Monitoring of Nutrient and Sediment Loading from Construction Sites

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INTRODUCTION

A recent assessment of the conditions of the rivers and streams in the United States indicated that 45% of the total length assessed was classified as impaired for their intended use, with sediment and siltation as the leading cause (US EPA 2002). Construction activity can be a significant contributor to sediment loading, with erosion rates up to 100 times that of cropland (Pitt et al. 2007; Wolman 1967). Concentrations of suspended sediment have been reported for construction site discharges well over 1,000 mg L^{-1} and as high as 160,000 mg L^{-1} (Markusic 2007; Wolman and Schick 1967; Line and White 2001). The effects of suspended solids on aquatic organisms has been shown to be dependent on exposure time and concentration, but even low concentrations for a matter of hours can have measurable effects (Newcombe and MacDonald 1991).

Construction sites are required to have sediment trapping systems to reduce the amount of sediment discharged. These devices generally involve pooling runoff temporarily to settle the heavier sediment fraction. Efficiencies of typical sediment traps with rock outlets monitored on actual construction sites have ranged from <40% to 69% (Markusic 2007; Schueler and Lugbil 1990; Line and White 2001). This capture rate can be markedly improved by controlled dewatering and surface outlets, porous baffles, and increased surface area (Thaxton and McLaughlin 2005; Markusic 2007; Fennessey and Jarrett 1997; Edwards et al. 1999; Millen et al. 1997; Bidelspach et al. 2004).

Nutrient loading is another leading source of pollution and impairment for the nation's waterways and is a serious concern for North Carolina's rivers and reservoirs (US EPA 2002). Excess nutrients, particularly nitrogen and phosphorus, can lead to eutrophication and algal blooms, which in turn can result in oxygen-depleted conditions and fish kills. The Neuse River experienced several such events in the 1990's, which led to legislation establishing a program tasked in achieving a reduction in nutrient loading into that watershed (Osmond et al. 2003; Johnson and Osmond 2005). Several other watersheds have since followed suit. The programs focus primarily on reducing nutrients through agricultural practices, including fertilizer management and riparian buffer strips. Construction site erosion was not considered in their reduction strategy, and has not been thought a likely source of significant nutrient loading as most of the site grading generally occurs in the deeper, relatively nutrient-poor soil horizons as opposed to the organic-rich top soil. Nevertheless, as nutrients can bind to soil particles, particularly phosphorus and particularly to the finer soil fraction, erosion has at least the potential to be a significant source of nutrient loading. Little data exists from construction sites to either accurately estimate the levels of nutrients exiting these sites or to evaluate their basins' effectiveness in removing them.

The objective of this study was to evaluate the sediment and nutrient removal efficiencies of various types of sediment basin designs on construction sites located in the Mountains, Piedmont, and Coastal Plain, as well as to gather general data on average sediment and nutrient discharge volumes per acre of construction disturbance.

PROJECT DESCRIPTION

This study was conducted on eight construction projects located throughout North Carolina; two in the mountains, five in the piedmont, and one in the coastal plain. Site designations were created using the first four letters of the name of the county in which the project was located. This was done in an effort to maintain a degree of anonymity for the participating developers and contractors as agreed upon prior to monitoring. A more detailed description and location of each site is given below in Table 1 and in Figure 1.

Table 1. General site descriptions

Site	County	Disturbed area (acres)	Type of construction activity	Length of sampling effort (months)	Average slope (%)	Total storms captured
Mountains						
Site JACK	Jackson	8	Residential development	12	25	11
Site BUNC	Buncombe	14	Vehicle testing facility	7	1	6
Piedmont						
Site GUIL						
Phase 1	Guilford	75	Airport runway	8	1	11
Phase 2	Guilford	35	Airport runway	12	1	13
Site ORAN	Orange	0.9	Educational facilities	4	5	4
Site DURH	Durham	1.5	Residential development	9	5	11
Site WAKE1	Wake	5.5	Educational facilities	5	2	10
Site WAKE2	Wake	3	Educational facilities	10	11	1
Coastal Plain						
Site GREE	Greene	51	Residential development	3	0.5	1

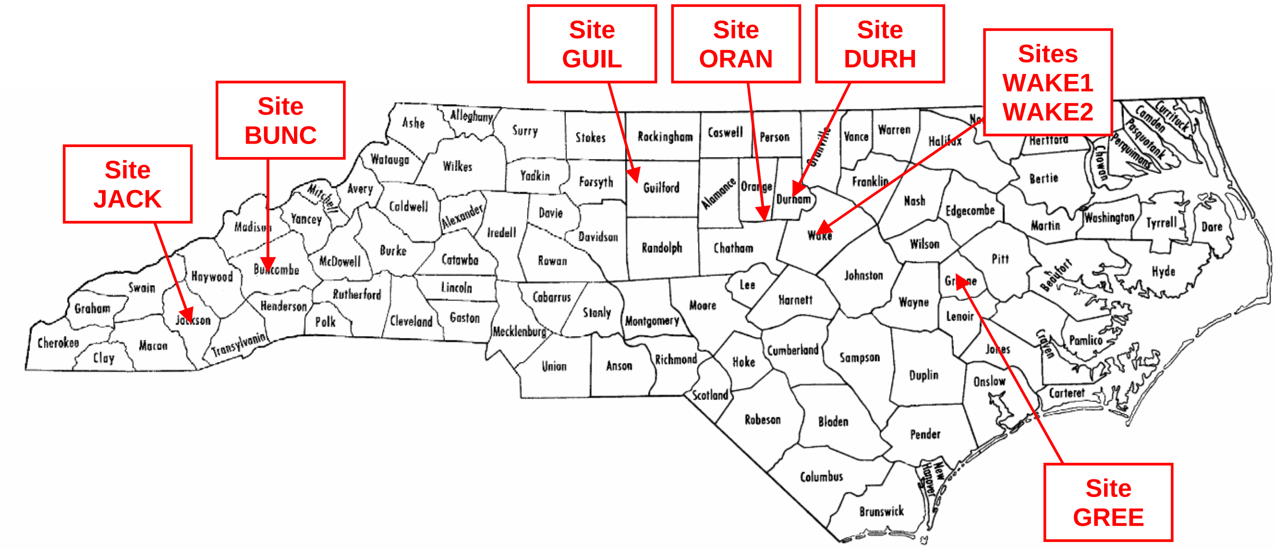


Figure 1. Monitoring site locations throughout North Carolina.

MATERIALS AND METHODS

Runoff was collected by Teledyne ISCO brand 6712 portable water samplers (Teledyne ISCO, Lincoln, NE). They were programmed to collect samples by either a pre-determined runoff volume or by set periods of time primarily using an ISCO 730 bubbler module, though sometimes with an ISCO 720 submerged probe. At some sites, wooden weirs were constructed to allow the determination of water flow rates and volumes. A tipping bucket rain gauge (ISCO model 674) was also installed at each site to determine exact precipitation rates for each storm event.

Figure 2. ISCO 7612 water sampler.

Figure 3. Weir used at Site WAKE2.

Runoff samples were measured for turbidity using the Analite Nepholometer, Model 152 (McVan Instruments, Australia). Each sample was shaken for 10 seconds and then allowed to settle for 30 seconds. Readings over the instrument limit of 3,000 NTU resulted in diluting a subsample to bring the reading down to <3,000 NTU, and then multiplying that value by the dilution factor. We did not make dilutions greater than 10:1 to avoid subsampling errors, so samples which remained above 3,000 NTU after a 10:1 dilution were entered as 30,000 NTU for statistical purposes. For each set of samples from rain events, the turbidity readings from the nepholometer were corrected against formazin standards. The standard readings were used to correct for any instrument error that may occur.

