Demonstrating and Evaluating Low Impact Development Techniques

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Submitted by:

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Executive Summary

Urban development is occurring at a rapid pace in central NC. Given that stormwater runoff from urban areas has the potential to significantly degrade downstream water resources, identifying methods to reduce the impact of development is a critical need. One such method is termed Low Impact Development (LID). This project partnered with a developer to monitor runoff from a 46-unit residential housing subdivision, named Pacifica, that used LID principles and practices. The purpose of this project was to monitor runoff data during the construction and post-development periods in order to provide data for a comparison with the pre-development monitoring data.

Rainfall, runoff, and pollutant concentrations were monitored, using automated samplers, prior to, during, and following construction of the Pacifica residential development. One site PC1 was maintained throughout the entire development process, while two other sites were installed at various places and times during development depending on where the runoff was being routed during the period. Runoff and pollutant (N, P, and TSS) export increased considerably from the pre-construction to during- and post-construction periods for the one monitoring station, PC1, that was maintained during the entire project. The increases were despite the fact that several LID measures including level spreaders, permeable pavement, and a riparian buffer were implemented in the drainage area.

Continuous monitoring of the effluent from a large sediment basin (site PC2), which received runoff from most of the site during construction, documented a sediment export rate of 8.0 ton/ac-yr and mean turbidity of 3,700 NTU in spite of the use of a skimmer outlet and flocculent logs (intermittent use when water pumped out of basin and over flocculent log(s)). This rate was similar to the export rate (8.5 ton/ac-yr) and mean turbidity (2,600 NTU) of a smaller adjacent monitored drainage area (PC1) on the same site that employed only a conventional sediment trap and a wooded riparian buffer.

Runoff and pollutant export from most of the development during the post-development period, which was monitored at the outflow from a retention pond (PC3), was greater than the corresponding export rates from the PC1 monitoring station. The difference was likely the combination of levels spreaders and wooded riparian buffer.

Modeling tools have been presented as a way to predict the runoff and pollutant export resulting from various types of development; thus, assessing the validity of the tools is needed. The Site Evaluation Tool (SET) was applied to the PC1 drainage area to assess how well it predicted the change in runoff and pollutant export associated with a portion of the Pacifica development. The predicted export rates for the SET model tended to be greater than the monitoring data for the pre-development period and less for the post-development resulting in the predicted increases in TN, TP, and TSS as a result of development being much less than the monitoring data indicated.

Introduction /Background

Residential development is occurring at a rapid pace throughout central NC and particularly Wake County. The impact of this development on water quality has been documented previously in several research papers including Line et al. (2002) and Line and White (2007). To lessen the negative impact of development, municipalities have begun placing a greater emphasis on controlling and/or treating stormwater on-site. One relatively new and innovative way of doing this is called LID. A guiding principle of LID is to maintain the pre-development hydrology of the site even after the site has been developed. This is very difficult given that development almost always increases the area of impervious surfaces on a site and often dramatically disturbs the soil structure which decreases infiltration of rainwater into the ground.

This project was designed to conduct pre-development runoff monitoring of a proposed LID site to document the predevelopment hydrology, which later can be compared to post-development hydrology. A nearby, topographically-similar conventionally-developed site is also being monitored to provide a ‘control’ drainage area for use in statistical analyses such as a paired watershed analysis.

Purpose and Goals

The purpose of this project was to monitor runoff from a residential LID subdivision during and following construction to compare to pre-development monitoring data. A secondary purpose was to compare runoff and pollutant export estimates from the Site Evaluation Tool (SET) to monitoring data.

