CITY of CHARLOTTE
Pilot BMP Monitoring Program

Pierson Pond
Final Monitoring Report

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Purpose

The purpose of this report is to document monitoring and data analysis activities undertaken by the City of Charlotte, NC and NC State University to determine the effectiveness and stormwater treatment capabilities of the Pierson Wet Pond.

Introduction

Small ponds are a common feature in urbanized areas, and may exist for a number of reasons. These systems can be rural ponds which were left during development of nearby areas, or newly constructed ponds which serve as water features. Where stormwater regulations are implemented, ponds are often used to remediate the impact of newly constructed imperious area. Previous studies have shown that wet ponds constructed for pollutant removal effectively remove pollutants in both particulate and soluble forms (Schueler, 1987). In North Carolina, properly designed wet ponds are an accepted BMP for the removal of total suspended solids (TSS), total nitrogen (TN), and total phosphorous (TP). NCDENR gives wet ponds credit for 85% TSS removal, 25% TN removal, and 40% TP removal (NCDENR, 2006). The primary pollutant removal mechanism for ponds is settling and adherence of pollutants to pond sediments.

Small urban ponds have promise as stormwater BMP retrofit sites. Many improvements can be made to a pond which may result in increased pollutant removal efficiency. The addition of forebays, littoral shelves, and detention may enhance several mechanisms of pollutant removal. Such features are well accepted design components, and are commonly used in recently developed BMPs such as wetlands and extended wet detention (wet ponds).

Site Description

Pierson Pond is located in a neighborhood of single family residences in Charlotte, North Carolina. While no records were available to indicate the age of

the pond, it is likely at least 50 – 70 years old and was likely constructed for agricultural, recreational, or aesthetic purposes. The pond is fed by a small, blue-line stream which exhibits the typical characteristics of a degraded, urban stream. The watershed draining into Pierson Pond consists of approximately 120 acres of mixed commercial and residential development, with the majority of the watershed containing single family residences on approximately ¼ to ½ acre lots.

The pond is less than 1 acre in size (0.8% of the watershed) and has no detention component. It is estimated from the local topography that the pond depth does not exceed 8 feet and the average depth is likely to be 3-6 feet. The pond banks are stable (not excessively eroding), having been improved by a pond retrofit by the City of Charlotte in the late 1990's. During the pond improvement activities, the pond outlet was enhanced and a littoral shelf was constructed at the water/bank interface; however, the shelf was not planted with vegetation. The area immediately surrounding the pond consists primarily of hardwood and coniferous trees and shrubs. Resident waterfowl, such as mallard ducks and Canadian geese, are usually observed on the pond during site visits. No emergent aquatic vegetation was observed on the littoral shelf during the monitoring period. It is suspected that poor soil conditions, water depth, and waterfowl browsing have limited the growth of aquatic plants on the littoral shelf.

Monitoring Plan and Data Analysis

The inlet to the pond consisted of two 48-inch reinforced concrete pipes. The inlet pipes are partially submerged during normal (non-storm event) conditions. A rip-rap apron downstream of the culverts provides erosion control. As a result of the dual-pipe inlet configuration, measurement of inflow rate by direct means was not practical. The outlet of the pond is a large riser-barrel system. The pond effluent spills over the weir-like riser trash rack before flowing into a 72- inch diameter, reinforced, concrete pipe barrel. This single barrel (culvert) provided the only suitable location to measure flow rates.

An ISCO low profile, area velocity meter (ISCO 750 module) was utilized in combination with an ISCO Avalanche portable refrigerated sampler to collect flow weighted composite samples at the outlet barrel (Figure 1). An ISCO tipping bucket rain gage was installed near the pond outlet to provide rainfall records for all monitoring events. As a result of the flow-through nature of the pond (no detention built into the riser system) the inflow rate is assumed to be nearly equal to the outflow rate. To utilize automatic sampling techniques at the inlet sampling location, a wireless communication system (developed by CCU, Inc.) was utilized which triggered the inlet sampler to collect an aliquot each time the outlet sampler collected a sample aliquot (Figure 2). In this manner, inflow and outflow flow paced composite samples were collected. For monitoring protocol, see Appendix B.

Figure 1: Area velocity meter installed in culvert

Figure 2: Wireless communication system

Monitoring efforts were initiated in March 2004. The data in this report was collected until June 2005, with 17 storm events being at least partially collected / measured. However, due to sample collection failures, inflow and outflow composite samples were collected for only 16 of these storms. Additional manual grab samples, from which levels of fecal coliform, E. coli, and oil & grease were measured, were collected for 11 of the 17 storm events.

Average inflow and outflow event mean concentration (EMC) values for each pollutant were used to calculate a BMP efficiency ratio (ER):

$$ER = (EMC_{inflow} - EMC_{outflow}) / EMC_{inflow}$$

where EMC_{inflow} and $EMC_{outflow}$ represent the mean BMP inflow and outflow EMCs across all storm events. Removal rates were also calculated on a storm-by-storm basis. Some authors have suggested that reporting BMP effectiveness in terms of percent removal may not give a completely accurate picture of BMP performance in some situations (Urbonas, 2000; Winer, 2000; Strecker et al., 2001; US EPA, 2002). For example, if the influent concentration of a pollutant is extremely low, removal efficiencies will tend to be low due to the existence of an "irreducible concentration", lower than which no BMP can achieve (Schueler, 1996). For these relatively "clean" storms, low removal efficiencies may lead to the erroneous conclusion that the BMP is performing poorly, when in fact pollutant targets may be achieved. Caution should be used when interpreting BMP efficiency results that rely on a measure of percent or proportion of a pollutant removed. Therefore, we reported not only removal efficiencies, but also effluent "quality" for major pollutants, i.e. the concentration of pollutants in BMP outflow.

Water quality data was compiled so paired events could be analyzed for significant changes in water quality from the inlet to the outlet. A student's t test is frequently used to test for statistical significance; however, this test relies on the assumption that the data set being analyzed is normally distributed. For data sets which contain less than 25 samples, it is difficult to determine how the data are distributed. Nevertheless, the data were checked for normality using the Kolmogorov-Smirnov (K-S) test. If the raw data set was not normally distributed, a log transform of the set was performed, and it was once again tested for normality. In the case that the K-S test showed normal distribution for both the raw and log-transformed data, the log transform data were chosen for analysis.

Fortunately, there are tests that can show statistical significance regardless of distribution. A Wilcoxian Signed Rank (WSR) test is one example of a non-parametric statistical procedure (can show significance regardless of the distribution of a data set). This procedure was performed in addition to the

Student's t test for all parameters. In the case that neither the raw data nor the log-transformed data could be verified as having a normal distribution, the outcome of the WSR was considered the only measure of statistical significance. If a particular data set had conflicting statistical results (Student's t test and WSR had two different results) the WSR was assumed correct. It should be noted that for the Pierson Pond data set, both procedures returned the same conclusions with respect to statistical significance. See Appendix A – Table A1.

