Energy Dissipation and Chemical Treatment to Improve Stilling Basin Performance

A. K. Bhardwaj, R. A. McLaughlin, D. L. Babcock

Abstract. *Surface water pumped from construction sites frequently contains high levels of turbidity and suspended sediment, which are not effectively removed using gravity-based systems. This study assessed the effects of modifying a permanent pool stilling basin with energy dissipaters and with the addition of polyacrylamide (PAM) on turbidity and suspended sediments. Turbidity was generated by injecting soil into flowing water at a fixed rate for 30 min in a source basin. Turbid water from this basin was pumped from the surface to the stilling basin with physical and chemical treatments. Three energy dissipater treatments were tested: bottom inlet level spreader (BILS; silt fence fabric installed with 40 mm opening from the basin bottom), coir baffles (900 g m^{-2} coir fabric with 0.45 open space fraction (OSF), and Pyramat baffles (synthetic fabric with 0.10 OSF). The tests were run either with or without PAM dosing by passing the flow over a solid PAM block at the stilling basin inlet. The physical treatments (i.e., energy dissipation) did not significantly affect the turbidity and total suspended solids (TSS) of the water exiting the basin, which were reduced by up to 29% and 36%, respectively. The chemical treatment was much more effective regardless of the physical treatment, either in combination or alone, reducing turbidity and TSS up to 88% and 84%, respectively. The baffle materials collected much more suspended sediment when PAM was added, with twice as much sticking to the coir than the Pyramat, although overall the latter may be more effective in settling the flocs. The patterns of turbidity and TSS within the basin suggest that only one porous baffle is adequate for PAM-treated water, and that the reduction observed near the outlet was likely floc interception by the sloped wall of the basin outlet. This study provides a relatively simple, inexpensive approach to improving the function of stilling basins for treating turbid water.*

Keywords. *Bottom inlet, Clay, Coir, Level spreader, Polyacrylamide, Porous baffle, Pyramat, Sediment, Silt fence.*

Sediment is widely recognized as a leading pollutant of surface waters. In the U.S. alone, around 2 billion tons of eroded soil are deposited in water bodies every year (Clark et al., 1985). Construction activities are a major contributor to sedimentation, with sediment loads as high as 2000 times that from forested lands and 10 to 20 times that from agricultural lands (Owen, 1975). Urban erosion-related pollutants impose net damage costs that have been estimated to range from $192 million to $2 billion per year (Clark et al., 1985; Paterson et al., 1993). Suspended solids in surface waters are a serious water quality problem that detrimentally affect aquatic biota, facilitate transport of organic and inorganic pollutants, and decrease the aesthetic value of lakes and rivers (Novotny and Chesters, 1989; Pitt, 1995). Increased suspended sediment reduces the amount of light penetrating the water, harms fish gills, smothers fish eggs, decreases feeding rates of fish, increases water temperature, alters water chemistry, and reduces the overall productivity of an aquatic community (Wilber, 1983). The disinfection and clarification processes at water treatment plants are also adversely affected, resulting in increased treatment costs (Le Chevallier et al., 1981).

Federal and state regulations require developers to design sediment and turbidity control programs for construction sites (USEPA, 1992; NCDEHNR, 1995). In an effort to reduce the sediment coming from construction activities, North Carolina enacted the Sedimentation Pollution Control act of 1973. This act requires that any land-disturbing activity that covers one or more acres must have an approved erosion and sedimentation control plan. Further, the plan must include structural or non-structural management practices that reduce nonpoint-source inputs to receiving waters, sufficient enough to prevent offsite sedimentation damage (NCDENR, 2004). In addition to this regulation, North Carolina Administrative Code 15A NCAC 02B.0211 states that the turbidity in the receiving waters adjacent to a site must not exceed 50 nephelometric turbidity units (NTU) in streams not designated as trout waters, and 10 NTU in water bodies designated as trout waters. If the receiving water already exceeds these levels, then runoff from a construction site cannot increase turbidity further. However, existing control measures are usually ineffective in reducing the elevated levels of turbidity in water discharged from construction sites.

Turbidities of water discharged from construction sites range from hundreds to thousands of NTU. Przepiora et al. (1997) observed turbidities of 120 to 3200 NTU from two construction sites during a one-year period. Suspended clay and fine silt particles escape detention by standard control structures due to their low settling velocities (Haan et al.,

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1994; Wu et al., 1996), regardless of particle shape (Simons and Senturk, 1992), unless residence time is increased or aggregation is induced by natural or artificial means (Chen, 1975). Line and White (2001) found that the trapping efficiency of sediment traps located on an active construction site in North Carolina ranged from 59% to 69%, with retention of only 43% of the silt and 21% of the clay-sized particles. Consequently, fine sediment resulted in turbidity ranging from 100 to 15,000 NTU in the discharged water.

