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Flow-Through Rates And Evaluation Of Solids Separation Of Compost Filter Media Vs. Silt Fence In Sediment Control Applications

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***Abstract*.** Soil loss rates from construction sites can be 1,000 times the average of natural soil erosion rates and 20 times that from agricultural lands. Silt fence (SF) is the current industry standard used to control sediment originating from construction activities. Silt fences are designed to act as miniature detention ponds. Research has indicated that SF sediment filtering efficiency is related to its ability to detain and pond water, not necessarily the filtration ability of the fabric. Design capacity and spacing is based on flow through rate and design height. In addition, increased detention of runoff and pressure from ponding may increase the likelihood of overtopping or failure of SF in field application. Testing was conducted on compost silt socks (SS) and silt fence to determine sediment filtering efficiency, flow through rate, ponding depth, overtopping point, design height, and design capacity. Results indicate flow through rate changes with time, as does pond depth, due to the accumulation of solids on/in the sediment filters. Changes in depth with time were a linear function of flow rate after ten minutes of flow, up to the time the sediment filter is topped. Predicting the capacity of SF and SS to handle runoff without the filter being topped requires consideration of both runoff rate and length of runoff time. Data showed SS 1/2 the height of SF are less likely to overflow than SF when sediment-laden runoff flow is less than 5 gpm/ft. Depth behind a 24 in. SF increased more rapidly than behind a 12 in. SS, and at the end of the 30 minutes, the depth behind the SF was 75% greater than that behind the SS. Removal of solids by the SF and theSS were not shown to be statistically different. Results were used to create an MS Excel™ based interactive design tool to assist engineers and erosion and sediment control planners on how to specify compost SS relative to SF in perimeter sediment control applications.

Keywords. Biofilter, compost, environmental protection, filtration, flume, hydrologic model, porous media, sedimentation, water pollution

Introduction

Soil loss rates from construction sites can be 1,000 times the average of natural soil erosion rates (Smoot et al., 1992) and 20 times that from agricultural lands (US EPA, 2000). In 2003, the federally mandated National Pollution Discharge Elimination System (NPDES) Phase II went into effect extending the storm water pollution prevention plan requirement to any land-disturbing activity over 0.4 ha (1 acre). Violators can be held in noncompliance with the federal Clean Water Act and can be fined up to $100,000 (USD) per day per violation. Although equal attention should be placed on soil erosion prevention, deleterious affects to receiving water quality is the result of sedimentation. When eroded sediment is transported from its site of origin to nearby surface waters it also carries fertilizers, pesticides, fuels, and other contaminants and substances commonly spilled at construction sites that readily attach to soil particles (Risse and Faucette, 2001). Ehrhart et al. (2002) reported that high suspended sediment concentration discharges from construction activities into streams persisted 100 meters (328 ft) downstream and negatively impacted macroinvertebrate populations. It is estimated that the national cost to society due to sedimentation of eroded soil is over $17 billion per year (Brady and Weil, 1996).

Silt fence is the current industry standard used for sediment control in construction activities; therefore, its performance has been widely evaluated (Wyant, 1981; Fisher and Jarret, 1984; USEPA, 1993; Barrett et al, 1998; Britton et al, 2000). Geosynthetic silt fences, when installed correctly, function as temporary runoff detention storage areas (Robichaud et al, 2001), designed to increase ponding depth (Goldman et al, 1986) to allow suspended particulates to settle out of storm runoff before discharging the runoff down slope of the sediment barrier. Barrett et al (1995) concluded that effective sediment trapping efficiency of silt fence is a result of increased ponding behind the silt fence, while Kouwen (1990) concluded that excessive ponding is largely due to eroded sediment clogging the fabric of the silt fence. Barret et al (1998) further concluded that sediment removal efficiency by silt fence was not attributable to the filtration by the fabric but due to length of runoff detention time behind the silt fence.

While this design may function well under relatively small runoff events, if runoff or ponding becomes excessive the silt fence may fail due to overtopping; in response, the design height of silt fence has steadily increased from 18 in. (46 cm) to 24 in. (61 cm) to 36 in. (91 cm) over the past few years. Additionally, the force created by the increase in head and the prolonged detention of storm runoff, may predispose silt fence to failure in field applications. Wyant (1981) and the USEPA (2005) recommend that silt fence have a sediment-laden flow through rate of 0.3 gal/ft^2/min (12.5 L/m^2/min). Sediment-laden runoff concentrations appropriate for testing silt fence according to ASTM D 5141 are 2890 mg L^{-1} (2890 ppm)(Barrett et al, 1995).

Although the USEPA (1993) reports sand trapping efficiencies for silt fence can be as high as 80 to 90%, silt-clay-loam, typically the fraction of eroded soil that remains in suspension is in the range of 0 to 20%. Horner et al (1990) reported a 2.9% reduction in turbidity by silt fence installed under field conditions, while Barrett et al (1998) similarly concluded that silt fences proved ineffective in reducing turbidity. Wishowski et al (1998) in a study evaluating the sediment trapping efficiency of silt fence observed that as sediment particle sizes decrease, trapping efficiency declines. Barrett et al (1998) adds that most studies reporting sediment removal efficiencies for silt fence are somewhat overstated since many have used a disproportionately large fraction of sand particles with relatively low sediment-laden concentrations in the stormwater runoff. They observed 92% of the total suspended solids were clay and silt, were an order of magnitude smaller than the openings in the silt fence fabric, and due to very low settling velocities are normally not removed by sedimentation (Barrett et al, 1998)

Although many new products designed to trap sediment are now available, there is very little research literature on these new devices relative to silt fence. Faucette et al (2005) reported on a 10% slope, under hydroseed conditions during construction, mulch filter berms reduced total solids loads between 16 and 64%, relative to silt fence. Demars and Long (2000) reported similarly that under a ¾ inch (1.9 cm) storm event mulch berms reduced total sediment by 80% relative to silt fence and by 97% relative to hay bales, respectively. Under a 4.4 in. (11.2 cm) storm event mulch berms reduced total sediment relative to straw bales and silt fence by 91% and 92%, respectively. Ettlin and Stewart (1993) found that compost filter berms reduced total solids concentrations by 72% and suspended solids concentrations by 91%, relative to silt fence.

These new sediment control devices have filters that are of three dimensional construction (opposed to a planar construction for silt fence) and are designed to allow runoff to flow through at higher rates. The larger, three dimensional construction of these sediment filters may allow the filter itself to trap suspended solids from runoff reducing the need to pond water to allow settling to occur. Less ponding and lower head pressure may reduce the propensity for failure from blowout and over topping in the field. Additionally, if sediment removal efficiency is a result of the performance of the filter, instead of its ability to pond water, then the design capacity, spacing, and height for these new sediment control devices should be based on flow through rate not ponding rate.