Data Analysis Results

Flow Results

As stated previously, the inlet configuration of Pierson Pond did not allow accurate measuring of flow entering the pond. However, the design of the pond resulted in little to no ponding during rain events; thus, the effluent flow volume is assumed to be a reasonable estimation of the influent flow volume. Figure 3 shows the effluent volume from Pierson Pond during a selection of storms.
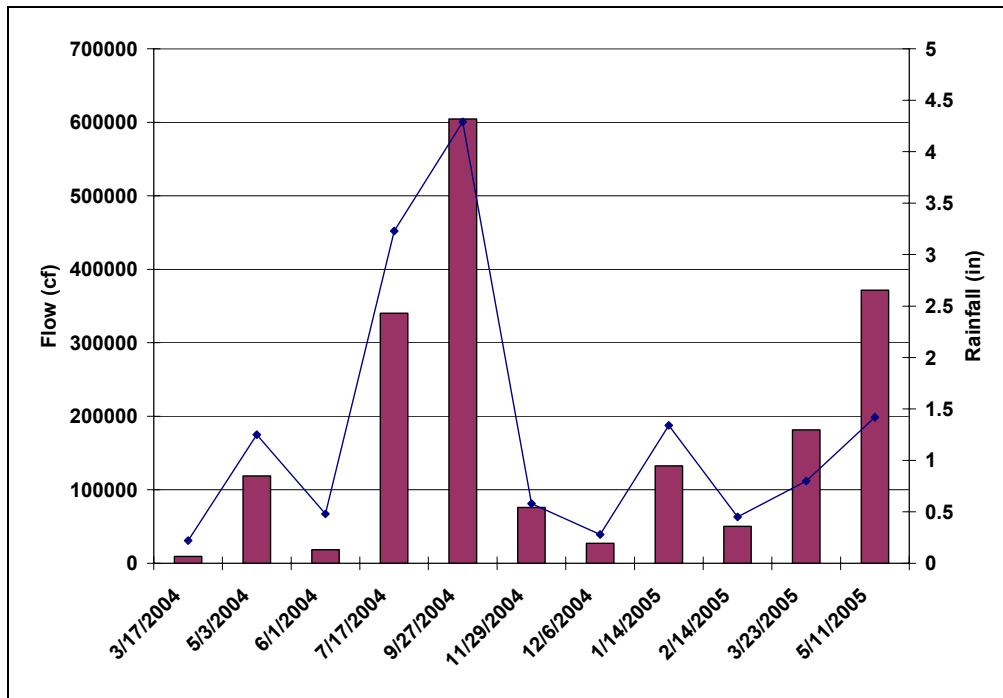

Figure 3: Rainfall – effluent volume relationship for Pierson Pond

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The area velocity meter used to calculate effluent flow had questionable accuracy in some instances; this judgment is based on the rainfall – flow relationship that is evident in this graph. Some storm events were removed from this graph due to missing or errant data. Nonetheless, flow data was sufficient to use for flow weighted sampling. An example of effluent flow data from an event on 7/17/2004 (3.23 inches) is shown in Figure 4, the data gathered from this event resulted in a well-formed hydrograph.
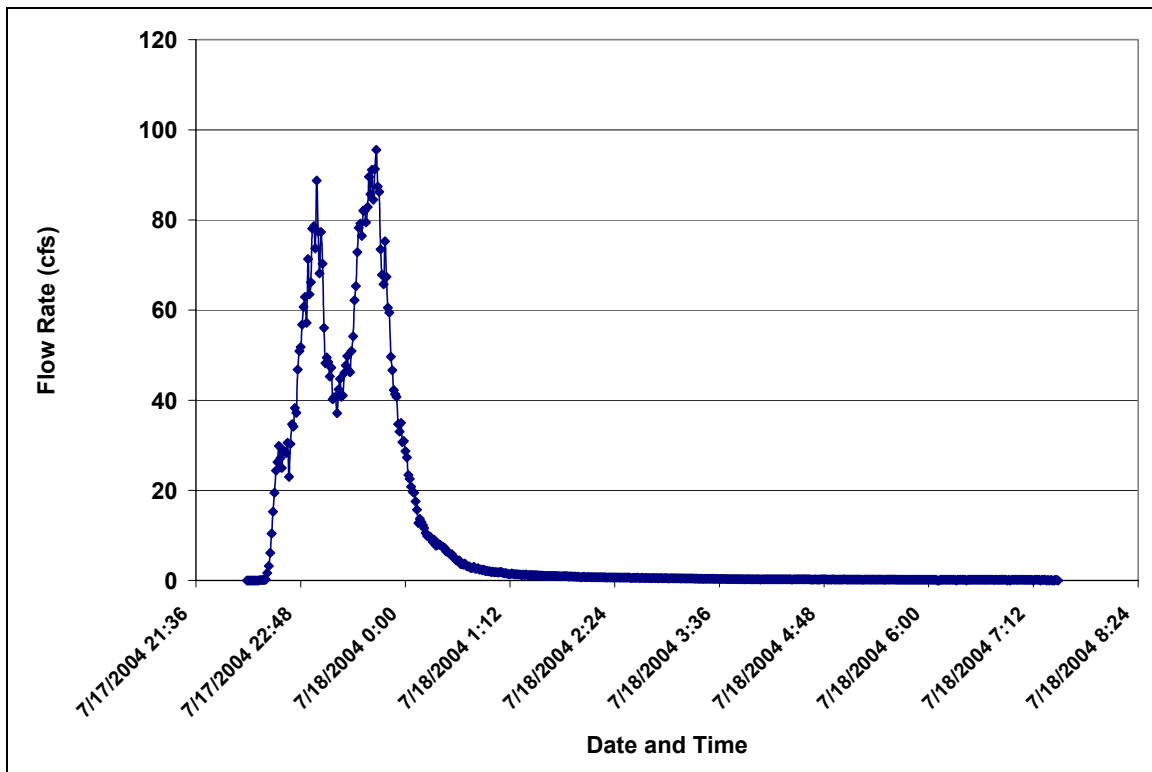

Figure 4: Example of effluent flow data – 7/17/2004

Water Quality Results

The water quality analyses herein are based on storms monitored between March 2004 and June 2005. It is assumed that in most cases the inflow to the pond was equal to the outflow. Thus, estimates of concentration reductions

(efficiency ratios) are assumed to be reasonable estimates of pond function. Mass reduction calculations are not necessary if the pond inflow is essentially similar to the outflow.