Methodology/Execution

Monitoring the runoff from this construction site was difficult due to the changing drainage from the site. At the start of construction, a ditch was installed near the north end of the cleared area to divert runoff to the northwest corner of the cleared area where a large sediment basin was installed. Hence, nearly all of the runoff was diverted to this point, so a monitoring station was installed at the outlet of the basin, which will be referred to as PC2 (Fig. 1). The other monitoring station, PC1, remained in operation because a small part of the cleared area continued to drain to it (Table 1). Near the completion of construction the sediment basin was removed and most runoff from the site was routed through the storm drain system to the detention/irrigation pond. So, the monitoring station was moved to the outlet of the pond where the station will be referred to as PC3 (Fig. 2). Moving the stations resulted in some lost monitoring data due to setup time, but this was appropriate given that new drainage systems require some time to stabilize anyway. Several months after installation of PC3, a drawdown riser pipe was added to the outlet of the detention/irrigation pond necessitating the addition of a weir box to monitor outflow from the pipe.

<u>Monitoring stations</u>: The PC1 monitoring stations was installed and maintained under a previous grant from March 15, 2003 to March 31, 2004. The monitoring equipment was reinstalled on May 10, 2005 under this grant with the first storm occurring on May 12, 2005. The station consisted of a 2 ft rectangular weir and an automated sampler with an integrated flowmeter to continuously measure water depth over the weir. A 0.5-1.5 ft high plywood diversion wall (fig. 3) had been

installed previously to direct the runoff from the wooded hillslope to the weir for monitoring purposes. This diversion was necessary because there was no well-defined channel through the wooded riparian buffer; hence, runoff often meandered through the woods using several different paths.

The PC2 monitoring station was installed and maintained (March, 2003 to Feb. 2004) under a previous grant in a roadside ditch along the west boundary of the property. It was anticipated that this station could be installed at the same location during and following construction of Pacifica; however, this was not the case due to the changes in grading and drainage that occurred during development and the changes that occurred on Hanna Street (recall that this station received runoff from Hanna Street and the area that Pacifica was built on, so now the effect of Pacifica could not be isolated). During the construction period of Pacifica, a curb and gutter system was installed on Hanna Street, thereby altering the hydrology of this drainage area. Thus, this station was moved during the construction phase to the outlet of the sediment basin (fig. 1). A 120 deg v-notch weir, wingwalls, and associated automated sampler were installed in May, 2005. The station monitored discharge from the skimmer and emergency spillway until the sediment basin was filled in in December, 2006. A tipping bucket raingage was installed and connected to the automated sampler to record rainfall accumulation on 15-minute intervals.

The PC3 monitoring station was installed in December, 2007 to monitor discharge from the detention/irrigation pond. By this time, the stormdrain system was fully functioning transporting most of the runoff from the development to the pond (fig. 2). Because the pond had both a normal and emergency outlets, two discharge monitoring weirs and flowmeters were installed. A 90 deg. v-notch weir box was installed on the end of the outflow riser pipe, while a 3ft rectangular weir and wingwall was installed across the emergency spillway. A flowmeter was used to monitor water height for each weir and standard weir equations were used to convert the measured heights to discharges. Discharge from both outlets was then summed to obtain the total discharge.

Sample Collection: Sample collection was basically the same at all monitoring stations, in that flow-proportional samples were collected and stored in individual bottles within the machine. For the PC1 and PC3 stations, duplicate samples were collected during discharge, with one of the samples being placed in a pre-acidified bottle and the duplicate in a nonacidified bottle. The acidified (H_2SO_4 to pH<2) samples were used for nitrogen and phosphorus analysis, while the nonacidified sample was used for sediment and turbidity analysis. For the PC2 station, flow-proportional sample were not duplicated as nitrogen and phosphorus analysis was not conducted.

Once every 2 weeks (more frequent if a lot of rain occurred) the sampler was visited and the individual flow proportional samples were combined into one acidified (for PC1 and PC3) and one nonacidified sample (for PC1, PC2, and PC3) for laboratory analysis. The lab sample was made by withdrawing and equal volume aliquots from each sampler bottle to make the laboratory sample.

