CLEAR-WATER AND SEDIMENT-LADEN-FLOW TESTING OF THE E-TUBE SEDIMENT RETENTION DEVICE

Prepared for

North American Tube Products, Inc.

Prepared by

Amanda L. Cox
Christopher I. Thornton
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Colorado State University
Daryl B. Simons Building *at the*
Engineering Research Center
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LIST OF SYMBOLS, UNITS OF MEASURE, AND ABBREVIATIONS

Symbols

±	plus or minus
<	less than
>	greater than
h	upstream flow depth (stage)
q	volumetric discharge of water in gallons per minute per linear foot of E-tube

Units of Measure

ft	foot or feet
ft/ft	foot per foot
gpm	gallons per minute
in.	inch(es)
lb(s)	pound(s)
mg/l	milligrams per liter
min	minute(s)
mm	millimeter(s)
NTU	Nephelometric Turbidity Units
sec	seconds
%	percent

Abbreviations

ASTM	American Society for Testing and Materials
Conc.	concentration
CSU	Colorado State University
DS	downstream
H:V	horizontal to vertical
ID	identification
PI	Plasticity Index
US	upstream
®	registered

1 INTRODUCTION

During the summer of 2011, performance testing was conducted by Colorado State University (CSU) on E-tube sediment retention devices (SRDs) manufactured by North American Tube Products, Inc. to determine the E-tube hydraulic capabilities and abilities to reduce sediment concentration within sediment-laden flow. A two-phase research program was completed which included evaluation of the E-tube in both clear-water and sediment-laden conditions. Phase 1 consisted of a series of tests to determine the hydraulic performance of the E-tube; while Phase 2 focused on quantifying the sediment retention capabilities of the product. The testing facility was a 4-ft wide by 30-ft long adjustable-slope flume. The flume had a rectangular cross section and was set to a bed slope of 33%. Sediment-laden flow was gravity fed into the flume from a 1,000-gallon mixing volume tank. The sediment-laden flow passed through a smaller constant–head tank to provide a uniform flow rate during testing.

The test program evaluated three E-tube sizes: 9, 12 and 18 inch diameters, with clear-water and sediment-laden flow. E-tube sediment retention devices were made with an outer expandable mesh fabric filled with mulch. Figure 1-1 presents a photograph of the 9-inch E-tube during clear-water testing and Appendix A provides the E-tube product datasheet. Each E-tube size was evaluated twice resulting in a total of 24 clear-water tests and 6 sediment-laden flow tests. The stage-discharge rating curve and maximum hydraulic capacity of each tube was determined under clear-water conditions and the percent reduction in sediment concentration and turbidity was determined from the sediment-laden-flow testing. For each E-tube size, sediment-laden-flow testing was conducted with two target sediment concentrations: approximately 4800 and 9500 mg/l. Information presented within this report documents testing procedures and presents the resulting data and analysis.

Figure 1-1. Photograph of the 9-in. E-tube sediment retention device

2 TEST SETUP

2.1 TEST FACILITY AND SEDIMENT SPECIFICATIONS

The flume used for testing was 4 ft wide, 30 ft long, and 4 ft deep with a bed slope adjustable between 0 and 50%. For this project, the slope of the flume was fixed at a 3:1 (H:V) bed slope (33.3%). Figure 2-1 provides a sketch of the flume setup. For the clear-water tests, water was supplied from a gravity-fed line from Horsetooth Reservoir with a pressure reducer. Discharge was measured using a stop watch and a calibrated volume tank located at the downstream end of the flume for both the clear-water and sediment-laden-flow testing.

A constant-head slurry tank was used to supply water for the sediment-laden-flow testing. Figure 2-2 presents a photograph of the constant-head slurry tank which was designed to provide a constant sediment-laden discharge during testing. To help maintain a uniform distribution of particles, the tank was equipped with a large paddle wheel attached to a hydraulic motor. A clayey sand soil type with a Plasticity Index (PI) of 8 was used to create the sediment-laden flow. The soil was well graded with a maximum particle size of 9.53 mm, which is classified as a fine gravel by the U.S. Department of Agriculture Soil Classification System. Documented soil information included the following:

- Standard Proctor data and plot (ASTM D1557);
- Soil texture (ASTM D2487 classification);
- Grain-size distribution curve (ASTM D422); and
- Atterberg limits (ASTM D4318).

The documented soil physical properties are provided in Appendix B.