Figure 5 and Table 1 illustrate the performance of Pierson Pond with regard to pollutant removal. The pollutant removal efficiency is described by the efficiency ratio (ER) which is discussed above. A positive ER indicates that the pollutant, which entered the pond as stormwater runoff, was retained by the pond. A negative ER represents a surplus of pollutant leaving the BMP, suggesting either internal production of nutrients within the pond, or loss of stored pollutant from previous storm events.
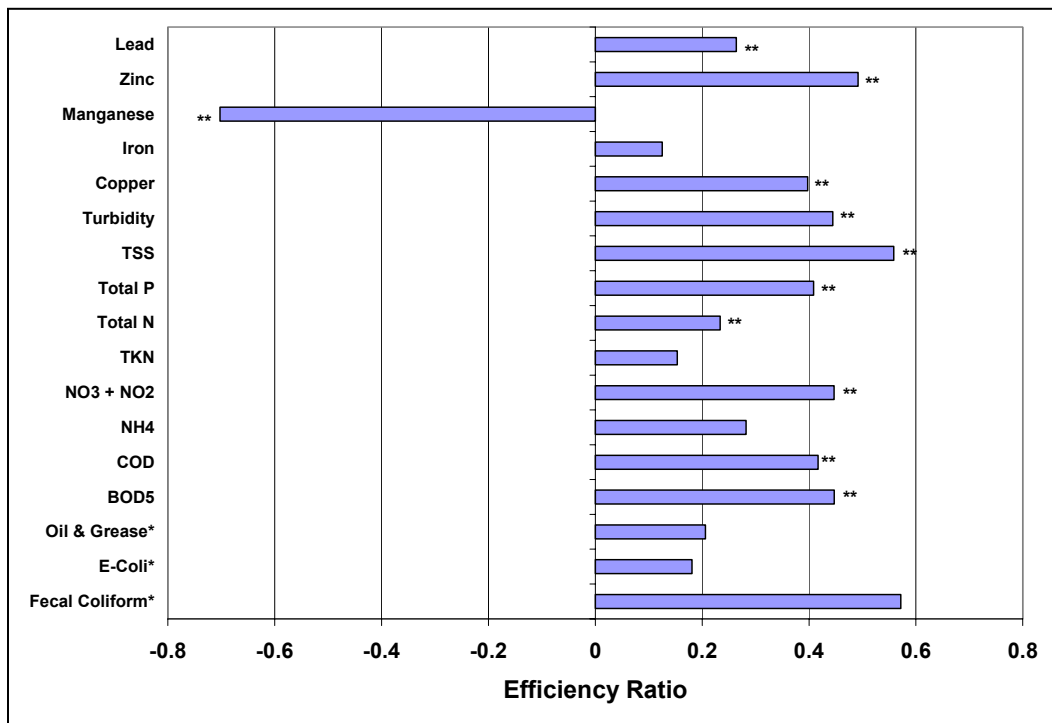

Figure 5: Efficiency ratios of selected pollutants based on inflow and outflow mean concentrations (EMCs) at Pierson Pond.

Efficiency ratio (ER) = (EMC$_{inflow}$ - EMC$_{outflow}$) / EMC$_{inflow}$

* = Grab samples collected to analyze for this pollutant
** = Indicates statistically significant relationship

Table 1: Summary of Water Quality Results

Parameter	Units	# of Samples	Influent EMC	Effluent EMC	ER	p-value	Significant (p < 0.05)
BOD	ppm	15	9.2	5.1	45%	0.0166	yes
COD	ppm	15	41.2	24.0	42%	0.0005	yes
Fecal	col. / 100 ml	11	24609.1	10545.5	57%	0.2402	no
NH_4	ppm	15	0.3	0.2	28%	0.0906	no
NOx	ppm	15	0.6	0.3	45%	<0.0001	yes
TKN	ppm	15	1.8	1.5	15%	0.104	no
TN	ppm	15	2.4	1.9	23%	0.002	yes
TP	ppm	15	0.3	0.2	41%	0.002	yes
TSS	ppm	15	127.0	56.1	56%	0.0009	yes
Turbidity	NTU	15	110.9	61.6	44%	0.0007	yes
Copper	ppb	15	13.5	8.1	40%	0.0002	yes
Iron	ppb	15	4861.9	4254.1	13%	0.2239	no
Manganese	ppb	15	175.7	299.1	-70%	0.0012	yes
Zinc	ppb	15	80.3	40.8	49%	0.0009	yes
Lead	ppb	14	9.0	6.6	26%	0.0313	yes

The only negative ER that was calculated was for manganese, which exhibited a statistically significant (p<0.05) increase. This indicates that the pond was not a source for any pollutants other than manganese. Overall, the performance of this pond from a water quality stand point was promising. Reductions in nutrients, sediment, and metals were all calculated.

According to statistical tests, Pierson Pond significantly (p<0.05) reduced the following pollutants in stormwater runoff: lead, zinc, copper, turbidity, TSS, TP, TN, NO_x-N, BOD_5, COD (Figure 5 and Table 1). With the exception of NO_x-N, all of these pollutants tend to be associated with particulate matter, suggesting that settling/sedimentation is a dominant mechanism of pollutant removal in Pierson Pond. This makes sense as vegetative uptake from this pond is likely limited due to the small amount of vegetative cover. When detention time is adequate (≥2 days), BMPs that slow water flow and promote settling, such as ponds, can be effective at removing these types of pollutants (ITRC, 2003).

Sediment

The ER for TSS removal in Pierson Pond was 0.56. This indicates that a substantial amount of treatment for TSS is occurring in the pond, likely through

sedimentation and filtration. This is likely related to the high ERs noted for other sediment-borne pollutants that were analyzed (Vaze and Chiew, 2004; Hipsey, et al., 2006). Although state regulations require wet detention ponds to achieve 85% TSS removal, this is unlikely for ponds sited in clayey watersheds. Small particles are not easily removed from the flow stream. An ER of 0.56 indicates that Pierson Pond is efficiently removing this pollutant from the flow stream. See Appendix A – Figure A1 for additional TSS data.

Turbidity reduction was somewhat lower than TSS (ER = 0.44). Burton and Pitt (2002) suggest that turbidity is associated with smaller particles than TSS. Smaller particles are harder to remove from a flow stream, as the energy required to carry such a particle is low. It is reasonable that the BMP would facilitate removal of large particles with more efficiency than it would reduce turbidity.

Table 2 shows the pollutant removal percentages reported by various studies performed on wet ponds. Pierson Pond falls within the range of TSS removal reported by the studies; however, the range of TSS removal that has been reported is large. Pierson Pond removes less TSS than was recorded by most of the studies; however, the soil characteristics of these watersheds are unknown. The two wet ponds represented in Table 2 that are sited in the Piedmont of North Carolina (Schueler, 2000 - Article 76) show results close to or lower than the results reported for Pierson Pond. The Davis wet pond TSS removal efficiency is reported at 60%, while the Piedmont wet pond TSS removal efficiency is reported as 20%. The soil conditions present at these two ponds is more likely analogous to those present at Pierson Pond. It should also be noted that the effluent TSS concentration reported by Winer, 2000, (Table 3) for wet ponds in the National Pollutant Removal Performance Database is also lower than that reported for Pierson Pond, further indicating that the pond functions slightly below other stormwater wet ponds that have been monitored. However, many of the ponds included in Winer (2000) were specifically designed to treat stormwater runoff, but Pierson Pond was not.

