CITY of CHARLOTTE
Pilot BMP Monitoring Program

CATS - Bus Maintenance Operations Facility
Downstream Defender® Stormwater Treatment Structure

Final Monitoring Report

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Charlotte-Mecklenburg Storm Water Services

Purpose

The purpose of this report is to document monitoring and data analysis activities undertaken by the City of Charlotte, Mecklenburg County, and NC State University to determine the effectiveness and stormwater treatment capabilities of the Downstream Defender® stormwater treatment structure installed at the City of Charlotte-CATS-Bus Maintenance Operations Facility (BMOF).

Introduction

Hydrodynamic separators are a class of structural stormwater BMP that rely on the mechanisms of settling and separation to remove heavy particles (such as sediment) and floating particles (oil, grease, and gross solids) from a given watershed. Stormwater is routed into the flow-through system where the energy of the water carries it through the system in a particular flow path (typically a swirl action or through some filtration mechanism) where pollutants can be removed and stored in the system (EPA, 1999). Currently, there are a number of different models of hydrodynamic separators sold by private companies designed for use in stormwater treatment.

Hydrodynamic separators are designed primarily to remove sediment, oil, and grease from a given watershed. In addition, these systems have been shown to remove some nutrients and metals by various studies, primarily by slowing influent stormwater and allowing suspended particles to settle out. When flood control is a primary concern, hydrodynamic separators will not act to remediate the impact of imperious areas.

This report will focus on the effectiveness of the Downstream Defender®, a hydrodynamic separator produced by Hydro International, plc that was installed at the CATS BMOF site. This unit works byway of a swirl action produced by introducing the stormwater into the system tangent to the circular internal cavity. The following description of the system function was taken from the product website: http://www.hydro-international.biz/stormwater/downstream.php

According to the website, “stormwater is introduced tangentially into the side of the vessel, initially spiraling around the perimeter. Oil and floatables rise to the water surface and are trapped in the outer annular space. As the flow continues to rotate about the vertical axis, it travels downward. Low energy vortex motion directs sediment toward the center and base of the vessel. Internal components at the base protect stored sediments and direct the effluent up through the inner annular space. A stable flow regime maximizes removal and prevents re-entrainment of stored pollutants.”

Site Description

The 6-ft model Downstream Defender® was installed at the Charlotte Area Transit System (CATS) Bus Maintenance and Operations Facility (BMOF). The drainage area for the system was approximately 2.25 acres and primarily consisted of concrete bus parking areas, driving lanes, and metal roofs (Figure 1).

Figure 1: Photo of watershed area draining to BMP

Monitoring Plan and Data Analysis

Inflow and outflow monitoring took place in the 24-inch reinforced concrete pipes located immediately upstream and downstream of the BMP, respectively.

During some storm events, the inlet pipe had the potential for a slight tail water condition. Monitoring consisted of measuring stormwater flows utilizing area-velocity flow meters and collecting flow-weighted composite samples using automated sampling equipment. Monitoring equipment was attached within the pipe system using expansion brackets as shown in Figure 2.

Figure 2: Typical installation of area-velocity probe (left) and sampler intake (right) with expansion bracket

Monitoring efforts were initiated in July 2005 and continued until March 2007, with 25 individual storm events being collected / measured approximately once per month.

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 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 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, 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. See Appendix A.

Data Analysis Results

Flow Results

The flow data collected at the site was somewhat inconsistent with what would be expected. This BMP is not intended to be a detention system; thus, the flow in should be equal to the flow out during a given rain event. The area velocity meters used for monitoring the CATS BMOF Downstream Defender® produced different flow values at the inlet and outlet (Figure 3), with the inlet volume being higher than the outlet in most cases. This is likely due to the wide variability of factors that can affect area velocity flow measurement in smaller pipe systems for any given storm event. In addition, during some storm events, backwater conditions were present in the system, which may also have contributed to the variability of flow measurements. Although inflow and outflow flow measurements did not match as expected, it is felt that the flow weighted samples collected were reasonable estimations of event mean pollutant concentrations produced. In addition, concentration data were analyzed as part of this study, which is the primary measurement factor being used to evaluate efficiency relationships between influent and effluent pollutants