The goal of this study was to evaluate the flow through rate, sediment removal efficiency, and design capacity of Filtrexx Silt Soxx™ (organic filter media contained in a geotextile mesh tube) relative to silt fence, and to create a user-friendly Excel™ based design tool to assist professionals that regularly design erosion and sediment control or storm water pollution prevention plans where sediment control devices will be employed.

The objectives of this study were to characterize: flow through capacity and filtration efficiencies of SiltSoxx™ (SS) compared to silt fence (SF) as a function of runoff flow rate and slope angles. Results will 1) provide insight on the effectiveness of various sediment control devices in mitigating pollution in the runoff from construction sites and material storage areas [i.e. agricultural-open feedlots, commercial-composting, governmental-DOT.] and 2) assist in the specification and design of runoff/sediment control devices utilizing SS in place of SF.

Materials and Methods

Research was carried out at the Ohio Agricultural Research and Development Center (OARDC) composting research center, Wooster, Ohio. For conducting the test a flume of nominal dimensions 2 ft wide, 3 ft sidewalls and 8 ft length was built from MDO plywood (fig. 1). The frame upon which it was mounted allowed the slope of the flume to be fixed at 10 or 20 degrees. The base of the flume was designed to mount removable fixtures which could hold in place an 8 in. SS, 12 in. SS, or 24 in. SF. The mounting system was designed to prevent short circuiting of flow under and around the filter being tested. For the studies with clear water, a 40 gallon tank, located at the exit of the flume was used to supply water to a pump and to capture outflow from the flume for recirculation. Water flow path (fig. 1) was from the 40 gallon tank to the 1/2 Hp Dayton High Head Straight Centrifugal pump via a two inch line, and then from the pump through a filter, water meter, brass gate valve (for regulating flow) to a header pipe at the top of the flume made of 1 in. PVC. Two 1 in. outlet openings delivered water to the flume. For the studies with sediment-laden water, a 170 gallon cone bottom tank provided water to the pump (fig. 2). In this case the water after the pump was split so a portion of the sediment-laden water was recirculated to the supply tank to maintain the soil in suspension and a portion was delivered to the header pipe at the top of the flume. For this study the header pipe had four 1/2 in. openings to evenly distribute the water across the flume at the lower flow rates. Water from the flume was discharged and not recirculated in these studies. For the sediment-laden water test requiring more than 150 gallons of water, the test was interrupted for 2.5 to 3.5 minutes during which time the tank was refilled with water from a 500 gallon nurse tank with a 200 gpm pump, soil added, and mixed.

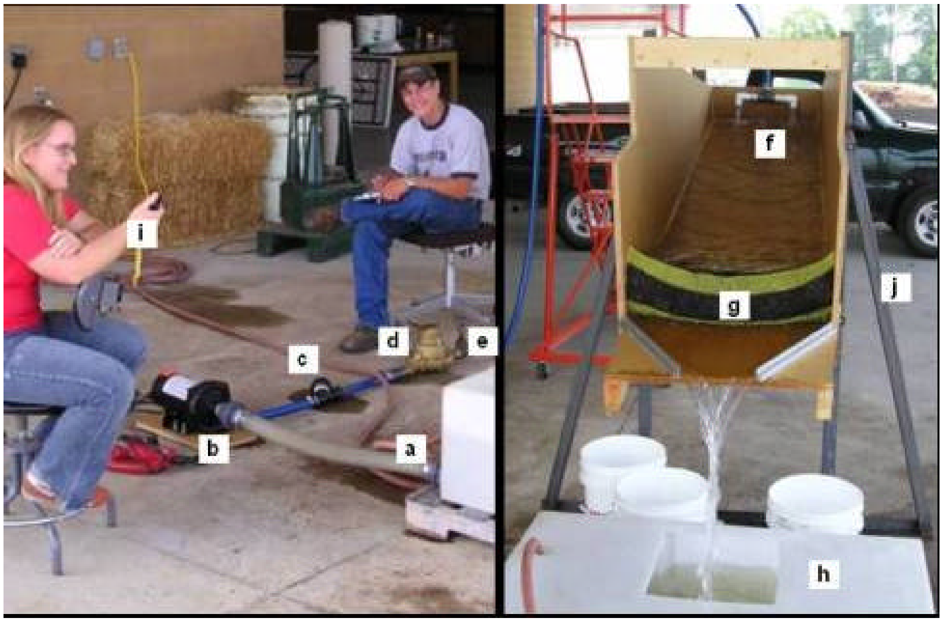

Figure 1. Laboratory test setup using a flume (2 ft. width by 8 ft. length) to determine flow through capacity of SiltSoxx™ and Silt Fence with clean water. (a) outlet from supply tank, (b) pump, (c) filter, (d) flow meter, (e) valve, (f) header, (g) 8 in SiltSoxx™, (h) 40 gallon water tank, (i) timer, (j) frame.

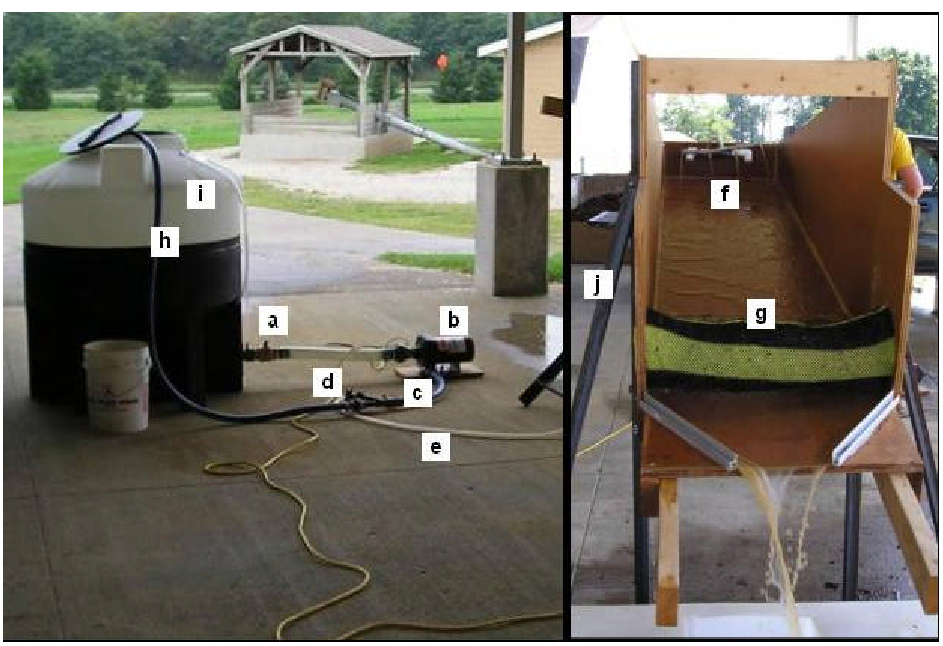

Figure 2. Laboratory test setup using a flume to determine filtration and flow through capacity of SiltSoxx™ and Silt Fence using soil laden water. (a) outlet from supply tank, (b) pump, (c) Y tee, (d) valve in recirculation line (e) delivery line, (f) header, (g) 8 in. SiltSoxx™ (h) by-pass flow line, (i) 170 gallon cone bottom tank, (j) frame.