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

Samples for nutrient analysis were collected within 48 hours of the rain event and immediately placed on ice. Once back in the lab, the samples were acidified with H_2SO_4 to a pH of 2 and stored in a refrigerator until they were submitted for analysis. All samples were submitted to the Analytical Service Laboratory at NC State University's Soil Science Dept for the following analytes: Nitrate (NO_3), Ammonium (NH_4), Total Kjeldahl Nitrogen (TKN), Phosphate (PO_4), Total Phosphorus (TP), and Total Organic Carbon (TOC).

RESULTS AND DISCUSSION

Mountain Sites

Site JACK:

This site was one phase of a large golf course and residential development that had a single sediment basin (approximately 60' long by 20' wide by 4'deep) with a rock-lined inlet channel and an 18" perforated riser pipe outfall surrounded with gravel (Figures 4 and 5). The sideslopes of the basin were poorly vegetated. A wooden weir and sampler were installed in the inlet channel to collect entrance flow data and water samples, while a sampler alone was placed at the outfall. The weir wasn't installed until June of 2006 and so only the final five storm events had flow data measurements collected. Basin discharge flow volumes were estimated for those storms by subtracting the basin volume from the known total inflow volume. While not taking into account basin volume changes from sedimentation or infiltration, this does provide a rough 'worst-case' estimate of sediment and nutrient discharge off site.

The upslope disturbed drainage area was approximately 8 acres in size and quite steep with an average slope of about 25%, though portions of the site varied between 20-30% slopes. The area was almost entirely bare at the start of the monitoring period and was slowly revegetated in turfgrass as the various stages of grading for the project were completed.

Figure 4. The upslope drainage area at Site JACK.


Figure 5. The sediment basin and samplers at Site JACK.

There were 11 storm events captured for this site, including several very large storms. Overall discharge water quality was very poor with an average turbidity of about 3,500 NTU, TSS of 7,500 mg/L, and with an estimated sediment discharge of 700 kg per disturbed acre (Table 2). The basin had a substantial and fairly consistent detrimental effect on water quality, actually increasing turbidity and TSS by 60% and 100%, respectively.

Nutrient concentrations were fairly low at this site and the basin did appear to provide some treatment, reducing most concentrations by about 25%, except for TP and TKN which did not change (Table 3). Nevertheless, nutrient loading here was among the greatest of any of the sites monitored due to the large volume of discharge from several of the larger storm events. In particular, it had the greatest PO_4 and TP loss at about 150 and 800 g per acre, respectively, over the 10 months when samples were obtained.

Table 2. Site JACK Turbidity and Sediment Loading

Storm Date	Rainfall (in)	Sampler Location in Basin	# of Samples		Average Turbidity (NTU)	Average TSS (mg/L)	Sediment Load (kg)
11/30/2005	2.23	Entrance	6		5,153	3,692	-
		Exit	6		10,324	19,574	-
				net	-100%	-430%	
12/7/2005	0.93	Entrance	8		370	208	-
		Exit	8		1,357	408	-
				net	-266%	-96%	
1/19/2006	1.53	Entrance	13		10,462	31,784	-
		Exit	13		11,070	41,823	-
				net	-6%	-32%	
3/21/2006	0.82	Entrance	9		283	280	-
		Exit	8		748	218	-
				net	-164%	22%	
4/22/2006	1.45	Entrance	14		2,483	2,502	-
		Exit	14		3,823	7,295	-
				net	-54%	-192%	
5/21/2006	1.51	Entrance	9		1,076	546	-
		Exit	9		1,599	623	-
				net	-49%	-14%	
6/27/2006	3.94	Entrance	14		438	283	322
		Exit	14		510	268	113
				net	-17%	6%	65%
7/5/2006	0.75	Entrance	6		337	255	11
		Exit	6		284	209	5
				net	16%	18%	54%
7/14/2006	0.66	Entrance	5		405	373	67
		Exit	6		321	163	16
				net	21%	56%	76%
9/1/2006	1.93	Entrance	24		509	517	586
		Exit	24		1,458	1,864	1,576
				net	-186%	-261%	-169%

9/25/2006	1.29	Entrance	22		2,008	1,116	645
		Exit	20		6,450	11,193	3,917
				net	-221%	-903%	-508%

Average Entrance Turbidity per Storm (NTU)	2,139
Average Exit Turbidity per Storm (NTU)	3,449
Average Basin Reduction	-61%
Average Entrance TSS per Storm (mg/L)	3,778
Average Exit TSS per Storm (mg/L)	7,603
Average Basin Reduction	-101%
Average Entrance Sediment Load per Storm (kg)	326
Estimated Average Exit Sediment Load per Storm (kg)	1,125
Estimated Average Basin Reduction	-245%
Total Sediment Load (kg)	5,627
Overall Average Sediment Load per Disturbed Acre[1] (kg)	703
Average Sediment Load per Disturbed Acre per Storm[2] (kg)	141

[1]Calculated by dividing the total sediment load by the disturbed acreage.
[2]Calculated by averaging the individual sediment loads per acre for each storm event.

Table 3. Site JACK Nutrient Loading

Date	Sampler Location		PO_4 (mg/L P)	NH_4 (mg/L N)	NO_3 (mg/L N)	TOC (mg/L C)	TP (mg/L P)	TKN (mg/L N)
11/30/05	Entrance		0.00	0.80	0.29	9.30	2.90	4.80
	Exit		0.00	0.37	0.21	3.70	0.22	0.46
		net	0%	53%	28%	60%	92%	90%
12/07/05	Entrance		0.00	0.86	0.38	2.80	0.51	0.95
	Exit		0.00	0.49	0.38	2.70	0.64	1.38
		net	0%	43%	0%	4%	-27%	-45%
01/19/06	Entrance		0.00	0.48	0.34	2.35	15.22	7.11
	Exit		0.00	0.45	0.32	2.13	7.63	4.84
		net	0%	6%	7%	9%	50%	32%
03/21/06	Entrance		0.00	0.70	0.24	8.63	0.03	0.97
	Exit		0.00	0.08	0.15	2.20	0.46	0.85
		net	0%	89%	38%	75%	-1379%	13%
04/22/06	Entrance		0.01	1.09	0.77	2.50	0.55	5.20
	Exit		0.02	0.26	0.39	4.05	0.90	1.25
		net	-56%	76%	48%	-62%	-64%	76%
05/21/06	Entrance		4.81	5.61	0.58	12.90	4.70	6.90
	Exit		3.58	4.79	0.56	11.46	5.47	7.96
		net	26%	15%	4%	11%	-16%	-15%
06/27/06	Entrance		1.27	0.33	1.05	-	-	-
	Exit		0.94	0.46	0.77	-	-	-
		net	26%	-41%	26%	NA	NA	NA
	Discharge load (g)		396	196	326			
07/05/06	Entrance		1.79	1.31	1.15	12.80	0.97	3.30
	Exit		1.08	0.98	0.92	-	-	-
		net	40%	25%	20%	NA	NA	NA
	Discharge load (g)		26	24	22			
07/14/06	Entrance		2.42	1.70	0.52	24.10	1.20	6.30
	Exit		2.04	1.88	0.46	22.30	1.00	5.10
		net	16%	-11%	11%	7%	17%	19%
	Discharge load (g)		198	183	45	2,169	97	496
09/01/06	Entrance		1.21	1.29	2.52	22.95	1.55	5.45
	Exit		0.60	0.91	1.92	16.05	4.10	7.55
		net	50%	29%	24%	30%	-164%	-39%
	Discharge load (g)		509	773	1,625	13,569	3,462	6,383

09/25/06	Entrance	0.12	0.25	0.34	10.80	2.25	3.05
	Exit	0.05	0.13	0.27	6.69	7.86	12.05
	net	59%	48%	20%	38%	-249%	-295%
	Discharge load (g)	17	45	94	2,340	2,749	4,217
	Average Entrance Concentration	1.06	1.31	0.74	10.70	3.21	4.53
	Average Exit Concentration	0.76	0.98	0.58	7.92	3.14	4.60
	Average Basin Reduction	29%	25%	22%	26%	2%	-2%

Nutrient loading estimates are from the last five storm events only:

Estimated Total Load (g)	1,146	1,221	2,112	18,078	6,308	11,096
Overall Average Load per Acre[1]	143	153	264	2,260	789	1,387
Average Load per Acre per Storm[2]	229	244	422	6,026	2,103	3,699

[1]An estimate calculated by dividing the total nutrient load by the disturbed acreage.