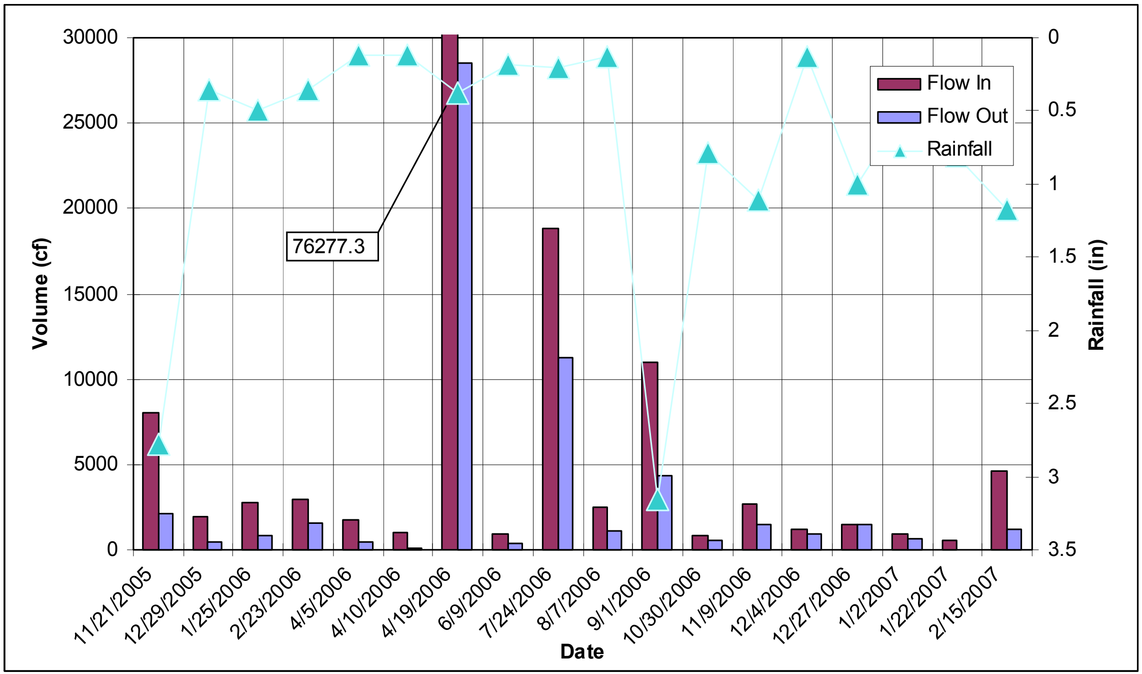

Figure 3: Influent and effluent volumes for various storm events

Water Quality Results

Figure 4 and Table 1 illustrate the performance of the CATS BMOF Downstream Defender® 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 BMP as stormwater runoff, was retained by the BMP. A negative ER represents a surplus of pollutant leaving the BMP, suggesting either internal production of pollutants, or more likely a loss of stored pollutants from previous storm events.

Negative ERs were calculated for all pollutants other than NOx and SSC; however, only the increase in TR was statistically significant ($p<0.05$). The performance of this BMP varied from a water quality stand point. Changes in the ER were noted from storm to storm for many pollutants. According to statistical tests performed on the data set collected from the site, the CATS BMOF Downstream Defender® did not significantly ($p<0.05$) reduce any pollutants (Figure 4 and Table 1).