The SS fabric and compost materials used in the studies were obtained from the Filtrexx International, Grafton, Ohio. The SS material were standard products of 8 in. and 12 in. diameter. It was made of HDPE plastic and has a 3/8 in. knitted mesh. The compost material used in these studies was yard trimmings compost and consisted of two grades, a fine grade < 1/8 in. size, and a coarse grade consisting of the overs from screening with a 3/8 in. trommel screen. Particle sizes of the materials used in the test were determined using a roto-tap shaker and six standard sized sieves ranging from 0.5 in. opening down to 0.0661 in. (# 12 ASTM sieve size). The silt fence was of 24 in. height. For test purposes it was mounted with 18 in. extending above and perpendicular to bottom of flume, as 6 in. is buried in normal field application.

Filling of the SS with compost was done by mounting the SS in the holder and plugging one end in the flume sidewall. Then compost was packed in the SS through the open end until the SS was stretched to the desired tension (defined by Filtrexx and based on no free play in SS material when pinched). For the clean water studies, the SS was filled horizontally. For the sediment-laden water studies, the SS was filled vertically (fig. 3.) by rotating the flume on its side with a forklift. After filling to the desired tension, as previously described, a 3/4 in. thick plug was inserted in the end of the SS to contain the compost and prevent end flow of water.

Figure 3. Filling of 12 in. SiltSoxx™ with coarse material.

Test Procedure

The 24 in. silt fence was used as a control in all studies. In the clean water test flow-through rates for each SS (8 in. fine, 8 in. coarse, 12 in. fine and 12 in. coarse) was achieved by applying 3 fixed flows (gpm/ft, gallons per minute per lineal foot) at the top of the flume for slopes of 10 and 20 degrees (18 and 36%). Test duration lasted until the depth behind the fence stabilized or 30 minutes had elapsed, whichever occurred first. Water depth behind the SS or SF was determined at steady state for each test. Also, a flow rate for failure of system (flow over top) was determined for each product by increasing flows until the flow overtopped the sediment control device. Flow rates for the clean water test were calculated using flow meter readings taken at 1/2 minute intervals prior to starting and during the test. Actual setting of the flow was by adjustment of the valve in the system. Each test was replicated 3 times. The number of tests ran were 120 (5 filters, 4 flow rates, 2 slopes, 3 replications). Results on flow-through capacity were evaluated as a function of slope (degrees), slope length (feet), rainfall intensity and 1 linear foot of sediment control device.

For the sediment-laden water studies, only 2 SS (8 in. coarse, 12 in. coarse) were tested along with the SF. Again 3 flow rates were tested initially. In addition, based on results from these flow rates, projected flow rate to top the filters were evaluated for an additional set of tests. The sediment-laden water was made by adding 6.4388 kg of air dried Wooster silt loam soil (A horizon), particle size less than 2000 micron (2mm), to 170 gallon of water (solids content of 10,000 mg L^{-1}) and allowing the pump to recirculate the slurry for 10-15 minutes while hand stirring with a 1 in. diameter rod. The soil was sifted prior to use in the test because preliminary tests with a 50/50 mix of sand and soil showed the sand and larger soil particles settled out at the top of the flume and never reached the quiescent water at the sediment control device. For the sediment-laden water studies, flow rate was set prior to a test by using a stop watch and measuring flow into a graduated 1000 L cylinder, and then adjusting the valve until the desired flow was achieved. During the actual test period, the sediment-laden water volume in the supply tank was recorded initially and at 5 minute intervals and the change in volume used to calculate flow rates. Slope of the flume for these studies was fixed at 10 degrees. Because depth changed behind the sediment control device as material accumulated at/on the filter, measurement of water depth at the sediment control device was made at 5 minute intervals over the thirty minute test periods. Also measured was solids content of sediment-laden water entering the flume and exiting the sediment control device by collecting approximately 250 g samples of sediment-laden water at a time = 0, 10, 20, and 30 minutes. Solids were analyzed by oven drying each runoff sample for 48 hours at 90^{o}C. Weighing of the samples was to the nearest 0.01g. Three replicates of each treatment were done. Results on flow-through capacity was evaluated as a function of slope (degrees), slope length (feet), rainfall intensity and 1 linear foot of filter. Treatments were ran were for the 8 in. and 12 in. coarse SS and the 24 in. SF at a 10 degree slope at flow rates of 2, 4 and 5 gpm. In addition two runs at 15 gpm were ran for the 12 in. coarse SS and the SF. Total number of tests conducted with the sediment-laden runoff was 29 (3 filters, 3 flow rates, 1 slopes, 3 replications + 2 filters, 1 slope, 1 flow rate, 1 replication).

Results

Clean Water Test

<u>Compost particle sizes</u> Distributions of fine and coarse material for the compost used in these studies are presented in Table 1. The compost was air dry to below 20% moisture before screening. Results show the fine material had about 8% coarse particles > ½ in., while the coarse compost had 27%. Over 58% of the coarse compost was greater than 5/16 in. size while the fine compost had 82% less than 5/16 in.

Table 1. Particle size distribution of compost, weight basis, used in flow through studies.

Sieve Size →	1/2"	5/16"	0.223"	0.157"	0.111"	0.0661"	BTM	Totals
Description[1]	1/2"	5/16"	#3.5	#5	#7	#12		
			Distribution					
	%	%	%	%	%	%	%	%
Fine Compost								
average[2]	7.7	10.8	12.3	13.4	12.7	13.3	29.3	99.5
standard deviation[3]	1.7	1.5	1.3	0.3	0.5	0.8	1.9	0.1
Coarse Compost								
average[4]	27.2	30.9	12.7	7.5	5.4	5.6	10.0	99.4
standard deviation[5]	6.6	3.2	1.3	1.9	2.0	2.1	4.1	0.2

[1] ASTM sieve numbers.
[2] 12 samples from 4 test; [3] standard deviation of 4 means; [4] 15 samples from 5 test; [5] standard deviation of 5 means.

