# Evaluating Sediment Capture Rates for Different Sediment Basin Designs

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16. Abstract

The effectiveness of sediment control devices was studied on a large NC DOT project to determine the effects of different designs and conditions. Flow and sediment content of water exiting six different traps and basins were measured and the amount of sediment trapped estimated from periodic surveys. Sediment trapping and discharges strongly suggested that commonly used designs are relatively ineffective. The three devices with rock dam outlets had sediment retention of <57% of sediment entering the traps and discharged up to 20 t $ac^{-1}$ during up to 12 months of monitoring. In contrast, the skimmer basins with surface outlets, stable sides and inlets, and porous baffles, retained more that 90% of sediment entering them, as long as they were properly maintained. While the skimmer basins retained most of the sediment entering it, the discharges were still relatively turbid and contained considerable suspended solids. The skimmer basin which was monitored longest (one year) had average turbidity of 891 nephelpmetric turbidity units (NTU) and total suspended solids (TSS) of 537 mg $L^{-1}$. It is likely that the remaining suspended materials are very fine and will not settle by gravity alone under typical retention times. The more efficient designs tended to retain more of the coarse fraction entering the basins than the less efficient designs. The improvement in sediment retention with the design improvements will significantly reduce the impacts of land disturbances from construction activity on water quality in nearby streams.

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# Disclaimer

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# EXECUTIVE SUMMARY

This study confirms the improvements in basin performance reported under controlled conditions in studies on skimmers (Millen et al., 1997), porous baffles (Thaxton et al., 2004, 2005), and basin sizing (Barfield et al., 1983). In combination, it is clear that design changes can considerably improve sediment capture on construction sites. Large, well-maintained basins with surface outlets can retain well over 90% of the sediment entering them, compared to 35-57% found for the standard traps. The data and observations from monitoring multiple sediment control devices suggest the following approaches to improving basin performance:

- Increased surface area and volume will decrease the total load of sediment leaving the basin/trap
- Baffles reduce the velocity of water entering the basin/trap allowing for the heavier sediment to fall out of the suspension more readily.
- Vertical walls should be avoided because they fail, producing sediment within the basins/traps and diminishing the effective volume of the device.
- Surface outlets decrease the total amount of sediment leaving the basin/trap by dewatering from the top of the water column.
- Continuous maintenance is crucial to achieve expected retention efficiencies for these devices.

Because the larger, more efficient basins may pose problems if they are placed within a construction corridor, we would recommend that temporary easements be obtained whenever possible to have sediment basins installed adjacent to it. These basins may replace some of the smaller traps that currently are installed throughout the construction zone. This study did not evaluate the efficiency of a surface outlet basin, properly installed with stable inlet and side slopes plus porous baffles, but sized for 10-year storm events instead of the 25-year design we evaluated. It is possible smaller basins could approach the same efficiencies as the larger ones.

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## OBJECTIVES

Sediment pollution from construction sites has been of increasing concern since the impacts on nearby streams can be severe. Controlling erosion is the most effective approach to reducing sediment loads, but construction sites typically have large areas of exposed soil during the active phase of clearing and grading. As a result, sediment traps and basins are required to capture eroded sediment on most of these sites.

The purpose of this research was to:

- Determine the trapping efficiencies of sediment basins of various designs installed on active construction sites.
- Conduct workshops, demonstrations, and training for staff from NCDOT, NCDENR, and other local and governmental programs and agencies.

## INTRODUCTION

Sediment traps and basins are commonly installed on construction sites to provide temporary pools for runoff to allow sediment to settle before the water is discharged from the site. Traps are devices which release pooled water through a rock dam, usually large stone covered with washed gravel. Basins are devices which have a riser barrel or similar device as the primary outlet. Their efficiency can be affected by many design factors, such as the principal spillway, dimensions, soil type, and storm characteristics. The length to width ratio affects the dead storage volume within a basin (Chen, 1975; Griffin et al., 1985), with a minimum length to width ratio of 2:1 usually recommended (Barfield et al. ,1983; Mills and Clar, 1976; NC DENR, 2001). Alternative outlets for sediment trapping devices have also been investigated for improving sediment capture rates. Under controlled conditions, engineered dewatering methods have been demonstrated to have sediment capture rates of 88% or better by using perforated risers (Fennessey and Jarrett, 1997; Ward et al., 1979; Edwards et al., 1999) or a floating skimmer (Millen et al., 1997). The skimmer was found to be the outlet device which provided the highest sediment capture rate.

Schueler and Lugbill (1990) found an average sediment retention of 46% in a brief study of sediment traps using grab samples during storms. The severity of the storm event was found to increase TSS up to four times the median value of 680 mg $L^{-1}$, reducing efficiencies. They indicated that the low retention was in part was due to the large amount of the material entering the devices was fine clays and silt, which are very difficult to settle in these devices. Near zero retention was reported for a rock berm based on paired grab samples (Barrett et al., 1995). A field study of sediment traps with rock outlets in North Carolina found they trapped 59% to 69% of the sediment that was entering the basins over a course of 20 months (Line and White, 2001). This study used flow-weighted sampling of trap outlets and surveys of sediment accumulations in the traps to estimate efficiency, which is likely to be more accurate than paired, instantaneous sampling of inlet and outlet.

