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BMP Efficiency in an Institutional Area: Minimizing the Impacts of Water Pollution Using a Stormceptor for Water Quality Improvement

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State University of New York
College at Buffalo

BMP Efficiency in an Institutional Area: Minimizing the Impacts of Water Pollution Using a Stormceptor for Water Quality Improvement

A Thesis in
Multidisciplinary Studies

by

Jameieka J.Price

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of the Requirements
for the Degree of

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1. INTRODUCTION

Buffalo State College (BSC) is an urban campus located in Buffalo, New York. BSC currently holds a National Pollutant Discharge Elimination System (NPDES) Permit to control point - source stormwater runoff that discharges from six different outfalls directly into Scajaquada Creek, untreated (Figure 1.1).

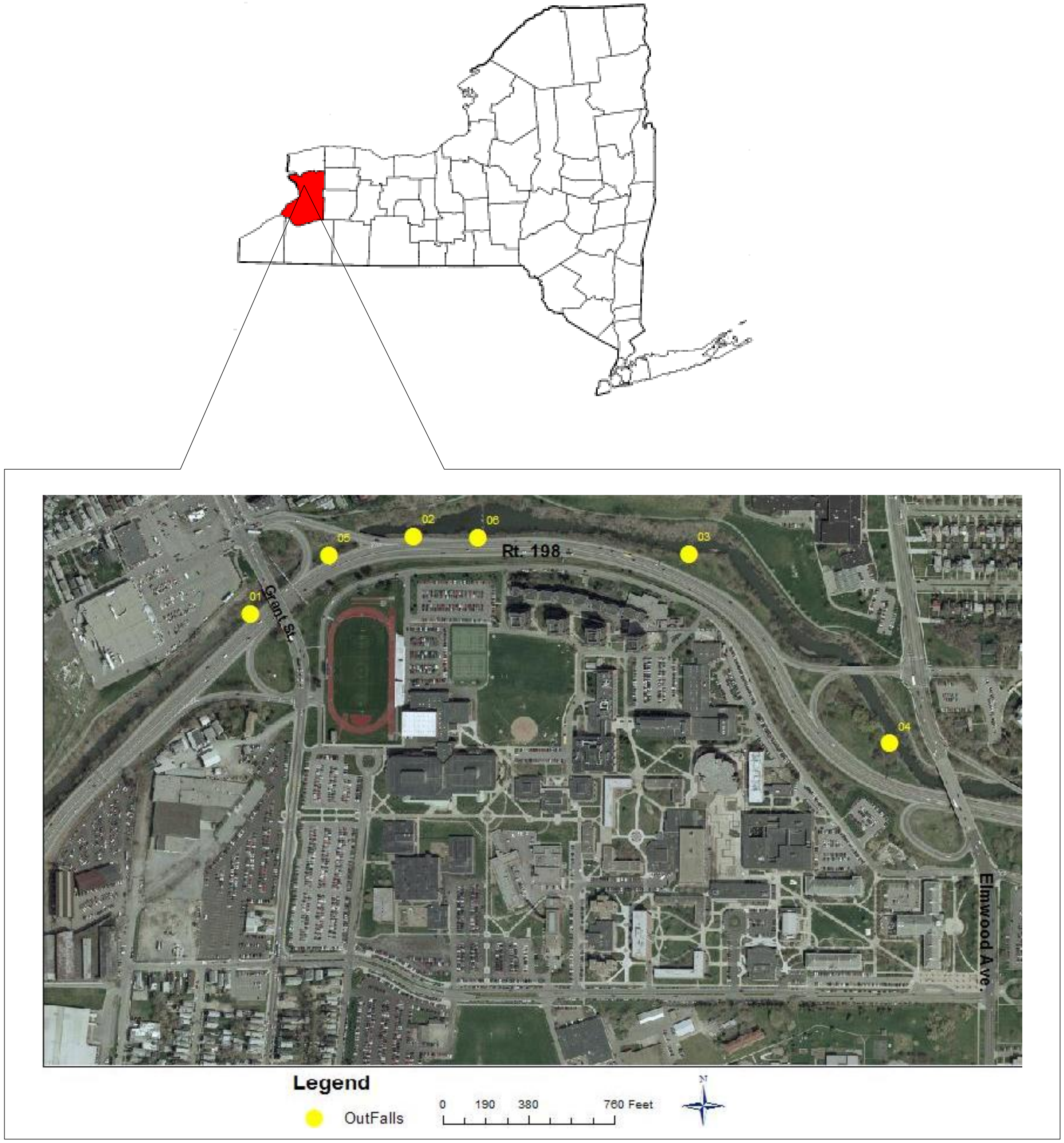


Figure 1.1: Six outfalls border the perimeter of BSC and discharge into Scajaquada Creek, Buffalo, NY

Stormwater runoff can considerably degrade the water quality of a receiving water body, affecting aquatic life, recreational usages, aesthetic appearance, and possibly drinking water supply as it empties out into Niagara River. As of 2010 New York State Department of Environmental Conservation (NYSDEC) designated Scajaquada Creek a Class C water body impaired by its excessive loads of nutrients, floatables, pathogens and oxygen demand (Table 1.1) and BSC is just one of the contributors to the impairment.

Table 1.1: NYS DEC Surface Water Classification

Classification Type	Best Usages Description
Class A	Best usages are: source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. The waters shall be suitable for fish, shellfish, and wildlife propagation and survival.
Class B	Best usages are: Primary and secondary contact recreation and fishing. These waters shall be suitable for fish, shellfish, and wildlife propagation and survival
Class C	Best usages are: fishing. These waters shall be suitable for fish, shellfish, and wildlife propagation and survival
Class D	Best usages are: fishing. Due to such natural conditions as intermittency of flow, water conditions not conducive to propagation of game fishery, or stream bed conditions, the waters will not support fish propagation. These waters shall be suitable for fish, shellfish, and wildlife survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.

www.dec.ny.gov

To counteract further degradation of the creek from BSC stormwater discharges one of the control measures established under the NPDES permit is to adopt Best Management Practices (BMP). BMPs are essential to minimize water pollution in stormwater runoff. BSC has developed a stormwater management plan that includes construction of a number of BMPs, one of them being a Hydrodynamic Separator System: In - Line Stormceptor STC - 2400 ® in one of its larger subcatchments (Figure 1.2). The Stormceptor is an optimal resolution to reducing stormwater pollution because it is designed to remove the sediment particles from stormwater runoff and a variety of pollutants that are associated with the particles.

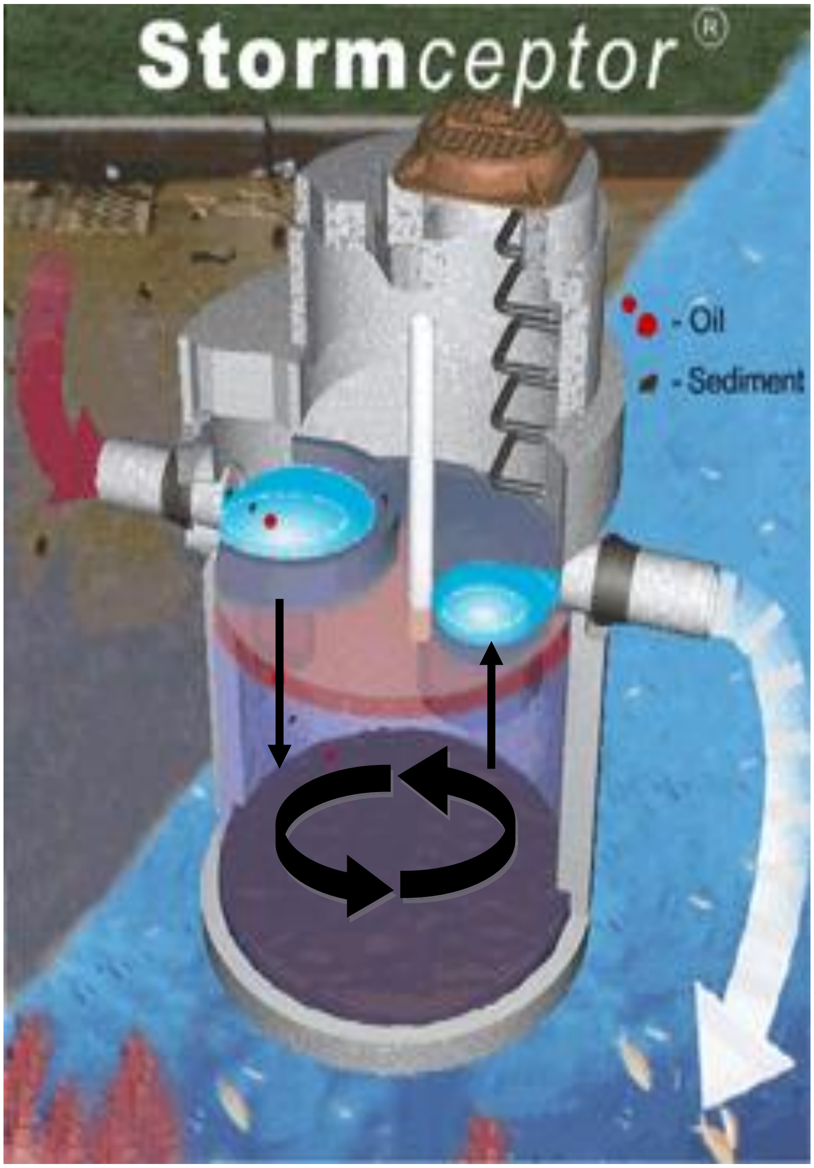


Figure 1.2: Rinker In - Line Stormceptor STC – 2400 ®. Stormceptor is a BMP used to remove oil and particle-bound sediments.

The objective of this study was to assess how effective the installed Stormceptor was at removing the design specific pollutants of Total Suspended Solids (TSS), heavy metals, oil and grease, and non-design specific pollutants that include all other particle-bound pollutants such as phosphorus and nitrate. Water quality samples were collected during four storm events and analyzed. A personal computer version of the Stormwater Management Model (PCSWMM) was calibrated and run to help assess stormwater runoff and the seasonal pollutant load discharging to Scajaquada Creek.

2. LITERATURE REVIEW

2.1 Urbanization

Urbanization on the one hand creates growth and economic opportunities in cities, but at the same time it leads to detrimental effects on the hydrology and water quality of local waterways. The hydrology is affected by an increased imperviousness which then increases the volume of runoff and peak discharges (Lee and Heaney 2003). When more roads, parking lots, and buildings are constructed pollutants build-up on these surfaces and ultimately are washed into stormwater or combined sewer systems and may be discharged to local receiving water bodies (Brabec et al. 2002; Ren et al. 2003). Hydrographs are a useful tool to observe the impacts of urbanization on water quality by taking into account the rate of flow over a period time during a storm event. Figure 2.1 shows what a typical hydrograph looks like after urbanization. Figure 2.2 shows that adding a BMP greatly reduces the peak flow back to a pre-urbanization stage. Figure 2.3 illustrates that before urbanization runoff is able to infiltrate into the soil over a longer period of time. After urbanization infiltration is minimized and surface runoff builds to a peak more quickly and as the storm comes to a halt so does the flow (Ferguson 1998). Impervious areas are a good indicator of environmental quality (Arnold and Gibbons 1996). An impervious surface prevents natural pollutant processing in the soil by preventing percolation. Therefore, pollutants can end up in water bodies by traveling through a series of underground pipes that collect only storm water known as municipal separate storm sewer systems (MS4s) or through combined sewer overflows (CSOs). There is a correlation between impervious surface and the hydrologic changes that degrade water quality.