Stilling basins are impoundments used on construction sites to settle suspended solids in turbid water being pumped from excavations. Baffles of various designs can be installed within the basin to dissipate flow energy and lengthen the flow path, providing suspended particles an increased opportunity to settle. Turbulence within the water column contributes to prolonged suspension (Graf, 1971; Goldman et al., 1986). Baffles installed in a pond increase sediment retention rates by reducing the flow energy and turbulence within the pond and increasing the hydraulically effective width, defined by Chen (1975) as "the width over which the flow is uniformly distributed." Jarrett (1996) and Millen et al. (1997) found that geotextile baffles reduce short-circuiting and thus increase trapping effectiveness, although in an undersized pond, baffles may not significantly improve total sediment capture (Rauhofer et al., 2001). In an evaluation of geotextiles for sediment control, Barrett et al. (1998) concluded that sediment removal from highway construction sites was due to the formation of pools behind the silt fabric fence and not by filtration by the geotextile material. Porous baffles have been found to be very effective at absorbing the inflow momentum, reducing turbulent energy, and diffusing the incoming energy and flow velocity such that more of the pond volume participates in the sediment settling process (Thaxton et al., 2004). Evidence of an optimal open space fraction (OSF, area occupied by open pores divided by total area) of 5% to 10% was suggested by Thaxton et al. (2004) but not investigated further. Although the porous baffles increase the retention of coarser sediment, fine suspended sediment remains largely uncaptured (Thaxton and McLaughlin, 2005). Due to the size and nature of the suspended particles, the decrease in turbulence does not have a significant effect on their settling (Holliday et al., 2003), especially without chemical treatment for flocculation.

Polyacrylamide in the anionic form, the subject of this study, has been used for water treatment in industrial and municipal operations for many years, and this use accounts for the majority of anionic PAM sales (Barvenik, 1994). Adsorption of negatively charged PAM to mineral surfaces is most often attributed to cation bridging, although numerous other mechanisms have been proposed (Laird, 1997; Ben-Hur et al., 1992; Sojka and Lentz, 1997). The resulting flocculation process can reduce suspended sediment concentrations by up to 99%, depending on the sediment mineralogy (McLaughlin and Bartholomew, 2007).

The present study was undertaken to evaluate the interactions between baffle OSF, a bottom inlet level spreader, and polyacrylamide (PAM) dosing on turbidity and TSS reduction in a stilling basin.

Materials and Methods

The study was conducted at the Sediment and Erosion Control Research and Education Facility (SECREF) at the Lake Wheeler Field Laboratory in Raleigh, North Carolina. The experimental setup consisted of a series of basins that were used to test a number of turbidity reduction options for pumped construction site water (fig. 1). Water from a source pond (~900 m^3) was delivered to a mixing pond (80 m^3) through a pipe (diameter = 0.3 m) with a control valve for regulating the flow (fig. 1). An inlet tee connection was located approximately halfway between the source pond and the mixing pond to allow the introduction of soil into the water passing through the pipe. The soil was obtained from a nearby construction site and was stockpiled on site at the Field Laboratory. The turbidity for the study was generated by releasing water from the source pond into the mixing pond at a fixed rate of 20 L s^{-1} (0.7 cfs) while adding soil to the pipe at a controlled rate of approximately 23 kg m^{-1} (for a total amount of 700 kg). The turbid water from the mixing basin was then pumped into a test basin (22 m^3) where all chemical and physical treatments were tested. The test basin functioned as a stilling basin in the experimental setup. The soil used for the tests had sandy clay loam texture and was found in prior studies to produce turbidity in the range of 250 to 400 NTU and 150 to 400 mg L^{-1} TSS under the conditions employed in this study. During the sampling period, there was little change in these values in the mixing basin. The selected properties of the soil and water used for the tests are provided in tables 1 and 2, respectively. A settling time of 5 min was provided between turbidity generation in the mixing basin and pumping of water into the test basin to allow the settling of large particles.