[2]Calculated by averaging the estimated individual nutrient loads per acre for each storm.

Site BUNC:
This site was a construction vehicle testing facility and had an oval-shaped sediment basin 50' long by 25' wide by 3' deep with an 18" metal pipe inlet and a rock spillway outlet (Figures 6 and 7). There were neither baffles nor a skimmer device installed and the sideslopes, while not steep, were poorly stabilized and significant rill formation was observed over the monitoring period. Samplers were installed with intakes at a weir in the inlet pipe and at the rock outlet. Flows were measured in the weir.

The basin drained a flat (1% slope) 14 acre disturbed area that was used as the testing grounds. The traffic kept the area continuously disturbed with a rough bare surface throughout. The basin was not well maintained and we abandoned the site in March 2008 when the basin filled in from a large storm and no plans by the owner to remove the sediment. Only six storm events produced discharges over the 7 months of monitoring, due largely to the severe drought during the monitoring period.


Figures 6 and 7. The disturbed area upslope and the sediment basin at Site BUNC.

The six storms revealed a negligible overall basin treatment for turbidity and TSS (Table 4). For half of the events, water quality improved through the basin, sometimes substantially, while water quality declined in the basin for the other events. As at Site JACK, estimated discharge flows were calculated by subtracting the volume of the basin from the total inflow volume. The estimated overall sediment discharge was 928 kg per acre, largely from the first storm, a hurricane remnant that brought 2.75" of rain. The other five storms averaged just 62 kg per acre.

Average differences between the entrance and exit samples revealed inconsistent basin treatment effects (Table 5). Three storms showed substantial decreases in both turbidity and TSS, while the others showed increases in both. Average nutrient concentrations were fairly low, again with an inconsistent basin treatment effect. Phosphate (PO_4), NH_4, and NO_3 all showed decreases of between 70-85%, while TOC, TP, and TKN all showed substantial increases, though largely due to the results from the final storm event. Nutrient loading for PO_4, NH_4, and NO_3 were relatively low, with each between 4-20 g per acre, but TOC, TP, and TKN loading was higher at 300-700 g per acre.

Table 4. Site BUNC Turbidity and Sediment Loading

Storm Date	Rainfall (in)	Sampler Location in Basin	# of Samples		Average Turbidity (NTU)	Average TSS (mg/L)	Sediment Load (kg)
9/14/2007	2.75	Entrance	24		7,709	16,208	10,400
		Exit	24		9,615	20,712	12,441
				net	-25%	-28%	-20%
10/23/2007	0.75	Entrance	3		2,726	1,512	39
		Exit	3		3,360	3,631	81
				net	-23%	-140%	-106%
11/14/2007	0.7	Entrance	4		3,288	1,915	196
		Exit	4		859	1,147	47
				net	74%	40%	76%
2/1/2008	0.42	Entrance	1		2,807	4,454	5.8
		Exit	1		224	364	0.5
				net	92%	92%	92%
2/4/2008	0.27	Entrance	3		3,742	5,041	29
		Exit	3		305	195	2
				net	92%	96%	93%
2/17/2008	0.9	Entrance	2		10,331	15,892	344
		Exit	2		15,458	19,709	417
				net	-50%	-24%	-21%

Average Entrance Turbidity per Storm (NTU)	5,100
Average Exit Turbidity per Storm (NTU)	4,970
Average Basin Reduction	3%
Average Entrance TSS per Storm (mg/L)	7,504
Average Exit TSS per Storm (mg/L)	7,626
Average Basin Reduction	-2%
Average Entrance Sediment Load per Storm (kg)	1,836
Estimated Average Exit Sediment Load per Storm (kg)	2,165
Average Basin Reduction	-18%
Estimated Total Sediment Load (kg)	12,988
Overall Average Sediment Load per Disturbed Acre[1] (kg)	928
Average Sediment Load per Disturbed Acre per Storm[2] (kg)	160

[1]Calculated by dividing the total sediment load by the disturbed acreage.
[2]Calculated by averaging the individual sediment loads per acre for each storm event.

Table 5. Site BUNC Nutrient Loading

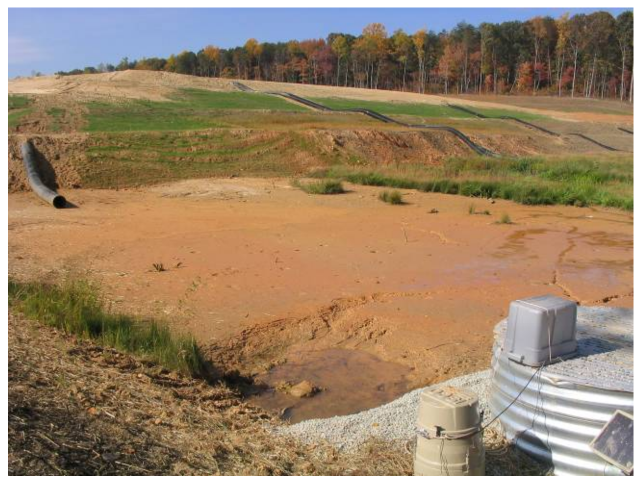
Date	Sampler Location		PO_4 (mg/L P)	NH_4 (mg/L N)	NO_3 (mg/L N)	TOC (mg/L C)	TP (mg/L P)	TKN (mg/L N)
9/14/2007	Entrance		0.05	0.34	0.11	4.27	4.90	7.53
	Exit		0.04	0.26	0.05	2.97	5.08	8.87
		net	23%	24%	53%	30%	-3%	-18%
10/23/2007	Entrance		0.35	0.16	0.41	3.40	1.10	2.70
	Exit		0.55	0.03	0.15	6.70	1.40	2.50
		net	-58%	81%	64%	-97%	-27%	7%
11/14/2007	Entrance		0.07	0.11	0.34	5.10	1.30	1.60
	Exit		0.12	0.18	0.20	9.00	0.43	1.30
		net	-69%	-56%	42%	-76%	67%	19%
2/1/2008	Entrance		1.87	0.00	3.91	NA	NA	NA
	Exit		0.51	0.00	3.40	NA	NA	NA
		net	73%	0%	13%	-	-	-
2/4/2008	Entrance		3.05	7.83	13.10	NA	NA	NA
	Exit		0.02	0.74	0.53	3.90	0.18	0.60
		net	99%	91%	96%	-	-	-
2/17/2008	Entrance		0.00	0.08	0.21	3.10	6.70	5.10
	Exit		0.00	0.08	0.54	4.60	131.50	63.30
		net	0%	0%	-165%	-48%	-1863%	-1141%
Average Entrance Concentration			0.90	1.42	3.01	3.97	3.50	4.23
Average Exit Concentration			0.21	0.21	0.81	5.82	34.60	18.99
Average Basin Reduction			77%	85%	73%	-47%	-888%	-349%
Total Load (g)			59	274	83	3,626	7,908	10,321
Overall Average Load per Acre[1]			4	20	6	259	565	737
Average Load per Acre per Storm[2]			0.5	2.0	0.7	35	84	97

[1]Calculated by dividing the estimated total nutrient load (g) by the disturbed acreage.