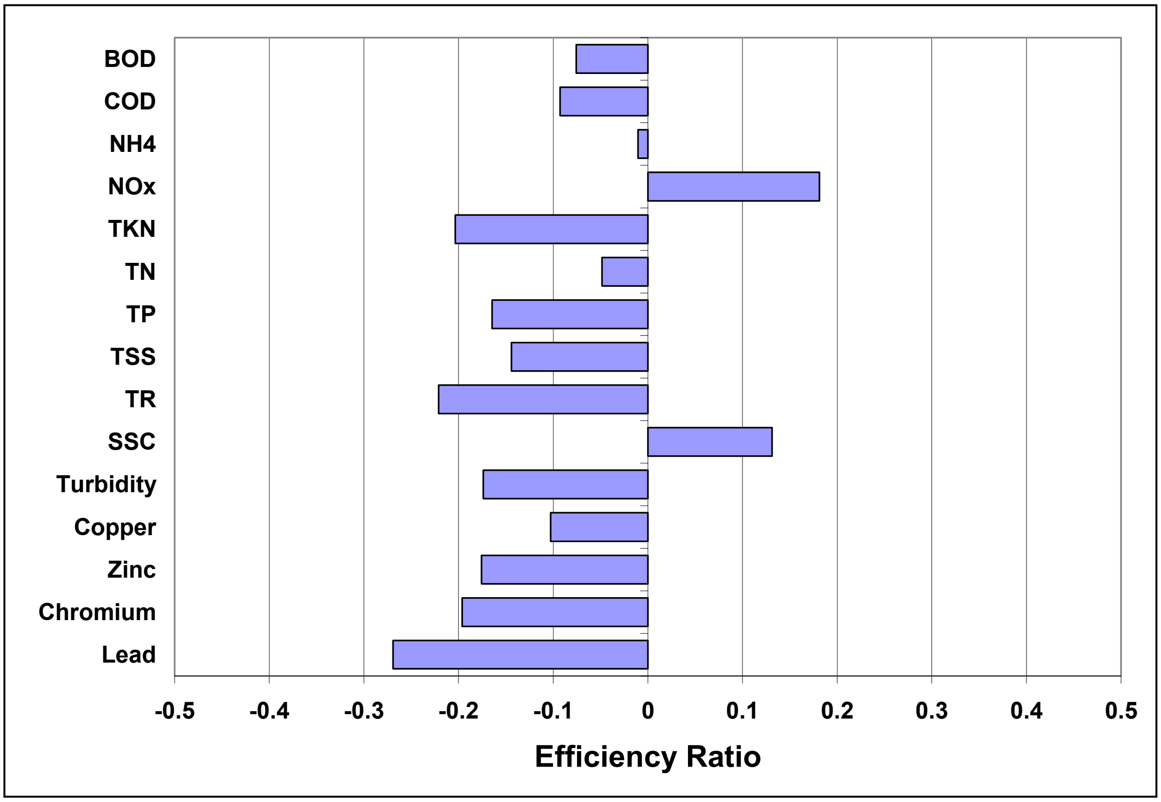

Figure 4: Efficiency ratios of selected pollutants based on pre- and post-BMP mean concentrations (EMCs) at the Downstream Defender®.

**** Indicates a statistically significant relationship**

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

Table 1: Summary of Water Quality Results

Parameter	Units	# of Samples	Influent EMC	Effluent EMC	ER	p-value	Significant ($p < 0.05$)
BOD	Ppm	**5**	231.9	249.4	-8%	0.500	**No**
COD	Ppm	**8**	657.4	718.3	-9%	0.742	**No**
NH4	Ppm	**19**	0.2	0.2	-1%	0.910	**No**
NOx	Ppm	**19**	0.6	0.5	18%	0.734	**No**
TKN	Ppm	**19**	0.9	1.1	-20%	0.164	**No**
TN	Ppm	**19**	1.5	1.6	-5%	0.602	**No**
TP	Ppm	**19**	0.1	0.2	-16%	0.325	**No**
TSS	Ppm	**20**	52.7	60.3	-14%	0.870	**No**
TR	Ppm	**9**	161.1	196.7	-22%	0.039	**Yes**
SSC	Ppm	**9**	31.6	27.4	13%	0.461	**No**
Turbidity	NTU	**20**	37.5	44.1	-17%	0.237	**No**
Copper	Ppb	**17**	21.2	23.4	-10%	0.901	**No**
Zinc	Ppb	**17**	156.6	184.1	-18%	0.353	**No**
Chromium	Ppb	**6**	7.7	9.3	-20%	0.563	**No**
Lead	Ppb	**10**	97.2	108.3	-27%	0.106	**No**

Sediment

The ER for TSS removal in the Downstream Defender® was -0.14 (not significant at $\propto=0.05$). The storm to storm variability in ER indicates that although there may be some treatment for TSS occurring in the BMP, likely through sedimentation and filtration, there may also be some resuspension of sediment during some storm events. Influent and effluent TSS concentrations substantially varied throughout the study, and statistically significant relationships were not found (Appendix A – Figure A1). The BMP was cleaned in early 2005 as part of the site construction close out and then again in March 2006, September 2006, and March 2007. Because only individual storm events were monitored, on a monthly basis, and not all storm events were captured, performing a mass balance was not feasible; therefore, it is possible for the BMP to show a negative pollutant removal (conservation of mass can not be applied).

In addition to the TSS samples taken at the site, 9 storm events were sampled for SSC as well. SSC is considered by some to be a more accurate analysis of sediment concentration in a given sample (Glysson et al., 2000). The

ER for SSC removal in the Downstream Defender® was 13%. SSC concentrations for each storm can be seen in Appendix A – Figure A2.

It should be noted that there was a significantly lower number of samples analyzed for SSC than TSS (Table 1) and that collecting samples from the bottom of the pipe (conventional method) could result in inaccurate representative samples during some storm events (Andoh et al., 2002). It is desirable to collect a sample which is pulled from the entire flow stream, which may not have occurred during some larger storm events. However, this was not a feasible goal for the purpose of this study, as the Pilot BMP monitoring program has employed conventional monitoring protocols to analyze a number of various BMPs, including both proprietary and non-proprietary practices.

A review of literature suggests that very few studies have been performed specifically on the function of the Downstream Defender®; however, it was tested as part of the New Jersey Corporation for Advanced Technology (NJCAT) Program. In the study, the manufacturer's claim of 70% solids mass removal efficiency (at a loading rate of 20 gpm/ft^3) was verified per the New Jersey Department of Environmental Protection (NJDEP) treatment efficiency calculation methodology. Observation of the testing method; however, showed that the performance was verified for F-95 sand (average d_{50} = 120 microns) at a concentration of 240 mg/l.

