

# CITY of CHARLOTTE Pilot BMP Monitoring Program

## Shade Valley Pond Final Monitoring Report

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City of Charlotte-Storm Water Services



## **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 Shade Valley 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 fore bays, 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**

This research was conducted at Shade Valley pond, an urban pond located in a fully developed watershed in Charlotte, North Carolina. Shade

Valley pond is located just upstream of Shade Valley Road and was constructed during the 1950's as a water feature for a nearby multi-family housing development. The area immediately surrounding the pond consists of an apartment complex and its associated parking areas. Additionally, a 27.3-acre watershed consisting of commercial, residential and transportation land uses feeds the pond via a small, perennial stream. Impervious area within the watershed is approximately 35%. The watershed contains substantial amounts of connected impervious areas which quickly route runoff into conveyance structures.

Prior to the summer of 2004, the condition of the pond was very poor. Mowing of the vegetated border of the pond and intense waterfowl activity resulted in a rapidly eroding pond bank. Conveyance structures at the pond edge had collapsed resulting in erosion of the adjacent areas. Sediment deposition at the main inlet of the pond had created an exposed sand bar which nearly encircled the inlet. Fecal matter and feathers were prevalent on the banks of the pond and in the pond itself. Conditions during this time are shown in Figures 1.a and 1.b.



**Figure 1.a and 1.b Condition of pond during pre-construction monitoring period.**

Runoff entered the pond through numerous, poorly maintained conveyances such as culverts and concrete channels. Approximately 78% of the contributing watershed entered the pond through three existing culverts which discharged into a scour pool. Shade Valley pond was approximately 0.6 acres in

area with an average depth of 3 feet. The banks of the pond were severely eroded due to the intense waterfowl activity in the area. The outlet of the pond consisted of an undersized 30-inch Reinforced Concrete Pipe (RCP) which went under Shade Valley Road and discharged into a nearby perennial stream. A 6-foot wooden weir maintained the level of water within the pond.

The City of Charlotte began a construction project in the summer of 2004 to modify the existing pond with the intent of improving its stormwater treatment capabilities and providing improved water quality downstream. The pond was drained and dredged to remove the accumulated sediment and to increase the average pond depth. The inlets were combined, where possible, and the failed conveyances were replaced. The undersized outlet was replaced with a concrete riser that allowed stormwater detention. In addition to the drainage system improvements, several design features were incorporated into the newly retrofitted pond, these features included a fore bay and a littoral shelf.

The fore bay was constructed at the inlet to provide storage of heavy sediment deposited in the pond and to facilitate the removal of such sediment during maintenance operations. In addition, a littoral shelf was constructed along the edge of the main pond body.

The littoral shelf was designed such that during periods of normal pool the water level at the shelf would be from 0 to 1 foot deep. Emergent aquatic vegetation was planted in the shelf. The littoral shelf of the new pond composed nearly 30% of the surface area of the pond. The banks of the pond were planted with brushy vegetation.

The drainage improvements required the replacement of the 30-inch RCP under Shade Valley road. The outlet was replaced with a cast-in-place riser which functioned as the low flow and overflow spillway. A 3-inch orifice was utilized as the low flow and drawdown control device. An overflow weir was constructed approximately 18 inches above the orifice so the new pond would provide detention for the runoff associated with the first 1-inch of any rainfall event. The orifice was sized such that the water level within the pond would return to pre event level within 24 hours of the end of the runoff event.

Construction activities were completed in the winter of 2005. The remainder of this monitoring report will discuss data collected prior to the pond retrofit improvements and represents the function of the pond prior to any water quality features being added. Post retrofit monitoring began in late 2006 and will continue through 2008 to document the effects of the improvements with respect to stormwater treatment.

## Monitoring Plan and Data Analysis

The existing 6-foot wooden rectangular weir would not provide an accurate flow measurement at the outlet. Thus, a 120° sharp crested V-notch weir was attached to the existing wooden outlet weir. The invert of the V-notch was installed at the pre-existing normal pool elevation, so no alteration of pond level occurred.



**Figure 2.a and 2.b. Locations of inlet and outlet sample collection**

Any detention which occurred during storm events was assumed to be minimal compared to the overall volume of runoff from the event. Inlet and outlet sampling locations were outfitted with ISCO 6712 samplers for flow monitoring and sample collection. The location of inlet and outlet sample collection is shown in figures 2a and 2b. An ISCO model 750 bubbler module was fitted to the outlet sampler for flow monitoring. In addition, an ISCO tipping bucket rain gage was installed on the outlet sampler to provide continuous measurement of rainfall depth and intensity during sampling events.

The intake for the inlet sampler was installed just downstream of the convergence of the three major RCP culverts in an area of well mixed flow. Accurate inflow measurements were not possible due to the multiple inlets entering the pond and the hydraulic conditions (submerged) at those inlets. Since the pond had no significant detention component, it was considered a flow through device. As a result, it was assumed that the inflow volume matched the outflow volume.

A system of sample collection was implemented using a wireless transmitter and receiver. The outlet sampler was fitted with the transmitter, which sent a wireless signal to the receiver (fitted to the inlet sampler) when flow paced outlet sampling was initiated. The signal from the outlet sampler, once received, notified the inlet sampler to collect a sample aliquot. Using this wireless system the inlet sampler collected a sample at the same time that the outlet sample was being taken. The wireless system was constructed and installed by Custom Controls Inc. For monitoring protocol, see Appendix B.