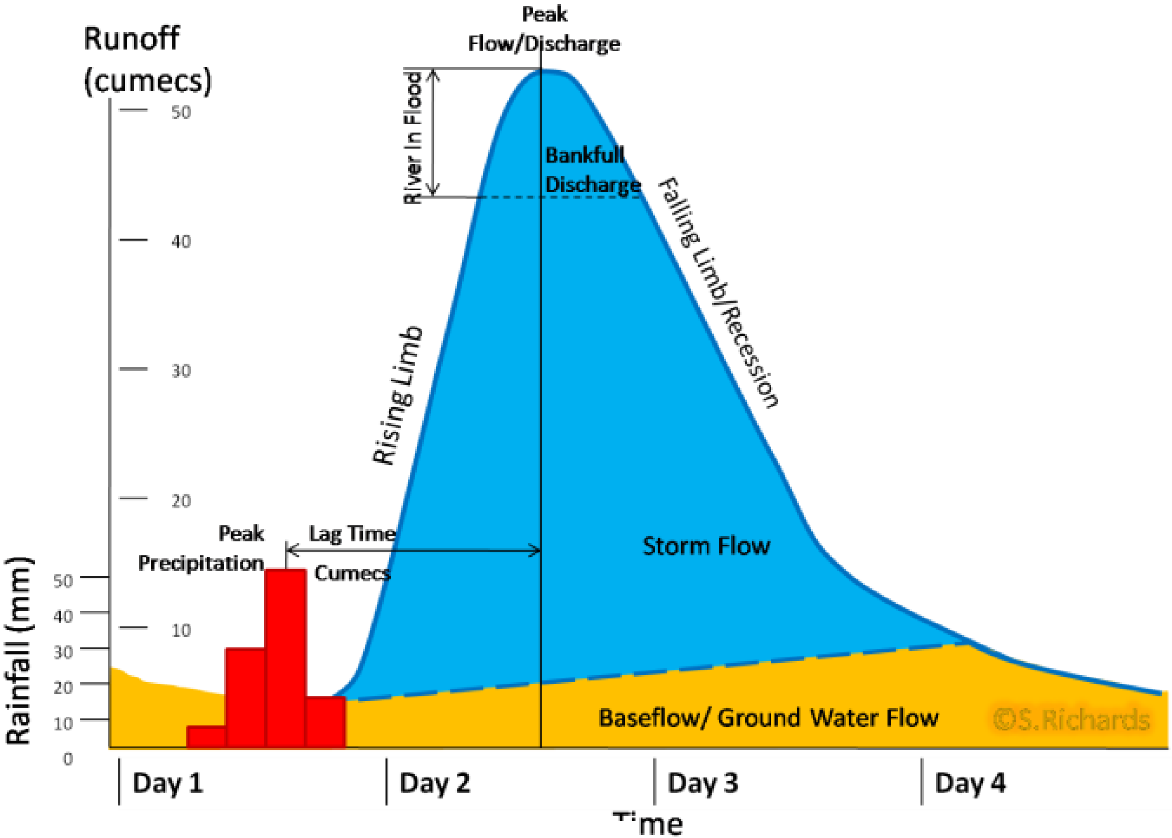


Figure 2.1: Storm Hydrograph

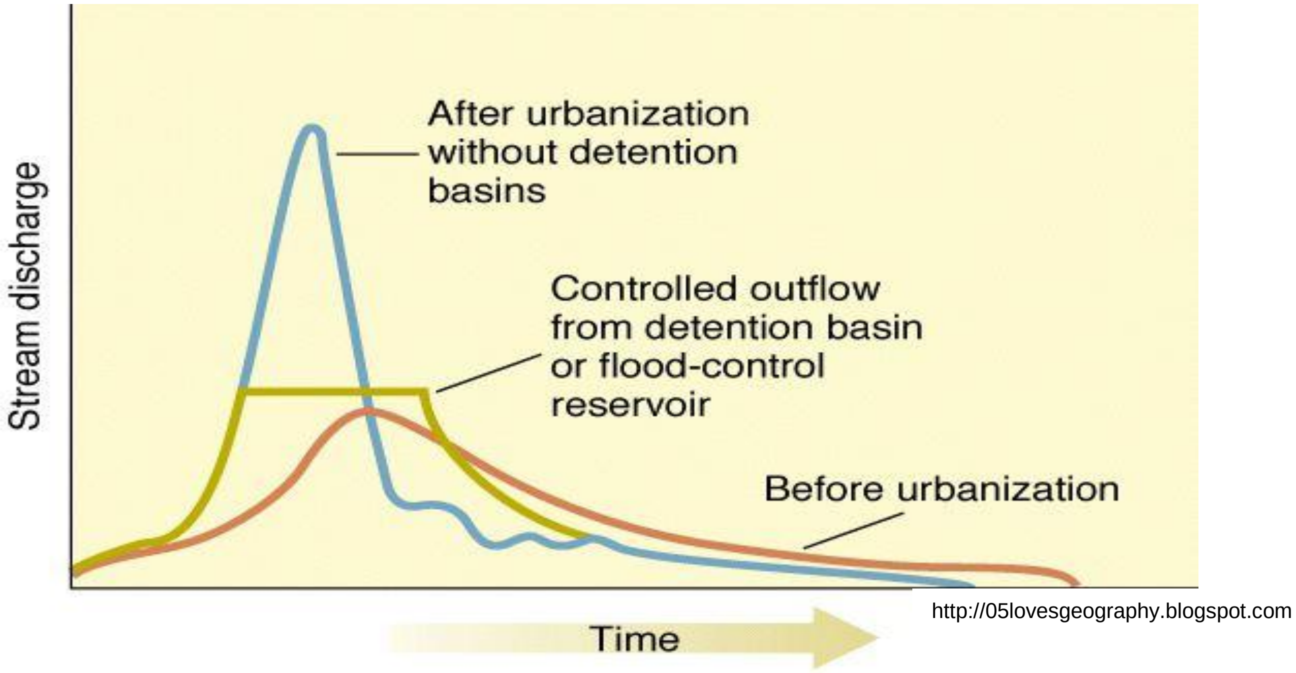
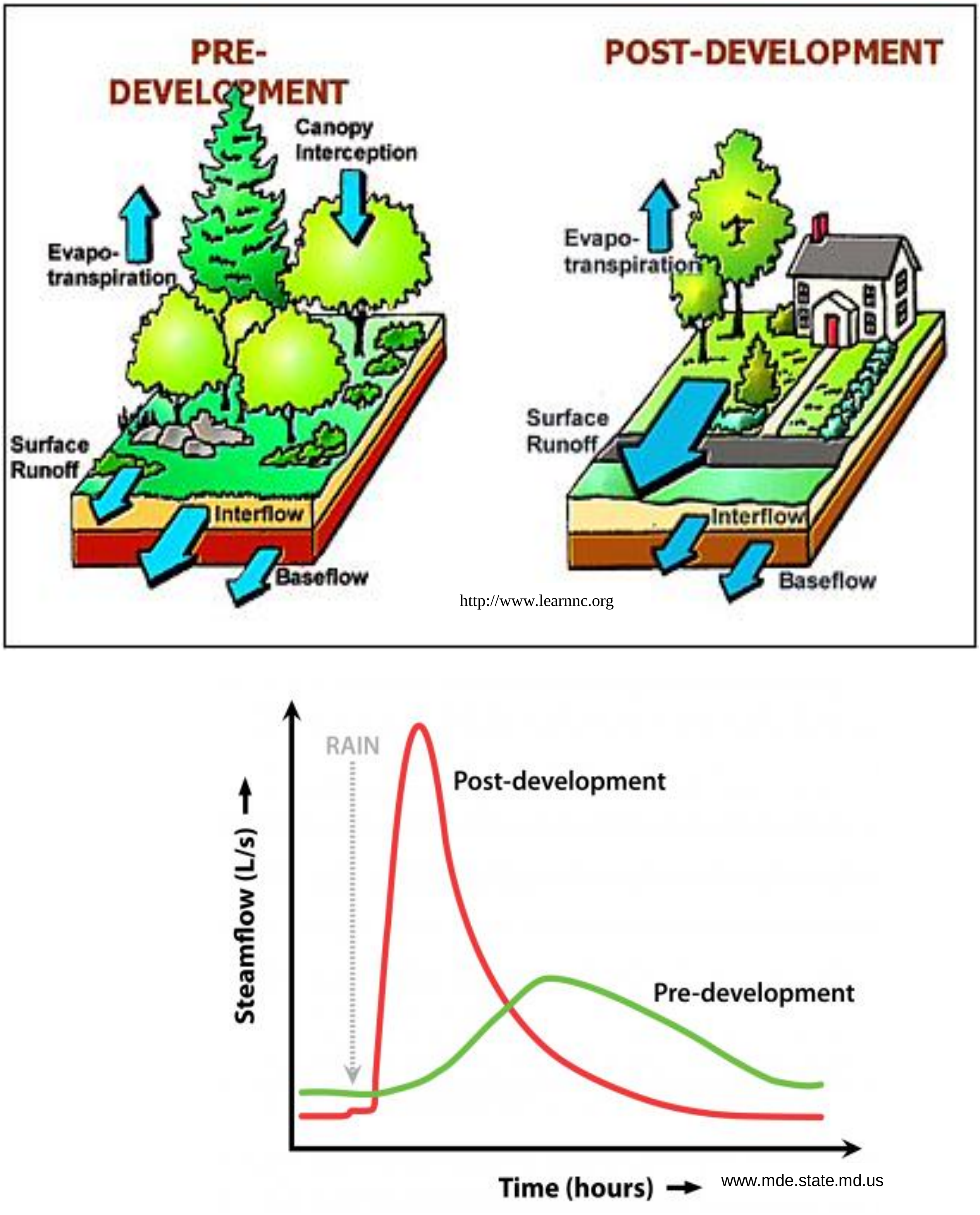


Figure 2.2: Hydrograph with BMP



http://www.learnnc.org

www.mde.state.md.us

Figure 2.3: Before and after urbanization. Pre – development (before urbanization) shows that surface water can be infiltrated into the ground and post development shows that there is a greater amount of surface runoff and a smaller amount of infiltration.

BSC has become more urbanized since it first opened its doors in 1871, from open spaces to more buildings and parking lots (BSC Stormwater Management Plan 2008) and this has led to an increase in hydrologic load. The college continues to expand, and to manage the pollutants in the stormwater runoff, BSC has installed a Stormceptor. When an area becomes more urbanized, the way the land is utilized can have an impact on the water quality (Tong and Chen 2002). Knowing the type of land use can assist in determining the types and amount of pollutants that may be found in the area (Goonetilleke 2005; Al-Hamdan 2006), although Maestre and Pitt (2007) had determined that land use cannot predict stormwater quality based on their study from collecting 594 samples for 16 different land uses. Likewise, they noted there are other ways to predict stormwater quality by looking at the characteristics of the precipitation the site or watershed receives, the physical characteristics of the site or watershed, and the anthropogenic activities that occur on each of the source areas within the site or watershed. Anticipating the type of pollutants in the runoff is beneficial for selecting pollutants to be analyzed for the monitoring protocol. BSC is an institutional land type and consists of four types of land uses: roads, lawns, roof tops, and parking lots (BSC Stormwater Management Plan 2008). Fewer pollutants would be found in lawns, whereas streets would contain the most pollutants (Baker 2006). Nutrients are more likely to be abundant in lawns, oil and grease in parking lots, TSS, and heavy metals on streets and zinc on roof tops (Sartor et al. 1974).

2.2 Stormwater Runoff

The natural occurrence of rainfall, which inevitably flows down streets, sidewalks and rooftops turns into stormwater runoff that causes hydraulic sorting, where it sweeps up everything in its pathway including trash, oil and dirt (Baxter 2004). Ever since the 1960’s it has become evident that stormwater runoff is a source of pollution (Granier et al. 1990). Many researchers have concluded that urban stormwater runoff contains high concentrations of heavy metals, bacteria, nutrients, and TSS that end-up in storm drains and outlets into rivers and lakes, negatively affecting receiving water bodies (Sartor et al. 1974; Bedient et al. 1980; Hall and Anderson 1987; Schroeter et al. 1989; Bannerman et al. 1993; Novotny et al. 1997). Locally, and for this study, the water body is Scajaquada Creek. Direct pollution from runoff affects dissolved oxygen levels, aquatic life, is aesthetically unpleasing and can cause eutrophication (Al-Hamdan et al. 2006; Pitt 2007).

Point- source pollution on BSC is regulated under the National Pollution Discharge Elimination System (NPDES) where the college is allowed to discharge the water directly into Scajaquada Creek from the MS4 as long as the amount of the pollutants are minimized using BMPs (BSC Stormwater Management Plan 2008).

In the 1800's and first half of the 1900s Sewers were constructed to collect and dispose of stormwater before being discharged into the nearest water body. To minimize the financial burden of constructing a new separate system, domestic wastewater was discharged into these large storm drains, automatically converting them into CSOs (Figure 2.4). Untreated overflows caused by exceeding the hydraulic capacity of the combined sewers during wet weather events have proven to be a substantial pollution source (Filippi 1971; Field and Struzeski 1972).

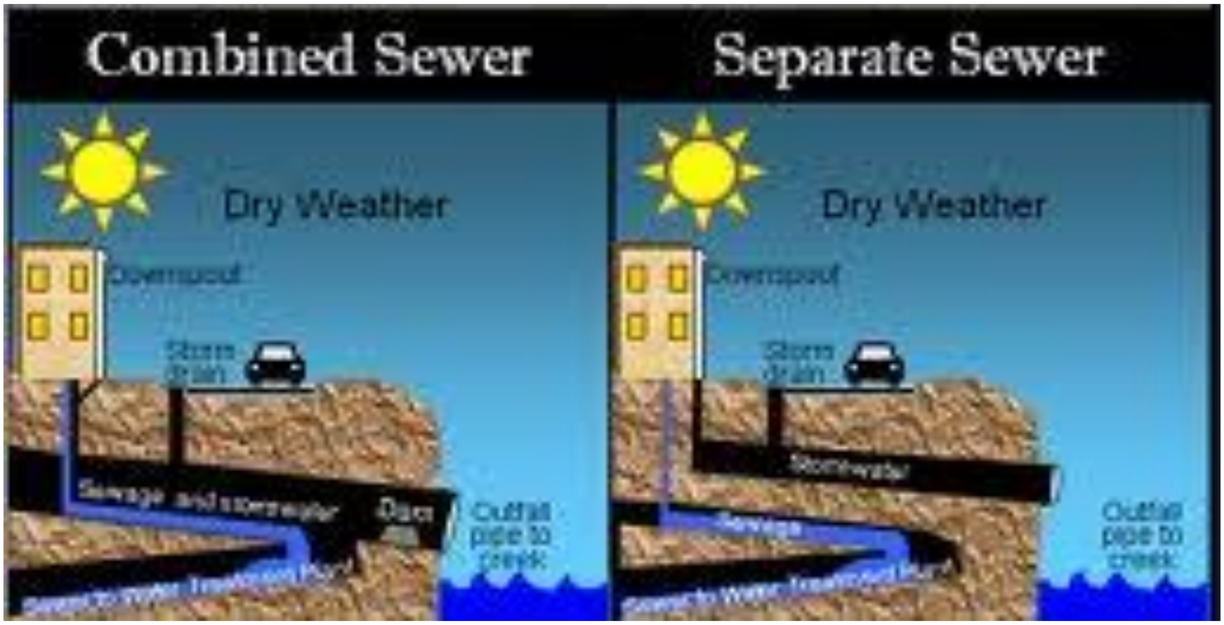


Figure 2.4: Types of Sewer System. Illustration of the distinction between a CSO and SSO, diagram shows wastewater flow through a CSO on a dry day there is no surface runoff.

Hydraulic overloading from stormwater runoff at the sewage treatment plant causes wastewater to back-up into residential properties and also not be properly treated. Build-up of pollutants in sewers and catchbasins can affect the performance of how the drainage system operates (Dauphin 1998). There are more CSOs located in the Northeast than any other region (Field and Struzeski 1972) and the city of Buffalo, NY is serviced by a Combined Sewer System that potentially discharges to local water bodies at 58 locations during storm events (Irvine et al. 2005).

2.3 BMPs

Stormwater management is an important strategy to managing water pollutants and stormwater runoff volume at BSC. Utilizing BMPs are the best defenses against water pollutants found in stormwater runoff (EPA 2007). BMPs can be structural or nonstructural methods that are used to control pollutants found in stormwater runoff from being discharged into nearby waterbodies. Ice (2004) has emphasized that BMPs can actually anticipate stormwater runoff, thus making this a proactive device. On the contrary other researchers have argued that BMPs do not effectively remove pollutants especially removing bacteria (Clary et al. 2008). This is based on the notion that BMPs are not being properly used (Roesner and Brashear 2001) and to what degree they remove pollutants. The quality of stormwater runoff can vary immensely because in a large part it is based on land use, traffic intensity, rainfall intensity, and climate which in turn are factors in the buildup and transport of pollutants in stormwater.

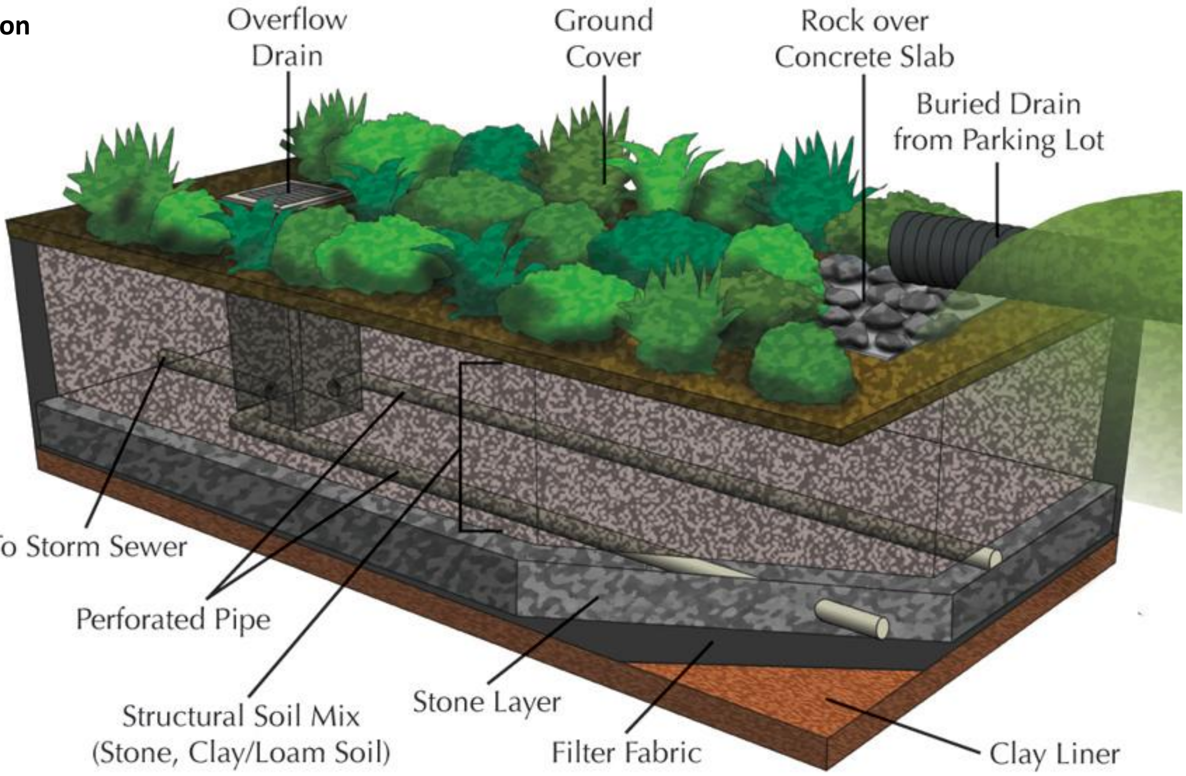
There are numerous BMPs to choose from and ultimately the desired area of installation, the end results, and cost are deciding factors in choosing the appropriate BMP for effective removal of pollutants. BMPs have different treatment functions. There are structural BMPs designed for water quality and peak flow reduction (i.e. hydrodynamic devices) and volume peak flow rate reduction by infiltration (i.e. bio retention ponds) (Pennsylvania Stormwater Best Management Practices Manual 2006). The treatment flow capacity is an added benefit for the BMP to be effective. Without the treatment flow capacity the BMP will need a by-pass device to properly handle an excess of flow (Charbeneau et al. 2004). Nonstructural BMPs can be designated for educational purposes such as stenciling catchbasins with catch phrases so the public knows not to throw anything down the drain.

