: A

Depth	*w%*	*Permittivity*
1	221.25	61.79
3	227.56	60.61
5	229.80	60.65
7	199.55	56.65
9	195.95	54.12
11	205.45	58.78
13	204.31	58.76
15	100.36	53.84
17	113.07	51.64
19	105.81	53.99
21	131.77	51.1

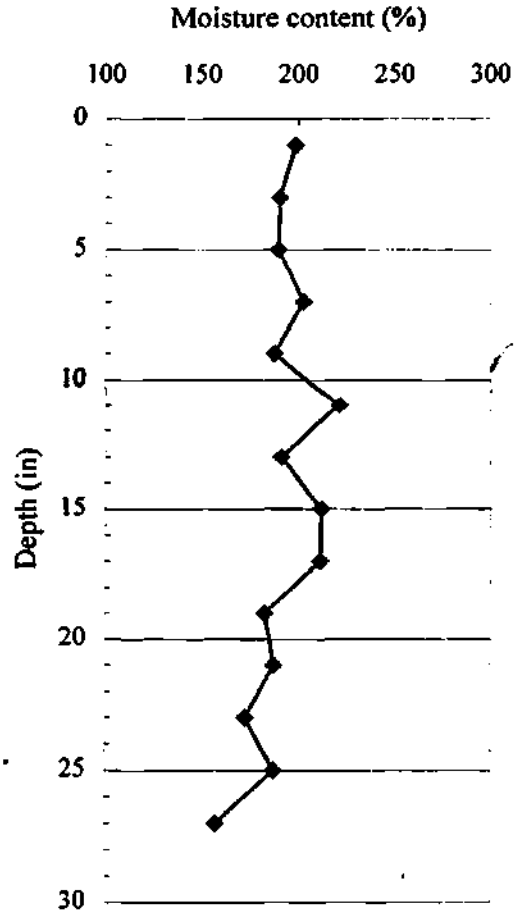


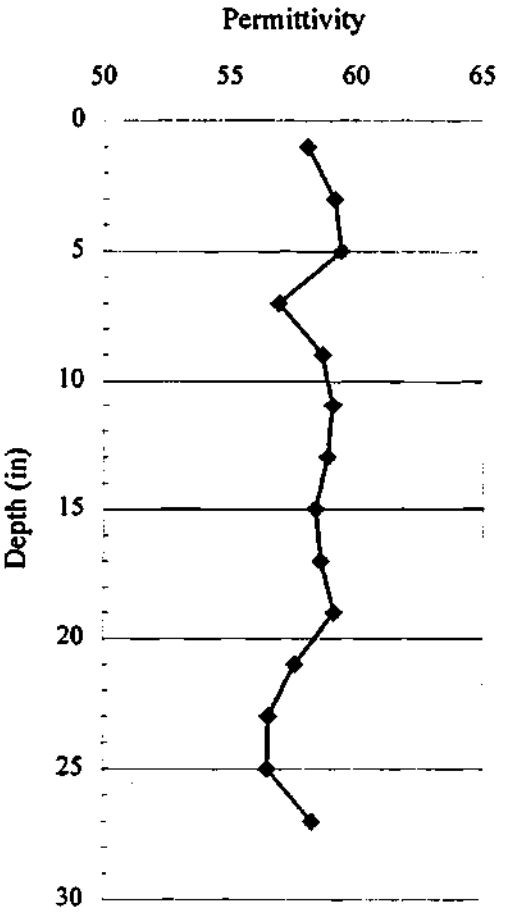


Tube number & description: E99-I

File code: B

Depth	*w%*	*Permittivity*
1	198.38	58.09
3	190.41	59.17
5	189.63	59.43
7	202.60	56.96
9	187.67	58.71
11	221.37	59.1
13	191.38	58.89
15	212.20	58.42
17	212.06	58.65
19	183.14	59.17
21	187.90	57.63
23	172.93	56.58
25	187.51	56.53
27	157.54	58.29