[2]Calculated by averaging the estimated individual nutrient load (g) per acre for each storm event.

Piedmont Sites

Site GUIL:
This site was an airport runway construction project consisting of two phases of monitoring, each distinguished by both the size of the disturbed drainage area and by the size of the sediment basin. During phase 1, the basin was about 300' long by 100' wide by 5' deep and had an approximate 75 acre drainage (Figures 8 and 9), while in phase 2 the basin was substantially filled-in to make it 50' long by 100' wide (about an 80% reduction in size) and with a reduced drainage area of 35 acres. At times during both phases, runoff from the flat (<1% slope) disturbed area adjacent to the basin was conveyed into the basin in plastic slope drains, though they frequently failed or were bypassed, eroding rills into the basin sides. Samples for the entrance to the basin were obtained either in a slope drain, or, once the erosion around them occurred, on a stake in the upper end of the basin. The basin itself had steep sideslopes that never established much in the way of vegetation. The outlet consisted of a large 72" perforated metal riser barrel with a gravel collar (Figure 8), which discharged water out of the basin in a 36" metal pipe. This discharge pipe was where a sampler was placed to measure flow and collect exit samples.



Figures 8 and 9. The disturbed area upslope and the sediment basin at Site GUIL.

There were 11 storms captured during Phase 1, but only two of them had any basin entrance data collected and thus these were the only storms in which a direct before-and-after treatment comparison can be used to evaluate basin effect on water quality. In these two storms, there were substantial reductions of 70-90% in both turbidity and TSS (Table 6). Overall discharge water quality for all 11 storms was good compared to other sites we have monitored, with averages of only 270 NTU and a TSS of 168 mg/L. The overall average discharge of 21 kg per acre is extremely low compared to typical construction sites. Nutrient results for basin discharge runoff for eight of the storms had low concentrations with average discharge rates of about 2-30 g per acre for all analytes except TOC and TKN, which had 3,000 g and 600 g per acre, respectively (Table 7).

There were 13 storm events monitored during Phase 2, with nine having data from both the entrance and exit of the basin. Basin effects were far more inconsistent during this phase with increases in both turbidity and TSS, several orders of magnitude higher, for six storms while the remaining storms (including two large storms with 20+ samples) showed decreases ranging from 25-70% (Table 8). In general, water quality was lower than for Phase 1 with an average discharge turbidity of 3,296 NTU, TSS of 2,308 mg/L, and sediment discharges of 511 kg per acre over the 12 months of monitoring. Nutrient concentrations remained fairly low during Phase 2 (Table 9), with average loading rates per acre comparable to those of Phase 1. The basin did not appear to have much of a treatment effect on nutrient concentrations relative to the turbidity and TSS changes.

Between the two phases the larger basin in Phase 1, despite having a much larger drainage area, appears to have been more effective than the smaller basin.

Table 6. Site GUIL Turbidity and Sediment Loading - Phase 1

Storm Date	Rainfall (in)	Sampler Location in Basin	# of Samples		Average Turbidity (NTU)	Average TSS (mg/L)	Sediment Load (kg)
1/17/2005	1.14	Exit	23		34	14	0.1
2/2/2005	0.51	Exit	9		50	34	645
2/26/2005	0.52	Exit	3		44	30	14
3/1/2005	0.8	Exit	15		222	133	325
3/28/2005	0.63	Exit	4		1515	805	88
6/8/2005	0.65	Exit	8		208	106	32
6/30/2005	0.71	Exit	24		33	27	105
8/1/2005	2.3	Exit	16		433	433	263
8/10/2005	0.6	Exit	15		75	81	3.1
8/18/2005	0.23	Entrance	5		354	171	-
		Exit	19		42	30	22
				net	88%	82%	
8/25/2005	0.85	Entrance	4		1218	560	-
		Exit	23		313	153	44
				net	74%	73%	

Average Entrance Turbidity per Storm (NTU)	786
Average Exit Turbidity per Storm (NTU)	178
Average Basin Reduction[1]	77%
Average Entrance TSS per Storm (mg/L)	366
Average Exit TSS per Storm (mg/L)	92
Average Basin Reduction[1]	75%
Total Sediment Load (kg)	1,539
Overall Average Sediment Load per Disturbed Acre[2] (kg)	21
Average Sediment Load per Disturbed Acre per Storm[3] (kg)	2

[1]Calculated using only those storms with both entrance and exit data.
[2]Calculated by dividing the total sediment load by the disturbed acreage.
[3]Calculated by averaging the individual sediment loads per acre for each storm event.

Table 7. Site GUIL Nutrient Loading - Phase 1

Date	Sampler Location	PO_4 (g P)	NH_4 (g N)	NO_3 (g N)	TOC (g C)	TP (g P)	TKN (g N)
1/17/2005	Exit	0	0	0	40	1	8
2/2/2005	Exit	0	48	0	177,693	1,767	40,874
2/26/2005	Exit	44	1,426	1,576	5,268	51	606
3/1/2005	Exit	47	73	100	45,347	487	3,203
3/28/2005	Exit	4	71	27	4,245	23	878
8/1/2005	Exit	2	37	122	6,876	144	773
8/10/2005	Exit	3	17	22	2,593	19	415
8/25/2005	Exit	13	98	114	1,073	3	161
	Total Load (g)	114	1,769	1,960	243,135	2,494	46,918
	Overall Average Load per Acre[1]	1.5	24	26	3,242	33	626
	Average Load per Acre per Storm[2]	0.2	2.9	3.3	405	4.2	78

[1]Calculated by dividing the total nutrient load by the disturbed acreage.
[2]Calculated by averaging the individual nutrient loads per acre for each storm event.

Table 8. Site GUIL Turbidity and Sediment Loading - Phase 2

Storm Date	Rainfall (in)	Sampler Location in Basin	# of Samples		Average Turbidity (NTU)	Average TSS (mg/L)	Sediment Load (kg)
10/8/2005	0.75	Exit	3		224	229	0.1
11/6/2005	0.33	Exit	1		840	1,070	0.2
12/24/2005	1.2	Entrance	1		1,249	1,299	-
		Exit	1		12,902	4,606	-
				net	-933%	-255%	
3/14/2006	0.33	Entrance	2		31	86	-
		Exit	2		2,543	1,413	21
				net	-8079%	-1535%	
4/28/2006	0.7	Entrance	6		651	548	-
		Exit	6		860	567	20
				net	-32%	-4%	
5/9/2006	0.6	Entrance	1		281	372	-
		Exit	1		199	133	0.5
				net	29%	64%	
5/18/2006	0.29	Entrance	20		2,612	2,206	-
		Exit	20		1,977	1,192	202
				net	24%	46%	
6/9/2006	1.55	Entrance	24		3,261	4,187	-
		Exit	24		2,190	1,228	1,450
				net	33%	71%	
7/2/2006	5.95	Entrance	24		3,120	6,933	-
		Exit	24		4,070	7,494	8,851
				net	-30%	-8%	
7/7/2006	1.73	Exit	24		715	407	481
7/24/2006	3.29	Exit	24		3,060	2,648	2,997
9/1/2006	1.82	Entrance	24		2,700	2,958	-
		Exit	24		3,068	3,322	2,834
				net	-14%	-12%	

