North Carolina Section 319(h) NPS Program
Final Report

Project Title: Toisnot Creek Stormwater BMP Project

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DWQ Project Number: EW-02003
Contract date: 01AUG01 to 30JUN04

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Project Summary & Background on Toisnot Creek Watershed in Wilson

The Toisnot Creek is affected primarily by urban non-point source pollution. Runoff from heavily urbanized areas is a major contributor of sediment, chemicals, nutrients, and metals to our receiving streams and lakes. Toisnot Creek, part of the Contentnea Creek watershed, is affected by both agricultural and urban non-point source pollution. While agriculture is considered the largest contributor of nutrients to the Contentnea, Toisnot Creek owes much of its pollution to urban stormwater runoff from the city of Wilson. At the time of this grant there were several sediment and erosion control practices being tested in North Carolina, but much less demonstration and research was being done on stormwater practices designed primarily to reduce nutrients, including nitrogen, from leaving urbanized areas. One such practice that needed considerable attention was the bioretention area (also called the Rain Garden).

Bioretention filters have become one of the most popularly used stormwater Best Management Practices (BMPs) across the United States, particularly in the Washington, DC, metropolitan area. They are a favored urban stormwater BMP because of the dual role they play: 1. Water quality and 2. Landscaping. Bio-retention design at the time of the grant award, however, was still in its infancy. Filter designs based upon different land uses and target pollutants were – and still are – rarely performed. Most of these designs were simply educated guesswork. Very few, if any, bioretention designs targeted nitrogen, which is a principal pollutant in both the Neuse and Contentnea basins as well as the neighboring Tar-Pamlico Basin.

Eight different bioretention Best Management Practice (BMP) demonstration (four of which were outfitted for research) were installed in a typical commercial area (Eagle Farms Crossing Shopping Center) off Tarboro Street in Wilson. The bioretention areas were be designed differently, so that testing attempted to differentiate which drainage configuration was most successful at removing Nitrogen and Phosphorus. Only one type of media ended up being tested. The bioretention areas presented in this study were compared to other bioretention areas constructed in Greensboro and Chapel Hill where different fill media mixes were employed.

Elsewhere in the Toisnot Creek watershed two constructed stormwater wetlands were installed. One was partially funded (in conjunction with a grant from NCDOT) at the NC DOT Wilson County maintenance yard off Goldsboro Street. The second, a small pocket wetland, was installed at the Silver Lake Firehouse off Tarboro Street. Testing was conducted at the NCDOT stormwater wetland. These two wetlands were the first stormwater wetlands constructed in the Contentnea Creek watershed.

All three sites served as demonstration areas and were used to train scores of practicing engineers, architects, planners, and contractors by both North Carolina Cooperative Extension and the city of Wilson. One workshop and several field tours were conducted in Wilson highlighting the practices installed using these 319(h) grant funds. Additionally, because so much was learned regarding design and construction of the Eagle Farms bioretention cells, that part of this project has been highlighted as a case study at presentations across North Carolina and the Southeast. The Wilson Bioretention presentation (included in the Appendix) has been presented at over 10 workshops before an estimated 400 designers by Mr. Bill Lord. A series of 17 “lessons learned” is presented in this report.

Eagle Farms Bioretention Areas: Overview

A shopping center was constructed on a sandy clay loam soil (Norfolk-urban land complex). According to the Wilson County soil survey (Sink, 1983) the soil’s conductivity within the top 1.5 m (5 ft) of the surface was moderate, K= 0.0035 to 0.014 mm/sec (0.6 to 2.0 in/hr). Due to construction compaction, underdrains needed to be installed in the bioretention areas. The water table, as verified on site, was noted to range 1.2 to 1.8 m (4 to 6 ft) below the surface and was not perched. The water table according to an engineering analysis was low enough so that bioretention areas could have been sited above the seasonally high water table. By way of a relatively long line of culverts, the site drained into Toisnot Creek. The watershed was comprised primarily of a parking lot with a few pervious areas accounting for about 8% of the total watershed. The parking lot served Eagle Farm Crossing strip mall shopping complex totaling 3 ha (8 acres), approximately one-half of which flowed to the bioretention areas. The use of the parking lot was almost exclusively leisure-commercial, i.e. shopping, with very little truck traffic in the area draining to the bioretention areas. Eight bioretention areas were constructed in March and April 2002 along the edge of the parking lot (detailed construction sequencing highlighted later). Monitoring equipment was installed at four of the cells. One parameter was tested at the Eagle Farm site: change in drainage configuration. This drainage design was employed in four of the eight cells (and two of the four bioretention cells monitored) (as seen pictorially in Figure 1). Anaerobic configuration was created by putting an elbow in the underdrain pipe, forcing a saturated zone to form (Figure 2). The carbon amount within the bioretention soil was kept to approximately 10% by adding peat during construction.