Sample analysis: Laboratory samples were analyzed for turbidity using a turbidimeter measuring in Nephelometric turbidity units (NTUs). For high turbidities (> 1000NTU) the sample was diluted and a linear extrapolation of the measured value and dilution ratio was used to estimate the turbidity of the runoff sample. Also, samples were analyzed for total suspended solids (TSS) using 2540D (Eaton et al., 1995) if the turbidity was (< ~5000 NTU) and total solids (TS) using 2540B if the turbidity was (> ~5000 NTU). Very high levels of turbidity indicated that there was too much sediment to accurately filter using the 2540D (Eaton et al., 1995) method and thus, the TS method was used. Past experience has shown that at very high sediment levels, TSS and TS are nearly equal most of the time. The 2-week holding time was greater than recommended in Standard Methods (Eaton et al., 1995) for TSS; however, the solids/sediment in the samples was nearly all inert soil particles (also this is what we were interested in); thus, the breakdown and/or conversion of these particles was assumed to be negligible.

Analysis methods and method detection limits (MDLs) for sediment, nitrogen forms, and total phosphorus are shown in Table 1. Standard methods were used for each analysis to provide accurate, reliable, and repeatable results (Eaton et al., 1995).

Construction phase/activity: Past experience monitoring runoff from construction sites has demonstrated that runoff and pollutant export is highly correlated to construction phase and activities (Line and White, 2007). Hence, the phases of construction and major activities were tracked through observation and recorded. The major phases are shown in Table l. During the pre-construction phase there were no significant activities occurring in the drainage area to PC1, except for the installation of the monitoring station. For the construction phase of monitoring (PC1 and PC2), the trees had already been removed, but major grubbing and grading had not yet begun. By late in June, 2005 the site had been cleared and mostly graded such that the site was being prepared for the start of the construction of the houses. While a single date is given for the end of the construction and start of the post-construction phase, a transition period was involved as activities such as individual lot landscaping and house construction continued to occur after April 11, 2007.

Site Evaluation Tool (SET): The SET (version 3.3d) was obtained and used to estimate runoff and pollutant export from the drainage area to PC1. The tool's input table is shown in Table 6. The 'total site area' of 1.95 ac. was chosen to match the post-construction drainage area to the monitoring site (Table 2) even though the pre-construction drainage area was 2.48 acres (2.48 acres of woods was also used in SET and resulted in the same areal loading rates as the pre-construction rates obtained using 1.95 acres). Other input parameters include slope, hydrologic soil group, design storm, land use, and BMPs. The average slope of the site was greater than 6%, so this was selected. Soils were Appling (group B), Wilkes (group C), and Enon (group C) with 15% of the drainage area having Appling soils. The pre-construction land use was 100% forest, which was reduced to 43% during post-construction. Impervious surfaces such as building roofs and walkways covered 12.2% of the drainage area during the post-construction period. The only BMP input was the riparian forest buffer with level spreaders. All or 100% of the developed drainage area was input as in the 'treatment zone' because both storm drains draining the area had level spreaders at their outlets near the upslope boundary of the wooded buffer.

Outputs and Results

Monitoring results were divided into pre-, during-, and post-construction phases for each site. While the timeline for the phases are shown in Table 2 with a date, there was a transition period between phases. For example, tree logging and removal could be included in the during construction phase, but this started to the 5/12/05 date shown in Table 2 and not all of the construction and landscaping on individual lots was completed by 4/11/07. Thus, the dates represent the end of major activities associated with each phase.

There were many LID management measures implemented by the developer including permeable concrete for walkways and parking spaces, permeable pavers for walkways, grass pavers, rainwater roof runoff collection and reuse, vegetated swales, bioretention areas, level spreaders, and minimizing impervious surfaces through reduced length parking spaces, smaller footprint homes, and narrow roads. The only LID measure implemented with cost share from this grant was a solar-powered pump and cistern system to facilitate using harvested rainwater roof runoff to irrigate a community garden (fig. 4). Pictures of many of the other LID measures are on the website