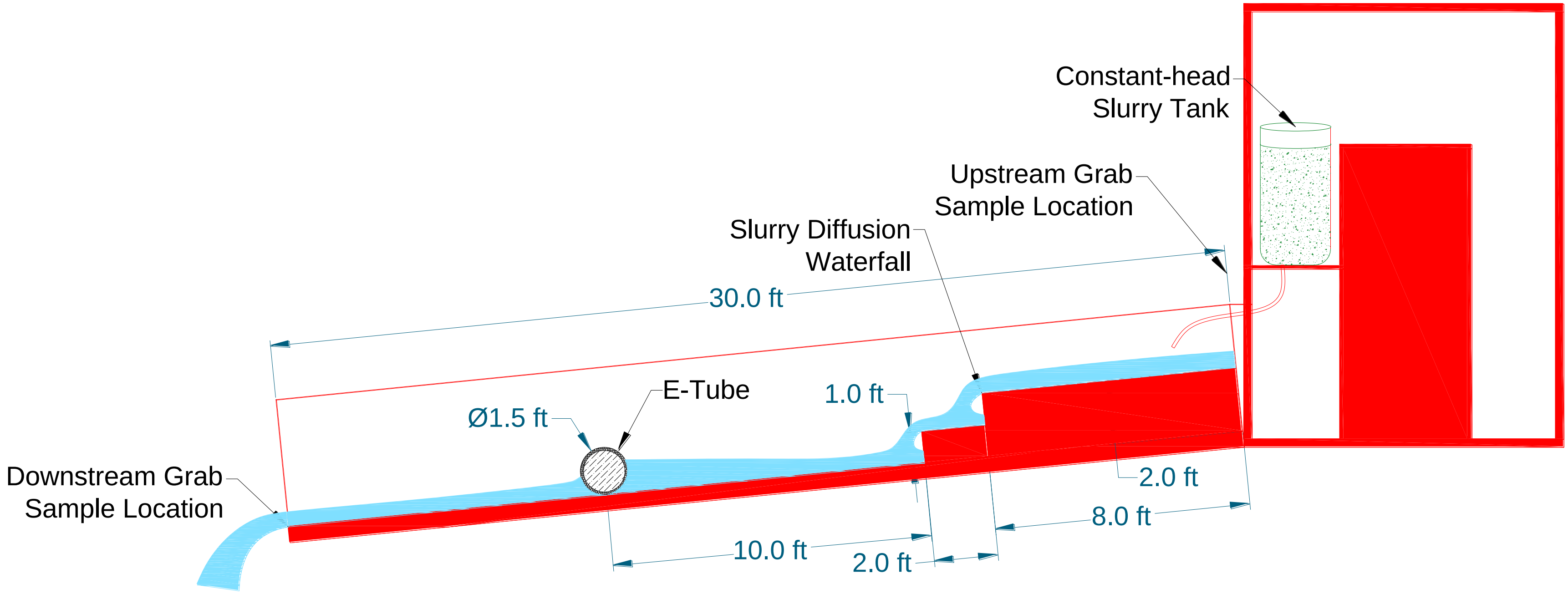


Figure 2-1. Sketch of flume setup for E-tube testing

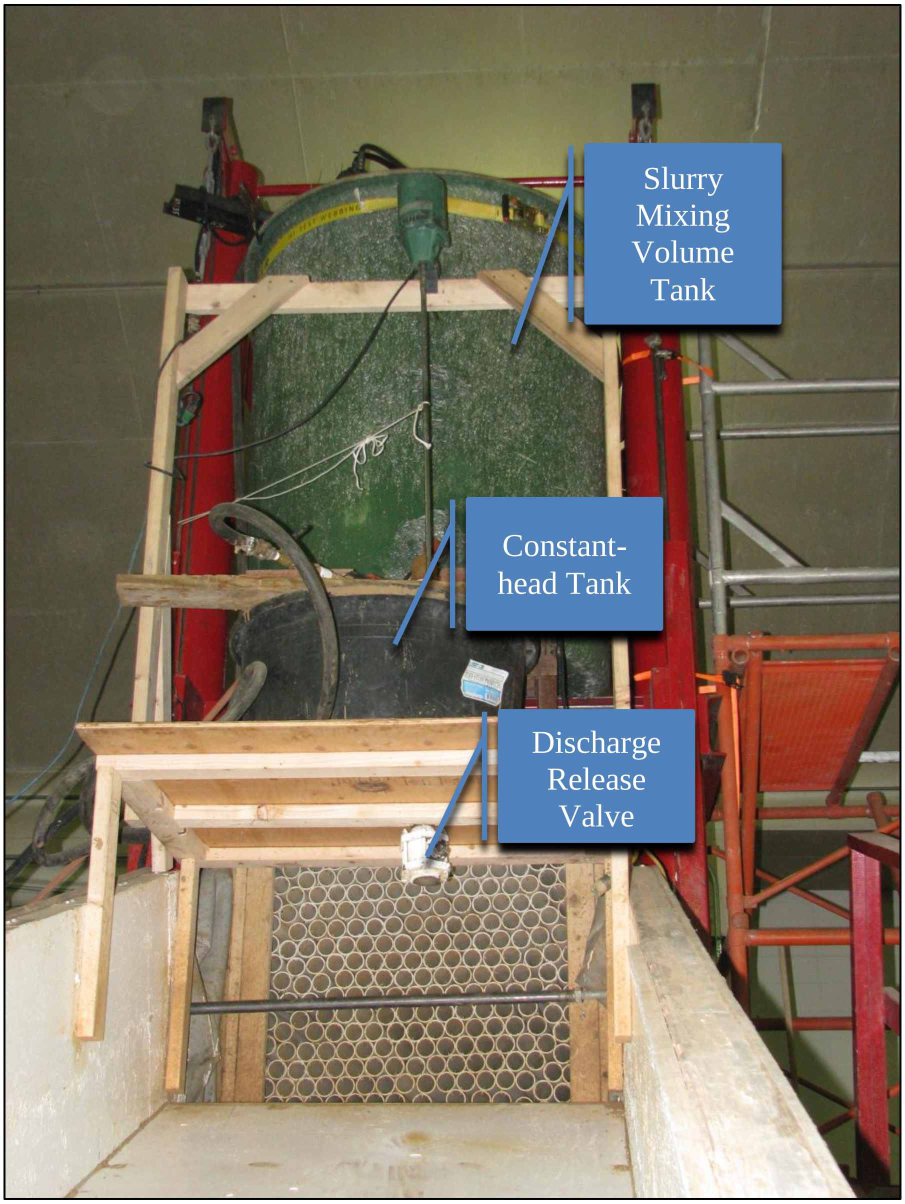


Figure 2-2. Four-foot adjustable-slope flume

2.2 INSTALLATION

Installation involved fabrication of a bracket to anchor the E-tubes in the flume during testing. The bracket was secured in the flume at the E-tube installation location 20 ft downstream of the flume entrance. The E-tubes were centered over the bracket and forced down and over threaded rods to the floor of the flume. Washers were placed over the threaded rods and nuts were used to secure the assembly. Finally, expanding foam was used to seal the sides and upstream edge. Figure 2-3 presents a schematic of the E-tube installation. After the E-tube was installed and secured in place, a point gage with an accuracy of 0.01 ft was anchored to a track-guided mobile cart running the length of the flume allowing for measurement of water-surface elevations at any location in the flume. Figure 2-4 is a photograph of the complete installation of a 12-inch E-tube.

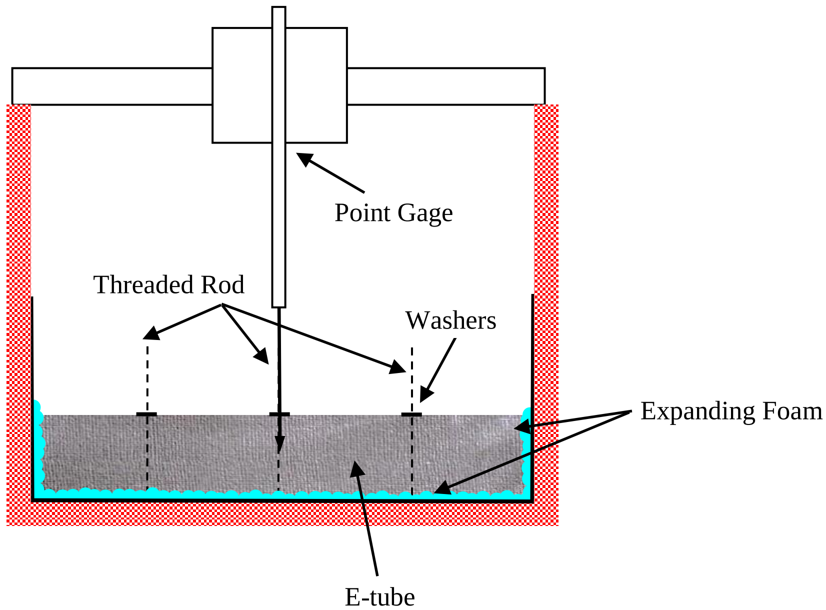


Figure 2-3. Schematic of E-tube installation

Figure 2-4. Photograph of 12-inch E-tube installation

3 TEST SUMMARY AND TEST MATRIX

3.1 TEST PROCEDURES

This section details the test procedures for the clear-water and sediment-laden-flow testing. It is important to note that the sediment-laden-flow testing was conducted in accordance with the ASTM D7351-07 standard: Standard Test Method for Determination of Sediment Retention Device Effectiveness in Sheet Flow Applications with the following exceptions. Instead of using a volume tank placed on a scale with periodic valve adjustments to maintain an approximate constant flow rate, a constant-head tank was used to provide sediment-laden flow at a constant rate to the test section. Furthermore, a soil base was not constructed beneath the SRDs. Installing the E-tube on a soil base introduces soil downstream of the SRD which would bias the sediment retention results when comparing the downstream sediment concentration to the sediment concentration measured upstream of the E-tube.

3.1.1 PHASE 1 – CLEAR-WATER TESTING

Following E-tube installation, four (4) flow rates, corresponding to 25, 50, 75, and 100 percent of the measured E-tube height, were conveyed through the flume with clear-water conditions. Data collected during each flow rate included water-surface elevations upstream and downstream of the E-tube and the corresponding discharge. In addition, the following data were recorded for each installation:

- Three (3) measurements of initial E-tube circumference;
- Initial dry weight;
- Initial installed height of E-tube;
- Time required for standing water upstream of the E-tube to drain following termination of the 100% flow and;
- Final height of E-tube.

During each flow event, non-professional video and photographic documentation were collected.

3.1.2 PHASE 2 – SEDIMENT-LADEN-FLOW TESTING

Phase 2 of the testing was designed to quantify the E-tube sediment retention capabilities and immediately followed Phase 1 testing utilizing the same E-tube installations. Each configuration was tested for a 30-minute duration with a flow rate equivalent to 75 percent of the maximum clear-water discharge capacity, as determined by Phase 1 testing, and target approach sediment concentration. To achieve the target sediment concentration in the approach flow, sediment-laden flow was gravity fed into the flume from a constant-head tank. A valve from the constant-head tank was adjusted to set the desired flow rate. If overtopping of the E-tube occurred during the 30-minute test, the time of occurrence and flow depth above the product were recorded. Sediment-concentration grab samples were collected both upstream and downstream of the E-tube at the start of the test and every five (5) minutes during the 30-minute test. In addition, the following data were recorded for each installed configuration:

- Time required for standing water upstream of the E-tube to drain following flow termination;
- Final height of E-tube;
- Final wet weight of E-tube; and
- Three measurements of final E-tube circumference.

During each flow event, non-professional video and photographic documentation were collected. After testing, the grab samples were processed to determine sediment concentrations and turbidity of the approach flow and flow exiting the SRD. The determination of sediment concentration from the grab samples was conducted in accordance with ASTM D3977-97 and particle-size distributions of the sediment within the grab samples were determined using a mechanical sieve in accordance with ASTM D422. Turbidity was measured using a Hach 2100P Turbidimeter meter which was accurate to ± 2% of the reading.

3.2 TEST MATRIX

A total of 24 clear-water tests and 6 sediment-laden-flow tests were conducted on three E-tube sizes: 9, 12 and 18 in. diameters. Table 3-1 presents the clear-water test matrix. Discharges associated with flow depths upstream of the E-tube equal to 25, 50, 75 and 100% of the installed E-tube height were measured during the clear-water testing. Table 3-2 presents the sediment-laden-flow test matrix which included evaluating each of the E-tube sizes at two upstream sediment concentrations: approximately 4800 and 9500 mg/l.

Table 3-1. Clear-water test matrix

Test No.	E-tube ID	Backwater Depth (% of Installed height)
1	9 in. #1	25%
2		50%
3		75%
4		100%
5	9 in. #2	25%
6		50%
7		75%
8		100%
9	12 in. #1	25%
10		50%
11		75%
12		100%
13	12 in. #2	25%
14		50%
15		75%
16		100%
17	18 in. #1	25%
18		50%
19		75%
20		100%
21	18 in. #2	25%
22		50%
23		75%
24		100%

Table 3-2. Test matrix for sediment-laden-flow conditions

Test No.	E-tube ID	Ave. Upstream Sediment Conc. (mg/l)
25	9 in. #1	9,018
26	9 in. #2	3,912
27	12 in. #1	9,357
28	12 in. #2	6,209
29	18 in. #1	10,051
30	18 in. #2	4,272

4 CLEAR-WATER RESULTS

At the conclusion of testing, data were entered into a database for analysis. The measured discharge in gpm was converted to a unit discharge in gpm per linear foot of E-tube by dividing the measured discharge by 4 ft, which was the length of all tested E-tubes. Table 4-1 presents a summary of data results for the clear-water tests including pre-test and post-test E-tube weights, heights and circumferences. Additionally, Figure 4-1 provides a plot of upstream flow depth (stage) versus discharge for all tests. The average maximum discharges, corresponding to an upstream flow depth equal to 100% of the E-tube height, for the 9, 12 and 18 inch E-tube were 3.37, 2.24 and 3.14 gpm per linear foot of E-tube, respectively. A logarithmic regression was used to develop stage-discharge equations for each E-tube size. Equations 4.1, 4.2 and 4.3 provide the stage-discharge equations for the 9, 12 and 18-inch E-tubes, respectively.

$$q = 1.82\ln(h) + 4.27 \qquad \text{Equation 4.1}$$

$$q = 1.25\ln(h) + 2.76 \qquad \text{Equation 4.2}$$

$$q = 1.82\ln(h) + 3.66 \qquad \text{Equation 4.3}$$

where:

q = unit discharge in gpm per linear foot of E-tube; and

h = upstream flow depth (stage) in ft.

Equations 4.1, 4.2 and 4.3 were developed from the clear-water testing dataset which had a minimum upstream flow depth of approximately 0.15 ft. Furthermore, the dataset was limited to upstream flow depths less than or equal to the E-tube installed height. Therefore, these equations should not be used for upstream flow depths less than 0.15 ft or greater than the installed E-tube height.

The time required to drain the pooled water upstream of the E-tube following termination of the 100% flow rate was measured for each test. Table 4-2 provides a summary of the required drain times which ranged from 94 to 263 seconds.