The ability of a pollutant to be removed by a BMP is a function of the type and magnitude of the BMP treatment processes (i.e. infiltration, settling) in combination with the susceptibility of the bio-physio-chemical properties of the pollutant to be removed by a particular kind of treatment process. Scholes et al. (2008) conducted a study on 14 different BMPS that included a detention basin and constructed wetland to assess BMP performance (Table 2.2). It was concluded that a settling tank was the worst at removing TSS, E.coli, nitrate and phosphorus and using a treatment process that involved infiltration was the best where runoff percolates into the ground and a sand media filters the pollutants (Figure 2.5).

Table 2.2: Scholes' BMP Case Study

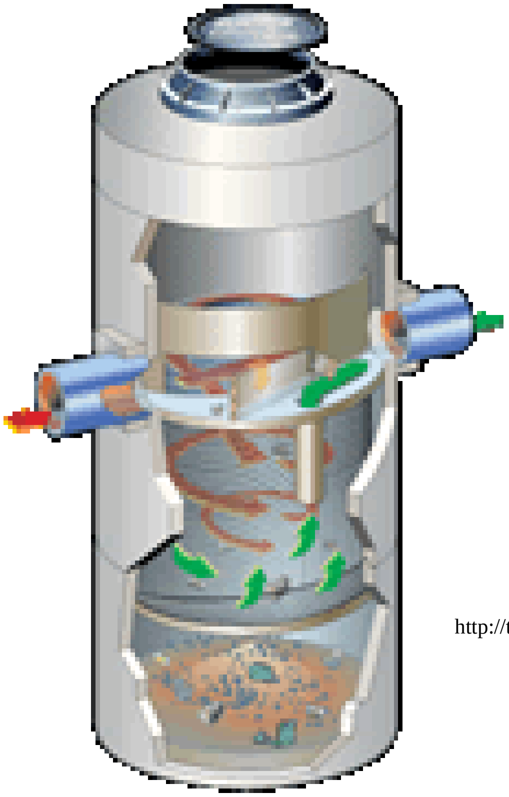
Types of BMPS		
Filter Drains	Porous Asphalt	Porous Paving
Sedimentation Tank	Filter Strip	Swales
Soakaways	Infiltration Trench	Infiltration Basin
Retention Ponds	Detention Ponds	Extended Detention Basin
Lagoons	Constructed Wetlands	

Infiltration



http://www.stormwater360.co.nz

Sedimentation Tank



http://twosweet.bse.vt.edu/Tess/stormwater/ITSS.asp

Figure 2.5: Infiltration vs. Sedimentation Tank BMP

2.4 Stormceptor

BSC currently has 16 different types of BMPs (Figure 2.6) and this literature review will focus on a hydrodynamic device known as an In - Line Stormceptor STC - 2400 ® manufactured by Rinker. There are several other proprietary hydrodynamic devices available including Continuous Deflective Separator (CDS units), Downstream Defender ™, and Vortechs ™. Hydrodynamic devices are flow through structures with a settling or separation unit to remove sediments using energy from flowing water (EPA 2010), primarily removing floatables, and coarser and heavier suspended sediments along with particle-bound pollutants from stormwater runoff (NJCAT 2004; Wilson et al. 2009).

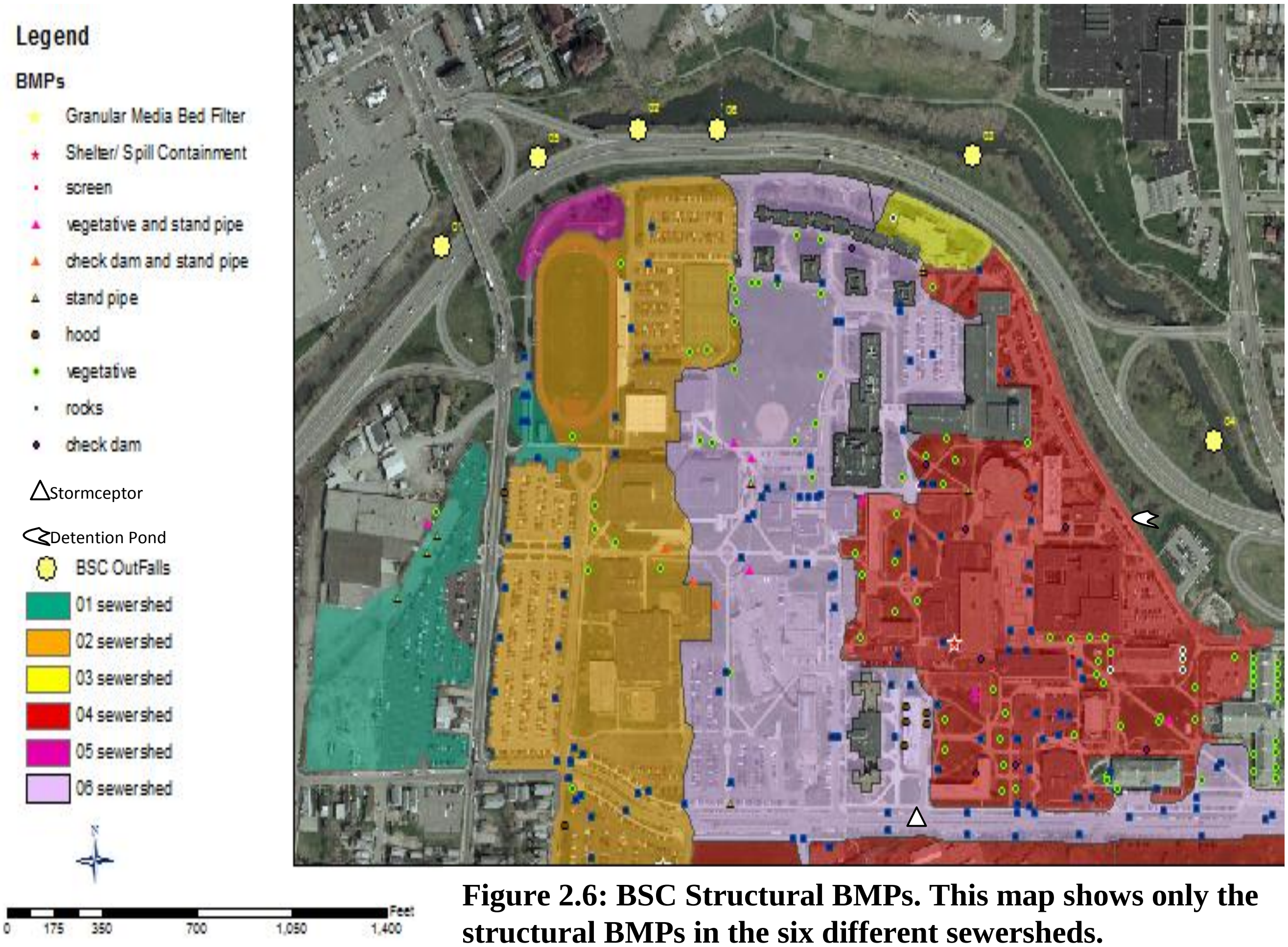


Figure 2.6: BSC Structural BMPs. This map shows only the structural BMPs in the six different sewersheds.

The In - Line Stormceptor STC- 2400 ® operates by separating sediments and other water pollutants by means of centrifugal force and a flow by – pass to prevent scouring. Also, it operates based on the drainage area and rate of stormwater flow rather than volume (Clayton 1999). The Stormceptor is divided into two components, the bypass chamber (upper chamber) and the treatment chamber (lower chamber). The flow enters the inlet of the Stormceptor and the weir allows for a max 9” head build-up and a design capacity of 475 gallons per minute (for the STC -2400 model) before by-passing. The 8” orifice plate (for the STC – 2400 model only) controls the rate of flow into the treatment chamber via a drop pipe. The pollutants from the treated water are then stored in a sedimentation tank while the treated water exits out of the riser pipe (which is located in the treatment chamber) and into the 36” round corrugated outlet pipe of the Stormceptor. The Stormceptor STC- 2400 series can hold a large amount of pollutants because the sedimentation tank is 60” x 96” and can hold 49 ft^3 of sediment and 840 gallons of oil for a total holding capacity of 2,462 gallons (Figure 2.7) (NJCAT 2004).

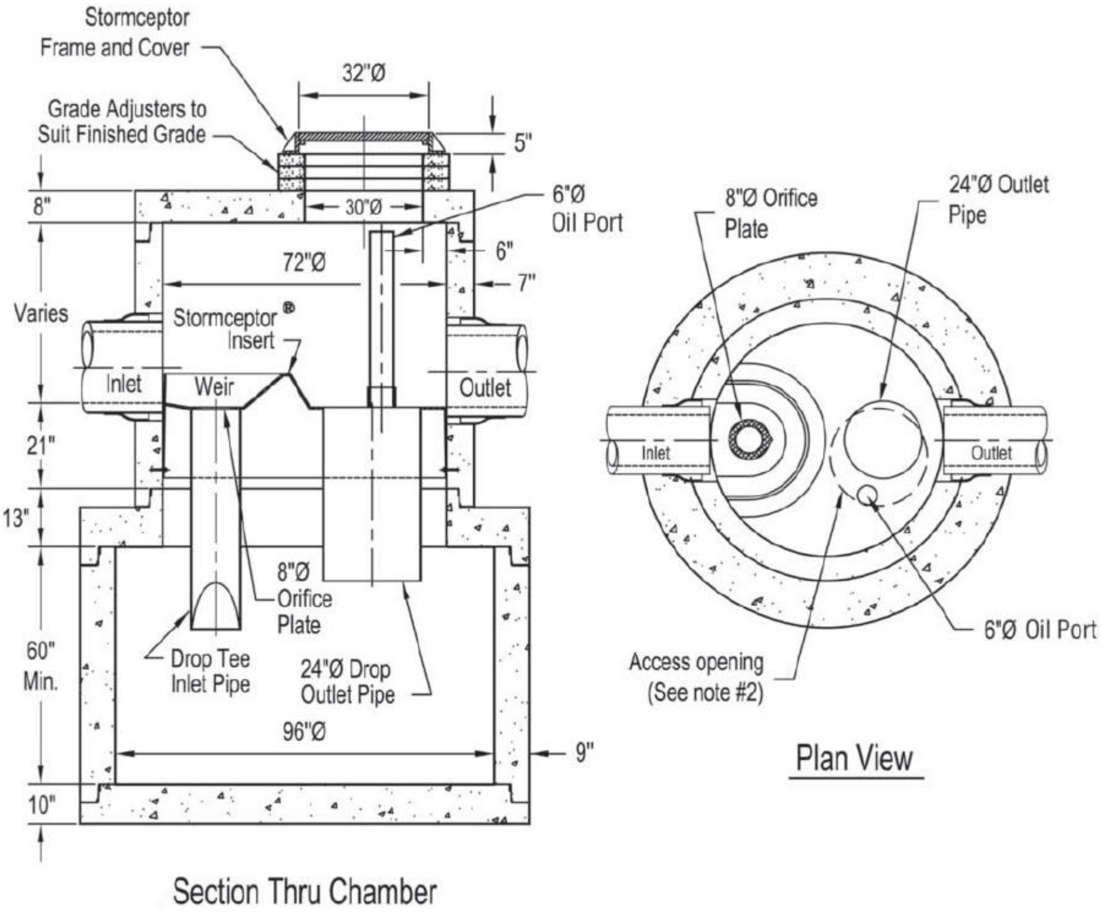


Figure 2.7: Schematic Views of Stormceptor Schematic drawing of the dimensions of the cross- sectional and plan view of the Stormceptor (Rinker Materials 2006)

Hydrodynamic devices are of the most popular BMPs sought because they generally have small footprints and can be installed anywhere including in manholes (Wilson et al. 2009; EPA 2010). It is normally suitable to install a Stormceptor in a hotspot where the largest amount of pollutants occurs such as a parking lot (EPA 1999; Sonstrom et al. 2002). The Stormceptor is an optimal resolution to reducing stormwater pollution during high and low flows. It is distinctive from other BMPs because it has the potential of removing small size particles that include clay and fine silts (20 µm) as opposed to other BMPs that can only remove larger particle sizes established by Tarp Tier 1 New Jersey Corporation for Advanced Technology particle size distribution (NJCAT PSD). Referring to Figure 2.8A under high flow conditions the built in by-pass prevents resuspension of sediments in the treatment chamber. Regular maintenance of oil and sediment removal from the 6” vent pipe (disposing of it properly) is imperative for the best performance of the Stormceptor (NJCAT 2004) especially when the sediment reach a depth of 12”. Figure 2.8B shows flows under normal conditions.

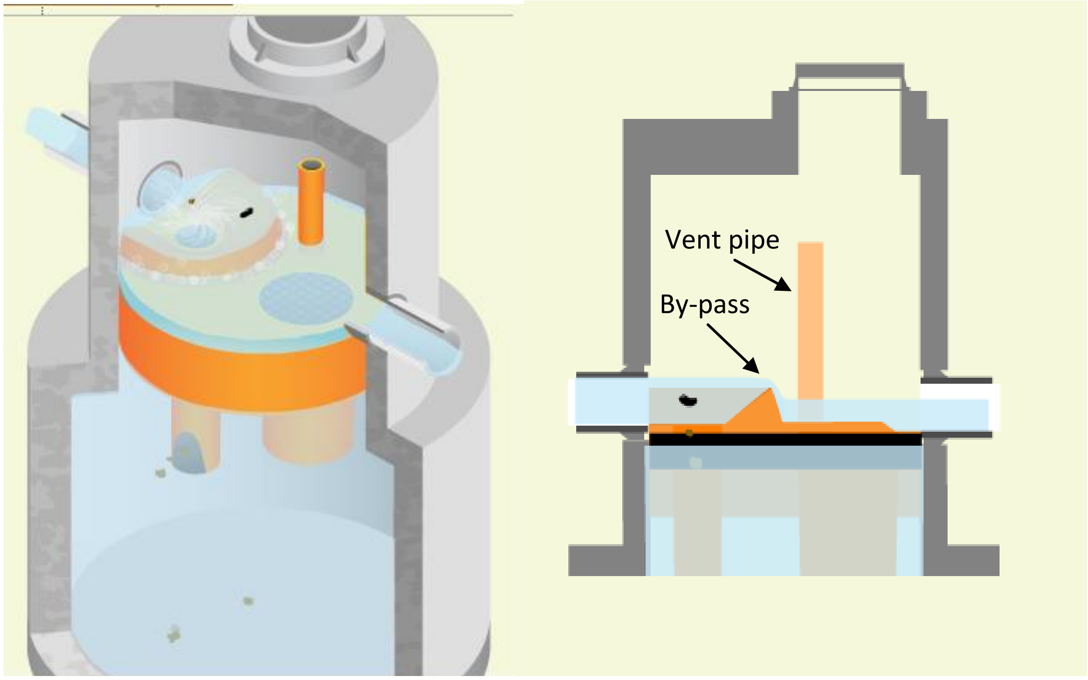


Figure 2.8A: High Flow Operation of Stormceptor.

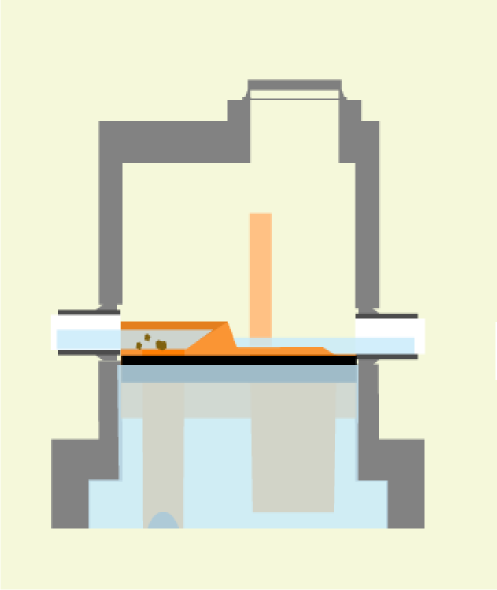

www.rinker.com

Figure 2.8B: Low Flow Operation of Stormceptor.

2.5 Sewer System

Since the Stormceptor performs in conjunction with the sewer system it is important to describe the characteristics of the sewer system in terms of flow, pipe size, slope, and material. The MS4 is designed to collect rain and melting snow (stormwater runoff) from the catch basins where it then flows through a system of varying sized pipes and manholes and discharges the runoff untreated, for example, as is the case in Scajaquada Creek (Figure 2.9).