Particles in the size range of 20 to 50 μm would theoretically (Stoke's law) have settled out of the turbid water during the mixing (30 min) and settling (5 min) periods, so most of the sediment in the turbid water being pumped would have been <20 μm. Sand and coarse silt do not contribute much to

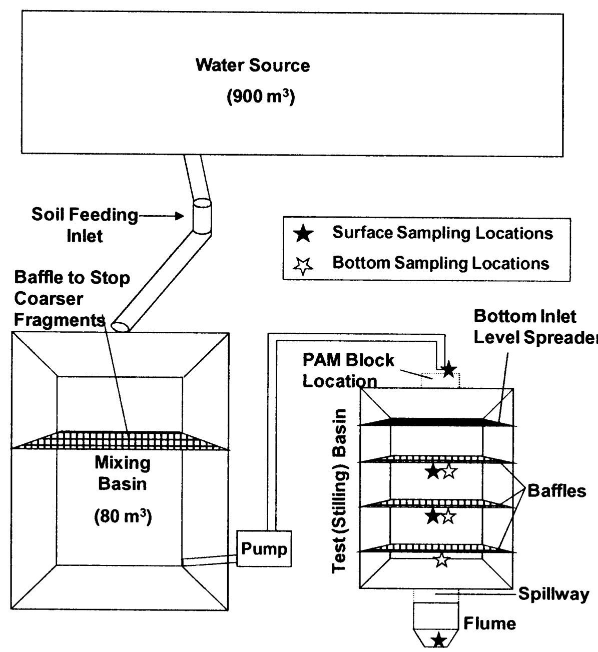

Figure 1. Schematic layout of the testing facilities as viewed from above (not to scale).

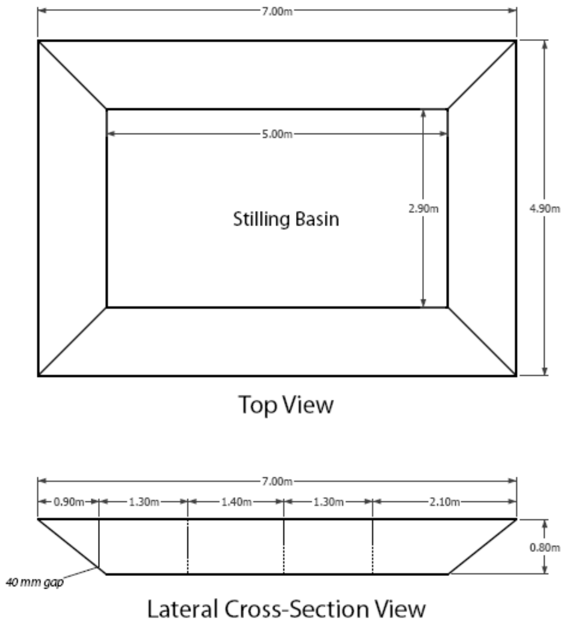

Figure 2. Dimensions and baffle locations for the stilling basin used in our tests.

turbidity and may not be present when pumping out standing or accumulated water from an excavation. The water from the mixing basin was pumped to the stilling basin using a centrifugal pump (51 mm outlet; Hypro C-35, Waterford, Wisc.) at a rate of 4 L s^{-1}, which provided a retention time of 1.5 h. The pump flow was calibrated before each test. The stilling basin was lined with polypropylene geotextile to prevent erosion of the basin bottom.

After approximately 90 min of pumping, the stilling basin was filled with turbid water and overflowing through a 1 m wide spillway. In-basin sampling began at that point, and pumping of turbid water was continued for 40 min to determine the effects of treatments on turbidity of water exiting the basin. Water sampling was accomplished using seven automatic samplers (Teledyne ISCO 6712 portable sampler, Lincoln, Neb.) installed at the inlet (in pipe) and at set distances from the inlet of 2.2 (bottom and surface), 3.6 (bottom and surface), 4.9 (bottom), and 7.0 m (outlet). The sampler intakes within the basin were attached to the middle support post on the downstream side of each baffle. The posts remained in place when no baffles were in place, and the intakes remained in the same position. The sampling at the stilling basin inlet was started from the time when pumping was started; at the other locations, it was started only once the basin was filled and water started running over the spillway. Water from the spillway passed through a flume, where it was sampled with an automatic sampler equipped with a bubbler flowmeter (Teledyne ISCO 640 bubbler module). The bubbler flowmeter was also used to further confirm the pumping rate during the test.

The testing constituted physical and chemical treatments for controlling turbidity. The physical treatments tested included two types of porous baffles and a bottom inlet level spreader (BILS). The two types of baffles tested were: (1) coir baffles with thread diameter of 4.0 mm and OSF of 0.45 (fig. 3) and (2) Pyramat (Propex, Inc., Chattanooga, Tenn.) baffles with thread diameter of 1.0 mm and OSF of 0.1

Table 1. Selected characteristics of the soil used for turbidity tests.