The conditions under which the system was tested as part of the NJCAT program differ from those experienced during the Charlotte pilot BMP monitoring program. Although no particle size analysis was performed on the influent or effluent sediment from the BMP, a brief study of the soils in Mecklenburg County shows that the dominant soils types in the area are loam, sandy loam, and sandy clay loam. The d_{50} for these soils ranges between 98 and 35 microns (Munoz-Carpena and Parsons, 2005), which suggests the potential for smaller soil particles in the studied watershed than those used in the NJCAT study. In addition, other non-sediment sources of suspended solids may occur in urban stormwater runoff based on watershed characteristics. This can not be verified due to the lack of a particle size analysis but is inferred from the soils present in the surrounding areas. Sediment makeup can impact hydrodynamic separator function (Andoh et al. 2002 and Barbaro, 2005). Very small sediment particles can be more difficult to remove from the flow stream and can be considered non-settleable suspended solids. The presence of settleable solids is important in the function of BMPs that rely of hydraulics instead of filtering to remove solids.

Likewise, the influent TSS concentrations for the CATS BMOF site were significantly lower than those present for the NJCAT study. The TSS EMC was 52.7 mg/L, substantially lower than the concentration of sand used in the NJCAT study. Low influent pollutant concentrations can lead to low removal efficiencies as the influent pollutant is closer to an irreducible concentration.

Although there has been little documentation on the function of the Downstream Defender with regard to pollutant removal efficiency, there have been hydrodynamic devices studied and input into the International Stormwater BMP database (ISBD). Table 2 shows the median pollutant effluent concentration for Hydrodynamic devices in the International Stormwater BMP database (Geosyntec, 2006). The median effluent TSS concentration determined for the Downstream Defender® (36.5 mg/L) is essentially the same as that reported by Geosyntec, 2006 (36 mg/L) in a report summarizing studies in the International Stormwater BMP database. Lower inflow concentrations likely contributed to the low TSS ER reported for the Downstream Defender® in this study. This indicates that the influent TSS concentration may have been at or below the irreducible concentration for hydrodynamic devices. It should be noted that the report by Geosyntec (2006) indicated a significant difference in the influent and effluent EMC for hydrodynamic devices in the national stormwater BMP database; however, the composition of the influent sediment and the influent concentrations are not reported.

Table 2: Comparison of Median Effluent Concentration for Various Hydrodynamic Devices

Parameter	**Downstream Defender at CATS - BMOF**		**International Stormwater BMP database (Geosyntec, 2006)**		
	Median of Effluent EMCs (mg/L)	Significant Difference between influent and effluent EMC ?	Median of Effluent EMCs (mg/L)	Significant Difference between influent and effluent EMC ?	Number of BMPs Studied
TSS	36.5	No	36	Yes	14
TN	0.98	No	2.16	No	2
TKN	0.5	No	1.31	No	4
NOx	0.32	No	0.25	No	4
TP	0.14	No	0.16	Yes	12
Zinc	130.0	No	100	Yes	11
Copper	20.0	No	15	No	9
Lead	13.0	No	6.7	Yes	8

Nutrients and Organic Material

Downstream Defender® Removal rates for TN and TP are not readily documented by other studies; however, the median effluent concentrations can be compared to the International Stormwater BMP database (Table 2). Based on this comparison, this study showed effluent concentrations that were consistent with other hydrodynamic separator studies. A major pollutant removal mechanism typical of hydrodynamic devices is sedimentation. Since many pollutants are associated with sediment, this pollutant removal mechanism can have a substantial impact (Vaze and Chiew, 2004) on some nutrients. In this case, however, a low TSS removal efficiency may be tied to the low removal efficiency of other pollutants.

Oxygen Demand:

Biochemical 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. The Downstream Defender® removed BOD with an efficiency of 22% and increased COD (-8%). This is likely tied to the low TSS removal efficiency determined for the device.

There was a lack of literature pertaining to the function of hydrodynamic devices in the removal of COD and BOD, so comparisons to national studies were not made.