Table 2: Comparison of Removal Efficiencies for Various Wet Ponds (%)

Parameter	Pierson Pond	Winer - CWP, 2000	Schueler, 2000			
			Article 74 St. Elmo	Article 74 LCRA Office	Article 76 Davis	Article 76 Piedmont
BOD$_5$	45	--	61	--	--	--
COD	42	--	50	--	--	--
NH$_4$	28	--	91	--	--	--
NO$_x$	45	43	40	85	18	66
TKN	15	--	57	52	--	--
Total N (TN)	23	33	50	55	16	30
Total P (TP)	41	51	87	52	46	40
TSS	56	80	93	83	60	20
Copper	40	57	58	--	15	--
Zinc	49	66	27	86	39	--
Lead	26	--	39	90	51	--

Table 3: Comparison of Median Effluent Concentration for Various Wet Ponds (mg/L)

Parameter	Pierson Pond	Winer - CWP, 2000
NOx	0.3	0.26
Total N (TN)	1.32	1.3
Total P (TP)	0.14	0.11
TSS	27	17
Copper *	4.6	5
Zinc *	28	30

* Values are in units of μg/L

Nutrients and Organic Material

The removal rates for major nutrient pollutants and oxygen demanding material (organic carbon) were reasonable compared to those found by others (Table 2). Besides particulate settling, other processes are known to contribute to the high removal of these pollutants.

Oxygen Demand:

Biological oxygen demand (BOD$_5$) and COD are typical measurements of the amount of organic matter in stormwater runoff. Any process that contributes to the decomposition of organic matter will cause a reduction of BOD$_5$ and COD. Physically, this can occur by adsorption onto particles and subsequent filtration and sedimentation. Microbial decomposition of organic

material can also significantly reduce levels of BOD_5 and COD through respiration and the reduction of elements such as nitrate and iron. Removal efficiencies in Pierson Pond were only slightly lower than those that have been reported at one site in Table 2 (45% and 42% for BOD_5 and COD, respectively).

Nitrogen:

Soluble pollutants are removed by chemical adsorption to suspended particles followed by sedimentation of those particles, and by plant uptake and microbial transformations. The major removal mechanism of the various forms of nitrogen present in a natural system is bacterial transformation. All nitrogen species can be incorporated into biomass, where they are stored, through various biochemical reactions, such as mineralization by microbes in the case of organic N, as well as uptake of NH_4 and NO_3 by plants and microbes. During anoxic periods or in anoxic micro sites, nitrate (NO_3) can be reduced to gaseous nitrogen (denitrification) and removed from the system by the action of denitrifying microbes. Removal rates of inorganic nitrogen species (NO_x) were above 45%, consistent with other studies represented in Table 2. Removal of NH_4 was approximately 28%, very low compared to the other study in Table 2 that presented a NH_4 removal efficiency. Due to the dearth of data for this nitrogen species, a removal of only 28% is not concerning. Removal of TKN was 15%, considerably less than other values reported in Table 2. Lastly, TN removal was approximately 23%, slightly lower than that reported by other studies. The median effluent concentrations of TN and NOx calculated for Pierson Pond, are very close to those reported in Table 3.

Because TKN and TN both include measurements of organic nitrogen, and because each of the species showed low removal efficiency, it is possible that inputs from waterfowl are contributing to the poor nitrogen removal in this system. The N.C. Stormwater BMP manual (2006) gives only 25% TN removal credit to wet ponds, which is consistent with the removal observed in Pierson Pond. See Appendix A – Figure A2 for additional TN data.

Phosphorous:

Total phosphorous removal by Pierson Pond was 41%. This was well within the expected range based on the studies presented in Table 2. Likewise, the median effluent concentrations of TP leaving Pierson pond are similar to those reported in Table 3. The reduction of TP that occurs within natural systems is not entirely biologically-mediated, like nitrogen, and is mostly due to abiotic factors. Adsorption onto iron-oxide and aluminum-oxide surfaces and complexation with organic acids accounts for a large portion of phosphorus removal from the water column. Through sedimentation of these particles, phosphorus can accumulate in pond sediments. This phosphorus is not technically removed from the system, but rather is stored at the bottom of the system. This accumulation can result in a reduced rate of phosphorous removal over time, as sediments become phosphorous laden.   Potential release of this stored phosphorus can occur under specific conditions. Due to the phosphorous accumulation that can occur in sediment over time, it is interesting that the TP removal continues to be relatively high in Pierson despite its advanced age. Sedimentation of influent particles is apparently a major mechanism of pollutant removal in the system.

Several other minor removal mechanisms exist for TP as well. When phosphorus is present in dissolved forms, it can be taken up by algae and plants. In addition, organic forms of P can be decomposed and used by microbial biomass, although phosphorus assimilation does not occur to the same degree as nitrogen assimilation. Less important are precipitation reactions with metals that may take dissolved P out of solution. See Appendix A – Figure A3 for additional TP data.

Pathogens and Hydrocarbons

Pierson Pond removed fecal coliform relatively well, with an efficiency of 57%. E. Coli removal in Pierson Pond was substantially less, a removal rate of 18%. The same pattern of lower E. Coli removal than fecal coliform removal was noted in reports from NCSU-BAE to the City of Charlotte for Edward's Branch stormwater wetland and Bruns Ave. stormwater wetland. It should be noted that

there was very high variability in pathogen removal from storm to storm. The pollutant removal was not found to be statistically significant. Effluent concentrations of fecal coliform were only less than the State standard of 200 cfu/100 ml for one event out of 11 (US EPA, 2003). See Appendix A – Figures A4 – A5 for additional fecal coliform and E. Coli data

There is limited knowledge as to the pathogen removal capabilities of stormwater wet ponds. In a study of three wet ponds during the growing season in Ontario (Schueler, 2000 - article 75), fecal coliform and E. Coli were sampled at two of the three ponds. The fecal coliform removal efficiency of the two ponds was 90% and 64%, while the E. Coli removal for the two ponds was 86% and 51%. In another study of a wet pond in Central Texas (Schueler, 2000 – Article 74), fecal coliform was reduced by 98%. Pathogens can be removed via both sedimentation and through photodegradation. Although Pierson did not perform as well as the sites presented by Schueler (2000), data still suggest relatively high removal rates. Pathogen removal can be linked to the physical characteristics of the pond, such as the presence of waterfowl and the amount of sunlight that reaches the water surface. Thus, it is possible that waterfowl activity in Pierson Pond added to the bacterial pathogens in the outflow, thus reducing the bacteria removal efficiency. Additionally, mature vegetation around Pierson Pond likely shields the sun, reducing pathogen photodegradation.