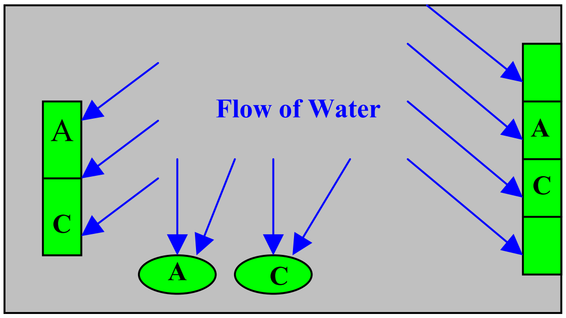

Figure 1. *Wilson, NC: Bioretention areas randomly paired (A=Anaerobic; C= Conventional Drainage Configuration)*

Figure 2*. An upturned elbow in the underdrain pipe created an anaerobic zone in two of the four bioretention cells tested in Wilson.*

Eagle Farms Bioretention: Construction Schedule
The construction schedule is summarized to highlight the difficulties experienced in installation and eventual monitoring this site. The adage that what looks good on paper (design-wise) is not always good in practice held true here. Because of the many difficulties experienced during the construction of the Eagle Farms bioretention areas, many lessons were learned about bioretention design and construction. These lessons have been passed on to hundreds of designers across the Southeast so that similar mistakes were not repeated. A "lessons learned" section follows after this one.

October 2000.

NCSU faculty including N.C. Cooperative Extension agents met with Mr. Fred Bunn, the land developer in Wilson, and Mr. Mike Tolson of Green Engineering in Wilson. An agreement was reached that bioretention devices would be installed and monitored on Mr. Bunn's property, Eagle Farms Crossing, a strip mall shopping center located off Nash Street in Wilson. All parties agreed that NCSU faculty would assist Green Engineering with the bioretention design and also came to an understanding of how the monitoring setup would change the appearance of the parking lot. Expected construction at that time was mid-late spring, 2001.

March 2001

NCSU faculty designed eight bioretention areas for Eagle Farm Crossing in Wilson. Four medians were designed to contain the eight bioretention areas. One median was designed with 4 bioretention cells, while a second median was divided into two bioretention cells. All 8 bioretention cells were planned to be tested. However, for reasons explained later, a total of 4 of these cells were initially able to be monitored. Four of the cells used the alternative drainage configuration and four sites employed an anaerobic design. Each cell had a soil layer approximately 2 feet deep.

April 2001.

NCSU faculty submitted the Wilson designs to Mr. Tolson. They were incorporated into the design plans by Green Engineering and submitted for approval to the City of Wilson. The project would be released for bidding later in spring 2001.

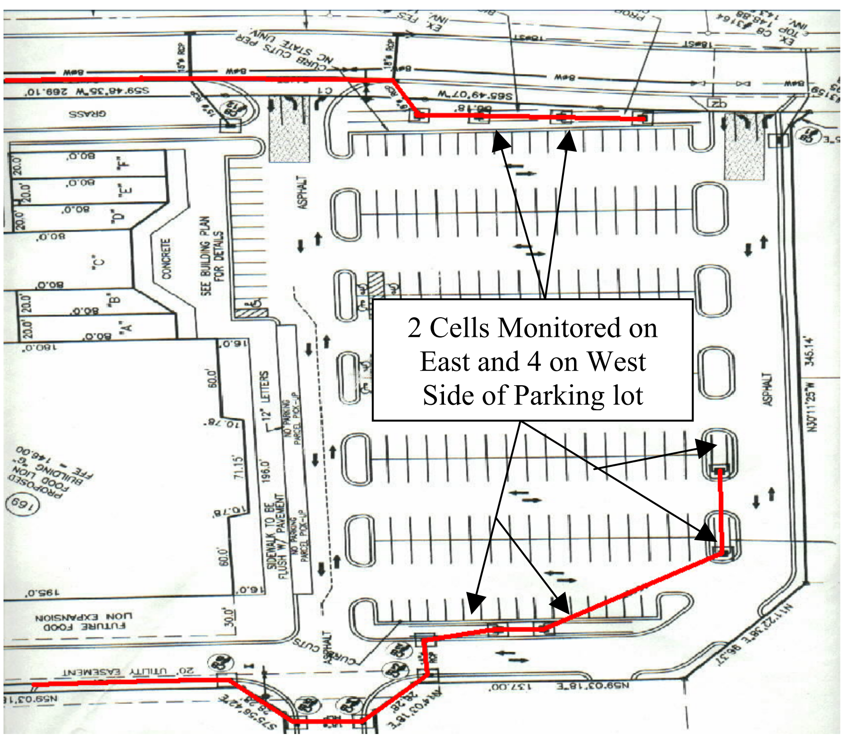

***Figure 3**. Diagram showing bioretention sites at Eagle Farms Crossing as shown on design plans of Green Engineering (2001). Six of the eight bioretention cells were monitored.*

August 2001.