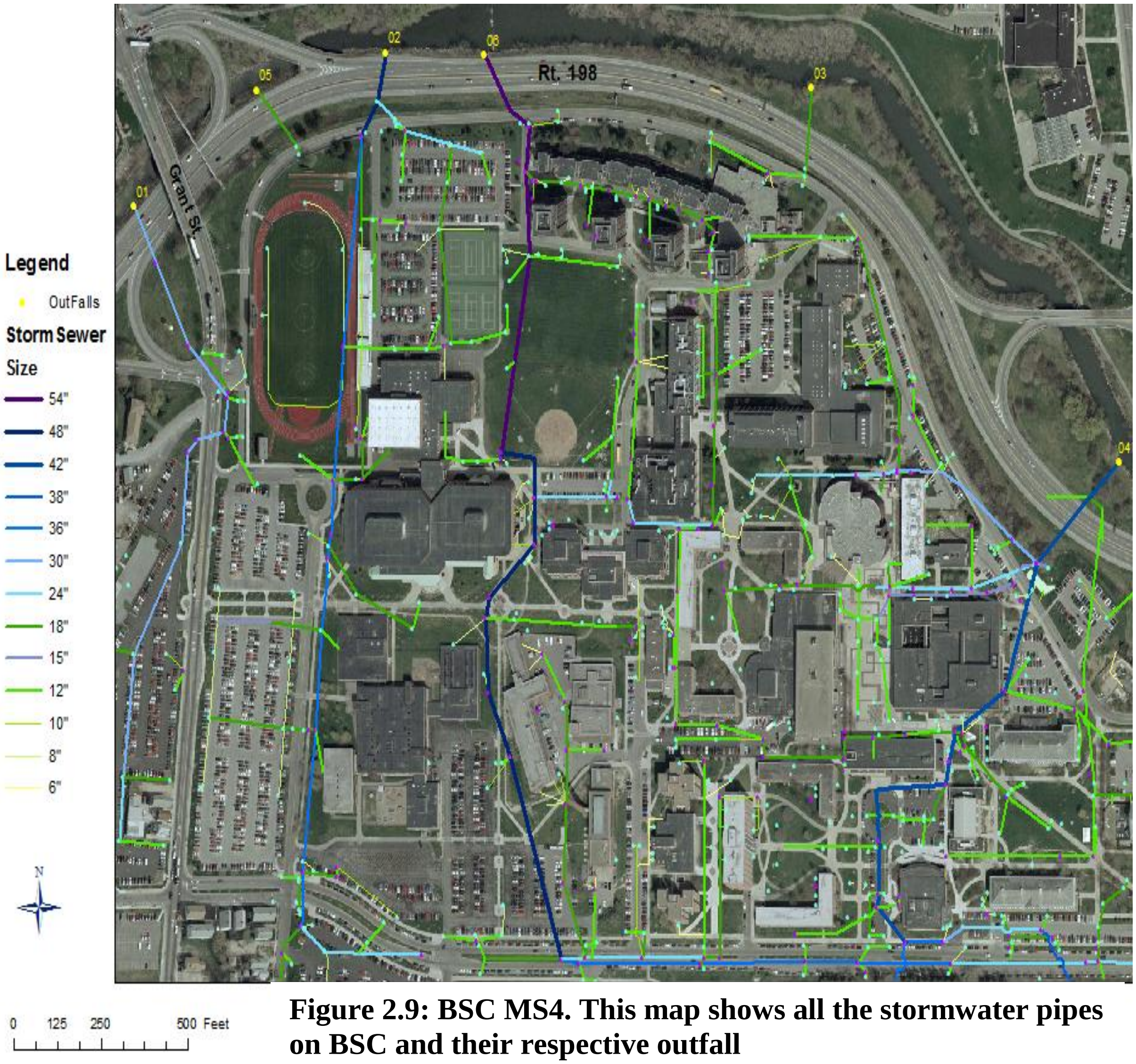


Figure 2.9: BSC MS4. This map shows all the stormwater pipes on BSC and their respective outfall

The Stormceptor is manufactured to accommodate everyday flows. The Stormceptor operates more efficiently in smaller drainage areas and when there is only one influent pipe connected to the Stormceptor (Rinker Materials 2006), and this is why the design of the MS4 should be taken into consideration.

2.6 MS4 Flow and Sediment

The storm sewer pipe size has to be of an appropriate diameter for it to be effective in carrying stormwater throughout the MS4. The larger pipe sizes are in the main trunk line of the MS4 and retain a higher volume of stormwater, whereas the secondary pipes are smaller in diameter (Iowa Stormwater Management Manual 2009). Normally water flows from smaller to larger size pipes. Ideally for retrofitted areas the Stormceptor should be installed on the lateral storm drains rather than trunk storm sewers to prevent a surge of water entering the Stormceptor (Rinker Materials 2006). The sewer pipe on BSC that leads into the Stormceptor is a 36 inch round corrugated diameter pipe (measured by Environment Health and Safety office at BSC) which means it has the capabilities of carry a large volume of stormwater right into the Stormceptor. This could also lead to stormwater flowing over the by- pass weir, preventing proper treatment. By – passing of the Stormceptor occurs more frequently when the sewershed is not appropriately sized to accommodate the BMP (Rinker Materials 2006). As a prevention factor to reduce pollutant deposition, pipes are sloped at 2% to allow water to flow at a minimum velocity of 2.0 fps when the pipe is at least half full (Iowa Stormwater Management Manual 2009). Storm sewer pipes can naturally self-cleanse with the right amount of hydraulic flow. In contrast to the Iowa Stormwater the American Society of Civil Engineers (1970) recommended a velocity of 3.0 fps (0.9 m/s) when the pipe is half-full or full to ensure self - cleansing .

Water pollutant particulates in the MS4 rely on the flow rate to be transported and Pitt and Clark (2007) have listed three phases for sediment transportation. As sediment is flowing it settles, becomes part of the bed load, or accumulates as sediment that can be scoured later. As part of Pitt and Clarks (2007) study they found that the drainage system does produce a build-up of sediment, primarily because larger sediments settle at the bottom of the sewer pipe and smaller particles stay suspended while settling out slowly becoming part of the bed load. As the flow stops the sediments will dry out and compact. When the next storm event occurs the settled sediment becomes resuspended and the cycle continues until the sediment eventually flows out the outfall (Pitt and Clark 2007).

2.7 First Flush

One of the key components of stormwater runoff is the first flush. The first flush occurs when the influent stormwater pollutant concentrations are higher at the start of a storm than at the end (Saget et al. 1996; Deletic 1998; Lee et al. 2002; Sansolone 2004). Conversely, other studies suggest the first flush might not even exist (Deletic 1998; Office of Environmental and Heritage 2011). Overall, research has concluded that the first flush can result in a substantial concentration of pollutants at the beginning of storm events however the concentration peak may vary for different pollutants during the same storm event. The high concentration detected during the first flush happens because materials build up between storm events and then are flushed with the initial high flow of an event (Charbeneau et al. 2004). Many studies have shown that the first flush is defined by different characteristics that include the impervious area, antecedent period, volume of rainfall or rainfall intensity (Hager 2001; Lee et al. 2002). It also is more evident in smaller sewersheds on impervious surfaces than in larger sewersheds on pervious surfaces (Kang et al. 2006).

The first flush typically carries a plethora of pollutants, and during water sampling the first flush is considered separately from the other water samples (Lee et al. 2007). The Stormceptor was developed to treat stormwater runoff and the first flush (Rinker Materials

2006). Saget et al. (1996) has noted more BMPs should be installed if the first flush occurs often. Selecting the right BMP to handle the first flush and volume is beneficial for improving water quality, particularly since the initial volume of water to treat is low, but the concentration of the pollutant is high.

2.8 Sources of Pollutants

It has been a major goal for many government agencies to remediate water pollution using BMPs. To counteract stormwater pollution, street sweeping and basic housekeeping can reduce the amount of pollutants. BSC employs these vehicles regularly and also has a contract service to pump out debris from catchbasins (BSC Stormwater Management Plan 2008; Irvine et al. 2009). Water pollutants associated in this particular type of area can range from materials being washed away from street asphalt, parking lots, automobile emissions, urban infrastructure, particulate atmospheric deposition, roof tops, old sewer pipes, vehicle by-products, litter, and lawns (Bannerman et al. 1993; Irvine et al. 2009). Most pollutants such as heavy metals, polycyclic aromatic phosphorus (PAHs), and organic compounds are particle bound to suspended solids, which makes TSS the most important indicator for water quality (Rossi et al. 2005).

2.8.1 TSS

Problems associated with TSS in stormwater runoff are that it affects water quality and aquatic life. Water becomes warmer when there are high concentrations of TSS lowering the dissolved oxygen level and also affecting photosynthesis. TSS is harmful to aquatic life by reducing growth and reproduction. It also clogs the fish gills and decreases resistance to disease (North Dakota Health Department 2005; Lake Superior Streams 2010). The most common source of TSS is from weatherization of rocks, debris and soil particles. Another commonly known source is road – deposited sediments (RDS) which is generated from particulates such as natural sources of soil material, plant and leaf litter, dry deposition, and also from vehicle by-products as mentioned above. RDS is associated with iron, copper, zinc, lead, magnesium, chromium, and cadmium (Robertson and Taylor 2007). Dirt accumulated on tires from construction sites can be deposited on the street and be broken down into finer particles by traffic and can lead to a buildup of sediments (Rogge et al. 1993). It is known that finer particulate matter such as pulverized dirt from heavy traffic use stays suspended longer in the stormwater runoff where larger particles settle out (Dong and Simsiman 1983). Feng et al. (2007) noted that air emissions from smoke stacks are also a source of TSS from atmospheric depositions.

2.8.2 Heavy Metals

Heavy metals found in stormwater runoff are primarily from vehicle by – products, roof tops, and parking lots. Metals such as copper are found in brake linings, and zinc and cadmium are present in worn tires (Mangani et al. 2005). Zinc is used as a metal coating in alloys and is often found in stormwater runoff. Galvanized rooftops and downspouts can lead to heavy zinc concentrations when it rains (Bannerman et al. 1993; Bolt and Bruggenwert 1977).The roughness of the road (asphalt vs. concrete) and traffic density affects the tire tread and can wear tires out leaving particulate matter left on the road, which produces zinc (Christensen et al. 1979; Rogge et al. 1993; Sansalone and Chrisitna 2004). Tire particulates can be associated with abrupt deceleration. A study showed that concrete has higher levels of lead and zinc versus asphalt roads (Ellis et al. 1981). Zinc can also come from motor oil and grease and lead can be sourced from bearing wear and atmospheric fallout (Soil & Water Conservation Society of Metro Halifax 2006).

A study analyzed a multitude of metals that included zinc, copper, lead, nickel mercury, and chromium and it showed zinc and lead had the highest concentration in runoff (Sartor and Agardy 1974). Higher metal levels are typically associated with finer (<63 µm) street sediment sizes (Irvine et al. 2009). Lead and zinc are both detrimental to aquatic life where reproduction, growth and survival are reduced. Aquatic organisms are affected when lead concentrations reach 1.0 – 5.1µg/l (Eisler 1988). Zinc not only causes problems with reproduction and growth but it affects behavior, blood and serum chemistry when concentrations reach 90µg/l (Sprague 1968).

2.8.3 Hydrocarbons

Hydrocarbons (detergents, oil and grease) are an issue in stormwater runoff because they can cause blockage in sewer systems once they solidify and can lead to back-up sewer problems. They negatively impact the water quality and can be harmful to aquatic life. Even the smallest concentration of 50µg/l starts to affect aquatic life while 0.3-0.6 mg/l is lethal for them (Stenstrom et al. 1982). Sources of oil and grease tend to be anthropogenic and can consist of fuel, motor oil, lubricating oil, hydraulic oil, cooking oil and animal fats (E.S. Babcock and Sons Inc. 2009).

Accident spills and dumping of oil and fuel into catchbasins can lead to oil being detected in stormwater runoff. Burning fuel from a smoke stack can cause atmospheric fallout which is another source of oil being detected in stormwater runoff. Typical vehicle usage can lead to exhaust particulates from the emission of the engine and this usually ends up in stormwater runoff .When there is an increase in rainfall the hydrocarbon load increases also, therefore the hydrocarbon load is correlated to the total rainfall (Stenstrom and Silverman 1982). One of the sources of hydrocarbons is from surfactants in detergents (Chiewet al.1997)

2.8.4 Bacteria

Bacteria are a water quality concern because they affect recreational activities such as fishing and swimming. It may seem unusual to find E.coli in an institutional area such as BSC where there are no pets or wildlife in this area that produce these bacteria. Taking into consideration that this is an MS4 and not a combined sewer overflow it may seem impossible to contract bacteria in the runoff and reviewing utility drawings indicates that there are no illicit connections of sanitary pipes to stormwater pipes. Irvine et al. (2011) collected samples during wet weather from 4 of the 6 MS4 outfalls for E.coli and their results showed that there was indeed high concentrations of E.coli at three of the sites (2500 – 4200 CFU/100ml). Bacteria are found in stormwater runoff and are attributed to non-anthropogenic sources (Clary et al. 2008). This can include trash being left on the ground causing bacteria to form. Stormwater runoff can carry fecal matter produced by squirrels and mice (Arnold et al. 1996). Bacteria often starts to multiply in warm weather conditions causing even more severe problems and may reach levels similar to ones found in sewage.

Bacteria are often accumulated in soil particles where they then become entrained by water (Arnold et al. 1996). Old sewer pipes can be the culprit to bacteria on BSC because the lateral truck lines are buried in the soil (BSC Stormwater Management Plan 2008). When concrete sewer pipes get old they can crack and since they are compacted by soil the bacteria in the soil can leach into the sewer pipes. Since bacteria are bound to the soil when the soil becomes saturated it allows bacteria to move more rapidly (Smith et al. 1985), which causes higher concentrations to be detected in the runoff. Another source of bacteria in stormwater runoff is attributed to airborne particulates as has been shown from collection of rainfall samples

(Berg, 1978). In the same study soil particles were a culprit and it was discovered there were high enough nutrient levels to start bacteria growth.

2.8.5 Nutrients

Nitrate and phosphorus are macronutrients naturally found in the soil. Level of these nutrients is very dependent on soil texture and structure and pH. Silty clay and loam soils increase nutrient retention. Since this area has silty clay loam soil it increases the nutrient retention. Plants take up all types of nutrients and when they cannot store or take-up these nutrients they are left in the soil. Likewise silty clay and loam soils are able to retain water (Holder 1997). Nitrate and phosphorous are both water pollution concerns because they can lead to harmful effects to aquatic life, eutrophication, and algae blooms. Eutrophication makes lakes aesthetically unpleasing while algae blooms decrease dissolved oxygen and increase turbidity levels making it difficult for aquatic life (Waschbusch et al. 1995; Hseih et al. 2007). Nitrate is highly soluble in water and has a low retention by soil particles (Majumdar and Gupta 2000) making it more susceptible to stormwater runoff. Nitrate and phosphorus occur naturally in soil, but adding fertilizer exacerbates these macronutrients in stormwater runoff.

2.9 Percent Removal Rate

In an effort to determine the effectiveness of a BMP at removing pollutants there are a few different methods that have been establish by the EPA. These methods include determining the percent removal rate by comparing pollution concentration from the influent and effluent samples before and after treatment by the Stormceptor, monitoring the volume reduction potential for infiltration of surface runoff and by taking into account the total pollutant load. The percent removal method is taking the concentration of the pollutant at the effluent and subtracting it from the influent and changing it into a percentage. This method can also give out false percentage readings because it relies on incoming stormwater that has variability in pollutant concentrations. If pollution concentrations are high in the influent then the percent concentration would have a high removal rate. If there is a low amount of pollutants coming into the inlet then there would be limited percent removal. In essence the percent removal method is a function of influent stormwater (Urbonas 2003; Wright Water Engineers and Geosyntec Consultants 2007; Center for Watershed Protection 2007).