These structures are less effective when swift, turbulent water moves straight through them to the outlet, so solid baffles near the inlet have been recommended (Goldman et al., 1985). Baffles constructed of silt fence with weirs have been shown to increase sediment retention in sediment basins compared to open basins (Millen et al., 1997) Porous baffles, constructed from erosion control blanket materials, are even more effective than silt fence baffles with weirs (Thaxton et al, 2005; Thaxton and McLaughlin, 2006). These are now required in North Carolina (NC DENR, 2006).

The principal spillway for a basin can also be considered a factor in efficiency performance.

## **Efficiencies**

Sediment basins and sediment traps are both enclosures for the temporary ponding of runoff. However, sediment traps differ from basins in that they contain a dam made of rocks covered on the upstream side with a layer of gravel to allow water to pass. The traps have different hydraulic characteristics than basins, and therefore different efficiencies (Line and White, 2001). In addition, efficiencies are affected by the particle size distribution of the material entering the device (Jarrett, 2001).

Sediment basin or trap retention efficiencies depend on many variables: intensity of the storm event, length of the storm event, soil type, topography, types of BMPs implemented, and also maintenance of those BMPs (Line and White, 2001). Line and White (2001) found the trapping efficiency of a trap located on a Coastal Plain soil was 69%, while the efficiencies of two other traps located on a Piedmont soil averaged 59%. These traps were monitored for an extensive amount of time (34 storm events for the Coastal Plain trap and 43 and 13 storm events for the Piedmont traps) and individual samples throughout the storm events were analyzed. This is the only comprehensive study of sediment trap efficiency on construction sites that has been published.

The objective of this study was to determine sediment retention in traps and basins with different designs and which were located on active construction sites. The approach was similar to Line and White (2001), in that we sampled discharges and surveyed accumulations in the devices to determine trapping efficiency. In particular, we were interested in the influence of baffles and outlet types on sediment retention.

## MATERIALS AND METHODS

### Basin Design

The I-270 Bypass was determined to be located on a watershed designated as "sensitive" due to the location of endangered fresh water mussels in the tributary (Swift Creek) that runs through much of the project. As a result, all basins and traps along this project were designed and built based on a 25-year storm event, as opposed to the standard 10-year event design. These basins and traps are much larger in overall volume and surface area holding capacity. The basin dimensions were built based on the following equation:

Equation 1 $A = 435 * Qp25$ (7.78 inches per 24 hour period)

where

A= the area of the basin

435= surface area (square feet) needed to be provided by basin/trap

Qp = peak flow for storms of X recurrence

X = Storm recurrence, usually 10 or 25 year.

Qp25 = xx cfs for 7.78 inches per 24 hour period for this site.

There were, however, traps built specifically for the purpose of our study based on a 10-year storm event using the following equation:

$A = 435 * Qp10$ (4.93 inches per 24 hour period for Raleigh)

The resulting dimensions and other characteristics are shown in Table 1.

Table 1. Basin and trap characteristics including dimensions and watershed area

| Basin/Trap Characteristics | | | | | | |
|---|---|---|---|---|---|---|
| | Standard 25 year Trap (25ST) | Skimmer Basin 2 (SkB2) | Skimmer Basin 1 (SkB1) | Standard 10-year Trap1 (10ST) | Standard 10-year Trap with standing pool 2 (STSP2) | Standard 10-year Trap with standing pool 1 (STSP1) |
| Baffles | ☒none | ☒ porous coir | ☒porous coir | ☒none | ☒none | ☒none |
| Outlet | ☒rock weir | ☒skimmer | ☒ skimmer | ☒rock weir | ☒rock weir | ☒rock weir |
| Design | ☒25-yr | ☒25-yr | ☒25 yr | ☒10 yr | ☒25 yr | ☒10 yr |
| Side Walls | ☒vertical | ☒2:1, blanket + grass | ☒2:1, blanket + grass | ☒vertical | ☒vertical | ☒vertical |
| Flow Device | 90 V-notch Weir | Rectangular Weir | Pipe | 90 V-notch Weir | Pipe | Pipe |
| Drainage Area (ac) | 3 | 1.5 | 3.5 | 2.5 | 1 | 2 |
| Dimensions (length, width, depth: ft) | 105 x 20 x 3 | 75 x 36 x 3 | 138 x 69 x 3 | 52 x 26 x 3 | 33 x 16 x 1 | 49 x 16 x 3 |
| Design Peak Flow (cfs) | 14 | 6 | 16 | 8 | 4 | 6.3 |

The Skimmer Basin (SkB1) used a Faircloth skimmer with a 2” (50 mm) orifice attached to a 4’ high concrete riser (Faircloth Skimmers, Hillsborough, NC, USA; Figures 1, 2). This basin was designed to be configured as a Hazardous Spill Basin which can be sealed off with a sluice gate in the event of a chemical spill on the highway. The sides of the basin had 2:1 slopes which were stabilized with grass and excelsior erosion control blankets. The flow was monitored in the 15” concrete pipe draining the riser box. The sampler was programmed to take samples based on flow calculated from water levels using the Manning equation. An ISCO 6700 Series Sampler with bubbler module was installed at the inlet of the pipe and programmed to take samples during storm events (ISCO, Lincoln, NE, USA). An ISCO 674 Rain Gauge with a tipping bucket was attached to the sampler and used to monitor rainfall amounts.