Construction began on Eagle Farm Crossing in Wilson. The curb cuts, which allowed water to enter into the bioretention area, were scheduled to be poured at the end of August. It appeared that the Wilson bioretention cells would be completed in October, at which time monitoring equipment would have been installed. However, construction did not commence in earnest for several months.

October – November 2001

Sampling equipment was received on NC State campus. Wilson parking lot construction began again after a stall that was due to financial negotiations associated with the shopping center's construction.

Figure 4. *Bioretention construction in November and December in Wilson, NC. Pictured above are three phases from left to right: (1) installation of impermeable liner and drawdown pipes, (2) gravel drawdown layer with permeable geofabric about to be placed over it, and (3) fill soil being added to the device.*

December 2001

First phase of bioretention construction (through soil installation) was completed in Wilson (pictured above in Figure 4). Parking lot construction inexplicably stalls. The parking lot was not to be completed – and relatively stable – until March 2002. Rainfalls continued to transport sediment into the bioretention devices, causing them to clog, as seen in Figure 5.

Figure 5. *Sediment clogged the bioretention areas for long periods during the parking lot construction.*

January - February 2002

During winter rains in Wilson, the contractor knocked holes in the outlet structures to alleviate drainage problems. The parking lot was not draining, thus postponing construction. The contractor decided to use the bioretention cells and their outlet boxes to help drain the parking lot. Additionally, he trenched water from across the parking lot construction to the bioretention areas, thus increasing the sediment loading into the devices. In February, the holes in the outlets were noticed by NCSU faculty and the contractor attempted to repair the outlets. However, leaks persisted and would continue to for nearly a year.

March 2002

Wilson parking lot was finally completed, as seen in Figure 6. All bioretention cells were clogged. The top 75 mm (3 in) of soil were removed in an effort to unclog the cells. Site stabilization began. Sod was added to protect exposed banks. Vegetation including river birch (*Betula nigra*), dwarf yaupon (*Ilex vomitoria*), and Virginia sweetspire (*Itea virginica*) trees was planted in bioretention cells.

Figure 6. *Four of the cells on the eastern side of the Wilson Parking lot pictured immediately after construction. These were the same bioretention cells pictured in Fig. 5.*

April 2002

Wilson site received a windy storm, which blew over most of the river birch. Wilson inlets were damaged and necessary repairs were made. The site parking lot was surveyed and it was found that 1 cell received very little runoff, due to incorrect sloping of the pavement. Two cells in Wilson continued to be clogged due to unstable surrounding soil. The soil source is pictured in Figure 7. It was decided to (1) stall monitoring equipment installation until site defects were remedied and (2) only monitor 6 of the cells. This latter decision was due to a lack of runoff entering one of the cells, a result of a misstep in laying down the asphalt on the parking lot, thus eliminating the cell and its pair from monitoring consideration. The cell in particular that was eliminated from the monitoring regime was the southern-most on the east side, as shown in Figure 8.

A first attempt by NCSU staff to plug the leaks in outlets damaged by contractor was made.

Figure 7. Wilson site stability continued to be a problem due to drought and unexpected traffic.

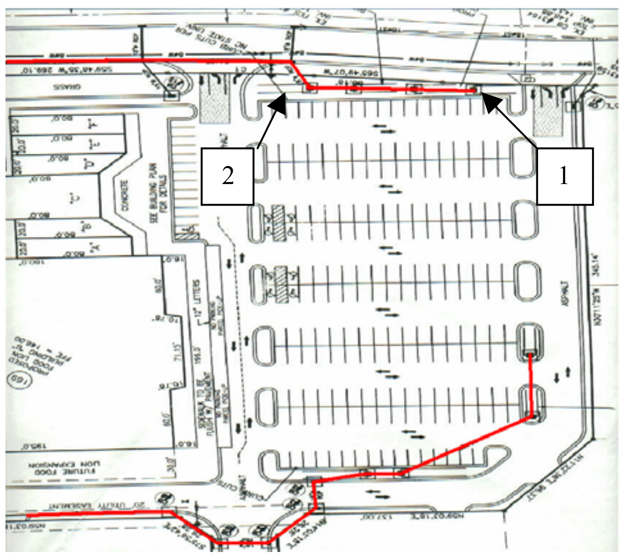

Figure 8. Two bioretention cells eliminated from monitoring plan. Cell #1 did not receive much runoff due to poor grading of asphalt. Cell #2 was eliminated to enable the two middle cells of the bioretention to serve as a match of anaerobic and conventional cells.

<u>May 2002</u>

Wilson site stabilization (seed and straw, hydroseeding) was begun by NCSU faculty and staff. This was repeated on a monthly basis through August 2002, with very little success due to continued disturbance and a drought.

<u>August - September 2002</u>

Wilson equipment installation was completed (Figure 9). After a lengthy drought, on August 24, over 200 mm (8 in) of rainfall fell onto the watershed in a 2-hour period. This caused massive localized flooding, particularly in the low-lying bioretention areas.