The volume reduction method takes into consideration the volume of water that is carrying the pollutants. If the BMP is capable of reducing the volume, the pollutants will also be reduced. The EPA has acknowledged that this is the best method to determine the effectiveness of a BMP. The total load is calculated using the volume of water that is discharged from the BMP over a given period and multiplied by the mean concentration of the pollutant. The basis of these methods is to measure discharge and analyze the pollutants being retained by the BMP and therefore a monitoring protocol has to be conducted in order for any of these three methods to be effective.

While there are three methods to determine the overall performance for the BMP the volume reduction method gives the most accurate results and the least recommended method determined by the EPA and other researchers is the percent removal (EPA 2009) because it involves greater uncertainty. URS Greiner Woodward Clyde (1999) has argued it can be strenuous determining the appropriate method to quantifying efficiency, performance, and effectiveness. Urbonas (2003) concluded that there are no standards for how to measure the performance of a BMP which can affect the overall evaluation of the effectiveness. A large factor has to deal with the variety of BMPs out there and their different functions. Utilizing a particular method to determine the effectiveness might work for one BMP, but may not be as promising for another. URS Greiner Woodward Clyde (1999) suggested that the methods could be made more comparable by classifying BMPs into four categories based on their functions. BMPs that have well-defined inlets and outlets and the treatment process is based on detention storage of stormwater is one category. The opposite of that is BMPs that do not depend on detention storage of stormwater and are classified into another category. BMPs that do not have a well-defined inlet and/or outlet and widely distributed BMPs that use reference watersheds to evaluate effectiveness go into two other categories.

Even after utilizing one of the three methods and following the sampling protocols, determining the effectiveness of the BMP can be affected by different types of parameters. Size and land use of the contributing subcatchment can be an issue and in the case of the Stormceptor it operates more efficiently in a smaller subcatchment located in an impervious area (parking lot). Regional differences in soil type play a role because of different climates and the ability for soil to retain water. Not taking the appropriate number of storm event samples can lead to bias in the results. The rainfall and particle size of the influent can affect the performance of the BMP. If there is not enough flow in the MS4 being produced by the rainfall then the water samples taken might be from stagnant water or the samples could collect build-up sediments. Most importantly the manner in which pollutant removal efficiency is computed and monitoring technique employed (Center for Watershed Protection 2007) could affect results. With the Stormceptor and other BMPS the by-passes and overflows can affect the efficiency because the pollutants are not being treated at the effluent (URS Greiner Woodward Clyde 1999). The Stormceptor does not work well at removing pollutants with poor settleability or dissolved pollutants, but it can be more effective if there were multiple BMPs connected to the MS4 (EPA 1999).

Manufacturers of hydrodynamic devices have varying claims regarding the effectiveness of treatment processes (Dan Cloak Environmental Consulting 2005). There are organizations that provide an evaluation of manufactured BMPS by testing their performance and establishing protocols. Some of these organizations are: New Jersey Corporation for Advanced Technology (NJCAT), Canadian Environmental Technology Verification program (CETV), American Public Works Association (Al- Hamdan et al. 2007). EPA (1999) states that the Stormceptor is capable of removing 50 to 80% of the TSS load when used properly. Rinker the manufacturer of the In-Line Stormceptor has a removal rate of 80% for TSS and 95% for oil and grease (standard) (Rinker Materials 2006). Certified lab results from CETV showed that there is a loading removal rate from 76% to 94% (from three different states) for TSS (CETV 2000). Lab results from the NJCAT showed that the Stormceptor removes 75% of TSS (NJCAT 2004). Another study done in Edmonton, Alberta, installed a Stormceptor in a commercial parking lot and their findings showed that the average percent removal rate for TSS was 52.7%, lead was 51.2%, oil and grease 43.2%, and zinc 39.1% (Imbrium 1996).

2.10 PCSWMM

The Stormwater Management Model (SWMM) is a computer software program that was originally developed in the 1970's for the Environmental Protection Agency to simulate rainfall-runoff quantity and quality in urban and non - urban areas for single or continuous events (Huber and Dickenson 1988; Ahyerre et al. 1998; EPA 2012). It has since branched out into a newer format known as the Personal Computer version of SWMM (PCSWMM) developed by Computational Hydraulic International (CHI). PCSWMM retains the U.S. EPA calculation engine, but facilitates data input, output and its visualization using a graphical user interface. PCSWMM incorporates low impact development (LID) technologies and BMPs. Engineering and other disciplines use this model as a tool to predict different situations such a quantifying pollutant build-up for different land uses, reduction in wash - off load due to BMPS, or even direct contribution of rainfall deposition for different storm events (EPA 2012). PCSWMM is an economical tool to evaluate, analyze and manage the quantity and quality of urban storm water runoff (James et al. 2003). PCSWMM can be used to determine the overall system performance and to help identify hydraulic constraints (Cheng et al. 2009).

Chan et al. (2009) describes the development of the hydraulic model that is based on obtaining physical properties of the storm sewer system. The surface runoff functionality of PCSWMM is based on user defined attributes from field investigations that are needed for each subcatchment. Subcatchment boundaries are delineated after inputting a conveyance collection sewer system that is replicated from utility schematic drawings. This set of attributes (i.e. diameter, invert elevations, Manning's n, imperviousness, slope) helps establish the conditions of the sewer pipes and sewershed. Some attributes such as Manning's n use a coefficient table where values are selected based on field observation (James et al. 2003). PCSWMM takes into consideration various hydrologic processes that produce runoff from urban areas that can also be input into each subcatchment's attributes table to better define the area. The hydrology parameters of PCSWMM are time-varying rainfall, evaporation of standing surface water, snow accumulation and melting, rainfall interception from depression storage, infiltration of rainfall into unsaturated soil layers, percolation of infiltrated water into groundwater layers, interflow between groundwater and the drainage system, nonlinear reservoir routing of overland flow (James et al. 2003), and the recent addition to PCSWMM are low impact developments (LIDs) control options for runoff reduction (Rossman 2010).

PCSWMM has a built in time series editor for selecting a design storm to calibrate the model or can use a user defined time series that is data collected from a rain gauge (James et al. 2003). Chan et al. (2009), states that it is imperative that the hydraulic model matches the observed data. Observing the real system can be done with the installations of flow meters and rain gauges. Vieux and Vieux (2005) discussed how rainfall monitoring is beneficial for the purpose of model calibration. In addition, better results are achieved between observed and predicted hydrographs when rainfall is representative over the sewershed. In general, however, most rain gauges are located in a centralized location and sample rain at distinct points which may not be representative of the targeted watershed. It is often preferred that a network of rain gauges is used, but a single rain gauge may be sufficient if the sewershed is small. A rain guage can become problematic and produce inaccurate measurements. Rain gauge errors include rain shadows caused by trees, wind effects, effects caused by heavy rainfall and a tipping bucket type of rain gauge is known to under report during heavy rainfall (Vieux and Vieux 2005).

3. METHODOLOGY

3.1 Site Description

Field work was conducted in the summer of 2010, at two sites designated the upstream (inlet) and downstream (outlet) of the Stormceptor in a 37 acre sewershed that discharges to outfall 06. The actual monitored contributing area was 2.69 acre along Rockwell Road within the 37 acres sewershed (Figure 3.1).

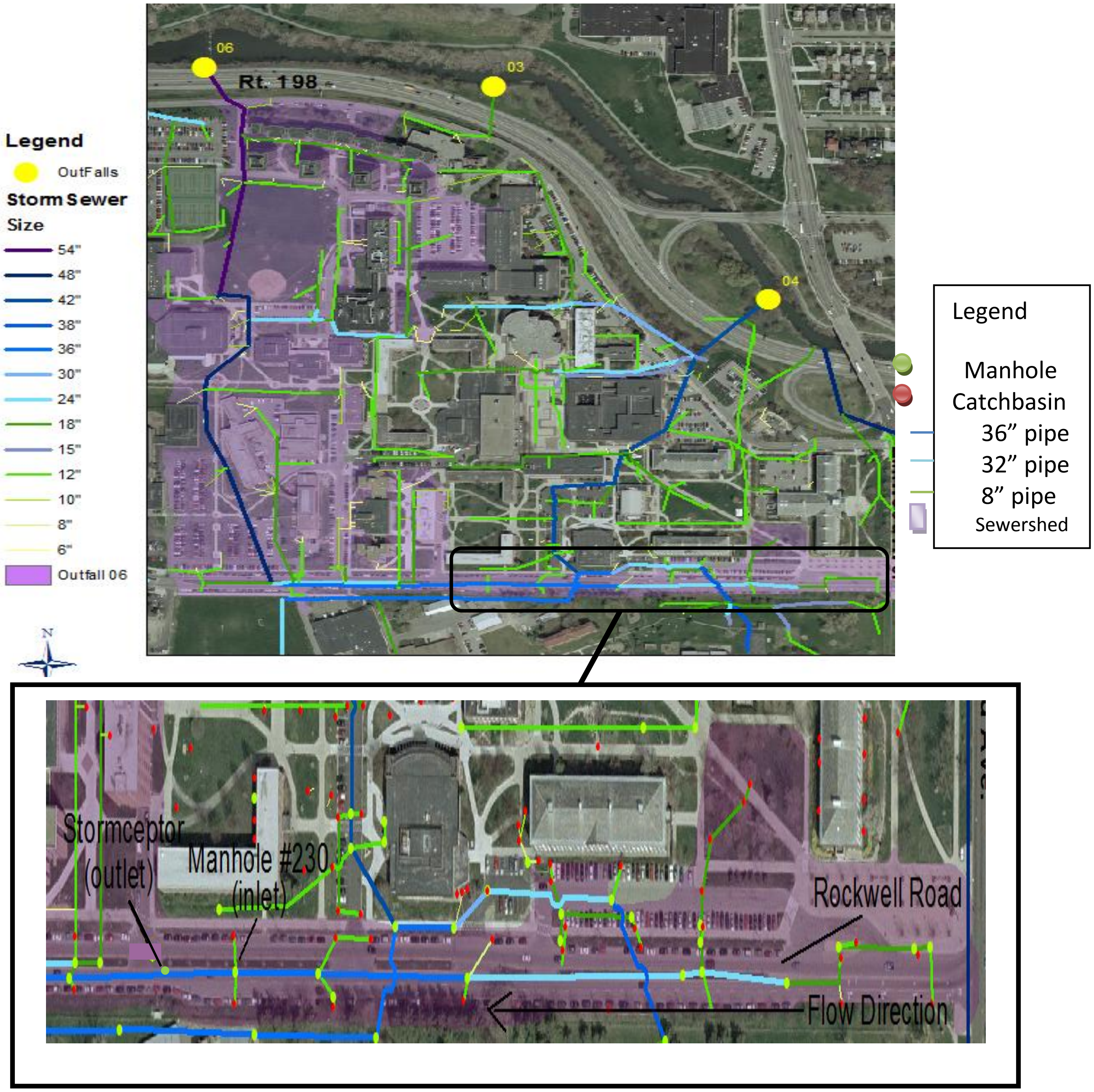


Figure 3.1: shows the 37 acre area sewershed and the 2.69 acre area of concern. This map shows the boundaries and the sampling locations

Figure 3.1 shows a complex system of storm sewer pipes. Storm sewer pipes follow specific guidelines. BSC uses a concrete pipe (class III) American Society for Testing and Materials (ASTM) C 478, which meets standards for precast reinforced concrete manhole sections to make sure it is uniform and reliable. The profile has gasket joints that conform to ASTM C443, which indicates that the joints are reliable for circular sewer pipes using rubber gaskets (Cretex Company 2001). In general, older sewers have pipes made out of concrete material and newer and smaller (< 6 inches) pipes are made out of polyvinyl chloride (PVC). Pipe sizes on BSC range from 4 – 40 inches in diameter (BSC Stormwater Management Plan 2008) to accommodate the flow.

With the onset of rainfall the runoff begins east on Rockwell Road and flows towards the west direction and eventually ends in Scajaquada Creek where the outfall discharges all the runoff from the 37 acre sewershed. For this research the downstream boundary is the outlet draining the 2.69 acre area. As the surface runoff flows down Rockwell Road it enters 17 catchbasins from four distinct land use areas (i.e. roads) prior to reaching the pipe leading to the Stormceptor. To determine the influent and effluent concentration of pollutants samples were retrieved upstream from the Stormceptor in the inlet of manhole #230 and from the outlet of the manhole designated Stormceptor. One lane on Rockwell Road was temporarily shut down and rerouted during sampling for safety precautions (Figure 3.2).

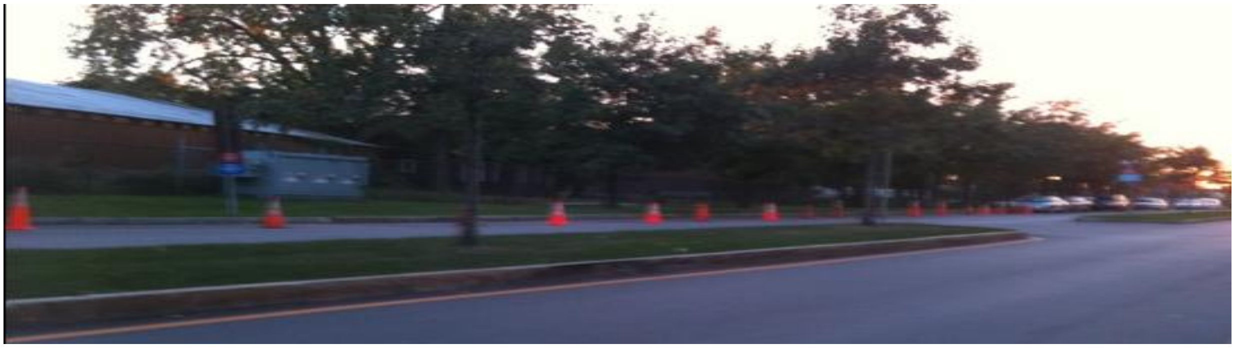


Figure 3.2: Rockwell Road upstream and downstream (left side) of Stormceptor. This is a two lane road in both directions. One lane is blocked off so sampling can be performed since both the upstream and downstream sites are located on the road.

The land uses within the 2.69 acre area consist of parking lots, asphalt roads, lawns, and roofs. Each of these land uses potentially contributes certain pollutants to stormwater runoff. Parking lots have more oil and grease associated with the parked cars. There is also a smoke stack located in the study area that burns number 6 fuel that potentially can be a source of atmospheric fallout. There are also numerous elevator oil tanks throughout the campus that are monitored on a monthly basis for leaks as a safety measure to prevent oil and grease from reaching the catchbasins (BSC Stormwater Management Plan 2008). Impervious areas such as roads and roofs can generate higher concentrations of lead and other heavy metals. Rockwell Road consistently had an abundant amount of white lather of soapy bubbles on the road (detergents) when it rained.

Lawn areas are more prone to nutrient runoff due to vegetation. Fertilization is a major contributor to poor water quality that causes eutrophication due to leaching or runoff into Scajaquada Creek. BSC applies fertilization with an average of 168 lbs of phosphorus and 1249 lbs of nitrogen being applied in the summer and spring semester. Only heavy trafficked playing fields such as football fields are fertilized, but there are exceptions. In 2009 BSC renovated Rockwell Road by adding new roads and new curb banks which modified the soils. Fertilization was applied to these soils to rejuvenate the grass and the fertilized area is part of the study area.

As illustrated in Figure 3.3 there is only one rooftop that drains into this sewershed, one major parking lot and there is on-street parking all along Rockwell Road. The median has a strip of vegetation and random patches of grass areas and the impervious areas are the sidewalks and the road. In the presence of rainfall pollutants from these surfaces become part of the stormwater runoff.

Figure 3.3: BSC land uses in study area

3.1.1 Sampling Considerations and Variable Flow Rates

Once the surface runoff flows into the catchbasins and reaches the municipal separate storm sewer system (MS4) it travels at variable rates. The upstream and downstream sites are approximately 30 feet apart and if it there is a low intensity rainfall then the flow is delayed downstream in the pipes, which affects the time interval of sampling. Low intensity rainfall is problematic because sampling may not occur at all since there is not enough flow to retrieve a grab sample. Also, sediment that is settled at the bottom of the storm sewer pipe may become resuspended, when using a grab pole to collect a water sample under low flow conditions. High rainfall intensities also can be problematic since the Stormceptor cannot handle large volumes of water and most water will go over a weir and the runoff will not be treated (system by-pass). To actually determine if the Stormceptor is an effective BMP it is ideal to have a range of different types of rain events.

