Minimizing Water Quality Impacts of Road Construction Projects

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16. Abstract

This study was initiated to determine the potential impacts of sediment from a large construction project on nearby streams, and to evaluate approaches to reduce those impacts. There were three main aspects of the project, which was located at the construction of Interstate 485 on the northwest side of Charlotte: evaluate ground covers, test and evaluate sediment capture using different designs, and quantify the current conditions of a stream that parallels the project. The clearest improvements over the standard straw + tackifier occurred as the result of adding polyacrylamide (PAM), which usually reduced erosion considerably. There was no obvious advantage of PAM in establishing vegetation, however. Among the alternative ground covers, the results were inconclusive due to high variability. The bonded fiber matrix product appeared to have the lowest erosion rate but excelsior was also usually low. The vegetation may have been favored by excelsior compared to the other covers, but the differences were not large. A system of ditch lining and frequent check dams, stabilized basin inlets, porous baffles, and skimmer/spillway outlets clearly reduced the magnitude of sediment loss from disturbed areas. Turbidity reduction by PAM was evident during low flow events or portions of events. Methods for dosing higher flow events with PAM need to be investigated as a method to reduce turbidity, which usually cannot be removed economically any other way. The structures installed to divert water and remove sediment often generate significant amounts of sediment. Unlined, deep perimeter ditches were a major source, and sediment traps with vertical walls and unprotected inlets also were sources. Large disturbances in a watershed will impact water quality using current systems for erosion and sediment control. There was no evidence that the aquatic biology of Long Creek changed over the four years of various levels of disturbance. However, it was in poor to fair condition biologically when we initially sampled in 2003. There was no evidence of increased bank erosion during the period 2003-2006 when we surveyed Long Creek. These surveys were intended primarily as baseline information for surveys 5-10 years from now, when the watershed becomes even more densely developed.

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DISCLAIMER

EXECUTIVE SUMMARY

1. **Ground Covers:**
    a. **The clearest improvements over the standard straw + tackifier occurred as the result of adding PAM, which usually reduced erosion considerably. There was no obvious advantage of PAM in establishing vegetation, however.**
    b. **Among the alternative ground covers, the results we inconclusive due to high variability. The bonded fiber matrix product, Flexterra, appeared to have the lowest erosion rate but excelsior was also usually low. The vegetation may have been favored by excelsior compared to the other covers, but the differences were not large.**
2. **Sediment Control:**
    a. **A system of ditch lining and frequent check dams, stabilized basin inlets, porous baffles, and skimmer/spillway outlets clearly reduces the magnitude of sediment loss from disturbed areas.**
    b. **Turbidity reduction by PAM was evident during low flow events or portions of events. Methods for dosing higher flow events with PAM need to be investigated as a method to reduce turbidity, which usually cannot be removed economically any other way.**
    c. **The structures installed to divert water and remove sediment often generate significant amounts of sediment. Unlined, deep perimeter ditches were a major source, and sediment traps with vertical walls and unprotected inlets also were sources.**
        i. **Perimeter and diversion ditches should be only as deep as necessary, usually 1-2 feet at most, and should have sloped walls. Lining with geotextile will also reduce the contribution of these conveyances to sediment leaving the site.**
        ii. **Additional check dams with protection from downslope erosion (geotextile), such as the Triangular Silt Dikes or wattles with matting, also reduce loads.**
        iii. **Sediment traps and basins should have stabilized inlets to avoid erosion. The sides should be cut back and stabilized with vegetation or erosion control blankets, or both.**
3. **Streams:**
    a. **Large disturbances in a watershed will impact water quality using current systems for erosion and sediment control.**
    b. **There was no evidence that the aquatic biology of Long Creek changed over the four years of various levels of disturbance. However, it was in poor to fair condition biologically when we initially sampled in 2003.**
    c. **There was no evidence of increased bank erosion during the period 2003-2006 when we surveyed Long Creek. These surveys were intended primarily as baseline information for surveys 5-10 years from now, when the watershed becomes even more densely developed.**

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INTRODUCTION

Erosion and sediment control on construction sites is an increasingly important aspect of project management. Most erosion control practices which are currently implemented as part of a sediment and erosion control plan are intended to prevent erosion through diversions, mulching, and seeding. Sediment control is designed to slow runoff to allow entrained soil to settle. This combination may be effective in retaining a large portion of potential sediment within the construction site, but runoff is likely to remain highly turbid. The suspended solids concentration in the discharge water has adverse impacts on the receiving waters and may result in complaints from the public.

Any change within and around a channel typically results in a period of instability and adjustments to reestablish a state of dynamic equilibrium with the sediment load and discharge of the stream (Leopold et al, 1964, Harvey et al., 1986, Simon, 1989 and Rosgen, 2000). This can result in excessive stream bank erosion rates, which is a major cause of non-point source pollution (Rosgen, 2001). Extensive streambank erosion rates tend to create a loss of instream habitats, leaving a homogenized environment due to excessive sedimentation (Waters, 1995, and Brooks et al., 2002).

Sedimentation is the greatest pollutant affecting the biology of streams (Waters, 1995). Macroinvertebrates, inhabit the channel bottom substrates (bedrock, cobble, sand or fine clay and silt sediments), leaf material, fallen wood debris and submerged roots or aquatic vegetation. High sediment deposition deteriorates these habitats and can deplete the taxonomic richness of the stream (Waters, 1995). Benthic macroinvertebrates also provide a trophic link between detrital organic resources and other aquatic species such as fish. Excessive sediment deposition not only impacts macroinvertebrate production, but also impacts food resources for fish.

The use of polyacrylamide (PAM) to reduce soil erosion has been receiving increasing attention in recent years. One of the most widely published uses is in furrow irrigation systems, in which PAM is added to the irrigation water to prevent erosion of the furrows (Lentz et al., 1992; Lentz and Sojka, 1995; Lentz et al., 1998). By adding PAM to the irrigation water, furrow erosion was reduced by up to 94%. This has become a standard practice among growers in many states in the western U. S. More recently, PAM is being tested for use for erosion control on exposed soil surfaces (Tobiason et al., 2000; Roa-Espinosa et al., 1999; Flanagan and Chaudhari, 1999). Erosion was reduced up to 93% and turbidity was reduced up to 82% in these test plots compared to bare soil. Numerous private firms are selling various products containing PAM to be added to seed/mulch mixes when they are applied to construction sites.

Clarifying runoff water before discharging it from a construction site is another approach to meeting regulatory guidelines. Przepiora et al. (1997, 1998) found that calcium sulfate in the form of molding plaster could successfully reduce turbidity in sediment basins to meet the 50 NTU (nepelometric turbidity units) requirement in North Carolina, although retention times could be up to two days. The plaster was added to the basins by hand. Turbidities of less than 10 NTU have been achieved when the runoff was stored and treated with PAM (Minton and Benedict, 1999). This was essentially a water treatment plant system, with pumps and multiple settling basins, and was estimated to cost up to 1.5% of the total construction costs.

There has been some concern about the potential for PAM to be toxic to aquatic species. PAM can be synthesized to be cationic, non-ionic, or anionic. The cationic form is known to be somewhat toxic to fish due to binding to their gills, so most tests of PAM in erosion and sediment control have been of anionic variety. Tobiason et al. (2000) report that the anionic PAM they are using was not found to be toxic to test species at their sites. An excellent review of toxicological issues and testing can be found on the Washington State Department of Transportation web site. In summary, PAM is used widely to treat municipal water supplies, wastewater, and as a food processing aid and is not considered a problem in those applications. Even cationic PAM is relatively non-toxic to fish when the aquatic environment includes humic acid at typical concentrations. The building block of PAM, acrylamide, is considered a human health hazard, but PAM itself is regulated to contain <0.05% acrylamide and does not break down into acrylamide in the environment.

OBJECTIVES

Highway construction usually requires large areas of disturbance in order to be cost efficient. This creates the potential for accelerated erosion and impacts on local streams and lakes. Additional tools, or Best Management Practices (BMP's), needed to be tested, demonstrated, and refined to obtain reductions in sediment and, in particular, turbidity beyond current practices.

The project goals were:

1. Compare a variety of erosion control systems for effectiveness, including combinations of standard straw, polyacrylamide, rolled erosion control products, and bonded fiber or wood fiber matrix mulching.
2. Install, evaluate, and improve (as needed) systems to increase sediment and turbidity control in standard and modified traps and basins.
3. Establish baseline information on stream water quality and stability in small watersheds as affected by the installation of standard and innovative erosion, sediment, and turbidity control systems.
4. Establish stream water quality and stability in small watersheds which are impacted by NCDOT and, by comparison, other commercial/residential development.
5. Establish the current stability of Long Creek and four tributaries and measure changes annually.
6. Conduct annual benthic macroinvertebrate and habitat surveys at five points along Long Creek and in two tributaries.
7. Conduct workshops, demonstrations, and training for staff from NCDOT, NCDENR, local programs, and private contractors.

MATERIALS AND METHODS

Effectiveness of Ground Cover

We applied different materials and ground covers to three sites as demonstrations or preliminary tests and an additional three sites for replicated, comprehensive testing. In all cases were included some testing of PAM, and at most sites were also used alternatives to straw as ground covers. For the replicated testing, we established eighteen plots, usually 25 by 20 feet unless space limitations required somewhat smaller plots. Six different treatments were replicated three times at each of these sites. These will be described for each site in the results section. Plastic landscape edging was installed into each plot in a V-shape 19 ft from the top corners of the individual plot. A small opening at the notch of the V-shape edging was connected and sealed to a pipe that drained into a 5 gallon bucket. Runoff in the bucket was measured for volume and then subsampled for laboratory analysis for turbidity and total suspended solids (TSS).

TSS and Turbidity Assessment

Instream, sediment traps, sediment basins, stilling basins and other sediment trapping devices were monitored for turbidity and TSS using ISCO automated samplers. We attempted to capture influent and effluent samples for each study site, although high sedimentation rates often buried intake. High sedimentation rates led to the use of surveying the basin with a total station. Surveys were conducted immediately following construction and following a period of rainstorms. This allowed us to calculate the amount of sediment accumulated over a period of rainfall/storms. If the basins sediment was cleaned out, the basin would be re-surveyed and the basin would then be surveyed after a certain amount of time/rainfall. Weirs (V-notch or rectangular) were installed, according to ISCO manual guidelines, where possible to determine flow based turbidity and sediment loading rates. All samples collected were sent for laboratory analysis.

Instream Morphological Assessment

The current stability of Long Creek and its tributaries were assessed using physical measurements of the channel dimension, substrate composition, turbidity and TSS. Permanent cross-sections were established along the main channel and tributaries of Long Creek following techniques described in the USDA Forest Service protocols (1994). Bankfull stage was determined within the Long Creek watershed using regional curves developed by North Carolina State University Stream Restoration Institute (NCSU SRI) (Harman et al., 1999). Width to depth ratios (W/D) developed by Rosgen (1996) to asses the stability of a stream, was calculated from surveyed field data. Any drastic changes in W/D ratios indicate instability within the channel that often leads to degradation and aggradation (Rosgen, 1996). Relationships between BHR and W/D ratio to a stream's stability were assessed following ratings developed by Rosgen (2001). Pebble counts were conducted following Wolman (1954) techniques as described in the USDA Forest Service protocols (1994). Reach wide pebble counts were collected before and after restoration within the restored reach at the time of cross-section survey. The median particle size (d50) and substrate percent composition were analyzed to determine shifts in bed material. ER, W/D ratio, sinuosity, slope and channel material (d50) were calculated to classify Long Creek and its tributaries using Rosgen's (1996) stream classification system.

Instream Biological Assessment

The distribution of benthic macroinvertebrates within Long Creek and its tributaries was evaluated in the spring of 2003, 2004 and 2006. Field and laboratory procedures followed protocols described by SCDHEC certified lab #39569001 of Clemson University Department of Forest Resources, Water Resources Macroinvertebrate Laboratory.

RESULTS

BMP Implementation

Effectiveness of Ground Cover

A variety of erosion control systems were compared to evaluate their effectiveness for reducing turbidity, runoff volume and rill formation. Combinations of standard straw, rolled erosion control products, bonded fiber matrix, wood fiber or cotton mulching and polyacrylamide (PAM) were applied on slopes within the I-485 corridor. All sites are listed below with results and conclusions.

Bellhaven Boulevard Site

Excelsior and standard straw, both with and without PAM were tested at this site (Figures 1.1 and 1.2). The plots were not replicated and so these results should be considered a demonstration only. Results have shown including PAM into standard erosion control applications aids in preventing rills/erosion from occurring (Figures 1.3 and 1.4). Excelsior with PAM showed a volume decrease (60% and 53%) in both storms (Figure 1.5 a and b). However, straw and PAM only showed a volume decrease (85%) in the first storm (Figure 1.5 a and b). In absolute volume, the effect of the PAM was much greater during the first storm event. Both straw and excelsior with PAM showed a significant turbidity reduction greater than 50% for both storms (Figure 1.5 a and b). Although conditions were favorable, very little grass emerged during this test, either due to poor seed quality or low seeding rates. An adjacent area was treated with municipal compost and seeded separately, but we did not collect data from this area.

Figure 1.1. Plot overview, including the compost-treated plot (green).

Figure 1.2. Runoff from PAM-treated plot showing flocculated sediment.

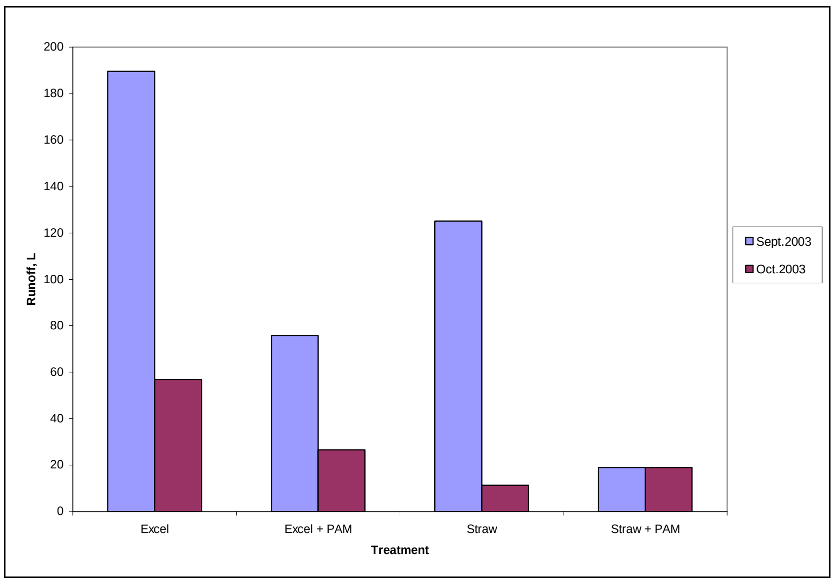


Figure 1.3. Runoff volume from Bellhaven plots.

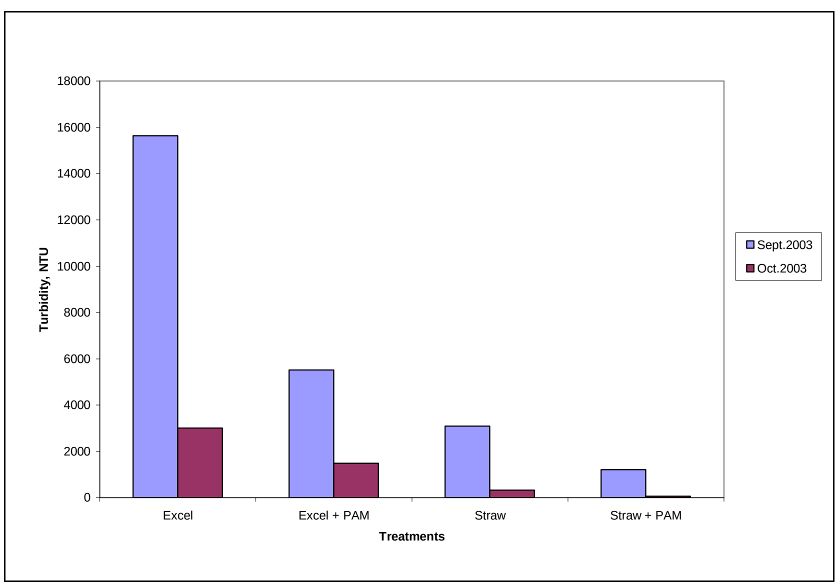
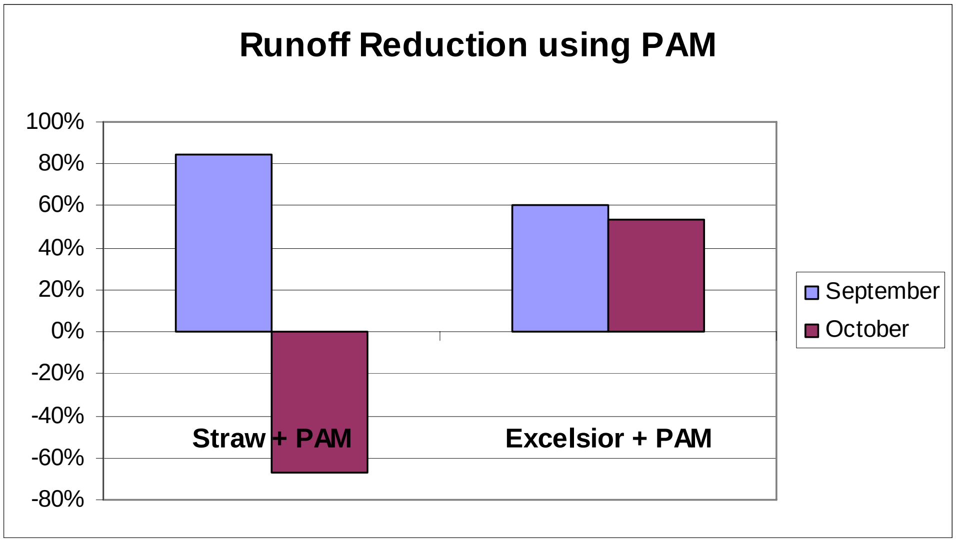
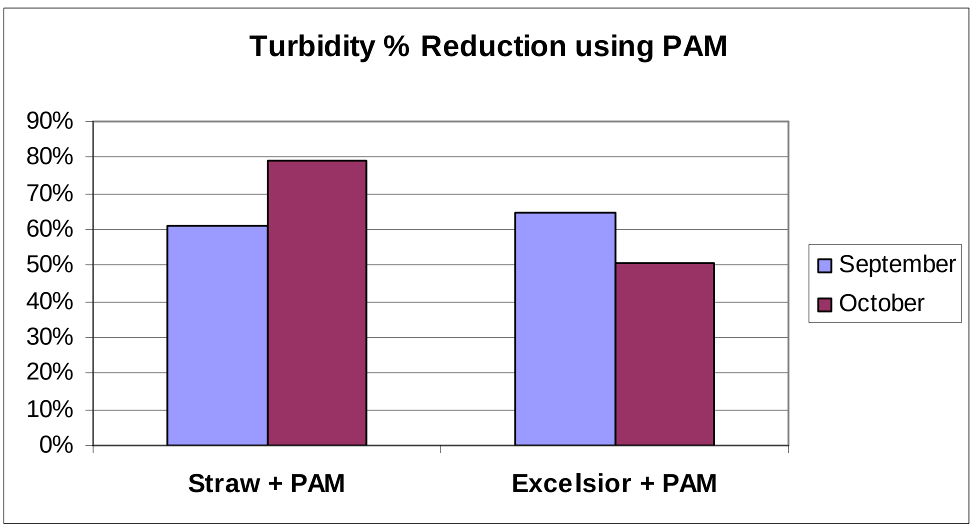


Figure 1.4. Turbidity levels from Bellhaven plots.



(a)



(b)

Figure 1.5. Bellhaven Boulevard intersection tests using PAM application (40 lb/ac as solution) with standard straw and excelsior matting. a. volume reduction and b. turbidity reduction.

Oakdale Road Site

A second demonstration area was established at the Oakdale Road overpass. A standard mixture of wood fiber mulch and seed with without and with PAM was applied to two sections (Figure 1.6 a and b). A seed mixture and PAM was applied to a third section already stabilized with straw and asphalt tackifier (Figure 1.6 c). All plots were fifty feet in length. No water sampling was attempted as we were interested in grass growth primarily. Grass growth between treatments was not noticeably different, but inclusion of PAM seemed to help slope stability (Figure 1.7). The study was cut short due to new grading activities in preparation for bridge installation (Figure 1.8).

(a) (b) (c)

Figure 1.6. Oakdale Rd I hydroseeding plots June 2005. a. Wood hydromulch. b. Wood hydromulch + 20 lb/ac PAM. c. Straw + tackifier + 20 lb/ac PAM.

(a) (b) (c)

Figure 1.7. Oakdale Rd hydroseeding plots July 2005. a. Wood hydromulch. b. Wood hydromulch + 20 lb/ac PAM. c. Straw + tackifier + 20 lb/ac PAM.

Figure 1.8. Newly established grade and cover at the Oakdale Road overpass site.

Oakdale Road Area Plots

A third demonstration area was established just east of Oakdale Road. The site was a 2:1 fill slope recently stabilized by the seeding contractor. We applied PAM (23 lbs/ac) on a section of slope that previously had seed, straw and fertilizer applied. We also applied the same amount of water without PAM on a second section. Each section was approximately 38 feet in length and 100 feet wide. Figure 1.9 shows the PAM plot at establishment (November) and Figure 1.10 shows them two months later (January). Figure 1.11 shows the slope without any PAM treatment. There were no obvious differences in grass growth, but the PAM appeared to have less rilling after two months (Figure 1.11).

(a) (b)

Figure 1.9. Oakdale PAM plot at establishment in November 2005 a. left side of plot. b. right side of plot.

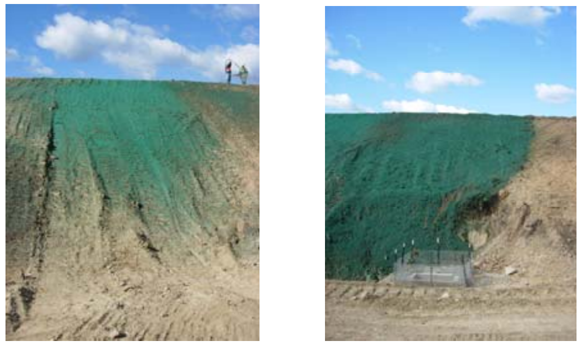
(a) (b)

Figure 1.10. Oakdale PAM plot in January 2006. a. right side of plot. b. left side of plot.

Figure 1.11. Oakdale plot with only standard straw mulch in January 2006.

Statesville Road Overpass

An area was also selected for a demonstration of wood fiber hydromulch and PAM at the Statesville Road overpass. However, at the time of our application, the slope was roughly graded very uneven. Because were had our materials and hydroseeder there, however, we did apply the mulch and PAM as planned. A mixture of wood fiber mulch without and with PAM was applied to two 40 x 50' sections (Figure 1.12a and b, respectively, below) over bare ground without seed, straw or fertilizer. A PAM solution was applied to another 50 ft section over standard straw, seed and fertilizer (Figure 1.13 c). Visual assessments seem to indicate the inclusion of PAM helped to maintain slope stability over the bare and seeded/straw ground cover (Figure 1.13a, b). No significant rills/erosion seemed to have formed (Figure 1.13 a, b and c).



(a) (b)

Figure 1.12. Statesville Road hydromulching plots October 2005. a. wood fiber b. wood fiber + PAM.

(a) (b) (c)

Figure 1.13. Statesville Road hydromulching plots January 2006. a. wood fiber b. wood fiber + PAM and c. seed, straw, fertilizer + PAM.

Brookshire Boulevard Area Plots

After completing the above series of demonstration tests, more comprehensive testing was initiated on a cut slope area near Brookshire Boulevard. This involved replicated treatment plots, runoff collection, and evaluation of the ground cover. We selected an area large enough to accommodate 18 plots 25' wide by 20' in length (slope length). Plots were established in three blocks of six randomly arranged plots. The treatments were standard straw + asphalt tackifier, wood fiber hydromulch, and excelsior matting, all with and without PAM at 33 lb/ac applied as a solution (Figures 1.14-1.15). On each plot, a runoff collection area was established by placing plastic garden edging in a "V" shape in the middle of the plot to channel water into a 4" pipe. The pipe carried the water down the slope to a 5 gallon bucket. This captured runoff from an area of approximately 88 ft^2 (18% of plot, or 0.002 ac). While this volume would only capture 0.1" of runoff, the water in the buckets is an indicator of relative erosion rates and potential runoff water quality. The volume of runoff in the buckets was recorded after each event and then the water was stirred vigorously and subsampled for laboratory analysis.

Turbidity was very high in the non-PAM treated plots after the first event, but declined sharply afterward (Figure 1.16). In all cases, the PAM treatment reduced turbidity significantly during that event. The PAM effect declined in the straw and excelsior plots, but continued to reduce turbidity in the wood fiber hydromulch plots. The straw and excelsior treatments tended to have similar turbidities while the wood fiber hydromulch tended to have higher turbidity, most likely due to areas of failure in the plots (Figure 1.15b). The total sediment followed the turbidity trends, with wood fiber hydromulch > straw > excelsior, and the PAM treatment reducing sediment losses at least initially (Figure 1.17). The hydromulch failure shown in Figure 1.15b resulted in very high sediment loads during the first several events, which partly explains the subsequent poor performance evaluation of this ground cover.

(a) (b)

Figure 1.14. Brookshire Boulevard area test plots a. application of PAM to excelsior plot. b. overview of all plots.

(a) (b)

Figure 1.15. Wood hydromulch without PAM a. February 2, 2006 b. February 10, 2006, showing some failure starting at mid-slope.

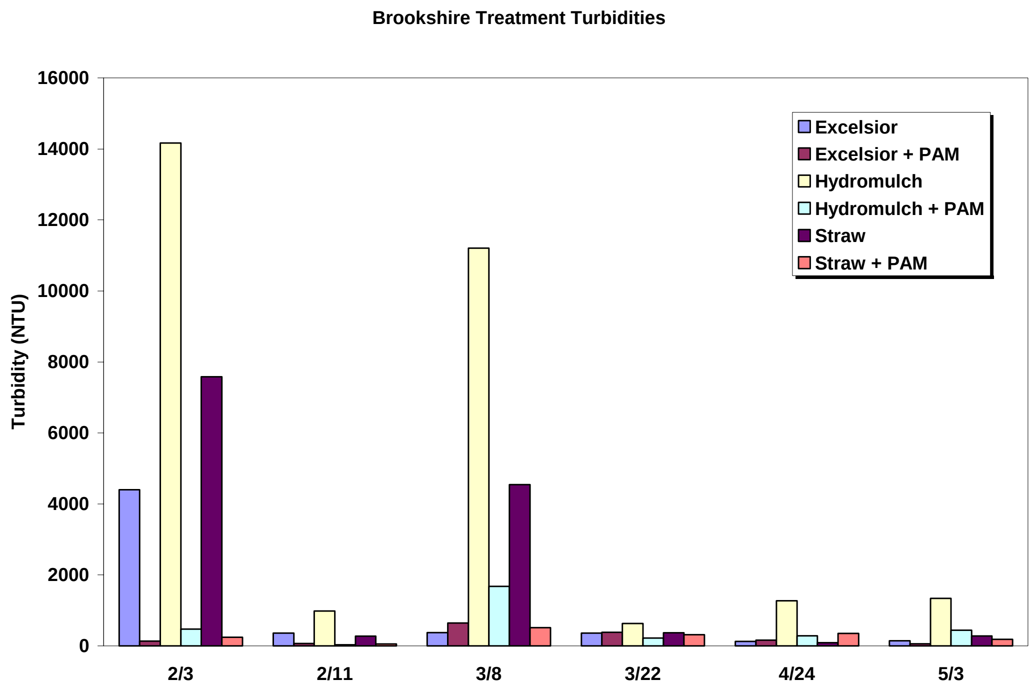


Figure 1.16. Turbidity for runoff from each storm event at the Brookshire Boulevard plots. Shown are averages of three plots per treatment.

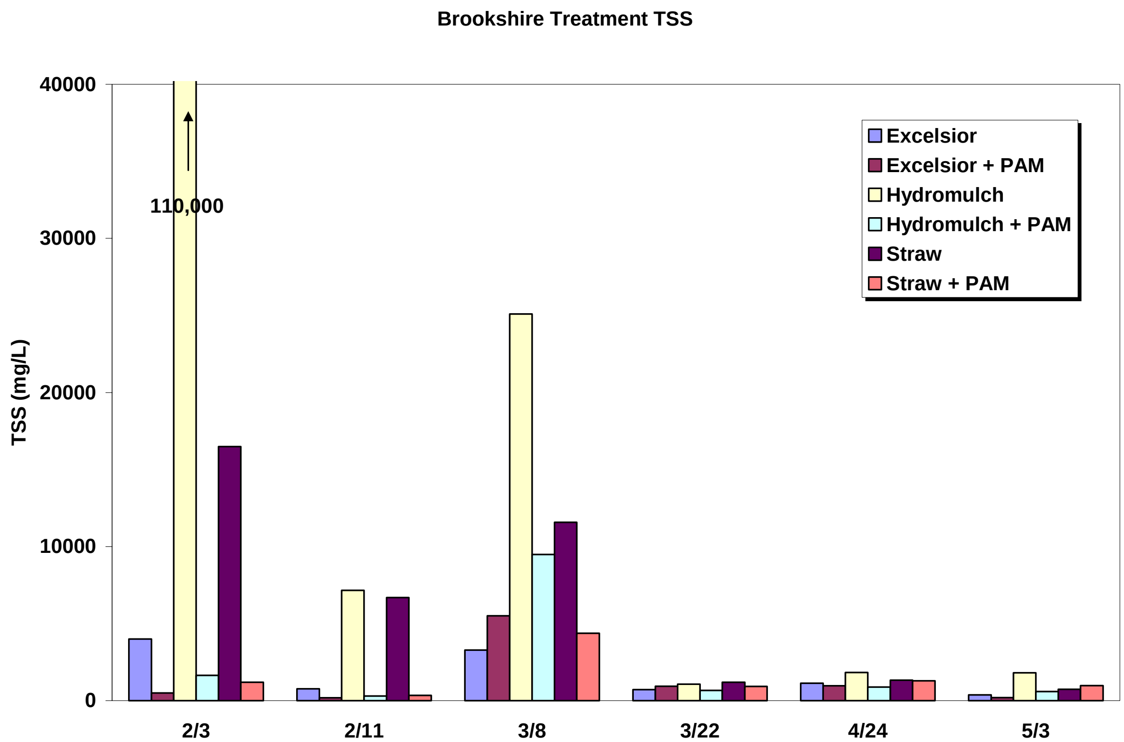


Figure 1.17. Total suspended solids in runoff from the plots at Brookshire Boulevard. Averages of three plots for each treatment.