Figure 1. Skimmer Basin 1 (SkB1)

Figure 2. Faircloth Skimmer

The Skimmer Basin 2 (SkB2) which was not converted into a hazardous spill basin was fitted with 2" orifice skimmer inserted through the outlet dam (Figure 3). Because this weir was an emergency spillway for the basin, we installed a 10 foot long rectangular weir with end contractions along the top of the spillway in order to calculate flow (Figure 4). An ISCO 6712 sampler with bubbler module was programmed to calculate flow based on the volume of water that exited the basin over top of the weir, not the water exiting through the skimmer outlet.

Figure 3. Skimmer Basin 2 (SkB2) with coir baffles

Figure 4. Rectangular weir installed to monitor flow rate discharge.

A standard trap (10ST) was also monitored at the DOT site (Figure 5). This trap was a typical silt trap type B installed with vertical walls. The dimensions of this trap were calculated based on 1800 ft$^3$ per acre of drainage, resulting in dimensions of 52' x 26' x 3' (length, width, depth). This trap was built specifically for our research to enable us to study the efficiencies of a typical 10 year storm standard trap, and it emptied into the already existing 25-year design trap to avoid regulatory issues. The outlet was a 6' wide rock weir comprised of class B stone with a layer of washed #57 gravel. We installed a 90° V-notch weir below the rock weir with dimensions 4' long x 2.6' high (Figure 6). Plywood side walls were installed on each end of the weir and buried in the side walls of the basin to prevent erosion along the edges and to maintain flow through the weir. The bottom of the weir was buried 6” into the ground with the V-notch 2” above ground. This left a total of 2’ that made up the head of the weir. An ISCO 6712 sampler with a bubbler module was then installed and programmed to measure flow and obtain samples at the outlet of the trap.

Figure 5 .Standard Trap (10ST) with entrance located near rock weir outlet.

Figure 6. Standard Trap (10ST) with a V-notch weir installed to monitor and calculate flow.

Standard traps with standing pools 1 and 2 (STSP1, STSP2) were also selected for monitoring (Figures 7, 8). The outlets used on these traps were 10’ wide rock weirs constructed as described above. These traps were designed as typical silt traps type B with vertical walls. However, they were installed 3’ below grade and the rock outlet was actually controlled by the adjacent storm drain inlet. This essentially transformed the traps into riser basins with a 3’ solid riser, with overflow through a gravel inlet protection device and into a storm drain. We monitored the flow at the inlet of the storm drains, which were 15” concrete pipes. ISCO 6700 Series Samplers with bubbler modules were installed at the base of the rock weirs and programmed to take samples during storm events based on flow.

Figure 7. Standard Trap with standing pool 1 (STSP1) with vertical walls

Figure 8. Standard Trap with standing pool 2 (STSP2 ) with vertical walls

Finally, a 25 year Standard Trap (25ST) was selected for efficiency monitoring. This trap is a typical temporary silt trap type-B with vertical side walls (Figure 9). The dimensions of the Woods trap were 104' x 52' x 3' calculated for the 3 acres of drainage for a 25 year storm event peak flow. The outlet for this trap was a 7 foot wide rock dam comprised of washed #57 gravel layered over large class B stone. We installed a 90° V-notch weir on the back side of the rock weir. The V-notch weir was 4' long and 2.8' tall (Figure 10). The weir bottom was buried 6" into the ground with the notch at 4" above the ground. This left a total of 20" for the head of the weir. An ISCO 6712 sampler with bubbler module was attached to the weir and programmed to take samples on a flow-weighted basis once flow was initiated (Figure 10). These individual samples that were obtained were then analyzed in the laboratory for turbidity levels and TSS (mg $L^{-1}$). An ISCO 674 Rain Gauge was attached to the sampler and used to monitor rainfall amounts. This instrument uses a tipping bucket design to measure the precipitation amounts for each storm event (ISCO, Inc. Lincoln, NE).

Figure 9. Standard 25-year Trap (25ST) during a substantial rainfall.

Figure 10. Standard 25-year Trap (25ST) V-notch weir with flow discharging.

## Site Surveys and Analysis

All basins and traps being monitored for trapping efficiencies were surveyed using a Sokkia Total Station (Series 30R model, Olathe, KS, 2004). This instrument provided three-dimensional coordinates of points within the basin, including the walls and deposition or erosion areas. An initial survey of each trap or basin provided the volume of the basin at the time the water sampling began. In most cases, we were able to survey the basins very soon after they were installed and before significant changes occurred to the original dimensions due to erosion or deposition. If the basin was modified or cleaned, another survey was taken to ensure proper calculation of sediment accumulation. If no activity occurred throughout the study of the basin, only the initial survey along with a final survey were used for sediment accumulation calculations. In order to avoid measurement errors, surveys were only conducted once the sediment accumulation was significant in each basin.