Many of the samplers floated and toppled over, allowing water to penetrate the display panel. Of the eight samplers, four were damaged and needed to be returned to the manufacturer. By the end of September, most of the Wilson automated samplers were ready again.

Figure 9. *Monitoring equipment including automatic samplers was installed in Wilson during Summer 2002.*

<u>October 2002</u>

The unstable and eroding areas of the parking lot began to stabilize (Figure 10). Ample rainfall in September accounted for this stabilization.

Figure 10. *The watershed remained unstable for several months. Sediment from the unstable areas found its way into two of the basins, as seen in the picture to the left. The entranceway was seeded and reseeded throughout the summer and fall of 2002. By November and December of 2002, the entranceway was deemed stable.*

<u>November 2002</u>

Two clogged bioretention cells were repaired by removing the top 150-300 mm (6-12 in) of the soil. The cells had mulch replaced by NCSU staff. City of Wilson crews assisted in the "declogging" of these two cells. It was deemed that this simple fix was preferable to replacing all the soil, gravel, and geofabric. It was later discovered that one of the cells needed to be completely reconstructed.

<u>January – February 2003</u>

Wilson outlets were outfitted with v-notch weirs to determine quantities of water leaving each of the bioretention cells. Initially, flow was to be measured at the end of each underdrain pipe. However, leaks continued to be observed after several attempts to seal the inlet boxes. It was decided to avoid attempting to measure flow from the underdrains and thus to measure at the outlet of each box in each cell. Three weirs were installed on each side of the bioretention devices (Figure 11). A final effort was taken to unclog the last bioretention device.

Figure 11. *Each of the inlets leaked, as evidence in the picture in the left hand side of the figure. Flow sensors installed in an outlet would not capture all the flow leaving the bioretention cells. V-notch weirs, as shown on the right hand side were installed to measure flow leaving each of the cells.*

<u>April 2003</u>

Samples finally successfully collected from the Wilson bioretention area. A second event was collected the following May. Sample collection continued through Spring 2004 from 4 of the cells.

Eagle Farms Bioretention Construction & Maintenance: Lessons Learned

As noted at the beginning of the prior section, many difficulties were faced and either overcome or dealt with during the installation of the bioretention areas at Eagle Farm Crossing Shopping Center. The lessons learned from this experience have yielded several new design and construction standards that are currently in use throughout North Carolina. It is perhaps in these lessons learned that the Toisnot Creek project has proven most successful.

1. We need to educate project engineers during design and installation phases about the theory and practice of bioretention.
2. We need to educate and supervise contractors about the theory and installation of bioretention.
3. We need to determine the depth to groundwater as a part of initial site evaluation and avoid shallow groundwater. Do not take this testing lightly, as higher than expected

water tables result in bioretention beds that are too shallow. Shallow media makes life difficult for taller trees and shrubs to survive high wind storm events.

4. We need to evaluate porosity and phosphorus index of any on-site potential bioretention bed fill soils. Overly tight or overly porous soils will impact pollutant removal and overall drainage efficiency.
5. Construction sequencing is critical to successful bioretention installation. Improper sequencing is the most likely cause of increased maintenance costs borne by the land owner *after* the contractor has left the site.
6. Parking lot grading is critical to properly apportion sub-watersheds to individual bioretention beds. Contractors tend to be too course in this fine grading. Unbalanced watersheds leading into bioretention areas make leave some bioretention cells undersized and others oversized, creating a very inefficient system.
7. Watershed stability is a critical part of bioretention installation and maintenance. Sedimentation will ruin bioretention cells. Out parcel and adjoining land stability must be maintained or extraordinary measures must be taken to prevent sediment from entering bioretention cells.
8. Asphalt parking lots generate substantial sediment loads.
9. Retrofitting or repairing bioretention cells is difficult, expensive, and time consuming. The amount of time spent retrofitting is nearly directly proportional to the amount of time the site was left exposed to disturbed portions of the watershed.
10. Three levels of bioretention bed repair were trialed at Eagle Farms due to sedimentation from out parcels:
    a. Partial cleanout with a small track hoe (surface skimming of sediment).
    b. Partial reconstruction (excavation of silted-in surface soil to filter fabric layer).
    c. Complete excavation and reconstruction including drop box reconstruction.
    d. Lesson learned: once sediment reaches the filter fabric in a bioretention bed the bed will need to be completely rebuilt.
11. Bioretention drop boxes should be waterproof, stable, and have good connections to bioretention underdrains.
12. Drop box grates should be cleaned of debris regularly, particularly after new mulch is installed.
13. Bioretention plant selection is limited in that few plants can survive in properly functioning bioretention beds. Successful plants include Virginia sweetspire (*Itea virginica*), inkberry (*Ilex glabra*), birches (*Betula sp.*), and maples (*Acer sp.*).
14. Most plants should be located just above the high water mark in beds on the sides of the beds or placed on mounds in the interior of the bed to insure aeration of roots during ponding phases. Very few desirable plants can handle the bottom of wet bioretention areas.
15. Trees should be staked during first year of bed life.
16. The most effective way to stabilize bioretention bed shoulders is to install sod a soon as possible after construction is complete.
17. Bioretention beds can be aesthetically pleasing and can be indistinguishable from standard landscape beds.