Nitrogen:

Soluble pollutants can be removed by chemical adsorption to suspended particles followed by sedimentation of those particles, and by plant uptake and microbial transformations. In stormwater treatment practices (such as wet ponds and wetlands) which rely on biogeochemical reactions, a major removal mechanism of the various forms of nitrogen present in a natural system is bacterial transformation. Hydrodynamic devices are not typically marketed as nitrogen reducing BMPs and are not expected to employ the same mechanisms of pollutant removal as other BMPs (oxidation-reduction reactions, plant uptake, etc.). Thus, nutrient removal in hydrodynamic devices would presumably be low. TKN, NOx, NH_4, and TN removal in the Downstream Defender® was -20%, 18%, -1%, and -5% respectively; however, none of these relationships were statistically significant. The relatively high removal of NOx indicates some anaerobic conditions within the system, likely in the sediment stored within the device.

The effluent concentrations of these nitrogen species can be compared, to some degree, with other hydrodynamic devices in the International Stormwater BMP database (ISBD). Geosyntec (2006) reported the median effluent concentrations for TKN, NOx, and TN as 1.31 mg/L, 0.25 mg/L, and 2.16 mg/L, respectively. The monitoring study performed at the CATS BMOF showed median effluent concentrations of 0.5 mg/L, 0.32 mg/L, and 0.98 mg/L, respectively for the Downstream Defender. Influent EMCs for TKN and TN were low, likely leading to low removal efficiencies. In comparison with the NSBD, the median effluent concentrations for TKN and TN were low. Median effluent NOx concentrations were comparable to those reported in the NSBD. Inflow and outflow TN concentrations for each storm can be seen in Appendix A – Figure A2.

Phosphorous:

TP removal in the CATS BMOF Downstream Defender® was -16%; however, this was not a statistically significant relationship. Thus, statistical analysis cannot verify that the effluent concentrations where higher than those of the influent. 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. In some natural systems, these particles can fall out of solution and be stored on the bottom of the treatment system. Under some conditions, phosphorous can be released from the sediment, adding to the effluent mass of TP. The removal of NOx would suggest some anoxic conditions occur in this device, the same conditions needed for phosphorous export; however, the low TSS removal indicates that TP that is bound to sediment is not being removed from the system.

The median effluent concentration of TP is essentially the same in the CATS BMOF data and for hydrodynamic devices in the ISBD. The median effluent concentration of TP determined for the Downstream Defender® (0.14 mg/L) is essentially the same as that reported by Geosyntec (2006) (0.16 mg/L). Since the median influent concentration of TP calculated for the device was 0.10 mg/L, it is probable that this hydrodynamic separator receives stormwater with a TP concentration so close to the irreducible concentration, that a low removal efficiency results; additionally, sediment bound TP was not readily removed. Inflow and outflow TP concentrations for each storm can be seen in Appendix A – Figure A3.

Metals

As for most of the 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 if conditions are favorable, particularly if their storage zone becomes saturated.

The Downstream Defender® exhibited a metal removal efficiency that would be expected based on the low TSS removal. Zinc, copper and lead removal in the system was -18%, -10 and -27%, respectively. Compared to other studies performed on hydrodynamic devices, the median effluent concentration of zinc, copper, and lead leaving the device was slightly higher, but relatively similar (Table 2). Again, this low removal efficiency is likely related to the low TSS removal that was shown at the site. Due to metals binding to sediment, the relationship between TSS removal and metals removal is likely.

CONCLUSIONS

Based on the monitoring data collected and analyzed for this study at the CATS BMOF, the Downstream Defender® did not significantly reduce measured stormwater pollutants at the site. Although the BMP was routinely maintained at semi-annual to annual intervals, removal efficiencies were found to be negative in regards to TSS, TN, and TP, likely due to resuspension of previously stored pollutants during some storm events. It is also likely that the low influent concentration of pollutants entering this hydrodynamic BMP was a factor which impacted these findings. In addition, sampling at the invert of the stormwater pipes may also have been a factor for some storm events monitored.

Effluent concentrations of TSS, TP, and TN were comparable to those reported for hydrodynamic devices in the International Stormwater BMP database. This indicates that although the efficiency ratios determined for various pollutants were less than the 85% removal efficiency desired by the City of Charlotte, the low influent concentrations likely played a major role in the BMP pollutant removal efficiency.

Compared to the study performed on the Downstream Defender® as part of the NJCAT program, the sediment removal efficiency at the CATS BMOF site was low. It should be noted, however, that the sediment entering the CATS BMOF

Downstream Defender® was presumably much different. The TSS concentration entering the CATS BMOF system was low compared to that of the NJCAT study, and was likely much finer than the F-95 sand used as part of the NJCAT program. As low concentrations of fine particles are hard to remove from the flow stream, the efficiency of the system would presumably (and understandably) be lower.

There is some debate among the water quality profession concerning the most appropriate methodology to quantify suspended sediment concentrations in surface water quality samples. While TSS is the most commonly evaluated parameter, suspended sediment concentration (SSC) is considered by some to be a more appropriate way to quantify this pollutant (Glysson et al., 2000); however, it should be noted that the City of Charlotte's NPDES stormwater permit requires stormwater BMPs to be adequately designed to reduce TSS by 85% in stormwater runoff. Therefore, a TSS removal efficiency of 85% is the predominate indicator of BMP performance within the City's BMP monitoring program.