<u>Pre-Construction Monitoring Data</u>: Summaries of monitoring data for PC1 during the pre-construction period are shown in Tables 2 and 3. Significant runoff from the mature, mixed hardwood forest occurred for only 4 storms (Table 4), 3 of which were successfully sampled (Table 4). While there were 11 storms of greater than 1 inch during the period, the only storms that produced significant runoff (>500 gal) had a rainfall accumulation of greater than 1.5 inch and an average intensity of at least 0.12 inches/hr (see appendix). The mean turbidity, nitrogen, phosphorus, and sediment levels in runoff samples were low, with the possible exception of the slightly elevated level of NH_4-N. Pollutant export from the pre-construction period (Table 3) was also low. Export rates were much lower than a mixed pine and hardwood forested area near Morrisville, NC as reported in Line and White (2007). As evidenced by the type and size of trees, much of the wooded area in Line and White (2007) was more recently converted to woods and in fact a small portion of the drainage area was still in cropland; hence, the export from the Pacifica site was expected to be less.

<u>During Construction Monitoring Data</u>: The PC1 and PC2 monitoring sites were maintained during construction. Summary totals for the during-construction period are shown in Tables 3 and 4, while data from individual storms are shown in the Appendix. For PC1, turbidity and pollutant concentrations increased considerably during construction as compared to pre-construction (Table 4). Runoff and pollutant export rates also increased considerably (Table 3). Given that only 0.36 acres of the 1.5 acre drainage area was cleared during construction makes the increased export much greater. For example, assuming that all of the increased sediment export originates from the cleared area, the sediment export from this area would be 19,140 kg/ha-yr (8.5 ton/ac-yr). This sediment export occurred in spite of the site having an approved erosion and sediment control plan with the drainage area having silt fence, a sediment trap, and the wooded riparian buffer.

Mean turbidity and TSS concentration in runoff samples collected at PC2 are shown in Table 4. These were considerably greater than PC1 even though this site was downstream of a large sediment basin equipped with a skimmer. Immediately after many events, water was pumped from the basin to the upslope end of a pipe and allowed to flow through the pipe over flocculent logs and back into the basin. While the flocculent log used was designed for the type of soil on site, it is not known whether the amount of flocculent used was appropriate for the volume of runoff and mass of sediment involved. Runoff and sediment export were also much greater than that of PC1 (Table 3). The runoff was more than twice PC1 probably due to increase grading and compaction in the PC2 drainage area. Sediment export from the drainage area was 17,874 kg/ha-yr (8.0 ton/ac-yr), which was similar to that estimated for the cleared area of PC1 (8.5 ton/ac-yr). While a direct comparison cannot be made, these data indicate that the combination of large basin and skimmer with intermittent flocculant useage was not significantly more effective than the standard sediment trap at reducing sediment loss from this site. Observation indicated that fine sediment remained in suspension for days and removing water from the top of the water column appeared to make little difference. In fact, the relatively long drawdown time associate with skimmer use may have hurt the efficiency of the basin for storms occurring in close succession. Further evidence of this was that the mean turbidity for samples from PC2 was 3700 NTU, while that from PC1 was 2600 NTU. One practice that appeared to be effective, although it was not monitored, was a temporary level spreader installed by the developer in the wooded buffer which received the effluent from the sediment basin and spread it out on the contour in the riparian wooded buffer.

Post Construction Monitoring Data: The post-construction monitoring period for PC1 began on 4/12/07 as finishing construction on only 1 or 2 houses in the drainage area remained and the storm drain system was in use including the level spreaders. Landscaping and other minor construction-related activities were continuing; however, major construction activities were completed several months before. As shown in Table 3, the runoff, TKN, NOx-N, TN, and TP export rates increased considerably from during construction period, while the NH_4-N and TSS export rates decreased. Of course the runoff and pollutant export rates were much greater than the corresponding pre-development rates. The nearly ten-fold reduction in TSS was expected given that nearly all exposed soil surfaces had been stabilized. The relatively small drop in the NH_4-N export rate could be attributed to natural variability.