When totaled over all storm events, there was no clear evidence of a PAM effect among the ground cover treatments (Table 1.1). However, both average turbidity and total sediment were reduced substantially for all three treatments. Most of this occurred during the first event. This is expected as the PAM effect is often reduced with each rain event. Straw alone was not substantially less effective than the other ground covers in total sediment loss, and was significantly better when PAM was added (Table 1.2). The exceptionally large difference with the wood fiber hydromulch is largely the result of the plot shown in Figure 1.15b, as previously noted.

Table 1.1. Effect of 33 lb PAM/ac on runoff from plots with three groundcover types. Positive values reductions compared to the untreated plots over all storm events.

Ground Cover	Total Runoff	Average Turbidity	Total Sediment
Straw	2%	79%	78%
Excelsior	-15%	75%	69%
Wood Hydromulch	-3%	79%	98%

Table 1.2. Comparison of sediment losses from straw or straw + PAM versus excelsior or wood hydromulch with no PAM. Values >100% represent higher losses than straw or straw + PAM, <100% represent lower losses.

	Straw	Straw + PAM
Excelsior	89%	231%
Wood Hydromulch	323%	7561%

Vegetative cover, as estimated by 4 different evaluators, was somewhat higher in the PAM treatments and lowest on the wood fiber hydromulch treatment (Figure 1.18), although the differences were not as dramatic as for the runoff samples. Biomass followed the same trend (Figure 1.19). Overall, grass growth was relatively uniform at this site, even though the tracking was apparently done across the slope instead of up and down the slope (Figure 1.20).

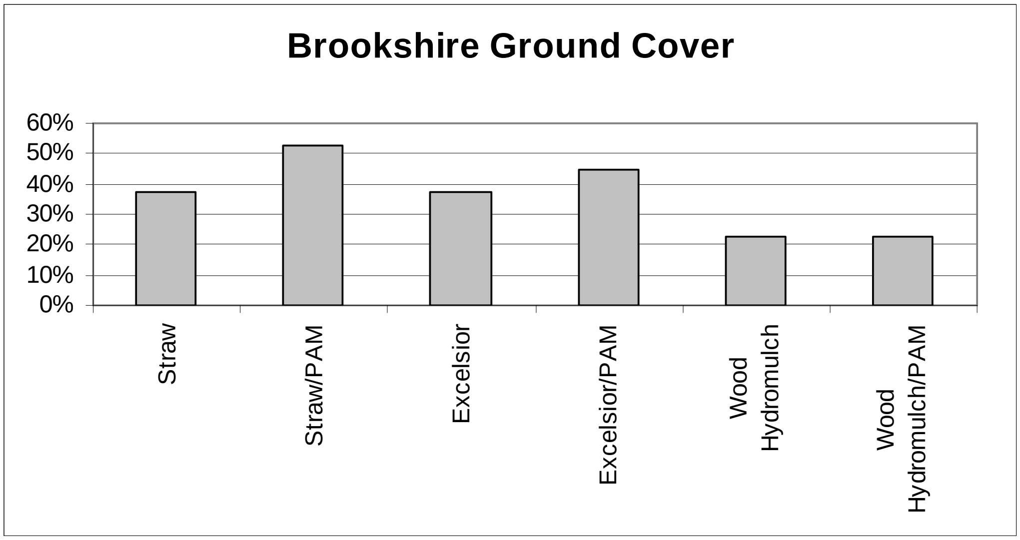


Figure 1.18. Vegetation cover for each treatment at the Brookshire Boulevard area site.

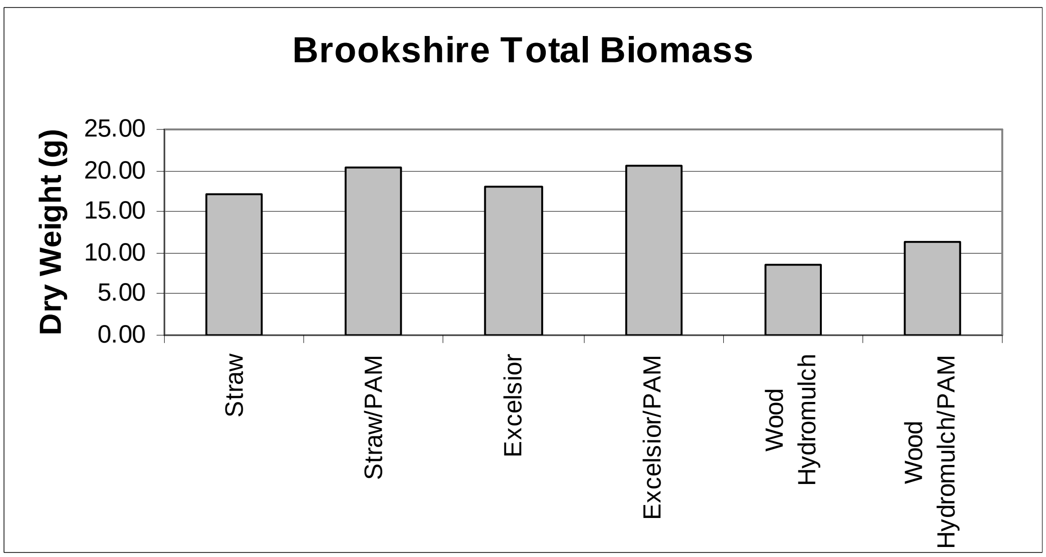


Figure 1.19. Total biomass collected from three 1 x 1 m subplots per plot. Average per treatment is shown.

Figure 1.20. Grass growth on a wood fiber hydromulch plot three months after planting.

Old Statesville Road Area Plots

A second full-scale ground cover test was located near the Old Statesville Road intersection with I-485. This was also a cut slope but slightly shorter than the Brookshire area plots, and the bank curved so that the plots faced slight different directions. There was a sunlight and moisture gradient, with plots in the first replication (Figure 1.21 a) have less sun and more moisture than the remaining plots (Figure 1.21 b). The plot layout and setup was the same as for the Brookshire plots, except that the plot length was 18’ instead of 20’. These were established in April instead of January, as well, so the conditions were warmer and also drier. We substituted Flexterra bonded fiber matrix for the wood fiber hydromulch and applied it at 3,000 lb/ac.

(a)

(b)

Figure 1.21. Old Statesville plots. a. Plots 1-5, and b. plots 6-18.

The straw plots again had the highest turbidity, but at this site PAM did not appear to be as useful in reducing it (Figure 1.22). The Flexterra ground cover had lower turbidities than the excelsior matting. A significant runoff event at the end of the evaluation (June) produced very high turbidity, relative to earlier events, in the straw plots but not in the excelsior or Flexterra plots. Overall, the greatest effect of PAM was in the Flexterra ground cover (Table 1.3), but the turbidity was quite low even without PAM in this treatment.

Sediment losses followed the turbidity results closely, but the straw and excelsior covers benefited more from PAM than Flexterra (Figure 1.23, Table 1.3). Both alternatives reduced sediment losses compared to straw, with excelsior reducing it by 75% and Flexterra by 91% (Table 1.4). Adding PAM to straw made it slightly better than excelsior in sediment losses, but Flexterra still reduced losses by 75%.

The coverage after two months of grass growth was better on the straw alone and both excelsior treatments compared to the straw + PAM and both Flexterra treatments (Figure 1.24). Biomass production was very similar in ranking, and the benefits of PAM were not evident in any cover treatment (Figure 1.25). For this location, the Flexterra had a clear advantage in reducing erosion but the grass did not grow as well as in the excelsior treatment. Visual assessments indicated that the excelsior matting had more evenly distributed grass growth compared to other treatments, which had most of the growth in the lower 1/3 of the slope.

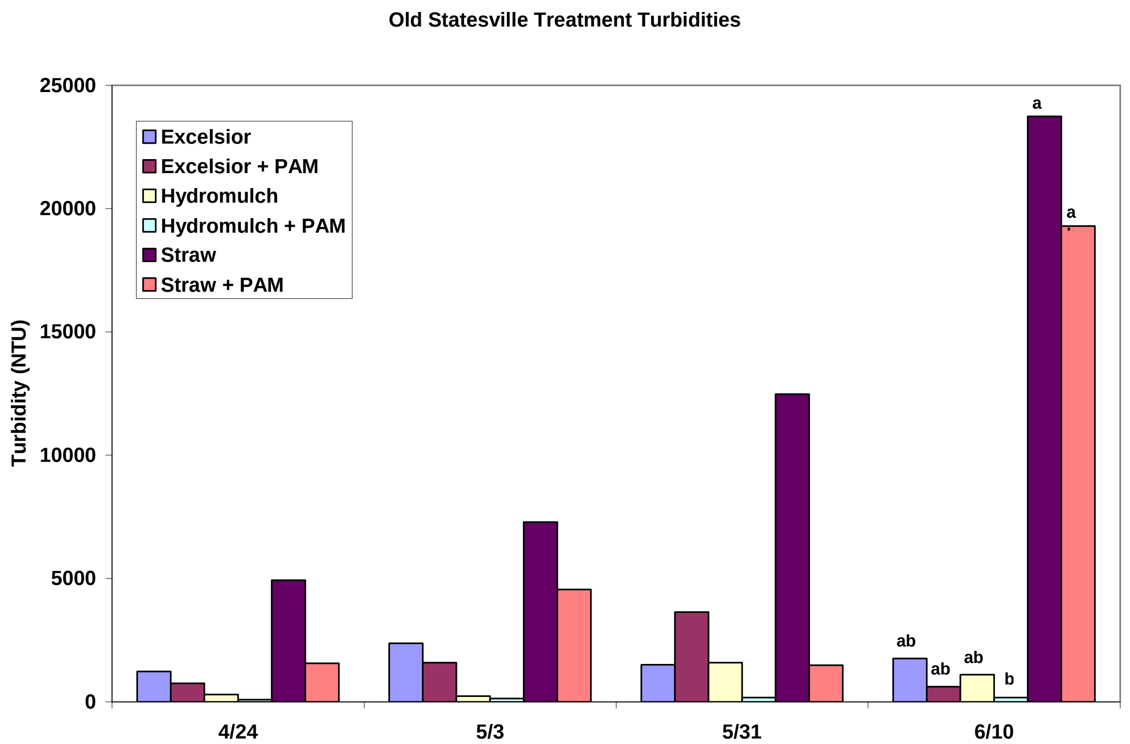


Figure 1.22. Turbidity in runoff from the plots at the Old Statesville Road site. Shown are averages of three plots per treatment. Bars with different letters are significantly different at P < 0.10.

Table 1.3. Effect of 33 lb PAM/ac on runoff from plots with three groundcover types. Positive values reductions compared to the untreated plots over all storm events.

Ground Cover	Total Runoff	Average Turbidity	Total Sediment
Straw	-1%	19%	49%
Excelsior	20%	16%	51%
Flexterra Hydromulch	-18%	77%	20%

Table 1.4. Comparison of sediment losses from straw or straw + PAM versus excelsior or Flexterra with no PAM. Values >100% represent higher losses, <100% represent lower losses.

	Straw	Straw + PAM
Excelsior	25%	131%
Flexterra Hydromulch	9%	33%

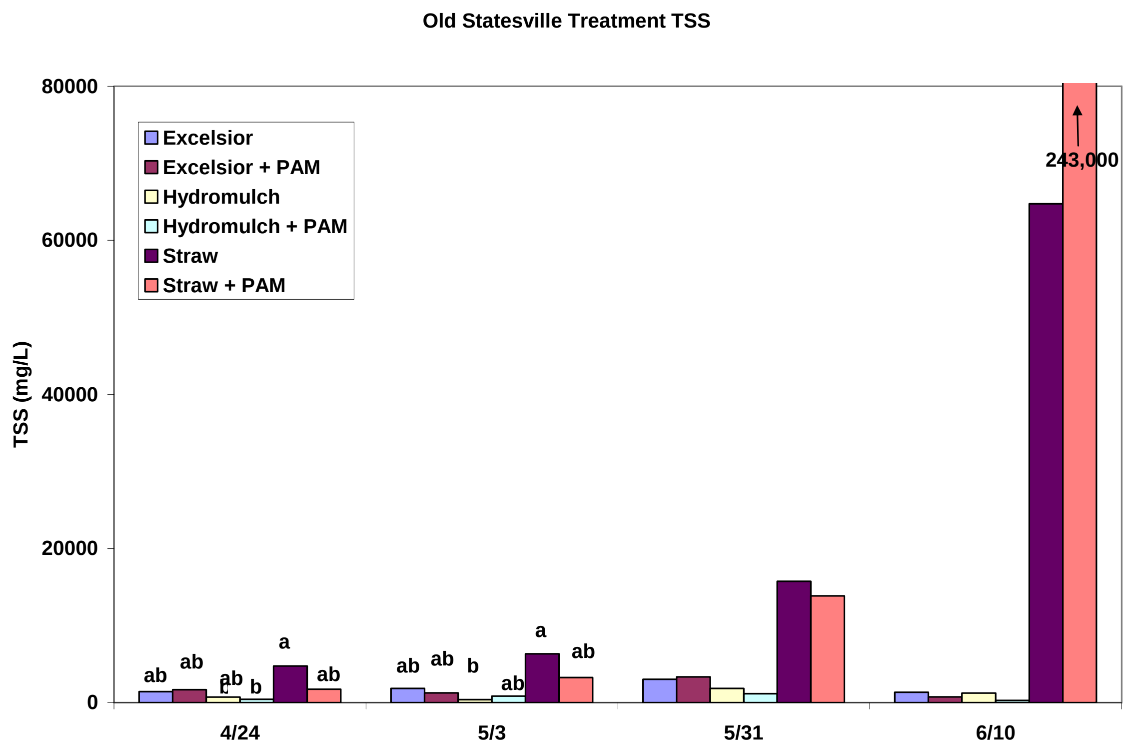


Figure 1.23. Total suspended from treatments from the Old Statesville Road plots. Bars with different letters are significantly different at $P < 0.10$. *Straw/PAM results include one plot for the June 10 event with abnormally high sediment compared to all other data.

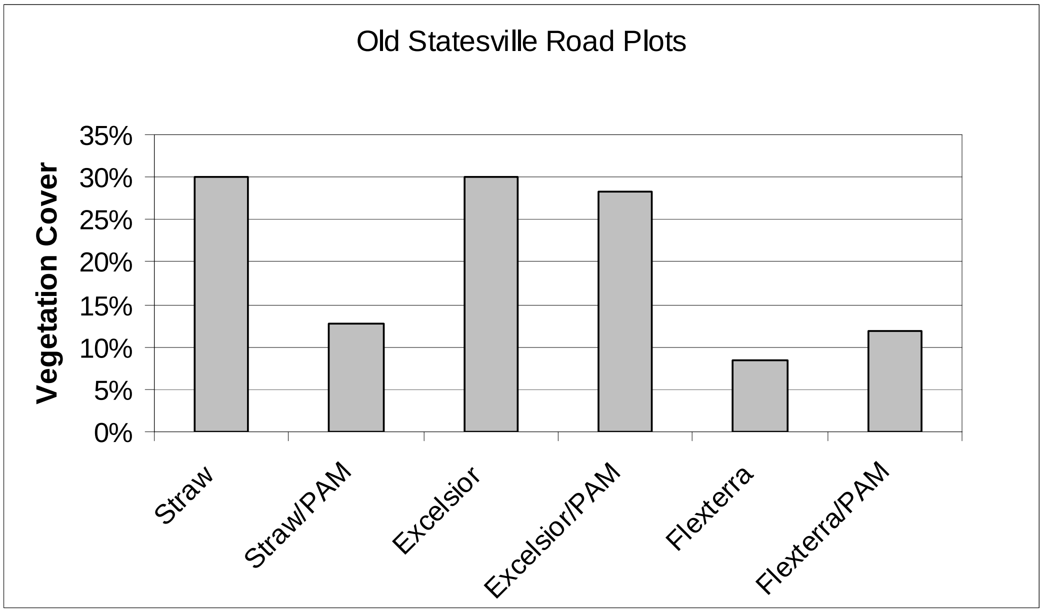


Figure 1.24. Vegetation cover on plots at the Old Statesville Road site, measured in June, approximately two months after establishment.

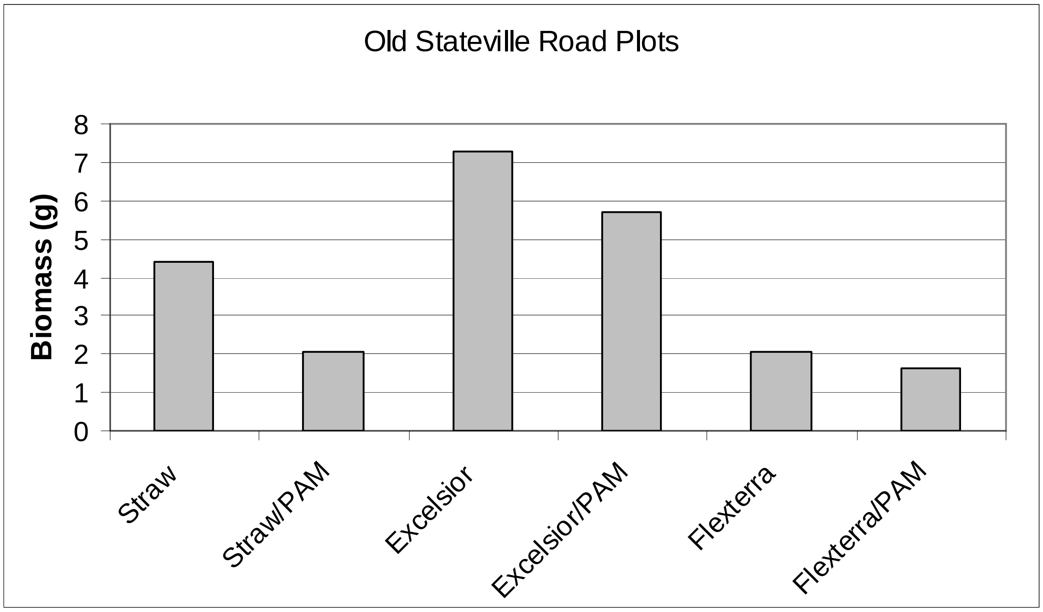


Figure 1.25. Total biomass measured in June, approximately two months after establishment.

Forest Drive Area Plots

This site included standard straw with and without PAM, Flexterra mulch, excelsior, cotton hydromulch with and without PAM. The plots were on a 270 ft area of slope, using 15'x 30' plots (Figure 1.26). PAM was applied at a rate of 33 lbs/acre. Soil material at this site was very loose saprolite. Because the seeding was done in the summer, lespedeza was used as a temporary cover.

Figure 1.26. Forest Drive plots at establishment.

The data was highly variable due to some individual plots apparently having major failure relative to the others with the same treatment, so large differences were not statistically significant (Figures 1.27-1.28). The straw + PAM treatment was the best at this site in reducing runoff turbidity and TSS. The PAM treatment appeared to be beneficial for the straw cover but not for the cotton hydromulch, which had a lot of erosion (Figure 1.29). Ground cover was evenly distributed for all plots except cotton with PAM (Figure 1.30). The overall biomass assessment was variable, but showed standard straw and cotton with PAM had the lowest amount on average (Figure 1.31).

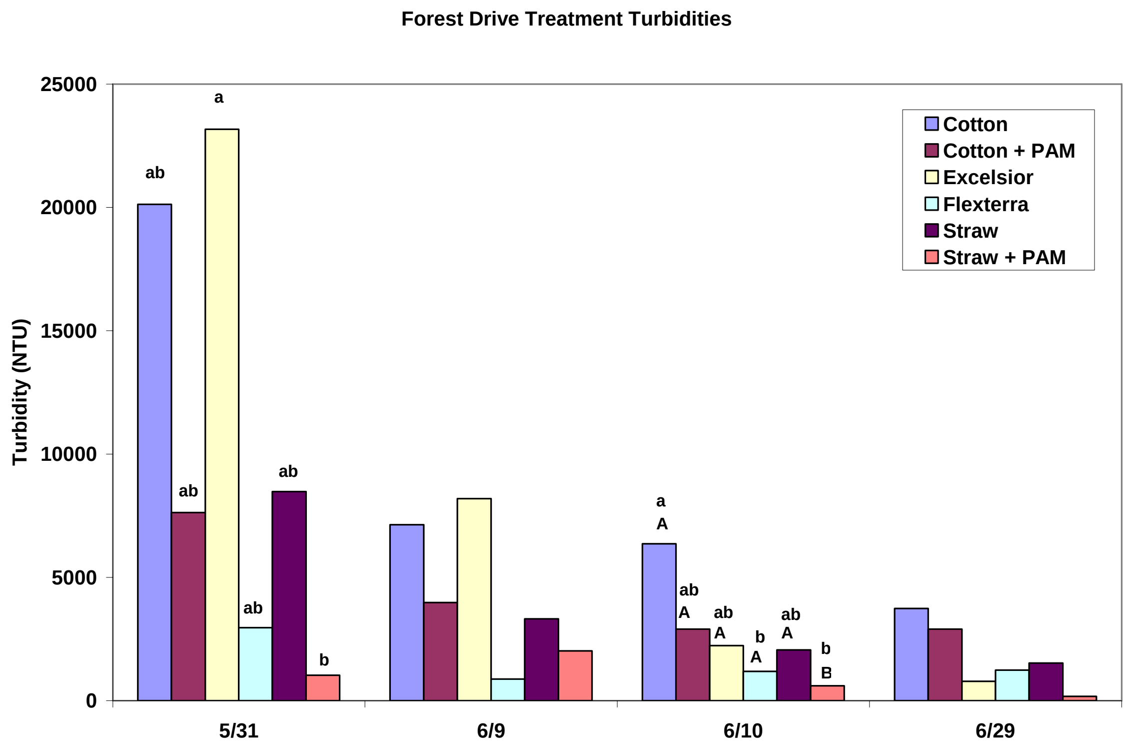


Figure 1.27. Turbidity in runoff from the plots at Forest Drive. Shown are averages of three plots per treatment. Bars with different capital letters are significantly different at $P < 0.05$; with different small letter at $P < 0.10$.

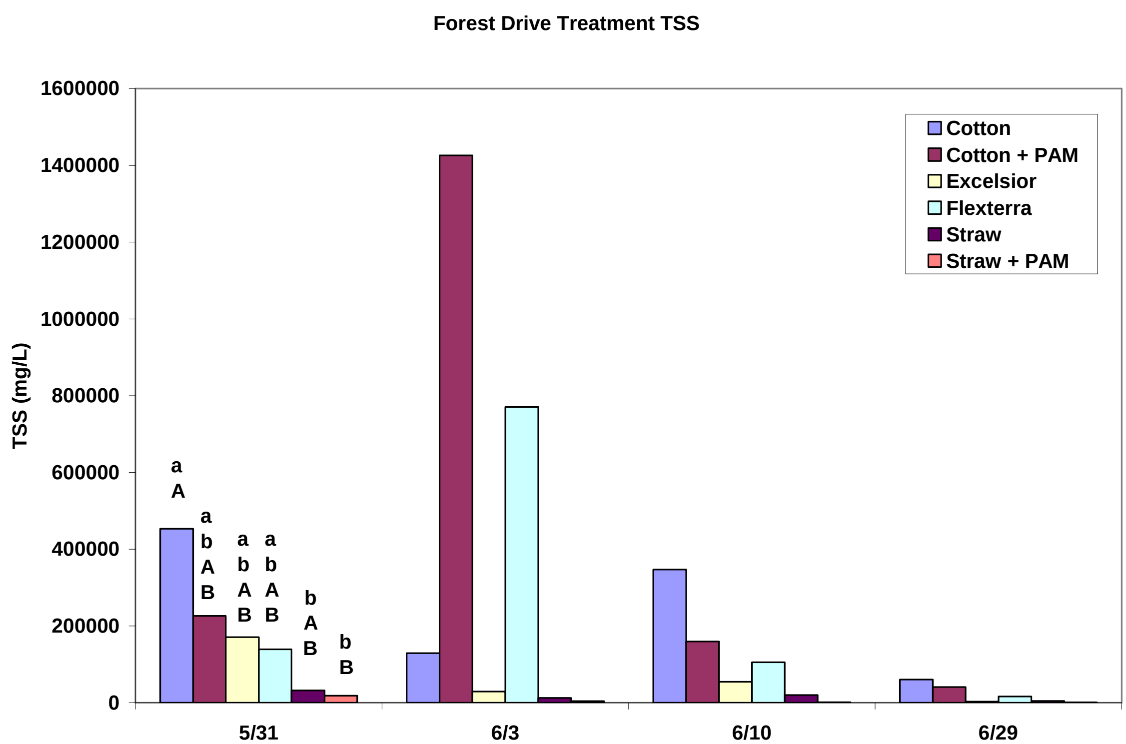


Figure 1.28. Total suspended solids for the Forest Drive plot runoff. Shown are averages of three plots per treatment. Bars with different capital letters are significantly different at $P < 0.05$; with different small letter at $P < 0.10$.

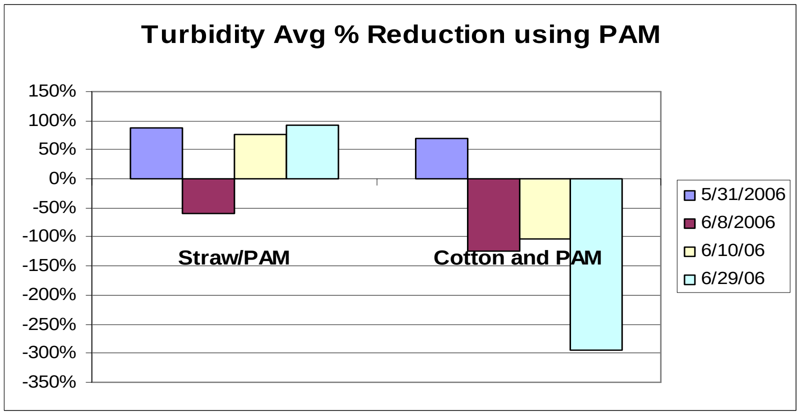


Figure 1.29. Percent reduction with use of PAM verses no PAM with standard straw and cotton mulch. a. runoff percent reduction, b. flow based turbidity average percent reduction, and c. sediment load percent reduction.

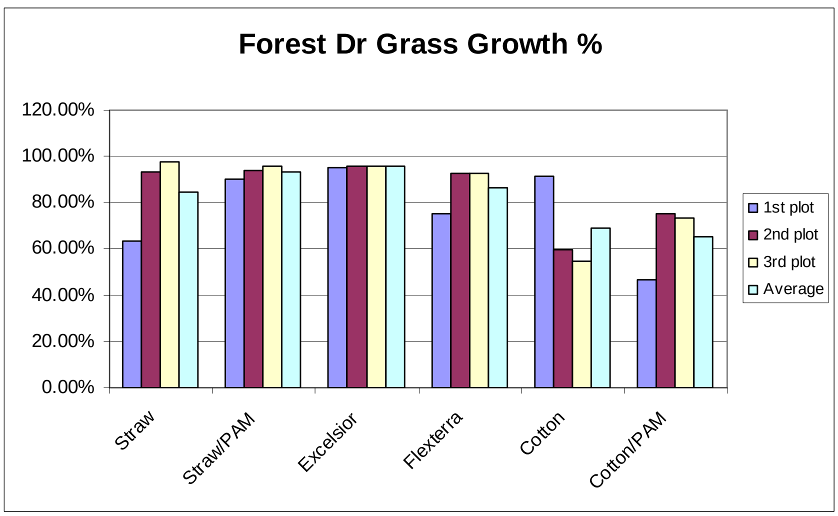


Figure 1.30. Ground cover by plot and average per treatment.

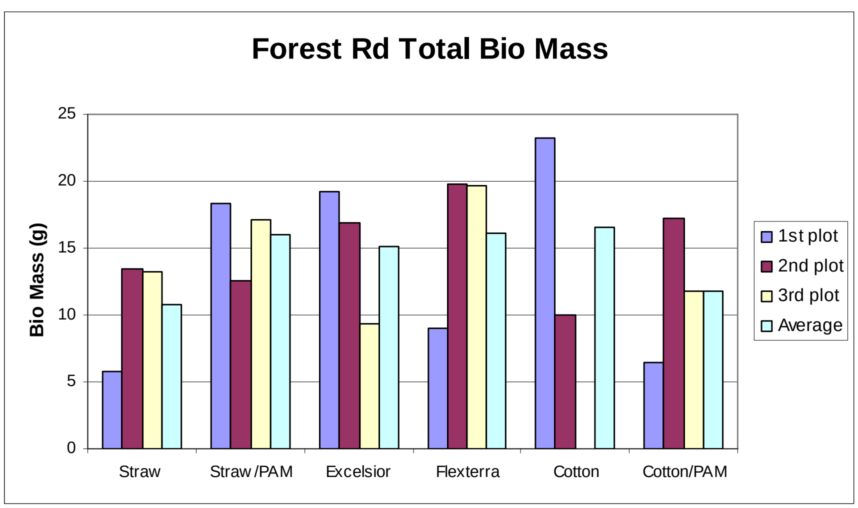


Figure 1.31. Total biomass per plot and average per treatment.

Chapter 2 - Sediment Control

<u>Sediment Control Testing</u>

A major effort in this project was the introduction of a number of modifications to standard sediment control practices to determine if these could improve sediment retention. Standard and modified traps and basins were evaluated to compare the benefits of changes in design and the addition of PAM. Modifications to basins included jute/coir fiber baffles, skimmer outlets and forebay inlets. PAM was used at sites in the form of solid blocks in channels, as a powder in channels and on baffles and in liquid form metered into the flow. We also modified ditches with jute lining and manufactured check dams.

As the construction project progressed, opening up new areas and establishing new sediment control structures, we selected new areas to modify. In each area, we placed samplers at the basin outlets and, where feasible, at the basin inlet. Turbidity and total suspended solids was measured on all samples, and nutrients (total N & P, ortho-P, nitrate-N, ammonium-N) on selected samples. In most cases, the samplers were set up to measure flow using a weir or pipe, but malfunctions of the sampler flow meter often interfered with this effort.