	Characteristics	Value
Physico-Chemical[a]	Clay (g kg^{-1})	250
	Silt (g kg^{-1})	188
	pH	4.70
	EC (dS m^{-1})	0.10
	FeOX (mmol kg^{-1})	8.9
	FeCBD (mmol kg^{-1})	357
	AlCBD (mmol kg^{-1})	92
Mineralogical	Fine clay (<1 μm)	
	Kaolinite (%)	87
	Gibbsite (%)	6
	Vermiculite (%)	7
	Coarse clay (1 to 2 μm)	
	Kaolinite (%)	78
	Quartz (%)	8
	Mica (%)	5
	Vermiculite (%)	5
	Gibbsite (%)	4

[a] EC = electrical conductivity, FeOX = ammonium oxalate extractable iron, and FeCBD and AlCBD = citrate bicarbonate dithionite extractable iron and aluminum, respectively.

Table 2. Selected chemical characteristics of the pond water used for the turbidity tests.

Parameter[a]	Value
pH	6.00
EC (dS m^{-1})	0.07
Turbidity (NTU)	3.00
TSS (mg L^{-1})	4.73
TOC (mg L^{-1})	7.10
NO_3 (mg L^{-1})	0.64
NH_3 (mg L^{-1})	0.59
PO_4 (mg L^{-1})	0.02
Al (mg L^{-1})	0.77
Ca (mg L^{-1})	3.52
Fe (mg L^{-1})	0.28
K (mg L^{-1})	3.56
Mg (mg L^{-1})	2.35
Na (mg L^{-1})	5.25
Mn (mg L^{-1})	0.15
Zn (mg L^{-1})	0.03

[a] EC = electrical conductivity, NTU = nephelometric turbidity units, TSS = total suspended solids, and TOC = total organic carbon.

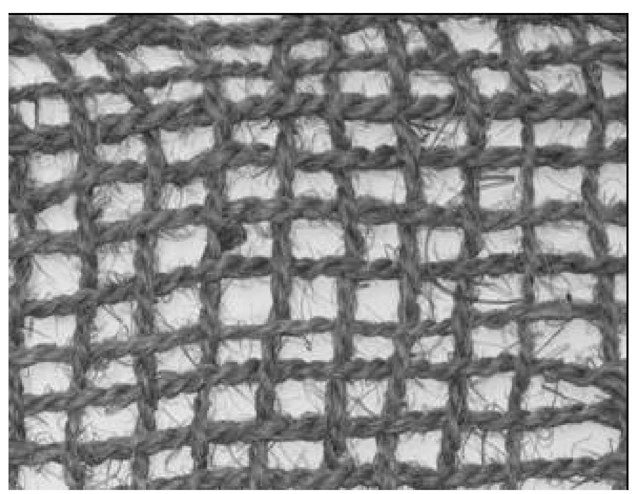

Figure 3. Example of the coir netting used as the first type of baffles.

(fig. 4). The open space fraction of the baffles was determined by image analysis using ArcView GIS v.3.2 (ESRI, Redlands, Cal.). The BILS was an impervious geotextile installed to have 40 mm open space between the lower end of the fabric and the basin bottom (fig. 2). The BILS was included to determine if spreading the flow across the basin bottom could enhance settling by reducing the distance particles needed to fall. Three baffles in the basin were installed at 2.2, 3.6, and 4.9 m from the entrance. The position of the baffles coincided with the locations of sampler intakes in the basin. The baffles were 0.8 m tall and were spread across the entire cross-sectional width of the basin. The chemical treatment included dosing with PAM by directing the pumped, turbid water over a solid PAM block (Floc Log APS 706b, Applied Polymer Systems, Woodstock, Ga.) installed at the basin inlet. The PAM block was a proprietary mixture of medium and high molecular weight anionic polyacrylamide, certified by the North Carolina Department of Environment and Natural Resources (NCDENR) for storm water treatment. The PAM release rate was estimated by the manufacturer to be 2.1 mg L^{-1} at pumping rates similar to the one used in this study. The PAM block was covered with galvanized hardware cloth (wire diameter = 1.6 mm) with 100 mm^2 openings to avoid disintegration as the water was discharged from the pump hose. The control treatment constituted an open basin with no chemical treatment of the pumped water. A summary of the treatments is shown in table 3.