3.1.2 Flow Meter

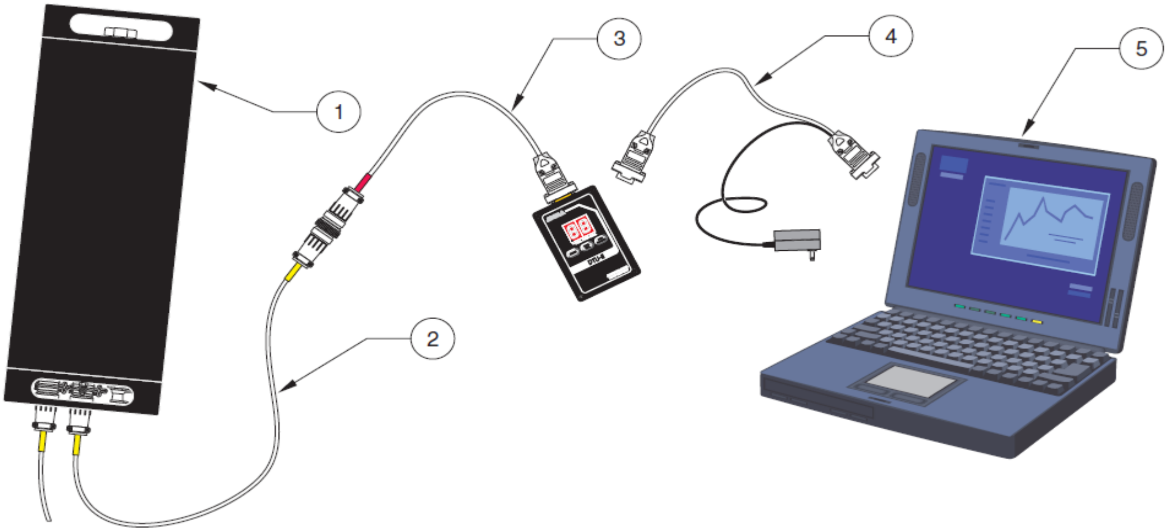
To determine the flow rate in the sewer system a Sigma 910 flow meter was installed on 06/01/10 at 4:40 pm on Rockwell Road, inside of a manhole in the same location as the upstream site (Figure 3.4). The installation was done by the maintenance crew of the Environmental Health and Safety Office using a harness to get lowered inside of the manhole. A Confined Space Four Gas Meter Rae Systems QRae + PGM 2000 (serial number 150-509736) was utilized to measure the air emission of toxic levels of chemicals that included carbon monoxide, hydrogen sulfide, lower exposure limit for flammables and oxygen levels before proceeding into the manhole.

flowmeterdirectory.com

Figure 3.4: Sigma 910 Flow Meter Installation. A 7.8 lbs, 4.5in x 17.625in Sigma 910 flow meter was installed inside manhole #230 on Rockwell Road using a harness apparatus to lower maintenance crew inside the manhole.

The velocity depth sensor must be located on a flat surface inside of the pipe so the runoff can submerge the sensor to receive a reading. The velocity sensor has an accuracy of +/- 2% reading and a +/- 0.20% full scale flow. The percentage of full scale means the flow meter absolute error will rise as the measured flow rate drops. In other words if it is a low intensity rain event less runoff is flowing over the velocity sensor and that makes the reading less accurate.

In order for the flow meter to communicate data to the field laptop (Figure 3.5) a software program called Insight® Data Analysis had to be downloaded to the laptop. The program was self-installed and programmed following the Sigma Flow Meter Models 910 & 920 Edition 11 User Manual (http://www.hachflow.com). After setup, a trial run was established to determine if the flow meter was communicating correctly. The depth of flow was 0.78 inches, the total volume inside of the 36” pipe was 44 gallons, and the velocity of flow was 0.14 feet per second. The first trial run was successful based on observed inspection and because data values were being recorded. To retrieve the data from the flow meter on a weekly basis an RS232 port had to be connected to the laptop and flow meter. The 6.0v battery that powered the meter had to be changed out every 1-2 weeks or data would be lost.



1.	Flow Meter	**4.**	DTU II Connection Cable
2.	RS232 Cable	**5.**	Personal Computer
3.	DTU II		

Figure 3.5: Setup of flow meter communicating with laptop.

www.hach.com

3.2 Flow Meter Data

The flow meter was used to record flow in five time steps and the data were downloaded to a laptop on a weekly basis. On the seventh day of every week a team of two went out to Rockwell Road and barricaded the road as a safety precaution to access the manhole where the flow meter was located. The InSight software receives the data from the flow meter, including the time data was downloaded, the flow in cubic feet per second, velocity in feet per second, the depth of flow in inches, the total volume in gallons and the battery life (Figure 3.6). This data was then plotted on a graph time vs. flow (discussed in more detail in Chapter 4).

Figure 3.6: Downloading flow meter data. The flow meter was connected to the laptop using a communication cable to retrieve data.

3.3 Monitoring Sampling Protocol

In order to detect water pollutants in the surface runoff water quality samples needed to be collected and analyzed. The benefit of the analysis was twofold as it will help conclude what types of pollutants are in the runoff and how well the Stormceptor is performing (a measure used for percent removal rate). Samples can be taken during dry or wet weather and this research focused on wet weather. To prevent sampling errors (i.e. cross contamination, bacteria multiplication, stirring up bottom sediment) and ensuring the samples are representative of the stormwater runoff there are sampling guidelines the EPA has established. The major criterion to taking a water sample is making sure there is enough rainfall to collect a sample. There has to be a rainfall depth of at least 0.1 inches of rainfall. To standardized antecedent conditions a 72 hour dry weather period was required in order to initiate sampling. The Stormceptor's manufacturer Rinker has proposed that there should be 6 storm events sampled (ideally 15) to get a range of conditions and to determine its effectiveness, while Erickson et al. (2010) suggest two or more rainy seasons should be monitored.

To make sure the water samples are representative there should not be a variance of more than 50% for the average rain depth and duration (EPA 1992). The duration of the storm event is important to produce enough samples and can be broken down into time intervals. After there is enough rainfall a sampling method has to be used to collect a sample for the influent and effluent. Grab or composite samples can be collected either manually or automatically. Grab sampling represents a discrete water sample for that given time interval and then analyzed separately whereas a composite sample combines all the water samples for each interval (Minkkinen and Esbensen 2009). Composite automatic samplers are commonly used because they are more representative than a grab sample whereas the grab samples show variability in the results.

Rinker Manufacturer recommends against using grab sampling to assess the performance of the Stormceptor. However, there are certain water pollutants that necessarily cannot be observed using an automatic sampler such as oil and grease because of its chemical properties.

Using an automatic sampler can be difficult to install, complex to operate and expensive (Lee et al. 2007). Automatic samplers also are not sterile and can produce E.coli contamination. Manual grab samples are easy to collect and can be collected in the most confined spaces and do not need a computer or battery to operate. The discreteness of a grab samples can determine the concentration of the water pollutant at a particular time. This can be beneficial to determine how often samples should be taken in a given storm event. These water quality samples are used in conjunction with other methods to determine the performance of the Stormceptor.

3.3.1 Sampling Procedures

For each sample a 22 foot Nasco Swing Sampler (grab pole) was used to collect 1000ml of stormwater. The water samples were analyzed for nitrate, phosphorous, lead, zinc, TSS, E.coli, detergents, oil and grease. For quality assurance, guidelines established by the EPA under section code 40 CFR 265.92 were used for collecting water samples and monitoring the project. Proper protection equipment was used for collecting samples which included a safety vest, rain coat, latex gloves, and boots (Figure 3.7). To proceed with sampling the attached bottle on the Nasco Swing Sampler was rinsed three times with the stormwater runoff to condition the bottle and on the fourth time a sample was taken at a 45 degree angle on the surface of the runoff, being very careful to not scrape the bottom of the pipe where the particulate bound pollutants settle.

Figure 3.7: Wet weather sampling upstream at the inlet in manhole #230. A team of students assisted in collecting water samples for various time intervals.The 22 foot Nasco Sampler was used to collect the 15min interval sample for oil and grease on Rockwell Road.

The sample in the attached bottle on the grab pole was transferred to two different types of sample bottles either a glass amber bottle or a plastic bottle depending on the type of pollutants to be tested (Figure 3.8). The amber glass bottle was used for oil and grease samples. The amber bottle blocks out sunlight which can break down the oil and grease particles in the stormwater. This particular container is also used because oil and grease typically binds to plastic whereas it does not bind to glass. The amber bottles were filled to the neck approximately, 700 ml for analysis. The other plastic sampling bottle was used for all other pollutants. Two 50 ml plastic bottles were used to analyze for lead and zinc and a 1000 ml plastic bottle was used to analyze for each of the following pollutants: E. coli, nitrate, phosphorus, lead, zinc, detergents, and TSS in the stormwater runoff.

Figure 3.8: Transfer of sample. Attached bottled was transferred over to sample bottle until it was filled to 1000ml. While one student holds the nasco sampler the other student pours it into the sample bottle and another student preps the bottle.

Sampling was done at various time intervals during four different wet weather events with a minimum of 0.25 inches of rainfall (for this study) to collect stormwater runoff samples (Figure 3.9). The sample time intervals varied depending on the duration of the storm event but ideally the aim was to collect water samples every 15 minutes for the first hour then every hour afterwards for a total duration of two hours (time intervals of 15,30,45,60,120,180 minutes).

The time intervals are significant because the first 15 minutes of the start of rainfall is considered the first flush. Over time the rain eventually dilutes the pollutants so the concentration towards the end of the intervals is small which is why it is important to collect samples throughout the whole rain event to account for the different ranges of pollutant concentrations. During the sampling of the four rain events, rainfall was unpredictable so not all the time intervals were utilized; sometimes rainfall only lasted for 45 minutes and others for 180 minutes. Due to time constraints, budget, and the difficult location of the Stormceptor (parked cars can sometimes blocked the roadway access) sampling was limited. Testing for lead, zinc, oil and grease was not taken at every time interval due to budget constraints.

Samples were labeled with the appropriate chain of custody and placed on ice in a cooler for preservation. The same process was done for the site downstream of the Stormceptor.

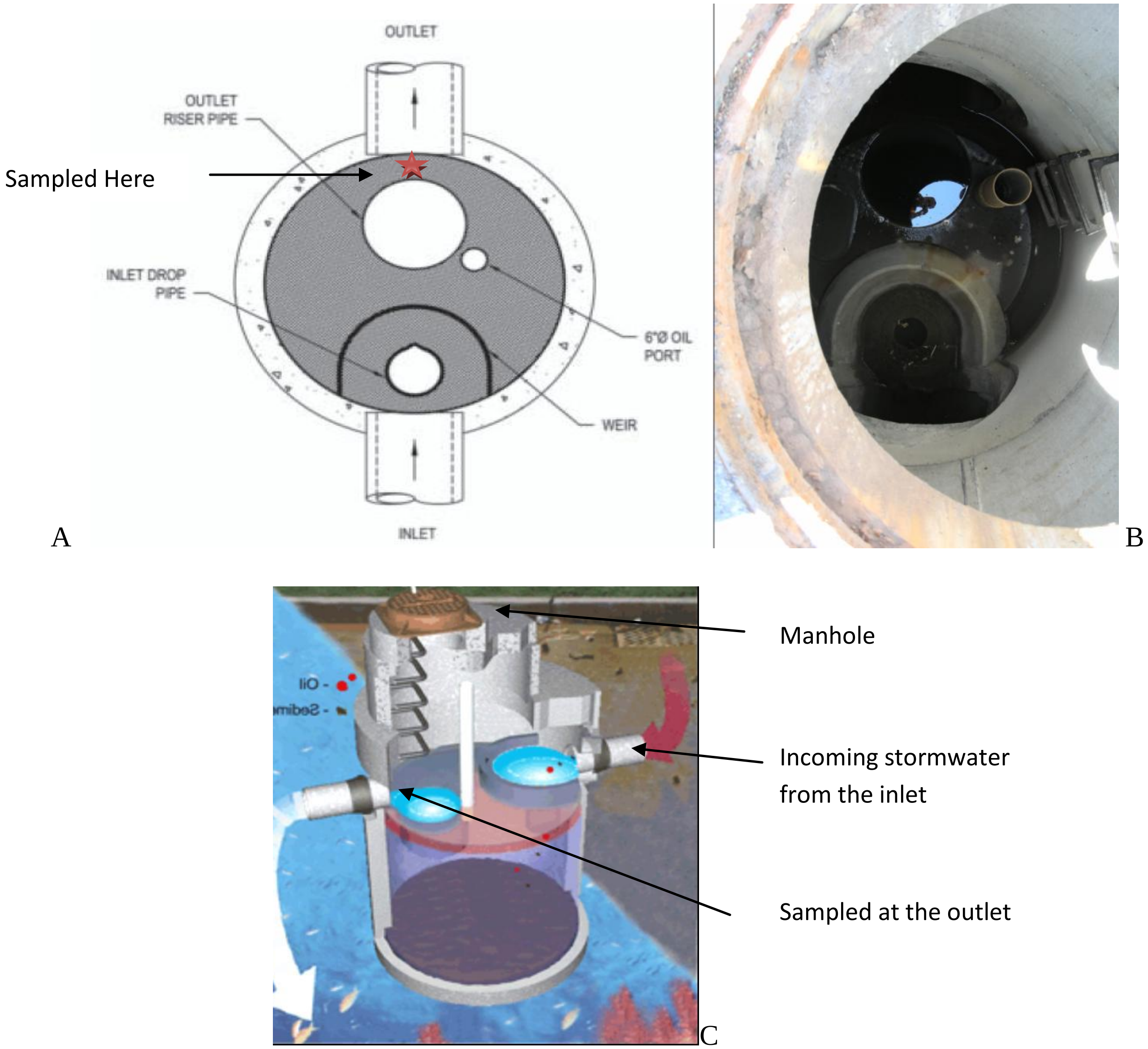


Figure 3.9: Stormceptor views. A.Schematic of Stormceptor looking down.This shows the runoff coming into the Stormceptor and flowing down the drop pipe and reemerging at the riser pipe and flowing out the outlet pipe. The red star indicates where the sample was taken. Samples were taken as the water entered the outlet pipe. B. Actual picture of Stormceptor looking down.C. Side profile of Stormceptor.

3.4 Pollutant Analysis

After samples were collected, analysis of nitrate, phosphorus, E.coli, detergent, and TSS was done in the Water Quality Lab in the Geography Department at BSC by the same party who took the water samples. Lead, zinc, oil and grease were analyzed by Waste Stream Technology Inc. (WST), in Buffalo, New York, which is a certified lab by NYSDOH ELAP # 11179, NJDEPE # 73977, PADEP # 68757, CTDPH #PH-0306, MADEP #M-NY068 and FLDOH # E87662.

3.4.1 E.Coli

To determine the levels of E.coli in the surface runoff 1 ml of unfiltered stormwater was used from the 1000ml stormwater sample and poured into a Coliscan Easygel ® vial (a medium) that is a product of Micrology Labs (http://www.micrologylabs.com). The Coliscan Easygel ® is not a standard method for measuring E.coli, but is approved by the EPA for compliance monitoring (http://micrologylabs.mennonite.net/:/WordDocs/wendelkin%20letter.pdf). Irvine et al. (2011) showed that Coliscan results match well with standard membrane filtration done by a certified lab. The mixed solution was then placed into a petri dish and incubated for 48 hours at room temperature. Afterwards each E.coli (purple dot) was counted in the petri dish to determine how many colonies per 1 ml were in the stormwater for that given storm event.

3.4.2 Total Suspended Solids

TSS was analyzed by weighing a membrane filter to get the beginning tare weight. The filter was placed using forceps in a filter holder in a flask. The sediment in the 1000ml bottle was resuspended by shaking it in a figure eight motion and pouring 500 ml into the filter holder reservoir. The filter with the sediment particles was then placed in a Tyson oven for one hour to dry the filter at 105 degrees Celsius and the dry membrane filter was placed in a desiccator for cooling before being reweighed for a final gross weight. The difference between the beginning tare weight and the final gross weight is the TSS concentration.