To determine the volume changes in each basin, the survey data was analyzed using an AutoCAD program (AutoCAD Land Desktop 2005, San Rafael

CA). The AutoCAD program was used to develop a three-dimensional map of each basin for each survey. The maps were then checked for accuracy to ensure there were no equipment or user errors. This was done by visual inspection of the images for unusual shapes or depths of sediment accumulation that did not match other numbers within the same survey. The basins were also frequently photographed and these images were used for further confirmation of the survey results. A volume report was generated for each survey and the net change in volume was calculated by simply subtracting the volumes from each volume report.

## TSS and Turbidity Assessment

Runoff samples were measured for turbidity using the Analite Nepholometer, Model 152 (McVan Instruments, Melbourne, Australia). Each sample was shaken for 10 seconds and a reading was taken 30 seconds later. Because turbidity continuously dropped as sediment settled, a set time provided a standard for all readings. Samples with turbidity over the instrument limit of 3,000 NTU were subsampled and diluted to bring the reading down to <30,000 NTU, and then multiplying that value by the dilution factor. We did not make dilutions greater than 10:1 to avoid subsampling errors, so samples which remained above 3,000 NTU after a 10:1 dilution were entered as ">30,000 NTU." For statistical purposes, they were calculated as 30,000 NTU. Turbidity readings from the nephelometer were corrected against formazin standards using a linear regression curve of the standards values and the instrument readings. This correction was performed each day for the samples analyzed that day.

Total suspended solids (TSS) was determined by the filtration method (Clesceri et al, 1998). Subsamples (50 mL) were removed by pipette from all parts of the sample volume while it was rapidly stirred on a magnetic stir plate. The subsample was filtered through 90 mm preweighed filters (Environmental Express, Mt. Pleasant, SC). The filters were then dried in an oven at 103°-105°C and weighed

Sediment in the basins/traps was sampled at the time of the last survey. Samples were obtained at different points representing the inlet, middle, and outlet areas in the basins. Particle size analysis was performed on these samples using the hydrometer method (Gee and Bauder, 1986).

Bulk density samples were taken from the basins to calculate the mass of sediment deposited in the basins. Samples were collected by inserting a metal cylinder (8 in$^3$) into the sediment.. The cylinder was carefully inserted into the sediment deposit until reaching the soil of the basin bottom, which was much more compact than the deposits. The columns of sediment collected represented all sediment deposited into the basin over the length of the monitoring time. Three cylinders were inserted into the soil deposited in each basin. Samples were collected from each basin at the inlet, the middle, and near the outlet of the basin. These cores were dried at 103-105° C until a constant weight was found. The samples were then weighed and the bulk density calculated.

## RESULTS

### Erosion

One of the obvious differences in the traps and basins was the erosion of vertical walls. As a result, a considerable amount of sediment in the traps was generated from these areas. One site was surveyed just for erosion rates and an estimated 4 tons of soil was lost due to the gully formed in the corner (Figure 11). The STSP1 gully was 27 $ft^3$ or approximately 1 ton of soil lost due to poor design and lack of soil stabilization (Figure 12). The sides of these traps and basins often fail and produce sediment (Figure 13). In contrast, the skimmer basins received most of the flow through 12" m slope drains with outlets stabilized with rock, so little erosion occurred at their inlets. They also had 2:1 sloped side walls stabilized with matting and grass which generated very little sediment (Figure 14). As a result, the differences in trapping efficiencies is an integration of the differences in hydraulic function and the stability of the devices itself.

Figure 11. An estimated four tons of soil eroded from the corner gully

Figure 12. An estimated one ton of soil eroded from the vertical wall entrance

Figure 13. Standard Trap with standing pool 2 (STSP2) with weakened vertical walls.

Figure 14. Proper installation of 2:1 sloping walls with ground vegetation established.

### Turbidity and TSS

The quality of the discharged water ranged widely in both turbidity and TSS (Tables 2 and 3). Surprisingly, the lowest mean values were found in the STSP1, followed by the SkB2 and SkB1 (prior to maintenance problems), even though the former discharged much more sediment. This is likely because the STSP1 remained full of water between storm events, so there was little detention when runoff was initiated. As previously mentioned, the SkB1 and SkB2 had considerable storage potential prior to discharge. The 10ST and 25ST traps had very high turbidity and TSS in their discharge, which was likely because of the standard design and poor maintenance of the traps. Both traps contained no baffles to slow the velocity of the water entering them. Also, water was entering the traps very close to the rock weirs allowing virtually no settling time. STSP2 took on a large load of sediment for the short time we monitored it and, as the pictures show (Figure 13), had severe failure of the vertical walls which likely contributed to the extremely high values for both TSS and turbidity.