Table 4-1. Clear-water test data

Test No.	E-tube ID	Weight		Installed Height		Circumference		Backwater Depth (% of installed height)	Backwater Depth (ft)	Discharge (gpm per linear ft of E-tube)
		Pre-test (lb)	Post-test (lb)	Pre-test (ft)	Post-test (ft)	Pre-test (ft)	Post-test (ft)			
1	9 in. #1	57.0	74	0.65	0.63	2.33	2.33	25%	0.16	0.99
2								50%	0.32	2.24
3								75%	0.49	3.14
4								100%	0.65	3.37
5	9 in. #2	47.0	59.5	0.58	0.58	2.30	2.39	25%	0.15	0.84
6								50%	0.29	1.68
7								75%	0.43	2.81
8								100%	0.58	3.37
9	12 in. #1	73.0	88.5	0.69	0.7	2.55	2.66	25%	0.17	0.86
10								50%	0.34	1.57
11								75%	0.52	2.69
12								100%	0.69	2.92
13	12 in. #2	61.0	81.5	0.63	0.63	2.56	2.63	25%	0.16	0.40
14								50%	0.31	0.85
15								75%	0.47	1.08
16								100%	0.63	1.57
17	18 in. #1	125.5	145	0.84	0.83	3.21	3.50	25%	0.21	0.09
18								50%	0.42	2.13
19								75%	0.63	3.03
20								100%	0.84	3.25
21	18 in. #2	116.5	140	0.78	0.78	3.51	3.72	25%	0.20	1.28
22								50%	0.39	1.91
23								75%	0.59	2.81
24								100%	0.78	3.03

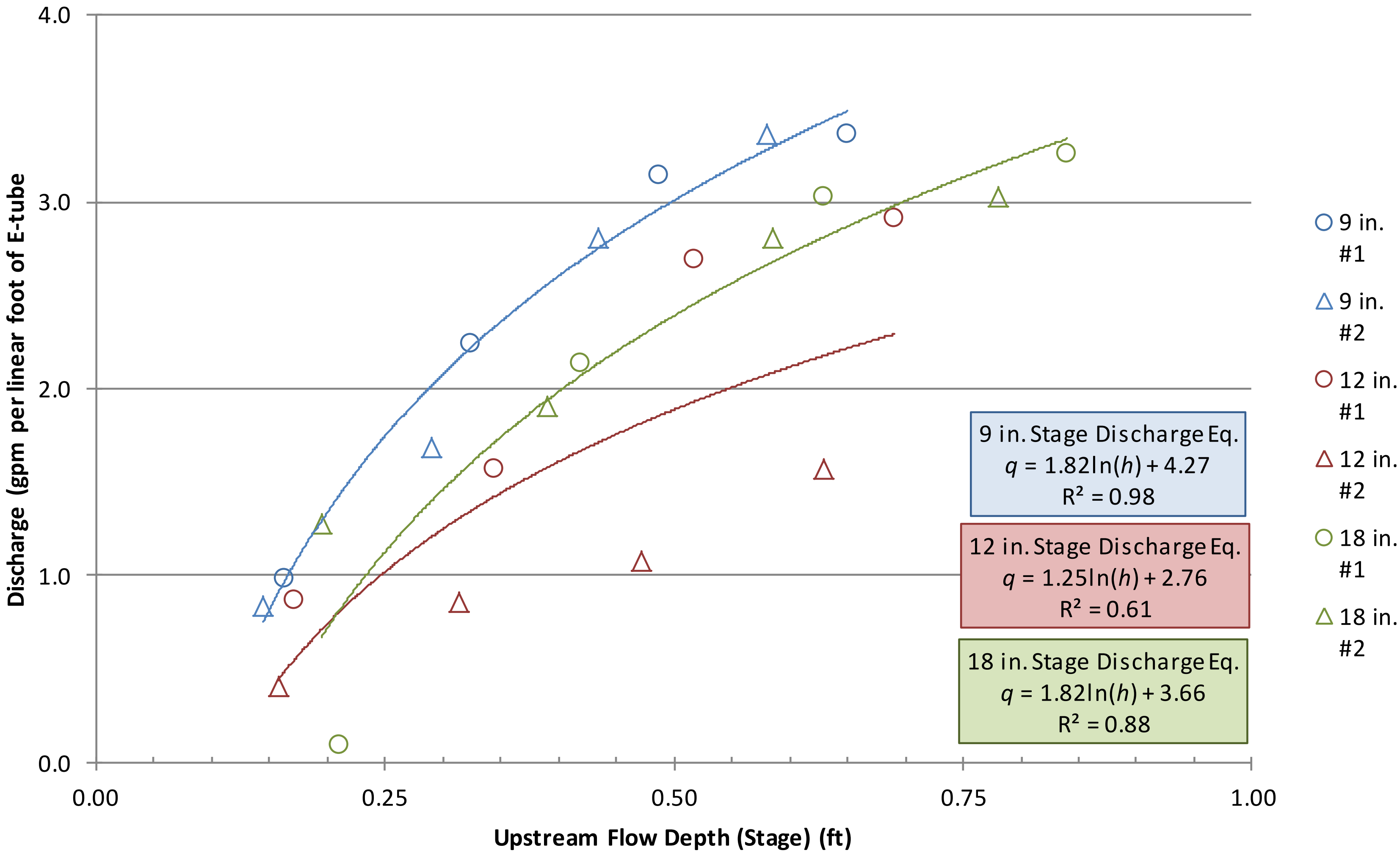


Figure 4-1. Stage-discharge data and regressions

Table 4-2. Required drain time following termination of 100% discharge

Test No.	E-tube ID	Drain Time (sec)
4	9 in. #1	95
8	9 in. #2	94
12	12 in. #1	144
16	12 in. #2	263
20	18 in. #1	178
24	18 in. #2	142

5 SEDIMENT–LADEN-FLOW RESULTS

5.1 SEDIMENT CONCENTRATION RESULTS

Table 5-1 presents a summary of data results for the sediment-laden-flow tests including average upstream total sediment concentration, average downstream total sediment concentration and percent reduction in average total sediment concentration. The results were obtained by averaging the individual measurements of the samples which were collected at 5-min intervals during the 30-min test. Additionally, Figure 5-1 presents a chart of the measured upstream and downstream total sediment concentrations. The maximum percent reduction in average total sediment concentration was observed to be 99% and occurred during testing of the 12 inch E-tube #2 with an upstream average total sediment concentration of 6,209 mg/l. Conversely, the minimum percent reduction in average total sediment concentration was observed to be 92% and occurred during testing of the 9-inch E-tube #1 with an upstream average total sediment concentration of 9,018 mg/l. Appendix C provides the individual concentration measurements that were collected at 5-minute intervals.

Table 5-1. Average total sediment concentration and percent reduction

Test No.	E-tube ID	Ave. US Total Sediment Conc. (mg/l)	Ave. DS Total Sediment Conc. (mg/l)	Ave. Conc. Percent Reduction (%)
25	9 in. #1	9,018	690	92%
26	9 in. #2	3,912	161	96%
27	12 in. #1	9,357	606	94%
28	12 in. #2	6,209	74	99%
29	18 in. #1	10,051	464	95%
30	18 in. #2	4,272	146	97%