Monitoring efforts were initiated in August 2003 and continued until July 2004, with 17 storm events being collected prior to any major retrofit changes being made to the pond. Additional manual grab samples, from which levels of fecal coliform were measured, were collected for 2 of the 17 storm events. This is not an adequate data set to make judgments on the fecal coliform removal performance of the pond.

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.

Water quality data were 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 fewer than 25 samples, it is difficult to determine how the data were distributed. Nevertheless, the data were checked for normality using the Kolmogorov-Smirnov (K-S) test. If the raw data were not normally distributed, a log transform of the data 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 sets, the log transform data were chosen for analysis.

Fortunately, there are tests that can show statistical significance regardless of distribution. A Wilcoxon 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. See Appendix A – Table A1.

## Data Analysis Results

### Flow Results

As discussed above, the characteristics of the pond inlet were not desirable for flow measurement; thus, an evaluation of variations in inlet and outlet flow data could not be made. Due to the design of the pond outlet, the pond likely provided minimal detention, thus inflow could be assumed to be nearly equal to outflow for monitoring purposes. With this assumption, inlet and outlet water quality samples could be analyzed without the need for mass removal calculations. The effluent volume and associated rainfall depth for each storm monitored can be seen in Figure 3. A typical hydrograph (0.5 inch storm – 2/12/2004) from the Shade Valley outlet can be seen in Figure 4.