A brief review of each basin study site and results is listed below.

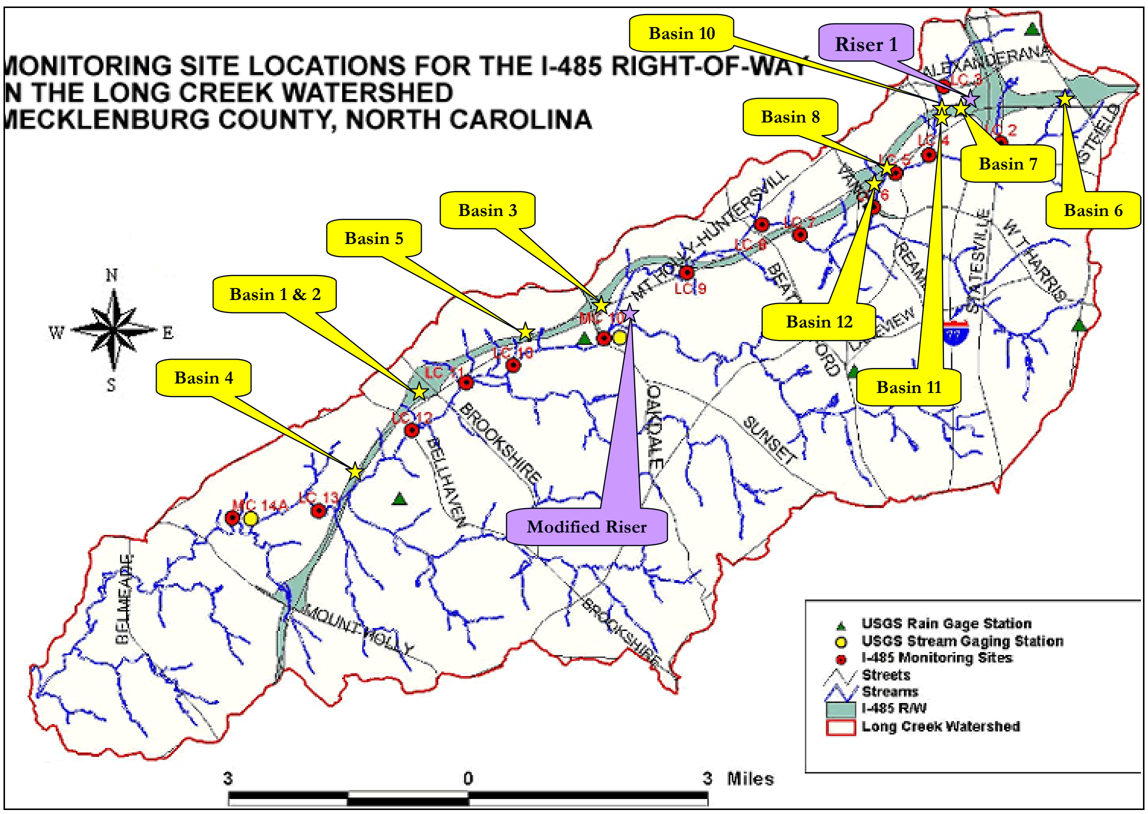


Figure 2.1. Sediment trap and basin site map.

Sediment Traps 1 and 2

Our first study area was installed as a paired trap study to evaluate the effects of porous baffles (Figures 2.2 and 2.3). Initially, the drainage areas had moderate slopes and were about two acres in size. In both cases, the flow was diverted into a forebay with a rock/stone outlet into the main pond. The standard traps have the perimeter ditch emptying into the side of the basin. Three baffles were installed using a combination of erosion control blanket (North American Green C-125) plus jute matting. We also experimented with jute matting, manufactured check dams, and PAM logs (Figure 2.4).

Results and field assessments from traps 1 and 2 illustrated that paired studies are difficult to conduct on an active construction site. One of the main problems was that there was a great deal of fill material being added next to trap 2 while the trap 1 watershed was largely mulched from chipped woody material. This created much higher sediment loads in trap 2. The samplers on the two trap outlets also tended to malfunction so that direct storm-by-storm comparisons were not possible (Tables 2.1 and 2.2).

The one potential comparison storm was on June 9-10, with turbidity higher in trap 1 without the baffles. Flow was measured and sampling accomplished for two storms in June so estimates of sediment losses could be determined for these events (Table 2.3). While we did not measure sediment delivery to the basin, the relatively small amounts of sediment (50-94 kg) leaving the basin suggests a relatively high retention rate. We had little success in our experiments with PAM in ditches at this location due to the very high sediment loads in the ditches and the constantly changing landscape.

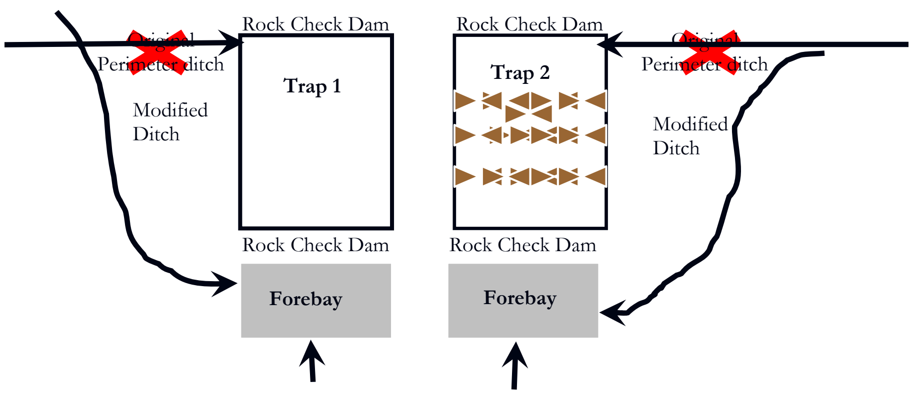


Figure 2.2. Traps 1 and 2 design for paired study.

Figure 2.3. Basin 1 and 2.

Figure 2.4. Floc log in bucket.

Table 2.1. Trap 1 Turbidity ranges.

Trap 1					
	Turbidity Range (NTU)				**Precip.**
Date	*Min*	*Median*	*Max*	*Avg*	*(In)*
4/9/2003	99	321	1394	438	1.54
5/9/2003	530	531	530	530	1.12
6/9/2003	1569	2683	4158	2915	2.45

Table 2.2 Trap 2 Turbidity Ranges (numbers noted in blue are calculated as a flow weighted turbidity average).

Trap 2					
	Turbidity Range (NTU)				Precip.
Date	*Min*	*Median*	*Max*	*Avg*	*(In)*
4/26/2003	505	1454	2533	1502	0.45
5/2/2003	501	1624	2463	1636	0.28
6/3/2003	897	1133	2673	1329	0.72
6/10/2003	272	1422	1905	1331	2.47
6/16/2003	1073	2569	4810	3949	0.24
6/18/2003	1208	1824	2337	2196	0.14

Table 2.3. Trap 2 sediment Loads, flow sum and weighted turbidity average for the duration of each storm.

Trap 2				
Date	**Sediment Discharge**	**Flow**	**Flow Wt Turb Avg**	**Precip.**
	kg	**cu ft**	**NTU**	**(In)**
6/16/2003	94	1142	3949	0.24
6/18/2003	50	1185	2196	0.14

Sediment Trap 3

This sediment trap was located on the perimeter of the highway project behind the DOT construction trailer on Oakdale Rd (Figures 2.1, 2.5, 2.6, and 2.7). The drainage area was relatively flat and about one acre in size. The original basin was modified by creating diversions from the two perimeter ditches to force the runoff away from the outlet dam. Porous baffles were also installed. A PAM log was placed in each ditch below the last check dam (Figures 2.7 and 2.8) and the ditch was lined with jute below that and PAM powder was periodically sprinkled on the matting.

The relatively flat terrain and small area resulted in very little runoff into this trap. However, the baffles appeared to work well in settling much of the sediment which did come to the trap (Figure 2.9). Overall, the turbidity leaving this trap was somewhat less than in trap 2, but with different soil, slope, and other factors there is no direct comparison possible. Compared to turbidity measured later in this project as well as at other locations, these turbidities were relatively low.

PAM logs were placed below a pipe outlet in a bucket (Figure 2.7) and in the open (Figure 2.8). The concept was to settle the heavy sediment behind the check dams and for the turbid water to fall onto the logs, dissolving the PAM. In the bucket, however, we had an accumulation of sediment on the logs which greatly reduced PAM release. The log left in the open also did not appear to be releasing much PAM due to hardening. While some turbidity reduction may have occurred as a result of the PAM treatments, we did not achieve results similar to our findings in controlled testing.

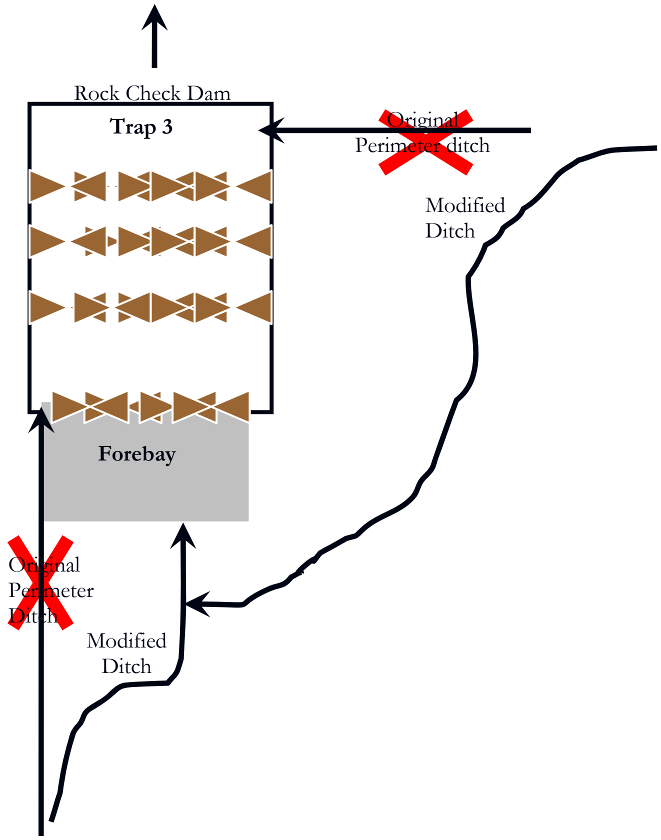


Figure 2.5. Trap 3 design

Figure 2.6. Trap 3.

Figure 2.7. Trap 3 ditch with PAM log and jute lining.

Figure 2.8. PAM log placement below check dam.

Figure 2.9. Sediment captured above baffle.

Table 2.4. Trap 3 Turbidity Ranges (numbers noted in blue are calculated as a flow weighted turbidity).

Trap 3					
	Turbidity Range (NTU)				Precip.
Date	*Min*	*Median*	*Max*	*Avg*	*(In)*
4/26/2003	700	700	700	700	0.45
5/9/2003	463	463	463	463	1.12
6/4/2003	424	634	1422	714	0.90
6/18/2003	452	1884	2417	587	0.14
7/15/2003	1487	2014	2879	2100	0.75
7/20/2003	641	670	684	665	0.23
7/27/2003	346	407	462	412	0.77
7/30/2003	289	381	414	367	0.62
7/31/2003	218	308	2317	906	0.53
8/6/2003	809	884	1199	907	2.47
8/10/2003	227	250	849	408	1.85
9/22/2003	487	507	689	544	1.48
12/14/2003	141	557	1095	566	0.95
2/6/2004	701	988	2819	1207	1.29
2/28/2004	112	166	190	159	0.51

Table 2.5. Trap 3 sediment load rates.

Trap 3				
Date	Sediment Discharge	Flow	Flow Wt Turb Avg	Precip.
	kg	cu ft	NTU	(In)
6/18/2003	9	636	586	0.14
8/10/2003	12	657	408	1.85
9/22/2003	134	2053	543	1.48

Sediment Trap 4

Sediment trap 4 was located at the bottom of a slope where two perimeter ditches collected runoff (Figure 2.10). One perimeter ditch had a relatively steep slope and this is where we installed multiple check dams (Triangular Silt Dikes) as well as PAM logs placed below the check dams and in corrugated pipe (Figure 2.13). Also on this side, we installed a forebay and porous baffles (Figures 2.11 and 2.12). On the other perimeter ditch, which had very little slope, we installed two check dams (Triangular Silt Dikes) with PAM logs (Figure 2.14).

We observed that the combination of ditch checks, lining with jute, and PAM treatment in the steep ditch appeared to be effective during low-flow events, or toward the end of larger events. This is visually apparent in Figure 2.11, showing very clear water in the forebay. The sampler on the forebay often only obtained one sample in each event, so we were not able to fully confirm our observations. The trap outlet integrated the runoff from both ditches, and the low-slope ditch had little evidence of PAM being effective. However, the turbidity measured leaving trap 4 was often lower than we typically observed (Table 2.6).

We concluded that the number of PAM logs (3 in the steep ditch) would have to be increased or additional powder placed on the ditch lining to achieve better results during high flow events. Where flows are much slower, as in the flat ditch, it is difficult to achieve the dosing and mixing needed for effective flocculation.

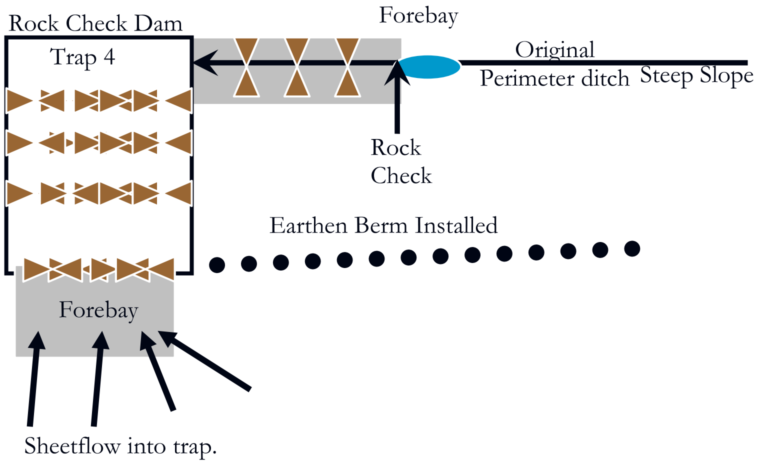


Figure 2.10. Basin 4 design.

Figure 2.11. Trap 4 with forebay after a storm event.

Figure 2.12. Trap 4 during storm event.

Figure 2.13. Perimeter ditch with check dams and PAM logs.

Figure 2.14. PAM log after check dam in low-slope ditch.

Tables 2.6 a, b, c and d. Basin 4 and Basin 4 side turbidity ranges and sediment loadings. a. Turbidity ranges from trap 4, b. Turbidity ranges from trap 4 forebay, c. Sediment load, flow sum and flow weighted turbidity averages at trap 4 outlet, and d. Sediment load, flow sum and flow weighted turbidity averages at trap 4 forebay. Numbers noted in blue are calculated as a flow weighted turbidity average.

(a)

Basin 4 Outlet					
	Turbidity Range (NTU)				**Precip.**
Date	*Min*	*Median*	*Max*	*Avg*	*(In)*
6/16/2003	412	1141	3754	1767	0.24
7/2/2003	183	277	341	289	0.51
7/7/2003	599	640	1315	1098	1.10
7/9/2003	82	637	1547	1180	0.45
7/19/2003	545	680	815	801	0.23
8/1/2003	353	353	353	353	0.53
8/6/2003	13	263	631	443	2.50
8/12/2003	654	654	654	654	1.40
8/13/2003	278	278	278	278	0.10
8/31/2003	1045	1387	1442	1384	0.70
9/14/2003	141	296	598	257	0.03
9/18/2003	63	273	1063	338	NA
9/19/2003	35	121	1415	345	NA
9/24/2003	1231	1336	1840	1349	1.54
11/19/2003	(1-24 >30000)				0.45

(b)

Trap 4 Forebay Outlet					
	Turbidity Range (NTU)				**Precip.**
Date	*Min*	*Median*	*Max*	*Avg*	*(In)*
7/18/2003	21	21	21	21	0.75
8/31/2003	121	726	1348	931	0.70
12/10/2003	3072	3072	3072	3072	0.97
1/2/2004	42	42	42	42	0.03
2/3/2004	488	488	488	488	0.51
2/8/2004	383	324	442	383	1.29
2/12/2004	163	163	163	163	0.46

(c)

Basin 4 Outlet				
Storm Event	**Sediment Discharged**	**Flow**	**Flow Wt Turb Avg**	**Precip.**
	kg	**cu ft**	**NTU**	**(In)**
6/16-6/17/2003	6080	32802	1766	0.24
7/2/2003	19.6	2896	289	0.51
7/7/2003	53.6	1431	1098	1.10
7/9-7/10/2003	466	14508	1180	0.45
7/19/2003	47.3	1133	801	0.23
8/4-8/6/2003	576.0	22237	443	2.51
8/31/2003	50.2	982	1384	0.70
9/14-9/17/2003	59.0	3339	257	0.03
9/17-9/19/2003	60	3057	338	NA
9/19-9/20/2003	52	2432	345	NA
9/24-9/25/2003	138	9832	1349	1.54

(d)

Basin 4 Forebay				
Storm	**Sediment Discharged**	**Flow**	**Flow Wt Turb Avg**	**Precip.**
	Kg	**cu ft**	**NTU**	**(In)**
7/12/03	0.40	48	21	0.92
7/18/03	0.22	26	21	0.75
8/31/03	72.49	3013	931	0.70

Basin 5

Basin 5 was very similar in physical layout to trap 4 except that it had a skimmer outlet (Figures 2.15-2.18). A forebay was constructed on the side where the steeper ditch was located. Multiple check dams (TSD) were installed in the ditches and they were lined with jute netting. PAM logs were placed below the check dams and powder was periodically applied to the ditch liners.

The initial results indicated much lower turbidity levels in both the outlet and the forebay compared to typical traps (Figure 2.19, Tables 2.7a and 2.7b). This was likely a result of the PAM treatment to some extent, but sediment loads were relatively low during that period because the site was not being actively disturbed. By June, however, the area above the basin was receiving large amounts of fill material and the turbidity levels increased more than an order of magnitude. We observed that the PAM logs became coated with sediment during this period and probably released very little PAM. Sediment in the ditches also covered up the PAM powder which was applied to the lining material.

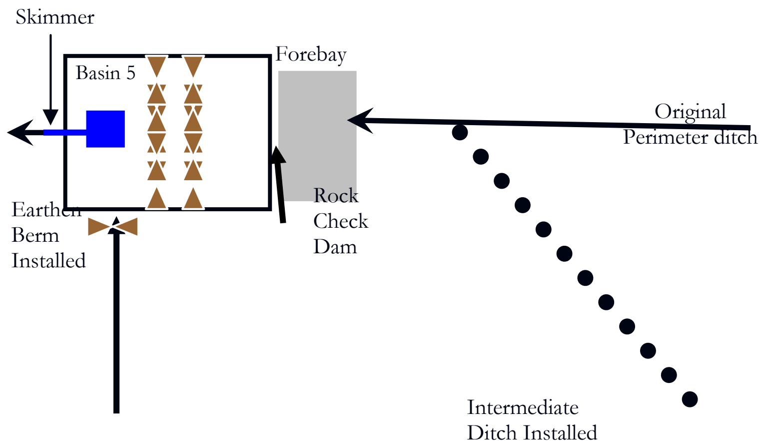


Figure 2.15. Basin 5 design.

Figures 2.16. Basin 5.

Figure 2.17. Ditch into forebay.

Figure 2.18. Skimmer outlet.

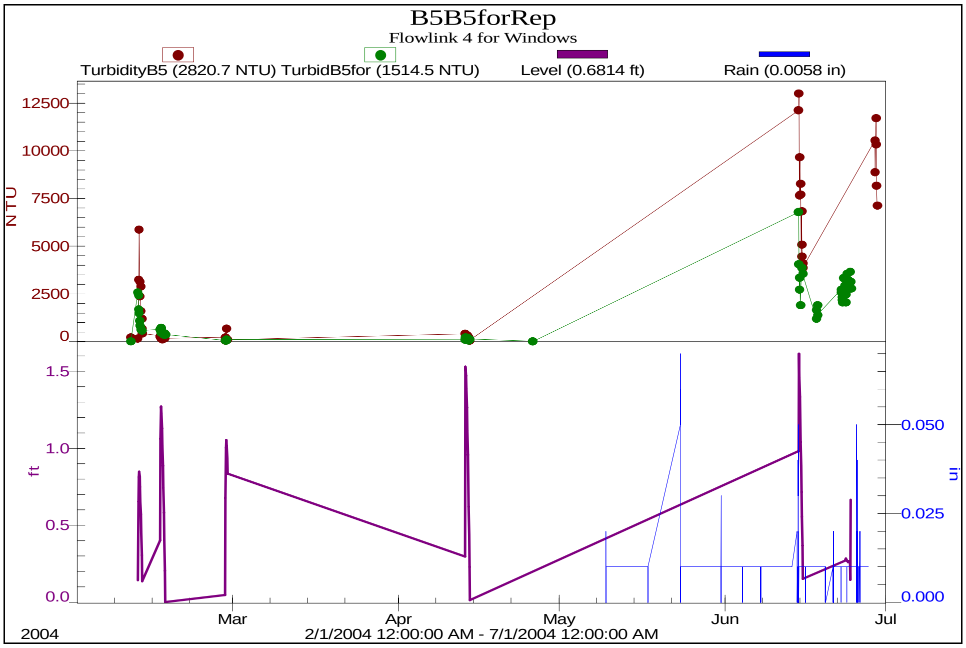


Figure 2.19. Basin 5 turbidity, rainfall and water levels from February 1, 2004 through July 1, 2004. The brown dots represent the basin outlet and the green dots represent the forebay outlet.

Tables 2.7 a and b. Basin 5 and Basin 5 side turbidity summary. a. Basin 5 turbidity ranges, b. basin side turbidity ranges.

(a)

Basin 5 Outlet					
	Turbidity Range (NTU)				**Precip.**
Date	*Min*	*Median*	*Max*	*Avg*	*(In)*
1/24/04	0	0	65	1.0	0.25
2/12/04	590	844	2598	1218	0.46
2/16/04	382	488	2598	569	0.25
2/28/04	44	69	338	94	0.51
4/13/04	82	139	249	146	0.95
4/26/04	8	11	15	11	0.10
6/14/04	1926	3562	6786	3762	2.49
6/18/04	1208	1671	1908	1586	2.46
6/22/04	2051	2803	3653	2823	1.03

(b)

Basin 5 Forebay					
	Turbidity Range (NTU)				**Precip.**
Date	*Min*	*Median*	*Max*	*Avg*	*(In)*
2/16/04	151	208	392	233	0.25
2/28/04	75	88	736	195	0.51
4/13/04	67	298	432	260	0.95
6/14/04	3885	7677	13028	7535	2.49
6/29/04	7138	9617	11741	9468	4.59

Basin 6

The basin 6 study consisted of a forebay, main basin with baffles and a skimmer outlet (Figure 2.1, 2.20 and 2.21). In this basin set up, two check dams (triangular silt dike and straw wattle) were installed in close succession with PAM logs placed between them to hold them in place and to keep them protected fro drying (Figure 2.22). PAM logs were also placed in the spillway from forebay to basin.

Soon after instrumenting this site, the basin had to be moved so we only obtained data from two storm events. In both cases, turbidity was very high exiting the basin, indicating both high sediment loads from this very active area and that the PAM treatment was ineffective (Table 2.8). We did not have time to adjust the treatment to see if more logs or powder might reduce the turbidity leaving the basin.

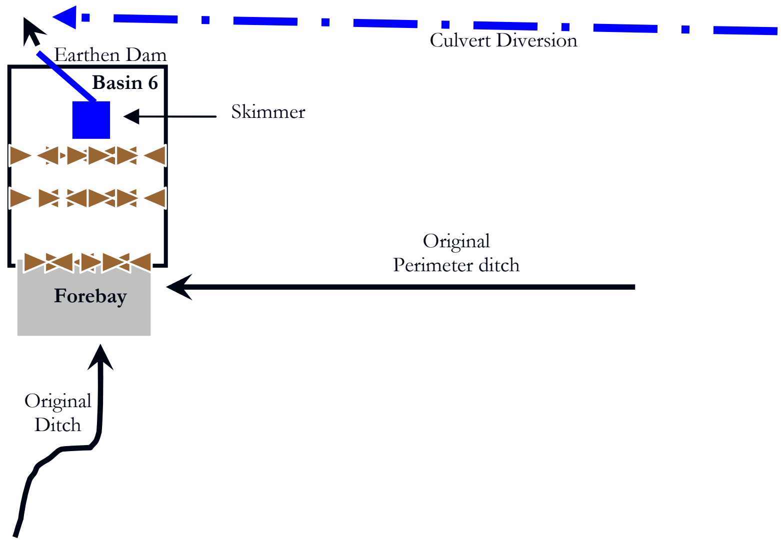


Figure 2.20. Basin 6 design

Figure 2.21. Basin 6.

Figure 2.22. Check dam.

Table 2.8. Basin 6 turbidity ranges.

Basin 6					
	Turbidity Range (NTU)				**Precip.**
Date	*Min*	*Median*	*Max*	*Avg*	*(In)*
5/5/04	1142	3575	7706	4029	1.39
5/26/04	2389	2758	17200	4637	0.16

Basin 7

The basin was modified to have a baffle in forebay and main basin with a skimmer outlet (Figure 2.1, 2.23 2.24, and 2.25. An intermediate drainage ditch was also added, diverting flow into forebay. PAM logs were placed in the ditches after check dams, inside corrugated pipes to prevent drying out (Figures 2.26 and 2.27). The inlets were all protected with coir blankets.

Turbidity levels were similar in the forebay and the basin outlet, only showing a small decrease with treatment train (Figure 2.28 and Table 2.9 a and b). The high sediment loads coming into the system tended to bury the PAM logs in corrugated pipe, preventing the release of PAM in the runoff (Figure 2.27). In addition, the second ditch entering the basin below the forebay probably reduced the effectiveness of the system. Often the turbidity in the forebay was lower than at the basin outlet.

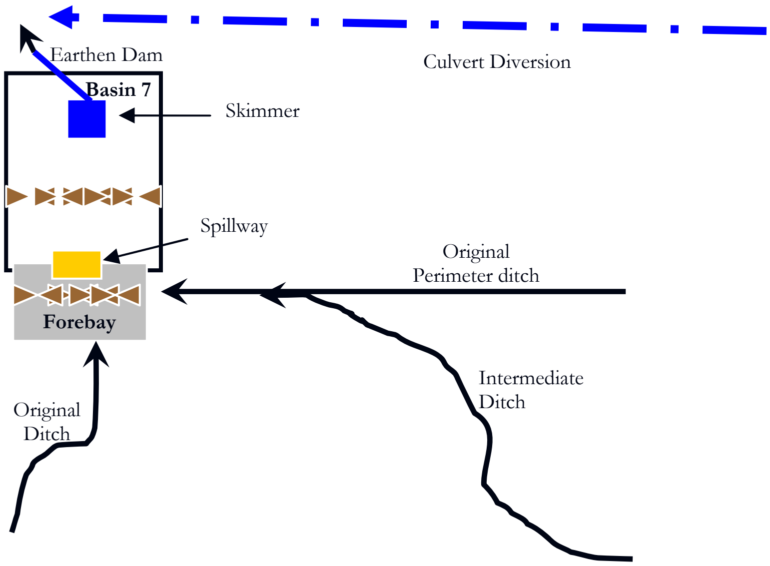


Figure 2.23. Basin 7 design.

Figure 2.24. Channel into forebay.

Figure 2.25. Main basin with baffle/skimmer.

Figure 2.26. Basin 7 during storm event.

Figure 2.27. Sediment load in pipe.

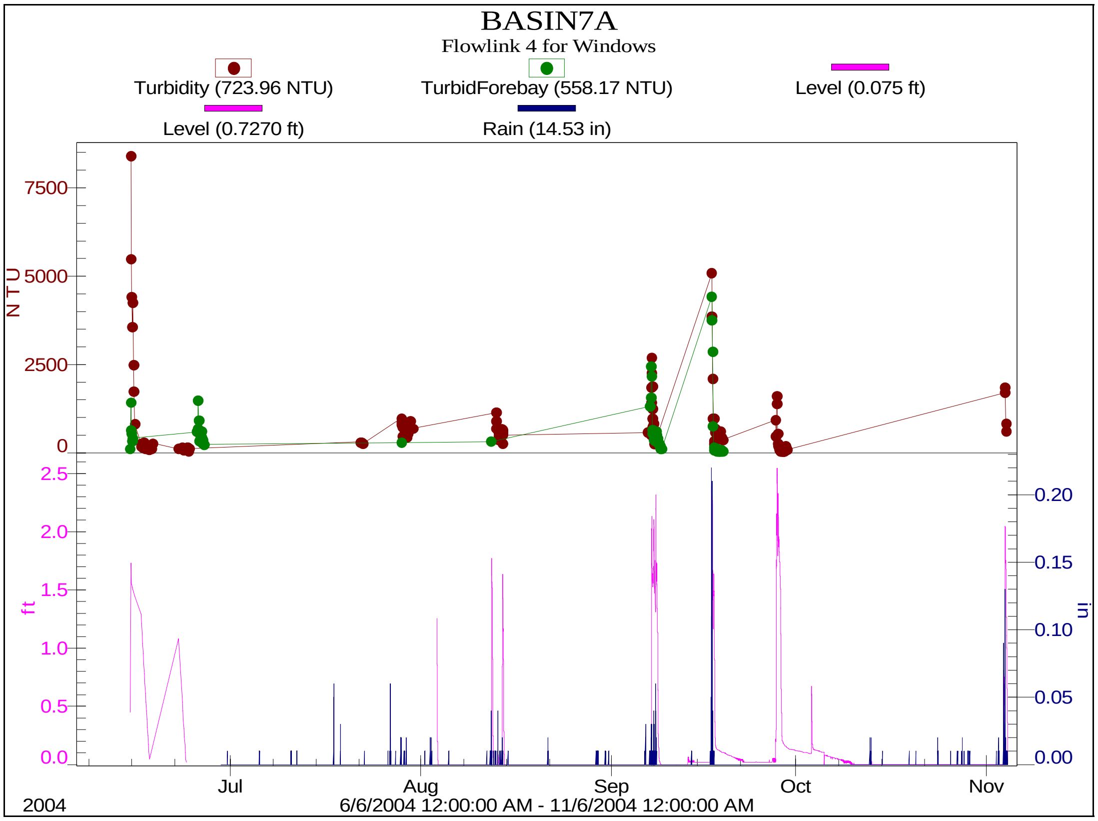


Figure 2.28. Basin 7 Turbidity levels from June 6, 2004 through November 6, 2004.