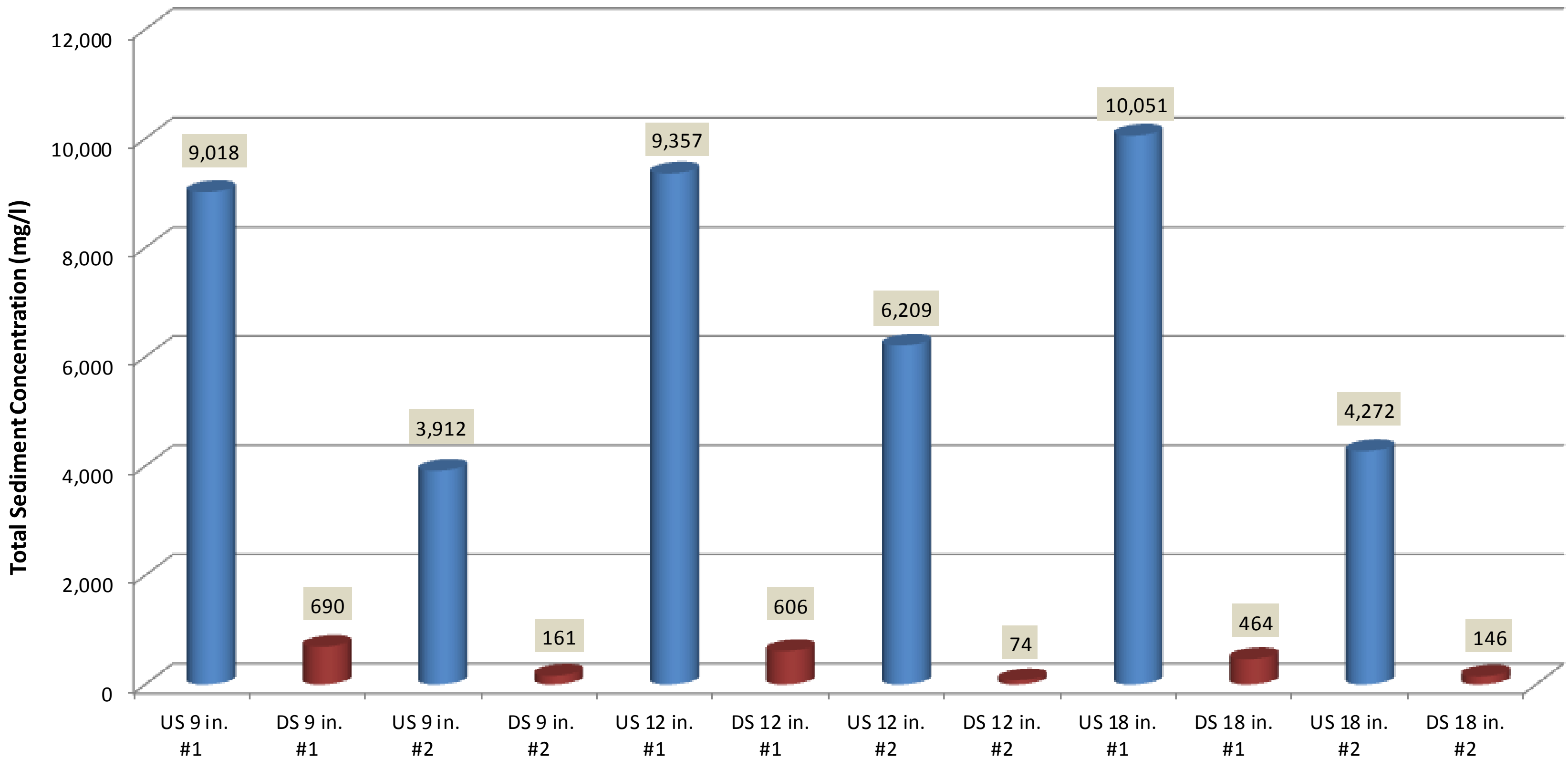


Figure 5-1. Upstream and downstream total sediment concentrations

In addition to evaluating total sediment concentrations, sediment concentrations of particle sizes less than and greater than 0.053 mm (#270 sieve) were investigated. Table 5-2 presents a summary of the results for average sediment concentration for particle sizes less than and greater than 0.053 mm (<0.053 mm and >0.053 mm) and Appendix C provides the individual concentration values computed from the samples collected at 5-minute intervals for particle sizes <0.053 mm and >0.053 mm. The grab-sample grain-size distributions were used to determine the percent of sediment concentration <0.053 mm and >0.053 mm. Appendix D provides the individual grain-size distribution for each grab sample. Figure 5-2 provides a chart of the upstream and downstream <0.053 mm sediment concentrations and Figure 5-3 presents a chart of the percent reduction in <0.053 mm sediment concentrations. The maximum percent reduction in average <0.053 mm sediment concentrations was observed to be 91% and occurred during testing of the 12 inch E-tube #2 with an upstream average <0.053 mm sediment concentration of 804 mg/l. Conversely, the minimum percent reduction in average <0.053 mm sediment concentration was observed to be 54% and occurred during testing of the 9-inch E-tube #1 with an upstream average <0.053 mm sediment concentration of 1,510 mg/l. Every test had a 100% reduction in >0.053 mm sediment concentration.

Table 5-2. Average <0.053 mm and >0.053 mm sediment concentration and percent reduction

Test No.	E-tube ID	Ave. US Conc. <0.053 mm (mg/l)	Ave. DS Conc. <0.053 mm (mg/l)	Ave. Conc. Percent Reduction <0.053 mm (%)	Ave. US Conc. >0.053 mm (mg/l)	Ave. DS Conc. >0.053 mm (mg/l)	Ave. Conc. Percent Reduction >0.053 mm (%)
25	9 in. #1	1510	690	54%	7508	0	100%
26	9 in. #2	691	161	77%	3222	0	100%
27	12 in. #1	1473	606	59%	6076	0	100%
28	12 in. #2	804	74	91%	5405	0	100%
29	18 in. #1	1292	464	64%	8759	0	100%
30	18 in. #2	799	146	82%	3472	0	100%

Ave. = Average; US = Upstream; DS = Downstream; Conc. = Concentration; < = less than; and > = greater than