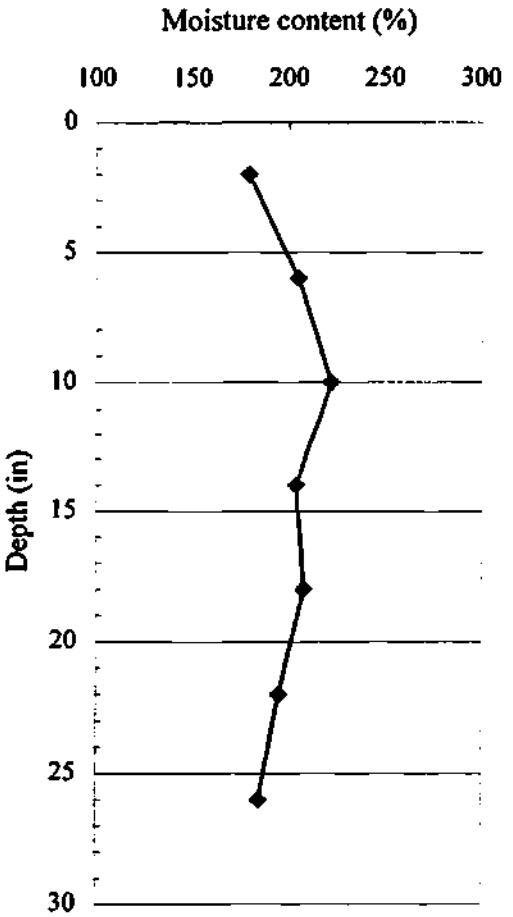


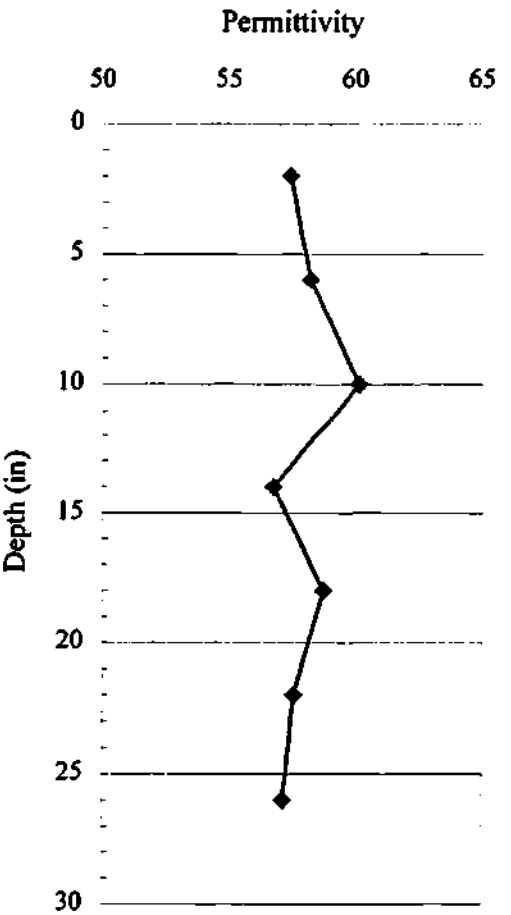


Tube number & description: E99-I, Bullocks Point Reach

File code: D

Depth	*w%*	*Permittivity*
2	179.30	57.46
6	205.01	58.24
10	221.89	60.17
14	204.01	56.78
18	207.88	58.75
22	195.08	57.6
26	184.89	57.17





APPENDIX C

Fig C-1: Erosion Rate vs. Shear Stress;
Combined Consolidated Samples (1-, 5-, and 15-Year)