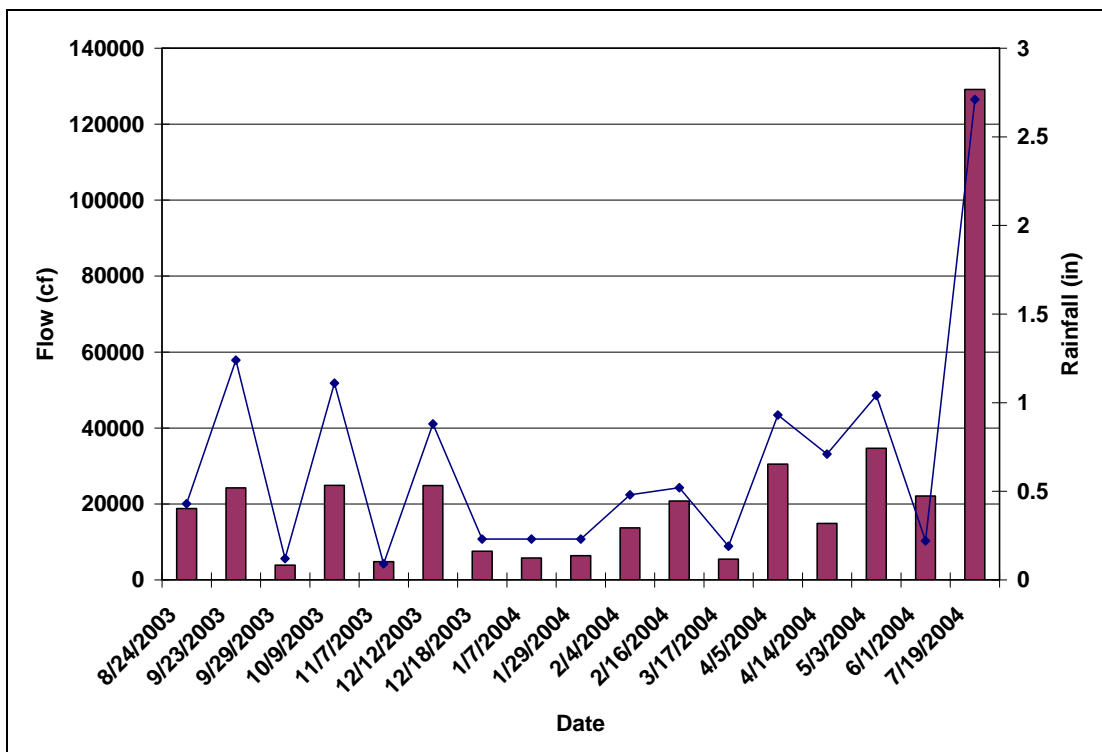


Figure 3: Effluent volume and rainfall depth for each event monitored



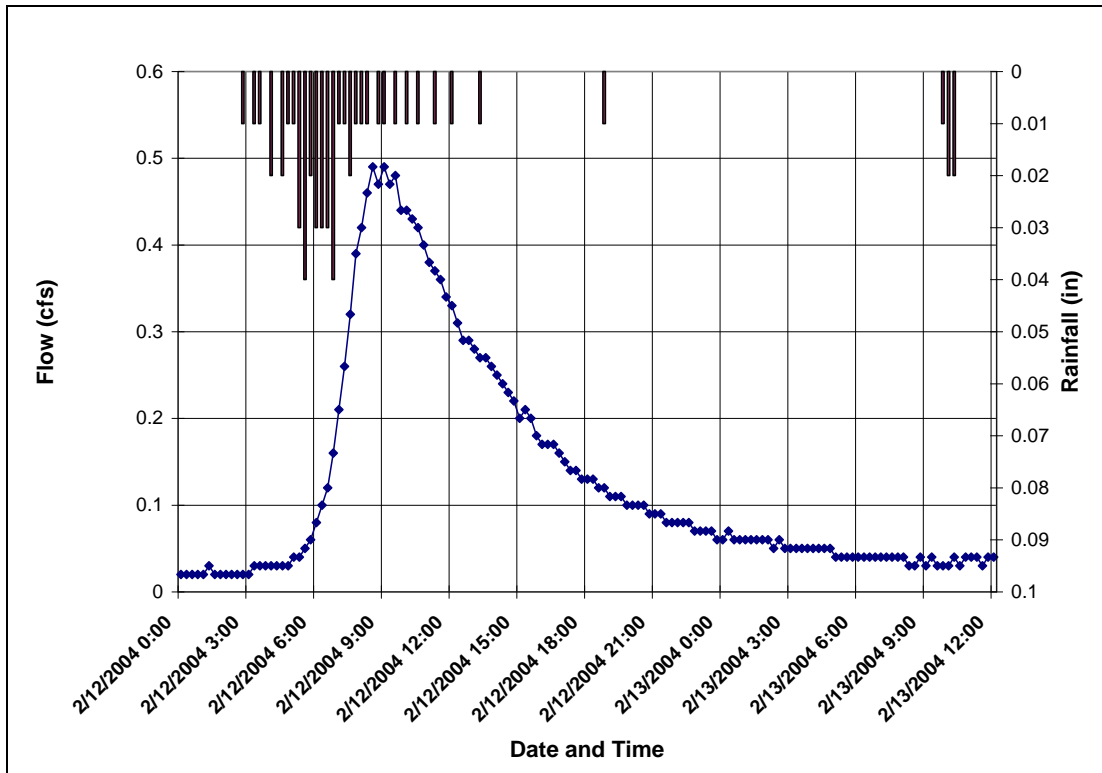


Figure 4: Outlet hydrograph from Shade Valley Pond

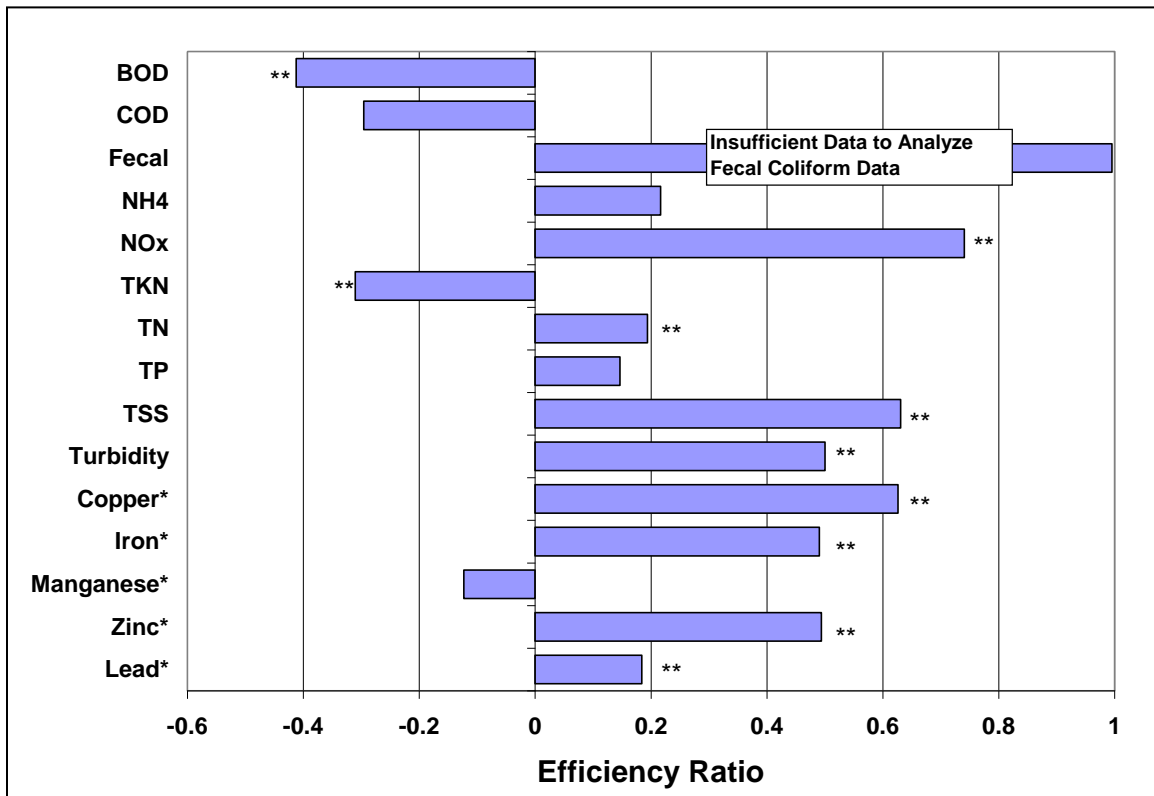
### Water Quality Results

Table 1 and Figure 5 illustrate the performance of Shade Valley 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 basin as stormwater runoff, was retained. A negative ER represents a surplus of pollutant leaving the BMP, suggesting either internal production of nutrients, or loss of stored pollutant from previous storm events.