For comparison purposes, both TSS and SSC samples were collected and analyzed for a number of storm events monitored at this BMP site. The resulting removal efficiencies for the two pollutants were substantially different and showed a TSS removal efficiency of -14% and a SSC removal efficiency of 13%.

Only one analysis produced a statistically significant result regarding the difference in influent and effluent pollutant concentration. Thus, no statistically significant conclusion can be made that would indicate that influent and effluent concentrations are different for the majority of the pollutants analyzed; however, this could also be an indication of the inconsistency of the BMP function in this particular application.

While the removal efficiencies reported for the Downstream Defender® BMP in this study were less than the 85% TSS removal efficiency criteria in the City's NPDES stormwater permit, the results apply to the BMP's performance within one specific land use type (that being impervious areas associated with commercial/municipal parking areas and roof tops). In addition, it should be noted that the influent EMCs reported at the CATS BMOF facility were comparable to influent EMCs reported for other conventional BMPs with similar land use types studied under the City’s program.

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Hydro International website: http://www.hydro-international.biz/stormwater/downstream.php

APPENDIX A

Additional Graphs and Tables

Table A1: Results of statistical between inlet and outlet BMP concentrations of selected pollutants at the CATS BMOF Downstream Defender®

Parameter	Assumed Distribution	Reject Based on KS Test	Paired *t*-Test	Wilcoxian Signed - Rank Test	Significant ?
			p - value		
BOD	Log	No	0.2914	0.5	**No**
COD	Log	No	0.7055	0.7422	**No**
NH4	Log	**Yes**	0.9184	0.9102	**No**
NOx	Log	**Yes**	0.0297	0.7337	**No**
TKN	Log	No	0.1208	0.164	**No**
TN	Log	No	0.7158	0.6023	**No**
TP	Log	No	0.3210	0.3247	**No**
TSS	Log	No	0.6459	0.8695	**No**
TR	Log	No	0.0459	0.0391	**Yes**
SSC	Log	No	0.8785	0.4609	**No**
Turbidity	Log	No	0.1146	0.2374	**No**
Copper	Log	No	0.9747	0.9014	**No**
Zinc	Log	No	0.2114	0.3529	**No**
Chromium	Log	No	0.3062	0.5625	**No**
Lead	Log	No	0.1080	0.1055	**No**

1. Rejection (α=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 except for copper, in which case raw data were used.