Eagle Crossing Bioretention Monitoring Data

Methods, Equipment and Protocol

Two tipping-bucket rain gauges (Global Water, RG600™), were installed in an area clear of interference within 30 m (100 ft) of the study sites Automated samplers (American Sigma 900™) were installed at the invert of each underdrain as it emptied into the drainage box. The inflow samplers (American Sigma900 Max™) were flow activated, but most outflow samplers simply took samples every 20 minutes if water were present.. Samples for outflow water quality were designed to be collected on a set time interval from non-flow-activated samplers, because flow through the soil was expected to be relatively constant. The inflow runoff was collected for water quality purposes at two cells (3 and 7). Two of the four cells were outfitted with equipment to sample inflow runoff. Not every cell had inflow captured because of financial and spatial constraints. The study did not have enough money to purchase samplers for every cell's inflow. Every cell in Wilson did not have enough elevation to install a v-notch weir to effectively measure overflow. Therefore only concentrations were compared among the cells and inflows – there was no mass comparison. It was assumed that the water entering the median at the sampling location would be characteristic of that across the entire bioretention watershed. Inflow samples were composited on a flow basis, which captured first flush and excess runoff. The total volume of water captured for each runoff event was dependent upon the event size. The sampler bottles stored up to 11.4 liters (3 gallons) of runoff.

The samples were collected within 24 to 36 hours of the event's completion. The additional time was budgeted for outflow from the bioretention area after the storm had completed. The samples were composited from the entire storm when the sample was collected by a Sigma 900Max™. The composite sample was collected in a 11.4-liter (3-gallon) glass container and was separated into specific plastic bottles segregated by pollutant type. These samples were taken to nearby laboratories. Samples were taken to either TriTest Laboratories in Raleigh, NC, or the NCSU Analytical Services Lab housed in the Soil Science Department in Raleigh, NC. Both labs were approximately minutes from Wilson. The sampling protocol differed from the state of North Carolina's stated procedure (NCDENR, 1998), which is based upon USEPA protocols, because no minimum period of dry weather was required before a sample was collected. For example, the state required a 72-hour period without rainfall for samples to officially meet their requirements. However, this study wanted to measure the impacts of antecedent rainfall on inflow and outflow quality from bioretention areas, so this guideline was not followed.

Water Quality Data

Four bioretention cells had 8 storm events collected from them (32 total). Two cells utilized the anaerobic configuration and the other two cells were of the conventional configuration. The cells were paired: one conventional configuration with one anaerobic configuration. The cell pairs were (a) 2 (anaerobic) and 3 (conventional) and (b) 7 (anaerobic) and 8 (conventional). There were not enough data to make any statistically valid statements. However, Figure 12 does show trends in the data. The mean concentration of TN and TP were similar when comparing inflow concentration to the concentrations found from the anaerobic cell outflow. However, outflow concentrations of TN and TP from the conventionally drained cells were somewhat higher than those of both the inflow and anaerobic outflow.