Oil and Grease removal in Pierson Pond was calculated to be 21%. However, pollutant removal from storm to storm was highly variable and the results were not statistically significant. Oil and Grease can be photodegraded; thus, the mature vegetation shading the pond may have had an impact on the Oil and Grease removal.

Metals

As for many other pollutants, trace metals can be removed from the water column through physical filtering and settling/sedimentation. Additionally, trace metals readily form complexes with organic matter, which can then become attached to suspended particles. As with phosphorus, the storage of metals on

sediments creates conditions under which the pollutant is susceptible to future loss/transformation. Pierson Pond removed moderate amounts of zinc (49%) and copper (40%), and low amounts of lead (26%). Compared to the other studies in Table 2, Pierson Pond removed comparable amounts of zinc, slightly lower amounts of copper, and substantially lower amounts of lead.

Effluent concentrations of zinc and copper are in agreement with those reported in Table 3, indicating acceptable performance. For many storms (7 out of 14 storms), influent and effluent lead concentrations were at or below the detectable limits (5 μg/L), resulting in 0% removal (See Appendix A – Figure A6). These low influent concentrations during many storms likely reduced the zinc removal efficiency. It is also possible that lead has accumulated in pond soils over time and is now leaching out of the considerably aged pond. Lead inputs would likely have been high in previous years, particularly before the use of unleaded gasoline.

CONCLUSIONS

- Pierson Pond functioned similar to the nutrient removal credit given for wet ponds in the N.C. Stormwater BMP Manual. Wet pond nutrient removal credit for TN and TP are 25% and 40%, respectively. Pierson Pond removed TN and TP with efficiencies of 23% and 41%, respectively. Research conducted in N.C. suggests that the State mandated 85% TSS removal efficiency is higher than should be realistically expected. Thus, the Pierson Pond removal rate of 56% is considered to be a reasonable TSS removal.

- Relatively low removal of Oil & Grease and Pathogens may indicate that the mature vegetation around the pond is providing shade, and thus reducing photodegradation of these pollutants. This may have impacts on pond management, but additional study is recommended on this issue.

- The total nitrogen removal efficiencies determined for Pierson Pond (23%) are less than those calculated for other Charlotte-NCSU BMP studies at the Bruns Ave. (35%) and Edward's wetlands (45%). This is consistent with the difference in TN removal credit given by NCDENR for wetlands (40%) and wet ponds (25%).

- Phosphorous removal in the pond remained high despite the age of the pond. This indicates that even older ponds can still perform well with respect to TP removal. Sedimentation of influent particles likely remains a pollutant removal mechanism despite the age of this system.

- Aged ponds are able to provide substantial stormwater treatment for various nutrients, sediment, pathogens, and metals.

- TSS reductions were higher than turbidity reductions. Turbidity is generally associated with small particles that are hard to remove in stormwater treatment practices.

- The establishment of a diverse, dense plant community around the perimeter of the pond may increase nutrient removal by encouraging microbiological activity and plant uptake. Establishment of a vegetated buffer around the pond may also discourage water fowl activity, potentially reducing organic nutrient and pathogen inputs. The sparsely vegetated littoral shelf has not deterred waterfowl population. Perhaps similar measures to those taken at Shade Valley Pond in Charlotte should be considered if waterfowl are a concern.

- It should be noted that Pierson Pond was not originally intended to be used as a stormwater facility and was not designed as such; however, the pond still functions similarly to wet detention devices which have been constructed for stormwater treatment. This is especially true in regard to water quality abatement.

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APPENDIX A

Additional Graphs and Tables

Table A1: Results of statistical between inlet and outlet BMP concentrations of selected pollutants at Pierson Pond

Parameter	Assumed Distribution	Reject Based on KS Test[1]	Paired *t*-Test[2]	Wilcoxian Signed - Rank Test	Significant?
			p - value	*p* - value	
Fecal Coliform	Lognormal	**Yes**	0.0911	0.2402	
E. Coli	Lognormal	**Yes**	0.335	0.5	
Oil & Grease	Lognormal	**Yes**	0.1949	0.5469	
BOD5	Lognormal	**Yes**	**0.0466**	**0.0166**	**Yes**
COD	Lognormal	**Yes**	**0.0019**	**0.0005**	**Yes**
NH4	Lognormal	No	0.2366	0.0906	
NO3 + NO2 (NOx)	Lognormal	No	**<0.0001**	**<0.0001**	**Yes**
Nitrogen, TKN	Lognormal	No	0.1165	0.104	
Nitrogen, Total	Normal	No	**0.0002**	**0.002**	**Yes**
Total Phosphorus	Lognormal	No	**0.0002**	**0.002**	**Yes**
Suspended Residue (TSS)	Lognormal	No	**0.0005**	**0.0009**	**Yes**
Total Residue	Lognormal	No	0.0842	0.073	
Turbidity	Lognormal	No	**0.0006**	**0.0007**	**Yes**
Copper	Lognormal	No	**<0.0001**	**0.0002**	**Yes**
Iron	Lognormal	No	0.1401	0.2239	
Manganese	Lognormal	No	**0.0013**	**0.0012**	**Yes (increase)**
Zinc	Lognormal	No	**0.001**	**0.0009**	**Yes**
Lead	Lognormal	**Yes**	**0.0215**	**0.0313**	**Yes**

1. Rejection (α=0.05) of Kolmogorov-Smirnov goodness-of-fit test statistic implies that the assumed distribution is not a good fit of the data.