The water sampling was done at 5 min intervals and constituted at least eight samples at the designated points in the basin for each test. Each sample was treated as a repeated measure for statistical analyses. The water samples collected during the tests were analyzed for turbidity using Analite NEP 260 turbidity probe (McVan Instruments, Melbourne, Australia) and TSS after filtering through 76 mm pre-weighed fiberglass filters (Proweigh, Environmental Express, Mt. Pleasant, S.C.) and drying for 24 h at 105°C. For turbidity measurement of each test sample, the apparent turbidity readings were corrected with standard curves generated using formazin solutions of defined turbidity. Turbidity and TSS reductions for each system were calculated from average inlet and outlet values. The sediment captured by the

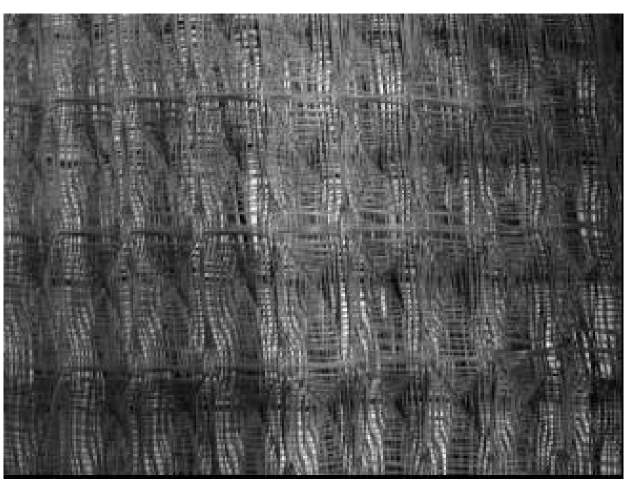

Figure 4. Example of the Pyramat erosion control blanket used as the second type of baffle.

Table 3. Summary of all treatments included in the testing.

Control (open basin)	Coir Baffles	Pyramat Baffles
Control + PAM	Coir baffles + PAM	Pyramat + PAM
	Coir baffles + BILS	Pyramat + BILS
	Coir baffles + BILS + PAM	Pyramat + BILS + PAM

baffle material was calculated by sampling two 0.25 m^2 sections of each baffle after a test, drying them in an oven at 105°C, and subtracting the weight of clean baffle material. Sediment captured by the baffles represented total sediment weight retained for all three baffles used in a test. Between tests, sediment was removed from the stilling basin manually with shovels, the liner was rinsed with a hose, and the water was removed by opening a bottom outlet.

Clay mineralogy (<2 μm) was determined by x-ray diffraction analysis (Whittig and Allardice, 1986). The soil was chemically and physically dispersed for mineralogical analysis (Kunze and Dixon, 1986). X-ray diffraction patterns were obtained for Na-saturated, K-saturated, Mg-saturated, and Mg glycerol-saturated samples (25°C and 550°C). The patterns were interpreted by integrating the peak area for each clay mineral. X-ray diffraction analysis is semi-quantitative in nature and provides relative proportion (±15%) of clay minerals in the soil samples. Soil pH was determined using a pH electrode with distilled water and a 1:1 soil to water ratio. The electrical conductivity (EC) of soil (2:1 soil to water ratio) and water was determined using an EC meter (EC testr, Oakton Instruments, Vernon Hills, Ill.). Extractable soil iron and aluminum were determined by ammonium oxalate and citrate bicarbonate-dithionite (CBD) extraction. Ammonium oxalate extraction was done to determine the amount of amorphous and organically bound Fe and Al. Citrate bicarbonate-dithionite extraction determines both crystalline and non-crystalline forms of iron oxide (Jackson et al., 1986). The particle size distribution was determined by hydrometer method (Gee and Bauder, 1986).

Statistical Analyses

A repeated measure analysis of variance (MANOVA) with interactions was used to determine significance of treatment effects using SAS PROC GLM (Cody and Smith, 1997). A completely randomized design was used with chemical treatment (PAM, no PAM dosing) and physical treatment (coir baffles, Pyramat baffles) of water as main treatment factors, and time as the repeated variable. The turbidity and TSS reduction data were found to be normally distributed and were analyzed by Tukey's comparative analysis (Steel and Torrie, 1960). For treatment comparisons, the reductions in turbidity and TSS were calculated from paired samples taken in the source basin and the stilling basin outlet. This provided a better comparison of treatment effects, given differences in initial turbidities and TSS for each test, and also accounted for the average 25% and 35% drop in source basin turbidity and TSS during sampling. Statistical significance was defined as $P \leq 0.05$, unless otherwise indicated. SAS v. 9.1 (SAS, 2005) and JMP v. 7.0 (SAS, 2005) were used for all analyses.