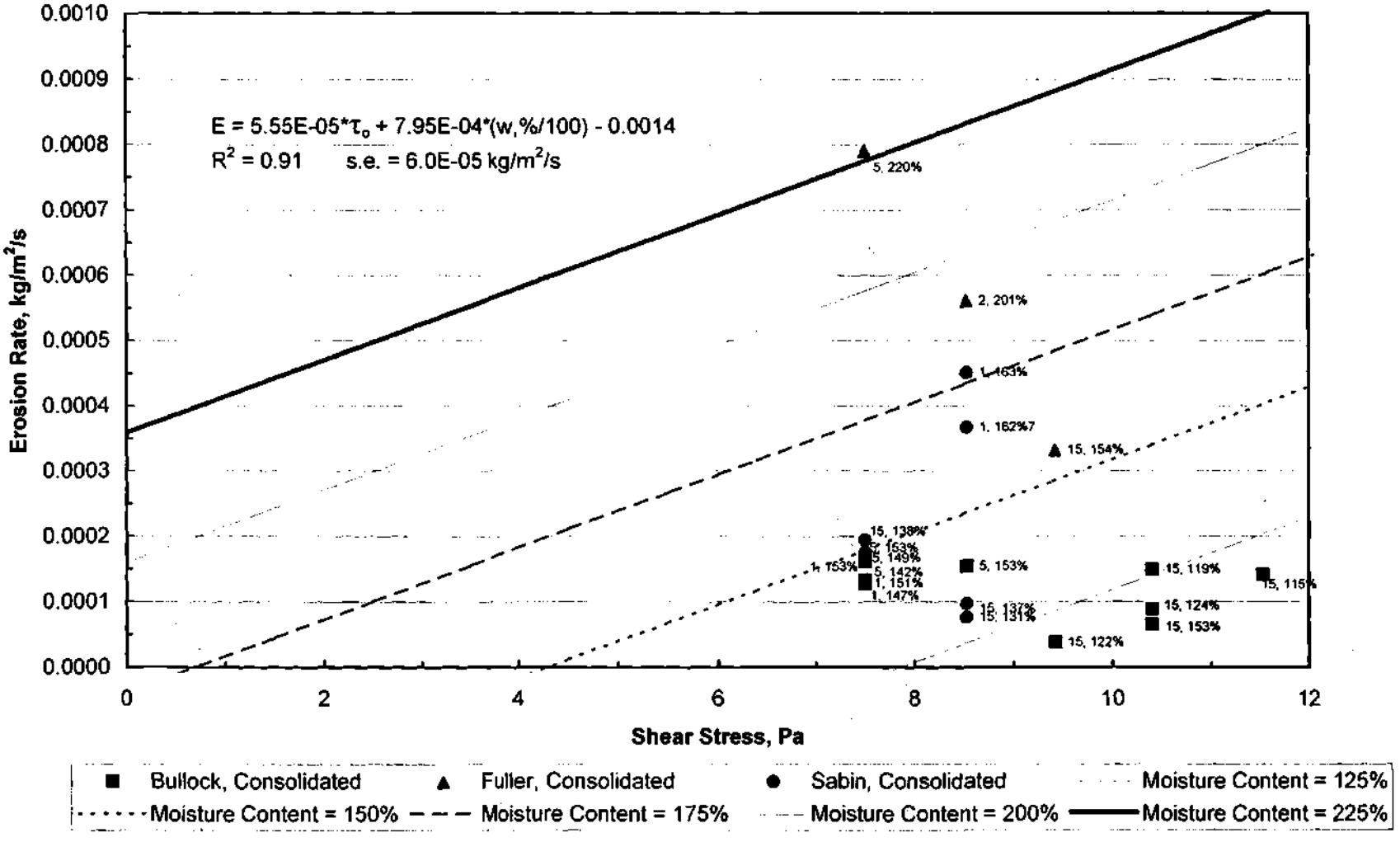


Fig. C-2: Critical Shear Stress vs. Moisture Content From Regression Analysis; Combined Consolidated Samples (1-, 5-, and 15-Year)

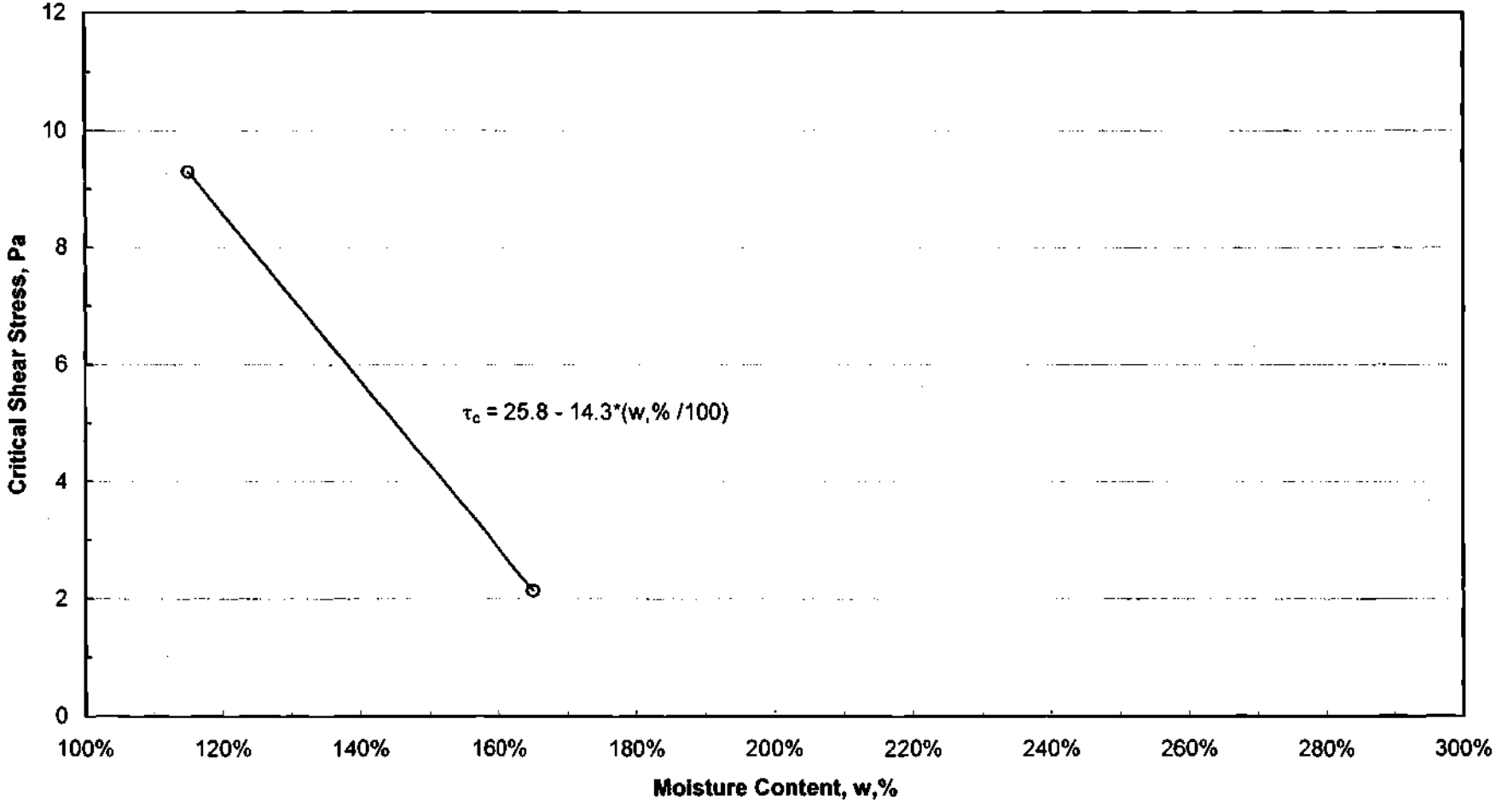


Figure C-3: Erosion Rate vs. (Shear Stress - Critical Shear Stress); Combined Consolidated Samples (1-, 5-, and 15-Year)