2. Statistical tests were performed on log-transformed data except for total residue and zinc, in which case raw data was used.
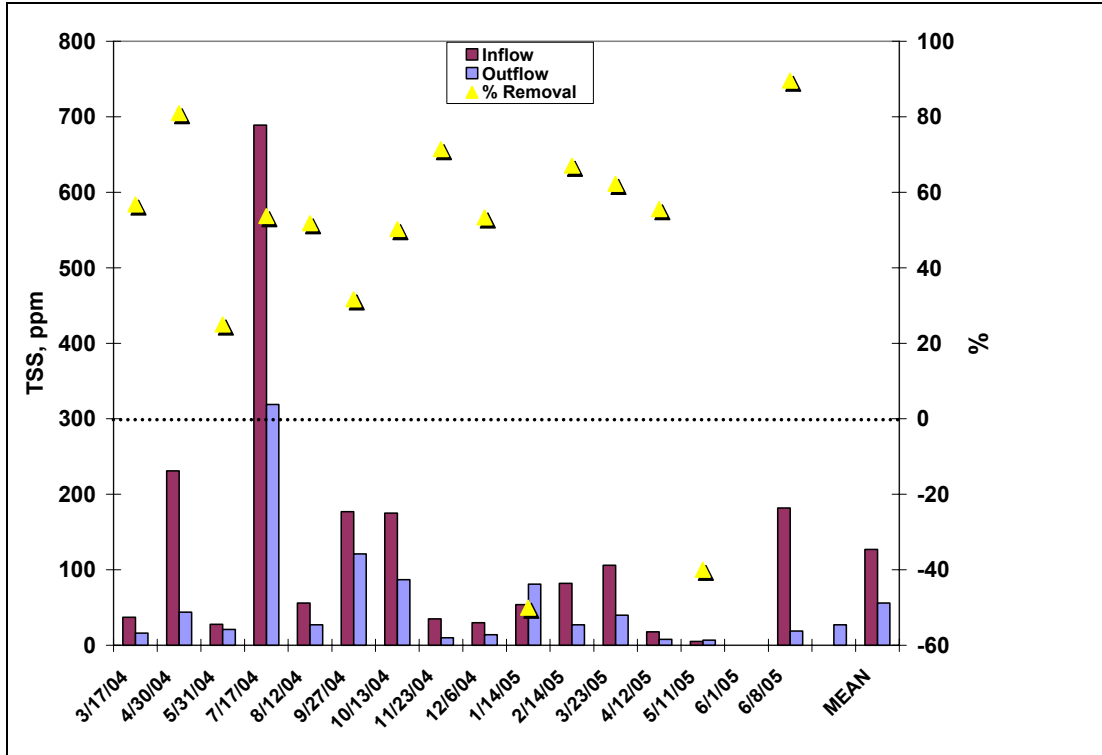
Figure A1: Change in TSS concentration due to BMP treatment by storm event.
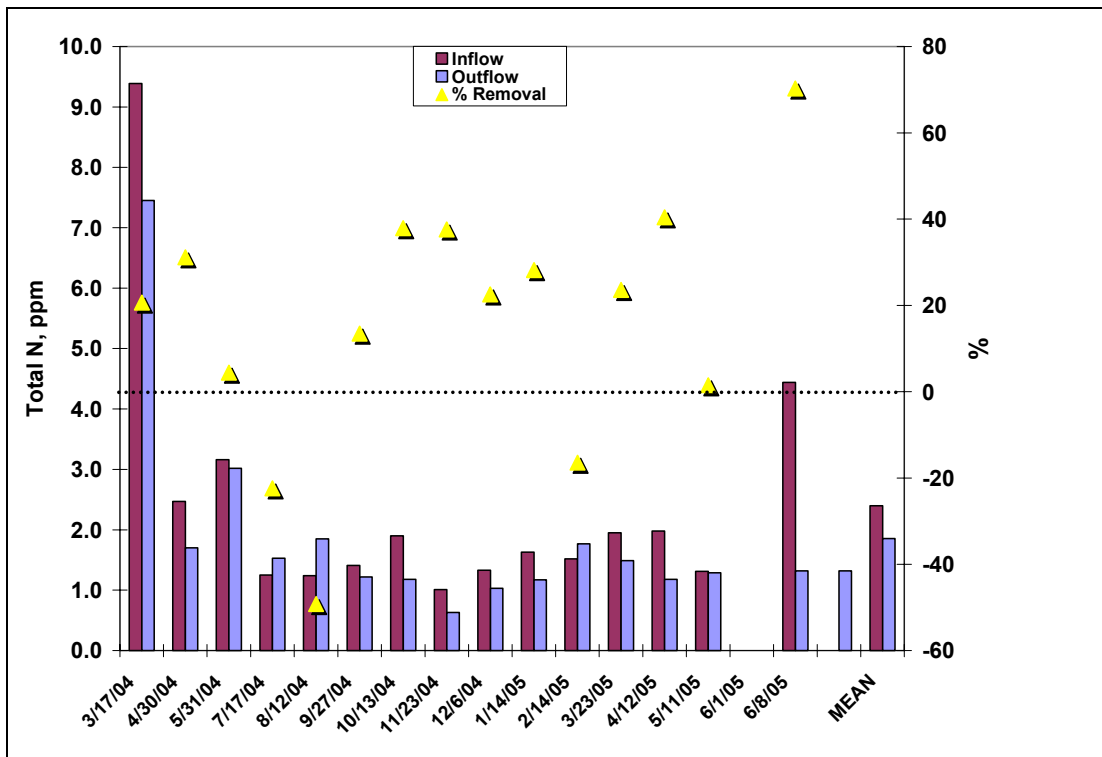