**Table 1: Summary of Water Quality Results**

Parameter	Units	# of Samples	Influent EMC	Effluent EMC	ER	p-value	Significant (p < 0.05)	
<b>BOD</b>	ppm	16	8.17	11.54	-41%	0.0008	<b>yes</b>	
<b>COD</b>	ppm	17	32.56	42.19	-30%	0.1008	no	
<b>Fecal</b>	col. / 100 ml	2	Insufficient data to analyze					
<b>NH<sub>4</sub></b>	ppm	17	0.28	0.22	22%	0.6322	no	
<b>NO<sub>x</sub></b>	ppm	17	1.43	0.37	74%	<0.0001	<b>yes</b>	
<b>TKN</b>	ppm	17	1.55	2.03	-31%	0.015	<b>yes</b>	
<b>TN</b>	ppm	17	2.98	2.40	19%	0.0202	<b>yes</b>	
<b>TP</b>	ppm	17	0.19	0.16	15%	0.1631	no	
<b>TSS</b>	ppm	17	109.18	40.29	63%	0.0008	<b>yes</b>	
<b>Turbidity</b>	NTU	16	90.19	45.06	50%	0.0063	<b>yes</b>	
<b>Copper</b>	ppb	17	13.53	5.06	63%	0.0016	<b>yes</b>	
<b>Iron</b>	ppb	17	4590.18	2338.71	49%	0.0021	<b>yes</b>	
<b>Manganese</b>	ppb	16	146.75	164.81	-12%	0.4332	no	
<b>Zinc</b>	ppb	17	70.35	35.59	49%	0.0026	<b>yes</b>	
<b>Lead</b>	ppb	17	6.71	5.47	18%	0.0313	<b>yes</b>	

According to statistical tests, Shade Valley pond significantly ( $p < 0.05$ ) reduced the following pollutants in stormwater runoff: NO<sub>x</sub>, TN, TSS, Turbidity, copper, iron, zinc and lead (Table 1 and Figure 5). With the exception of NO<sub>x</sub>-N, all of these pollutants tend to be associated with particulate matter, suggesting that settling/sedimentation is a dominant mechanism of pollutant removal in Shade Valley 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 ( $\geq 2$  days), BMPs that slow water flow and promote settling, such as ponds, can be effective at removing these types of pollutants (ITRC, 2003).



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

\* = Grab samples collected to analyze for this pollutant

\*\* = Indicates statistically significant relationship

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

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## Sediment

The ER for TSS removal in Shade Valley Pond was 0.63. This indicates that a substantial amount of treatment for TSS is occurring in the pond, presumably through sedimentation and filtration. This is likely related to the high ERs noted for other sediment borne pollutants that were analyzed, specifically metals (Vaze and Chiew, 2004). Although state regulations require wet detention ponds to achieve 85% TSS removal, this is unlikely for ponds sited in watersheds with clay type soils. Small particles are not easily removed from a given flow stream. An ER of 0.63 indicates that Shade Valley Pond is efficiently removing this pollutant from the flow stream. Inflow and outflow TSS concentrations for each storm can be seen in Appendix A – figure A1.

Turbidity removal was somewhat lower than TSS (ER = 0.5). This is an expected occurrence. 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 remove TSS.

Table 2 shows the pollutant removal percentages reported by various studies performed on wet ponds. Shade Valley shows efficiency only slightly lower than other studies for TSS removal, however, Shade Valley functions very close to nearby Pierson Pond (also part of the Charlotte BMP study) for TSS. The soil characteristics of the watersheds being treated by the BMPs represented in Table 2 are unknown. Since particle size can have an impact on TSS removal, it is difficult to compare these studies with certainty. Based on data collected by NCSU-BAE from other studies, 63% TSS removal is considered acceptable. 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 Shade Valley and Pierson Pond, further indicating that the Pond functions slightly below stormwater wet ponds that have been monitored. Again, the impact of influent particle size can not be neglected and could be partially responsible for these results.

Additionally, Shade Valley Pond was not constructed to be a stormwater facility; thus, it is not expected to perform as well as the stormwater wet ponds reported in Winer (2000).

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

Parameter	Shade Valley	Pierson Pond	Winer - CWP, 2000	Schueler - Article 74 (St. Elmo)
BOD <sub>5</sub>	-41	45	--	61
COD	-30	42	--	50
NH <sub>4</sub>	22	28	--	91
NO <sub>x</sub>	74	45	43	40
TKN	-31	15	--	57
Total N (TN)	19	23	33	50
Total P (TP)	15	41	51	87
TSS	63	56	80	93
Copper	63	40	57	58
Zinc	49	49	66	27
Lead	18	26	--	39

**Table 3: Comparison of Median Effluent Concentration for Various Wet Ponds**

Parameter	Shade Valley	Pierson Pond	Winer - CWP, 2000
NO <sub>x</sub>	0.4	0.3	0.26
Total N (TN)	2.2	1.32	1.3
Total P (TP)	0.1	0.14	0.11
TSS	29.0	27	17
Copper *	4.0	4.6	5
Zinc *	26.0	28	30

\* Values are in units of ug/L

### Nutrients and Organic Material

The removal rates for major nutrient pollutants and oxygen demanding material (organic carbon) were low compared to those found by others (Table 2). Due to the age and condition of this pond many pollutant removal mechanisms are likely not being employed within this system.

### *Oxygen Demand:*

Biological oxygen demand (BOD) 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 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 and COD through respiration and the reduction of elements such as nitrate and iron.