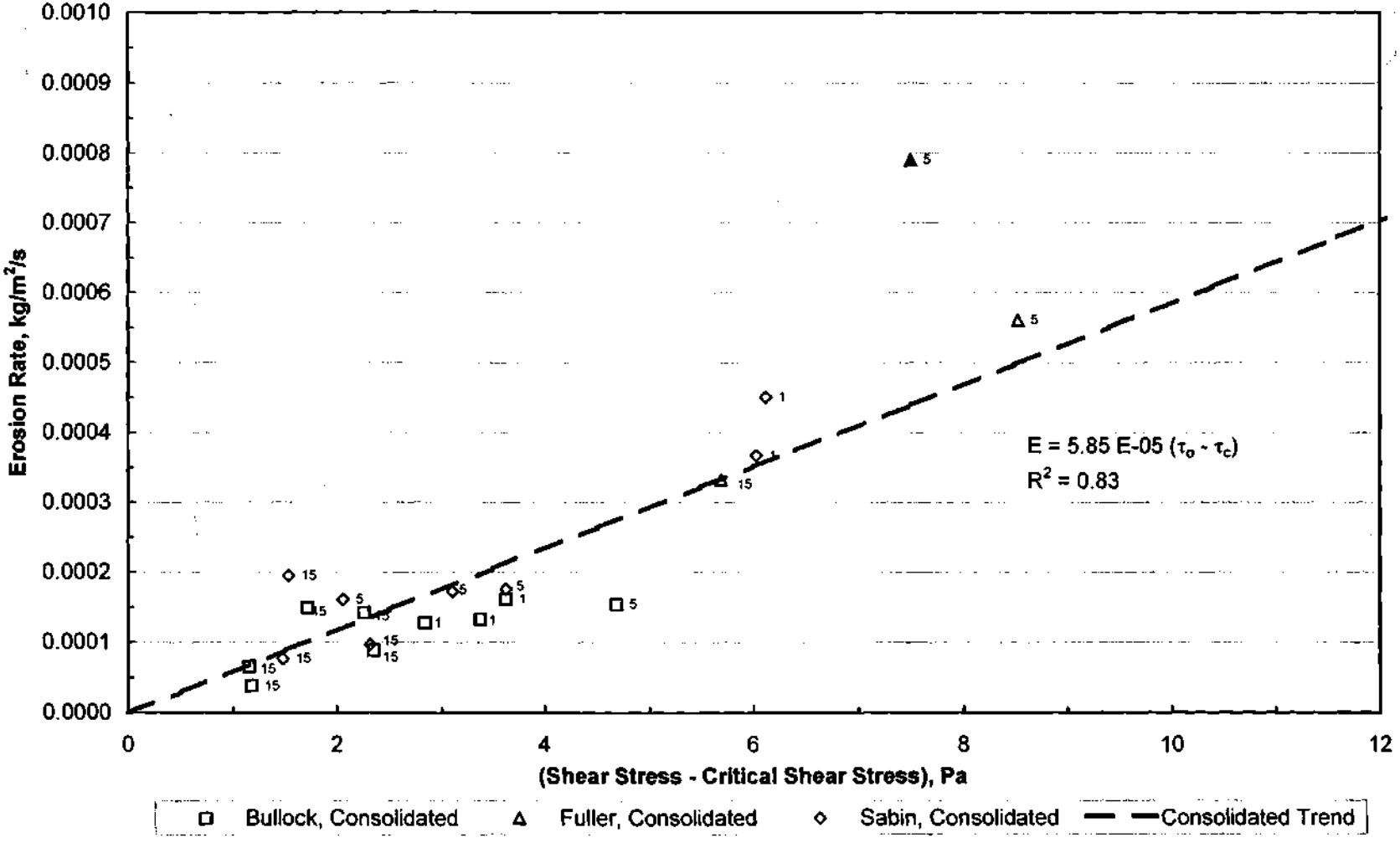


Fig. C-4: Erosion Rate vs. Shear Stress;
Undisturbed Samples for Fuller Rock Reach