Table 2. Minimum, Maximum, Median, and Mean turbidity values.

| | Turbidity (NTU) | | | |
|---|---|---|---|---|
| | Min | Max | Median | Mean |
| SkB1 | 0 | 31,219 | 410 | 1,068 |
| SkB2 | 41 | 1,294 | 143 | 269 |
| 10ST | 378 | 15,962 | 1,456 | 2,088 |
| 25ST | 325 | 29.772 | 3,171 | 4,414 |
| STSP1 | 18 | 29,091 | 88 | 126 |
| STSP2 | 50 | 49,840 | 754 | 5,592 |

* Maximum value measurable by turbidimeter.

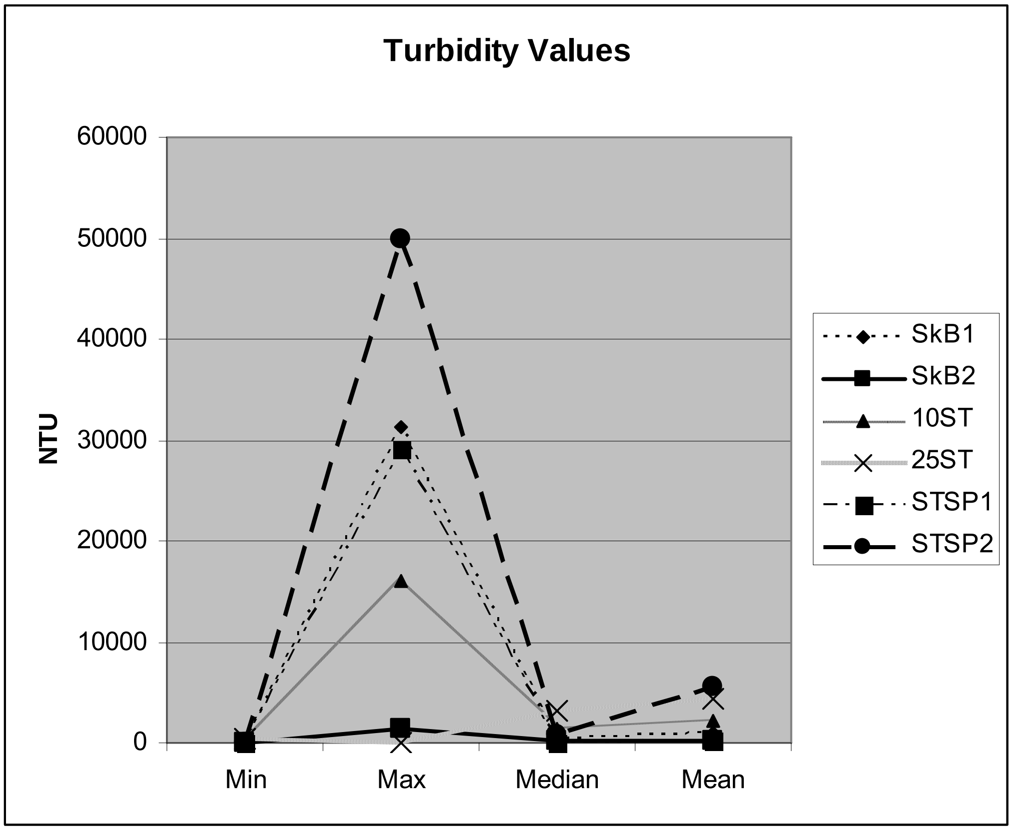

Figure 15. A comparison of all six devices turbidity values.

Table 3. Minimum, Maximum, Median, and Mean TSS values

| | TSS (mg $L^{-1}$) | | | |
|---|---|---|---|---|
| | Min | Max | Median | Mean |
| SkB1 | 2 | 97,762 | 168 | 1,042 |
| SkB2 | 27 | 6,489 | 84 | 289 |
| 10ST | 84 | 20,096 | 434 | 1,084 |
| 25ST | 120 | 47,733 | 868 | 3,807 |
| STSP1 | 10 | 168,155 | 34 | 79 |
| STSP2 | 30 | 48,309 | 203 | 1,085 |