Flow Rates. Preliminary studies on the sediment control devices with clean water showed that steady state flow was achieved after 3-4 minutes test duration. Thus, tests were run for 7 minutes, and average flow was based on data points collected at 5, 5.5, 6, 6.5 and 7 minutes. Visual observations on flow distribution along the 2 ft long sediment control devices showed no apparent edge effect of flume sidewalls and data was analyzed based on the full 2 ft section of filter.

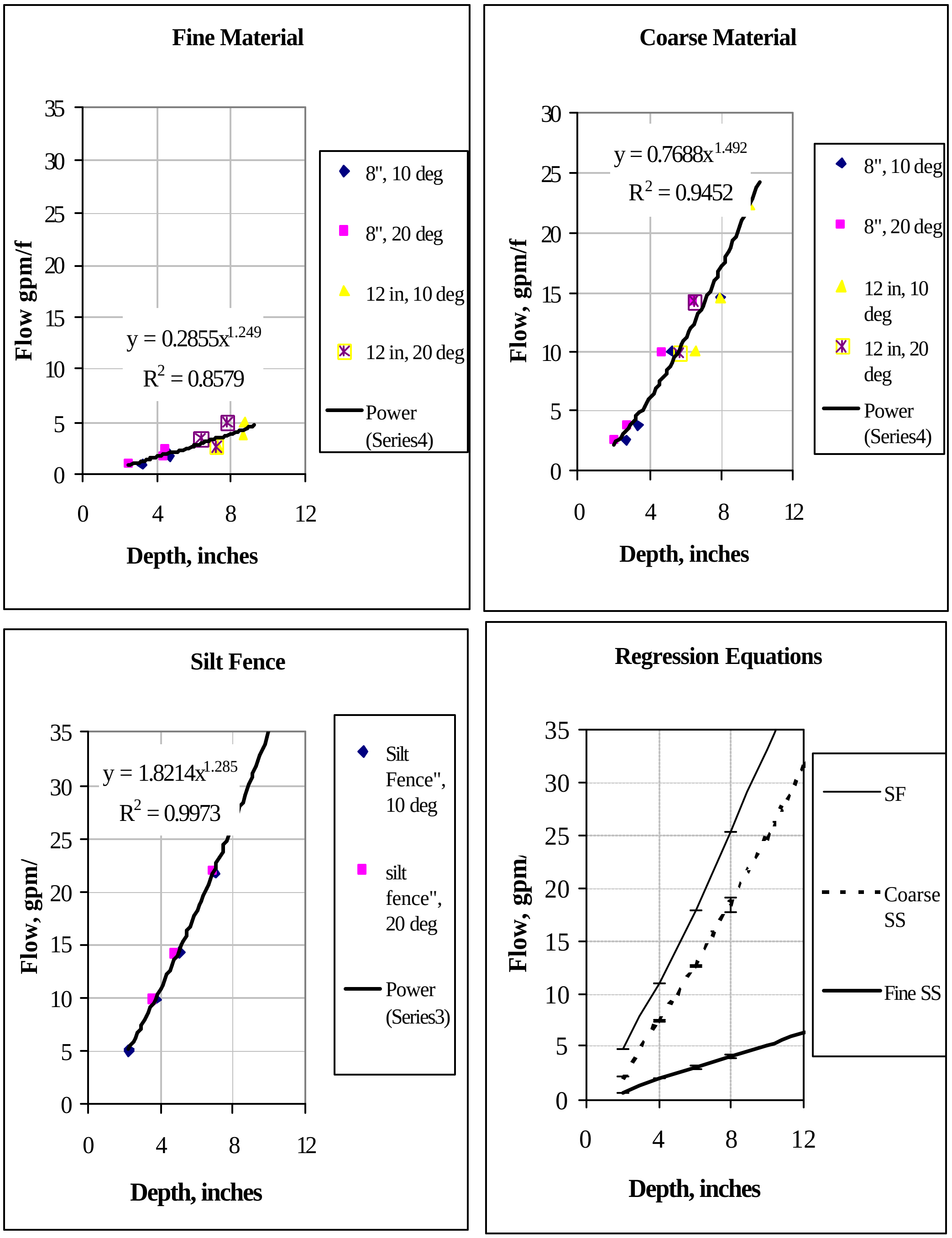

Figure 4. Flow through rates versus depth of water on SiltSoxxTM and Silt Fence. (a) Flow rate for SS using fine compost for both 10 and 20 degree slopes vs. depth. (b) Flow rate for SS using coarse compost for both 10 and 20 degree slopes vs. depth. (c) Flow rate for SF for both 10 and 20 degree slopes vs. depth. (d) Flow rate versus depth using regression equations for fine SS, coarse SS and SF.

Output flow rate, q_o, versus depth of water for the sediment control devices is given in figure 4. Because the 8 in. and 12 in. SS gave similar q_o at a given water depth, data for a specific compost (fine or coarse) were pooled and plotted on the same graph. Results showed that the flow rates for clean water was a power function of water depth, which would be expected since as water depth increases the pressure increases vertically along the filter (Vennard, 1963). A theoretical analysis for flow through a uniform porous media gives 1.5 for the exponent on depth (d_f), i.e. $q_o = C\ d_f^{1.5}$. From the regression equations, the exponents on d_f were 1.054, 1.313 and 1.202 for the fine SS, coarse SS and SF, respectively.

Results with clean water showed large differences in q_o for the different sediment control devices. For example, when water depth was 8 in., the SS with fine compost had only 16% of the flow of the SF (or about 20% of the coarse SS) and the coarse compost SS was about 75% of the SF. Although no statistical analysis was done on data, observation of flow rates with the regression lines for all data points (fig. 4 a,b,c) suggest that a 20 degree slope causes flow rates to be slightly higher than for the 10 degree slope at the same water depth.

Slurry Test

Sediment-laden runoff Wooster silt loam soil less than 2 mm in size, with a solids content of 92.6 ± 1.9. (7.4% moisture), was added to the water to form a 1.0% w/w (0.93% dry matter concentration) sediment-laden runoff water. Results of analysis of 12 samples (4 samples per replicate) taken during each treatment gave average dry matter contents of the incoming sediment-laden runoff to the flume of 0.51% to 0.78% dry weight for 8 in. SS, 0.58% to 1.04% for the 12 in. SS and 0.72% to 0.93% for the SF test.

Compost For the SS treatments, only the coarse particle size compost, described earlier under the clean water test section, was used.