Table 2.9 a and b. Basin 7 and Basin 7 side turbidity ranges. a. Basin 7 and b. Basin 7 forebay

(a)

Basin 7					
	Turbidity Range (NTU)				**Precip.**
Date	*Min*	*Median*	*Max*	*Avg*	*(In)*
6/14/04	807	4248	16306	5272	2.46
6/16/04	96	173	292	175	0.39
6/23/04	55	111	171	107	1.91
7/22/04	258	282	329	289	1.31
7/28/04	452	697	982	694	0.50
8/13/04	266	587	1133	603	3.54
9/13/04	249	705	2692	1013	2.71
9/20/04	249	611	5082	1068	1.13
10/5/04	35	91	1597	286	0.26
11/4/04	632	1262	1855	1253	0.91

(b)

Basin 7 Forebay					
	Turbidity Range (NTU)				Precip.
Date	*Min*	*Median*	*Max*	*Avg*	*(In)*
6/14/04	109	479	1438	582	2.46
6/25/04	232	387	1477	519	1.58
7/27/04	286	286	286	286	0.56
8/12/04	320	320	320	320	2.24
9/13/04	108	379	2466	607	2.71
9/20/04	40	71	4430	549	1.13

Basin 8

Our most significant modification to a basin, up to this point, was at Basin 8. This location had a steep slope which provided an opportunity to establish a more aggressive treatment design. The area draining to the sediment basin was approximately three acres. A forebay was constructed to intercept one perimeter ditch and a new diversion ditch was installed to capture most of the flow on the other side and direct it into the forebay (Figures 2.30 and 2.31). Two 12" pipes were installed in the dam between the forebay and basin along with a lined emergency spillway. The basin had a skimmer outlet and a lined emergency spillway. A single porous baffle was installed in both the forebay and the basin (Figure 2.32). PAM logs were placed in the pipes between the forebay and basin. In addition, the ditches were lined with jute and PAM powder was applied periodically. Additional check dams (TSDs) and PAM logs in pipes were placed in the ditches as well (Figure 2.30). We also experimented with a liquid PAM dosing system (Figure 2.34) in the perimeter ditch.

The turbidity averages were much lower in the forebay than had occurred in previous monitoring efforts (Table 2.10). For several storm events, the water was so clear that our turbidity meters had difficulty obtaining a reading. This was the result of our treatment system of ditch lining, additional check dams, and PAM dosing. As with Basin 7, a second diversion ditch was installed which directed runoff from the lowest points of the site to the basin, bypassing the forebay treatment system. This probably explains why the forebay generally had lower turbidity than the basin outlet. However, we were able to stabilize this last ditch with jute and check dams, plus we applied PAM powder there periodically. The turbidity averages at the basin outlet were significantly lower that from typical basins on this project, strongly suggesting the effects of the system we installed. We believe that this basin exemplified what can be achieved with the right system in place.

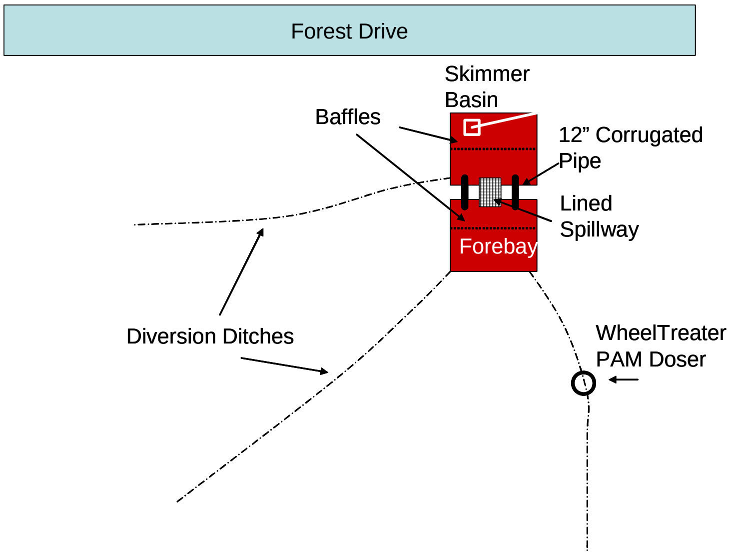


Figure 2.29. Basin 8 design.

Figure 2.30. Basin 8 forebay with PAM log in pipe.

Figure 2.31. Basin 8 after a storm.

Figure 2.32. Lower perimeter ditch.

Figure 2.33. Liquid PAM dosing system.

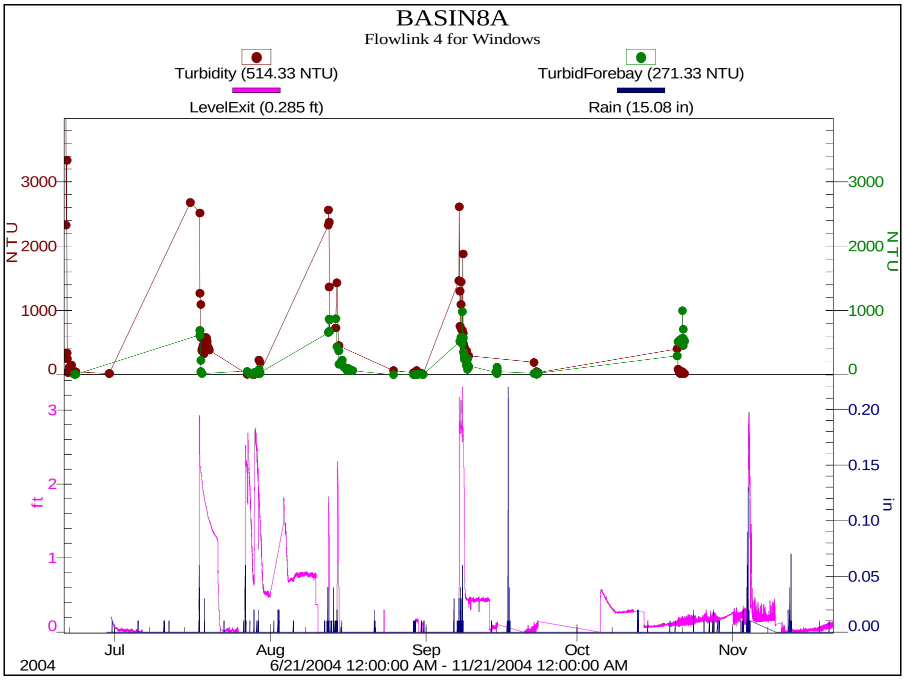


Figure 2.34. Basin 8 turbidity levels from June 21, 2004 through November 21, 2004.

Tables 2.10 a and b. Basin 8 and Basin 8 side turbidity ranges. a. Basin 8 and b. Basin 8 forebay

(a)

Basin 8					
	Turbidity Range (NTU)				**Precip.**
Date	*Min*	*Median*	*Max*	*Avg*	*(In)*
6/21/04	32	61	11356	1389	0.94
6/23/04	42	46	48	45	1.91
6/29/04	42	46	48	45	1.80
7/17/04	17	27	2686	910	1.31
7/27/04	330	469	2525	611	0.56
7/29/04	5	14	25	14	0.57
8/12/04	0	32	225	98	2.24
9/1/04	455	1399	2561	1490	0.44
9/13/04	6	14	65	21	2.66
10/5/04	136	479	2616	750	0.26
11/4/04	24	30	193	42	0.91

(b)

Basin 8 Forebay					
	Turbidity Range (NTU)				Precip.
Date	*Min*	*Median*	*Max*	*Avg*	*(In)*
6/22/04	0	8	60	16	1.03
6/30/04	0	1	8	2	1.80
7/17/04	20	137	701	276	1.31
7/27/04	0	30	62	26	0.56
7/29/04	0	0	0	0	0.57
8/12/04	63	232	872	372	2.24
9/1/04	0	0.02	6	1	0.44
9/13/04	87.80	253.75	984.70	352.72	2.66
9/20/04	87.80	253.75	984.70	352.72	1.13
11/4/04	16	52	118	61	0.91

Basin 10

Note: We selected a basin to modify as Basin 9, but that sediment trap became too difficult to access due to construction activity.

Basin 10 was a sediment trap which we modified largely based on our apparent success in Basin 8. The location of the basin was relatively flat but there were about 4 acres of sloping land draining to it (Figure 2.35). Both it and its watershed underwent many transformations during our 9 months of monitoring. Essentially all the elements from Basin 8 were installed initially, including a skimmer outlet on the basin (Figure 2.36) and large forebay with three baffles (Figure 2.37). Liquid PAM was dispersed using the wheel treater in the side ditch to forebay, but only for a few storms (Figure 2.38).The ditches were lined with jute and additional check dams (Triangular Silt Dikes and GeoRidges, Figure 2.39). PAM powder was applied to the ditches and check dams periodically, and PAM logs were placed below several check dams in the ditches.

Samplers were installed at the inlet to the forebay, at the forebay outlet, and at the basin outlet. This was intended to allow us to follow the change in water quality through the treatment system. However, the sampler intake at the forebay inlet was often buried in sediment, so this sampler did not collect as many samples as the others. We also installed samplers in the adjacent stream upstream and downstream of the culvert adjacent to Basin 10 to assess changes in stream water quality as it passed through the project.

For the first month the turbidity coming into the basin was relatively moderate and was reduced considerably after passing through the forebay (Table 2.11). Turbidity was quite low exiting the basin, as well, and only on the 4/12 storm was it higher than the forebay during that period. As shown in Table 2.12, the system was very effective in reducing turbidity. By the June sample period, however, the site was becoming very active with fill material and turbidity rose considerably. We had to abandon the sampling point above the forebay because heavy sediment loads buried our sampler intake. The forebay was essentially non-existent because it had completely filled with sediment.

In late June the forebay was removed by the contractor as well as the skimmer, although it was not clear why. The next three storm events produced the highest turbidities at the basin outlet that we had seen at this site (Figure 2.40 and Table 2.10c). The monitoring results are shown for the whole time period (Figure 41) and for two example storms (Figures 42-43), and indicate a trend toward higher turbidities in the summer as a result of significant disturbances in the watershed. There may also have been a change in sediment type because considerable fill was being added to the roadbed. Because the basin was modified to a smaller, standard trap in July, we considered it a new site and named it “New Basin 10”, which will be discussed in the next section.

Figure 2.35. March 2005 Basin 10 before modification.

Figure 2.36. Main basin w/baffle and skimmer.

Figure 2.37. Forebay with baffle.

Figure 2.38. Wheel treater in ditch.

Figure 2.39. Lined perimeter ditch with check dams.

Figure 2.40. June 2005 Overflow into stream.

Tables 2.11 a, b, c and d. Basin 10 in, inbetween, and exit turbidity ranges (numbers noted in blue are calculated as a flow weighted turbidity average).

(a)

Basin 10 IN				
Date	**Turbidity Range (NTU)**			**Precip.**
	Min	*Max*	*Avg*	*(In)*
3/8/05	34	335	116	0.68
3/22/05	84	56461	4360	0.56
3/27/05	165	10473	2152	0.66
3/31/05	605	702	654	0.44
4/2/05	227	279	251	0.44
4/8/05	386	12362	3705	0.55
4/12/05	121	37177	4286	1.06

(b)

Basin 10 InBetween				
Date	**Turbidity Range (NTU)**			**Precip.**
	Min	*Max*	*Avg*	*(In)*
3/8/05	38	122	81	0.68
3/16/05	25	480	124	0.78
3/22/05	68	2915	437	0.56
3/27/05	128	3028	987	0.66
3/31/05	266	509	386	0.44
4/8/05	294	5691	1047	0.55
4/12/05	84	125	93	1.06
6/10/05	1568	24625	4525	1.44

(c)

Basin 10 EXIT: Weir installed 4/19/05				
Date	**Turbidity Range (NTU)**			**Precip.**
	Min	*Max*	*Avg*	*(In)*
3/8/05	56	69	63	0.68
3/16/05	1	80	32	0.78
3/21/05	92	92	92	0.93
3/22/05	17	233	54	0.56
4/8/05	93	2161	466	0.55
4/12/05	20	2660	776	1.06
6/7/05	1755	26445	5819	0.60
6/9/05	2175	25114	14208	1.18

(d)

Basin 10 EXIT: Basin Modified no forebay or skimmer				
Date	**Turbidity Range (NTU)**			**Precip.**
	Min	*Max*	*Flow wt avg*	*(In)*
6/27/05	3390	22633	18166	2.23
7/11/05	588	30000	13867	0.52
7/18/05	282	30000	11061	0.21

Table 2.12. Turbidity at three points in the Basin 10 treatment system. No sample is indicated by “ns”.

Date	In	Forebay Outlet	Basin Outlet	Precip.
	Turbidity (NTU)			(In)
3/8/05	116	81	63	0.68
3/16/05	ns	124	32	0.78
3/22/05	4360	437	54	0.56
3/27/05	2152	987	ns	0.66
3/31/05	654	386	ns	0.44
4/8/05	3705	1047	466	0.55
4/12/05	4286	93	776	1.06

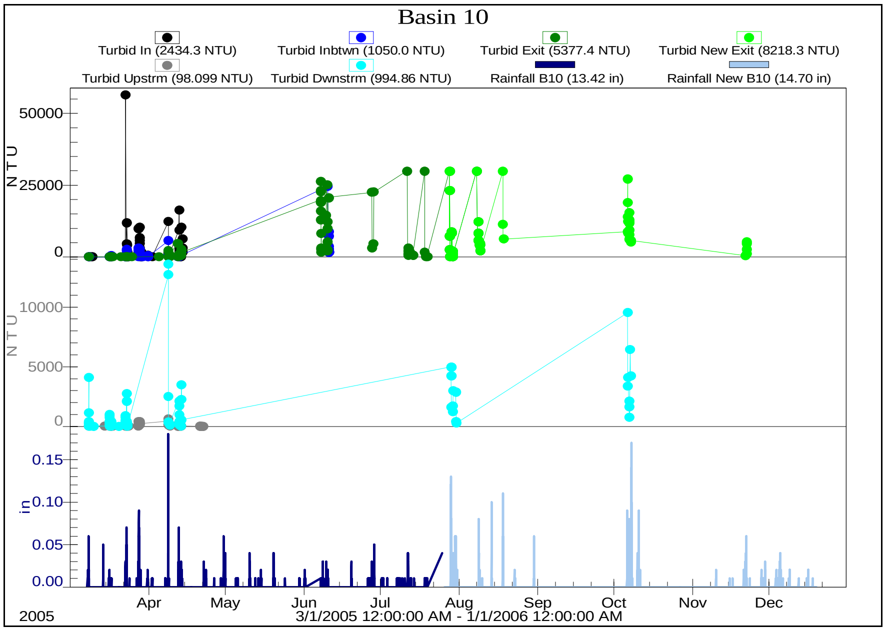


Figure 2.41. Basin 10 and stream turbidity levels from March 2005 through January 2006.

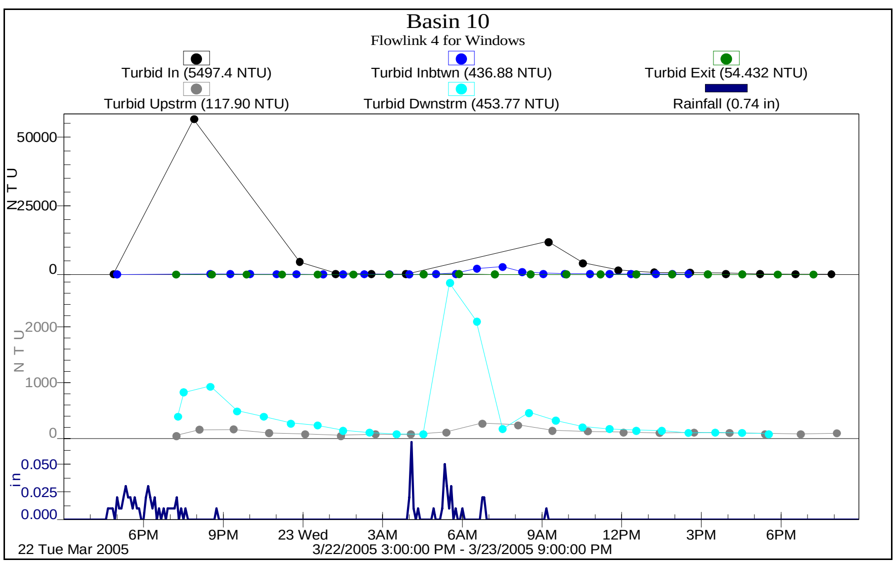


Figure 2.42. Basin 10 and stream turbidity levels from March 22-23, 2005.

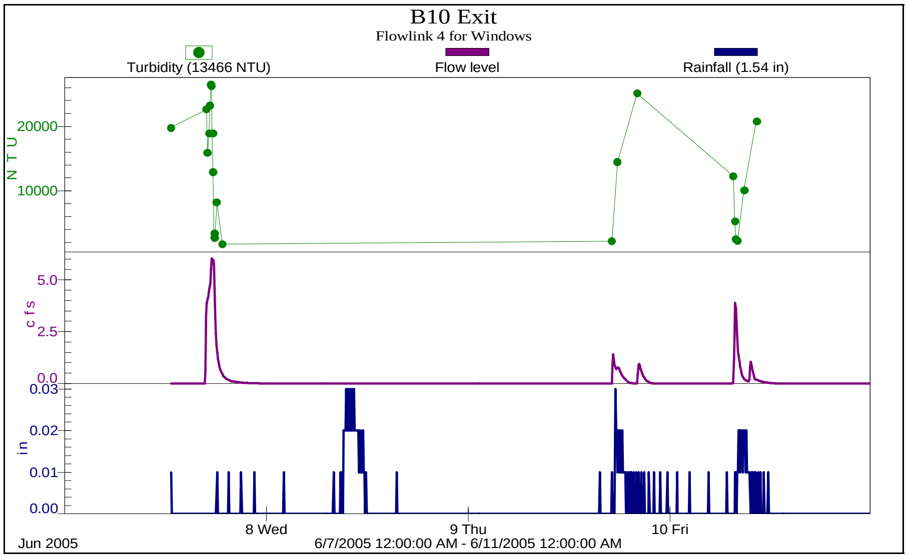


Figure 2.43. Basin 10 flow and turbidity levels from June 7, 2005 to June 11, 2005.

New Basin 10 (Basin 10 modified)

New Basin 10 was a modification from Basin 10, and was actually a sediment trap since the outlet was changed to a rock dam. A single baffle was installed using 700 g/m^2 coir matting and installed using fence posts and wire. All ditches and channels were lined with jute matting. Two slope drains were installed, draining into main basin and ditch (Figure 2.1, 2.44 and 2.45). PAM logs were installed in each slope drain (1 log 706d/ 2 logs 703d3; each log cut in half). Two check dams (TSDs) were installed in ditch (Figure 2.46).

The sediment loading to the ditch was very high and clogged the sampler intake so frequently that we discontinued sampling there (Figure 2.46). The slope drains were initially too short and caused significant erosion at their exit, but these were later extended to the ditch or trap (Figure 2.46). Overall, turbidity was quite high exiting new basin 10 throughout the remainder of our monitoring at that site (Table 2.13 and Figures 2.47, 2.48, and 2.49).

Figure 2.44. New basin 10.

Figure 2.45. New Basin 10 with baffle.

Figure 2.46. New Basin 10 with silt dikes.

Table 2.13. New Basin 10 Exit Turbidity and TSS levels.

New Basin 10 Exit				
Date	**Turbidity Range (NTU)**			**Precip.**
	Min	*Max*	*Avg*	*(In)*
7/28/2005	245	>30000	6666	0.76
8/8/2005	2241	>30000	8210	1.02
10/17/2005	5521	>30000	12319	3.97
11/21/2005	419	5362	2874	1.93

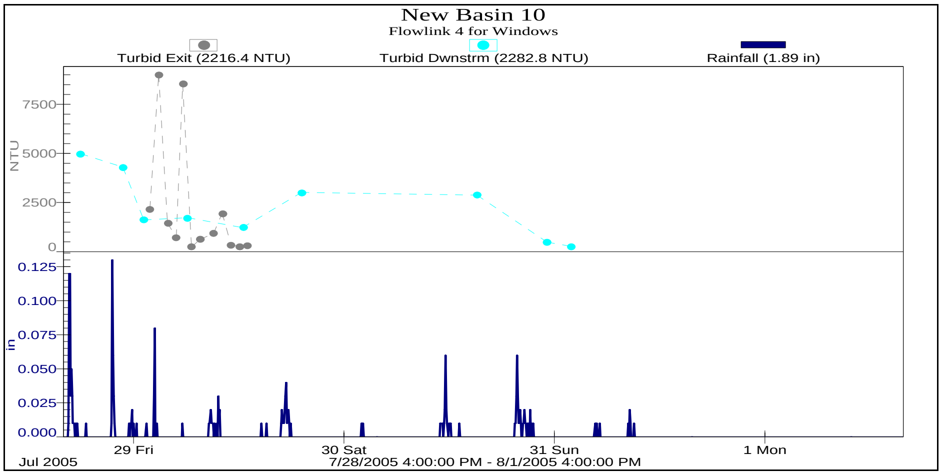


Figure 2.47. New Basin 10 turbidity levels exiting basin and downstream (tributary to Long Creek) turbidity levels form July 28, 2005 to August 2, 2005.

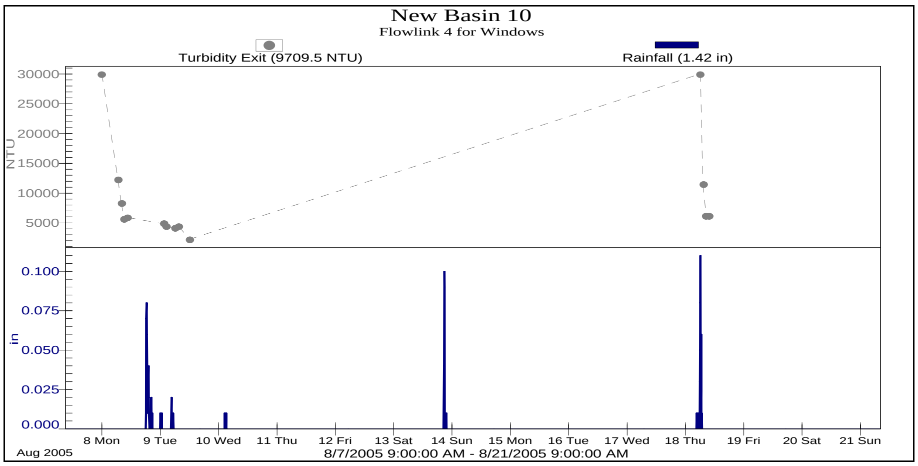


Figure 2.48. New Basin 10 Turbidity levels exiting basin from August 7, 2005 to August 21, 2005.

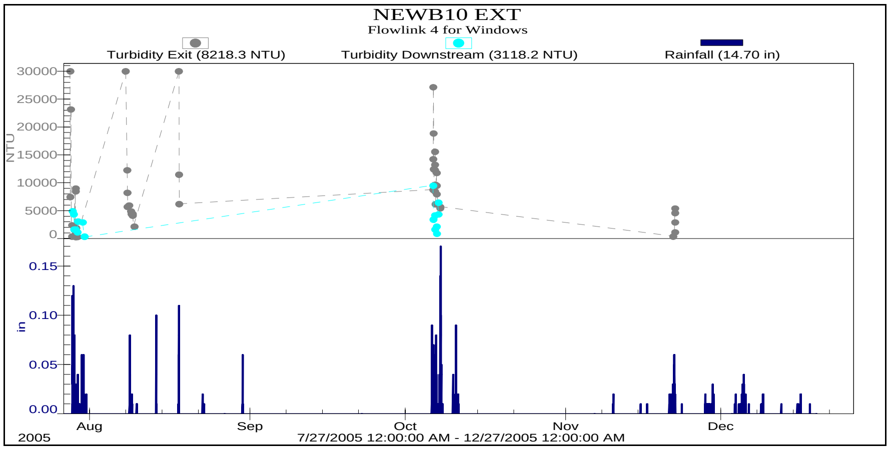


Figure 2.49. New Basin 10 turbidity levels exiting basin and downstream (tributary to Long Creek) turbidity levels from July 27, 2005 to December 27, 2005.

During the period we were monitoring Basin 10, a slope drain failure occurred (Figures 2.50 and 2.51). We surveyed the resulting gully to estimate the amount of material eroded as a result of this event. We determined that approximately 1430 cubic feet of soil was lost from the slope, although we did not determine how much of this made it into the basin.


Figure 2.50. Gully from slope drain failure.


Figure 2.51. Failed Type A inlet protection.

Trap 10 Opposite

Trap 10 opposite was a standard basin with a rock outlet located directly across the creek from Basin 10. No modifications were made to this trap or any part of the area draining to it – our interest was in monitoring a typical sediment trap in a relatively similar watershed to Basin 10. This basin was used as a control site to compare our modifications to (Figure 2.1, 2.52 and 2.53).

Turbidity levels were highly variable in this basin, probably reflecting activity in the watershed (Table 2.14 and Figures 2.54-2.58). The one storm with data from both traps, November 21, showed turbidity lower on New Trap 10, which had a baffle, TSD check dams, and PAM in the pipes. However, it is difficult to draw conclusions from this single storm event. Turbidity levels were often relatively low primarily because the watershed was being stabilized with ground cover in the December-January period.

Figure 2.52. Basin 10 opposite.

Figure 2.53. Ditch into basin 10 opposite.

Table 2.14. Basin 10 opposite turbidity values.

Basin 10 Opposite				
Date	**Turbidity Range (NTU)**			**Precip.**
	Min	*Max*	*Avg*	*(In)*
11/21/2005	488	9323	1559	1.93
12/8/2005	207	1668	493	1.95
12/13/2005	207	1668	493	0.40
12/15/2005	368	3209	1622	1.76
1/12/2006	959	3290	1693	0.25
1/19/2006	676	805	823	0.42
2/11/2006	585	682	700	0.40
5/26/2006	868	15589	5288	0.66
6/3/2006	1177	22666	5410	0.07
6/29/2006	149	4322	611	0.93

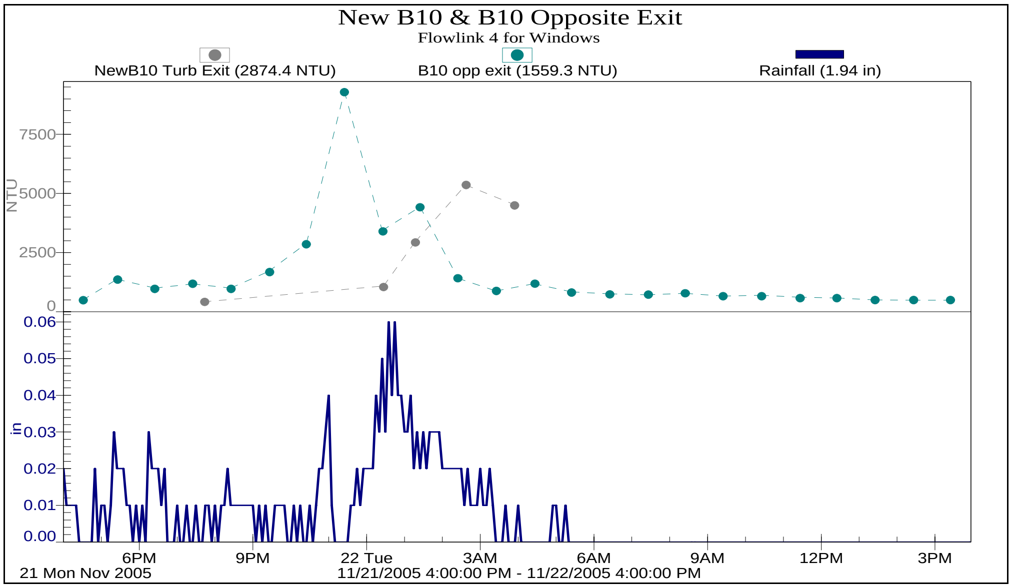


Figure 2.54. New basin 10 and basin 10 opposite turbidity levels exiting basin from November 21-22, 2005.

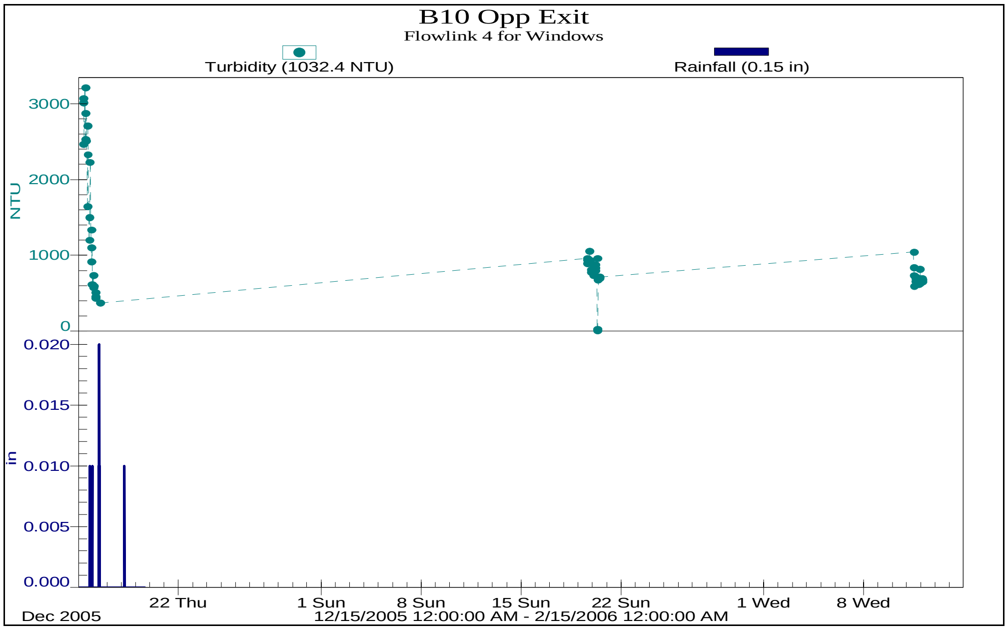


Figure 2.55. Basin 10 opposite turbidity levels exiting basin from December 15, 2005 through February 15, 2006.