Although the post-construction runoff and export rates were much greater than pre-construction, they were still less than those for Carpenter Village (Table 3), which was a conventional subdivision with no BMPs (Line and White, 2007). Data on the row labeled ‘Built’ was for the period right after construction, so this compares to the ‘Post’ period for PC1. Both sites were monitored for about 1.4 years and had similar total rainfall during the period of monitoring. The pollutant export rate from PC1 was also generally less than that for the ‘post’ period, which was the time following lawn and landscape establishment, of Carpenter Village even though this period was less than the ‘Built’ period (Table 3). Combination of permeable pavement, level spreaders, and riparian buffer likely contributed to the reduced pollutant export from Pacifica’s PC1 drainage area. Like Carpenter, pollutant export from the PC1 drainage area is expected to decrease as the vegetation becomes more established and needs fewer inputs.

The post-construction monitoring period for PC3 began on 4/5/08. Most of the construction in the drainage area had been completed several months prior to this (the last house closed on 12/17/07); however, alterations on the detention/irrigation pond were not complete. The detention/irrigation pond was being converted from a sediment basin with a skimmer into a detention pond with a riser pipe. The riser drawdown pipe was installed in March, 2007 to facilitate dropping the water level in the pond 0.75 to 1.3 ft below the spillway, which was necessary to drop the water level in the nearby bioretention areas. Because the monitoring site was at the outlet of the pond, monitoring could not be accomplished until the outlet configuration was complete.

The rainfall, runoff, and pollutant export for PC3 were greater than those for the PC1 post development period. While the PC1 post-development monitoring period includes that of PC3, it also includes about a year before, which was a time of less overall rainfall (Table 5). In addition, the peak 30-minute and overall intensity of storms during the PC1 post-development period were less than those during monitoring at PC3; hence, the runoff and pollutant export would be expected to be less. Compared to the Carpenter 'Built' period, rainfall, runoff, NOx-N, and TP export rates for PC3 were greater, while TKN, NH_4-N, TN, and TSS were less. Given that the rainfall was so much greater (~21 in/yr), increases in pollutant export would be expected.

The main difficulty with comparing these sites is the short duration of monitoring at PC3. The PC3 monitoring period was composed mostly of relatively large and intense summer storms. These often overwhelm the LID management measures rendering them ineffective. The export would likely be much less during fall and winter storms which generally have less accumulation and lower intensities. Thus, these reported export rates for PC3 have limited value.

Site Evaluation Tool (SET) Assessment: The SET was applied to the PC1 drainage area to compare its output to the monitoring data. It is important to note that the SET is a planning tool, which is designed for long-term estimates of runoff and pollutant export, and thus the absolute estimates of loading are not expected to coincide with monitoring data, but the differences between pre- and post-development monitoring data should be similar to SET model output. As shown in Table 7, the predicted export rates for the SET model tended to be greater than the monitoring data for the pre-development period and less for the post-development resulting in the predicted increases in TN, TP, and TSS as a result of development being much less than the monitoring data indicated. The cause of the discrepancy is unknown, but may be related to the relatively short period of post-development monitoring. The project by Line and White (2007) documented that pollutant export from a residential development decreased after the initial (~1.4 yr) post-development period, which might bring the monitoring results closer to the SET model, but this would be unlikely to make up the entire difference. More likely is that the SET model is too simplistic to accurately estimate the complex hydrologic processes involved in runoff and pollutant export, especially when LID measures such as level spreaders and riparian buffers are involved.

Outcomes and Conclusions

Rainfall runoff and pollutant export were monitored at three sites prior to, during, and following construction of the Pacifica residential development. The following conclusions can be drawn from the monitoring data:

1. Runoff and pollutant (N, P, and TSS) export increased considerably from the pre-construction to during- and post-construction periods for the one monitoring station, PC1, that was maintained during the entire project. The increases were despite the fact that several LID measures including level spreaders, permeable pavement, and a riparian buffer were implemented in the drainage area.
2. Continuous monitoring of the effluent from a large sediment basin (site PC2), which received runoff from most of the site during construction, documented a sediment export rate of 8.0 ton/ac-yr and mean turbidity of 3,700 NTU in spite of the use of a skimmer outlet and flocculent logs (intermittent use when water pumped out of basin and over log). This rate was similar to the export rate (8.5 ton/ac-yr) and mean turbidity (2,600 NTU) of a

smaller adjacent monitored drainage area (PC1) that employed only a conventional sediment trap and a wooded riparian buffer.