9/15/2006	1.14	Entrance	24		1431	812	-
		Exit	24		1858	813	1021
				net	-30%	0%	

Average Entrance Turbidity per Storm (NTU) 1,704
Average Exit Turbidity per Storm (NTU) 3,296
Average Basin Reduction[1] -93%

Average Entrance TSS per Storm (mg/L) 2,156
Average Exit TSS per Storm (mg/L) 2,308
Average Basin Reduction[1] -7%

Total Sediment Load (kg) 17,878
Overall Average Sediment Load per Disturbed Acre[2] (kg) 511
Average Sediment Load per Disturbed Acre per Storm[3] (kg) 43

[1]Calculated using only those storms that had both entrance and exit data.
[2]Calculated by dividing the total sediment load by the disturbed acreage.
[3]Calculated by averaging the individual sediment loads per acre for each storm event

Table 9. Site GUIL Nutrient Loading - Phase 2

Date	Sampler Location		PO_4 (mg/L P)	NH_4 (mg/L N)	NO_3 (mg/L N)	TOC (mg/L C)	TP (mg/L P)	TKN (mg/L N)
10/8/2005	Exit		0.05	0.25	0.14	3.90	0.18	1.10
4/28/2006	Entrance		0.04	1.12	0.42	9.40	0.26	2.95
	Exit		0.05	1.72	2.60	3.93	0.59	4.30
		net	-26%	-54%	-522%	58%	-131%	-46%
5/9/2006	Entrance		0.00	0.14	0.72	-	-	-
	Exit		0.05	0.00	0.32	-	-	-
		net	0%	100%	56%			
5/18/2006	Entrance		0.03	0.50	0.19	3.95	1.30	2.26
	Exit		0.06	0.47	0.60	2.88	0.78	3.34
		net	-107%	6%	-209%	27%	40%	-48%
6/9/2006	Entrance		0.01	0.03	0.36	9.35	2.30	4.00
	Exit		0.02	0.02	0.32	8.61	0.97	1.26
		net	-147%	51%	10%	8%	58%	68%
7/2/2006	Entrance		0.01	0.03	0.13	8.40	2.25	5.75
	Exit		0.02	0.00	0.04	4.35	6.55	1.85
		net	-88%	100%	67%	48%	-191%	68%
7/7/2006	Exit		0.07	0.11	0.03	6.05	0.56	1.35
7/24/2006	Exit		0.04	0.03	0.14	16.03	2.02	2.50
9/1/2006	Entrance		0.01	0.05	0.17	7.60	0.66	0.98
	Exit		0.02	0.02	0.19	7.75	0.64	0.74
		net	-67%	62%	-13%	-2%	3%	24%
9/15/2006	Entrance		0.03	0.14	0.01	6.50	0.36	0.37
	Exit		0.04	0.03	0.01	5.10	0.81	0.83
		net	-32%	79%	0%	22%	-124%	-125%
Average Entrance Load			0.02	0.29	0.29	7.53	1.19	2.72
Average Exit Load			0.04	0.32	0.58	5.44	1.72	2.05
Average Basin Reduction[1]			-100%	-12%	-104%	28%	-45%	24%
Total Load (g)			264	189	862	31,595	10,796	6,316
Overall Average Load per Acre[2]			7.6	5.4	25	903	308	180
Average Load per Acre per Storm[3]			1	1	3	181	44	34

[1]Calculated using only those storms that had both entrance and exit data.
[2]Calculated by dividing the total nutrient load by the disturbed acreage.
[3]Calculated by averaging the individual nutrient loads per acre for each storm event.

Site ORAN:
This site was an educational facility construction project that had a sediment basin (60' long by 15' wide by 3' deep) with three porous baffles made of plastic tree protection fence and both a rock spillway and a 2" diameter skimmer dewatering device (Figures 10 and 11). There was one designed inlet to the basin, though it was not stabilized and eroded significantly during the sampling period. The basin sidewalls were fairly steep and were not stabilized until rills had already begun to form, at which point the jute matting placed along the slopes was ineffective. The rills that formed got progressively worse and no doubt contributed to an increase in sediment in the basin. Unfortunately, a second inlet channel eroded into the sidewall near the skimmer drain, where a large volume of sediment was deposited, despite attempts to stabilize it with geotextile matting.

The drainage area was approximately 0.9 acres with a 5% slope. It had been a mature pine forest until cleared, and it was continually disturbed throughout the sampling period. The perimeter of the basin was heavily covered with wood mulch made from trees ground up on site.


Figures 10 and 11. The disturbed area upslope and the sediment basin at Site ORAN.

Four storm events were captured for this site, but only one set of samples was submitted in time for a laboratory analysis of nutrients. Samplers were installed at the outlet structures (one each at the skimmer and rock spillway) to obtain basin discharge samples and flows. With an average turbidity of almost 6,000 NTU and a TSS of almost 4,000 mg/L, the discharge from this basin was among dirtiest monitored in spite of the skimmer outlet (Table 10). As a result, it lost 592 kg of sediment per acre over the monitoring period of four months, again among the highest observed.

An explanation for the surprisingly poor runoff treatment observed here might be that the skimmer outlet was installed at the very bottom of the basin and thus it discharged until almost all the water was drained. The bottom of the water column in these basins is often very heavily sediment-laden, even muddy, and this site was no exception. The most turbid water occurred at the beginning of all four storm events, when the skimmer was on the basin bottom. Discharge water quality improved during the storm event, but turbidity increased for the last few samples in most cases. Again, the skimmer was discharging from near the bottom at that point. This suggests that the skimmer outlet should be raised off the bottom of the basin for maximum water quality benefits relative to sediment, assuming the resulting standing pool does not create other problems.

For the one storm event for which samples were analyzed for nutrients, very low nutrient concentrations were found (Table 11). Total discharge loads were 14 g P per acre for TP and 38 g N per acre for TKN, among the lowest observed of all the project sites. The grading process removed the nutrient-rich topsoil and the underlying subsoil apparently has low nutrient content. In addition, no attempts have been made to establish a ground cover due to the continued disturbance of most of the site. This eliminates the chance of fertilizers, normally part of ground cover establishment, from contributing to the nutrients in runoff.

Table 10. Site ORAN Turbidity and Sediment Loading

Storm Date	Rainfall (in)	Sampler Location in Basin	# of Samples	Average Turbidity (NTU)	Average TSS (mg/L)	Sediment Load (kg)
2/1/2008	0.8	Exit	7	4,594	3,098	47
2/13/2008	0.94	Exit	6	6,670	3,656	48
2/26/2008	0.4	Exit	18	3,951	3,140	123
3/4/2008	1.47	Exit	19	8,515	5,453	314
Average Exit Turbidity per Storm (NTU)				5,933		
Average Exit TSS per Storm (mg/L)					3,837	
Average Exit Sediment Load per Storm (kg)						133
Total Sediment Load (kg)						532
Overall Average Sediment Load per Disturbed Acre[1] (kg)						592
Average Sediment Load per Disturbed Acre per Storm[2] (kg)						148

[1]Calculated by dividing the total sediment load by the disturbed acreage.
[2]Calculated by averaging the individual sediment loads per acre for each storm event.