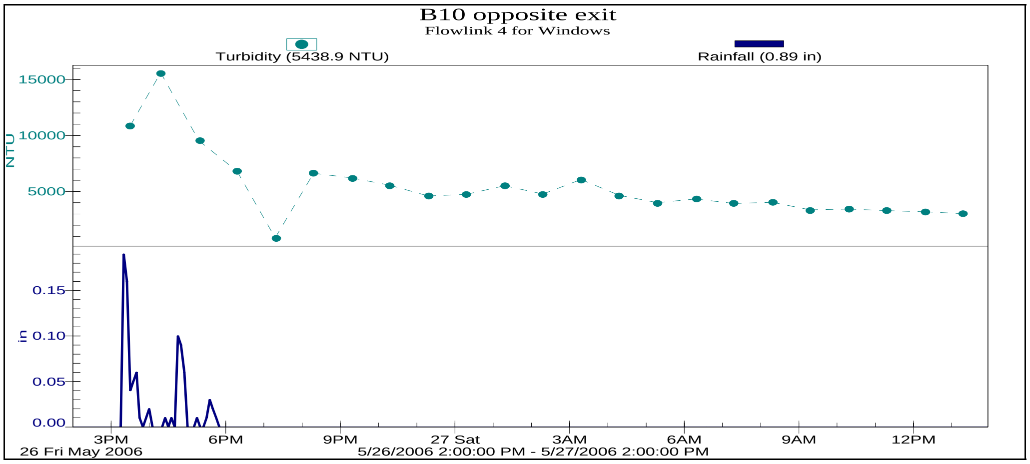


Figure 2.56. Basin 10 opposite turbidity levels exiting basin from May 26-27, 2006.

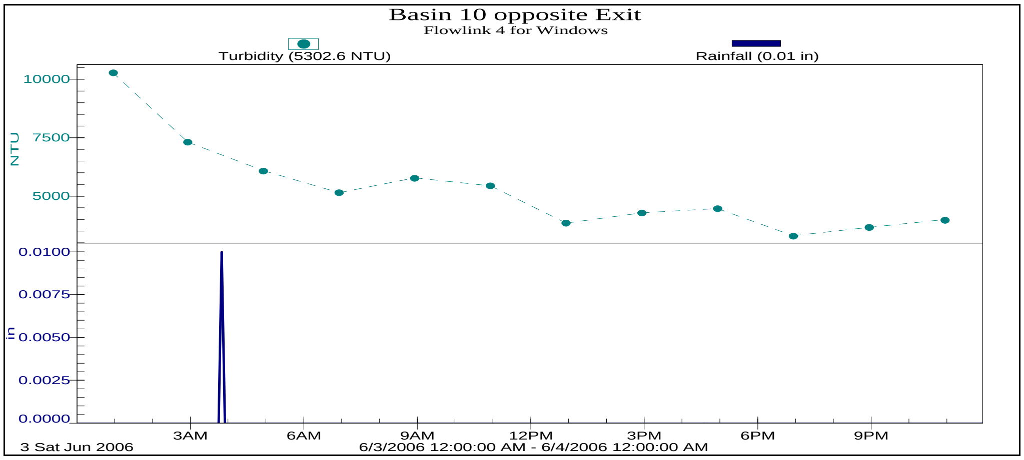


Figure 2.57. Basin 10 opposite turbidity levels exiting basin from June 3-4, 2006.

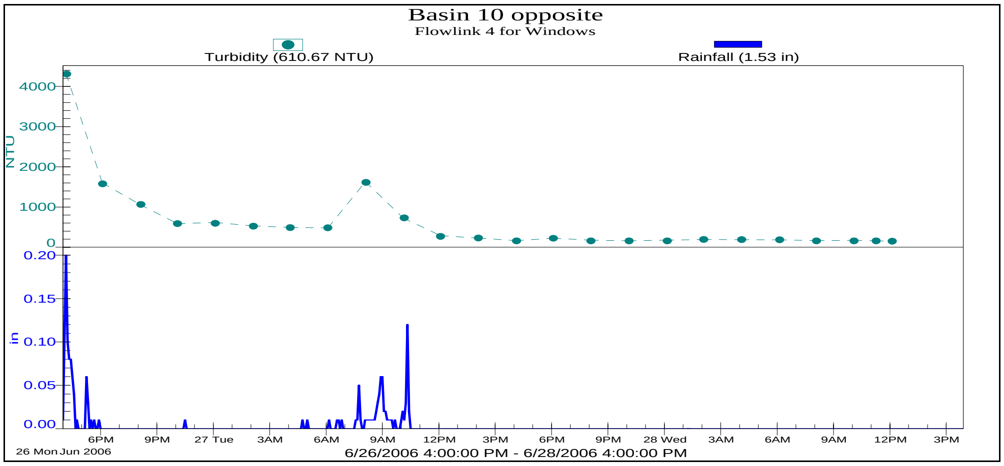


Figure 2.58. Basin 10 opposite turbidity levels exiting basin from June 26-28, 2006.

Site 11

Our interest at Site 11 was to evaluate the efficiency of a typical inlet protection device (Figures 2.59 and 2.60). We installed samplers in the ditch and inside the rock dam for this purpose. However, problems with the ditch sampler, including sediment clogging, sampler errors, and removal of the intake by unknown persons, resulted in no data from that sampler. The results we did obtain are shown in Table 2.15 and Figure 2.61.

Figure 2.59. Site 11 set up.

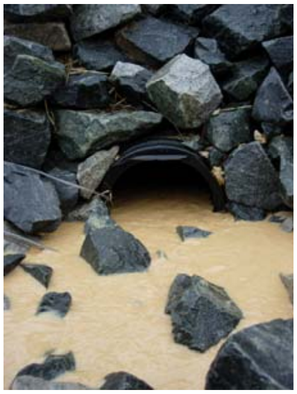


Figure 2.60. Storm flow outlet into slope drain.

Table 2.15. Site 11 turbidity values.

Basin 11: Inlet Protection Exit					
Date	**Turbidity Range (NTU)**				**Precip.**
	Min	*Median*	*Max*	*Avg*	*(In)*
12/8/2005	297	740	2652	842	1.95
3/23/2006	6114	6114	6114	6114	0.86

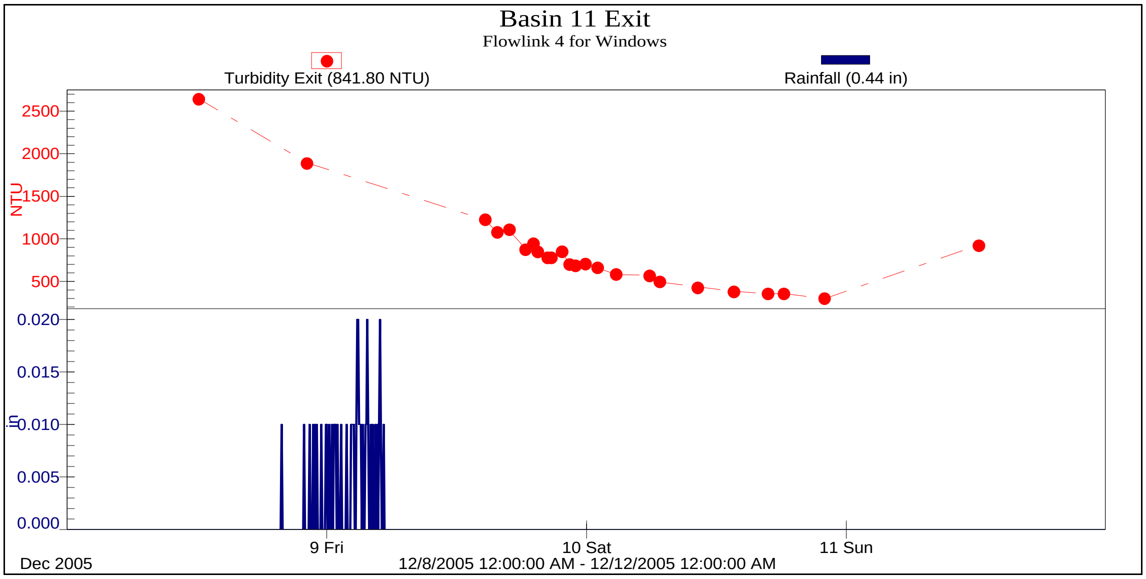


Figure 2.61. Site 11 exit turbidity levels from December 8-12, 2005.

Trap 12

Trap 12 consisted of a culvert draining a fill area of several acres and a slope drain from a small section of road both draining into a standard trap with a rock outlet (Figures 2.62 and 2.63). No modifications were made physically to this location, but we attempted to introduce PAM in several ways. PAM logs (703d3) were installed in both the culvert and the slope drain inlets (Figure 2.64). In addition, we attempted to dose with PAM solution through the use of a 300 gallon tank with approximately 1 ½ lbs of PAM and water mixed with a sump pump. This later system, which we assembled from spare sampler parts, never functioned properly during the period of testing at this site.

The PAM logs did not appear to have much effect reduction on turbidity, most likely because they did not have sufficient flow to dissolve (Figure 2.64). Before further tests could be run, this site was modified for pipe installation. Table 2.16 a and b illustrate the turbidity levels at this location.

Figure 2.62. Basin 12 inlet.

Figure 2.63. Basin 12 outlet.

Figure 2.64. Basin 12 PAM Log.

Table 2.16 a and b. Basin 12 in turbidity values. a. Basin 12 influent and b. Basin 12 effluent.

(a)

Basin 12 In					
Date	**Turbidity Range (NTU)**				**Precip.**
	Min	*Median*	*Max*	*Avg*	*(In)*
11/21/05	2128	3276	4627	3337	1.93
12/15/05	1906	3189	3798	3100	1.76
5/3/2006	5875	5893	5910	5893	0.66

(b)

Basin 12 Exit					
Date	**Turbidity Range (NTU)**				**Precip.**
	Min	*Median*	*Max*	*Avg*	*(In)*
12/8/05	1872	2966	27409	4441	1.95
12/15/05	1789	2458	5024	2621	1.76
1/12/2006	148	1811	3208	1950	0.25
2/15/2006	1923	2352	2587	2304	0.40

Trap 13

This was a standard sediment trap with a weir installed below the rock dam (Figures 2.1, 2.65 and 2.66). The flow of water at this site was very small as a result of diversions in the ditch and general topography. The data, due to lack of runoff to this basin (Table 2.17 a and b, Table 2.18 and Figures 2.67, 2.68, 2.69 and 2.70).

Figure 2.65. Basin 13.

Figure 2.66. Weir at basin 13 exit.

Table 2.17 a and b. Basin 13 turbidity levels. a. Basin 13 influent samples and b. Basin 13 effluent samples (numbers noted in blue calculated as a flow weighted turbidity average).

(a)

Basin 13 In					
Date	**Turbidity Range (NTU)**				**Precip.**
	Min	*Median*	*Max*	*Avg*	*(In)*
7/13/2006	2752	3768	4928	3761	0.70

(b)

Basin 13: Weir at exit					
Date	**Turbidity Range (NTU)**				**Precip.**
	Min	*Median*	*Max*	*Avg*	*(In)*
12/15/05	696	1239	1500	999	1.76
1/12/2006	2489	2489	2489	2489	0.25
2/15/2006	3039	3039	3039	3039	0.40
6/3/2006	418	10174	30000	5088	0.07
7/6/2006	2630	2855	3461	3007	0.70
7/13/2006	3342	3545	3748	3422	0.70

Table 2.18. Basin 13 sediment load.

Basin 13 Exit				
Storm Event	**Sed.load**	**Flow**	**Flow Wt Turbidity Avg**	**Precip.**
	(kg)	(cf)	NTU	(In)
7/6/2006 6:50	16.2	197	3007	0.70
7/13/2006 19:40	25.2	158	3422	0.70

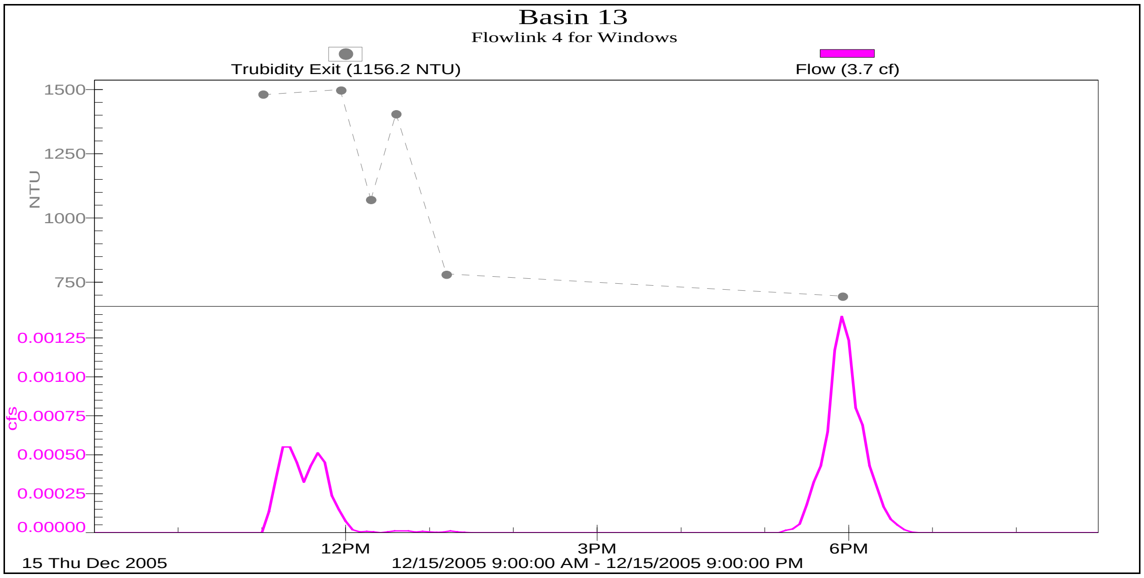


Figure 2.67. Basin 13 turbidity levels from December 15, 2005.

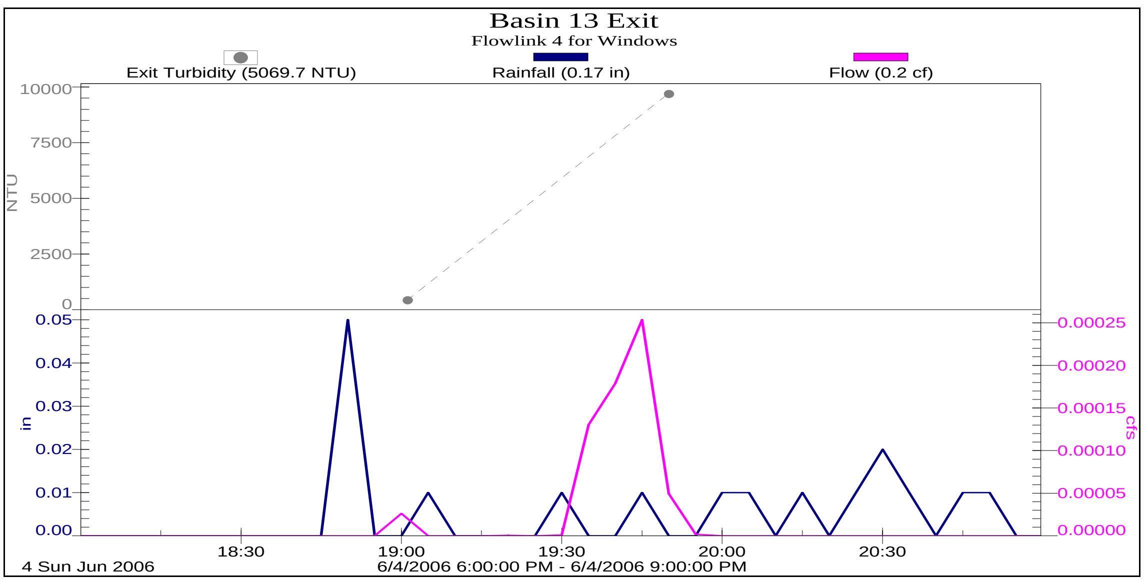


Figure 2.68. Basin 13 turbidity levels from June 4, 2006.

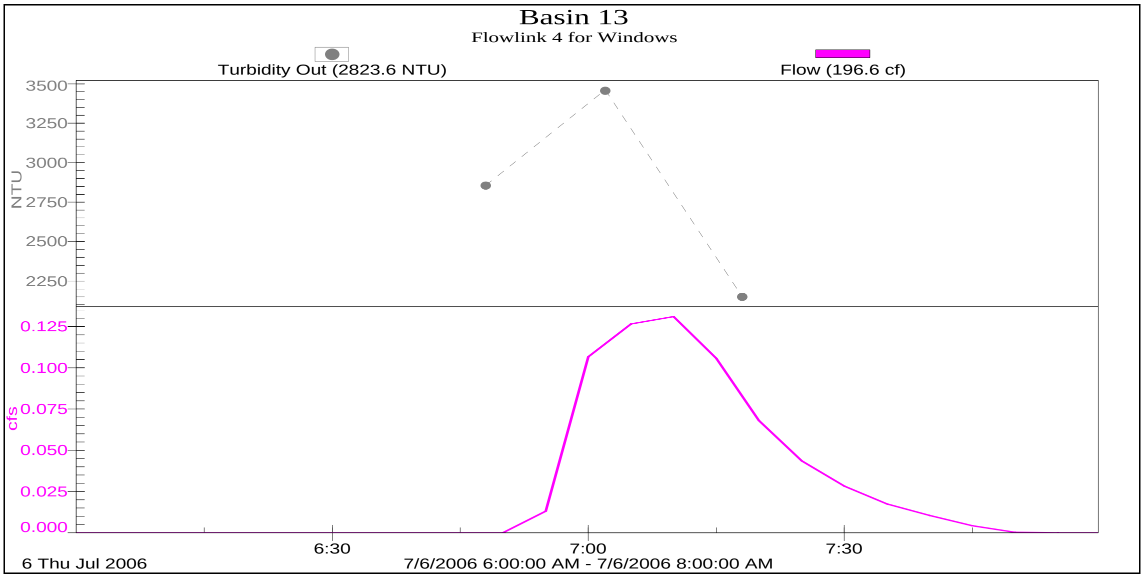


Figure 2.69. Basin 13 turbidity levels form July 6, 2006.

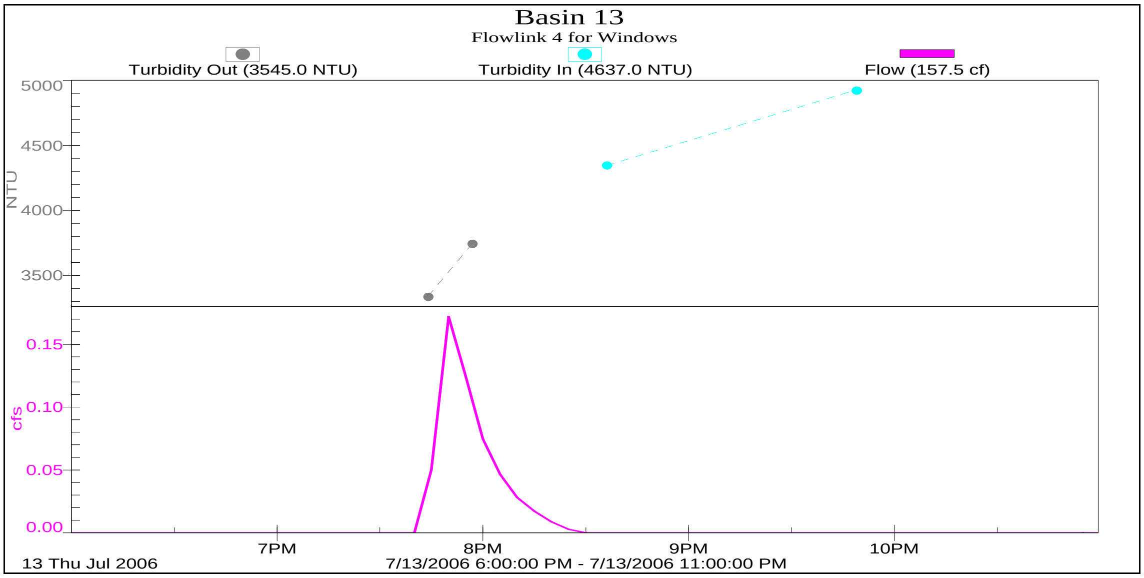


Figure 2.70. Basin 13 turbidity levels from July 13, 2006.

Trap 14

Sediment Trap 14 was a typical Type B trap in an area near final grade (Figure 2.1, 2.71 and 2.72). We installed a sampler in the trap near the inlet to obtain "in" samples. We also installed a weir below the rock dam and a sampler to measure flow and obtain samples at the outlet. Table 2.19 a, b and c illustrate the very high turbidity levels which occurred in this basin. On average, the inlet and outlet turbidity levels were similar, although the inlet water was sometimes less turbid (Figures 2.73, 2.74 and 2.75). Surveys were completed after storm events to determine the capture rates for this basin.

Figure 2.71. Basin 14.

Figure 2.72. Basin 14 sediment accumulated.

Table 2.19. Basin 14 Turbidity and sediment loading rates. a. Inlet turbidity levels, b. Exit turbidity levels (numbers noted in blue calculated as flow weighted turbidity average) and c. sediment loads, total flow for storm event and weighted turbidity averages.

(a)

Basin 14 In					
Date	**Turbidity Range (NTU)**				**Precip.**
	Min	*Median*	*Max*	*Avg*	*(In)*
5/26/2006	241	578	30000	11480	0.66
6/3/2006	346	1708	30000	7297	0.07

(b)

B14 Exit					
Date	**Turbidity Range (NTU)**				**Precip.**
	Min	*Median*	*Max*	*Avg*	*(In)*
5/26/2006	220	362	30000	11203	0.66
6/3/2006	340	455	30000	11676	0.07
6/25/2006	313	7531	30000	14430	2.76

(c)

B14 Exit				
Storm Event	**Sed Load**	**Flow**	**Wt Avg Turb**	**Precip.**
	(kg)	(cf)	NTU	(In)
5/26/2006	770.0	1576	11203	0.66
6/2/2006	603.5	1546	11676	0.07
6/25/2006	3035.8	6254	14430	2.76

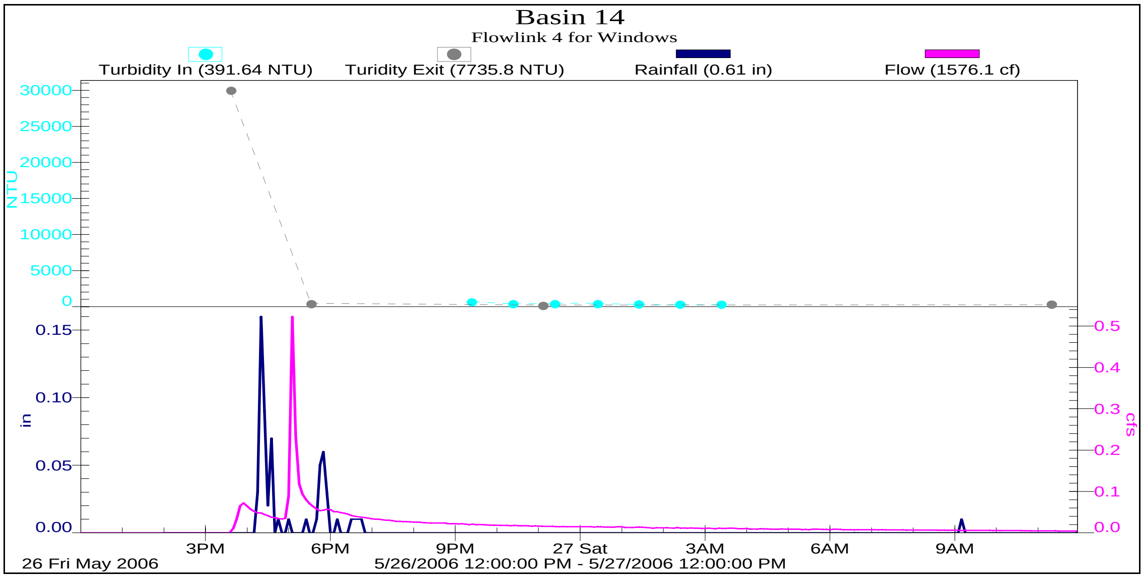


Figure 2.73. Basin 14 turbidity levels entering and exiting basin from May 26-27, 2006.

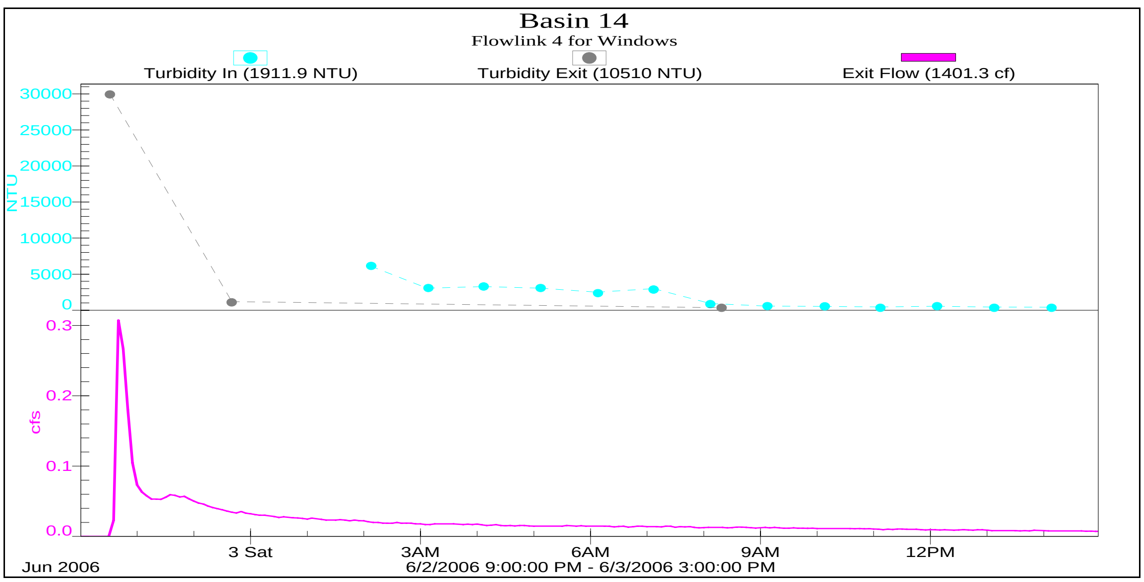


Figure 2.74. Basin 14 turbidity levels entering and exiting basin form June 2-3, 2006.

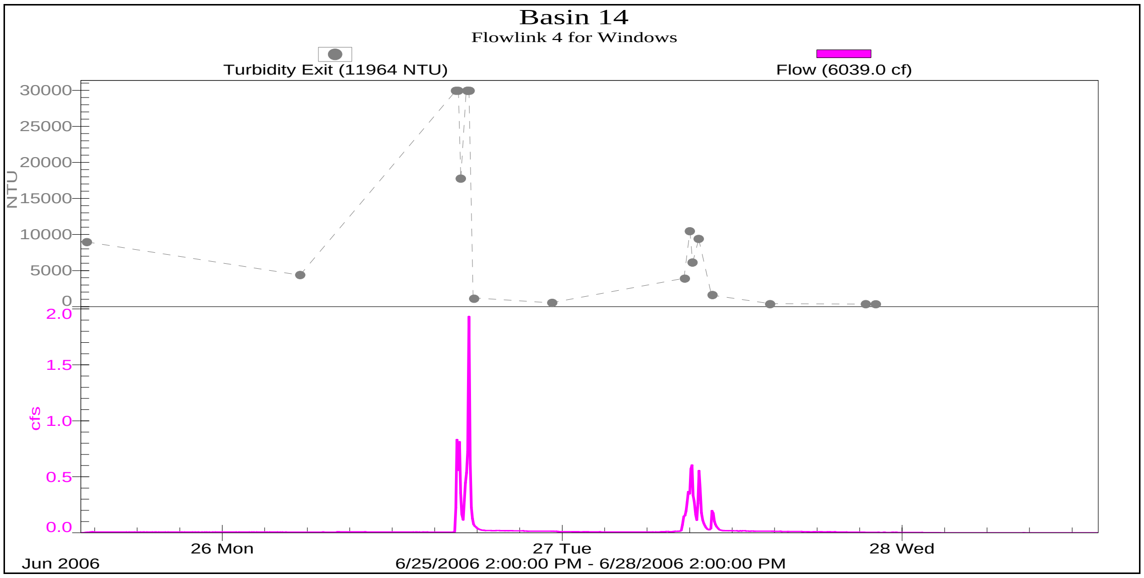


Figure 2.75. Basin 14 turbidity levels exiting basin from June 25-28, 2006.

Puckett Road Riser Basin

A standard riser basin was installed in 2004 just west of Puckett Road. A small sediment trap remained at the pipe outlet, so we installed a sampler there to obtain water samples. We also installed two PAM logs inside the riser barrel, since this was an ideal location for them. The watershed was relatively small for this structure during the period of monitoring, with much of the water diverted elsewhere. As a result, the basin filled in with vegetation and it essentially became a constructed wetland with a standing pool (Figures 2.76 and 2.77). The combined effects of a large, shallow basin and the PAM treatment resulted in relatively low turbidity and sediment concentrations for most storms, at least compared to the other sediment control structures we were monitoring (Tables 2.20-2.21).

Figure 2.76. Riser basin from dam.

Figure 2.77. Riser basin outlet.

Table 2.20. Riser basin turbidity levels

Riser Basin					
Date	**Turbidity Range (NTU)**				**Precip.**
	Min	*Median*	*Max*	*Avg*	*(In)*
4/13/2004	994	3211	3687	3227	0.95
6/14/2004	2736	3035	3687	2667	2.49
7/2/2004	17	62	151	71	1.50
7/27/2004	277	1980	3511	2068	0.56
7/28/2004	535	1184	3682	1695	0.50
9/13/2004	22	115	2646	465	2.26
9/20/2004	32	48	2866	489	1.13
10/5/2004	31	31	31	31	0.26
11/16/2004	0	43	85	49	0.52
12/2/2004	0	4	36	8	0.45
12/16/2004	0	20	139	59	1.41
1/19/2005	3	3	5	4	1.09
2/3/2005	14	11	120	16	0.60
2/17/2005	0	17	210	61	0.29
3/3/2005	271	306	406	255	0.94
6/20/2005	0	37	138	59	1.06
7/10/2005	0	196	385	192	0.52
8/1/2005	0	119	316	146	1.06

Table 2.21. Riser basin TSS levels.