Results and Discussion

Turbidity

The turbidity of the water in the control test changed very little between the entrance and the exit of the stilling basin (fig. 5). Similar findings have been shown for sediment basins on construction sites, with turbidity changing very little over time (Przepiora et al., 1998). The treatment with coir baffles had significantly lower turbidity than the control, but these reductions were relatively minor. The addition of the BILS to the coir baffles resulted in a significant turbidity reduction compared to coir baffles alone. The turbidity decreased from 227 to 155 NTU within 2.2 m and changed little from this point to the outlet. We did not test the BILS alone, but it appeared to significantly improve turbidity reduction when used with at least one coir baffle.

The greatest reduction in turbidity was achieved with PAM treatments. With no baffles, the turbidity dropped at the first sampling point and did not change until the water reached the outlet, where the turbidity dropped significantly. This could have been a result of the flocs being intercepted by the sloped (2:1) wall of the basin at the outlet. Turbidity was greater at the surface after the first and second coir baffle, but the BILS dampened that trend, and the two systems produced similar turbidity at the outlet. The Pyramat baffles, with or without the BILS, had no apparent effect on turbidity in the basin compared to the open-basin control (fig. 6). When PAM was added, the BILS improved Pyramat performance within the basin, but turbidity was relatively similar among all three PAM treatments at the outlet. The Pyramat baffle + PAM treatment had a much higher initial turbidity and actually reduced it more after the first baffle compared to the other PAM treatments.

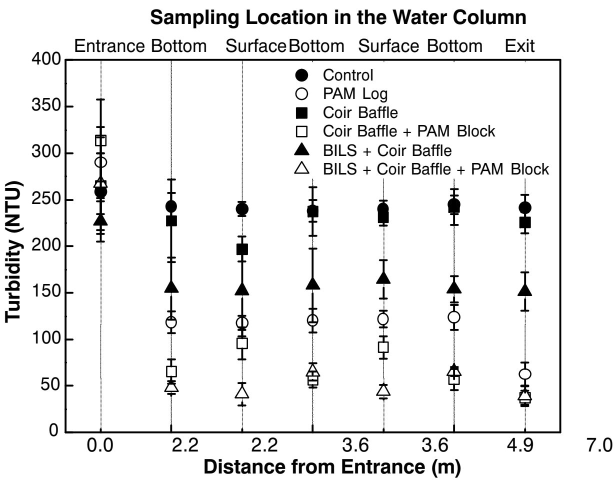

Figure 5. Effects of coir baffles and PAM, with and without BILS, on turbidity within the stilling basin. Error bars represent standard error of the mean for each point.

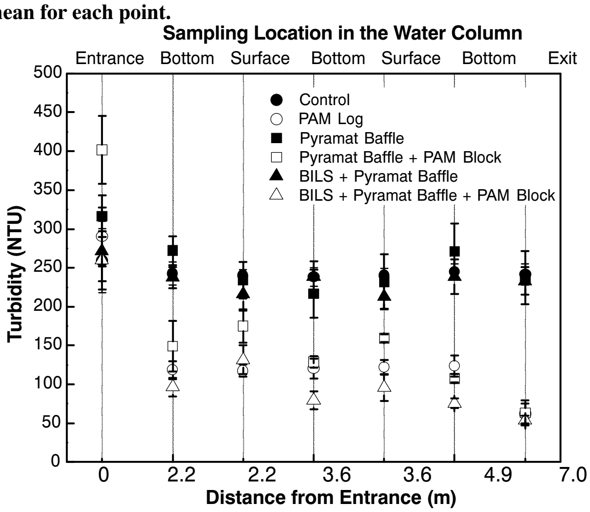

Figure 6. Effects of Pyramat baffles and PAM, with and without BILS, on turbidity within the stilling basin. Error bars represent standard error of the mean for each point.

Turbidity was not significantly reduced compared to the open basin using any combination of physical barriers, with the maximum reduction occurring with the coir baffles (table 4). The BILS appeared to have no positive effect on turbidity reduction by either baffle material. By comparison, however, the addition of PAM far exceeded the impacts of the physical treatments. Even with no baffles, PAM reduced turbidity by 83%, and this was not significantly improved with the physical treatments. The most significant changes in the turbidity were also produced within 2.2 m (first sampling location), indicating that the flocculation process was relatively complete once the water passed through the first baffle. There was a great deal of turbulence in the cell before the first baffle, enhancing mixing and contact between particles and PAM. Polyacrylamide dosing reduced the turbidity 49% to 70% over the same treatments without PAM, and was the only factor that significantly affected turbidity in the MANOVA tests (table 4).