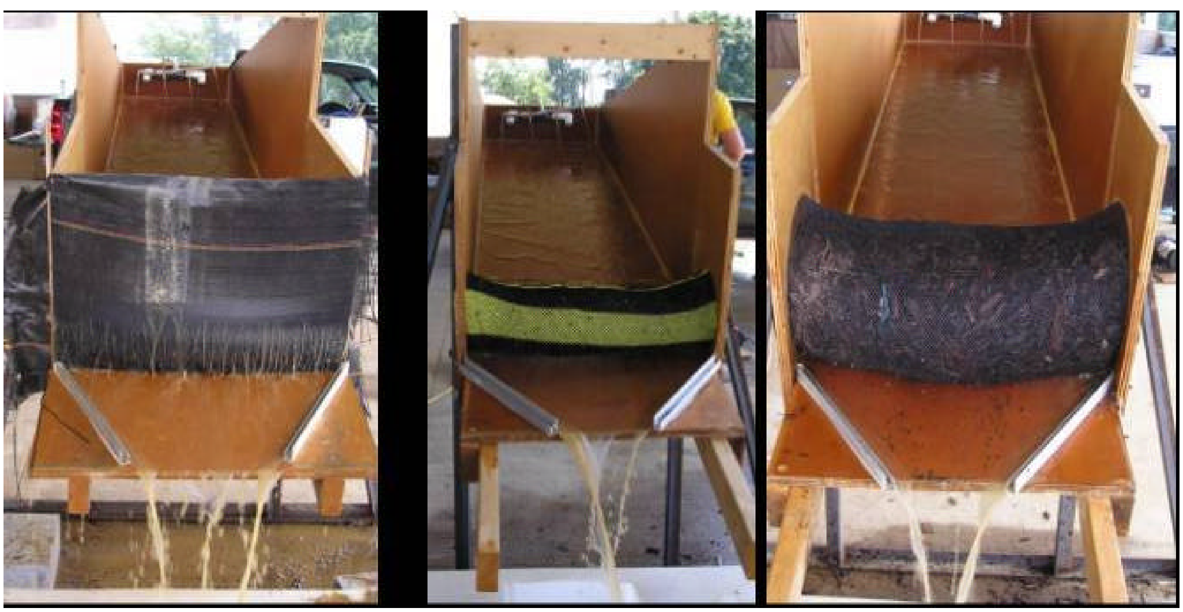

Figure 5. Flow of sediment-laden runoff through sediment control devices at 2 gpm at 10 minutes time. From left to right, 24 in. silt fence (mounted with 18 in. above flume bottom), 8 in. coarse SiltSoxx™, and 12 in. coarse SiltSoxx™.

Flow Rates Studies with sediment-laden water were done by measuring water depth behind the 8 in. SS coarse, 12 in. coarse SS and the 24 in. SF as a function of time over a 30 minute test period. Flow rates of 2, 4, 5 and 15 gpm were used and ponding depth of the sediment-laden runoff was measured at 5 minute intervals. Figure 5 shows the 3 sediment control devices being tested at the 2 gpm flow rates. For these tests the sediment-laden water entering the flume was split into 4 streams to achieve sheet flow conditions down the flume.

Depth versus time of application of sediment-laden runoff to the 12 in. coarse SS and 24 in. SF are given in Figure 6 for the flow rates 4, 5 and 15 gpm. For a given flow rate, depth behind the sediment control devices increased with time as the suspended solids in the sediment-laden runoff plugged the smaller pores of the filter. However, depth behind the SF increased more rapidly than behind the 12 in. SS and at the end of the 30 minute test, the depth behind the SF was 75% greater that that behind the SS. In particular, at the 15 gpm, the 24 in. (18 in. effective) high SF topped at 20 minutes with a pond depth slightly less than 16 in. and the 12 in. coarse SS topped at 20+ minutes with a pond depth slightly above 9 in. The lower topping depths were due to the SF bowing and sagging under the weight of the pond and the SS sagging to a more elliptical shape after being put in place.

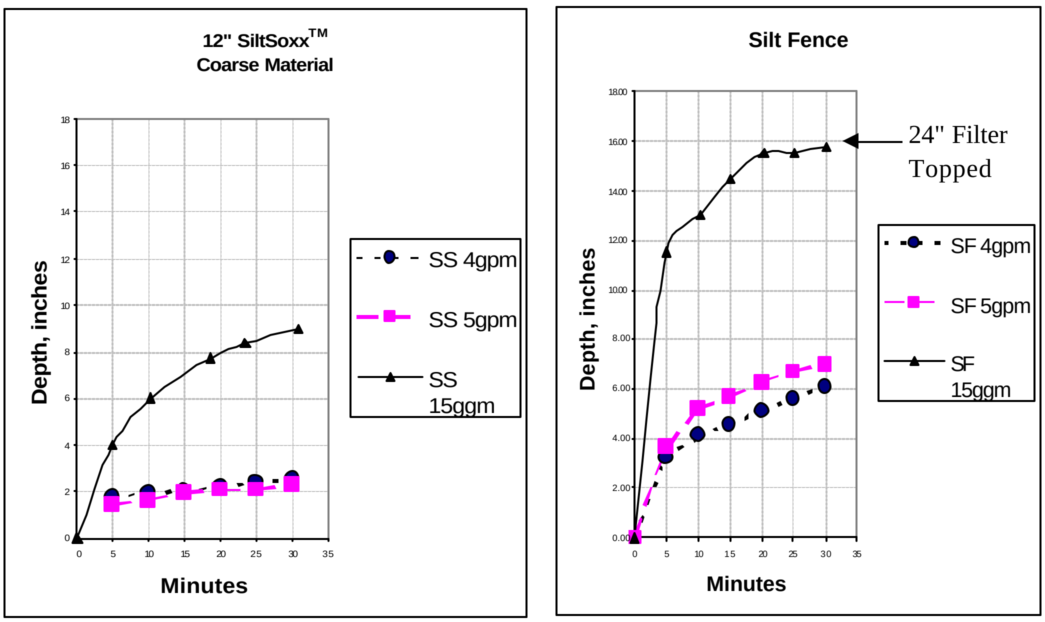

Figure 6. Effect of time on depth of slurry behind the 12" coarse SiltSoxx™ and Silt Fence.