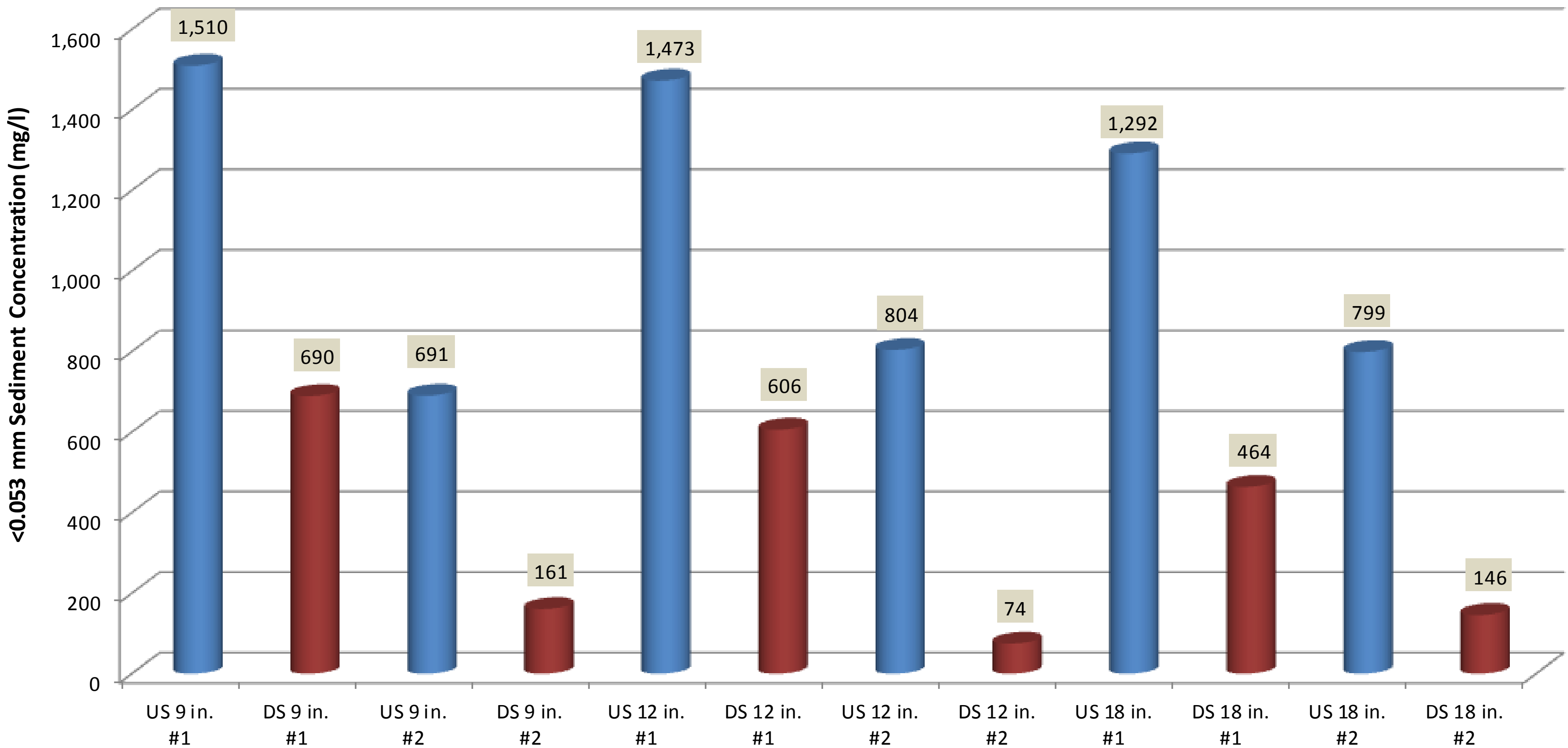


Figure 5-2. Upstream and downstream <0.053 mm sediment concentrations

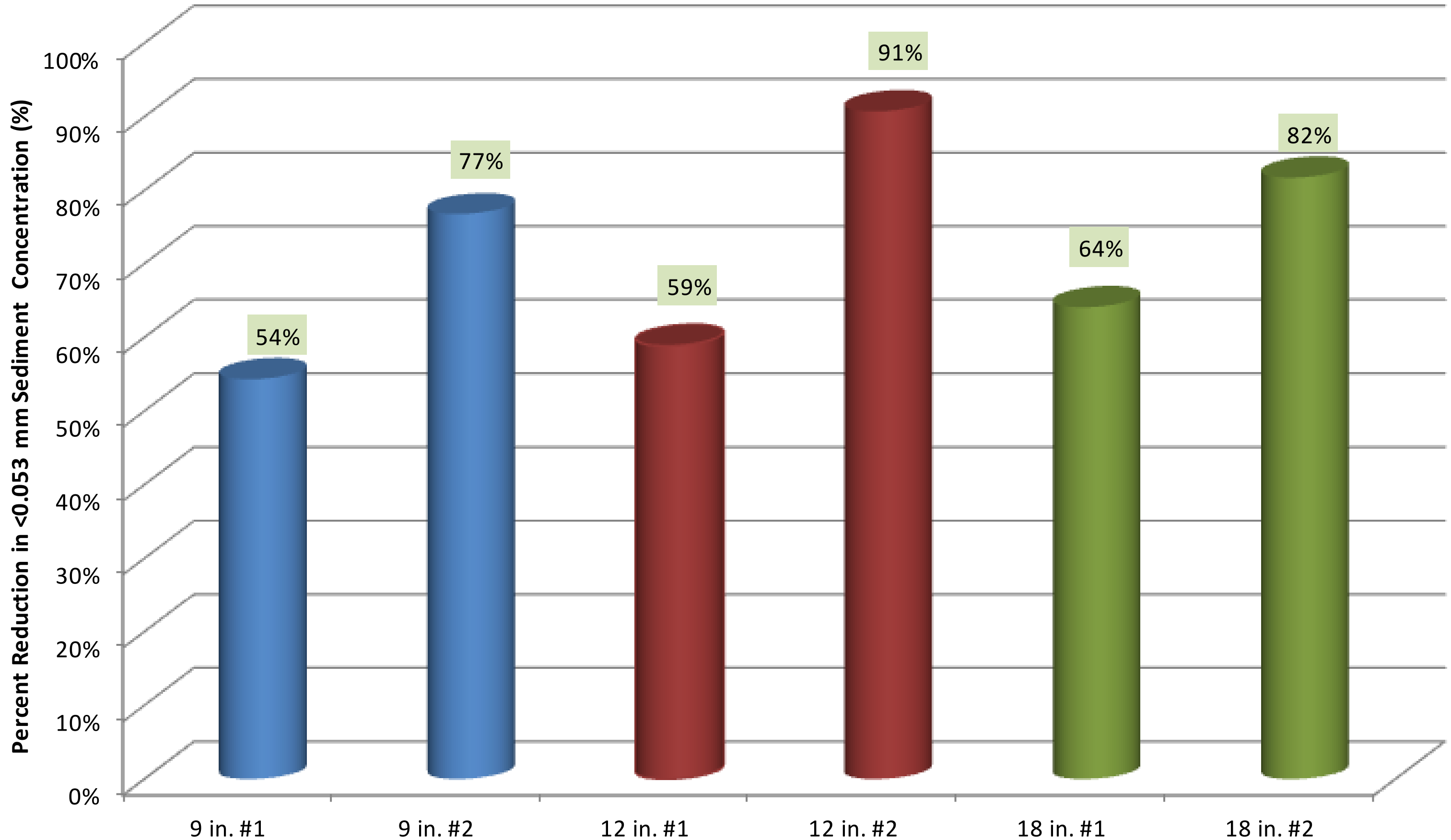


Figure 5-3. Average percent reduction in <0.053 mm sediment concentrations

5.2 TURBIDITY RESULTS

Table 5-3 presents a summary of turbidity results for the sediment-laden-flow tests including average upstream turbidity, average downstream turbidity and percent reduction in average turbidity. Some of the upstream turbidity measurements for the larger concentration tests exceeded the maximum range of the turbidimeter, 1,000 NTU. A value of 1,000 NTU was assumed for the upper limit of turbidity measurements which provides a conservative calculation of the percent reduction in turbidity. Figure 5-4 presents a chart of the measured upstream and downstream turbidity and Figure 5-5 presents a chart of the percent reduction in turbidity. The maximum percent reduction in turbidity was observed to be 74% and occurred during testing of the 12 inch E-tube #2 with an upstream turbidity of 272 Nephelometric Turbidity Units (NTU). Conversely, the minimum percent reduction in turbidity was observed to be 16% and occurred during testing of the 9-inch E-tube #1 with an upstream turbidity of 782 NTU. Appendix E provides the individual turbidity measurements that were collected at 5-minute intervals.

Table 5-3. Average turbidity and percent reduction

Test No.	E-tube ID	Ave. Upstream Turbidity (NTU)	Ave. Downstream Turbidity (NTU)	Ave. Turbidity Percent Reduction (%)
25	9 in. #1	782[A]	657	16%
26	9 in. #2	377	149	61%
27	12 in. #1	951[A]	619	35%
28	12 in. #2	272	72	74%
29	18 in. #1	969[A]	586	40%
30	18 in. #2	247	125	49%

[A]Average included turbidity measurements which exceeded the maximum value for the range of the turbidimeter of 1,000 NTU. A value of 1,000 NTU was used for each value exceeding 1,000 NTU.

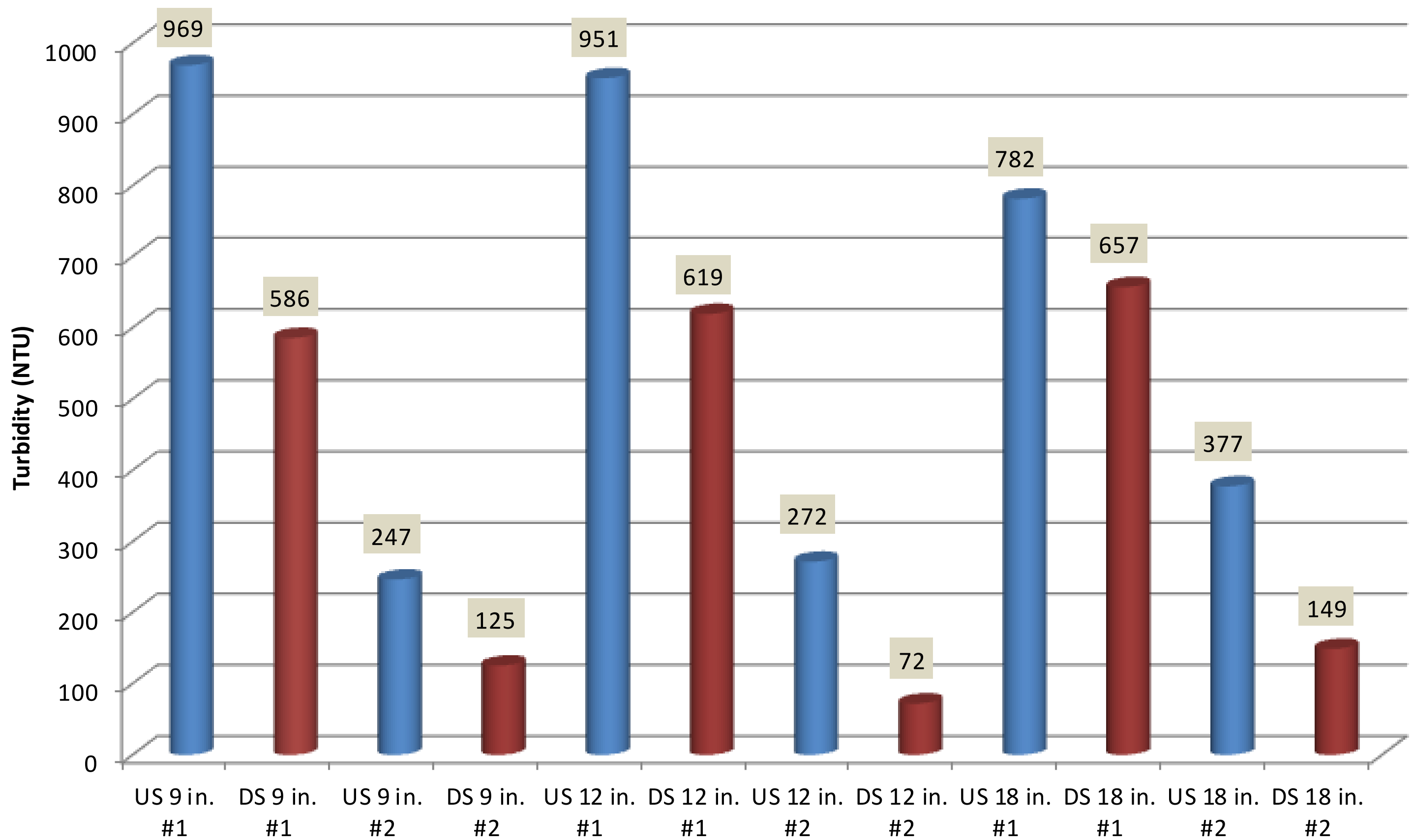


Figure 5-4. Upstream and downstream turbidity measurements

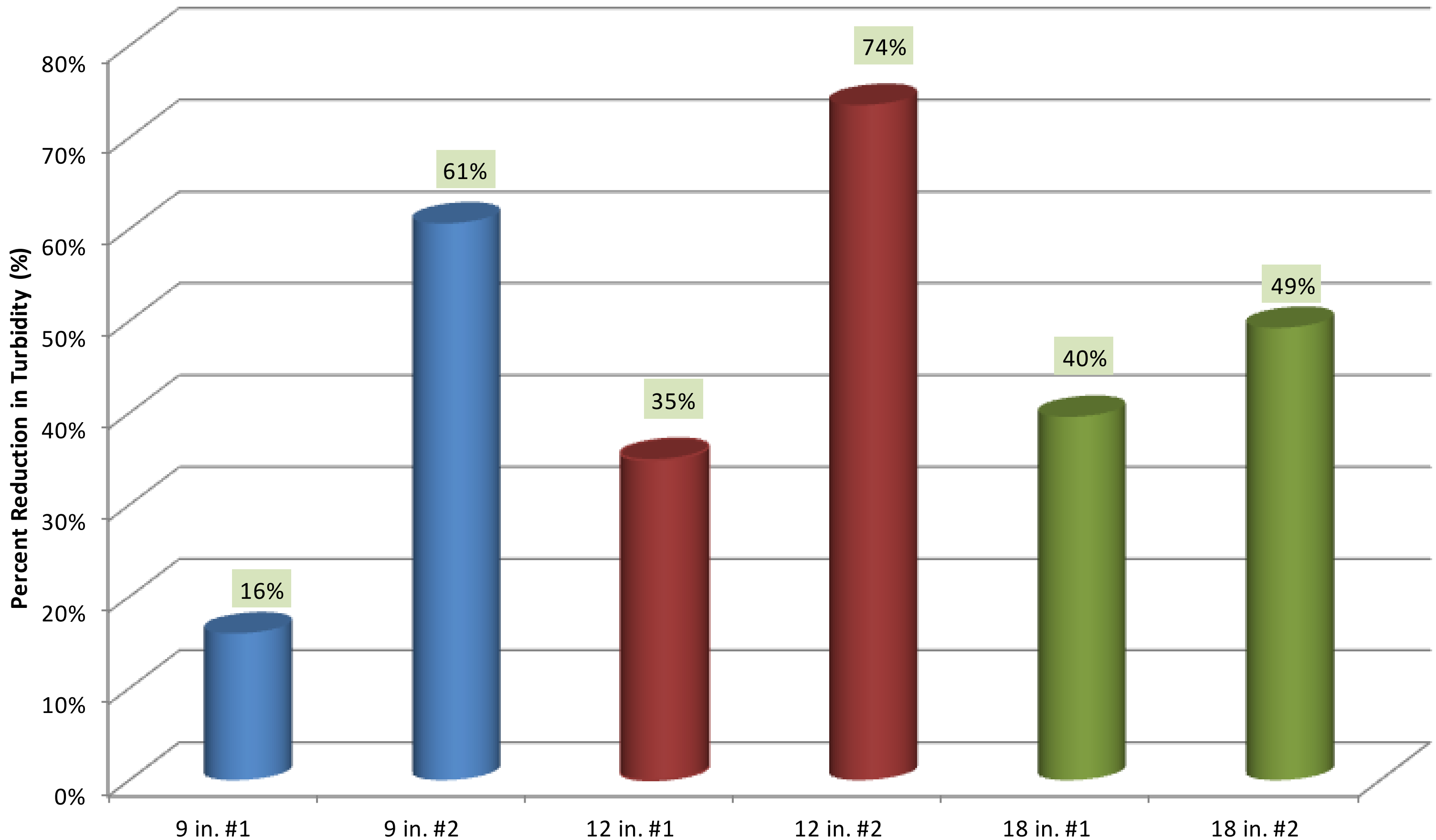


Figure 5-5. Percent reduction in turbidity

5.3 REQUIRED DRAIN TIME RESULTS

The time required to drain the pooled water upstream of the E-tube following termination of the sediment-laden-flows was measured for each test. Table 5-4 provides a summary of the required drain times which ranged from 151 to 544 seconds.