BOD and COD removal efficiencies in Shade Valley Pond were negative, -41% and -30% for BOD and COD, respectively. This represents a substantial increase in BOD and COD from the inlet to the outlet, with the increase in BOD being statistically significant. This is caused by an addition of organic matter to the flow stream. The presence of waterfowl likely played a part in this addition; however, it is also likely that BOD and COD removal mechanisms are not active in this pond. Compared to the removal efficiencies determined for nearby Pierson Pond, it is evident that Shade Valley performed poorly in this regard.

### *Nitrogen:*

The nitrogen analysis performed on Shade Valley gives some indication as to the internal function of the pond. Total nitrogen removal was 19%, below what was determined for wet ponds in other studies (Table 2). However, TN removal was consistent with that determined for Pierson Pond. In analyzing other nitrogen species, there was moderate removal of  $\text{NH}_4$  (ER = 0.22), very high removal of  $\text{NO}_x$  (ER = 0.74), and very poor removal of TKN (ER = -0.31). Compared to the studies in Table 2, Shade Valley performed slightly worse in TN removal, poorly in TKN removal, better in  $\text{NO}_x$  removal, and relatively consistent with other studies in  $\text{NH}_4$  removal. Effluent concentrations were slightly higher for  $\text{NO}_x$  and substantially higher for TN compared to the studies in Table 3. Median effluent concentrations of TN were 2.2 mg/L; this can be compared to the median effluent concentration reported for other sites (1.3 mg/L).

Analysis of the various nitrogen species results in the assumption that anoxic conditions prevailed in Shade Valley pond. Since NO<sub>x</sub> gets converted to nitrogen gas (and potentially other compounds) under anoxic conditions, the very high NO<sub>x</sub> removal leads to this assumption. There was moderate NH<sub>4</sub> removal in the pond. Since TKN includes both organic nitrogen and NH<sub>4</sub>, it is evident that the increase in TKN from influent to effluent is due to the addition of organic nitrogen. The increase in BOD and COD strengthens this conclusion. It is possible that waterfowl activity is adding to the organic load in the pond, creating a source of nitrogen.

Overall, the TN removal in the pond was approximately 19%. NCDENR (2006) gives 25% TN removal credit to wet ponds, which Shade Valley falls slightly under. It is possible that the exclusion of water fowl would result in a TN removal efficiency much closer to that in the N.C. Stormwater BMP Manual (NCDENR, 2006). Inflow and outflow TN concentrations for each storm can be seen in Appendix A – Figure A2.

#### *Phosphorous:*

Total phosphorous removal by Shade Valley Pond was 15%. This was low based on the studies presented in Table 2, and based on the 40% TP removal credit given to wet ponds in NCDENR, 2006. The median effluent concentrations of TP leaving Shade Valley Pond are surprisingly close 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 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 reduced phosphorous removal over time, as sediments become phosphorous laden. Due to the age of Shade Valley pond, a high TP removal efficiency would not be expected due to the likely TP accumulation that has occurred over time. It

should be noted that median influent TP concentrations (0.16 mg/L) were very low, thus, a water quality improvement that brings effluent concentrations near to the irreducible concentration may result in an ER that appears low. Inflow and outflow TP concentrations for each storm can be seen in Appendix A – figure A3.

### **Pathogens**

Only two grab samples for fecal coliform bacteria were taken from Shade Valley Pond, making analysis of these data impossible.

### **Metals**

Shade Valley performed well in regard to metal removal. Significant reductions were made in copper (ER = 0.63), iron (ER = 0.49), zinc (ER = 0.49), and lead (ER = 0.18). There was an increase in manganese (ER = -0.12) from the inlet to the outlet. Copper and zinc removal was consistent with the studies in Table 2, with lead removal being slightly lower than that shown in other studies. Median copper and zinc effluent concentrations were lower than what was observed by Winer (2000) and in Pierson Pond (Table 3). Median lead effluent concentrations were not reported by Winer (2000).

It should be noted that for many storms (11 out of 17 storms), influent and effluent lead concentrations were at or below the detectable limits (5 mg/L), resulting in 0% removal (See Appendix A – Figure A4). Low influent concentrations during many storms likely reduced the zinc removal efficiency. It is also possible that lead had 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.

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. Since physical removal is the dominant mechanism of trace metal improvement in many natural systems, trends can sometimes be found between



TSS and trace metal removal. Due to the substantial TSS improvement made by Shade Valley Pond, it is logical that metal improvements would be made as well.

## CONCLUSIONS

- Shade Valley Pond functioned reasonably well, though slightly worse when compared to the pollutant removal credit the North Carolina Stormwater BMP Manual gives to wet ponds for TSS and TN, but poorly compared to the credit given for TP. The NCDENR manual (2006) assigns TSS, TN, and TP removal for wet ponds of 85%, 25%, and 40% respectively. Shade Valley Pond removed TSS, TN, and TP with efficiencies of 63%, 19%, and 15%. NCSU-BAE considers the 85% TSS removal assumed by NCDENR to be an exaggerated value, and thus 63% is considered to be a moderately high efficiency of TSS removal.
- Based on the analysis performed on BOD, COD, and various nitrogen species, Shade Valley Pond added organic matter to the flow stream. This is likely due to the high amount of water fowl activity in the pond.
- High NO<sub>x</sub> removal rates suggest that the pond is anoxic, creating an environment for NO<sub>x</sub> conversion to nitrogen gas.
- Low TP removal could be due to the advanced age of the pond (potential phosphorous accumulation in soils over time, reducing phosphorous binding sites), the low median influent TP concentrations, or a combination of the two.
- Trace metal removal was high in the pond. This can likely be associated with the high TSS removal that is being achieved. Sedimentation is considered a major pollutant removal mechanism in this system.
- Overall, Shade Valley Pond functions relatively well considering the age of the pond and the condition of the pond during this study. Water fowl exclusion, the addition of a littoral shelf, and enhanced vegetation in the pond will likely lead to increased nutrient removal. Due to the relatively high TSS and metal removal shown in this study, it is unknown if additional