Figure A2: Change in TN concentration due to BMP treatment by storm event.
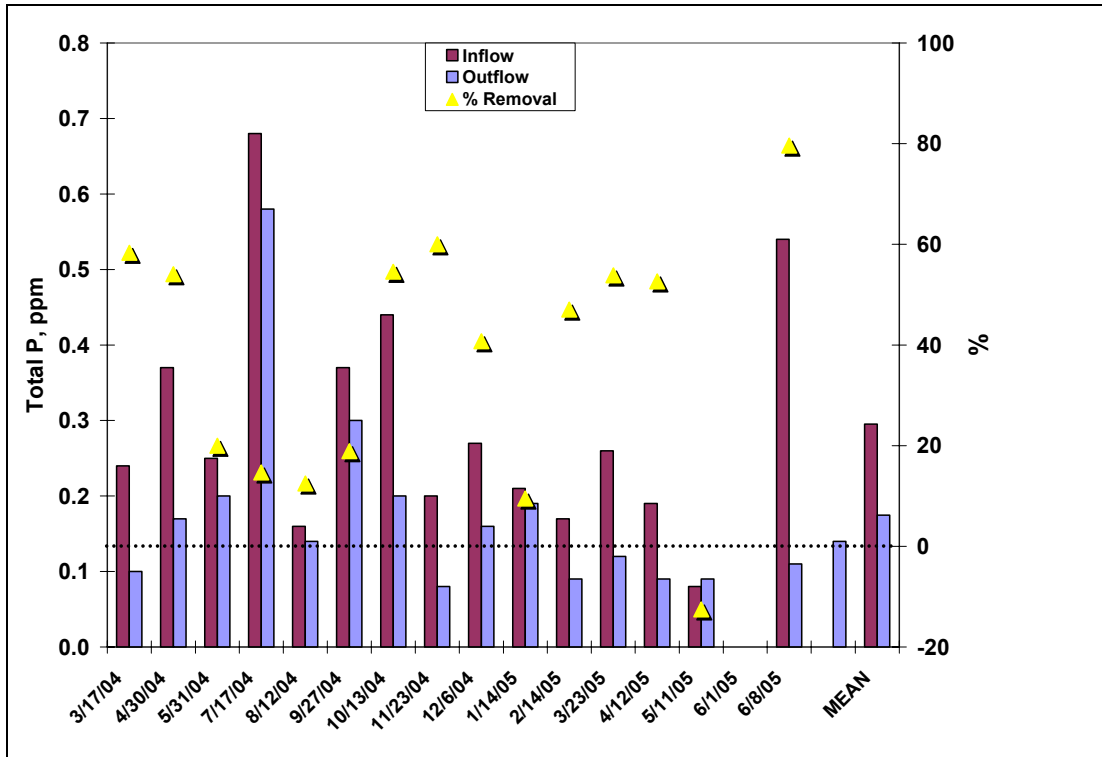
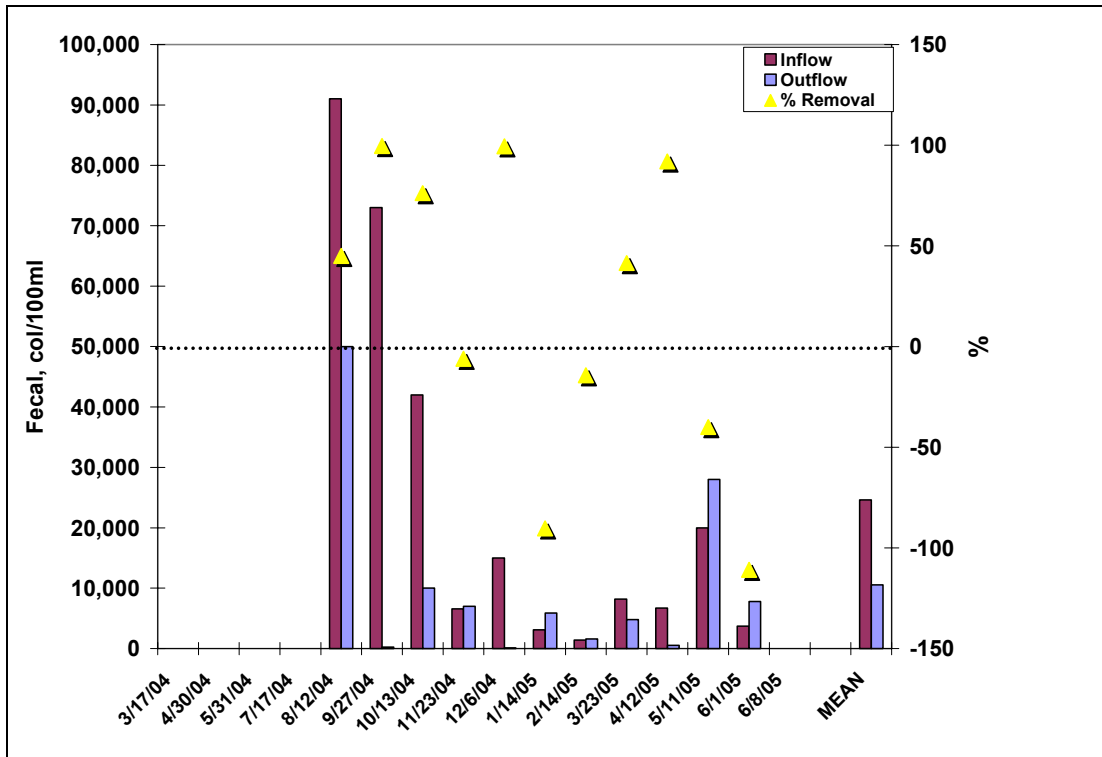**Figure A3: Change in TP concentration due to BMP treatment by storm event.**

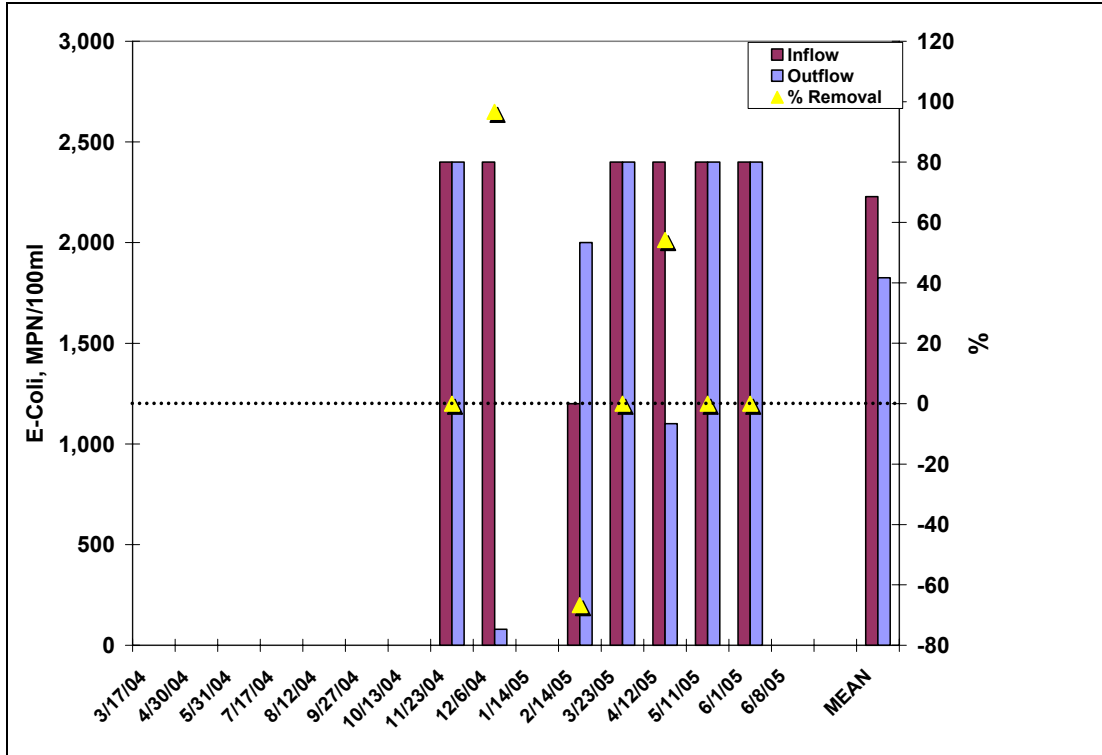**Figure A4: Change in fecal coliform concentration due to BMP treatment by storm event.**