Table 5-4. Required drain time following termination of sediment-laden discharge

Test No.	E-tube ID	Drain Time (sec)
24	9 in. #1	327
25	9 in. #2	151
26	12 in. #1	544
27	12 in. #2	334
28	18 in. #1	277
30	18 in. #2	200

6 SUMMARY

During the summer of 2011, hydraulic performance testing of the E-tube, manufactured by North American Tube Products, Inc., was conducted by Colorado State University. Descriptions of the E-tube product, testing facility, test setup, test matrix, and resulting database are presented in this report. A two-phase research program was completed which included evaluation of the E-tube in both clear-water and sediment-laden conditions. Three E-tube sizes: 9, 12 and 18 in., were evaluated twice resulting in a total of 24 clear-water tests and 6 sediment-laden flow tests. For each E-tube size, sediment-laden-flow testing was conducted with two sediment concentrations: approximately 4800 and 9500 mg/l.

Analysis of the clear-water test data was conducted to determine the maximum capacity and stage-discharge relationship for each E-tube size. Table 6.1 provides a summary of the average maximum clear-water discharge capacities for each E-tube size. Furthermore, percent reduction in sediment concentration and turbidity was computed. Some of the upstream measured values of turbidity for the larger concentration tests exceeded the maximum range of the turbidimeter, 1,000 NTU. A value of 1,000 NTU was assumed for the upper limit of turbidity measurements which provides a conservative calculation of the percent reduction in turbidity. Table 6.2 and Table 6.3 provide summaries of the sediment concentration and turbidity reduction results, respectively. Finally, the required time to drain the pooled water upstream of the E-tube was measured following the termination of each maximum clear-water test and sediment-laden-flow test. Table 6.4 provides a summary of the measured drain times.

Table 6.1. Average maximum clear-water discharge capacity

E-tube ID	Average Maximum Clear-water Discharge Capacity (gpm per linear ft of E-tube)
9 in.	2.24
12 in.	3.37
18 in.	3.14

Table 6.2. Summary of sediment concentration reduction results

Test No.	**E-tube ID**	Ave. US Conc. (mg/l)	Ave. DS Conc. (mg/l)	**Ave. Total Conc. Percent Reduction (%)**	Ave. US Conc. <0.053 mm (mg/l)	Ave. DS Conc. <0.053 mm (mg/l)	**Ave. Conc. Percent Reduction <0.053 mm (%)**	Ave. US Conc. >0.053 mm (mg/l)	Ave. DS Conc. >0.053 mm (mg/l)	**Ave. Conc. Percent Reduction >0.053 mm (%)**
25	**9 in. #1**	9018	690	**92%**	1510	690	**54%**	7508	0	**100%**
26	**9 in. #2**	3912	161	**96%**	691	161	**77%**	3222	0	**100%**
27	**12 in. #1**	7549	606	**92%**	1473	606	**59%**	6076	0	**100%**
28	**12 in. #2**	6209	74	**99%**	804	74	**91%**	5405	0	**100%**
29	**18 in. #1**	10051	464	**95%**	1292	464	**64%**	8759	0	**100%**
30	**18 in. #2**	4272	146	**97%**	799	146	**82%**	3472	0	**100%**

Ave. = Average; US = Upstream; DS = Downstream; Conc. = Concentration; < = less than; and > = greater than

Table 6.3. Summary of turbidity reduction results

Test No.	E-tube ID	Ave. Upstream Turbidity (NTU)	Ave. Downstream Turbidity (NTU)	Ave. Conc. Percent Reduction (%)
25	9 in. #1	782[A]	657	16%
26	9 in. #2	377	149	61%
27	12 in. #1	951[A]	619	35%
28	12 in. #2	272	72	74%
29	18 in. #1	969[A]	586	40%
30	18 in. #2	247	125	49%

[A]Average included turbidity measurements which exceeded the maximum value for the range of the turbidimeter of 1,000 NTU. A value of 1,000 NTU was used for each value exceeding 1,000 NTU.

Table 6.4. Summary of drain time results

E-tube ID	Clear-water Drain Time (sec)	Tested US Total Conc. (mg/l)	Sediment-laden-flow Drain Time (sec)
9 in. #1	95	9,018	327
9 in. #2	94	3,912	151
12 in. #1	144	7,549	544
12 in. #2	263	6,209	334
18 in. #1	178	10,051	277
18 in. #2	142	4,272	200

REFERENCES

ASTM. Standard Test Method for Particle-Size Analysis of Soils. D422, developed by Subcommittee D18.03 of the American Society for Testing and Materials.

ASTM. Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3)). D1557, developed by Subcommittee D18.03 of the American Society for Testing and Materials.

ASTM. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System). D2487, developed by Subcommittee D18.07 of the American Society for Testing and Materials.

ASTM. Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils. D4318, developed by Subcommittee D18.03 of the American Society for Testing and Materials.

ASTM. Standard Test Methods for Determination of Sediment Retention Device Effectiveness in Sheet Flow Applications. D7351-07, developed by Subcommittee D18.25 of the American Society for Testing and Materials.

ASTM. Standard Test Methods for Determining Sediment Concentration in Water Samples. D3977-97(07), developed by Subcommittee D19.07 of the American Society for Testing and Materials.

APPENDIX A   E-TUBE PRODUCT SPECIFICATIONS

Description of Netting

Circular knit filter netting comprised of black textured polyester yard. The pattern used for the netting is a standard pique pattern. The thread size of the yarn is 150 denier, 36 filament.

9/12 Netting Specifications

3.05 mm opening

1.05 mm thickness

18 Netting Specifications

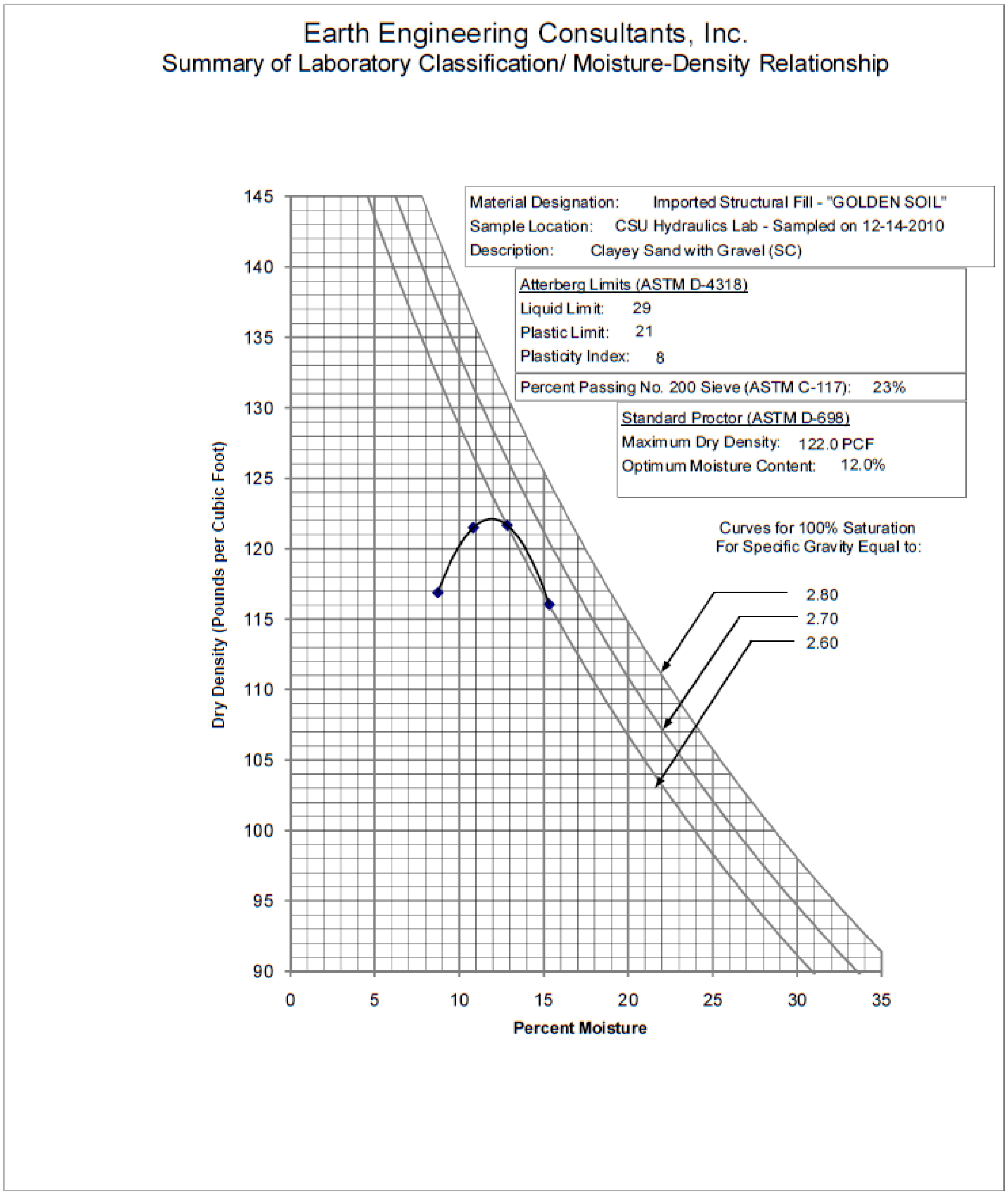
2.5 mm opening

1.35 mm thickness

North American Tube Products
P.O. Box 738
Grimes, Iowa 50111
1-888-623-8823
Visit us at: www.natubeproducts.com
Email us at: info@natubeproducts.com