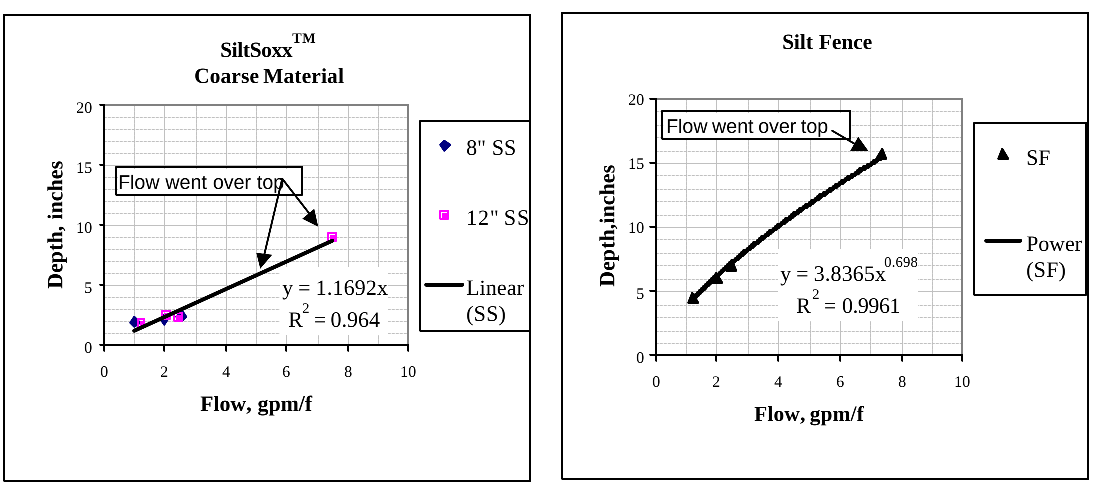

Figure 7. Depth vs. sediment-laden runoff flow rate at time = 30 minutes of testing for the 8 in. coarse SS, 12 in. coarse SS and 24 in. SF (18 in effective height).

Because ponding depth was changing with time, the pool depth (d_f) versus flow rate, q_f were plotted (fig. 7) instead of q_o vs. d_f , as was done for the clean water test (fig. 4). Since the 8 in. and 12 in. SS gave similar depths for a given flow, data was pooled and plotted on the same graph. Results showed that the depth vs. flow rates for the sediment-laden water could be approximated by a power function. The exponents on flow were 0.698 and 1.0 for the SF and coarse SS, respectively.

Because pond depth behind the porous sediment control devices was changing with time when the inflow was a sediment-laden runoff water, the solution of the flow rate to top either the SS or SF, could not be solved by using the simple power functions such as given in figure 7. Observation of the data for sediment-laden flow indicated pond depth at the sediment control device increased rapidly at the start of flow and then leveled off to where it increased at approximately a linear rate over time until the sediment control device was topped (Figure 8a,b).

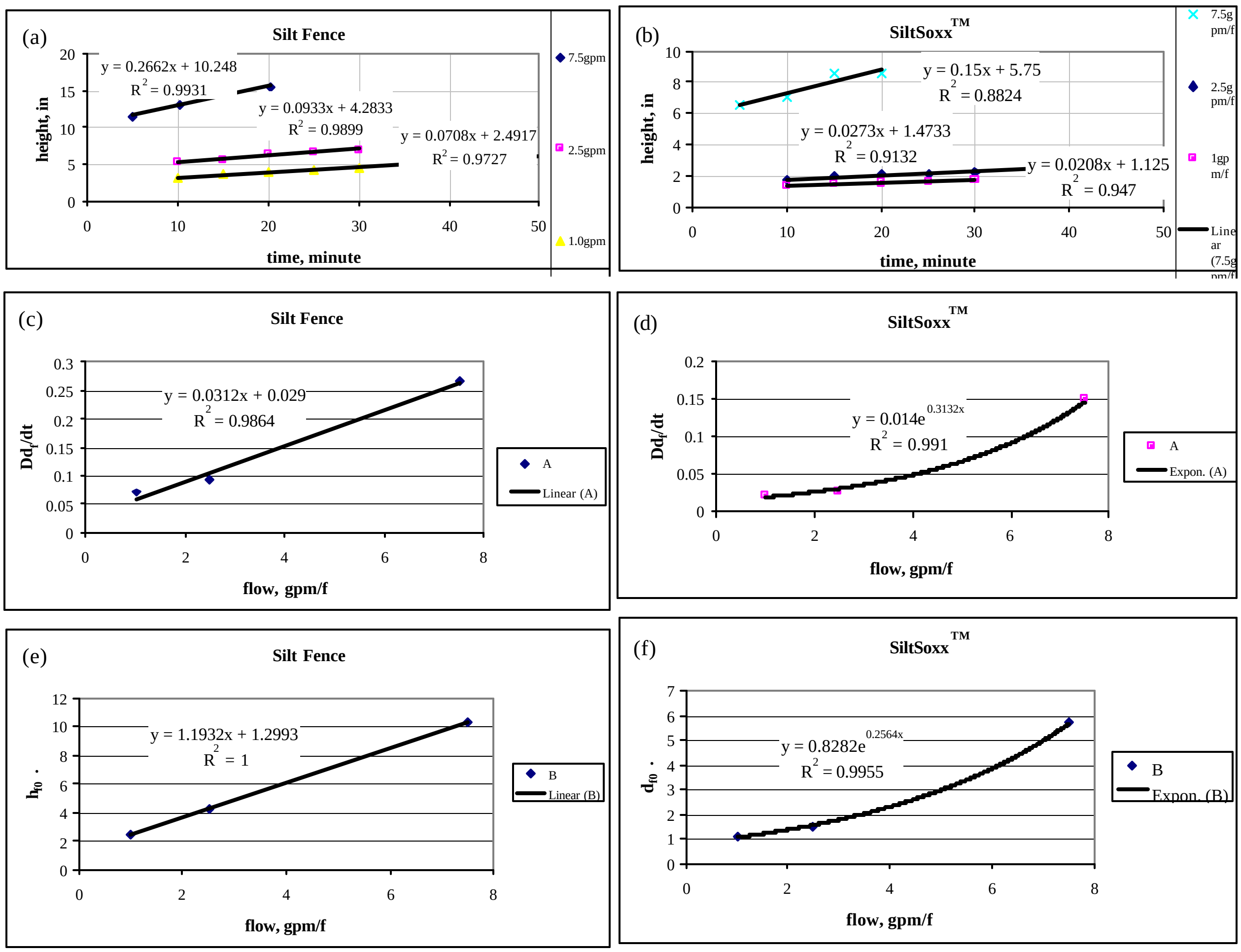

Figure 8. Evaluation of pond depth behind a Silt Fence and SiltSoxx™ as a function of flow rate and time.

Recognizing this effect allowed formulating the following relationship for depth as a function of time.

$$d_f = A(q_f)\, t + B(q_f) \qquad (1)$$

where

d_f = pond depth, inches

q_f = slurry flow rate, gpm/f

t = time, min

$A(q_f)$ = rate of increase in depth as a function of slurry flow rate and slurry suspended solids concentration, inches/min

$B(q_f)$ = initial pond depth behind filter before filter begins to plug, inches.