Riser Basin				
Date	**TSS Range (mg/L)**			**Precip.**
	Min	*Median*	*Max*	*(In)*
7/2/2004	22	50	218	1.50
7/27/2004	683	1181	2446	0.56
7/28/2004	401	829	1975	0.50
9/13/2004	43	174	1645	2.66
9/20/2004	28	121	1412	1.13

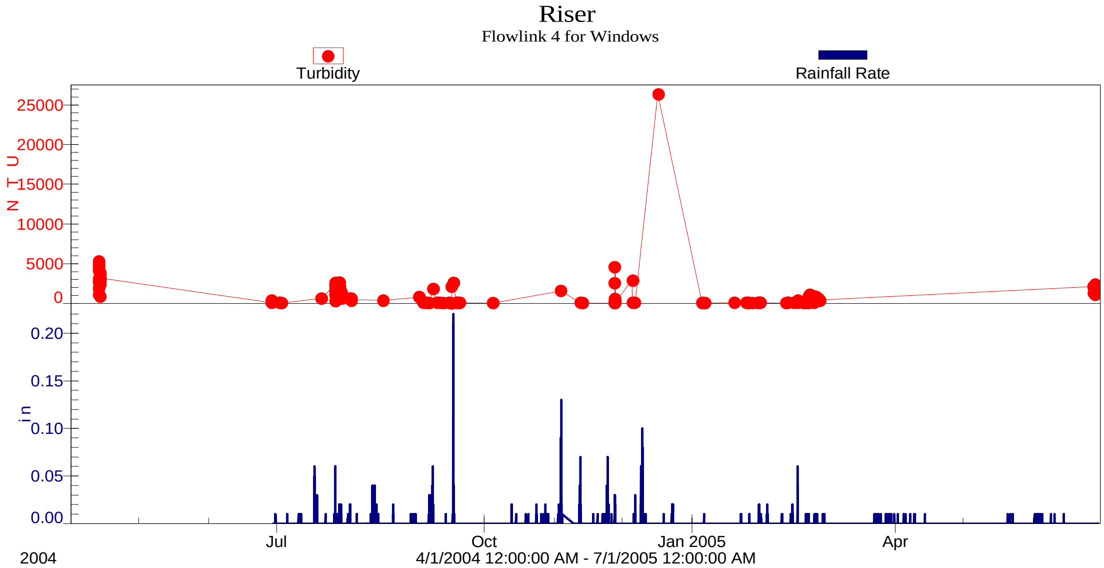


Figure 2.78. Riser basin turbidity levels from April 2004 through July 2005.

PAM Tests at Stilling Basins

When stilling basins were active and available for testing, we tried using a passive-dosing system for PAM. This essentially involved either PAM logs or powder, or both, placed in 12" corrugated pipe with the pumped water being routed through the pipe prior to discharge into the basin.

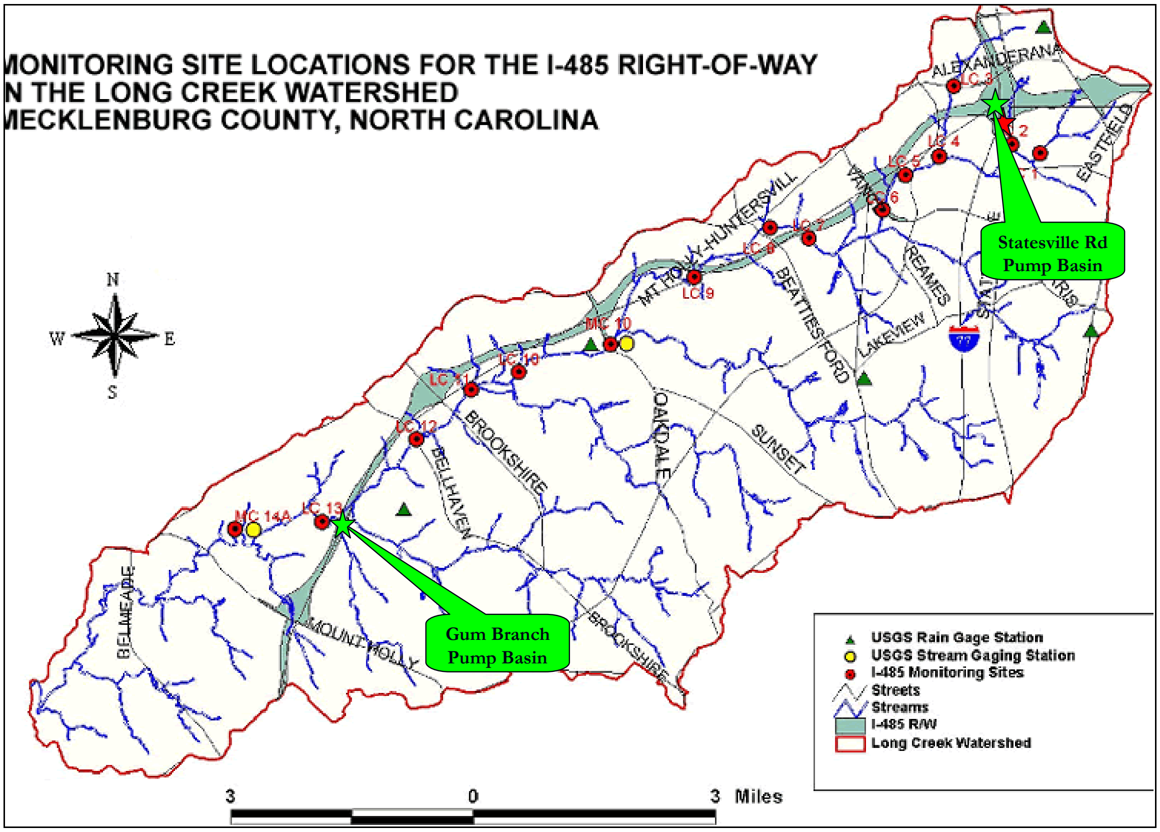


Figure 2.79. Stilling basin site map

Statesville Road Site (Above Stream 4)

This stilling basin was located off Statesville Rd (Figure 2.79). PAM was incorporated into pumped water prior to entrance into stilling basin by passing the water over two PAM logs and powder spread inside the 60 feet of pipe (Figures 2.80 and 2.81). Only limited testing was done with grab samples at this site, but generally the suspended material was flocculated successfully. Because of the sporadic nature of the pumping there, we did not install samplers.

Figure 2.80. Stilling basin initially.

Figure 2.81. Flocs formed on right after pumping.

Gum Branch

This site had two phases for testing. Initially, we attempted to try the passive dosing system in the existing stilling basin (Figures 2.82 and 2.83). This basin was very small and we had great difficulty in keeping our system functioning. Eventually, a second, much larger stilling basin was installed at a considerable distance and drop in elevation from the first basin (Figure 2.84). Two modifications were made. First, we covered the rock baffle in the basin center with coir erosion control matting and sprinkled PAM on it. Second, we stabilized the inlet with coir matting and sprinkled PAM on it as well. A sampler was placed at the outlet of that stilling basin and the results are shown in Figure 2.85. The pumping often occurred as a result of rainfall but not always, since there was a groundwater source where the pumping was being done. The peak of turbidity reflects the pumping activity. This indicates that the PAM dosing was working at low flow, but at peak flow the flocculation was not as complete.

Figure 2.82. Stilling basin setup

Figure 2.83. Flocs forming in basin

Figure 2.84. Stilling basin setup.

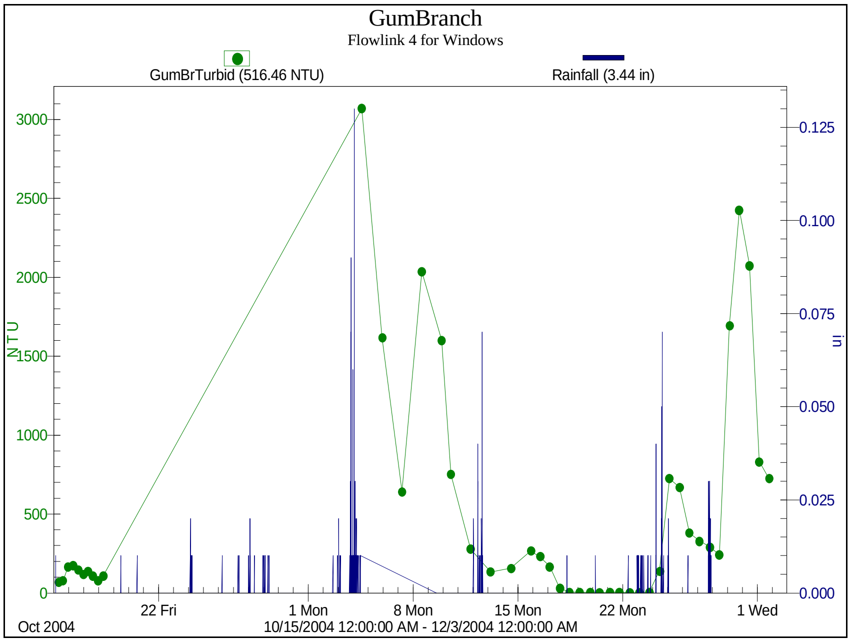


Figure 2.85. Gum Branch turbidity and rainfall levels from October 15, 2004 through December 3, 2004.

Old Statesville Rd

A small stilling basin was located on Old Statesville Rd at stream crossing (Figure 2.79). Figure 2.86 illustrates the treatment system. We placed 40' of 12" pipe adjacent to the basin and added 2 ½ lbs of PAM throughout the pipe length in four different spots. Collection started after 1 minute, 2 minutes, 3 minutes (stopped pump at this time) and at 4-5 minute when water velocity significantly decreased. Figures 2.87 and 2.88 illustrate the clear water and floc formation that was visually assessed following PAM treatment. This site had very little pumping occur and the basin was removed before we could do further testing.

Figure 2.86. Pumping set up.

Figure 2.87. Clear water treated with PAM.

Figure 2.88. Flocs formed in the stilling basin.

Chapter 3 - STREAM WATER QUALITY

We conducted water monitoring on several tributaries to Long Creek which passed through the I-485 construction site (Figure 3.1). These were installed to assess any direct impacts that the runoff from the construction site was having on stream sediment loads and turbidity. Two paired sites were located and installed during our study.

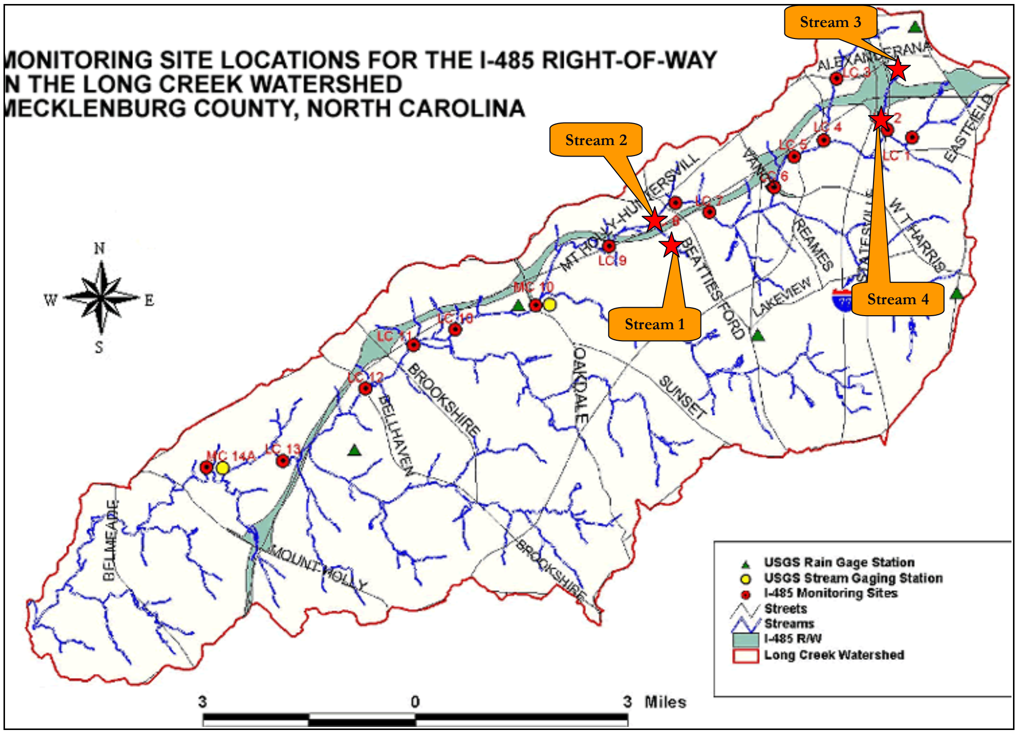


Figure 3.1. Stream monitoring sites.

Stream 1 and 2

The Stream 1site was located above any road construction work and downstream of a housing development being constructed (Figure 3.2). Stream 2 had very similar characteristics (Figure 3.3), but it was affected by a culvert below it which was damaged and as a result backed water into the weir. As a result, the Stream 2 data are not as complete as Stream 1. The large area of disturbance associated with the housing development resulted in considerable sediment and turbidity in the stream (Table 3.1). Overall, it did not appear that the stream had significant additions of sediment from the 485 project above what was coming from the upstream construction site.

Figure 3.2. Typical cross section in stream 1.

Figure 3.3. Stream 2 monitored cross section with rectangular weir.

Table 3.1. Stream 1 sediment load, total flow per storm and flow weighted turbidity averages.

Stream 1			
Date	**Sed.load**	**Flow**	**Flow Wt Turbidity**
	kg	**cf**	**NTU**
12/13/2003	8782	51049	3072
2/6/2004	26640	100137	9704
2/12/2004	3334	49011	4327
2/28/2004	2359	72312	2217
5/9/2004	65	13810	5441
6/14/2004	46583	123698	10901
6/21/2004	16794	91021	6171
7/27/2004	5344	29845	4513
7/28/2004	13074	101654	5318
8/12/2004	1192	15254	2901
9/7/2004	34075	176225	3390
10/7/2004	1122	23487	1446
11/9/2004	401	15619	388
11/12/2004	568	18505	628
12/9/2004	3242	86177	959
12/23/2004	683	27123	363
1/4/2005	464	10353	1305
2/3/2005	463	17776	406
2/21/2005	486	15522	657
2/24/2005	2785	72954	986
3/8/2005	6985	112363	2135
3/16/2005	2719	98685	478
3/22/2005	5370	130371	1131
3/27/2005	10024	182508	1788
4/12/2005	8538	134016	2209

Table 3.2. Stream 1 and 2 Turbidity levels (numbers noted in blue are calculated as flow weighted turbidity averages).

	Stream 1				Stream 2			
	Turbidity Range				Turbidity Range			
	NTU				NTU			
Date	*Min*	*Median*	*Max*	*Average*	*Min*	*Median*	*Max*	*Average*
12/13/2003	3072	3072	3072	3072	1168	-	3072	7212
1/5/2004					2924	2924	2924	7371
2/6/2004	1593	7432	25746	9704	690	3846	18223	6371
2/12/2004	1208	3305	7999	4327	568	6986	10902	6572
2/28/2004	279	1849	4680	2217				
5/9/2004	2978	4934	7844	5441				
6/14/2004	2801	5993	28160	10901				
6/21/2004	1047	3695	11217	6171				
7/17/2004	803	3695	11217	4166				
7/27/2004	2708	4295	7521	4513				
7/28/2004	1974	5411	7204	5318				
8/3/2004					44	54	340	1139
8/12/2004	2149	2393	3763	2901				
9/7/2004	427	2980	6147	3390				
9/13/2004					8	18	92	23
9/20/2004					6	10	226	26
9/27/2004	504	1626	1903	1503				
10/7/2004	77	197	3904	1446				
11/9/2004	404	574	816	388	677	677	677	677
11/12/2004	222	1023	3427	628				
12/9/2004	133	689	2850	959				
12/23/2004	208	396	451	363	213	213	213	213
1/4/2005	976	2461	5025	1305				
1/30/2005					290	290	290	290
2/3/2005	209	299	742	406				
2/21/2005	166	704	2345	657	299	299	299	299
3/8/2005	294	2004	2774	2135	19	-	75	-
3/16/2005	324	479	600	478	0	-	18	-
3/22/2005	236	686	2107	1131	13	13	13	13
3/27/2005	364	1508	2858	1788				
4/8/2005					405	405	405	405
4/9/2005					308	308	308	308
4/12/2005	155	1363	6557	2209	158	158	158	158
4/15/2005					36	42	130	61
5/3/2005					23	42	170	64
5/18/2005	1884	2142	2399	2142	27	40	52	40
5/20/2005					19	40	111	57

Table 3.3. Stream 2 sediment load, total flow per storm and flow weighted turbidity averages.

Stream 2			
Date	**Sed.load**	**Flow**	**Flow Wt Turbidity**
	kg	**cf**	**NTU**
12/13/03	19917	99093	7212
01/05/04	20584	95217	7372
02/06/04	14000	100786	6371
02/12/04	8644	94928	6573
08/03/04	2617	1719780	1139

Stream 3 and 4 (Paired Study)

The Stream 3 and 4 paired site was the opposite of the Stream 1 and 2 site. The Stream 3 site had two culverts draining an office park area with no evidence of surface disturbances (Figures 3.4-3.5). As a result, the turbidity levels were relatively low at this site (Table 3.4). Because of the nature of the site, having two culverts, we did not measure flow but only samples the water during storm events.

Figure 3.4. Stream 3.

Figure 3.5. Stream 3 during storm.

Figure 3.6. Stream 4.

Figure 3.7. Stream 4 during storm.

Table 3.4. Stream 3 and 4 Turbidity levels.

	Stream 3				Stream 4			
	Turbidity Range				Turbidity Range			
Date	NTU				NTU			
	Min	*Median*	*Max*	*Avg*	*Min*	*Median*	*Max*	*Avg*
2/3/2004					85	173	221	163
2/6/2004					748	1700	4915	2002
2/12/2004					223	787	1392	765
2/27/2004					114	194	446	205
2/29/2004					70	99	914	239
3/19/2004					36	36	36	36
4/1/2004	25	86	186	88				
4/15/2004	57	86	124	88				
5/5/2004	93	130	168	130	123	267	1106	444
6/7/2004	27	81	216	102				
6/16/2004	145	145	145	145	3089	3089	3089	3089
6/29/2004	118	167	216	167	1750	1750	1750	1750
7/15/2004					260	1149	3159	1466
7/16/2004					3	26	180	59
7/21/2004	81	87	92	87	25	25	25	25
7/27/2004	39	62	85	62	319	554	9409	1043
7/28/2004	59	72	85	72				
9/1/2004	403	403	403	403				
9/20/2004	41	41	41	41	2247	2247	2247	2247
10/5/2004					145	266	341	251
11/16/2004					591	591	591	591
11/27/2004	137	184	272	198	2230	2230	2230	2230
12/6/2004	86	110	1405	339				
12/10/2004					6734	6734	6734	6734
12/21/2004	59	166	318	170	37	37	37	37
1/19/2005	53	81	455	155				
1/26/2005	221	221	221	221	2199	2199	2199	2199
1/30/2006	37	55	136	68	430	430	430	430
2/3/2005	54	100	331	135	285	323	612	407
2/10/2006	59	215	2272	449				
2/14/2005					152	256	520	296
2/21/2005					263	300	336	300
2/24/2005					303	334	364	334
3/8/2005					536	536	536	536
3/14/2005					12	149	200	120
3/28/2006					532	1681	2379	1531
4/8/2005					6162	6162	6162	6162
4/12/2005					212	278	345	278
4/30/2005					198	198	198	198
5/1/2005					948	948	948	948
5/18/2005	6	15	280	36	366	366	366	366
6/1/2005					585	585	585	585
8/4/2005	31	168	438	178				
10/18/2005	14	157	293	155	260	3156	6051	3156

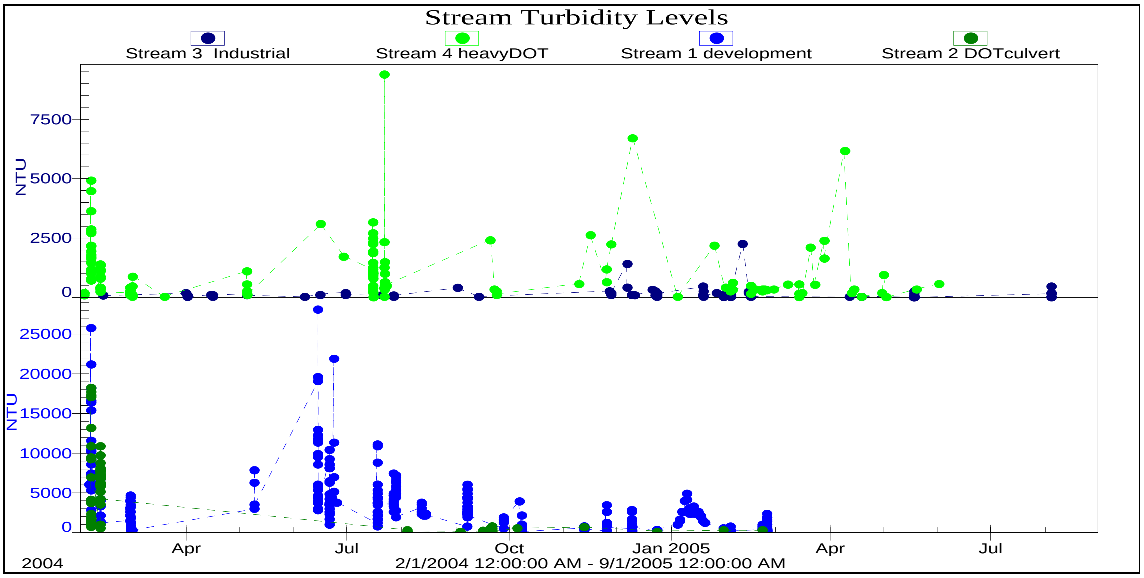


Figure 3.8. Stream 1, 2, 3 and 4 turbidity levels from February 2004 through September 2005.

Results illustrated higher turbidity levels below the I-485 construction site at stream 4, but the opposite with stream 2 due to construction within a housing development upstream of stream 1.

Instream Morphological Assessment

The current stability of Long Creek and its tributaries were assessed using physical measurements of the channel dimension, substrate composition, turbidity and TSS. Permanent cross-sections were established along the main channel and tributaries of Long Creek following techniques described in the USDA Forest Service protocols (1994). All cross sectional measurements are calculated from existing top of bank conditions. Pebble counts were conducted at each study section collecting 100 samples at a transect from toe of channel bank to toe of channel bank. The median particle size (d50) and substrate percent composition were analyzed to determine shifts in bed material.

Morphological Assessment

The goal of the channel morphology assessment is to attempt to determine if highway construction activities are adversely impacting existing channel morphology. One example adverse impact would be if the existing channel filled significantly with sediment disrupting the channel flow regime. To determine morphology changes, cross-sections and channel substrate measurements were conducted at 15 sites throughout the Long Creek watershed. Four types of areas were selected for study. Reference sites were selected with minimal construction disturbance (stations 100 and 109) from highway or development. Upstream/downstream paired sites were selected (107/108, 121/122, 131/132). Sites along Long Creek (stations 106, 110, 120, 123, 130, and 140) were selected along the project to see how the larger channel changed over the study period. One site was selected (station 141) directly downstream of a major interchange (Statesville road). All measurements were calculated from the channel top of bank since many sites did not have distinguishable bankfull features. A brief description, pictures and annual data collected are listed below.

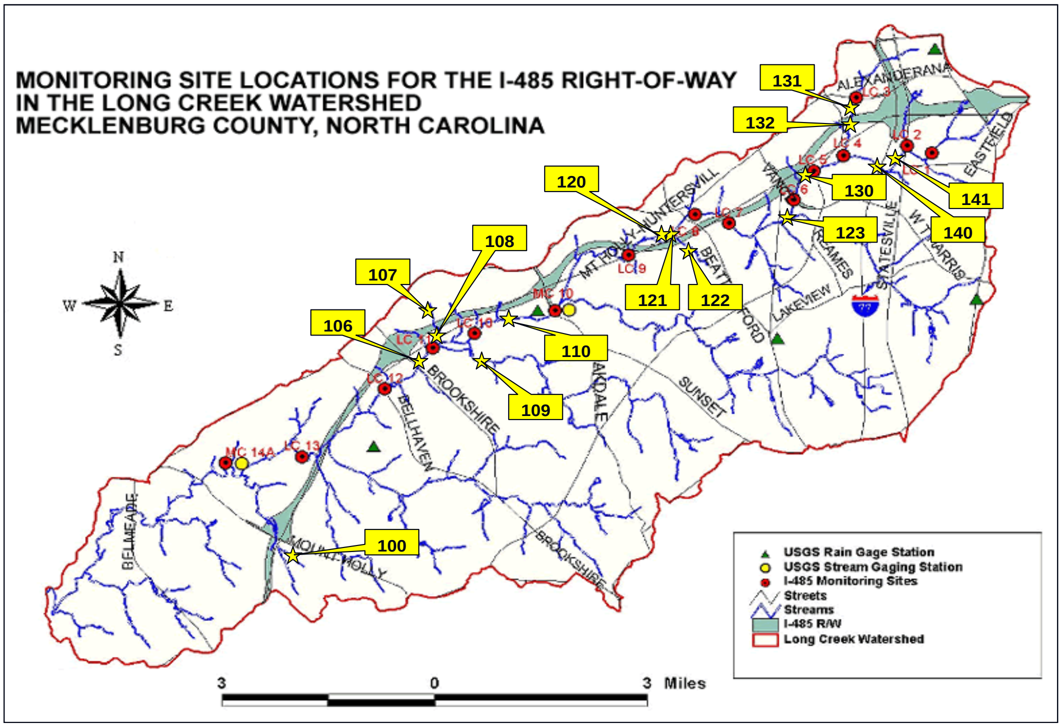


Figure 3.9. Cross-section monitoring stations.

Cross-Section 100

This cross-section is located on a small tributary to Long Creek off Mt. Holly Rd downstream from I-485 construction (Figures 3.9 and 3.10). This site was selected as a reference area, undisturbed by recent construction activities. The survey location for 2003 was relocated in 2005 due to construction impacts at the 2003 location. The cross-section dimensions and substrate measurements from 2005 to 2006 showed no significant changes (Figure 3.11 and Tables 3.5 and 3.6).

(a)

(b)

Figure 3.10. a. Typical cross-section looking upstream. b. Typical cross-section looking downstream.

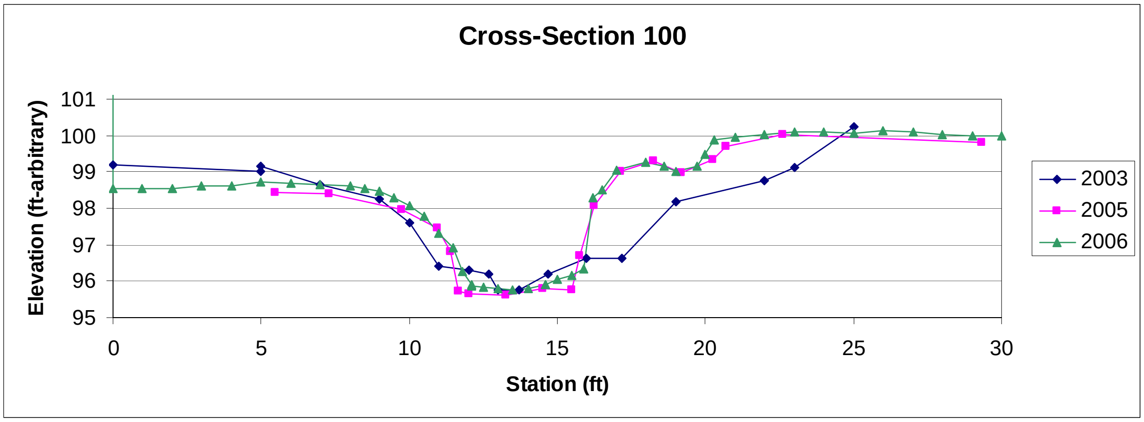


Figure 3.11. Cross-section 100 morphological survey from 2003, 2005 and 2006.

Cross-Section 106

This cross-section is located the furthest downstream on the main stem of Long Creek. The site is directly upstream of highway 16 (Figures 3.12 and 3.13). No significant changes were noted during the study period (Figure 3.14 and Tables 3.5 and 3.6).

(a)

(b)

Figure 3.12. a. Typical cross-section looking upstream. b. Typical cross-section looking downstream.

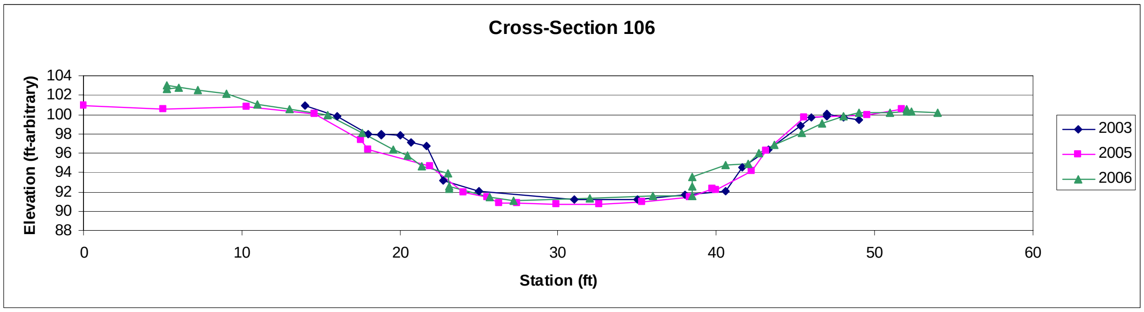


Figure 3.13. Cross-section 106 morphological survey from 2003, 2005 and 2006.

Cross-Section 107

This cross-section is upstream portion of the upstream/downstream study along with station 108. Station 107 is located on a tributary to Long Creek, near Chastain Park, upstream of the I-485 construction project (Figures 3.9 and 3.14). The cross section remained uniform over the monitoring period with a slight increase in area from 76 to 88 square feet. The channel remained a sand dominated channel with what appeared to be excessive sediment loads coming from prior development and existing bank erosion. (Figure 3.15 and Tables 3.5 and 3.6)

(a) (b)

Figure 3.14. a. Typical cross-section looking upstream, b. Typical cross-section looking downstream.