Figure A-1. Product data sheet for E-tube

APPENDIX B SOIL PHYSICAL PROPERTIES

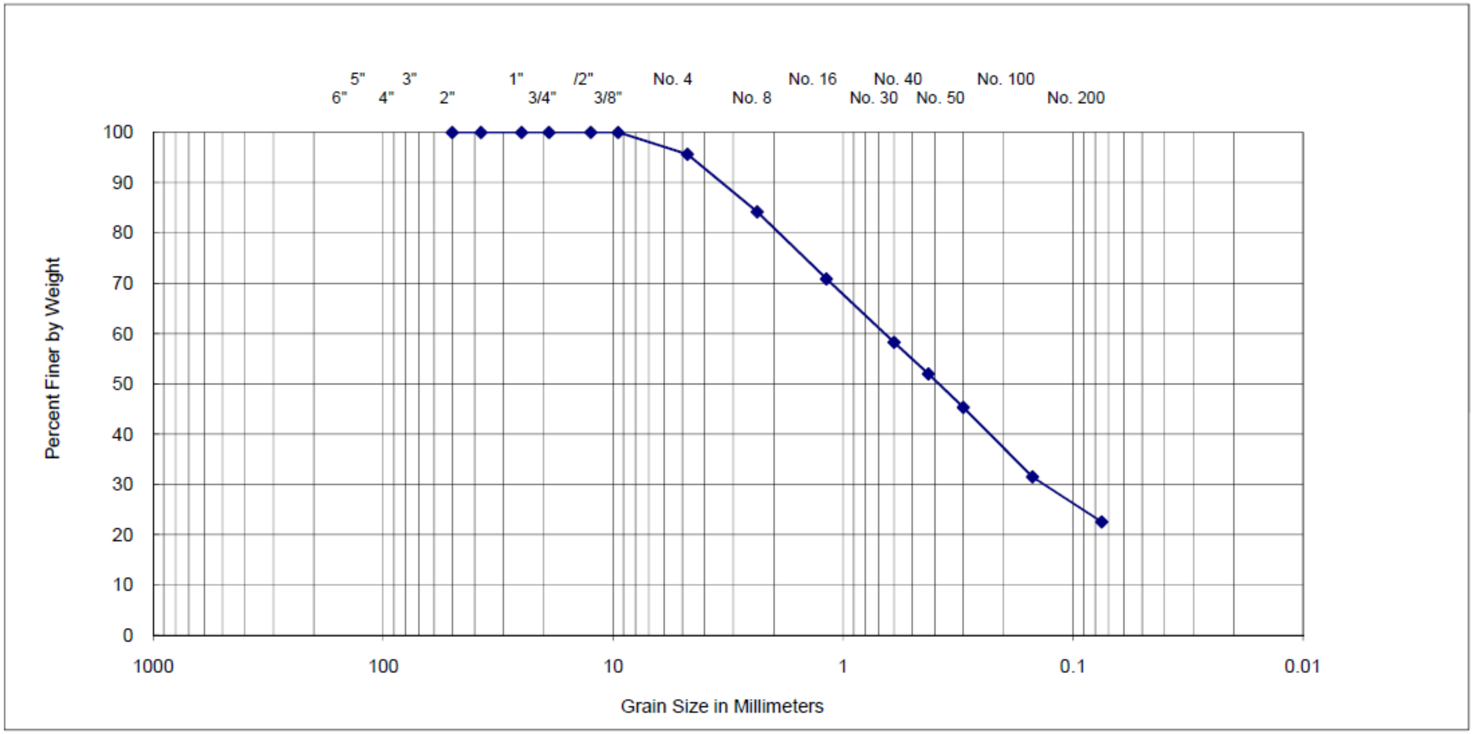


Client: CSU Hydraulics Laboratory
Project: CSU Hydraulics Laboratory - "GOLDEN SOIL"
Fort Collins, Colorado
Project No: 1105031A
Date December 2010

Figure B-1. General sediment properties

EARTH ENGINEERING CONSULTANTS, INC.

Summary of Washed Sieve Analysis Tests (ASTM C-117 & C-136)



Cobble	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Project: CSU Hydraulics Lab - GOLDEN SOIL
Project Number: 1105031A
Date: January 2011
Sample Id: "GOLDEN SOIL" - Sampled on 12-14-2010

Figure B-2. Sediment grain-size distribution

Table B-1. Sediment grain-size distribution

EARTH ENGINEERING CONSULTANTS, INC.

SUMMARY OF LABORATORY TEST RESULTS

Sieve Analysis (AASHTO T 11 & T 27 / ASTM C 117 & C 136)	
Sieve Size	**Percent Passing**
2"	100
1 1/2"	100
1"	100
3/4"	100
1/2"	100
3/8"	100
No. 4	96
No. 8	84
No. 16	71
No. 30	58
No. 40	52
No. 50	45
No. 100	31
No. 200	22.5

Liquid Limit, Plastic Limit and Plasticity Index of Soils (AASHTO T 89 & T90/ASTM D 4318)	
Liquid Limit	29
Plastic Limit	21
Plasticity Index	8

Initial Moisture Content of Delivered Sample	6.9%

Client:	CSU Hydraulics Laboratory
Project:	CSU Hydraulics Lab - GOLDEN SOIL
Project No:	1105031A
Date:	January 2011
Sample Id:	"GOLDEN SOIL" - Sampled on 12-14-2010

APPENDIX C   SEDIMENT CONCENTRATION DATA

Table C-1. 9-in. E-tube #1 grab-sample sediment concentrations

Time (min)	US Conc. (mg/l)	US Conc. <0.053 mm (mg/l)	DS Conc. (mg/l)
0	19694	2111	507
5	10859	1502	618
10	9350	1506	651
15	5641	1350	723
20	3559	1245	741
25	1818	1204	799
30	12203	1650	788
average	9018	1510	690

Table C-2. 9-in. E-tube #2 grab-sample sediment concentrations

Time (min)	US Conc. (mg/l)	US Conc. <0.053 mm (mg/l)	DS Conc. (mg/l)
0	10314	1094	98
5	8651	718	116
10	3439	688	143
15	1944	519	182
20	1390	567	196
25	840	441	202
30	807	807	187
average	3912	691	161

Table C-3. 12-in. E-tube #1 grab-sample sediment concentrations

Time (min)	US Conc. (mg/l)	US Conc. <0.053 mm (mg/l)	DS Conc. (mg/l)
0	18353	2030	379
5	11213	1905	476
10	7124	1526	534
15	5537	1420	651
20	5822	1390	716
25	2908	1260	709
30	1888	778	776
average	7549	1473	606

Table C-4. 12-in. E-tube #2 grab-sample sediment concentrations

Time (min)	US Conc. (mg/l)	US Conc. <0.053 mm (mg/l)	DS Conc. (mg/l)
0	12683	1108	88
5	9744	876	65
10	7841	766	42
15	6399	746	74
20	2043	698	79
25	2360	845	100
30	2393	588	74
average	6209	804	74

Table C-5. 18-in. E-tube #1 grab-sample sediment concentrations

Time (min)	US Conc. (mg/l)	US Conc. <0.053 mm (mg/l)	DS Conc. (mg/l)
0	20751	1699	406
5	14995	1770	469
10	10911	1526	581
15	8090	1403	502
20	2914	741	551
25	8481	1046	372
30	4213	858	366
average	10051	1292	464

Table C-6. 18-in. E-tube #2 grab-sample sediment concentrations

Time (min)	US Conc. (mg/l)	US Conc. <0.053 mm (mg/l)	DS Conc. (mg/l)
0	4043	1014	111
5	7282	925	123
10	5266	775	141
15	2592	738	141
20	3133	688	151
25	959	593	174
30	6627	861	181
average	4272	799	146

APPENDIX D   GRAIN-SIZE DISTRIBUTION DATA

Table D-1. 9-in. E-tube #1 grab-sample grain-size distribution

Sieve Number	Diameter (mm)	Percent Finer (%)
Time = 0 min		
5	4	98%
10	2	93%
18	1	84%
35	0.5	63%
60	0.25	34%
120	0.125	17%
270	0.053	11%
Time = 5 min		
5	4	96%
10	2	88%
18	1	75%
35	0.5	56%
60	0.25	38%
120	0.125	23%
270	0.053	14%
Time = 10 min		
5	4	98%
10	2	85%
18	1	65%
35	0.5	46%
60	0.25	33%
120	0.125	24%
270	0.053	16%
Time = 15 min		
5	4	85%
10	2	48%
18	1	39%
35	0.5	38%
60	0.25	36%
120	0.125	32%
270	0.053	24%
Time = 20 min		
5	4	91%
10	2	72%
18	1	61%
35	0.5	56%