Previous work suggests that this soil, with relatively high CBD-extractable Fe, should be well flocculated with anionic PAM (McLaughlin and Bartholomew, 2007). However, although the PAM did reduce turbidity significantly, the water continued to retain turbidity of about 50 NTU regardless of treatment combination. The work of McLaughlin and Bartholomew (2007) was conducted with whole soil, while these tests were conducted with only sediment remaining in suspension after a settling period. Recent laboratory testing has suggested that the fine fraction remaining is more difficult to flocculate than the whole soil (McLaughlin, unpublished data), possibly due to the presence of 2:1 clays, which are less reactive to PAM (Laird, 1997).

Total Suspended Solids

The patterns of TSS in the basin were very different from those of turbidity. The coir baffles, with or without the BILS, had somewhat higher TSS at the bottom and less at the surface when compared to the open-basin control (fig. 7). This is consistent with the reduced turbulence and better flow characteristics that the porous baffles have been shown to provide (Thaxton et al., 2004). The addition of PAM reduced

Table 4. Paired sample analysis of turbidity and total suspended solids (TSS) reduction in the stilling basin as affected by baffles, bottom inlet level spreader (BILS), and polyacrylamide (PAM). Within a column, values followed by different letters are significantly different ($P < 0.05$).

	Turbidity Reduction (%)		TSS Reduction (%)	
Treatment	No PAM	PAM	No PAM	PAM
No baffle	13.4 a	83.2 ab	36.2 a	78.9 a
Coir	29.0 a	88.1 b	14.1 a	33.4 a
BILS + Coir	21.1 a	86.0 ab	-32.2 a	59.2 a
Pyramat	24.1 a	84.1 ab	35.4 a	66.4 a
BILS + Pyramat	21.1 a	80.6 a	23.6 a	84.2 a

TSS at most sampling points, but the majority of the effect occurred after the final baffle, again suggesting interception by the sloped wall of the outlet dam. The patterns were similar in the Pyramat baffle treatments, with the differences between bottom and surface being even larger, although addition of the BILS tended to reduce the contrasts (fig. 8). The Pyramat baffles were somewhat more effective in enhancing the PAM effect for TSS within the basin, but these differences were largely not apparent at the outlet of the basin. The BILS also reduced TSS at several points in the basin and at the outlet, relative to Pyramat alone.

Total suspended solids reductions by the physical treatment combinations were not significantly different from those of the open basin (table 4). There was much greater variability in TSS compared to turbidity, reducing our ability to differentiate among treatments. As with turbidity, TSS was reduced much more with the PAM dosing than with the physical treatments alone. There were no significant differences in TSS reduction when physical treatments were included with PAM dosing. Again, the only significant treatment factor in the MANOVA tests was PAM (table 5).

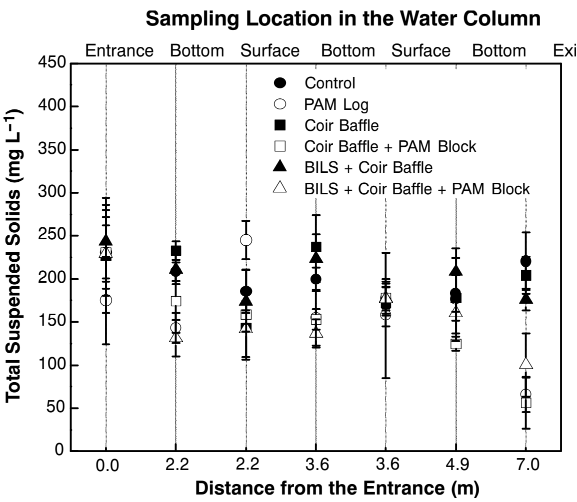

Figure 7. Effects of coir baffles and PAM, with and without BILS, on TSS within the stilling basin. Error bars represent standard error of the mean for each point.

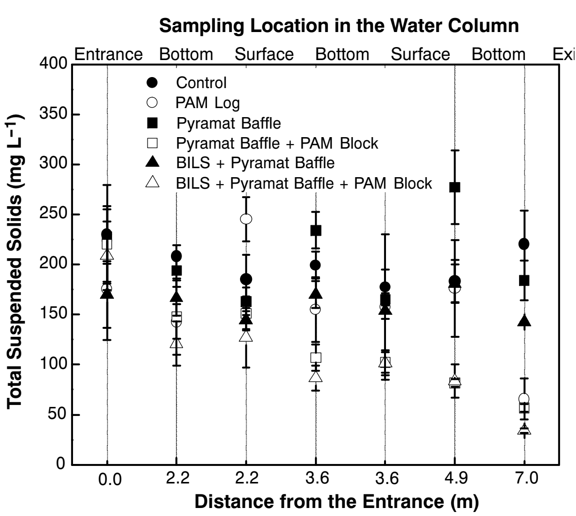

Figure 8. Effects of Pyramat baffles and PAM, with and without BILS, on TSS within the stilling basin. Error bars represent standard error of the mean for each point.