Table 11. Site ORAN Nutrient Loading

Date	Sampler Location	PO_4 (mg/L P)	NH_4 (mg/L N)	NO_3 (mg/L N)	TOC (mg/L C)	TP (mg/L P)	TKN (mg/L N)
2/13/2008	Exit	0.05	0.13	0.32	9.80	0.97	2.60
		PO_4 (g P)	NH_4 (g N)	NO_3 (g N)	TOC (g C)	TP (g P)	TKN (g N)
2/13/2008	Exit	0.7	1.7	4.2	128	13	34
Average Load per Acre		0.8	1.9	4.7	142	14	38

Site DURH:
This residential development had a sediment trap approximately 70' long by 35' wide by 3'deep with silt fence baffles (Figures 12 and 13). The outlet for this trap was a 15' wide rock dam comprised of gravel layered on larger stone. As it was a trap and not a basin, meaning it had a rock dam outlet, runoff flowed directly out the dam at the back of the trap. The basin had 2:1 sloping sidewalls that were initially seeded and covered with straw, but vegetation was not well established (Figure 13) and eroded during the monitoring period. A rectangular weir with end contractions was installed on the back side of the rock weir, where a sampler with bubbler module was installed to measure flow and collect samples. An attempt was made to install a wooden weir in the large inlet channel as well, but the channel experienced so much flow bypass and was quickly and consistently buried in sediment during each storm that little useful data was collected here.

The site had a 1.5 acre disturbed drainage area at an approximate 5% slope which was continually disturbed throughout the project, resulting in large sediment loads coming into the trap.


Figures 12 and 13. The upslope disturbed area and sediment basin at Site DURH. The photo on the right shows an attempt at maintenance, with a small amount of sediment removed and a new rock dam.

There were 11 storms captured for this site, with 2 events collected in time for nutrient analysis. A very large volume of sediment was discharged at this site, the largest by far of any of the sites monitored for this report (Table 12). Overall, there were 30,000 kg of sediment lost per disturbed acre during the 10 month monitoring period, largely by a few large storm events, with an average sediment discharge per acre per storm of 2,700 kg. The turbidity and TSS averaged 13,000 NTU and 11,000 mg/L respectively, again the highest of any site monitored for this report. This site had large areas of subsoil exposed made of Triassic Basin materials, which include 2:1 expanding clays which are generally difficult to settle.

The first storm with nutrient data had an average TKN loss just over 1.5 kg per acre, high for a single storm relative to the sites described above (Table 13). A substantial difference in overall loading rates was observed between the two storm events analyzed for nutrients. The second storm was 6 months after the first and only had between 10 and 50% of the nutrient loss of the first, depending upon the specific analyte. Sediment losses were also at the lowest of all 11 storms, possibly because this was one of the lowest rainfall totals. Compared to the first storm, there were two storms with similar amounts of sediment and two with more sediment discharged. Assuming a relationship to nutrients, the amount discharged is likely much higher than the totals for the two storms for which we have nutrient data.

Table 12. Site DURH Turbidity and Sediment Loading

Storm Date	Rainfall (in)	Sampler Location in Basin	# of Samples	Average Turbidity (NTU)	Average TSS (mg/L)	Sediment Load (kg)
6/28/2005	1.08	Exit	13	9,568	8,387	1,439
7/7/2005	1.79	Exit	20	19,489	15,007	3,211
7/14/2005	1	Exit	24	25,600	22,448	10,045
7/29/2005	1	Exit	2	22,761	19,534	1,275
8/9/2005	1.38	Exit	24	18,070	10,538	6,567
8/13/2005	0.6	Exit	3	1,566	1,204	339
9/20/2005	1.18	Exit	5	30,000	26,914	6,324
10/8/2005	1.73	Exit	11	8,923	9,986	10,082
12/5/2005	0.25	Exit	24	12,124	9,870	5,631
1/18/2006	0.48	Exit	2	2,904	2,064	66
2/8/2006	0.68	Exit	18	1,037	488	79

Average Exit Turbidity per Storm (NTU)	13,822
Average Exit TSS per Storm (mg/L)	11,495
Average Exit Sediment Load per Storm (kg)	4,096
Total Sediment Load (kg)	45,057
Overall Average Sediment Load per Disturbed Acre[1] (kg)	30,038
Average Sediment Load per Disturbed Acre per Storm[2] (kg)	2,731

[1]Calculated by dividing the total sediment load by the disturbed acreage.

[2]Calculated by averaging the individual sediment loads per acre for each storm.

Table 13. Site DURH Nutrient Loading

Date	Sampler Location	PO_4 (mg/L P)	NH_4 (mg/L N)	NO_3 (mg/L N)	TOC (mg/L C)	TP (mg/L P)	TKN (mg/L N)
8/9/2005	Exit	0.03	0.24	0.52	5.22	0.77	3.84
2/8/2006	Exit	0.09	0.03	0.11	7.20	0.47	1.28

Date	Sampler Location	PO_4 (g P)	NH_4 (g N)	NO_3 (g N)	TOC (g C)	TP (g P)	TKN (g N)
8/9/2005	Exit	20	65	143	2,813	395	2,037
2/8/2006	Exit	14	4	15	1,155	81	220
Total Load		35	70	158	3,968	475	2,256
Average Load per Storm		17	35	79	1,984	238	1,128
Average Load per Acre[1]		23	46	105	2,645	317	1,504
Average Load per Acre per Storm[2]		12	23	53	1,323	158	752

Site WAKE1:
This site was an educational facility construction project that had a large oval-shaped sediment basin approximately 150' long and 100' wide with a rock-stabilized inlet channel and a concrete culvert outlet (Figures 14 and 15). The sidewalls were steep but well vegetated with little rill formation observed. The basin was converted into a general stormwater basin upon project completion and as a result was slightly more complex in design than most temporary sediment basins. It had two separate, 2' deep chambers connected by a perforated riser pipe with a gravel collar. Sampling was done at a weir installed in the rock inlet channel and in the culvert outlet, allowing flow to be calculated for both the basin entrance and exit.

The drainage area was approximately 5.5 acres at an average slope of about 2% and included the construction area, a hard-packed gravel parking lot, and a small, vegetated field. The entire area immediately adjacent to the basin was established turfgrass, which acted as a buffer filter for the runoff entering the basin from sources other than the inlet channel. Unfortunately after several storm runoff events, including one observed in the field, it was concluded that this entire area was not fully draining into the basin as was designed in the project plans. Some of the construction site runoff was apparently flowing into the drainage ditch of a nearby road. Since the basin was very non-standard in design and essentially oversized due to the diversions of construction site flow to the road ditch, we moved to another site.


Figures 14 and 15. The drainage area (current condition) and the sediment basin at Site WAKE1.

There were 7 storms captured at this site, each with both basin entrance and exit samples. The basin was quite effective capturing sediment for most storms (Table 14). Turbidity was reduced an average of 72% and TSS by 86%, resulting in relatively low discharge values of 400 NTU and 300 mg/L respectively. Sediment discharge was relatively low with an overall discharge 414 kg per acre. Soluble phosphorus concentrations entering and exiting the basin were quite low and with negligible changes observed (Table 15). Total P decreased on average in the basin, but the N species had mostly small changes in the basin. The exception was NH_4 , which increased substantially, possibly as a result of decaying organic material washed into the basin. Most of the N was in the form of NO_3. Overall nutrient discharges for NO_3 and TKN were around 3 kg per acre each, and TOC at almost 15 kg per acre.