efficiency (for these pollutants) can be gained by taking the aforementioned actions.

- It should be noted that Shade Valley Pond was not originally intended to be used as a stormwater facility; however, the pond still functions similarly to wet detention devices which have been constructed for stormwater treatment. This is especially true in regard to particulate-bound pollutants, excluding phosphorous.

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## APPENDIX A

### Additional Graphs and Tables

**Table A1: Results of statistical analysis between inlet and outlet BMP concentrations of selected pollutants at Shade Valley Pond**

Parameter	Assumed Distribution	Reject Based on KS Test <sup>1</sup>	Paired t-Test <sup>2</sup>	Wilcoxon Signed - Rank Test	Significant ?
			p - value		
BOD5	Lognormal	No	0.0014	0.0008	<b>yes</b>
COD	Lognormal	No	0.0873	0.1008	
NH4	Lognormal	No	0.4871	0.6322	
NO3 + NO2 (NOx)	Lognormal	No	<0.0001	<0.0001	<b>yes</b>
Nitrogen, TKN	Lognormal	No	0.0149	0.015	<b>yes</b>
Nitrogen, Total	Lognormal	No	0.0192	0.0202	<b>yes</b>
Total Phosphorus	Lognormal	No	0.1567	0.1631	
Suspended Residue (TSS)	Lognormal	No	0.0003	0.0008	<b>yes</b>
Turbidity	Lognormal	No	0.006	0.0063	<b>yes</b>
Copper	Lognormal	No	0.0013	0.0016	<b>yes</b>
Iron	Lognormal	No	0.0012	0.0021	<b>yes</b>
Manganese	Lognormal	No	0.4634	0.4332	
Zinc	Lognormal	No	0.001	0.0026	<b>yes</b>
Lead	Lognormal	<b>Yes</b>	0.0186	0.0313	<b>yes</b>

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

2. Statistical tests were performed on log-transformed data

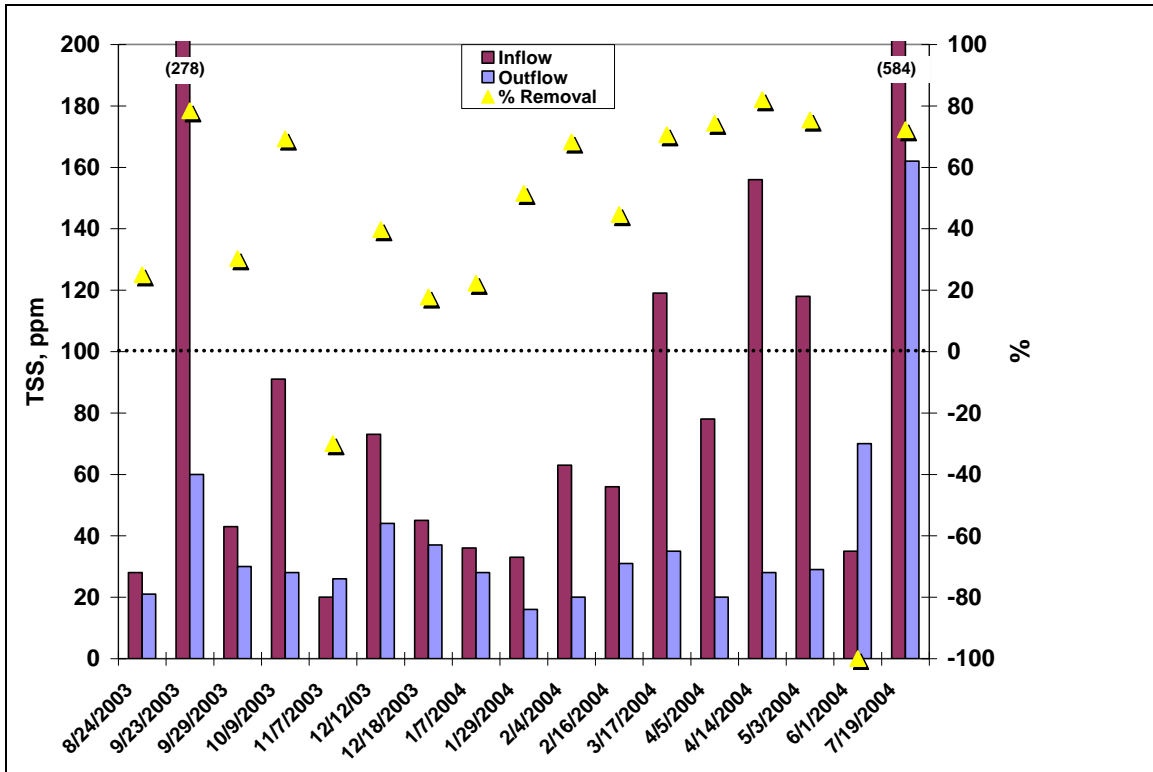


Figure A1: Change in TSS concentration due to BMP treatment by storm event.