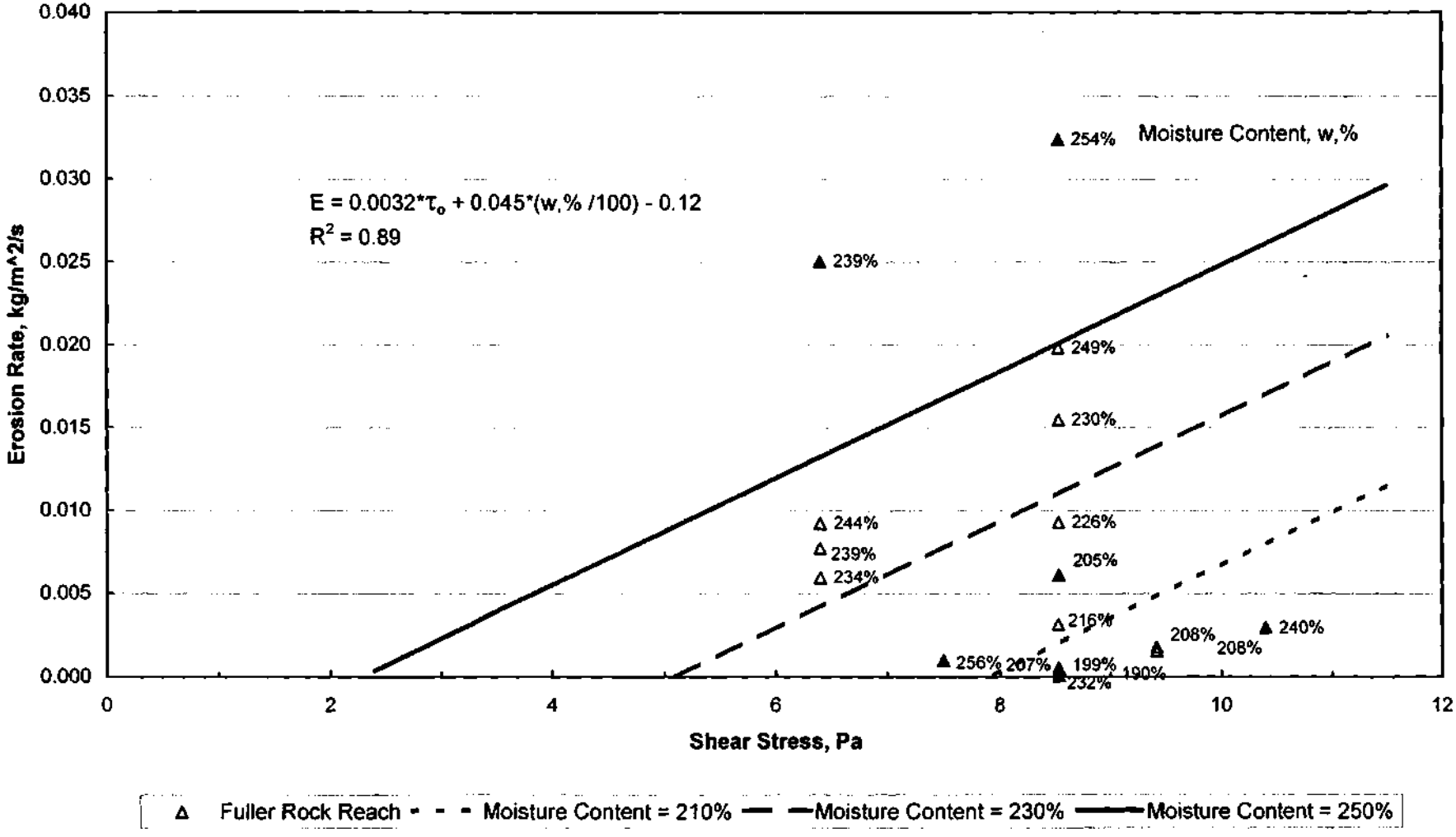


Fig. C-5: Erosion Rate vs. Shear Stress
Undisturbed Samples for Sabin Point Reach