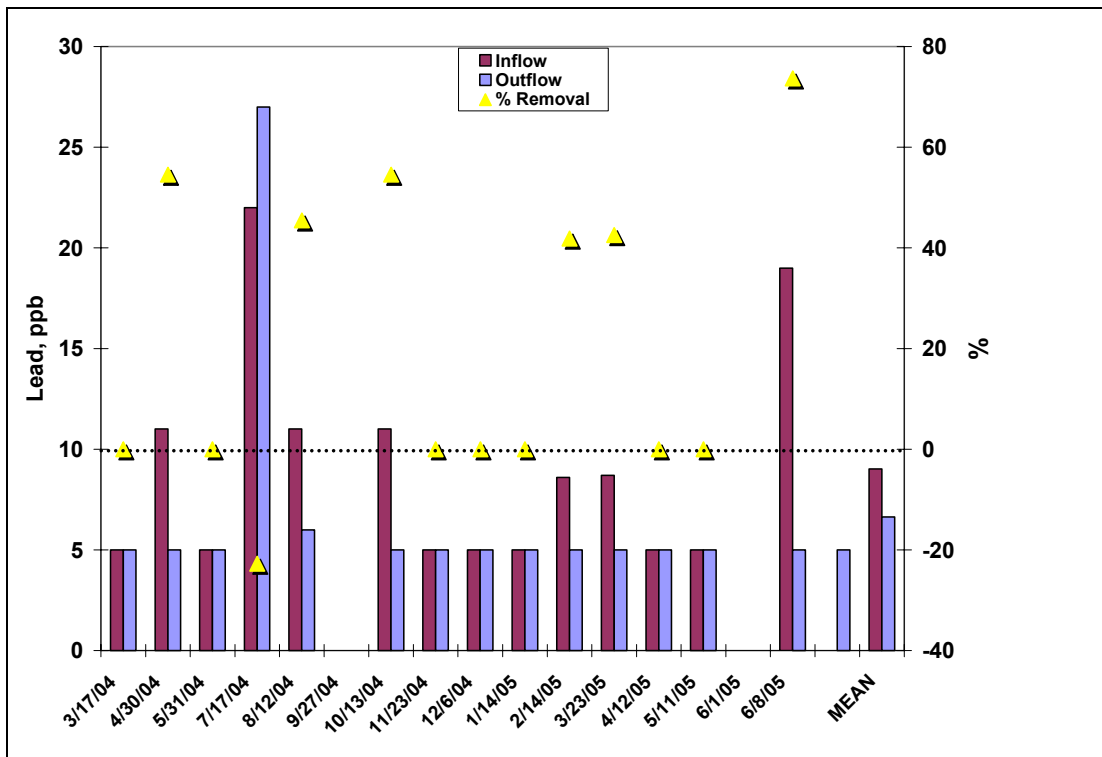**Figure A5: Change in E. Coli concentration due to BMP treatment by storm event.**

Figure A6: Change in lead concentration due to BMP treatment by storm event.

APPENDIX B

Monitoring Protocol

Stormwater BMP performance Monitoring Protocol for:

Pierson Pond

Description of Site:
The Pierson wet pond is a non detention BMP providing stormwater treatment to an area of residential and commercial lots. The wet pond has no water quality features such as littoral shelves or fore bays

Watershed Characteristics (estimated)
Size: 119.43 acres
Use: Residential and commercial lots

Sampling equipment
Inlet conditions do not allow flow monitoring at this location. However since the wet pond is effectively a flow-through device it is possible to use a primary device and a flow monitor at the outlet to trigger the inlet sampler. A wireless signal device has been constructed to trigger the inlet sampler to take samples simultaneously with the outlet sampler. A 5 ft diameter un-submerged circular culvert at the outlet allows measurement of flow rate using an area velocity meter. The wireless device is custom manufactured for this application by Custom Control Unlimited of Raleigh, NC.

Inlet Sampler
Primary device: N/A
Secondary Device: N/A
Bottle Configuration 24 1000mL Propak containers

Outlet Sampler
Primary Device: 6 ft circular culvert
Secondary Device: ISCO Model 750 Area-Velocity meter
Bottle Configuration 24 1000mL Propak containers
Rain gage   ISCO model 763 Tipping Bucket rain gage

Sampler settings

      <u>Inlet Sampler</u>
      Sample Volume   200mL
      Distribution   5/bottle
      Pacing   External Flow meter
                                  1 pulse
      Set point enable   None

      <u>Outlet Sampler</u>
      Sample Volume   200mL
      Distribution   5/bottle
      Pacing   1000 cu ft
      Set point enable   None

Sample Collection and Analysis
      Samples should be collected in accordance with Stormwater Best Management Practice (BMP) Monitoring Protocol for the City of Charlotte and Mecklenburg County Stormwater Services.

General Monitoring Protocol

Introduction
      The protocols discussed here are for use by City of Charlotte and Mecklenburg County Water Quality personnel in setting up and operating the stormwater BMP monitoring program. The monitoring program is detailed in the parent document "Stormwater Best Management Practice (BMP) Monitoring Plan for the City of Charlotte"

Equipment Set-up
      For this study, 1-2 events per month will be monitored at each site. As a result, equipment may be left on site between sampling events or transported to laboratory or storage areas between events for security purposes. Monitoring personnel should regularly check weather forecasts to determine when to plan for a monitoring event. When a precipitation event is expected, sampling

equipment should be installed at the monitoring stations according to the individual site monitoring protocols provided. It is imperative that the sampling equipment be installed and started prior to the beginning of the storm event. Failure to measure and capture the initial stages of the storm hydrograph may cause the "first flush" to be missed.

The use of ISCO refrigerated single bottle samplers may be used later in the study if future budgets allow. All samplers used for this study will be configured with 24 1000ml pro-pak containers. New pro-pak containers should be used for each sampling event. Two different types of flow measurement modules will be used depending on the type of primary structure available for monitoring

Programming

Each sampler station will be programmed to collect up to 96 individual aliquots during a storm event. Each aliquot will be 200 mL. in volume. Where flow measurement is possible, each sampling aliquot will be triggered by a known volume of water passing the primary device. The volume of flow to trigger sample collection will vary by site depending on watershed size and characteristic.

Sample and data collection

Due to sample hold time requirements of some chemical analysis, it is important that monitoring personnel collect samples and transport them to the laboratory in a timely manner. For the analysis recommended in the study plan, samples should be delivered to the lab no more than 48 hours after sample collection by the automatic sampler if no refrigeration or cooling of samples is done. Additionally, samples should not be collected/retrieved from the sampler until the runoff hydrograph has ceased or flow has resumed to base flow levels. It may take a couple of sampling events for the monitoring personnel to get a good "feel" for how each BMP responds to storm events. Until that time the progress of the sampling may need to be checked frequently. Inflow sampling may be completed just after cessation of the precipitation event while outflow samples may take 24-48 hours after rain has stopped to complete. As a result it may be convenient to collect the inflow samples then collect the outflow samples several hours or a couple of days later.

As described above, samples are collected in 24 1,000mL containers. In order for samples to be flow weighted these individual samples will need to be composited in a large clean container; however, future use of single bottle samplers will likely reduce the need for this step. The mixing container should be large enough to contain 24,000mL plus some extra room to avoid spills. Once the composited sample has been well mixed, samples for analysis should be placed in the appropriate container as supplied by the analysis laboratory.

Chain of custody forms should be filled in accordance with Mecklenburg County Laboratory requirements.

Collection of rainfall and flow data is not as time dependent as sample collection. However it is advised that data be transferred to the appropriate PC or storage media as soon as possible.

Data Transfer

Sample analysis results as well as flow and rainfall data should be transferred to NCSU personnel on a quarterly basis or when requested. Transfer may be completed electronically via email or by file transfer.