Evaluation of A and B for the SF and SS were done for the flow rates 1, 2.5 and 7.5 gpm/f and time 10-30 minutes. Results for the SF gave A and B as linear functions of flow rate (fig. 8c,e), whereas, results for the 12 in. SS gave A and B as exponential functions of flow rate (fig. 8d,f). The very high R^2 values (0.9844, 1.00, 0.9891, 0.9938) are partly the result of having only limited test to evaluate, but does show the data fits the model. In order to have the A term go to zero, an additional term of $(1\text{-}\exp(-5q_f^{\,n}))$ was added, where n = 3 for silt fence and n = 2 for SiltSoxx™.

Based on these results the following equations were derived for time to top a filter.

Silt Fence:

$$t = \frac{d_f - (1.1932q_f + 1.2993)}{0.0312q_f + 0.029(1 - \exp(-5q_f^{\,3}))} \qquad (2)$$

Silt Soxx™:

$$t = \frac{d_f - 0.8282\exp^{0.2564q_f}}{0.014(1 - \exp(-5q_f^{\,2}))\exp^{0.3132q_f}} \qquad (3)$$

Equation 2 was solved for silt fences with heights of 24 in., 30 in. and 36 in., assuming effective SF height would be 85% of the total above ground height. Equation 3 was solved for SS with diameters of 8 in., 12 in., and 18 in., assuming effective height was 80% of the total diameter. Results (figure 9 and appendix table) indicate that when flows are less than 5 gpm/f the 12 in. and 18 in SS with coarse compost will out perform even the 36 in. SF (30 in. above ground) and the 8 in. SS is approximately equivalent to the 24 in. SF (18 in. above ground).

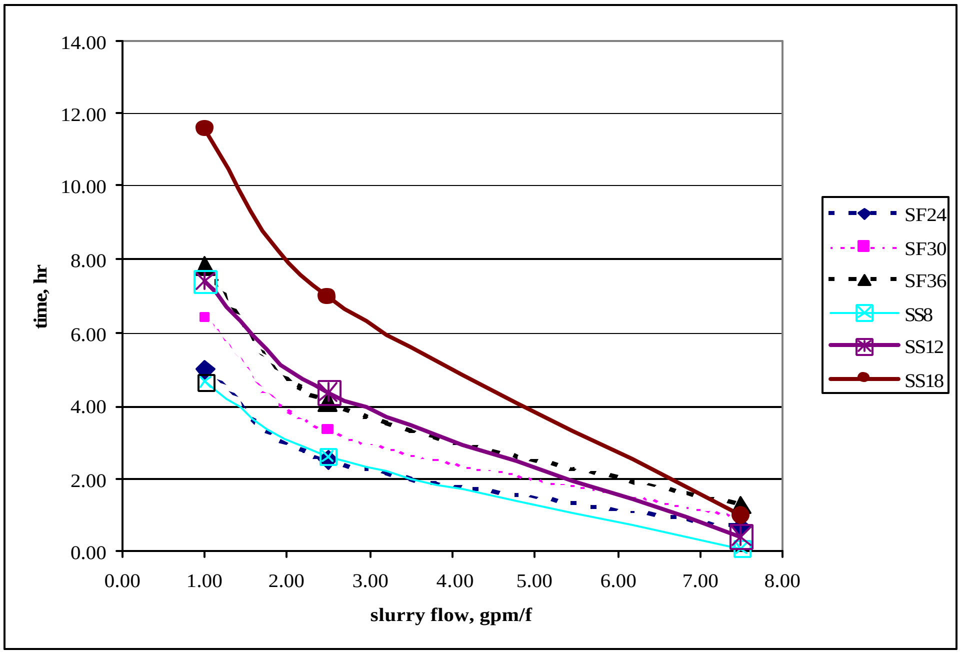

Figure 9. Time to top Silt Fence and Silt Soxx™ as a function of sediment-laden runoff flow rate.

Figure 10 shows the average removal efficiency over the 30 minute test periods for the three sediment control devices. Filtration efficiency for the SF was found to be higher than the 8 in. coarse SS in these tests, but based on standard errors was not significantly higher than the coarse 12 in. SS. Even for the studies at a flow rate of 7.5 gpm/f (i.e. the 15 gpm test) when topping of the sediment control devices occurred, the SF had a higher removal efficiency than the coarse 12 in. SS. However, only one test was run for the SF and the SS at the 7.5 gpm/f level and during the 30 minute run, the % removal was highly variable. More tests would likely reduce the standard error. An issue that came out of the test procedures are, is there a correct filling procedure or density for the SS and how does it correlate with what industry is doing (e.g. measure diameter of sock after filling).

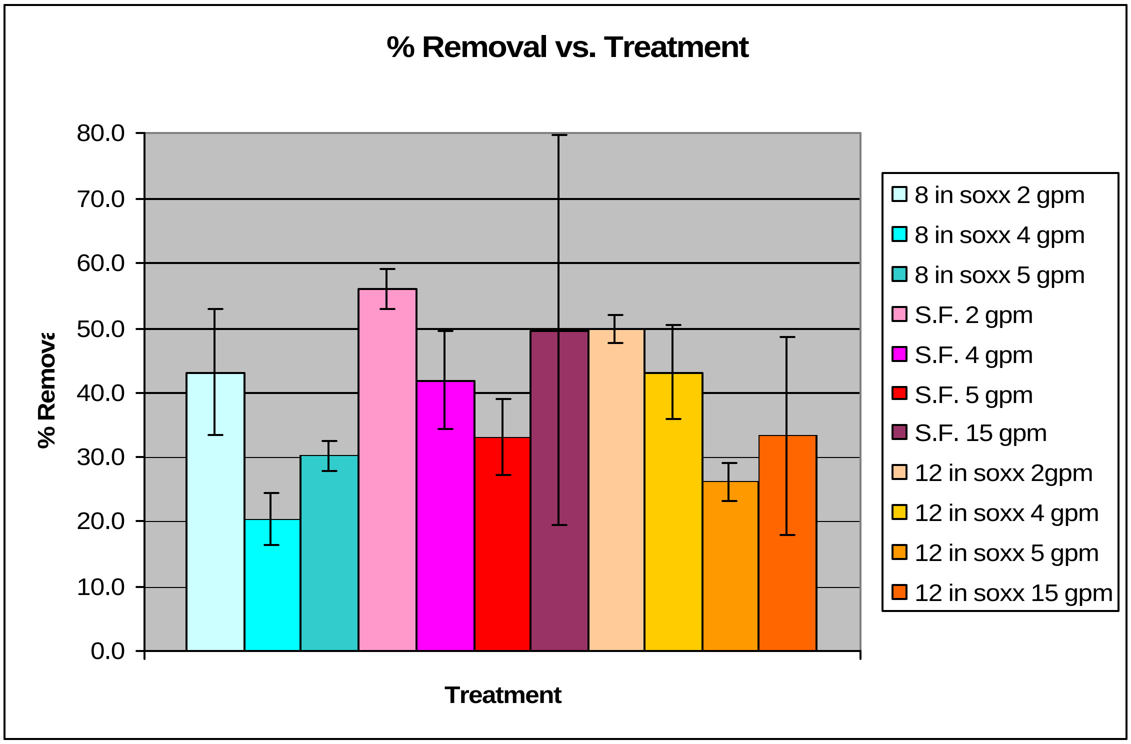

Figure 10. Removal efficiency of 8 in. coarse SiltSoxx^{TM},12 in. coarse SiltSoxx^{TM}, and 24 in. Silt Fence.