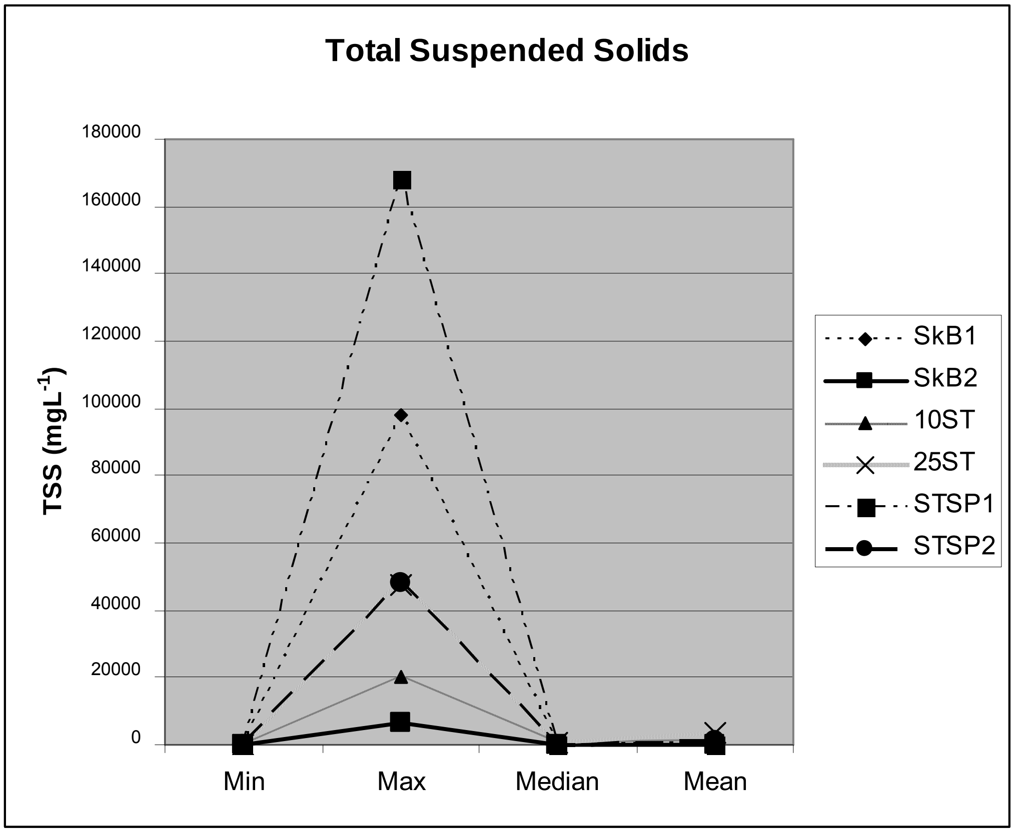

Figure 16. A comparison of all six devices TSS values.

There were between 3-35 storm events monitored among the six devices, with total precipitation ranging from 0.03 – 9 inches in each event (Table 4). Most devices were monitored for approximately one year, but STSP2 and SkB2 had jeopardized watersheds, not allowing for lengthy observations. The flow rate of discharge for each site varied but specifically looking at the skimmer basins there was a noticeably lower overall rate of discharge due to the controlled release of water through the 2” orifice. Because of its larger size and the fact that it had to fill completely before significant discharge occurred, less water was discharged.

Table 4. Storm total ranges for each device, including rainfall.

| | | Storm Ranges | | | |
|---|---|---|---|---|---|
| Device Name | Monitoring Period | Total Rain Events | Rainfall | Sediment Discharged | Sediment loss |
| | dates | # | (inches) | (tons) | tons ac$^{-1}$ |
| 25-year Skimmer Basin (SkB1) | March 20, 2006-April 18, 2007 | 35 | 0.12-2 | 0.001-75[†] | 0.0003-22[†] |
| 25-year Skimmer Basin (SkB2) | October 22, 2005-December 23, 2005 | 4 | 0.03-1.5 | 0.3-8 | 0.2-6 |
| Standard 10-year Trap with Standing Pool 1 (STSP1) | April 7, 2006-March 2, 2007 | 17 | 0.4-9 | 0.002-19<br>0.002-3.4<br>(w/o October storm) | 0.001-9.5<br>0.001-1.7 |
| Standard 10-year Trap with Standing Pool 2 (STSP2) | April 13, 2007-May 12,2007 | 3 | 0.25-0.75 | 0.1-9 | 0.1-9 |
| Standard 10-year Trap (10ST) | October 7, 2005-February 23, 2006 | 18 | 0.03-1.5 | 0.002-1.6 | 0.0008-0.64 |
| *Standard 25-year Trap (25ST) | October 22, 2005-August 22, 2006 | 29 | 0.04-3.6 | 0.006-3.6 | 0.0002-1.2 |

* Estimations only based on visual survey.

[†] Includes period when skimmer was mired in mud.

For STSP1, we calculated discharge rates and trapping efficiency for both with and without the October storm (1.7”) event because it represented the majority of the sediment discharged from that trap. There was no evidence of sampler problems or other errors, and it could have been the result of grading activity in the watershed, but the sediment discharge was unusually high for that trap during that storm. Overall, the range in sediment loss was the lowest in the SkB1 (prior to complications with maintenance) compared to the traps.

The amount of discharged sediment varied widely, from as little a 2.2 lb to as much as 75 tons. This corresponded to 0.0003-22 tons ac$^{-1}$ using the design area for each device. The highest discharges occurred in the SkB1 after the skimmer became buried in the sediment. This forced the skimmer to expel only sediment and little to no water. This brings in the importance of maintenance for these devices. Even over sized and well designed basins need monitoring. Areas under construction produce as much sediment as several years of urban runoff (Pitt et al, 2007). Maintenance is absolutely essential in delivering maximum efficiencies.

Figure 17. Level spreader at outflow of skimmer. Not maintained and full of sediment backing up into discharge pipe.