Table 14. Site WAKE1 Turbidity and Sediment Loading

Storm Date	Rainfall (in)	Sampler Location in Basin	# of Samples		Average Turbidity (NTU)	Average TSS (mg/L)	Sediment Load (kg)
12/23/2004	0.46	Entrance	2		2226	1733	-
		Exit	18		260	200	386
				net	88%	88%	
1/14/2005	2.00	Entrance	17		1214	2290	-
		Exit	24		392	248	675
				net	68%	89%	
2/3/2005	1.43	Entrance	1		1276	840	-
		Exit	20		370	158	358
				net	71%	81%	
2/24/2005	1.35	Entrance	4		825	779	-
		Exit	2		770	788	179
				net	7%	-1%	
2/28/2005	1.56	Entrance	6		607	509	-
		Exit	5		172	260	147
				net	72%	49%	
3/8/2005	1.31	Entrance	1		2676	7536	-
		Exit	18		341	221	451
				net	87%	97%	
3/22/2005	1.04	Entrance	6		845	562	-
		Exit	4		369	180	81
				net	56%	68%	

Average Entrance Turbidity per Storm (NTU)	1,381
Average Exit Turbidity per Storm (NTU)	382
Average Basin Reduction	72%
Average Entrance TSS per Storm (mg/L)	2,036
Average Exit TSS per Storm (mg/L)	294
Average Basin Reduction	86%
Total Sediment Load (kg)	2,277
Overall Average Sediment Load per Disturbed Acre[1] (kg)	414
Average Sediment Load per Disturbed Acre per Storm[2] (kg)	163

[1]Calculated by dividing the total sediment load by the disturbed acreage.
[2]Calculated by averaging the individual sediment loads per acre for each storm event.

Table 15. Site WAKE1 Nutrient Loading

Date	Sampler Location		PO_4 (mg/L P)	NH_4 (mg/L N)	NO_3 (mg/L N)	TOC (mg/L C)	TP (mg/L P)	TKN (mg/L N)
12/23/2004	Entrance		0.00	0.23	1.40	18.8	0.73	1.90
	Exit		0.03	0.00	1.16	5.0	0.22	0.62
		net	NA	100%	17%	73%	70%	67%
1/14/2005	Entrance		0.04	0.03	1.33	7.2	0.67	1.72
	Exit		0.07	0.16	2.11	9.0	0.36	0.82
		net	-84%	-443%	-59%	-24%	46%	52%
2/3/2005	Entrance		0.02	0.16	2.80	4.0	0.41	3.30
	Exit		0.03	0.16	2.10	6.3	0.26	1.97
		net	-58%	0%	25%	-58%	35%	40%
2/24/2005	Entrance		0.05	0.00	2.25	9.4	0.65	2.65
	Exit		0.01	0.28	1.35	8.1	0.62	7.10
		net	89%	NA	40%	14%	4%	-168%
2/28/2005	Entrance		0.05	0.00	1.95	11.9	0.29	4.60
	Exit		0.02	0.08	2.38	8.0	0.21	1.11
		net	64%	NA	-22%	33%	27%	76%
3/8/2005	Entrance		0.00	0.00	1.40	4.6	1.80	3.50
	Exit		0.02	0.38	1.41	11.5	0.26	2.64
		net	NA	NA	-1%	-149%	85%	24%
3/22/2005	Entrance		0.02	0.10	2.06	7.3	0.37	2.00
	Exit		0.02	0.18	0.71	7.7	0.34	0.98
		net	0%	-69%	66%	-5%	8%	51%
Average Entrance Concentration			0.02	0.07	1.88	9.04	0.70	2.81
Average Exit Concentration			0.03	0.18	1.60	7.94	0.33	2.18
Average Basin Reduction			-11%	-135%	15%	12%	54%	22%
Total Load (g)			365	1,752	17,568	81,510	2,956	15,971
Overall Average Load per Acre[1]			66	319	3,194	14,820	537	2,904
Average Load per Acre per Storm[2]			9	46	456	2,117	77	415

[1]Calculated by dividing the total nutrient load by the disturbed acreage.
[2]Calculated by averaging the individual nutrient loads per acre for each storm event.

Site WAKE2:
This site was an educational facility construction project that had a large rectangular basin (80' long by 30' wide by 5' deep) with a solid dam (surface) spillway (Figures 16 and 17). Three rows of baffles made of thin jute netting were also installed in the basin. The sidewalls were fairly steep though the contractor did seed and straw with mixed success at establishing vegetation. As a result, rill formation was observed and two significantly large channels quickly eroded into the sidewalls. A wooden rectangular weir was installed in the rock spillway along with a sampler, but multiple inlets precluded monitoring water entering the basin.

The upslope disturbed area was approximately 3 acres in size at an average 11% slope initially, although this was drastically changed over time. This area was worked and graded throughout the entire sampling period resulting in a continually disturbed soil surface that generated very turbid standing water in the basin. Geese were also observed on a few occasions in and around the basin, so there was a potential for impacts from waste deposits. Unfortunately, due to both the size of the basin and the extraordinary drought experienced in the region during the monitoring period, only 1 storm event resulted in any overflow.


Figures 16 and 17. The disturbed area upslope and the sediment basin at Site WAKE2.

The results from the one storm event were relatively low as compared to the other sites monitored with a turbidity of 300 NTU and a TSS of 1,100 mg/L (Table 16). The overall average sediment discharge per acre was also low, at only 22 kg. The size of the basin likely contributed to these low sediment rates. By maintaining a standing pool of water for long periods and by having three baffles, runoff entering the basin was immediately slowed down or stopped altogether, allowing large quantities of sediment to fall out of suspension.

There was very little nutrient loading observed in the discharged flow as well (Table 17). Average loads per acre for TP and TKN were just 4 g and 9 g respectively. As there was no fertilizer applied to the disturbed area and since it was heavily graded with no remaining organic-rich surface soil layers, there were apparently very little nutrients present to be transported through the basin.

Table 16. Site WAKE2 Turbidity and Sediment Loading

Storm Date	Rainfall (in)	Sampler Location in Basin	# of Samples	Average Turbidity (NTU)	Average TSS (mg/L)	Sediment Load (kg)
10/27/2007	1.42	Exit	5	308	1,156	65

Average Exit Turbidity per Storm (NTU)	308
Average Exit TSS per Storm (mg/L)	1,156
Average Exit Sediment Load per Storm (kg)	65
Total Sediment Load (kg)	65
Average Sediment Load per Disturbed Acre (kg)	22

Table 17. Site WAKE2 Nutrient Loading

Date	Sampler Location	PO_4 (mg/L P)	NH_4 (mg/L N)	NO_3 (mg/L N)	TOC (mg/L C)	TP (mg/L P)	TKN (mg/L N)
10/27/2007	Exit	0.04	0.18	0.64	3.30	0.22	0.48

Date	Sampler Location	PO_4 (g P)	NH_4 (g N)	NO_3 (g N)	TOC (g C)	TP (g P)	TKN (g N)
10/27/2007	Exit	2	10	36	187	12	27
Total Load		2	10	36	187	12	27
Average Load per Acre		1	3	12	62	4	9

Coastal Plain Site

Site GREE:
This site was a large residential development with a large basin (500' long by 150' wide by 11' deep) with a concrete riser outlet at an elevation 3' above the floor of the basin (Figures 18-21). The outlet had a 6" diameter skimmer dewatering device attached as well. The sides were 4:1 slopes and were quickly stabilized with vegetation, except for a small section by the outlet. As a result, there was very little erosion on the basin slopes. The basin drained a 51 acre disturbed area with multiple drop inlet structures that fed into two 4' diameter concrete culverts. These emptied into the basin at opposite corners from the outlet. The surrounding drainage area had an estimated 0.5% slope and was initially completely bare. Sporadic seeding efforts were attempted in some parts of the drainage as grading was completed, but low rainfall during the period prevented a successful establishment. Samplers were installed at the skimmer outlet and in each of the two inlet drain pipes in order to obtain flow and water quality data at the inlet and outlet.