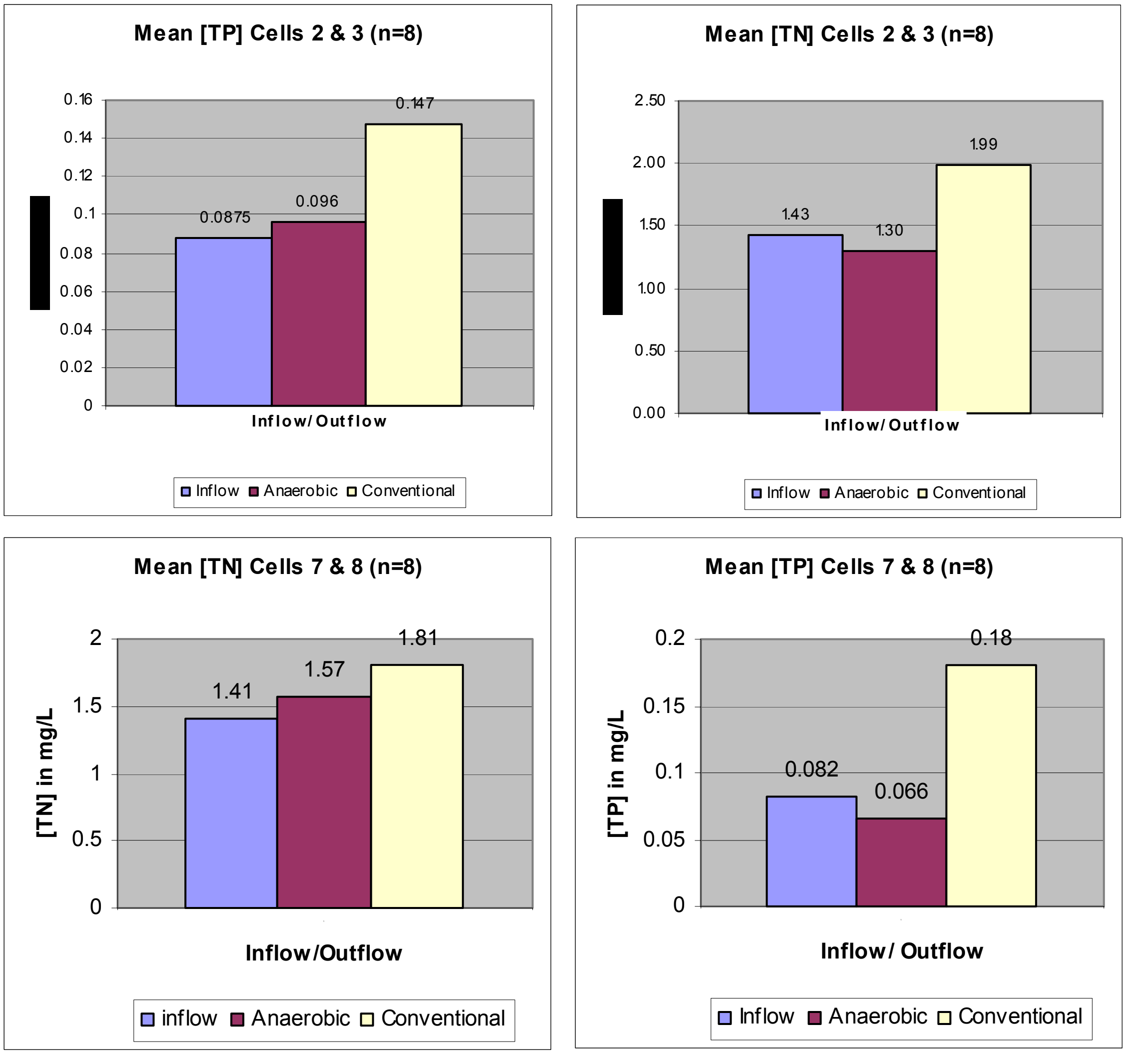

Figure 12. *Mean concentrations of TN and TP from four bioretention cells at the Eagle Farms Crossing Shopping Center in Wilson, NC.*

Potential explanations for these results follow. The purpose of the anaerobic configuration is to hold water inside the cell for a longer period of time, giving microbes a longer period to convert ammonia to nitrate and then nitrate to nitrogen gas. Because phosphorus is often sorbed to sediment, any system that captures sediment better would remove phosphorus better. The anaerobic configuration essentially creates a reservoir to store sediment and, therefore, the phosphorus that is sorbed to the sediment. This study was not, in itself, conclusive, but when coupled with another study conducted in Greensboro, it appears that the anaerobic configuration does make a difference in outflow concentrations.

Silver Lake VFD Wetland

The Silver Lake Volunteer Fire Department wanted to expand its fire station in 2001, giving an opportunity to install a retrofit stormwater BMP in the City of Wilson. The small, or pocket, stormwater wetland would be the first stormwater wetland on government property in the city. A request for assistance came to Bill Lord, Neuse Education Team member for Wilson County, by the fire department's consulting engineer, Ron Sutton of PLT Construction. Following a site visit, plans were drawn up for a small stormwater wetland to be installed to serve as a demonstration for the Toisnot Creek. A stormwater wetland was chosen for the site because of the site's high water table (no less than 18 inches from the surface). Because there was such a limited space for a BMP, conditions for constructing a wetland were "tight." However, the wetland was designed to serve such a small watershed (2 acres) that only a small space was needed on the lot for a BMP. The stormwater wetland was designed to both (1) control stormwater outflow, and (2) more importantly the need to reduce N and P concentrations of stormwater flowing through the site from a residential trailer park located just above the fire department. A small serpentine wetland was designed with baffles separating treatment cells. Plants installed include *Juncus sp*., *Carex sp*., *Sagittaria*, and *Pontederia cordata*. The wetland is approximately 600 sq. ft. in size, draining a 2 acre watershed, 15% of which is impervious surface. The wetland has acclimated to the site and is functioning very well. It has been used for a number of tours and stormwater demonstrations to illustrate the use of small stormwater wetlands. The wetland served a solely demonstration purpose as no data has been collected from this site. Figure 13 shows pictures of the stormwater wetland. The success of this small wetland helps dispel the belief that watersheds of at least 10-15 acres are needed for a stormwater wetland to succeed.