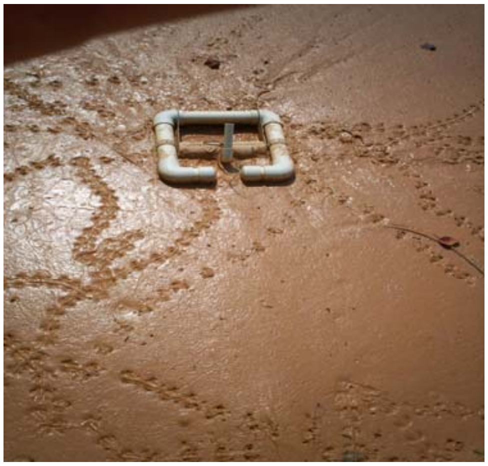

Figure 18. Faircloth Skimmer submerged and clogged with sediment.

The overall trapping efficiencies for the devices followed the expected pattern, although the actual numbers were surprising. The traps had 34-57% trapping efficiencies, even lower than those reported by Line and White (2001). The 25ST efficiency rating (96%) was based strictly on visual estimations due to errors in the actual surveying, so this may be an overestimate. This trap also never had the full area of runoff coming into it for the design due to bypass flow associated with the haul road. The amount of sediment delivered to the traps ranged from about 9 tons to over 38 tons, yet the efficiencies were very similar. Leaving out the one major sediment discharge event for STSP1 brought the efficiency up to 73%, which actually makes some sense considering the beneficial effects of a standing pool (Bidelspach and Jarrett, 2004). This event accounted for 81% of the total sediment discharged from this device even though the rainfall was only 1.2” over 24 hours, while there were four events which had more rainfall. It is possible that this event generated that much sediment, but it didn't fit the pattern for the other events.

The SkB1 and was extremely efficient, trapping more than 99% of the sediment entering it from March 20, 2006 to August 22, 2006. The combination of larger size, porous baffles, and surface outlets, along with better construction techniques, was clearly effective in retaining sediment. It is important to note, however, that the SkB1 was still discharging water with an average turbidity of more than 800 NTU and the peak turbidity was similar to the other devices at almost 30,000 NTU. This illustrates the difficulty in settling the finer particles entrained in construction site runoff. Between the dates of August 30, 2006 and April 18, 2007 however, the results change dramatically when the skimmer became settled in the sediment that had accumulated within the basin. The area which was designated for the skimmer to rest in was filled with sediment causing serious discharge problems. The basin discharged 120 tons of sediment during these monitored months compared to a total of 122 tons for the life of the basin. The final survey done on the basin showed a 76% trapping efficiency rate. This decrease in efficiency was due to the lack of maintenance performed in the latter part of the monitoring period, possibly due to the difficulty of accessing this basin.

The SkB2 was also very efficient with an overall 90% sediment retention. This basin was only monitored for a short period of time due to a number of factors. There was a spring which constantly fed the basin, which of course is not representative of storm runoff and would artificially dilute runoff that did come into the basin. For some period, the runoff that was collected entered the basin in the middle, bypassing much of the basin. Finally, the spillway eroded on the back side and had to be repaired. At that point, we looked for another basin.

Table 5. Trapping efficiency for each site.

| Trapping Efficiency for each site | 25-year Skimmer Basin (SkB1) | 25-year Skimmer Basin (SkB1) | 25-year Skimmer Basin (SkB2) | Standard 10-year Trap with Standing Pool 1 (STSP1) | Standard 10-year Trap with Standing Pool 2 (STSP2) | Standard 10-year Trap (10ST) | Standard 25 year Trap (25ST) |
|---|---|---|---|---|---|---|---|
| | 03/20/06–08/20/06 | 8/30/06 – 04/18/07 | 10/22/05-12/23/05 | 04/07/06-03/02/07 | 04/13/07-05/12/07 | 10/07/05-02/23/06 | 10/22/05-08/22/06 |
| Sediment Entered (tons) | 424 | 506 | 108 | 37 | 38 | 9 | 212 |
| Sediment lost (tons) | 2 | 121 | 11 | 24 | 17 | 6 | 9 |
| Sediment Captured (tons) | 422 | 385 | 97 | 13 | 21 | 3 | 203 |
| % efficiency | **99.6%** | **76%** | **90%** | **34%** | **57%** | **35%** | **96%** |

## Particle Size Analysis

An analysis of the particle size distribution of soil samples taken from within each device was done. Core samples were taken (1) near the entrance (2) in the middle and (3) near the outlet of each device. The most efficient design would most likely have settled the sand portion of the sediment load nearer the inlet, as indicated by a higher sand content in those cores. The two skimmer basins (SkB1 ankd SkB2) did have a drop in sand content from the inlet to the outlet, while two of the standard traps (STSP1 and 10ST) had very little change in sand content throughout the trap (Figure 19). The second standard trap with a standing pool (STSP2) was only monitored for a three storms so the sediment distribution was not likely well established. The oversized standard trap (25ST) did have a very large drop in sand content near the outlet, with little difference in the inlet and middle samples. This was probably due to the low flows in this trap, which had a fan of heavier materials spreading out from the inlet. Previous work has shown that porous baffles substantially reduce velocity and turbulence in water moving through these devices compared to those that had none and the heavier fractions are more efficiently trapped (Thaxton, et. al., 2004; Thaxton and McLaughlin, 2005).