3. Runoff and pollutant export from most of the development during the post-development period, which was monitored at the outflow from a retention pond (PC3), was greater than the corresponding export rates from the PC1 monitoring station. The difference was likely the combination of levels spreaders and wooded riparian buffer.
4. The predicted export rates for the SET model tended to be greater than the monitoring data for the pre-development period and less for the post-development resulting in the predicted increases in TN, TP, and TSS as a result of development being much less than the monitoring data indicated.

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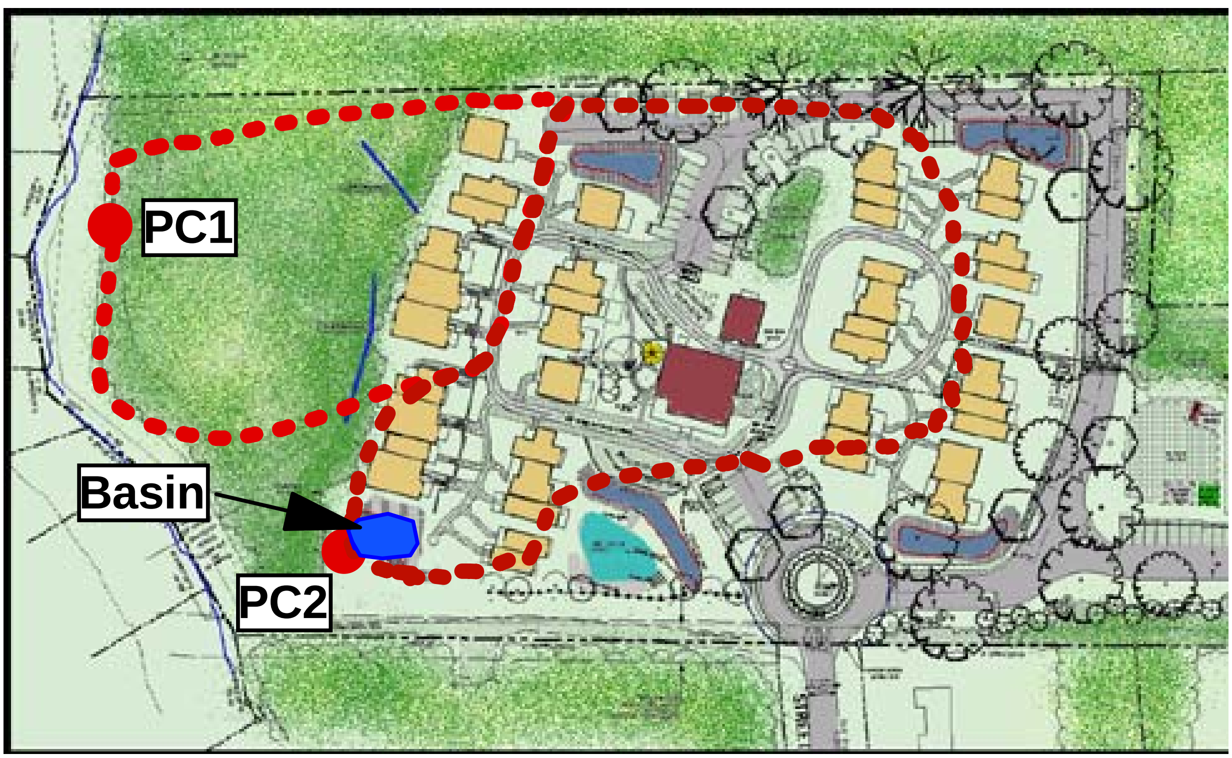

Figure 1. Map of the drainage areas during construction.