***Figure 13**. Spring Lake VFD Pocket Wetland. Left view is from the rear of the wetland in the winter. Right view is the front of the small wetland in early fall.*

Wilson DOT Stormwater Wetland

Some financial assistance from the Toisnot Creek 319 project (including design, construction supervision, vegetation purchase, and vegetation installation) went to the construction of a stormwater treatment wetland on NC DOT property. The Wilson County DOT Maintenance Yard (CMY) and treatment wetland are off Goldsboro Street, in the city of Wilson. The monitored drainage area averages about 325 ft in width and

600 ft in length encompassing about 4.5 acres. Surface slopes in the area are on the order of 1-4%. The upper half of the area is almost totally covered by impervious roof and road surfaces while the lower half is about half imperious asphalt and half gravel parking area and grass; hence, about 75% of the drainage area is impervious. The gravel parking lot normally has between 15 and 30 pickup trucks several dump trucks and other road working equipment. The drainage area is extensively used by trucks and other roadwork related equipment. This equipment enters the drainage area for maintenance in the garage. Before maintenance work begins, the equipment is pressure washed to remove accumulated road dirt. The pressure wash wastewater drains into and through the storm drain system to the treatment wetland via concrete and steel pipes. Stormwater runoff from roofs, gravel parking areas, and the asphalt driveways also drain through the storm drains and into the treatment wetland.

The treatment wetland was constructed in July and August, 2001 by widening a stormwater drainage ditch (figure 6) using DOT equipment and personnel and under Bill Hunt's (NCSU) design and construction guidance. Wetland vegetation was planted sometime after construction under the guidance of DOT personnel. In October, 2001, during visits to install monitoring equipment, observation indicated volunteer vegetation in the standing water areas of the wetland, but few viable wetland plants. The design submitted by NCSU recommended 500 Pickerel weed, 200 Arrow arum, 100 *Juncus effuses*, 20 open water lilies, and an assortment of other wetland plants. However, observation indicated that only 2-3 water lilies, several *Juncus* along one side, and some Arrow arum along the same side survived until October of 2002 (Figure 14). The scarcity of viable plants may have been the result of fewer plants than recommended actually being planted, planted vegetation was not hardy, an extended period of drought resulted in plant mortality, or plants were improperly planted or in the wrong location given the water depths.

Figure 14. *Stormwater Wetland at Wilson DOT CMY immediately after construction (left) and after two years of growth (right).*

The lack of viable plants likely made the wetland act more like a wet detention pond during the first 8 months of monitoring than a wetland because most stormwater could flow through the wetland with very little contact with vegetation. In order to improve this situation, on June 7, 2002 NCSU and DOT planted 50 water lilies, 200 Pickerel weed, 50 arrow arum, and several lotus plants in the wetland. The plants were concentrated in the shallower water, middle area of the wetland to maximize their chance of survival and their contact with water. Also, 4-5 clumps of *Juncus* were transplanted from the good stand along the one side of the wetland to the other side where few, if any, wetland plants were growing. Most plants lived and thrived, especially the Pickerel weed to the fall when monitoring restarted.

Description of Monitoring

A 3 ft sharp-crested, rectangular weir and associated wingwalls were installed in the channel about 75 ft downstream of the outlet of the storm drain system and 50 ft upstream of the wetland inlet. The weir was installed such that its crest was at least 3 inches above the bottom of the channel to insure ponding and relatively tranquil water just upstream of the weir and free flow of water over the weir. These two elements are essential for accurate measurement of discharge past the weir. A 120 degree v-notch weir was installed in the 3.8 ft wide flashboard riser outlet from the wetland. Here again the weir crest was 3-4 inches above the bottom of the outlet culvert to insure free flow of water away from the weir.

An automated sampler with an integrated flowmeter was installed at each weir. The flowmeter used the bubbler method to continuously measure water depth at a point approximately 1-2 ft upstream of the weir crest. Water depth was measured upstream to avoid measuring in the drawdown of the weir. The flowmeter measured depth of water over the weir and continuously converted the depth to discharge using the standard equation for each weir. A stainless steel strainer was connected to the end of the sampler intake tube and mounted vertically to a wooden stake such that 2-3 inches of the strainer was above the water level and 1-2 inches was below. The vertical orientation of the strainer facilitated vertical integration of sample collection, which is very important where oil and grease and other floating contaminants may be present in the runoff.

Rainfall amounts were continuously recorded via an 8-inch tipping bucket recording rain gage. A 4-inch plastic non-recording rain gage was also installed at the sites within 3 ft of the recording rain gage. When a sufficient amount of rainfall (usually >1 in.) was collected in the non-recording rain gage, the rainfall water was transferred into a laboratory container and shipped with the runoff sample for analysis of nitrogen species. Costs for monitoring design, sample collection, and sample analyses were borne by NC DOT and another grant received by NCSU from NC DOT under the direction of Dan Line. Bill Hunt served as a co-PI.

Monitoring Results

Summary statistics for monitoring data from 12 of the 13 storm events are shown in Table 1. Only 12 were used in the statistical analyses because the 12/10/01 event was excluded due to low temperature conditions altering the operation of the sampler. The table also contains the efficiency of the wetland at reducing levels or concentrations (column 7) and loads (column 8) of incoming contaminants. Efficiency was computed by subtracting the outflow concentration or load from the inflow and then dividing by the inflow concentration or load. Since the concentrations are flow-proportional, the difference between concentration and load efficiencies then is simply a factor of the differences in runoff volume. For example, if inflow runoff equaled outflow runoff, then the concentration reduction efficiency would be equal to the load reduction efficiency.