The analysis of the overall treatment effects, measured as reductions in turbidity and TSS from inlet to outlet, suggests that the physical treatments were relatively ineffective compared to PAM. The open basin (control) reduced turbidity by only 13%, and adding the porous baffles only brought this up to 21% to 24% (table 4). However, dosing the water with PAM brought turbidity down by 81% to 88%, regardless of the physical layout of the basin, far exceeding the performance of any combination of physical systems that was tested. There were no significant differences among treatment combinations for TSS reduction, but the two baffle materials were almost significantly different ($P = 0.0588$) in the MANOVA analysis. This suggests that the Pyramat material, with less pore space than the coir, might be more effective as a porous baffle. Thaxton and McLaughlin (2005) also found that pore space in the range of 5% to 10% may be optimal in settling suspended solids. Since Pyramat is currently priced at about five times the cost of coir netting, it may be more cost-effective to use a double layer of coir to reduce pore size, or to find an alternative material with an OSF similar to Pyramat.

Previous work has suggested that the primary effect of porous baffles on improving sediment settling is to reduce turbulence and velocities within the basin (Thaxton et al., 2004; Thaxton and McLaughlin, 2005). Those tests were performed using whole soil mixed into the inflow to the basin, as opposed to first settling the larger particles and pumping the turbid fraction into the basin, as in this study. Under the much lower sediment loads and smaller size sediments that we used, the relative contribution of the baffle material as a "filter" could have been important. However, without PAM, the coir and Pyramat baffle material retained only 7% and 2% of the total sediment trapped in the basin, respectively (table 6). When PAM was added, this increased to 40% and 22%, respectively. The coir material retained more sediment

Table 5. General linear model (GLM) procedure repeated measure analysis of variance (MANOVA) for the effects of baffles (coir, Pyramat), polyacrylamide (PAM) dosing, and bottom inlet level spreader (BILS) on turbidity and total suspended solids (TSS).

	Pr > F	
Source	Turbidity	TSS
PAM	<0.0001	0.0060
Baffle	0.3272	0.0588
BILS	0.6135	0.8964
Baffle × PAM	0.3529	0.6354
BILS × PAM	0.7648	0.1280
Baffle × BILS	0.8334	0.6157
PAM × Baffle × BILS	0.7245	0.5262

Table 6. Sediment capture effectiveness of the two baffles (coir, Pyramat) with and without polyacrylamide (PAM) treatment of turbid water. Standard error of the mean shown in parentheses.

Treatment	Coir Baffle	Pyramat Baffle
Open space fraction (OSF)	0.45 (±0.03)	0.1 (±0.02)
Sediments fraction captured by baffles[a]		
Without PAM	0.07 (±0.02)	0.02 (±0.00)
With PAM	0.40 (±0.05)	0.22 (±0.06)
Sediments fraction trapped in the basin[a],[b]		
Without PAM	0.10 (±0.10)	0.19 (±0.01)
With PAM	0.75 (±0.33)	0.74 (±0.09)

[a] Designates fraction of total amount of sediments entering the basin.
[b] Including the fraction on the baffles.

in spite of its much higher OSF, probably because of the roughness (high surface area) of the coir threads relative to the smooth plastic of the Pyramat. Since the Pyramat treatment tended to result in overall greater reductions in TSS, this must have been the result of improved settling hydraulics within the basin.

Conclusions

The objective of this study was to determine the effectiveness of different energy dissipaters in basins for settling fine, suspended particles, in the presence or absence of PAM dosing. An open basin provided very little treatment, reducing turbidity and TSS by 13% and 36%, respectively. Adding the physical treatments (baffles, BILS) did not significantly improve treatment compared to the open basin. Dosing the water with PAM at the inlet had a much greater effect on turbidity and TSS, with reductions ranging from 81% to 88% and from 33% to 84%, respectively, among all treatments. Little of the trapped sediment was present on the baffles except when PAM was used, with the coir and Pyramat baffles trapping 40% and 22% of the sediment captured in the basin, respectively. Although the Pyramat material had much smaller pores than the coir, the roughness of the coir fibers may have enhanced floc capture. However, the overall effect of the Pyramat on TSS capture was greater, likely due to improved settling conditions. A substantial portion of the reductions in suspended sediment by PAM occurred after the last baffle, probably as the flows encountered the sloping bank at the outlet. This suggests that having a progressively shallower basin, in conjunction with a porous baffle to reduce turbulence, may improve sedimentation rates for chemically flocculated systems.

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