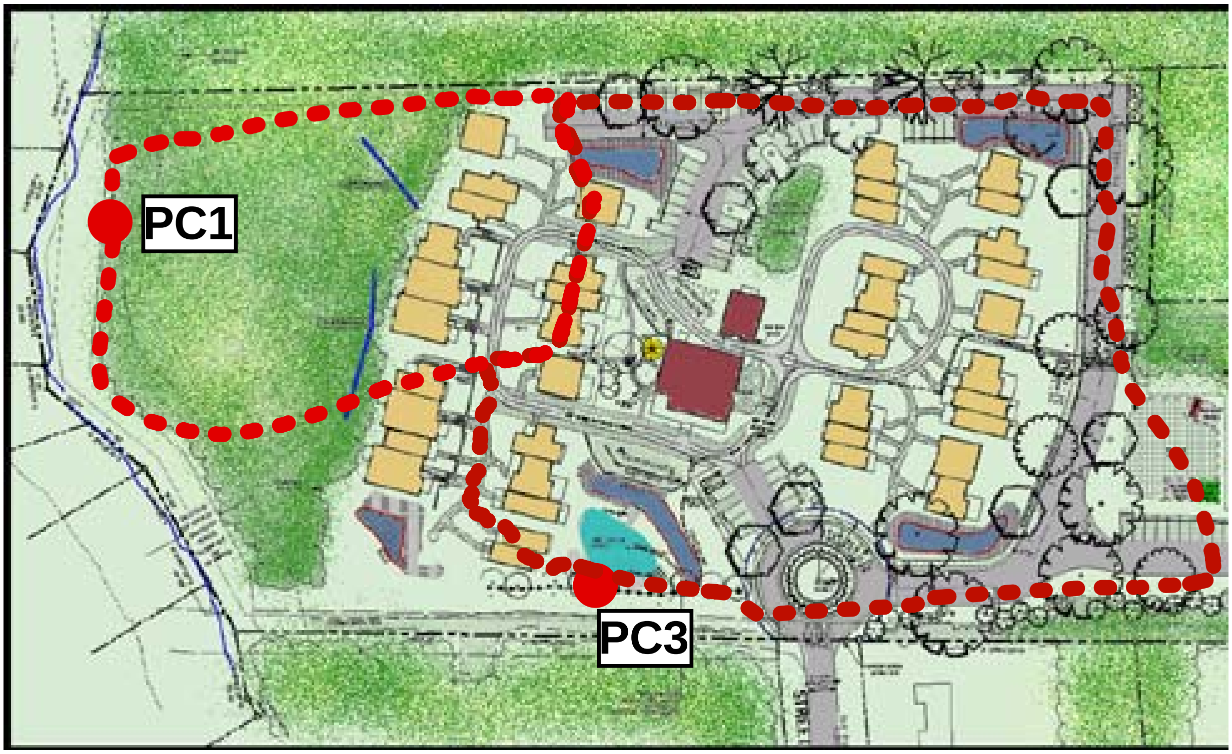

Figure 2. Map of drainage areas to monitoring stations post-construction.


Figure 3. Plywood diversion near the PC1 monitoring site.

Figure 4. Community garden cistern

Table 1. Methods of Sample Analysis.

Parameter	Method	MDL
TSS	2540D[1]	1 mg/L
TP	4500-P E[1]	0.01 mg/L
TKN	EPA 351.1	0.14 mg/L
NH_4-N	4500 NH_3 H[1]	0.007 mg/L
$NO_3 + NO_2$ (NO_x-N)	4500-NO_3-F[1]	0.006 mg/L
Turbidity	HACH 2100P	0.1 NTU

[1] Eaton et al., 1995.

Table 2. Monitoring Timeline and Drainage Areas.

Start Date	End Date	Stage	Drain Area	Cleared Area
			ac	ac
PC1				
3/15/03	3/31/04	Pre-construction	2.48	0
5/12/05	4/11/07	During construction	1.50	0.36
4/12/07	9/25/08	Post-construction	1.95	0.83
PC2				
5/12/05	11/30/06	During construction	3.65	3.65
PC3				
4/5/08	9/25/08	Post-construction	3.87	3.87