The range and average of the 12 individual storm event reduction efficiencies for concentrations and loads are shown in Table 6. The storm of December 10, 2001 was omitted from the efficiency analysis due to uncertainties regarding the proper operation of the sampling equipment (possibly due to icing). Inflow and outflow concentrations and loads for individual storm events were compared using a paired t-test. This statistical test was used because it compares paired data, which reduces the effect of storm to storm variability.

Table 1. Summary Statistics for Reduction Efficiency of the Wilson DOT Wetland.

Parameter		Concentration			Loads		
		Range	Mean		Range	Mean	rf<1.0
		%	%		%	%	
Peak flow		-50 to 64	8				
Runoff/discharge		-117 to 17	-37[a]		-	-	-
pH		-48 to 7	-4		-	-	-
Turbidity		-52 to 76	13		-	-	-
Metals							
Cadmium		ND	ND		ND	ND	-
Chromium		-140 to 69	-2		-200 to 76	-23	-
Copper		ND	ND		ND	ND	-
Lead		3 to 71	42[a]		-38 to 81	20[a]	40
Nickel		ND	ND		ND	ND	-
Zinc		-24 to 47	19[a]		-108 to 65	-12	25
Inorganic Non Metals							
Chloride		-1200 to 53	-549[a]		-1886 to 46	-385[a]	-558
Nitrogen, Ammonia		-80 to 85	28		-106 to 90	22	26
Nitrogen, Nitrate+Nitrite		-660 to 82	-79		-772 to 81	-34	-154
Nitrogen, TKN		-84 to 68	-22		-222 to 64	-52	-18
Nitrogen, Total		-103 to 62	-16		-186 to 56	-52	-6
Phosphorus, Dissolved		-400 to 96	-30		-608 to 95	24	-39
Phosphorus, Total		-136 to 95	-13		-413 to 94	11	-4
Residue, Suspended		-74 to 83	47[a]		-117 to 78	22	57
Residue,Total		-78 to 71	-6		-252 to 49	-29	12
Aggregate Organics							
COD		-69 to 68	0		-264 to 64	-26	3
Oil and Grease		-180 to 91	21		-293 to 89	54	ND
Surfactant		-100 to 80	-24		-262 to 77	-27	-22
Semi-Volatile Organics							
Bis(2-ethylhexyl) Phthalate		-380 to 88	19[a]		-574 to 82	37	-47

* indicates statistical significance at the 0.05 level.

Although variable between storms, overall average peak flow rates for storm events decreased by 8% as a result of the wetland (Table 1). However, during the last 3 events, peak flow rates for outflow were 67% greater than inflow, which may have been caused by runoff water from the lower part of the drainage area bypassing the inflow monitoring station as described above. Outflow discharge volumes from the wetland were generally greater than inflow as shown by the -37% mean reduction. The increase was found to be statistically significant at the 0.05 level using a paired t test. The pH of and outflow was

4% greater than inflow, while the turbidity of outflow was 13% less than inflow on average. Neither of the differences was significant.

Stormwater BMP Workshops & Tours

One workshop and four BMP training tours were held during the grant period in Wilson highlighting the three stormwater BMPs described previously.

A stormwater BMP Academy was held in Wilson in March 2003 at the County Agricultural Center. Twenty-five engineers, land surveyors, architects, planners, and other members of the development community attended the one day workshop. The workshop included a case study presentation (attached as Appendix) on the Eagle Farms Bioretention area. Six Professional Development Hours (PDH's) were awarded to Professional Engineers (PE's) and Professional Land Surveyors (PLS's) who attended.

Two Upper Coastal Plain Stormwater BMP Tours were held during the life of the grant. The first was in September 2001 and the second was in March 2003. Four PDH's were awarded to PE's and PLS's for each. Eighteen and sixteen professionals attended each respective tour. In addition to visiting the sites above (please note that the 2001 tour visited only the Eagle Farms site as the BMP was not yet constructed), the tour itinerary also included stops at a Wilson CVS pharmacy sand filter, and sites in Smithfield and Goldsboro. These two tours are highlighted in Figure 15.

An NCSU BAE graduate student and staff tour was conducted which highlighted the stormwater practices in Wilson in August 2003. A total of 9 students and staff participated.

An NC Cooperative Extension Stormwater BMP field tour was held in September 2003 where all the Wilson BMPS were examined by a team of 8 NC Cooperative Extension agents and faculty. No continuing education credits were awarded.

Figure 15*. Tour participants at the CVS Pharmacy StormFilter™ site in Wilson in September 2001 (left), and two participants of the March 2003 tour examining plant survival at the Eagle Farms Crossing bioretention areas (right).*