3.4.3 Nutrients and Detergents

The filtered stormwater from the TSS sample was used for nitrate, phosphorus and detergent analysis. To determine the concentration of nitrate, 5 ml of filtered stormwater was used and a nitrate reagent packet was poured into a test tube with the filtered water. The reagent changes to a particular color, once it is reconstituted, from clear to orange. The higher the concentration the darker the orange color. The reconstituted test tube was placed inside a Hanna C 200 Mulitparameter Bench Photometer, with the nitrate setting on for analysis. After five minutes the instrument detects the nitrate concentration. Nitrate results were reported in nitrate-nitrogen by using a simple conversion (multiplying by 4.43). The same instrument and similar procedure was used to determine the concentration of phosphorous in the surface water. This time 10 ml of filtered water was used and reconstituted with a phosphorus reagent packet where the contents turns from clear to dark shades of blue based on the concentration. These procedures were followed using the Hanna Instrument Manual C 99 and C 200 HI 83000 Series Photometer.

Analyses for detergents were done by using 5 ml of filtered stormwater and pouring a detergent reagent ampoule into a reaction tube using a CHEMetrics, Inc. test kit. The reconstituted solution turns different shades of blue based on the concentration found in the stormwater. Another ampoule is placed inside the reaction tube to draw up the contents. The ampoule is then placed inside of a comparator (colormatrix visual scale kit) that measures detergent concentration from a range of 0 – 3 ppm. Each value on the sliding scale corresponds to eight different shades of blue that is also found on the sliding scale. The comparator is rotated until the shade on the comparator matches the shade in the ampoule. This was done following procedures from the Detergents CHEMets Kit K-9400 instructions (http://www.chemetrics.com). If the concentration of the detergents found in the stormwater was higher than the maximum reading of 3 ppm then a dilution factor had to be used. This was the exact case for Storm Event 2 during the first peak when the measurement was off the scale. Instead of 5 ml a 1 ml water sample had to be used and be diluted with 4 ml of dionized water, therefore there was a 1:4 dilution factor used.

3.4.4 Metals, Oil and Grease

To test for lead and zinc WST followed the EPA 6000/7000 Series Methods, specifically EPA 6010B, which is used to test for hazardous wastes using advanced analytical instrumentation and techniques (i.e. inductively coupled plasma – mass spectrometry). The 1000 ml water sample bottle was transferred into two 50 ml plastic bottles one for lead and the other for zinc and each contained $HN0_3$ as a preservative for analysis. These methods have a minimum detection limit of 0.015 mg/l for lead and 0.013 mg/l for zinc.

Oil and grease in the stormwater was analyzed using EPA 1664A (Revision A on February 1999) method. The sample is extracted using n- hexane and gravimetric analysis, with a minimum detection limit of 5.0 mg/l is the done. The sample amber glass bottle contained a H_2S04 as a preservative.

3.5 Stormwater Modeling

In order to model the stormwater runoff from the 2.69 acre sewershed on Rockwell Road a program called Stormwater Management Model (PCSWMM) version 5.043 was used. Information about the sewershed that is needed to run the model includes sewer lines and catchbasin location. This information was obtained using blueprints of utility lines and field verification. Land surveying was done to determine the elevation and rim to inverts for the catchbasins. This information shows how the sewer lines slope. To figure out how the water drains into each catchbasin, field verification was done to determine the aspect on the land slopes. This step was imperative to creating subcatchments for the sewershed. All of these steps were done by previous student assistants working for the Department of Environmental Health and Safety Office.

3.5.1 Rainfall

Another important attribute required for the model is rainfall data. Rainfall data is used to determine the time series in PCSWMM and is the most important characteristic for generating runoff. Rainfall data was collected using a Davis Vantage Pro Plus 6161C (cabled not wireless) Tipping Bucket Rain Gauge (Figure 3.10) from 06/2010 – 10/2010, which is located on the Classroom Building rooftop on BSC. The data is automatically programmed to communicate to a desktop computer in the Classroom Building Meteorology Lab at BSC using a software program called Weatherlink 5.8.0 where data is recorded in one hour increments. The tipping bucket operates when precipitation enters the collection orfice where it fills the calibrated tipping bucket section. Once the calibrated amount (0.01” per tip for this model) has been collected the bucket tips, emptying the water and sending an electrical signal to the recorder (http://www.omega.com). The accuracy for this model is +0.01inches and rainfall rates up to two inches per hour (rainfall in this case study never exceeded 2”) and it measures a rain depth from 0-199.99” (http://www.davisnet.com). The rainfall data was also used to create a hydrograph as a visual inspection to determine if the flow data from the flow meter was similar to the rain data.

www.ifamilysoftware.co

Figure 3.10: Davids Vantage Pro Tipping Bucket Rain Gauge

4. RESULTS

4. 1 Storm Event 1

The first set of water samples collected on 06/09/10 was a semi-qualifying storm event because the antecedent dry period was only 48 hours, while the EPA guidelines typically call for a 72 hour antecedent period. Even though this was a short rainfall event, approximately lasting from 11:43 to 13:25 that accumulated 0.10 inches of rainfall, there was enough flow to sample. Due to the short duration of rainfall only four samples were taken instead of the recommended 10 samples and only two time intervals were used: 15 and 30 minutes, for collecting samples. Figure 4.1 shows when the samples were collected and the corresponding flow. There was 0.048 cfs of water recorded by the Sigma 910 Flow Meter during sampling at the 15 minute interval. As the rainfall slowed down so did the flow at the 30 minute sampling interval with the flow rate being 0.013cfs. For this particular storm event the water samples were analyzed for conventional parameters that included TSS, nitrate, phosphorous, E.coli, detergent, oil and grease (it should be noted that E.coli, oil and grease was only tested for the first 15 minutes due to budget constraints for this particular storm event). The pH of the stormwater was also measured and was neutral at 7.44.

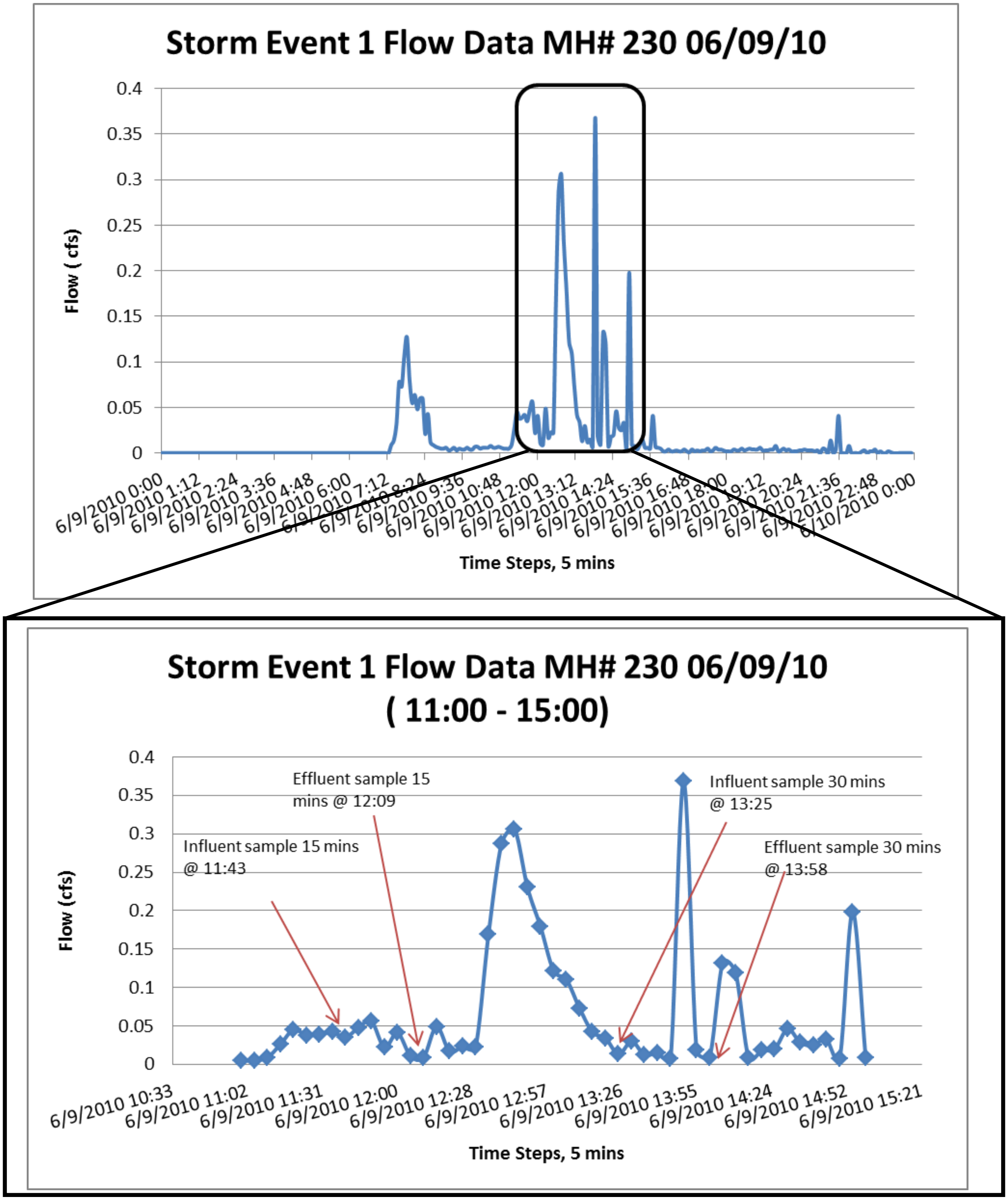


Figure 4.1: Flow data for Storm Event 1. This graph shows the flow data in cfs from the time sampling began and ended on 06/09/10 in 15 minute increments.

4.1.1 E.coli Results

An influent and effluent sample was taken at 11:43 and 12:09 respectfully during the first flush to quantify the amount of E.coli present in the stormwater runoff. There were 400 colonies/100 ml of E.coli in the influent and the effluent contained 0 colonies/100 ml, which is a 100% reduction in removing E.coli from the runoff using the Stormceptor.

4.1.2 Detergents Results

From visual inspection during the first flush the road had a build-up of anionic surfactants (detergents), as a white residual substance was highly visible when cars drove through puddles. The concentrations of detergents at first 15 minutes were 1.5 mg/l in the influent and 0.25 mg/l in the effluent samples that were collected upstream and downstream of the Stormceptor. With a flow rate of 0.048 cfs 83% of the detergents were removed. For the 30 minute interval 1 mg/l of detergents was detected in the influent and 0.5 mg/l of detergents was in the effluent sample as shown in Table 4.1.

Table 4.1: Detergent Time Variations

Interval	**Time**	**Influent**	**Time**	**Effluent**	**Reduction**
minute		**mg/l**		**mg/l**	**%**
15	11:43	1.5	12:09	0.25	**83**
30	13:25	1.0	13:58	0.5	**50**

4.1.3 TSS Results

The results for TSS for the first storm event were omitted due to technical difficulties with lab equipment.

4.1.4 Nitrate Results

Referring to Table 4.2 nitrate in the influent of the Stormceptor was 20.8 mg/l while the effluent was 1.3 mg/l during the first 15 minutes, a 94% reduction. At the 30 minute interval the influent had 14.2 mg/l of nitrate and 0.9 mg/l of nitrate was detected in the effluent downstream of the Stormceptor. This showed the Stormceptor removed 94% of nitrate from the runoff.

Table 4.2: Nitrate Time Variations

Interval	**Time**	**Influent**	**Time**	**Effluent**	**Reduction**
minute		**mg/l**		**mg/l**	**%**
15	11:43	20.8	12:09	1.3	94
30	13:25	14.2	13:58	0.9	94

4.1.5 Phosphorus Results

Table 4.3 shows during the first flush the influent had 0.5 mg/l of phosphorus and the effluent had 2.3 mg/l of phosphorous. There was no reduction in phosphorus. For the next sampling round there was 0.1 mg/l of phosphorus detected in the influent and 0.0 mg/l was detected in the effluent sample, a 100% reduction.

Table 4.3: Phosphorus Time Variations

Interval	**Time**	**Influent**	**Time**	**Effluent**	**Reduction**
minute		**mg/l**		**mg/l**	**%**
15	11:43	0.5	12:09	2.3	[redacted]
30	13:25	0.1	13:58	0.0	100

4.1.6 Oil and Grease Results

The lab report (from WST) showed that there was non-detection in the influent and effluent sample collected upstream and downstream of the stormceptor during the first 15 minutes of the rain event. In case of non-detect, one half of the MDL was used to represent a value (MDL for oil and grease is 5 mg/l, one half of the MDL is 2.5 mg/l).

4.2 Storm Event 2

The second wet weather sampling took place a month later on 07/09/10. There was a 72 hour antecedent period and the event had a total rainfall of 0.52 inches with an approximate peak flow rate of 1.0 cfs (Figure 4.2) during the sampling times from 10:26 until 14:45. The following analytes were sampled during this rain event: E.coli, detergents, TSS, nitrate, phosphorous, oil and grease. Metals were included in this sampling event because a budget was available during this time to send the samples to WST. These metals included lead and zinc and were tested only once at random time intervals. For quality assurance and quality control a duplicate sample was taken for analysis of nitrate, lead, zinc, oil and grease. This particular storm event had two peak intensity periods that were categorized into two separate sampling events: first peak and second peak. During the first peak there was a high intensity rainfall during the first 15 minutes starting at 10:26 am and ending around 10:45 am. It was important to catch the first flush (15 minutes) in this event because this is where the highest concentration of pollutants can be obscured. The second peak rainfall started back up again at 13:30 and lasted until 14:45. Sampling occurred over a longer period of time, with samples collected at: 15, 30, 45, 60, and 90 minutes.

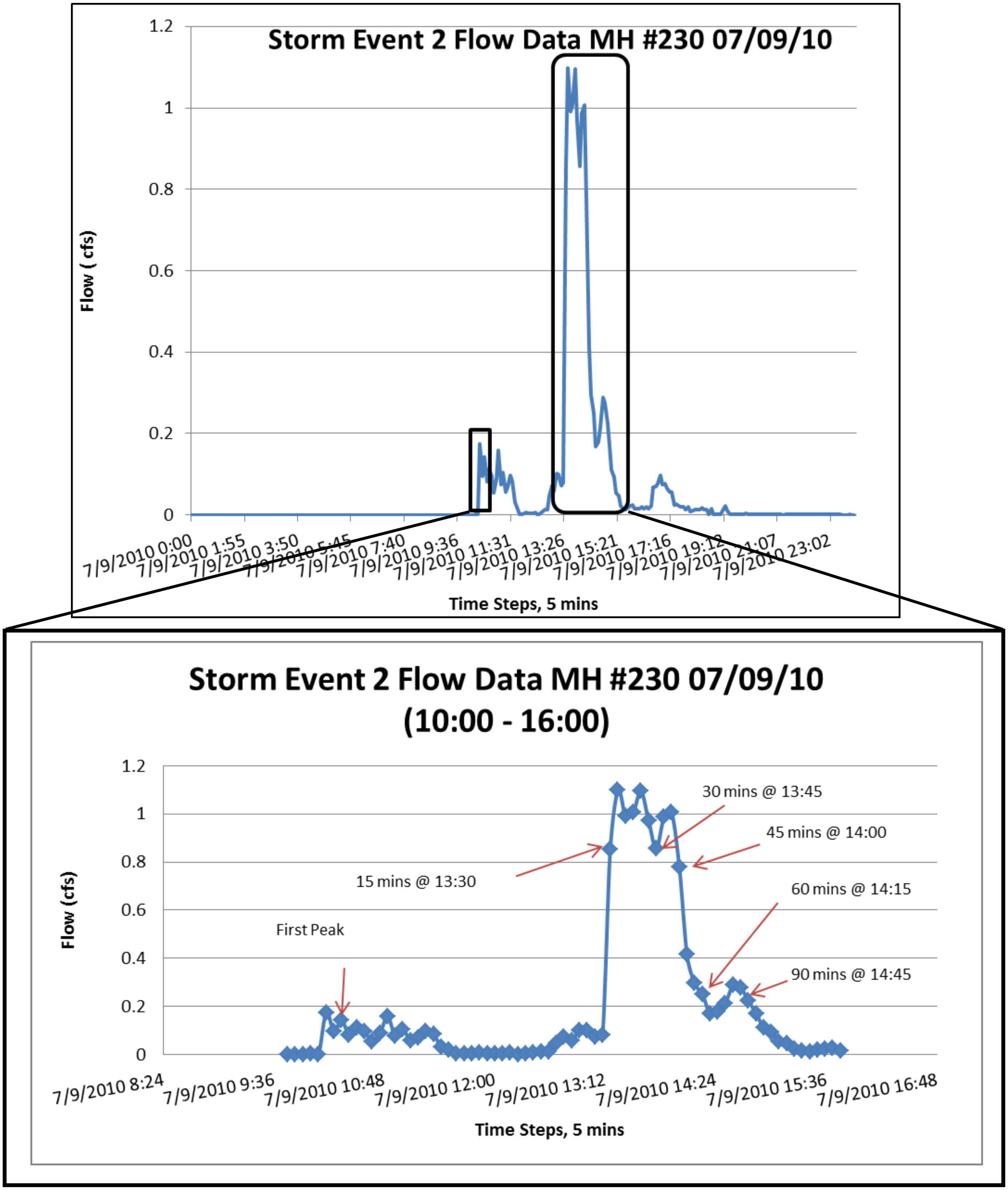


Figure 2.2: Flow data for Storm Event 2. This graph shows the flow data starting from 13:00 to 15:00 in 15 minute increments when sampling began and end on 07/09/10.