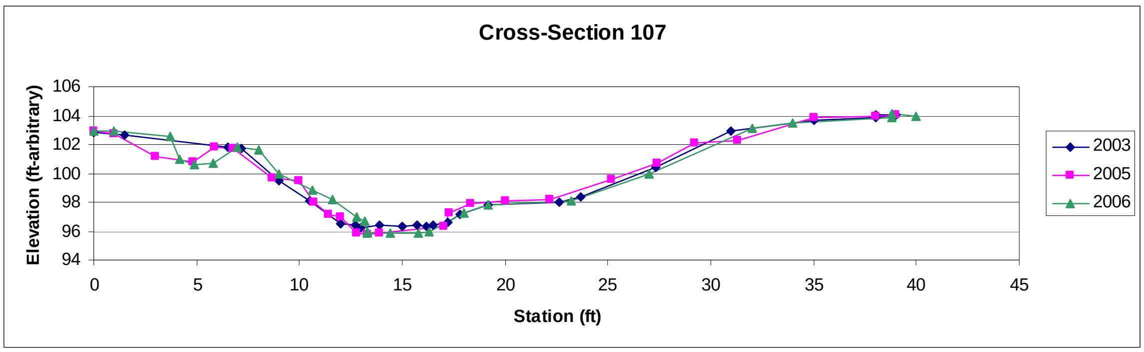


Figure 3.15. Cross-section 107 morphological survey from 2003, 2005 and 2006.

Cross-Section 108

This cross-section is located on a tributary to Long Creek, near Chastain Park, downstream of the I-485 construction project (Figure 3.9 and 3.16). This cross-section is the downstream portion of the upstream/downstream study along with station 107. The channel showed a decrease in cross sectional area over the monitoring period from 30 to 26 square feet. Aggradation is evident in the area of this cross section but there was no change in mean particle size along the bed. Due to the significant amount of bank erosion, the sediment source can not be determined. (Figure 3.17 and Tables 3.5 and 3.6)

(a) (b)

Figure 3.16. a. Typical cross-section looking upstream, b. Typical cross-section looking downstream.

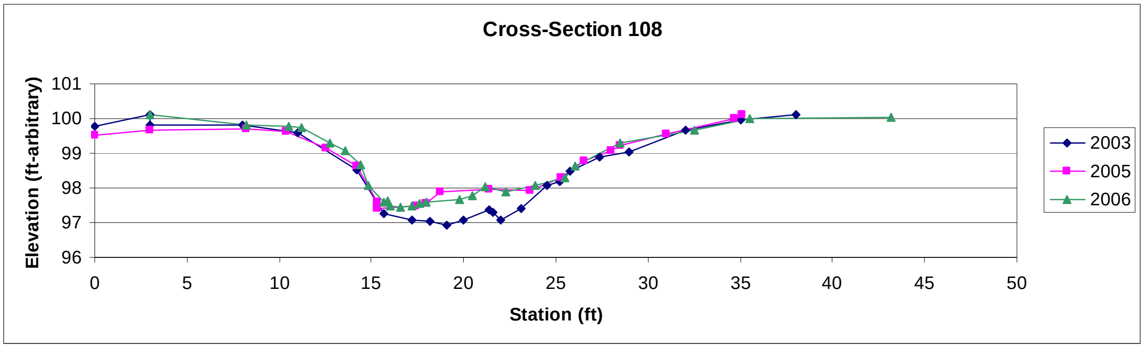


Figure 3.17. Cross-section 108 morphological survey from 2003, 2005 and 2006.

Cross-Section 109

This cross-section was located on a tributary to Long Creek, near Simpson Dr This section is contained within a watershed un-impacted from highway construction and is used as a reference (Figures 3.9 and 3.18). Some erosion was observed on the left bank. The channel in this area is severely incised and some erosion is expected. There was no change in mean particle size during the study. (Figure 3.19 and Tables 3.5 and 3.6)

(a) (b)

Figure 3.17 a. Typical cross-section looking upstream, b. Typical cross-section looking downstream.

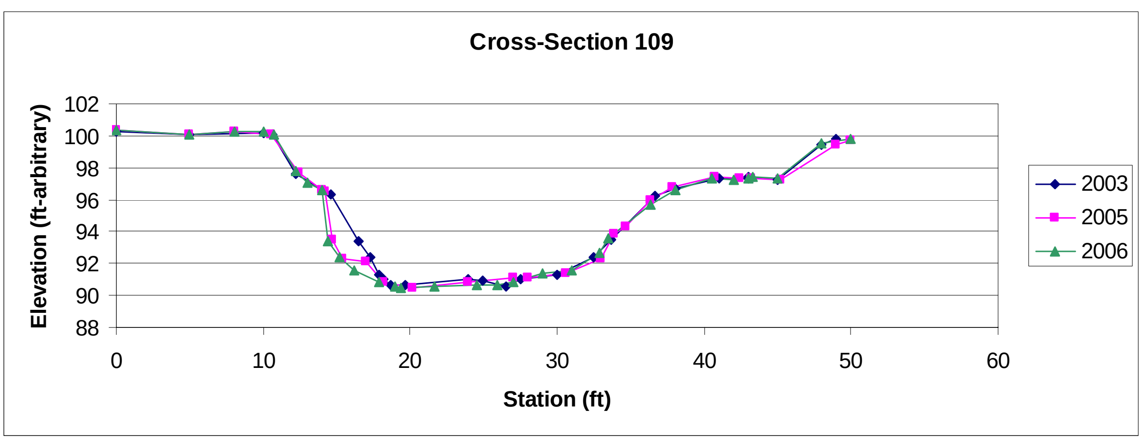


Figure 3.18. Cross-section 109 morphological survey from 2003, 2005 and 2006.

Cross-Section 110

This cross-section was located on the main stem of Long Creek, upstream form USGS gaging station and downstream from I-485 construction site (Figures 3.9 and 3.19). A small increase in channel cross sectional area occurred but overall the channel remained stable with only a small decrease in mean channel particle from 0.5 to .25mm. A sand dominated system is an indication of channel bank instability upstream but this cannot be directly linked to the highway construction. (Figure 3.20 and Tables 3.5 and 3.6)

(a)

(b)

Figure 3.19 a. Typical cross-section looking upstream, b. Typical cross-section looking downstream.

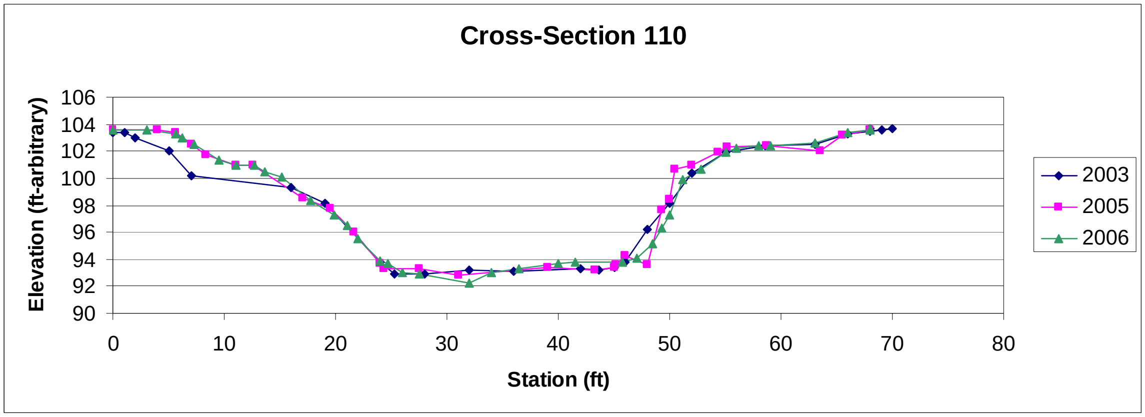


Figure 3.20. Cross-section 110 morphological survey from 2003, 2005 and 2006.

Cross-Section 120

This cross-section was located on the main stem of Long Creek, near Beatties Ford Rd downstream form I-485 construction (Figure 3.9 and 3.21). The channel cross sections remained similar throughout the study period with minor fluctuations in area. The bed scoured 0.5 feet over the study period but well within expected limits for a sand dominated system of this size. No channel aggradation was evident. (Figure 3.22 and Tables 3.6 and 3.6)

(a)

(b)

Figure 3.21. a. Typical cross-section looking upstream, b. Typical cross-section looking downstream.

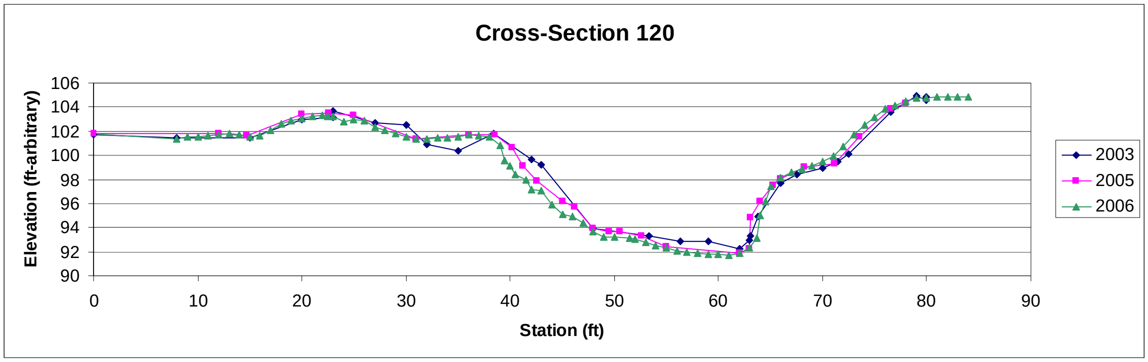


Figure 3.22. Cross-section 120 morphological survey from 2003, 2005 and 2006.

Cross-Section 121

This cross-section was located on a tributary to Long Creek, near Beatties Ford Rd, downstream from I-485 construction site (Figures 3.9 and 3.23). This section is the upstream portion of the upstream/downstream pair (121/122). This site was chosen due to its proximity to a housing development that was under development during the study. Aggradation is evident from the cross section as the area went from 43.9 to 40.4 square feet. Upstream sediment source is likely at this section since it follows a similar pattern as the upstream cross section (station 122). Mean bed material remained silt/clay for duration of the study. (Figure 3.24 and Tables 3.5 and 3.6) The 2005 cross section survey was skipped due to site access limitations.

(a)

(b)

Figure 3.23 a. Typical cross-section looking upstream, b. Typical cross-section looking downstream.

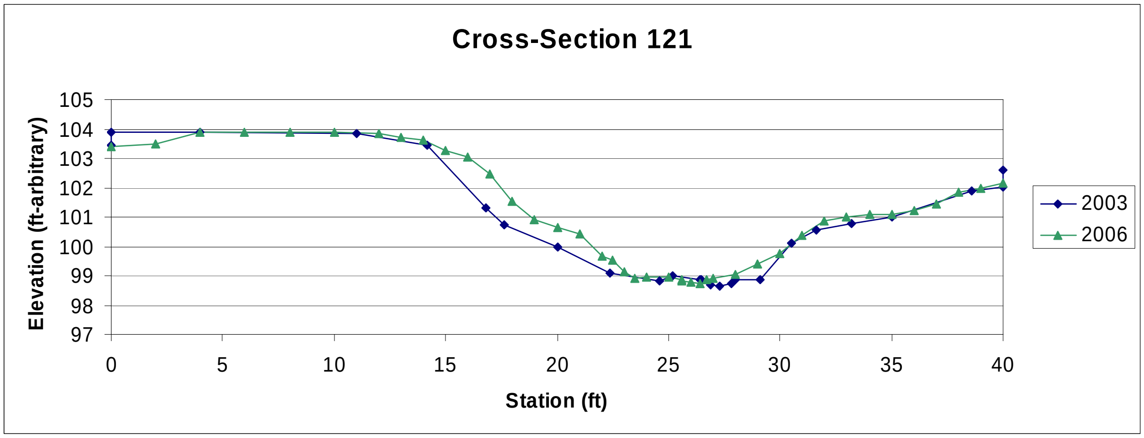


Figure 3.24. Cross-section 121 morphological survey from 2003 and 2006

Cross-Section 122

This cross-section was located on a tributary to Long Creek, upstream from the I-485 construction site (Figures 3.9 and 3.25). This section is the upstream portion of the upstream/downstream pair (121/122). This site was chosen due to its proximity to a housing development that was under development during the study. Some aggradation occurred between 2003 and 2005. Sediment source is likely the development upstream of the section. Aggradation in the channel and along the floodplain was evident in this area. (Figure 3.26 and Tables 3.5 and 3.6)

(a)

(b)

Figure 3.25. a. Typical cross-section looking upstream, b. Typical cross-section looking downstream.

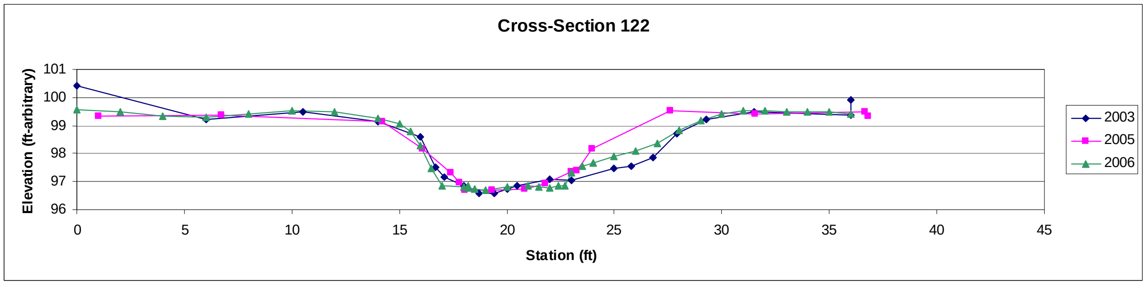


Figure 3.26. Cross-section 122 morphological survey from 2003, 2005 and 2006.

Cross-Section 123

This cross-section was located on the main stem of Long Creek, below WT Harris Blvd and downstream from I-485 construction (Figure 3.9 and 3.27). An overall increase in channel cross sectional area can be seen in the cross section and no aggradation. Mean bed particle size decreased from 0.5 to 0.2mm. (Figure 3.28 and Tables 3.5 and 3.6)

(a)

(b)

Figure 3.27. a. Typical cross-section looking upstream, b. Typical cross-section looking downstream.

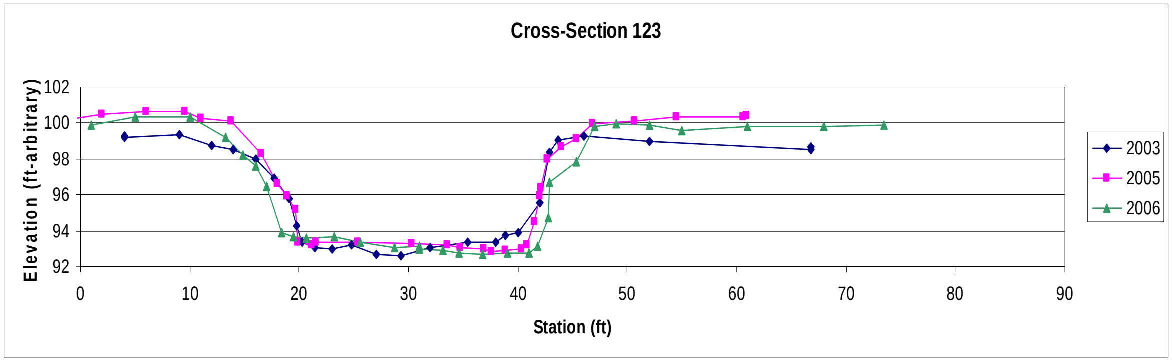


Figure 3.28. Cross-section 123 morphological survey from 2003, 2005 and 2006.

Cross-Section 130

This cross-section was located on the main stem of Long Creek by Forest Drive downstream from I-485 construction (Figures 3.9 and 3.29). The channel remained similar between years 2005 and 2006. The 2003 section was taken at different location. That section was unable to be field located in subsequent years. No bed aggradation or degradation was evident in the cross sections. (Figure 3.30 and Tables 3.5 and 3.6)

Figure 3.29.Typical cross-section looking upstream.

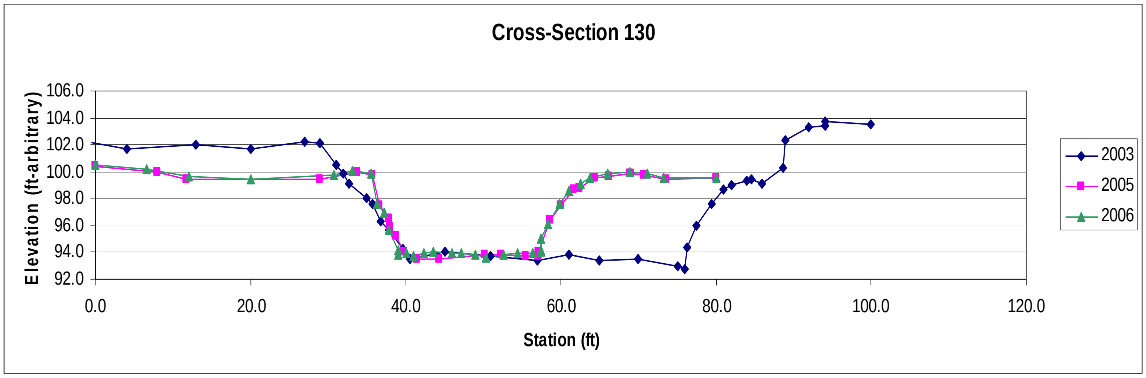


Figure 3.30. Cross-section 130 morphological survey from 2003, 2005 and 2006.

Cross-Section 131

This cross-section was located on a tributary to Long Creek where Alexanderana Rd crosses, upstream from I-485 construction site (Figures 3.9 and 3.31). This section is the upstream portion of the upstream/downstream pair (131/132). This site was previously impaired with a large amount of sediment likely from upstream farming practices. The left channel bank eroded during the study, which increased the cross sectional area from 42.5 to 51.4 square feet between 2005 and 2006. The channel bed remained relatively consistent and the substrate decreased from 1.0 to 0.4mm. Aggradation within the channel is evident at this cross section which is upstream of the highway project. (Figure 3.31 and Tables 3.5 and 3.6)

(a)

(b)

Figure 3.31 a. Typical cross-section looking upstream, b. Typical cross-section looking downstream.

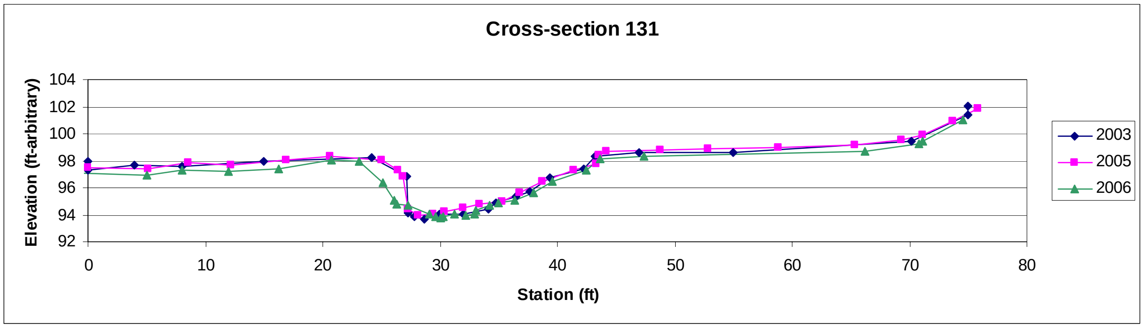


Figure 3.32. Cross-section 131 morphological survey from 2003, 2005 and 2006.

Cross-Section 132

This cross-section was located on a tributary to Long Creek where Alexanderana Rd crosses, downstream from I-485 construction site (Figures 3.9 and 3.33. This section is the downstream portion of the upstream/downstream pair (131/132). This site was previously impaired with a large amount of sediment likely from upstream farming practices. The channel remained consistent during the study period with some aggradation within the channel. Cross sectional area decreased slightly but the sediment source could not be singled out. The channel substrate decreased from 6.9 to 0.4mm. (Figure 3.34 and Tables 3.5 and 3.6)

(a)

(b)

Figure 3.33. a. Typical cross-section looking upstream, b. Typical cross-section looking downstream.

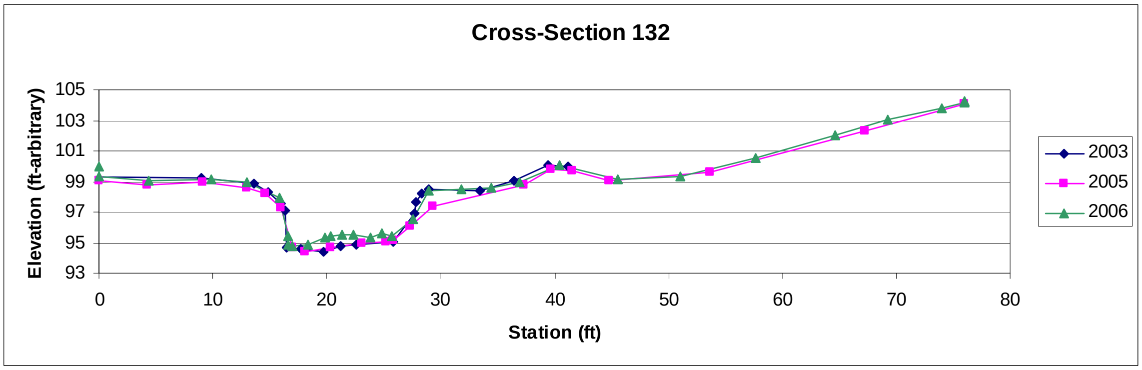


Figure 3.34. Cross-section 132 morphological survey from 2003, 2005 and 2006.

Cross-Section 140

This cross-section was located at the most upstream sample site on the main stem of Long Creek, near Hwy 21and downstream from I-485 construction (Figures 3.9 and 3.35). The channel cross section increased during the study period from 112 to 125 square feet due mostly to bed degradation. Channel banks remained stable. Channel substrate decreased from 0.35 to 0.2mm. (Figure 3.36 and Tables 3.5 and 3.6)

(a)

(b)

Figure 3.35. a. Typical cross-section looking upstream, b. Typical cross-section looking downstream.

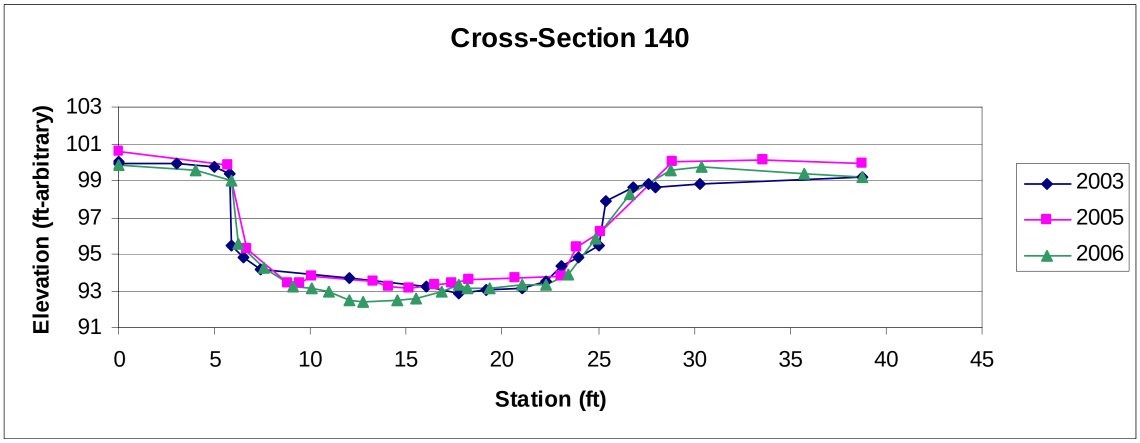


Figure 3.36. Cross-section 140 morphological survey from 2003, 2005 and 2006.

Cross-Section 141

This cross-section was located on a tributary to Long Creek, off Hwy 21 downstream from I-485 construction at the Statesville road intersection. (Figures 3.9 and 3.37). The channel in this area had the most potential to be directly impacted by construction activities since a large percentage of its watershed was being disturbed by highway construction activities. The 2003 section was relocated because it was originally established within the footprint of the highway project. 2005 and 2006 sections showed a little widening and deepening but no significant aggradation. Mean channel particle decreased from 5.7mm in 2005 to 0.25mm in 2006. Highway construction directly upstream of the cross section is the likely source of the decrease in particle size. (Figure 3.38 and Tables 3.5 and 3.6)

(a) (b)

Figure 3.37 a. Typical cross-section looking upstream, b. Typical cross-section looking downstream.

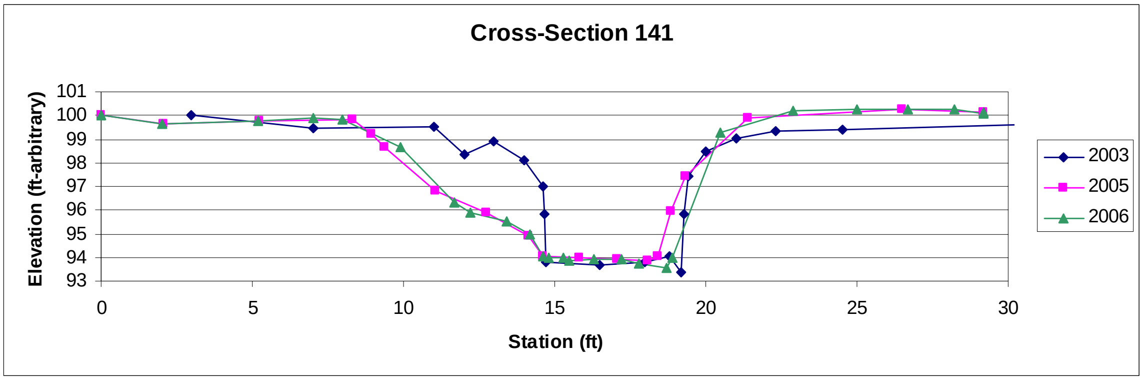


Figure 3.38. Cross-section 141 morphological survey from 2003, 2005 and 2006.

The results from the cross-sectional surveys showed little change over the study period for the majority of the sites. Reference site morphology changes were similar in magnitude to changes observed at the other study locations. Results from the upstream/downstream study sites showed all sites below construction had a decrease in cross sectional area but not to the point of altering channel morphology. The macroinvertebrate study will suggest if there has been any significant impact to in-stream habitat, but morphology appears to have been minimally impacted during the period of this study.

All sites along Long Creek increased in cross sectional area which indicates that the main channel has been able to transport any additional sediment load, if any, supplied to the channel from highway construction. The one site which had the greatest potential for immediate adverse impacts (Long Creek tributary station 141) showed changes similar to those of the reference stations.

Mean channel particle size remained the same or decreased at all study locations. In some cases, the decreases were very significant and suggested that there was significant increase in fine sand and silt material. There were some periods of relatively high loading from the sediment basins which may have contributed to the finer materials in the stream. The impacts were not immediately obvious in the macroinvertebrate sampling, however.

Overall the highway construction did not drastically impact the channel morphology at the sites studied. The existing condition of the stream channels were fair to poor and remain as such at the conclusion of this study.

Table 3.5. Morphological summary assessing cross-sectional morphology (Drainage area and Regional Curve information provided for reference use).

A: Cross-sectional area
W: Width of cross-section
Max D: Max depth

XS	Drainage Area	Regional Curve A_{BKF} (sq.ft)		Measured A_{TOB} (sqft)			W_{TOB}			Max D_{TOB}		
	sq.mi	*Rural*	*Urban*	*2003*	*2005*	*2006*	*2003*	*2005*	*2006*	*2003*	*2005*	*2006*
100*	0.26	9	28	26.1	13.9	14.1	18	9.8	9	3.3	2.8	2.9
106*	15.21	150	300	187.6	195.1	194.9	33	30.9	36	8.9	9	9
107	0.09	-	-	76.2	73.3	88.3	23.8	22.4	25	5.5	6	5.8
108	0.15	-	-	30.4	26.4	26.2	21	22.2	21.3	2.7	2.2.	2.3
109	2.34	38	99	120.0	132.0	129.0	30.4	28.4	28.3	6.8	7	6.8
110	11.75	125	275	259.0	279.9	272.1	39	44.2	46.5	9	9.1	9.7
120	7.12	80	200	203.4	195.7	218.0	38.1	35	37	9.5	9.8	10
121*	0.21	7.1	12	43.9	Missed	40.3	24.5	Missed	23	3.4	Missed	3.4
122	0.19	7	11	22.6	22.1	24.0	13.9	17.3	14	2.5	2.4	2.6
123	5.66	65	190	142.0	172.9	182.2	34.7	39.7	35.7	6.4	7.3	7.1
130*	2.68	45	125	398.4	128.9	133.2	60	28.6	30.5	9.3	6.1	6.2
131	0.41	12	35	49.2	42.5	51.4	19	18.5	20.6	4.6	4	4.2
132	0.45	12	35	38.1	42.1	36.2	13.4	14.4	15.9	3.8	3.9	3.7
140	1.51	30	80	112.2	130.6	124.6	21.8	26.9	24.8	6.6	6.8	7.2
141*	0.31	9	28	29.3	47.9	49.5	9.3	13.1	14.9	6	6	6.3

* Cross sections relocated between 2003 and 2005

Table 3.6. Median substrate over last three years (numbers noted in red, were a new cross-section established in 2005).

XS	Median Substrate (mm)		
	2003	*2005*	*2006*
100	0.062	0.125	*0.062*
106	0.2	0.25	0.25
107	0.5	0.25	0.25
108	0.3	0.25	0.25
109	0.5	0.5	0.5
110	0.5	0.25	0.25
120	0.125	0.25	0.25
121	0.061	0.061	0.061
122	0.062	0.061	0.061
123	0.5	0.5	0.2
130	0.5	0.25	0.25
131	1	0.25	0.4
132	6.9	0.125	0.35
140	0.35	0.25	0.2
141	0.45	5.7	0.25

Biological Assessment

Macroinvertebrate sampling was initiated March 10, 2003 with follow-up sampling conducted on March 18, 2004. Final sampling occurred on April 5, 2006. Sampling was not done in 2005 because construction in the watershed was not completed. Ten sites in the Long Creek Watershed were sampled on each of three sample dates (Figure 3.39). Of the ten biological water quality-monitoring locations initially selected in 2003, only nine were used in 2004 and 2006. Site 6, located parallel to Oakdale Road, was not sampled due to the absence of water. A new monitoring site (site 11) was located on the main channel of Long Creek upstream of Old Statesville Road. This upstream-most monitoring site was located above any highway construction. The downstream-most water-quality monitoring site remained on Long Creek (Site 1), and was 50m below its confluence with Gum Branch.