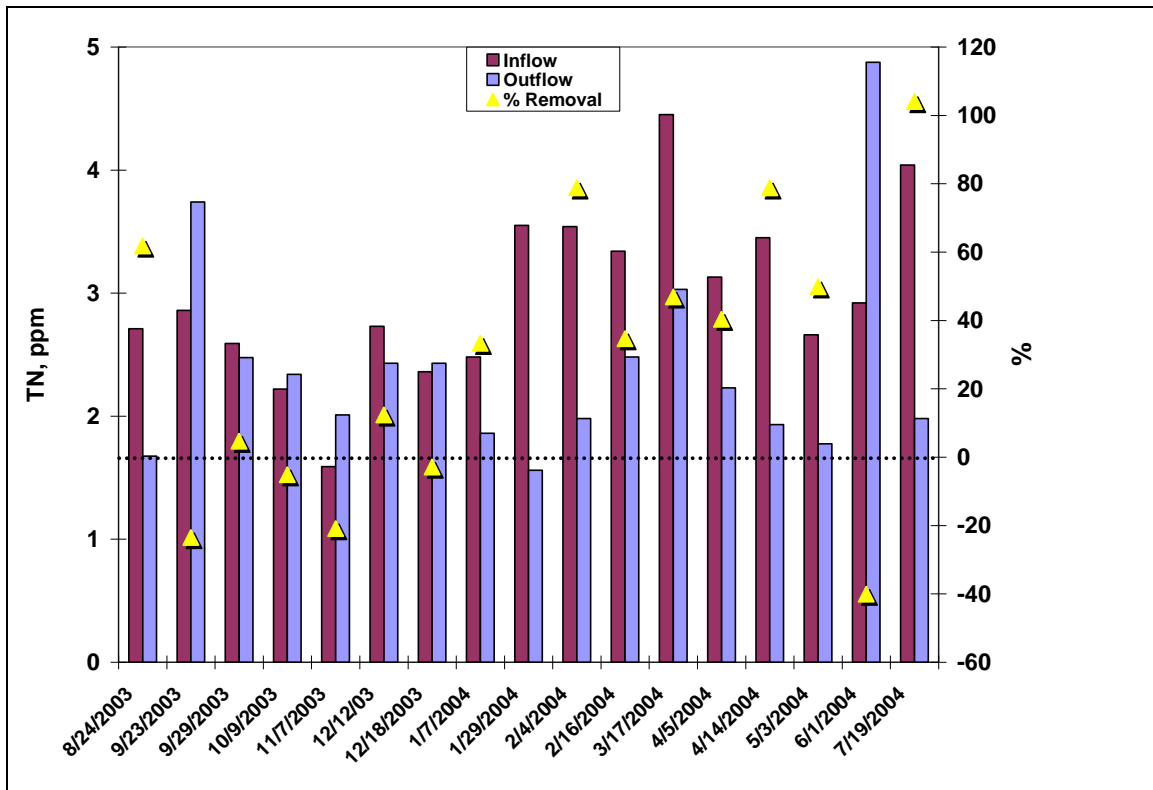


Figure A2: Change in TN concentration due to BMP treatment by storm event.