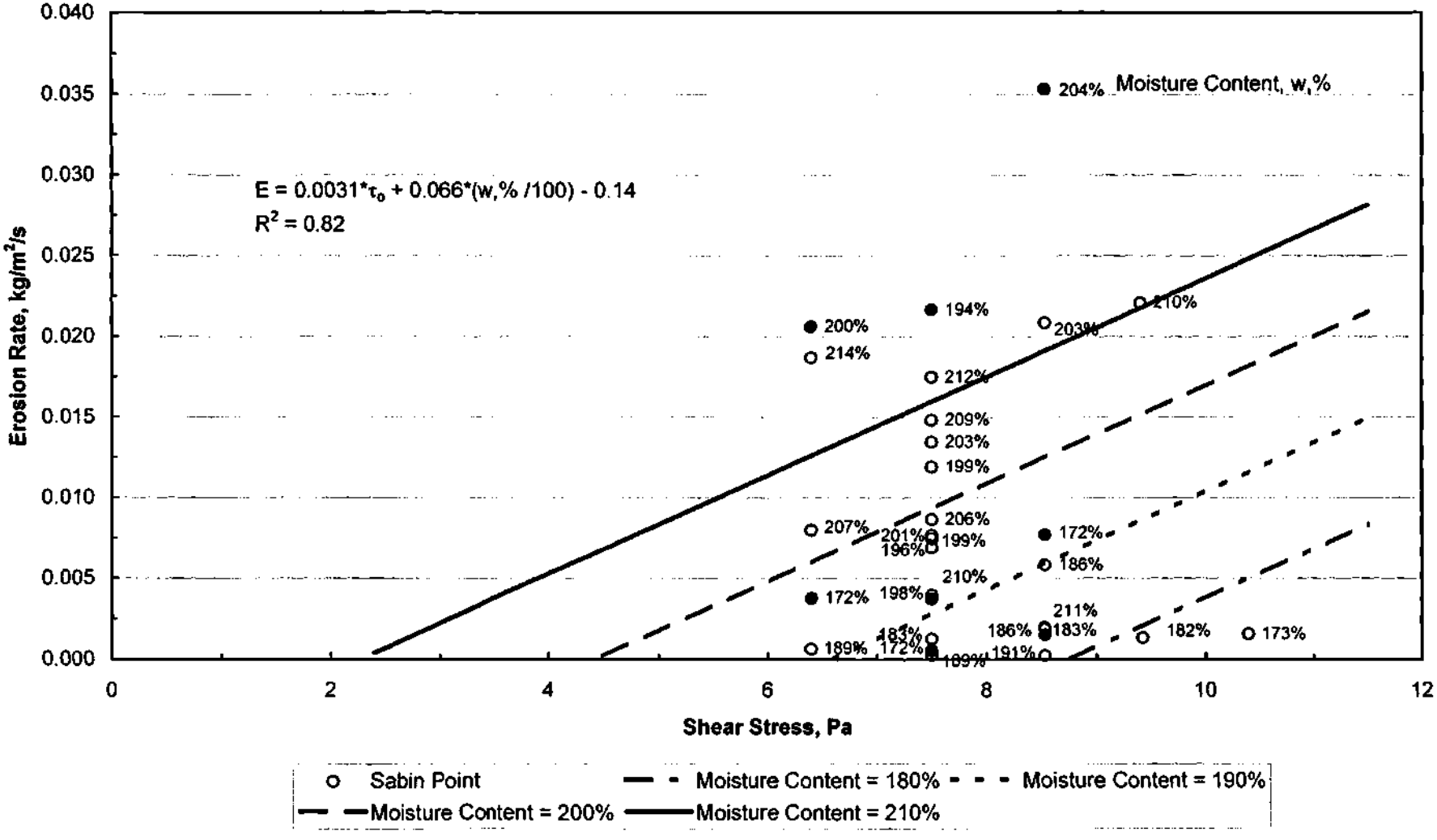


Fig. C-6.: Erosion Rate vs. Shear Stress
Undisturbed Samples for Bullock Point Reach

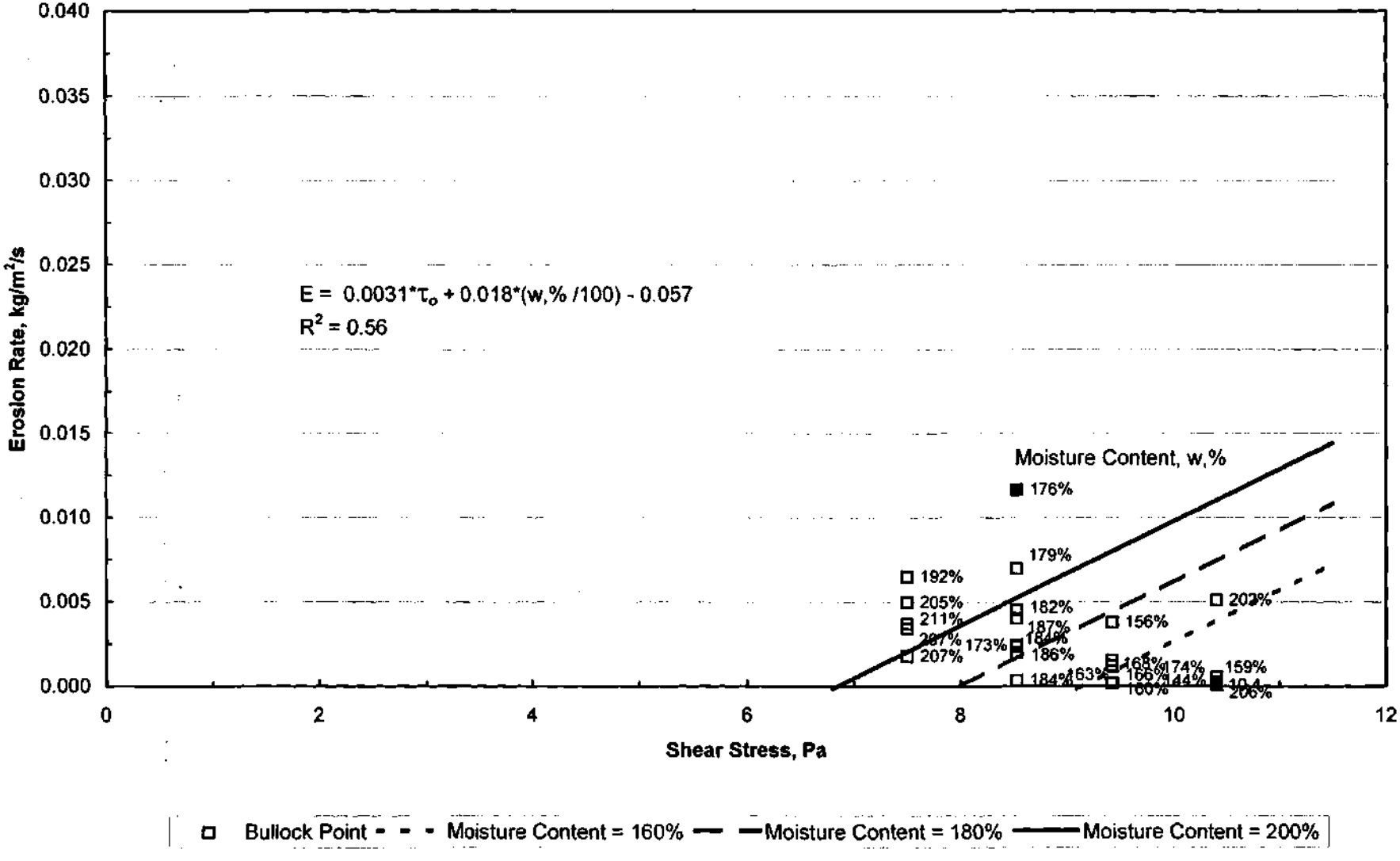


Fig. C-7. Critical Shear Stress vs. Moisture Content From Regression Analysis; Consolidated and Undisturbed Cores