Macroinvertebrate data was evaluated using North Carolina's Department of Water Quality's (NCDWQ) criteria and the U.S. Environmental Protection Agency's Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers.

2003

In the initial year of the study (Figure 3.39), few differences in water quality metrics were found throughout the main channel of Long Creek (sites 1, 3, 5, 7, 8, 9). Overall bioclassification ratings indicated "Fair" biological water quality values at all sites along the main channel of Long Creek. In the main channel, differences in individual metrics (Table 3.7) were apparent in the total number of taxa, functional feeding groups, and numbers of mayfly taxa (one of the three major groups of pollution intolerant organisms). "Poor" biological water quality values were found at the two monitoring sites located on the Gum Branch tributary (site 2) and an unnamed tributary (site 6). Obvious anthropogenic influences, such as channel straightening, little if any riparian vegetation and a high degree of human use (trash) impacted Gum Branch. Clear-cutting of sensitive headwater areas appeared to have impacted site 6. Initial monitoring showed highest water-quality metrics on Gutter Branch (site 4). We considered this the control site; it had an overall bioclassification rating of "Good-Fair".

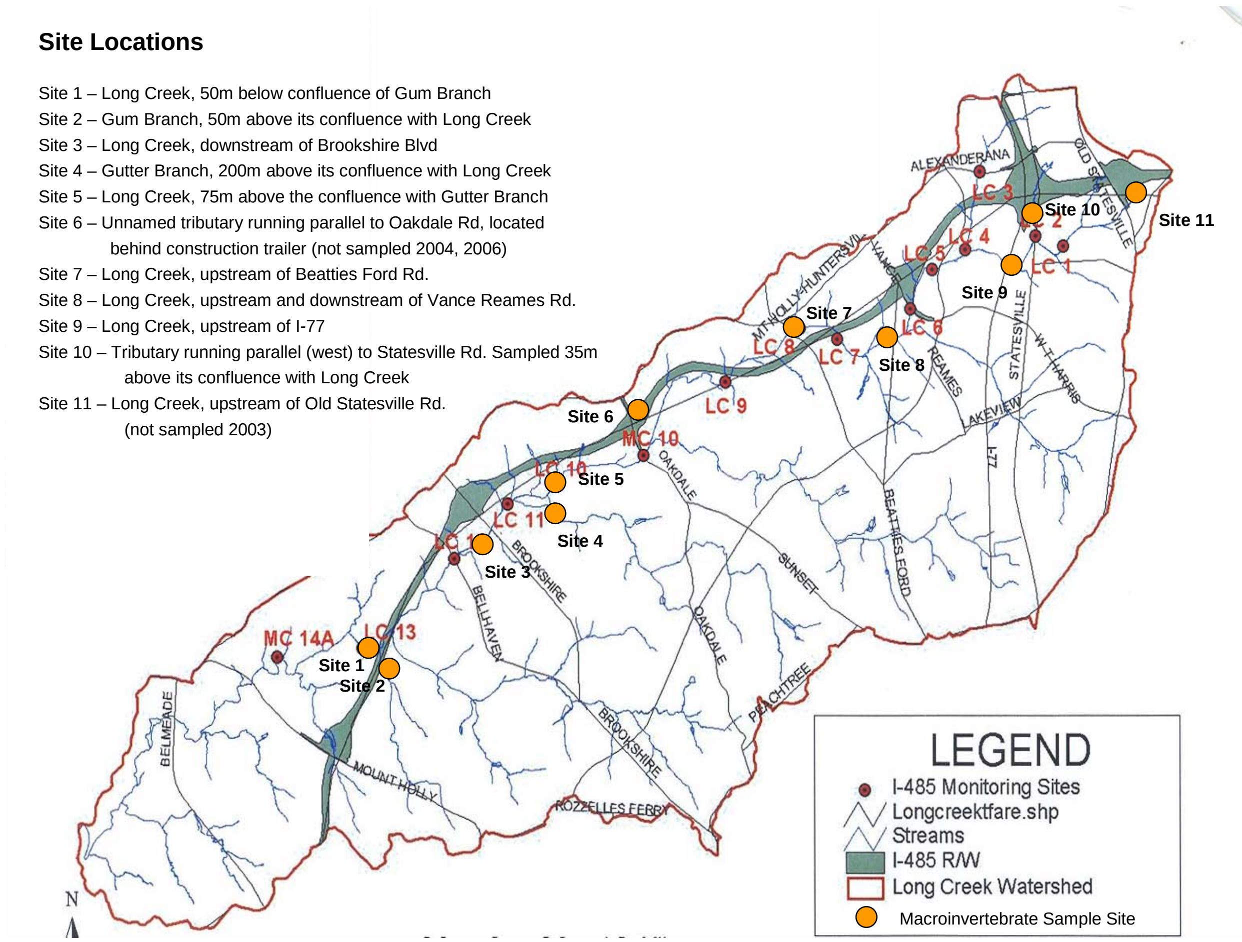


Figure 3.39. Macroinvertebrate sampling sites and location information within the Long Creek Watershed.

2004

Second round monitoring results (Figure 3.39) showed highest values of water-quality metrics in the headwaters of Long Creek (site 11). It had an overall bioclassification rating of "Good". Site 4 (Gutter Branch) and site10, both tributaries of Long Creek, showed the 2nd and 3rd highest of water quality values, with overall ratings of "Good-Fair". Little differences in water quality were found throughout the remaining seven sites all located in the main channel of Long Creek. Overall bioclassification ratings indicated "Fair" biological water quality values with differences found only in total numbers of taxa, functional feeding group compositions, and numbers of mayfly and caddisfly taxa (two of the three major groups of pollution intolerant organisms) (Table 3.8). As in 2003, "Poor" biological water quality values were found at Gum Branch (site 2), a tributary near the downstream section of the study area.

2006

The final monitoring of the Long Creek Watershed along the I-485 corridor showed highest values of water-quality metrics in the headwaters of Long Creek (site 11) (Figure 3.39). It had an overall bioclassification rating of "Good-Fair" declining with no apparent reason from the 2004 bioclassification rating of "Good". Tributaries, sites 4 (Gutter Branch) and 10 (un-named tributary), with previously bioclassification ratings of "Good-Fair" fell to "Fair" biological water quality. Removal of sensitive stream-side riparian areas appeared to have impacted site 10. Currently, site 10 is undergoing a significant channel renovation 20 meters west of its current location (this channel renovation may return biotic scores to those attained in 2004). Gutter Branch showed no apparent local impacts; upstream influences may be the only explanation for the lowered water quality ratings. Overall bioclassification ratings indicated "Fair" biological water quality values on the main channel of Long Creek throughout its entire length. In the main channel, differences in water quality metrics (Table 3.9) were found only in total numbers of taxa and functional feeding groups. Gum Branch (site 2) showed a bioclassification rating of “Fair” for 2006 whereas the 2 pervious monitoring years (2003 and 2004) Gum Branch had “Poor” water quality.

Comparisons between the sampling years, 2003, 2004 and 2006 show no significant differences in the overall ratings of site health. Total taxa and EPT scores showed declining trends throughout the majority of sites on the main channel (Figures 3.40, 3.41 and 3.42) and tributaries, including the headwaters and control site that had no apparent impacts from the I-485 project. Site 10 (an un-named tributary) improved and then declined from “Fair” to “Good-Fair” to “Fair” water quality values due to riparian vegetation removal and channel relocation. Improvements in biological water quality were monitored at site 2 (Gum Branch).

The biological assessment at 10 sites in the Long Creek watershed located within the construction corridor of I-485 showed little change during the construction period (Figure 3.39). Initial sampling of sites along the main stem had only “Fair” water quality and none of those sites showed a decline. Headwater site 11 was not impacted by construction and declined from “Good” to “Good-Fair” water quality status from 2004-2006. Tributaries 4 and 10 both declined from “Good-Fair” to “Fair” standings throughout the study suggesting an overall decline in biological water quality even in areas not impacted by I-485 corridor (Gutter Branch). Gum Branch biological water quality showed signs of improvement during the 2003-2006 period of study. Although tributary site 6 was dewatered between 2003 and 2004, our notes indicate the stream was very small at this site and may have been ephemeral or intermittent. Site 10 did show signs of declining biological water quality but may be improved by further channel renovations preformed on-site by NCDOT.

Although the water quality along the main stem of Long creek is rated only as “Fair”, the I-485 corridor activities did not further degrade its biological water quality. We must conclude that the I-485 corridor construction had minimal impact on the macroinvertebrate in the Long Creek Watershed.

Water Quality Metrics

Water quality metrics varied slightly over the four year span of this study. Typical cross-sectional pictures of sampling sites are shown in Figures 3.43 – 3.52.

Table 3.7. Benthic macroinvertebrate richness, composition, feeding, and water quality metrics by site in Long Creek Watershed for the year of 2003.

Category	**Metric**	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**	**Site 8**	**Site 9**	**Site 10**
Richness measure	Total No. taxa	**46**	**20**	**43**	**42**	**40**	**13**	**34**	**40**	**52**	**31**
	No. EPT taxa	**8**	**3**	**11**	**15**	**8**	**0**	**6**	**6**	**11**	**10**
	No. Ephemeroptera taxa	**5**	**2**	**6**	**7**	**5**	**0**	**3**	**2**	**7**	**4**
	No. Plecoptera taxa	**1**	**0**	**2**	**4**	**0**	**0**	**0**	**1**	**2**	**2**
	No. Trichoptera taxa	**2**	**1**	**3**	**4**	**3**	**0**	**3**	**3**	**2**	**4**
	No. Diptera taxa	**22**	**10**	**20**	**14**	**21**	**9**	**20**	**22**	**21**	**11**
	No. Chironomidae taxa	**21**	**8**	**18**	**11**	**19**	**6**	**18**	**19**	**19**	**10**
	Total No. Organisms	**279**	**282**	**276**	**270**	**214**	**282**	**179**	**244**	**281**	**323**
Composition Measures	% EPT	**24%**	**3%**	**25%**	**27%**	**36%**	**0%**	**45%**	**31%**	**23%**	**61%**
	% Ephemeroptera	**9%**	**1%**	**16%**	**16%**	**13%**	**0%**	**9%**	**4%**	**18%**	**24%**
	% Plecoptera	**0%**	**0%**	**1%**	**4%**	**0%**	**0%**	**0%**	**0%**	**2%**	**9%**
	% Trichoptera	**14%**	**2%**	**9%**	**7%**	**23%**	**0%**	**35%**	**26%**	**2%**	**28%**
	% Diptera	**34%**	**38%**	**41%**	**55%**	**40%**	**62%**	**40%**	**39%**	**27%**	**17%**
	% Chironomidae	**32%**	**36%**	**34%**	**52%**	**37%**	**34%**	**35%**	**35%**	**26%**	**15%**
	% Corbicula	**7%**	**0%**	**0%**	**0%**	**0%**	**0%**	**1%**	**0%**	**0%**	**0%**
	% Oligochaeta	**9%**	**1%**	**4%**	**0%**	**7%**	**24%**	**9%**	**14%**	**9%**	**2%**
Feeding Measures	% Predators	**10%**	**10%**	**32%**	**9%**	**18%**	**2%**	**6%**	**12%**	**39%**	**30%**
	% Omnivores	**4%**	**2%**	**15%**	**4%**	**11%**	**0%**	**6%**	**2%**	**4%**	**2%**
	% Gatherers	**25%**	**6%**	**19%**	**38%**	**35%**	**68%**	**28%**	**39%**	**43%**	**41%**
	% Filterers	**23%**	**2%**	**12%**	**5%**	**25%**	**26%**	**39%**	**30%**	**4%**	**1%**
	% Scrapers	**33%**	**78%**	**15%**	**35%**	**7%**	**3%**	**11%**	**9%**	**6%**	**18%**
	% Shredders	**5%**	**2%**	**7%**	**10%**	**5%**	**1%**	**9%**	**7%**	**4%**	**8%**

Table 3.7 (Continued). Benthic macroinvertebrate richness, composition, feeding, and water quality metrics by site in Long Creek Watershed for the year of 2003.

Category	Metric	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
Water Quality Values	Biotic Index	**6.47**	**7.21**	**6.72**	**5.91**	**6.76**	**7.43**	**6.61**	**6.47**	**7.33**	**6.92**
	Bioclassifcation score	**2.1**	**1.5**	**2**	**2.7**	**1.8**	**1.5**	**1.7**	**2**	**2**	**2**
	Bioclassification rating	**Fair**	**Poor**	**Fair**	**Good-Fair**	**Fair**	**Poor**	**Fair**	**Fair**	**Fair**	**Fair**

Table 3.8. Benthic macroinvertebrate richness, composition, feeding, and water quality metrics by site in Long Creek Watershed for the year of 2004.

Category	Metric	Site 1	Site 2	Site 3	Site 4	Site 5	Site 7	Site 8	Site 9	Site 10	Site 11
Richness measure	Total No. taxa	**35**	**21**	**37**	**45**	**32**	**31**	**24**	**33**	**35**	**41**
	No. EPT taxa	**5**	**1**	**7**	**12**	**5**	**8**	**2**	**4**	**10**	**13**
	No. Ephemeroptera taxa	**3**	**0**	**3**	**5**	**2**	**4**	**1**	**3**	**5**	**3**
	No. Plecoptera taxa	**0**	**0**	**0**	**3**	**0**	**0**	**0**	**0**	**3**	**3**
	No. Trichoptera taxa	**2**	**1**	**4**	**4**	**3**	**4**	**1**	**1**	**2**	**7**
	No. Diptera taxa	**20**	**13**	**21**	**23**	**21**	**18**	**15**	**18**	**15**	**21**
	No. Chironomidae taxa	**17**	**13**	**18**	**18**	**19**	**16**	**13**	**16**	**14**	**18**
	Total No. Organisms	**263**	**201**	**294**	**271**	**291**	**298**	**257**	**205**	**269**	**301**
Composition Measures	% EPT	**9%**	**1%**	**12%**	**31%**	**22%**	**34%**	**6%**	**9%**	**36%**	**28%**
	% Ephemeroptera	**6%**	**0%**	**6%**	**24%**	**12%**	**13%**	**6%**	**8%**	**20%**	**11%**
	% Plecoptera	**0%**	**0%**	**0%**	**2%**	**0%**	**0%**	**0%**	**0%**	**2%**	**6%**
	% Trichoptera	**2%**	**1%**	**5%**	**5%**	**10%**	**21%**	**0%**	**0%**	**14%**	**10%**
	% Diptera	**60%**	**56%**	**80%**	**57%**	**65%**	**62%**	**76%**	**49%**	**52%**	**53%**
	% Chironomidae	**39%**	**56%**	**34%**	**37%**	**36%**	**33%**	**37%**	**48%**	**38%**	**36%**
	% Corbicula	**1%**	**5%**	**0%**	**1%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
	% Oligochaeta	**22%**	**32%**	**2%**	**3%**	**8%**	**0%**	**14%**	**13%**	**1%**	**14%**

Table 3.8 (Continued). Benthic macroinvertebrate richness, composition, feeding, and water quality metrics by site in Long Creek Watershed for the year of 2004.

Category	Metric	Site 1	Site 2	Site 3	Site 4	Site 5	Site 7	Site 8	Site 9	Site 10	Site 11
Feeding Measures	% Predators	**11%**	**4%**	**16%**	**13%**	**10%**	**5%**	**6%**	**29%**	**3%**	**19%**
	% Omnivores	**13%**	**8%**	**9%**	**9%**	**4%**	**6%**	**2%**	**11%**	**3%**	**8%**
	% Gatherers	**33%**	**40%**	**12%**	**21%**	**20%**	**19%**	**34%**	**35%**	**16%**	**25%**
	% Filterers	**27%**	**13%**	**55%**	**28%**	**46%**	**52%**	**45%**	**9%**	**23%**	**24%**
	% Scrapers	**11%**	**32%**	**7%**	**21%**	**16%**	**11%**	**7%**	**7%**	**21%**	**4%**
	% Shredders	**3%**	**0%**	**0%**	**5%**	**3%**	**5%**	**5%**	**5%**	**25%**	**15%**
Water Quality Values	Biotic Index	**6.53**	**7.04**	**6.24**	**6.24**	**6.13**	**6.31**	**6.39**	**7.14**	**5.72**	**5.08**
	Bioclassifcation score	**1.7**	**1.5**	**2.2**	**2.5**	**2**	**2.3**	**2**	**1.5**	**3**	**3.5**
	Bioclassification rating	**Fair**	**Poor**	**Fair**	**Good-Fair**	**Fair**	**Fair**	**Fair**	**Fair**	**Good-Fair**	**Good**

Table 3.9. Benthic macroinvertebrate richness, composition, feeding, and water quality metrics by site in Long Creek Watershed for the year of 2006.

Category	Metric	Site 1	Site 2	Site 3	Site 4	Site 5	Site 7	Site 8	Site 9	Site 10	Site 11
Richness measure	Total No. taxa	**40**	**38**	**37**	**49**	**28**	**42**	**25**	**39**	**23**	**32**
	No. EPT taxa	**5**	**5**	**6**	**8**	**4**	**5**	**5**	**3**	**5**	**9**
	No. Ephemeroptera taxa	**3**	**4**	**4**	**4**	**2**	**3**	**3**	**1**	**1**	**2**
	No. Plecoptera taxa	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**1**	**1**	**2**
	No. Trichoptera taxa	**2**	**1**	**2**	**2**	**2**	**2**	**2**	**1**	**3**	**5**
	No. Diptera taxa	**23**	**21**	**21**	**22**	**16**	**25**	**13**	**19**	**9**	**16**
	No. Chironomidae taxa	**20**	**19**	**19**	**19**	**15**	**22**	**12**	**18**	**8**	**14**
	Total No. Organisms	**266**	**266**	**311**	**282**	**240**	**310**	**235**	**252**	**188**	**287**

Table 3.9 (Continued). Benthic macroinvertebrate richness, composition, feeding, and water quality metrics by site in Long Creek Watershed for the year of 2006.

Category	Metric	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 7**	**Site 8**	**Site 9**	**Site 10**	**Site 11**
Composition Measures	% EPT	**19%**	**12%**	**26%**	**33%**	**10%**	**39%**	**38%**	**5%**	**9%**	**29%**
	% Ephemeroptera	**13%**	**10%**	**21%**	**29%**	**4%**	**9%**	**31%**	**3%**	**5%**	**13%**
	% Plecoptera	**0%**	**0%**	**0%**	**1%**	**0%**	**0%**	**0%**	**0%**	**1%**	**14%**
	% Trichoptera	**6%**	**2%**	**5%**	**2%**	**7%**	**30%**	**8%**	**1%**	**3%**	**3%**
	% Diptera	**39%**	**40%**	**34%**	**42%**	**43%**	**35%**	**49%**	**41%**	**59%**	**36%**
	% Chironomidae	**38%**	**39%**	**33%**	**36%**	**42%**	**33%**	**46%**	**41%**	**59%**	**35%**
	% Corbicula	**12%**	**27%**	**2%**	**1%**	**1%**	**2%**	**0%**	**0%**	**0%**	**0%**
	% Oligochaeta	**5%**	**5%**	**4%**	**2%**	**7%**	**6%**	**3%**	**18%**	**2%**	**1%**
Feeding Measures	% Predators	**32%**	**10%**	**34%**	**14%**	**44%**	**17%**	**6%**	**27%**	**24%**	**17%**
	% Omnivores	**8%**	**3%**	**4%**	**2%**	**8%**	**1%**	**0%**	**4%**	**1%**	**10%**
	% Gatherers	**23%**	**36%**	**27%**	**45%**	**33%**	**36%**	**49%**	**52%**	**59%**	**33%**
	% Filterers	**18%**	**33%**	**8%**	**9%**	**9%**	**35%**	**10%**	**2%**	**1%**	**6%**
	% Scrapers	**12%**	**11%**	**20%**	**12%**	**4%**	**5%**	**30%**	**7%**	**10%**	**1%**
	% Shredders	**3%**	**0%**	**4%**	**1%**	**0%**	**2%**	**1%**	**1%**	**3%**	**2%**
Water Quality Values	Biotic Index	**7.24**	**6.69**	**7.18**	**6.23**	**7.43**	**7.16**	**6.55**	**6.79**	**6.60**	**5.78**
	Bioclassifcation score	**1.5**	**1.5**	**1.7**	**2.3**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**2.6**
	Bioclassification rating	**Fair**	**Fair**	**Fair**	**Fair**	**Fair**	**Fair**	**Fair**	**Fair**	**Fair**	**Good-Fair**

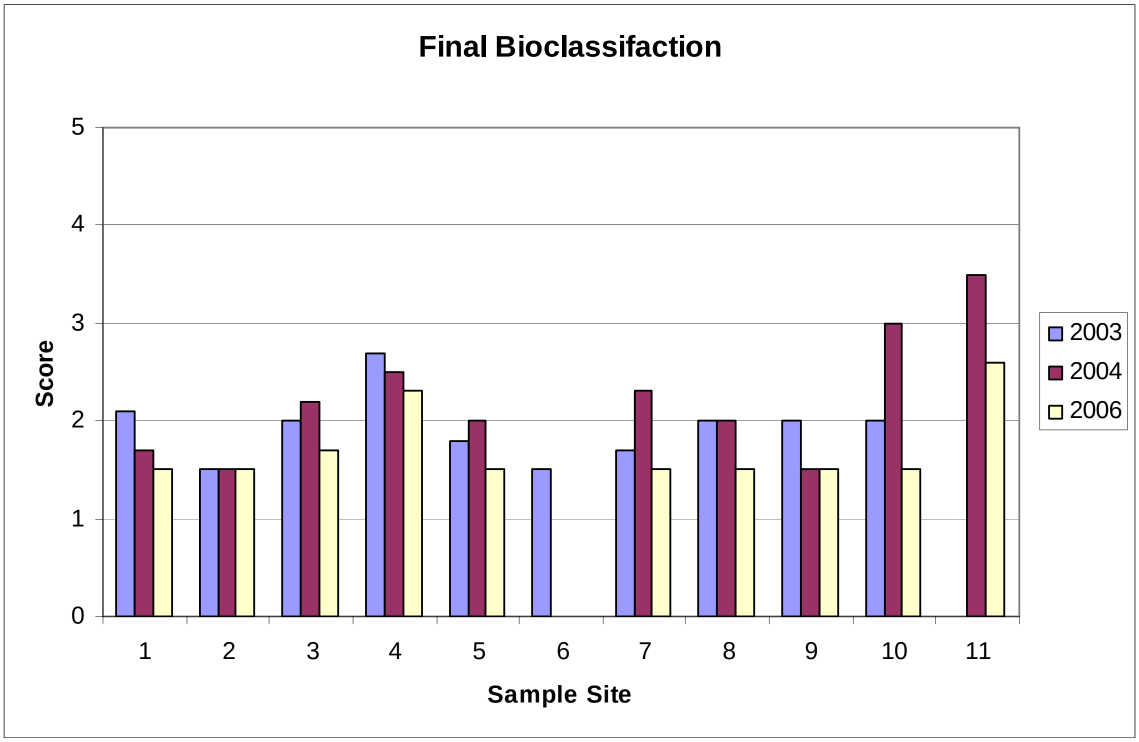


Figure 3.40. Bioclassification by sample site in Long Creek Watershed for the years of 2003, 2004, and 2006.

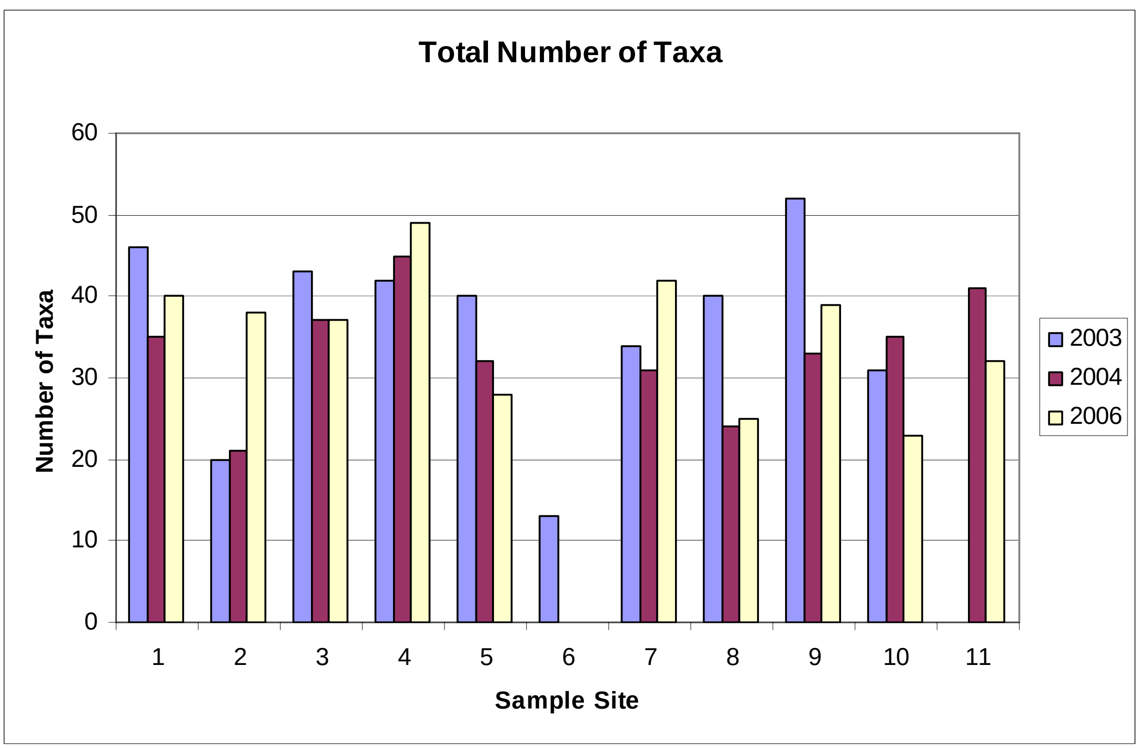


Figure 3.41. Total number of taxa by site in Long Creek Watershed for the years of 2003, 2004, and 2006.

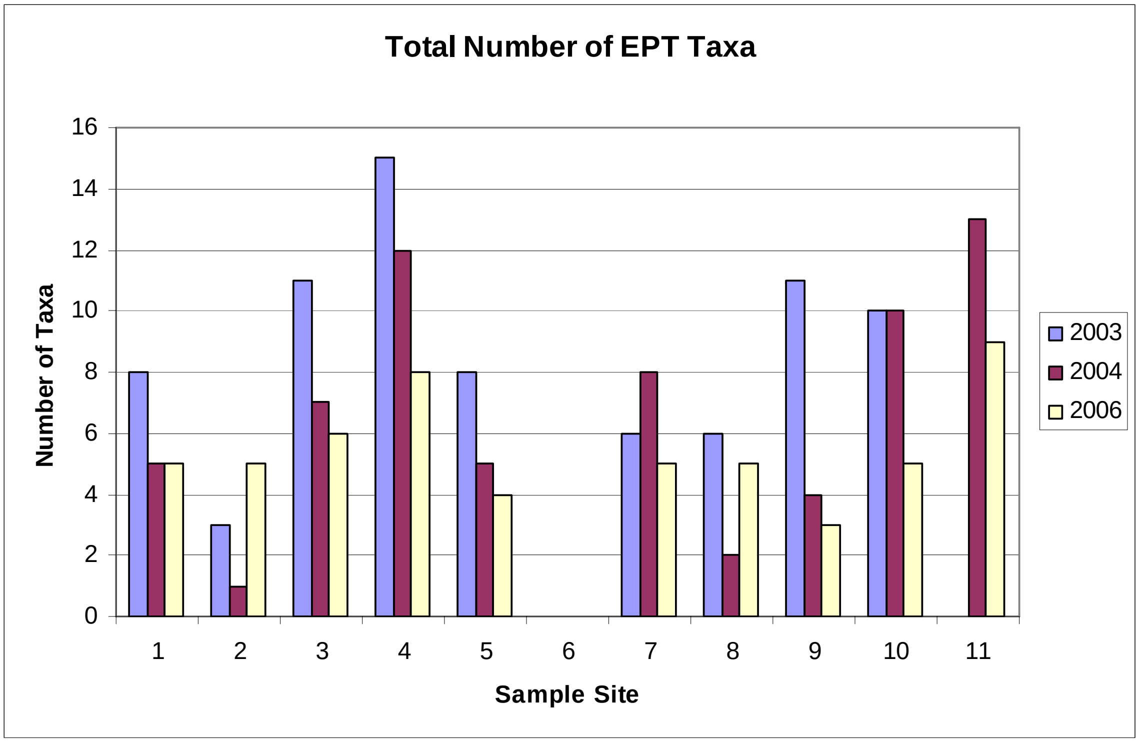


Figure 3.42. Total number of EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa by site in Long Creek Watershed for the years of 2003, 2004, and 2006.

(a)

(b)

Figure 3.43. Site 1 a. Looking upstream, b. Looking downstream.

(a)

(b)

Figure 3.44. Site 2 a. Looking upstream, b. Looking downstream.

(a)

(b)

Figure 3.45. Site 4 a. Looking upstream, b. Looking downstream.

(a)

(b)

Figure 3.46. Site 5 a. Looking upstream, b. Looking downstream.

(a) (b)

Figure 3.47. Site 7 a. Looking upstream, b. Looking downstream.

Figure 3.48. Site 8 a. Looking upstream, b. Looking downstream.

(a) (b)

Figure 3.49. Site 9 a. Looking upstream, b. Looking downstream.

(a) (b)

Figure 3.50. Site 10 a. Looking upstream, b. Looking downstream.

(a) (b)

Figure 3.51. Site 11 a. Looking upstream, b. Looking downstream.

(a) (b)

Figure 3.52. Site 12 a. Looking upstream, b. Looking downstream.

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