Sieve Number	Diameter (mm)	Percent Finer (%)
60	0.25	50%
120	0.125	45%
270	0.053	35%
Time = 25 min		
5	4	100%
10	2	100%
18	1	97%
35	0.5	92%
60	0.25	87%
120	0.125	81%
270	0.053	66%
Time = 30 min		
5	4	96%
10	2	88%
18	1	70%
35	0.5	50%
60	0.25	34%
120	0.125	21%
270	0.053	14%

Table D-2. 9-in. E-tube #2 grab-sample grain-size distribution

Sieve Number	Diameter (mm)	Percent Finer (%)
Time = 0 min		
5	4	100%
10	2	92%
18	1	82%
35	0.5	60%
60	0.25	34%
120	0.125	18%
270	0.053	11%
Time = 5 min		
5	4	100%
10	2	87%
18	1	66%
35	0.5	42%

Sieve Number	Diameter (mm)	Percent Finer (%)
60	0.25	26%
120	0.125	15%
270	0.053	8%
Time = 10 min		
5	4	100%
10	2	75%
18	1	52%
35	0.5	44%
60	0.25	40%
120	0.125	31%
270	0.053	20%
Time = 15 min		
5	4	78%
10	2	46%
18	1	39%
35	0.5	32%
60	0.25	31%
120	0.125	40%
270	0.053	27%
Time = 20 min		
5	4	100%
10	2	79%
18	1	63%
35	0.5	62%
60	0.25	58%
120	0.125	54%
270	0.053	41%
Time = 25 min		
5	4	100%
10	2	92%
18	1	89%
35	0.5	85%
60	0.25	80%
120	0.125	75%
270	0.053	53%
Time = 30 min		
5	4	100%
10	2	100%

Sieve Number	Diameter (mm)	Percent Finer (%)
18	1	100%
35	0.5	100%
60	0.25	100%
120	0.125	100%
270	0.053	100%

Table D-3. 12-in. E-tube #1 grab-sample grain-size distribution

Sieve Number	Diameter (mm)	Percent Finer (%)
Time = 0 min		
5	4	99%
10	2	93%
18	1	85%
35	0.5	66%
60	0.25	34%
120	0.125	17%
270	0.053	11%
Time = 5 min		
5	4	100%
10	2	96%
18	1	82%
35	0.5	60%
60	0.25	39%
120	0.125	26%
270	0.053	17%
Time = 10 min		
5	4	95%
10	2	83%
18	1	70%
35	0.5	55%
60	0.25	43%
120	0.125	31%
270	0.053	21%
Time = 15 min		
5	4	98%
10	2	71%

Sieve Number	Diameter (mm)	Percent Finer (%)
18	1	52%
35	0.5	46%
60	0.25	43%
120	0.125	36%
270	0.053	26%
Time = 20 min		
5	4	91%
10	2	45%
18	1	34%
35	0.5	34%
60	0.25	33%
120	0.125	30%
270	0.053	24%
Time = 25 min		
5	4	90%
10	2	72%
18	1	65%
35	0.5	60%
60	0.25	57%
120	0.125	53%
270	0.053	43%
Time = 30 min		
5	4	93%
10	2	86%
18	1	75%
35	0.5	71%
60	0.25	67%
120	0.125	58%
270	0.053	41%

Table D-4. 12-in. E-tube #2 grab-sample grain-size distribution

Sieve Number	Diameter (mm)	Percent Finer (%)
Time = 0 min		
5	4	99%
10	2	95%

Sieve Number	Diameter (mm)	Percent Finer (%)
18	1	82%
35	0.5	58%
60	0.25	31%
120	0.125	15%
270	0.053	9%
Time = 5 min		
5	4	100%
10	2	90%
18	1	75%
35	0.5	49%
60	0.25	28%
120	0.125	15%
270	0.053	9%
Time = 10 min		
5	4	98%
10	2	87%
18	1	65%
35	0.5	42%
60	0.25	27%
120	0.125	16%
270	0.053	10%
Time = 15 min		
5	4	100%
10	2	84%
18	1	55%
35	0.5	33%
60	0.25	25%
120	0.125	18%
270	0.053	12%
Time = 20 min		
5	4	100%
10	2	71%
18	1	59%
35	0.5	57%
60	0.25	55%
120	0.125	49%
270	0.053	34%
Time = 25 min		

Sieve Number	Diameter (mm)	Percent Finer (%)
5	4	100%
10	2	58%
18	1	49%
35	0.5	48%
60	0.25	47%
120	0.125	45%
270	0.053	36%
Time = 30 min		
5	4	90%
10	2	67%
18	1	43%
35	0.5	38%
60	0.25	36%
120	0.125	33%
270	0.053	25%

Table D-5. 18-in. E-tube #1 grab-sample grain-size distribution

Sieve Number	Diameter (mm)	Percent Finer (%)
Time = 0 min		
5	4	99%
10	2	96%
18	1	82%
35	0.5	57%
60	0.25	30%
120	0.125	14%
270	0.053	8%
Time = 5 min		
5	4	98%
10	2	85%
18	1	65%
35	0.5	45%
60	0.25	30%
120	0.125	18%
270	0.053	12%
Time = 10 min		

Sieve Number	Diameter (mm)	Percent Finer (%)
5	4	93%
10	2	77%
18	1	50%
35	0.5	33%
60	0.25	26%
120	0.125	20%
270	0.053	14%
Time = 15 min		
5	4	88%
10	2	46%
18	1	25%
35	0.5	25%
60	0.25	24%
120	0.125	23%
270	0.053	17%
Time = 20 min		
5	4	91%
10	2	85%
18	1	71%
35	0.5	64%
60	0.25	52%
120	0.125	40%
270	0.053	25%
Time = 25 min		
5	4	97%
10	2	86%
18	1	66%
35	0.5	47%
60	0.25	32%
120	0.125	20%
270	0.053	12%
Time = 30 min		
5	4	88%
10	2	53%
18	1	43%
35	0.5	41%
60	0.25	39%
120	0.125	31%

Sieve Number	Diameter (mm)	Percent Finer (%)
270	0.053	20%

Table D-6. 18-in. E-tube #2 grab-sample grain-size distribution

Sieve Number	Diameter (mm)	Percent Finer (%)
Time = 0 min		
5	4	100%
10	2	95%
18	1	92%
35	0.5	82%
60	0.25	60%
120	0.125	38%
270	0.053	25%
Time = 5 min		
5	4	97%
10	2	89%
18	1	69%
35	0.5	48%
60	0.25	31%
120	0.125	20%
270	0.053	13%
Time = 10 min		
5	4	97%
10	2	73%
18	1	51%
35	0.5	34%
60	0.25	27%
120	0.125	21%
270	0.053	15%
Time = 15 min		
5	4	100%
10	2	52%
18	1	41%
35	0.5	40%
60	0.25	39%
120	0.125	37%

Sieve Number	Diameter (mm)	Percent Finer (%)
270	0.053	28%
Time = 20 min		
5	4	100%
10	2	75%
18	1	42%
35	0.5	34%
60	0.25	30%
120	0.125	27%
270	0.053	22%
Time = 25 min		
5	4	100%
10	2	100%
18	1	88%
35	0.5	83%
60	0.25	78%
120	0.125	74%
270	0.053	62%
Time = 30 min		
5	4	97%
10	2	90%
18	1	78%
35	0.5	57%
60	0.25	36%
120	0.125	21%
270	0.053	13%

APPENDIX E TURBIDITY DATA

Table E-1. 9-in. E-tube #1 grab-sample turbidity measurements

Time (min)	US Turbidity (NTU)	DS Turbidity (NTU)	Percent Reduction (%)
0	1000[A]	512	49%
5	817	688	16%
10	1000[A]	427	57%
15	965	760	21%
20	1000[A]	408	59%
25	1000[A]	505	50%
30	1000[A]	799	20%
average	969	586	39%

[A]Reading was greater than the maximum turbidity meter reading of 1000 NTU

Table E-2. 9-in. E-tube #2 grab-sample turbidity measurements

Time (min)	US Turbidity (NTU)	DS Turbidity (NTU)	Percent Reduction (%)
0	237	87	63%
5	229	104	55%
10	254	114	55%
15	242	130	46%
20	237	139	41%
25	264	149	44%
30	263	153	42%
average	782	657	49%

Table E-3. 12-in. E-tube #1 grab-sample turbidity measurements

Time (min)	US Turbidity (NTU)	DS Turbidity (NTU)	Percent Reduction (%)
0	1000[A]	437	56%
5	1000[A]	597	40%
10	1000[A]	342	66%
15	1000[A]	712	29%
20	1000[A]	611	39%
25	1000[A]	748	25%
30	656	888	-35%
average	951	619	31%

[A]Reading was greater than the maximum turbidity meter reading of 1000 NTU

Table E-4. 12-in. E-tube #2 grab-sample turbidity measurements

Time (min)	US Turbidity (NTU)	DS Turbidity (NTU)	Percent Reduction (%)
0	254	47	81%
5	242	57	76%
10	287	68	76%
15	266	74	72%
20	298	79	73%
25	275	87	68%
30	279	91	67%
average	782	657	74%

Table E-5. 18-in. E-tube #1 grab-sample turbidity measurements

Time (min)	US Turbidity (NTU)	DS Turbidity (NTU)	Percent Reduction (%)
0	966	633	34%
5	706	642	9%
10	1000[A]	733	27%
15	1000[A]	774	23%
20	571	822	-44%
25	766	501	35%
30	463	494	-7%
average	782	657	11%

[A]Reading was greater than the maximum turbidity meter reading of 1000 NTU

Table E-6. 18-in. E-tube #2 grab-sample turbidity measurements

Time (min)	US Turbidity (NTU)	DS Turbidity (NTU)	Percent Reduction (%)
0	237	87	63%
5	229	104	55%
10	254	114	55%
15	242	130	46%
20	237	139	41%
25	264	149	44%
30	263	153	42%
average	782	657	59%