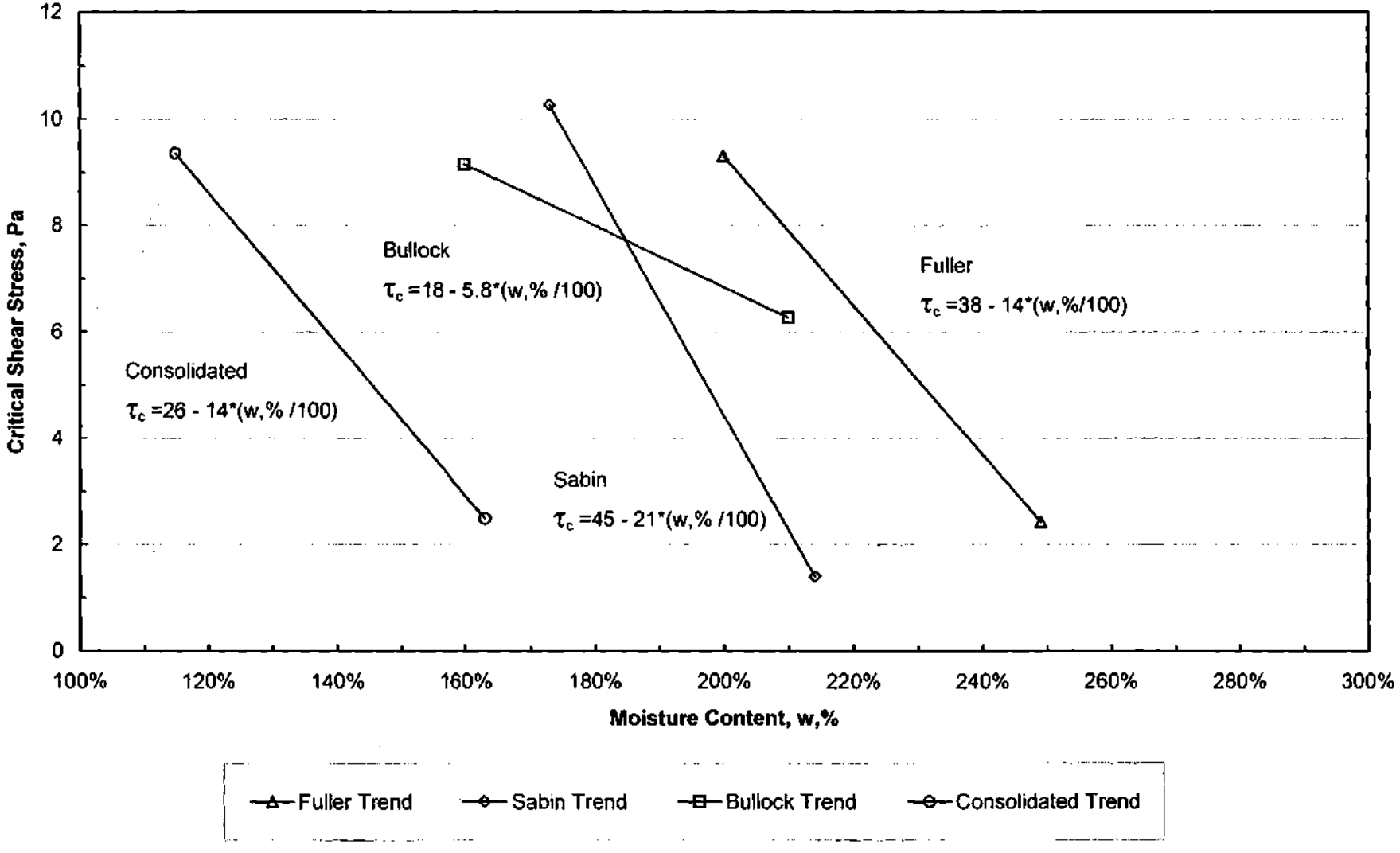


Fig. C-8: Erosion Rate vs. Excess Shear Stress
Undisturbed Samples

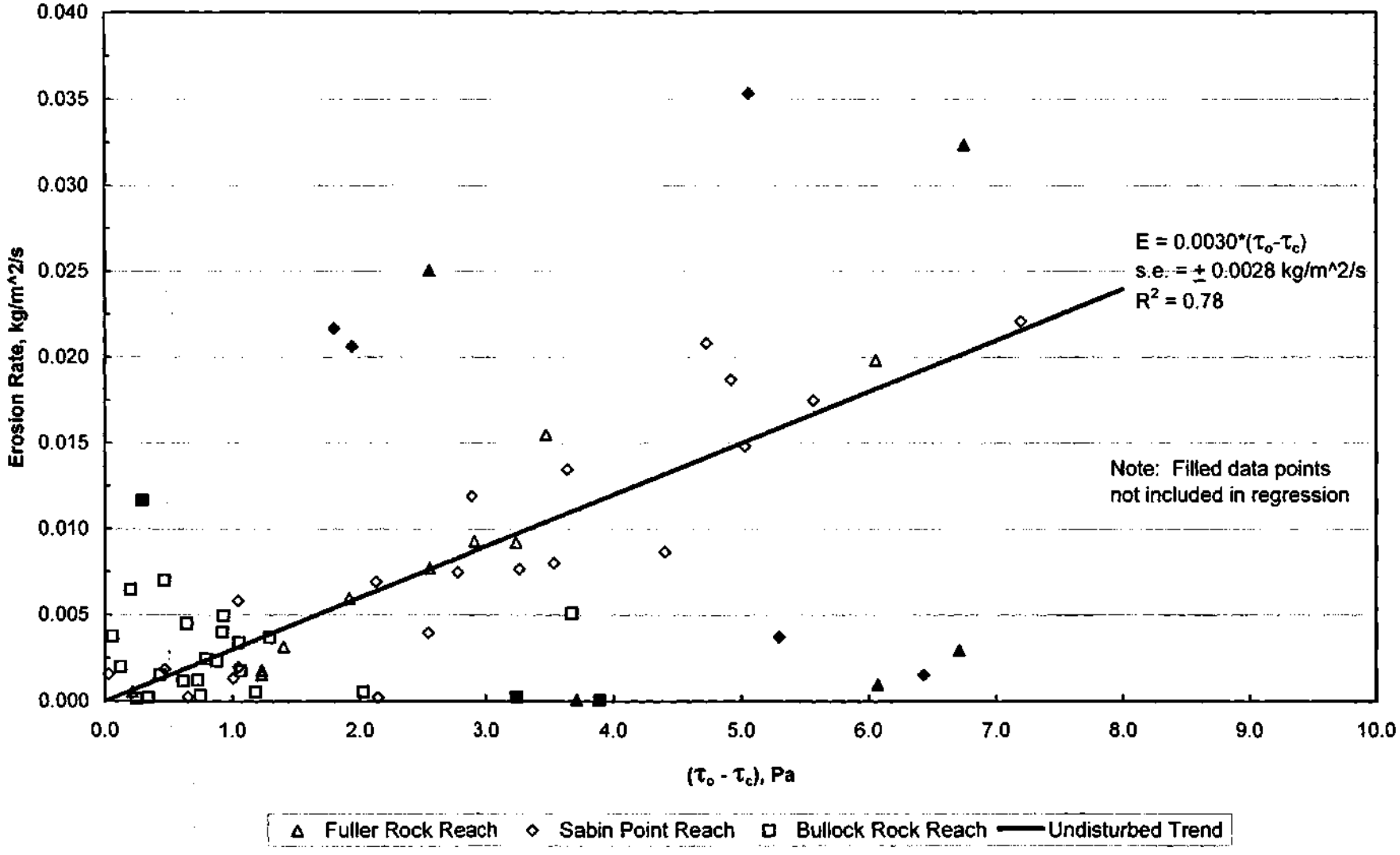


Table C-1. Organic Content Measurements of Providence River Sediments in % by Weight.

Sample	Depth, in.	% Organic Content
Fuller Rock Reach		
1 yr	1.5-3.5	12.57
	4.0-5.5	12.20
	5.5-7.5	12.67
	8.0-10.0	12.34
5 yr	2.5-4.5	12.42
	4.5-6.0	12.54
	6.0-8.0	12.38
E99-A	0-6.0	11.06
	6.0-9.0	11.48
	9.0-12.0	11.41
	12.0-14.0	10.34
	14.0-18.0	7.77
	18.0-22.0	8.75
E99-B	0-4.0	11.10
	4.0-8.0	10.24
	8.0-12.0	11.00
	12.0-16.0	11.41
	16.0-20.0	10.98
	20.0-24.0	10.21
	24.0-28.0	10.49
	18.5-20.0	11.99
	18.5-20.0	11.91
E-99B (dup)	1.0-3.0	12.98
	5.0-7.0	11.63
	10.0-12.0	12.52
	14.0-16.0	12.18
Sabin Point Reach		
E99-D	1.0-3.0	11.29
	5.0-7.0	11.32
	9.0-11.0	11.76
	15.0-17.0	11.86
	19.0-21.0	11.45

Table C-1 Continued

E99-F	3.0-5.0	12.30
	5.0-7.0	11.52
	10.0-12.0	12.29
	12.0-14.0	11.70
	14.0-16.0	11.27
Bullock Point Reach		
E99-G	3.0-5.0	11.85
	8.0-10.5	11.29
	14.0-15.5	10.86
	18.5-20.0	10.42
E99-H	4.0-5.0	10.56
	5.0-6.0	10.02
E99-I	7.0-9.0	10.76
	9.0-13.0	11.33
	17.0-21.0	11.66
	23.0-27.0	10.35
	35.0-39.0	11.74
E99-I (dup)	12.0-13.5	12.04
	15.0-16.5	12.15
	17.0-18.5	10.97