Table 3. Summary of Monitoring Results

Site	Dur	Rain	Runoff	TKN	NH_4-N	NOx-N	TN	TP	TSS
	yr	in/yr	in/yr	------------------------ kg/ha-yr ---------------------					
PC1									
Pre	1.04	46.6	2.29	0.18	0.05	0.01	0.19	0.02	3.13
During	1.92	38.2	5.26	1.89	1.07	0.21	2.10	0.53	3,540
Post	1.43	36.7	17.7	5.65	0.90	1.82	7.47	0.77	359
Post[1]									
PC2									
During	1.56	36.8	13.8	na	na	na	na	na	17,870
PC3									
Post	0.48	57.7	46.0	21.0	2.92	9.60	30.6	1.93	492
Carpenter Village									
Woods[2]	5.6	31.5	7.0	5.3	0.2	1.0	6.3	0.5	349
Built[2]	1.4	37.0	22.2	25.6	3.3	5.9	31.5	1.3	6170
Post[2]	3.5	27.8	15.2	16.2	1.7	1.8	18.0	1.7	1958

[1] Assumes all pollutants originate from 0.36 ac. developed area.
[2] From Line and White (2007).

Table 4. Summary of Sample Analysis Results.

Site	Large[1]	Samples	Turb	TKN	NH_4-N	NOx-N	TN	TP	TSS
	Storms		NTU	------------------------ mg/L ---------------------					
PC1									
Pre	11	3	7	0.30	0.08	0.01	0.32	0.04	5.3
During	27	20	2600	1.35	0.50	0.18	1.53	0.54	2820
Post	18	8	62	1.41	0.23	0.44	1.85	0.17	60.9
PC2									
During	22	36	3700	na	na	na	na	na	4220[2]
PC3									
Post	9	10	62.9	1.99	0.29	1.00	2.99	0.18	46

[1] Rainfall accumulation of greater than 25.4 mm.
[2] Samples with a very high turbidity were analyzed for TS instead of TSS.

Table 5. Rainfall Characteristics for Monitoring Periods.

Site	Duration	Mean Storm Rain	Median Storm Rain	Peak 30 Minute Intensity	Mean Storm Duration	Mean Storm Intensity	Number of Storms
	yr	in	in	in/hr	hr	in/hr	
PC1							
Pre	1.04	0.92	0.72	0.17	10.6	0.22	31
During	1.92	0.97	0.91	0.31	7.72	0.43	43
Post	1.43	0.95	0.88	0.37	8.50	0.31	40
PC3							
Post	0.48	1.04	0.89	0.44	4.57	0.40	24

Table 6. Input Data from the PC1 Drainage Area for the SET.

General Site Information

Project Information	
Company/Org:	NCSU Water Quality Group
Project:	Pacifica
Jurisdiction:	Carrboro
Scenario:	Forested Buffer-210ft with LS

Site Information	
Area (acres)	1.950
Average Site Slope (%) (Enter value or select from range)	○ (enter) ○ < 2% ○ 2% - 6% ◉ > 6%

Soil Hydrologic Groups (% of Site Area)	
Group A	
Group B	15.00%
Group C	85.00%
Group D	

Totals OK

Design Storm Selection

Peak Flow
☑ 1-year 24-hour
☑ 2-year 24-hour
☐ 10-year 24-hour

Runoff Volume (storm event)
☑ 1 inch storm
☐ 1-year 24-hour
☐ 2-year 24-hour

Runoff Volume (uniform depth)
☐ ½ inch

Pollutant Target Selection

Upper Neuse Nutrient Zone
○ Rural/Conservation Area
◉ Urban Residential
○ Urban Non-Residential

☐ 85% TSS Removal Requirement

Table 7. Monitoring and SET output for the PC1 Drainage Area.

	Area	Runoff	TN	TP	TSS
	ac	in/yr	lb/ac-yr	lb/ac-yr	ton/ac-yr
PC1					
pre	2.48	2.29	0.17	0.02	2.79
post	1.95	17.7	6.67	0.86	320
Increase (%)		673	3820	4200	11370
SET model					
pre	2.48	2.01	0.66	0.11	0.011
post	1.95	5.91	2.91	0.47	0.031
Increase (%)		194	341	327	182