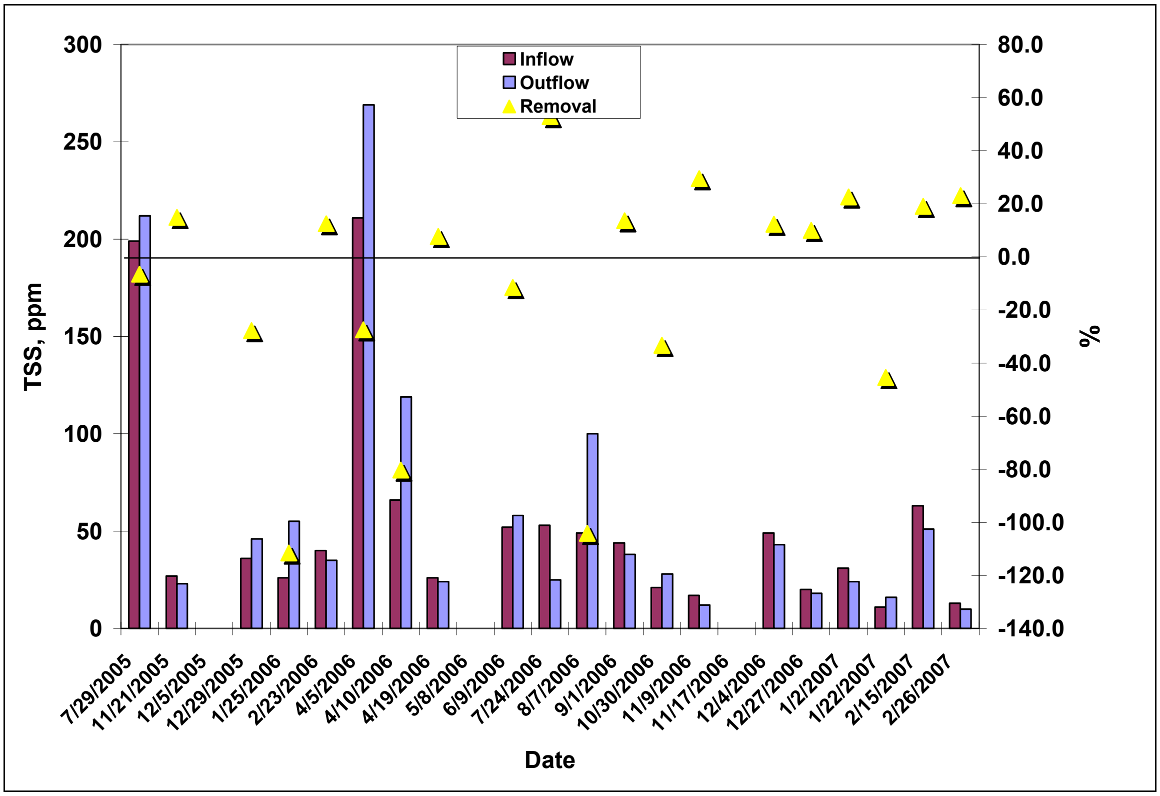

Figure A1: Change in TSS concentration due to BMP treatment by storm event.

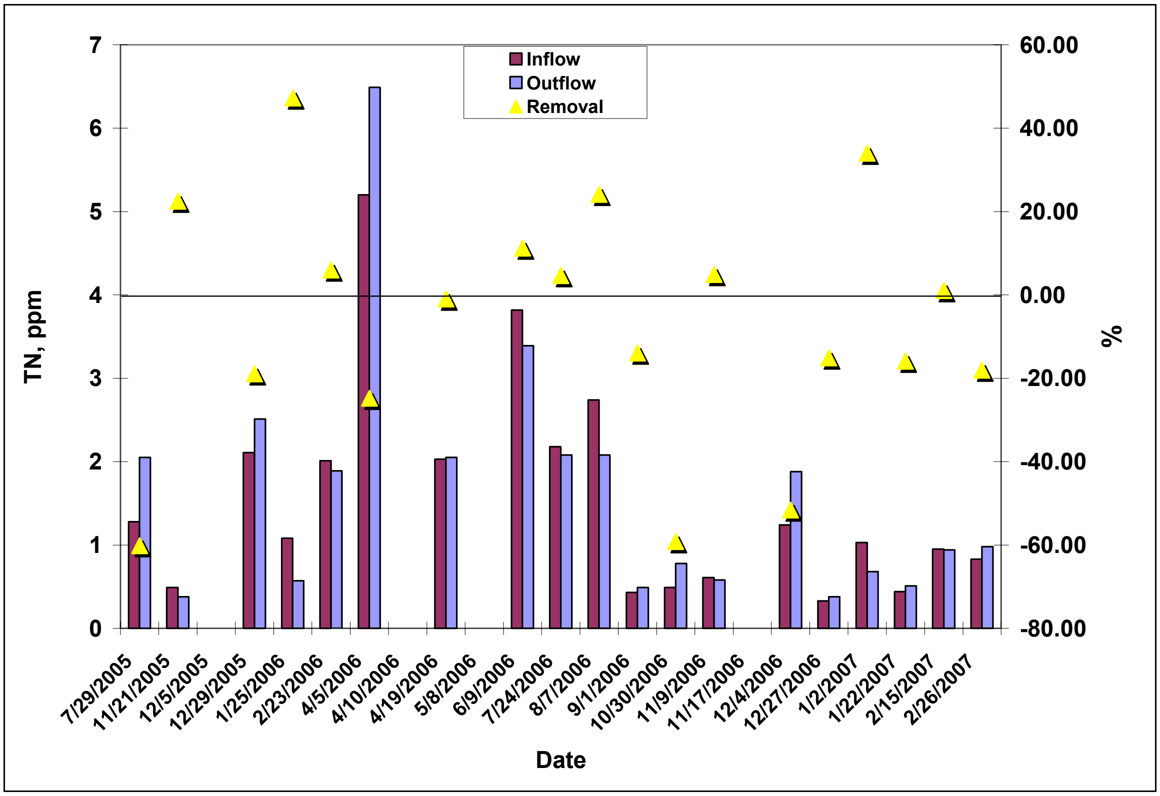

Figure A2: Change in TN concentration due to BMP treatment by storm event.