Discussion

Results with clean water showed (a) the 8 in. SS and 12 in. SS gave similar flow through rates as a function of pond depth when filled with the same material; (b) the SS with fine compost had flow rates <1/3 that of the SS with coarse compost (see equations) as a function of pond depth when depth exceeded 2 in.; and (c) the SF had higher flow rates than the coarse compost SS over the 2 in. to 8 in. depths tested (d) flow rates through the sediment control devices were a power function of depth and didn't change appreciably with time. Results suggested that a 20 degree slope causes flow rates through sediment control devices to be slightly higher than for the 10 degree slope at the same water depth.

Results with the 1% sediment-laden runoff water showed (a) the 8 in. SS coarse and 12 in. SS coarse gave similar flow rates as a function of pond depth when depth was less than 3 in.; (b) the pond depth steadily increased with time behind the 8 in. SS, 12 in. SS and 24 in. SF at a given flow rate; (c) at flow time of 30 minutes, pond depth for the SS and SF was a power function of flow; (d) maximum topping depth for the SS and SF were approximately 15 to 25%

less than the design height. For example, a 24 in. silt fence (design height) with an initial above ground height of 18 in. high (which assumes a 6 in. underground trench installation) SF topped at 15.75 in. (effective height) and the 12 in. high SS topped at 9 in.; (e) the SS had approximately 50% more flow through rate with a sediment-laden water than the SF for a given depth of water.

Comparison of the flow rates for clean water and sediment-laden water through SS and SF showed there was a complete reversal in performance. The SS had lower flow rates than the SF for the clean water at a given depth (e.g. 25% lower at d_f = 8 in.), whereas for the sediment-laden runoff the SS had much higher flow rates for a given depth (e.g. 238% higher, 6.84 gpm/f vs. 2.87 gpm/f at d_f = 8 in.). However, changes in packing or density of compost or changes in particle size would affect these overall results. During the study the amount of compost added per foot for the 8 in. and 12 in. SS was not based on a unique weight, but rather was based on a subjective volume determined by the tension in the SS fabric.

Design of Runoff Control Structure

Runoff from a sloped surface is shown schematically in figure 11. The equations for runoff are:

$$Q = [I\ W\ L\ \cos(s)\ 7.48 / (60 * 12)] = 0.01039\ I\ W\ L\ \cos(s)$$

$$Q = 0.01039\ I\ W\ L\ \cos(s)$$

$$q_f = Q/W$$

where

Q_f = flow rate to filter, gpm

I = rainfall intensity, in./hr

W = width, i.e. length of filter, feet

L = length of slope, feet

s = angle of slope, degrees

d_f = depth of water at the filter measured ⊥ to slope, inches

q_f = flow rate to filter, gpm/linear ft

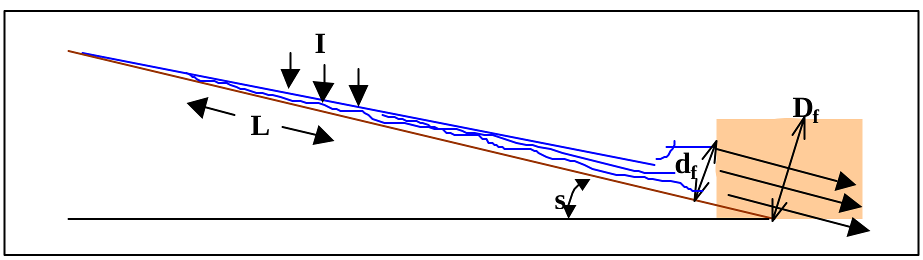

Figure 11. Diagrammatic representation of control structure in operation and a listing of variables used to calculate water runoff rates from a slope of length L.

Selection of sediment control device height, D_f, can be done by calculating q_f and then going to figure 9 for a particular sediment control device and expected storm length.

Conclusion

Results of this study showed that the SF and SS behave differently for under clean water and sediment-laden runoff (~0.9% solids) conditions. For clean water, flow through rate is relatively constant over time and can be represented by a simple power function of pond depth. For the sediment-laden runoff water, flow through rate is changing with time, as is pond depth, due to the accumulation of solids on/in sediment control devices. Changes in depth with time were a linear function of flow rate after ten minutes of flow, up to the time the sediment control device is topped. Prediction of capacity of the SF and SS to handle runoff without the filter being topped requires consideration of both runoff rate and length of time. Graphs, based on the laboratory data showed SS 1/2 the height of SF would be less likely to overflow than the SF when sediment-laden flow is less than 5 gpm/f. Removal of solids by the SF and the SS were not shown to be statistically different and were 30-50% in most tests.

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APPENDIX

Table A1. Predicted time and total flow to top filter.

←-----Equations 2&3-----→					←-Regression eq Fig 8a,b→	
q_f	Depth[1]	eff. Depth	time	Total Flow	time	Total Flow
gpm/f	in	in	hr	g/f	hr	g/f
Silt Fence						
1.00	24.00	15.30	3.56	213	3.02	181
2.50	24.00	15.30	1.72	257	1.97	295
7.50	24.00	15.30	0.32	144	0.32	142
1.00	30.00	20.40	4.97	298	4.22	253
2.50	30.00	20.40	2.51	377	2.88	432
7.50	30.00	20.40	0.64	289	0.64	286
1.00	36.00	25.50	6.39	383	5.42	325
2.50	36.00	25.50	3.30	496	3.79	569
7.50	36.00	25.50	0.97	435	0.95	430
SiltSoxx™						
1.00	8.00	6.40	4.64	278	4.23	254
2.50	8.00	6.40	2.63	394	3.01	451
7.50	8.00	6.40	0.08	38	0.07	33
1.00	12.00	9.60	7.42	445	6.79	408
2.50	12.00	9.60	4.37	655	4.96	744
7.50	12.00	9.60	0.45	201	0.43	193
1.00	18.00	14.40	11.60	696	10.64	638
2.50	18.00	14.40	6.98	1047	7.89	1184
7.50	18.00	14.40	0.99	447	0.96	433

1 Depth of silt fence is total height. Six (6) inches is assumed to be buried in ground when calculating