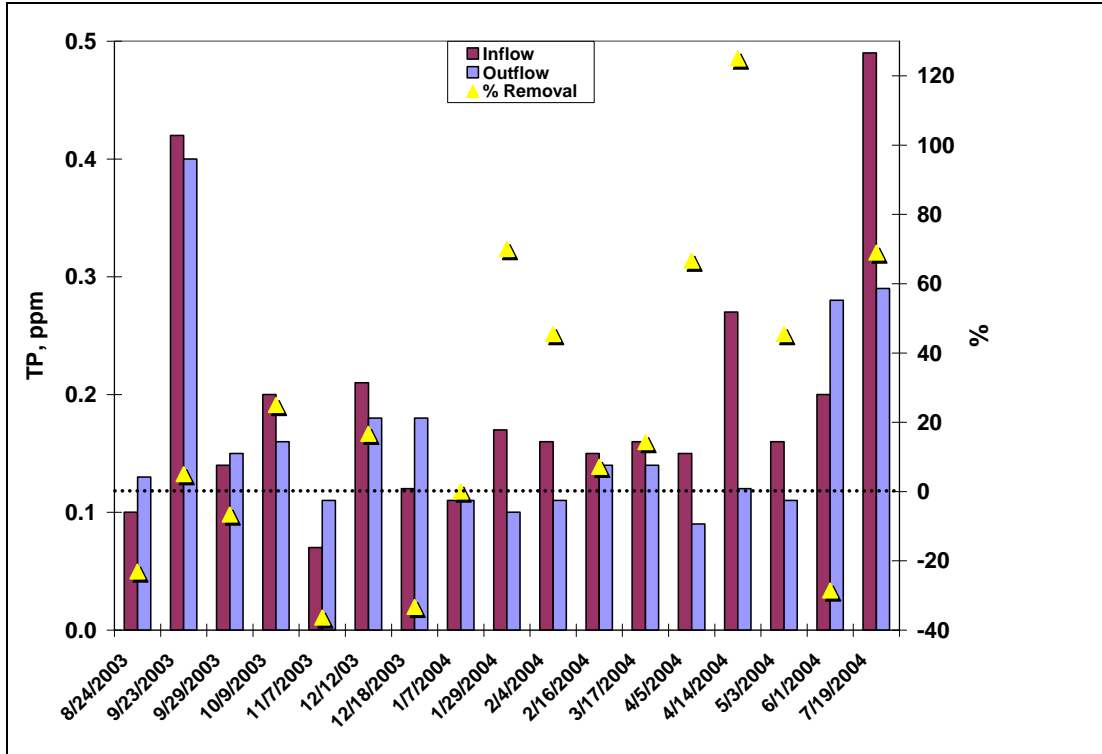


Figure A3: Change in TP concentration due to BMP treatment by storm event.

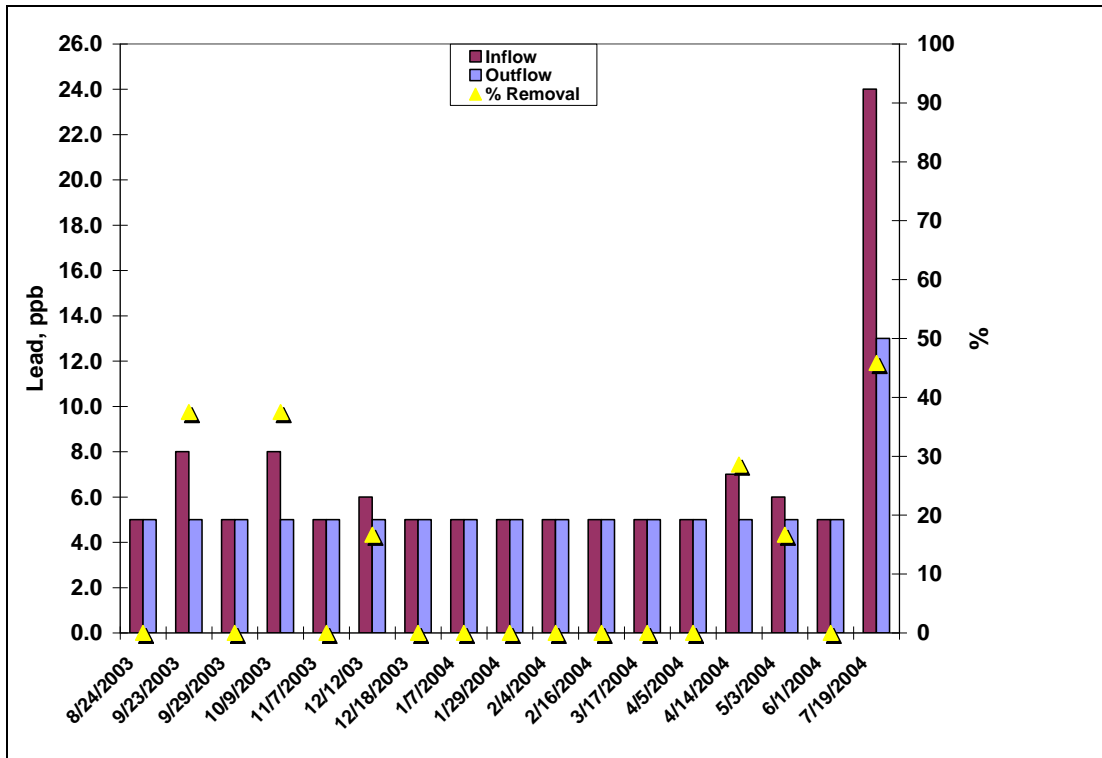


Figure A4: Change in Lead concentration due to BMP treatment by storm event.

## APPENDIX B

### *Monitoring Protocol*

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## Stormwater BMP performance Monitoring Protocol for:

### *Shade Valley Wet Pond*

#### **Description of Site:**

The Shade Valley wet pond is a non detention BMP providing stormwater treatment to the storm drainage system of Shade Valley apartments. The wet pond is currently in a state of some degradation as the banks are mowed to the water level and are currently eroding. The short grass along the edge encourages waterfowl to use the area extensively as habitat and for feeding. The City of Charlotte has funded a “retrofitting” project to convert the wet pond to a water quality treatment wet pond by the addition of a littoral shelf along the edge and the excavation of a fore bay.

#### **Watershed Characteristics (estimated)**

Size: 27.36 acres  
Use: Residential

#### **Sampling equipment**

Inlet conditions do not allow flow monitoring at this location. However since the wet pond is effectively a flow thru 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 120 degree v-notch weir has been installed at the outlet. An ISCO model 720 flow meter should be used measure flow. 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: 120 degree V- notch weir  
Secondary Device: Model 720 Bubbler  
Bottle Configuration 24 1000mL Propak containers





Rain gage

ISCO model 763 Tipping Bucket rain gage

**Sampler settings**Inlet Sampler

Sample Volume	200 mL
Distribution	5/bottle
Pacing	External Flow meter
	1 pulse
Set point enable	None

Outlet Sampler

Sample Volume	200mL
Distribution	5/bottle
Pacing	8000 Lit
Set point enable	> .02 cfs

**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.