Figures 18 and 19. The disturbed area upslope and an example inlet structure at Site GREE.


Figures 20 and 21. The large sediment basin and concrete riser outlet with skimmer.

Due to the high infiltration rates of the sandy soil in this area and to the large size of the basin, which was to be converted to a permanent pond upon project completion, there was only one storm event (of 1.85” of rain in 2 hours) that resulted in runoff flow. Two other storm events resulted in ponding in the basin but fill it to the level of the skimmer outlet. Surface water grab samples were taken for these storms by the outlet drain.

The one captured storm resulted in 4 kg of sediment discharge per disturbed acre with an average discharge turbidity of 785 NTU and an average TSS of 529 mg/L (Table 18). The basin did treat the water to some degree with a 34% reduction in NTU and 42% reduction in TSS. The two grab samples taken the day after storm events were quite clean as well, averaging a turbidity of just 78 NTU and a TSS of only 47 mg/L. The aforementioned basin size and high soil infiltration rate in the area are the likely explanations for the high water quality observed here. By reducing the overall volume of runoff, by holding and slowing large volumes of water prior to discharge, and by placing the outlet so far from the inlet pipes, substantial amounts of sediment were allowed to fall out of suspension.

There were low rates of nutrients as well (Table 19), with nothing except TOC exceeding 3 mg/L in concentration. This is somewhat surprising as fertilizer had been added along with the seed when the basin sideslopes were vegetated, as well as with the temporary seeding effort attempted in those portions of the drainage area where grading had been completed. Nevertheless, the basin did provide some treatment in reducing nutrient concentrations, with resulting discharge loads that were among the lowest of any site monitored. Total phosphorus (TP) and TKN were especially low at just 9 and 11 g per disturbed acre.

Table 18. Site GREE Turbidity and Sediment Loading

Storm Date	Rainfall (in)	Sampler Location in Basin	# of Samples		Average Turbidity (NTU)	Average TSS (mg/L)	Sediment Load (kg)
4/30/2008	0.7	Grab	1		126	126	-
5/12/2008	0.67	Grab	1		30	30	-
5/22/2008	1.85	Entrance 1	13		1232	912	126
		Entrance 2	7		1148	907	210
		Exit	24		785	529	190
				net	34%	42%	43%

Average Entrance Turbidity per Storm (NTU)	1,190
Average Exit Turbidity per Storm (NTU)	785
Average Basin Reduction	34%
Average Entrance TSS per Storm (mg/L)	910
Average Exit TSS per Storm (mg/L)	529
Average Basin Reduction	42%
Average Entrance Sediment Load per Storm (kg)	336
Average Exit Sediment Load per Storm (kg)	190
Average Basin Reduction	43%
Total Sediment Load (kg)	190
Overall Average Sediment Load per Disturbed Acre (kg)	4

Table 19. Site GREE Nutrient Loading

Date	Sampler Location		PO_4 (mg/L P)	NH_4 (mg/L N)	NO_3 (mg/L N)	TOC (mg/L C)	TP (mg/L P)	TKN (mg/L N)
10/23/2007	Grab		0.02	0.13	0.00	-	-	-
10/23/2007	Entrance1		1.23	0.26	0.62	4.59	1.58	1.92
	Entrance2		1.25	0.18	2.13	6.46	1.69	2.94
	Exit		0.29	0.53	0.93	4.49	0.62	1.63
		net	76%	-145%	32%	19%	62%	33%

		PO_4 (g P)	NH_4 (g N)	NO_3 (g N)	TOC (g C)	TP (g P)	TKN (g N)
10/23/2007	Exit	101	184	311	1,490	204	543
Overall Average Load per Acre (g)		2	4	6	29	4	11

Table 20. Mountain Sites Summary

Site	Storms	Average discharge Turbidity (NTU)	Average discharge TSS (mg/L)	Average discharge per acre Sediment (kg)	PO_4 (g P)	NH_4 (g N)	NO_3 (g N)	TOC (g C)	TP (g P)	TKN (g N)
JACK (Nov 05 - Oct 06)	11	3,449	7,603	141	143	153	264	2,260	789	1,387
BUNC (Aug 07 - Feb08)	6	4,970	7,626	962	4	20	6	259	565	737
	Median Values	**4,210**	**7,615**	**552**	**74**	**87**	**135**	**1,260**	**677**	**1,062**

Table 21. Piedmont Sites Summary

Site	Storms	Average discharge Turbidity (NTU)	Average discharge TSS (mg/L)	Average discharge per acre Sediment (kg)	PO_4 (g P)	NH_4 (g N)	NO_3 (g N)	TOC (g C)	TP (g P)	TKN (g N)
GUIL - Phase 1 (Jan 05 - Aug 05)	11	270	186	20	2	24	26	3,242	33	626
GUIL - Phase 2 (Oct 05 - Sept 06)	13	2,654	1,932	511	8	5	25	903	308	180
ORAN (Jan 08 - Apr 08)	4	5,933	3,837	592	1	2	5	142	14	38
DURH (Jun 05 - Feb 06)	11	13,822	11,495	30,038	23	46	105	2,645	317	1,504
WAKE1 (Dec 04 - Apr 05)	7	336	294	414	66	319	3,194	14,820	537	2,904
WAKE2 (Jul 07 - Apr 08)	1	308	1,156	22	1	3	12	62	4	9
	Median Values	**1,495**	**1,544**	**463**	**5**	**15**	**26**	**1,774**	**171**	**403**

Table 22. Combined Regions Summary

Region	Storms	Median discharge: Turbidity (NTU)	Median discharge: TSS (mg/L)	Median discharge per acre: Sediment (kg)	PO_4 (g P)	NH_4 (g N)	NO_3 (g N)	TOC (g C)	TP (g P)	TKN (g N)
Mountain	17	4,210	7,615	552	74	87	135	1,260	677	1,062
Piedmont	37	1,495	1,544	463	5	15	26	1,774	171	403
Coastal Plain	1	785	529	4	2	4	6	29	4	11

CONCLUSIONS

Discharges from eight construction sites around the state had highly variable discharge water quality, with values differing by up to several orders of magnitude (Tables 20-22). It is likely that a combination of site factors, such as soil and topography, and management factors, such as BMPs used and their maintenance, are influential in determining discharge water quality. Turbidity and TSS in discharges were very high compared to typical stream values reported elsewhere. As we have reported previously, the effect of sediment traps and basins ranged from negative (adding sediment to inflow) to relatively efficient sediment removal. There was some evidence that basin size relative to drainage area was the principal factor.

The amount of sediment and nutrients in the discharges also had a wide range. During the periods being monitored, sediment discharged ranged up to 30,000 kg per acre, although most sites were discharging <1,000 kg per acre. We did not fully explore the relationship between sediment and nutrients discharged, but there does not appear to be any connection. For the two mountain sites, JACK had much lower sediment discharged and much high nutrients discharged compared to BUNC. For the Piedmont sites, a relatively low sediment discharge site (WAKE1) had the highest nutrient discharges. At one site (GUIL), sediment discharges increased when the drainage area and basin decreased in size substantially, but nutrient discharges declined sharply. For the one Coastal Plain site monitored, two storms actually produced no discharge due to apparent infiltration. A third storm did generate discharges which we sampled, but sediment and nutrient content were very low.

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