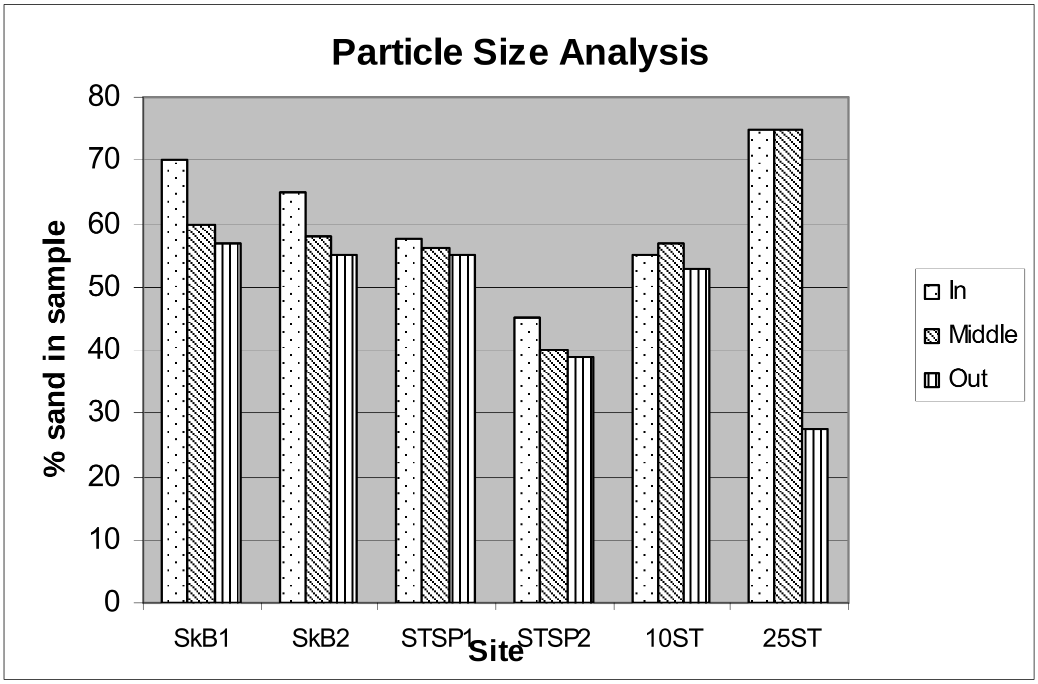

Figure 19. Sand content for soil samples taken within the devices at the end of the monitoring period..

## CONCLUSIONS

The effectiveness of sediment control devices was studied on this construction site to determine the effects of different designs and conditions. Sediment trapping and discharges strongly suggested that commonly used designs are relatively ineffective. The four devices with rock dam outlets had sediment retention of <57% of sediment entering the traps and discharged up to 20 Mt ac$^{-1}$ during the 12 months of monitoring. In contrast, the SkB1 and SkB2 design, with surface outlets, stable sides and inlets, and porous baffles, retained more that 90% of sediment entering them, as long as they were properly maintained.

While the SkB1 retained most of the sediment entering it, the discharges were still relatively turbid (891 NTU avg.) and contained considerable TSS (537 mg L$^{-1}$ avg.). It is likely that the remaining suspended materials are very fine and will not settle by gravity alone under typical retention times. However, the improvement in sediment retention alone will significantly reduce the impacts of land disturbances from construction activity on water quality in nearby streams.

In comparing the six different devices, the skimmer basins had the greatest trapping efficiencies. This would indicate that some combination of increasing the surface area, the volume, a surface outlet, and porous baffles greatly improves trapping efficiencies. Because of the nature of this study, there were many variables which were not controlled and so the comparisons between the devices cannot be precise in what variable was the most critical. However, it was clear that the standard traps were significantly worse for trapping sediment than those with recently developed refinements. The trapping efficiencies were somewhat lower than those reported by Line and White (2001) for similar rock-outlet devices.

By most regulatory standards, the three traps likely failed to provide adequate retention of sediment. The current standard is for 70% retention of 40 um size sediment, which was probably not achieved. They also tended to have a lower proportion of sand in the sediment compared to the better performing basins, suggesting that they were releasing more coarse materials. Rock outlet devices tended to have significantly higher peak turbidity and TSS compared to those with surface outlets.

Strong correlations between turbidity and TSS were found for all traps and basins. The slope factors were quite different among the tested sites, which are probably related to the particle size distribution of the suspended materials. Lower slope factors were found with devices with higher efficiencies and sand retained, suggesting the suspended sediment was higher in clay and therefore had less TSS per unit of turbidity.

Sediment analysis of the basin/traps indicated that a large amount of the sediment being captured was sand. To increase the capture rate of the silt and clay particles, the basin/trap needs to be equipped for longer settling times, which in turn increase the overall efficiency rates.

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