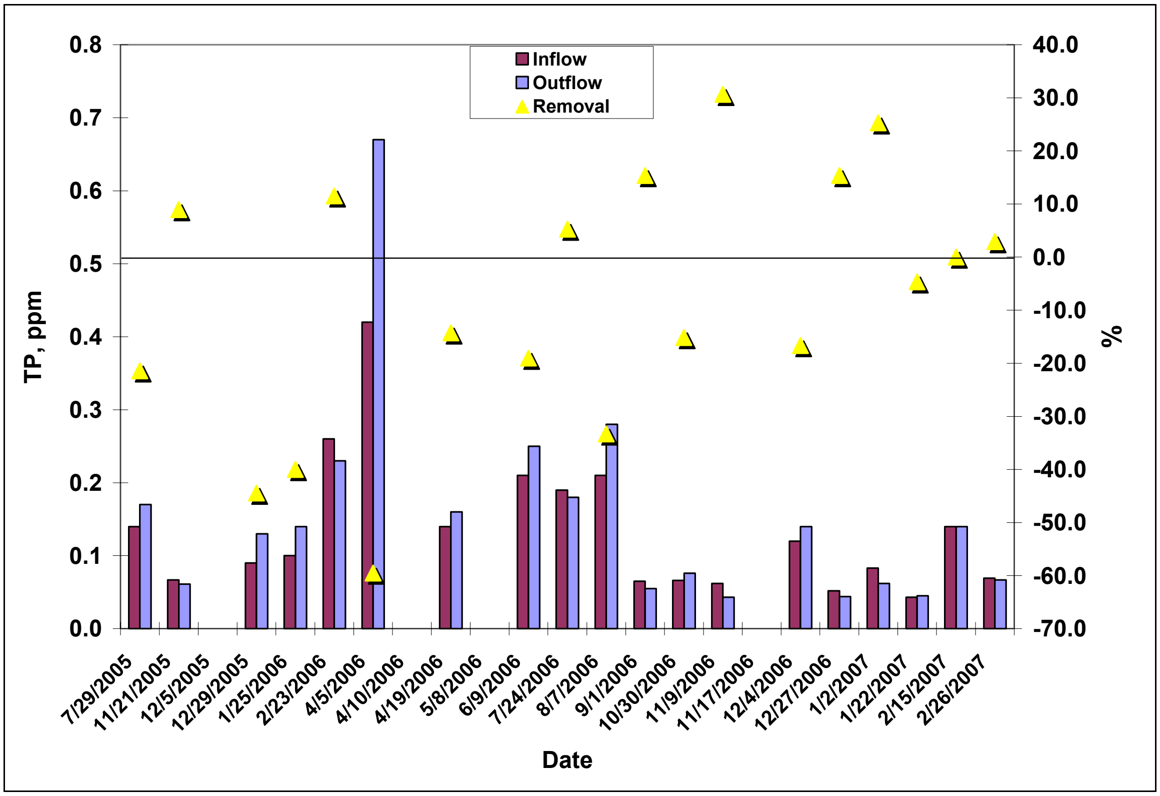

Figure A3: Change in TP concentration due to BMP treatment by storm event.

APPENDIX B

Monitoring Protocol

Stormwater BMP performance Monitoring Protocol for:

CATS Bus Maintenance and Operations Facility
Downstream Defender® BMP

Description of Site:

The CATS-BMOF Downstream Defender® BMP is a manufactured proprietary BMP serving a portion of the Bus Maintenance and Operations facility for the City of Charlotte.

Watershed Characteristics (estimated)

Watershed served by Downstream Defender® BMP is approximately 2.25 acres and is 100% impervious concrete and metal roof surfaces. Primary use of the watershed is for bus parking.

Sampling equipment

Monitoring will take place in the 24” RCP pipes at the sampling manholes located immediately upstream and downstream of the BMP. During storm events this pipe may experience a tail water condition. As a result it is necessary to utilize a low profile Area-Velocity meter at this location. The Area-Velocity meter should be positioned just upstream of the flared section of RCP and not further upstream to avoid any potential turbulence caused by upstream structures.

Inlet Sampler

Primary device:	24” diameter RCP
Secondary Device:	ISCO model 750 area-velocity meter
Sampler	ISCO 3712 Avalanche
Bottle Configuration	four 1 gal polypropylene bottles

Outlet Sampler

Primary Device:	24” diameter RCP
Secondary Device:	ISCO Model 750 area- velocity meter
Sampler	ISCO 3712 Avalanche
Bottle Configuration	four 1 gal polypropylene bottle

Rain gage	ISCO model 674 installed onsite

Sampler settings

Inlet Sampler

Sample Volume	200 mL
Pacing	102 Cu Ft.
Set point enable	None

Outlet Sampler

Sample Volume	200mL
Pacing	102 cu ft
Set point enable	none

As monitoring efforts continue it is very likely that the user will need to adjust the sampler settings based on monitoring results. The user should keep detailed records of all changes to the sampler settings. One easy way to accomplish this is to printout the settings once data has been transferred to a PC.

Sample Collection and Analysis

Samples should be collected and analyzed in accordance with the *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.