4.2.1 E.coli Results

The first peak event sampling showed that there were 4,300 colonies/100 ml of E.coli in the effluent. The team could not mobilize quickly enough and it was noticeable that the rain was coming to a halt, so the decision was made to collect a sample downstream of the Stormceptor rather than upstream. The second peak rain event showed inconsistency between the influent and effluent samples. Table 4.4 shows that the first sample had the highest levels of E.coli of 3,700 colonies/100 ml detected in the influent and 2,900 colonies/100 ml in the effluent. This was a 22% removal of E.coli from the system. The 30 minute interval sample from the upstream site had a 60% reduction in the amount of E.coli in the influent compared to the first sample. There was also a 7.7% reduction in the removal of E.coli for the 90 minute sampling time. The inconsistencies started at the 45 minute interval where there were higher levels of E.coli in the effluent than in the influent samples and overall the levels started to increase rather than decrease in the effluent samples. There was a large discrepancy at the 60 minute interval where there was 500 colonies/100 ml of E.coli detected in the influent and 3,500 colonies/100ml of E.coli in the effluent. This is a 600% increase of E.coli in the effluent and a 20% increase of E.coli from the first flush in the effluent. There was a rather steady decrease in the influent until the last sampling round where it increased to a level almost similar to the first flush with 2,600 colonies/100ml of E.coli.

Table 4.4: E.coli Time Variations

Interval	Time	Influent	Effluent	Reduction
minute		**c/ 100 ml**	**c/ 100 ml**	**%**
15	13:30	3700	2900	22
30	13:45	1500	1300	60
45	14:00	1000	1700	[redacted]
60	14:15	500	3500	[redacted]
90	14:45	2600	2400	7.7

4.2.2 Detergents Results

The first peak rain event showed the concentrations were higher than the maximum reading on the comparator testing kit of 3.0 ppm (mg/l), but with the dilution factor in place the concentration was 7.5 mg/l in the influent and no samples were collected downstream of the Stormceptor. For the second peak rain event analysis conducted upstream of the Stormceptor showed there was 1.25 mg/l of detergents in the influent and 0.5 mg/l in the effluent during the first 15 minutes, a 60% reduction.

4.2.3 TSS Results

TSS was analyzed at every time interval. The results during the first peak rain event showed 41 mg/l of TSS in the influent and there was no samples collected downstream of the Stormceptor during the first peak because the rain came to a halt. For the second peak rain event the results indicated (Table 4.5) that there were fairly low concentrations. The first sample had the highest concentration in the influent (186 mg/l) and effluent (719.6 mg/l), a 287 % increase. The 30 minute interval of sampling showed the same fluctuations between the influent and effluent concentrations, for which there was a 222% increase in the effluent concentration.

Comparing the 30 minute interval to the first flush influent there was a 73% reduction in a matter of 15 minutes. Likewise, comparing the 30 minute interval to the first flush effluent there was a 77% reduction of TSS that was being removed from the Stormceptor. After 45 minutes of sampling the TSS was still decreasing over time in the influent samples, with 27.8 mg/l detected in the runoff. The effluent sample also had decreased compared to the first two samples with 60 mg/l of TSS in the effluent. The 60 minute interval had a slight increase of TSS in the influent but overall there was a 48% reduction of TSS being removed by the Stormceptor. The 90 minute sampling round there was 7 mg/l in the influent which is a 96% reduction rate from what the first flush sample was at 186 mg /l. There was a 98% reduction rate in the effluent from when sampling first started at the first peak. When comparing the influent and effluent at the 90 minute interval there was a 68% increase of TSS.

Table 4.5: TSS Time Variations

Interval	**Time**	**Influent**	**Effluent**
minute		**mg/l**	**mg/l**
15	13:30	186	719.6
30	13:45	50.2	161.4
45	14:00	27.8	60
60	14:15	28.6	14
90	14:45	7.0	11.8

4.2.4 Nitrate Results

For the first peak rain event there was 7.9 mg/l of nitrate at the influent, but no sample was collected at the downstream site. Table 4.6 shows the percent reduction for nitrate. For the second peak rain event the results showed that at the 15 minute interval there was 10.2 mg/l detected in the influent and 0 mg/l detected in the effluent. During the 30 minute interval there was no nitrate coming into the system, but there was 2.2 mg/l leaving the system, and similarly for the 45 minute interval there was lower nitrate (1.3 mg/l) coming into the system and more nitrate leaving the system (4 mg/l). The 60 minute interval of sampling had the highest level of concentrations of nitrate with 10.6 mg/l in the influent, which is 0.4mg/l higher than the first flush, and 5.8 mg/l in the effluent. The last sample taken upstream of the Stormceptor had 8.4 mg/l of nitrate coming into the system (a random triplicate sample was also collected upstream) and due to instrument error there were no results for the effluent sample.

Table 4.6: Nitrate Time Variations

Interval	**Time**	**Influent**	**Effluent**	**Reduction**
minute		**mg/l**	**mg/l**	**%**
15	13:30	10.2	0.0	100
30	13:45	0.0	2.2	
45	14:00	1.3	4	
60	14:15	10.6	5.8	46
90	14:45	8.4	SA	

SA= Instrument Error

4.2.5 Phosphorus Results

The results for phosphorus were consistently higher at the downstream site than at the upstream site. The first peak rain event showed that there was 0.8 mg/l of phosphorus in the influent and there was no water sample collected downstream of the Stormceptor. Table 4.7 shows the first sample of the second peak had 0.7 mg/l of phosphorus in the influent and 1.1 mg/l of phosphorus in the effluent samples, which resulted in a 57% increase of phosphorus at the downstream site. At the 30 minute time interval there was a higher concentration in the effluent (1.7 mg/l) compared to the first sample with only 1.1 mg/l in the effluent. This time interval also showed an increase in phosphorus in the effluent by 240%. The 45 minute interval had the same concentration of 0.1 mg/l of phosphorus coming in to and leaving the system. The 60 minute interval had a 66% increase in phosphorus. The last sampling round had instrumentation errors for both the influent and effluent samples.

Table 4.7: Phosphorus Time Variations

Interval	Time	Influent	Effluent	Reduction
minute		mg/l	mg/l	%
15	13:30	0.7	1.1	
30	13:45	0.5	1.7	
45	14:00	0.1	0.1	0
60	14:15	0.3	0.5	
90	14:45	SA	SA	

SA= instrument error

4.2.6 Oil and Grease Results

There were a total of four water samples collected and delivered to WST for oil and grease analysis in the runoff. This included taking a sample during the first peak rain even which resulted in 7.1 mg/ l of oil and grease in the influent and no samples were collected at the downstream site. During the second peak rain event another water sample was taken at the 90 minute interval which resulted in 24.8 mg/l of oil and grease in the influent and 11.1 mg/l in the effluent. A duplicate sample was also collected which is discussed in the QA/QC section. With a flow rate of 0.21 cfs at the 90 minute interval (14:45) 55% of oil and grease was removed by the Stormceptor.

4.2.7 Lead Results

Water samples for lead analysis were only taken during the 90 minute interval of the second peak rain event and included a duplicate sample. There was a non-detection (<0.015 mg/l) of lead in the influent, effluent and the duplicate sample. These samples were also collected as the rain event was ending and there was not much flow.

4.2.8 Zinc Results

To analyze for zinc in the runoff a sample was taken during the first peak rain event and during the second peak rain event only at the 90 minute time and this too included a duplicate sample. The first peak event findings showed that zinc was not detected because the concentration was less than the MDL of 0.013mg/l in the influent and there were no water samples collected downstream of the site. Half of the MDL was calculated to get a value of 0.00065 mg/l for the influent sample. The results at the 90 minute interval were 0.03 mg/l in the influent and 0.043 mg/l in the effluent.

4.3 Storm Event 3

The third rain event took place on 09/16/10 with a magnitude of 0.28 inches of rain and a peak flow rate of 0.77 cfs (Figure 4. 3) that started at 09:15 and ended at 13:15. This was a qualifying storm event because all the requirements were met under the EPA guidelines including a 72 hour antecedent period. Water samples were collected every 15 minutes for the first hour and then more samples were collected for the 120 and 180 minute interval, which is very different from the first storm event. The change of time intervals was due to the duration of the rain event itself. The water samples were analyzed for E.coli, TSS, nitrate, phosphorus, oil and grease, lead, and zinc.

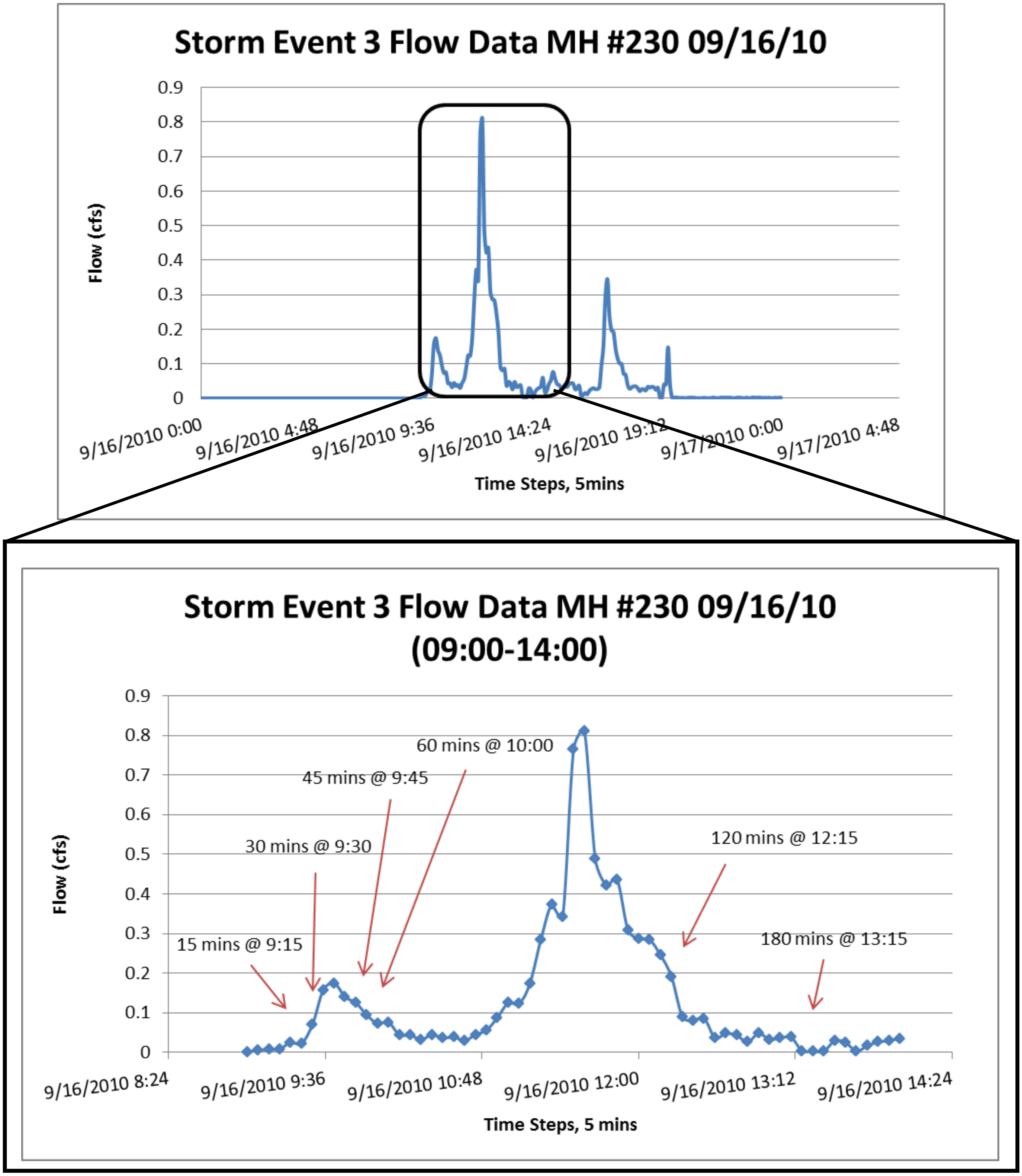


Figure 4.3: Flow data for Storm Event 3.This graph illustrates the flow associated with the rainfall over a 5 hour period.

4.3.1 E.coli Results

This storm event had the highest levels of E.coli in the stormwater runoff. The first flush was comparatively high, but not the highest with 6,000 colonies/100 ml detected in the influent and 15,300 colonies/100 ml in the effluent (Table 4.8). The first flush only had a flow rate of 0.009 cfs as this was the onset of the storm event. As the storm started picking up with a flow rate of 0.07 cfs the water sample taken at the 30 minute interval had no effluent reduction in E.coli with 1,500 colonies/100 ml in the influent and 27,300 colonies/100 ml in the effluent. Water samples taken at the 45 minute interval did show an 8.7% reduction in E.coli with 15,000 colonies/100ml in the influent and 13,700 colonies/100ml in the effluent. The flow rate had doubled by the time it reached the 45 minute interval. At the 60 minute interval there was approximately equal level E.coli in the influent (7,300 colonies/100ml) and effluent (7,900 colonies/100 ml). There was a 58% reduction with a flow rate of 0.191 cfs for the 120 minute interval with 2,600 colonies/100 ml in the influent and 1,100 colonies/100 ml in the effluent. The last sampling round had the least amount of E.coli in the runoff. As the storm concluded the influent had 1,200 colonies/100 ml and the effluent had 1,600 colonies/100ml.

Table 4.8: E.coli Time Variations

Interval	**Time**	**Influent**	**Effluent**	**Reduction**
minute		**c/100 ml**	**c/100 ml**	**%**
15	09:15	6000	15300	■
30	09:30	1500	27300	■
45	09:45	15000	13700	8.7
60	10:00	7300	7900	■
120	12:15	2600	1100	58
180	13:15	1200	1600	■

4.3.2 TSS Results

Referring to Table 4.9 the highest concentration of TSS was during the first flush with 66.4 mg/l and decreasing to 7.0 mg/l during the last sampling round in the influent. The concentration of TSS started to decrease from a concentration of 66.4 mg/l to 7.0 mg/l with a slight increase at the 60 minute interval throughout the course of sampling upstream of the site. For the effluent samples, there were points in time that the concentration of TSS was higher than the concentration in the influent particularly at the last interval when there was 7 mg/l of TSS in the influent and 18.4 mg/l in the effluent. Reductions in concentration of TSS occurred when the flow rate was 0.009 cfs during the first flush and had an 83% reduction, during the 45 minute sampling interval with 38% reduction when the flow was higher at 0.14 cfs, and during the 60 minute sampling interval with a 15% reduction when the flow rate was 0.07 cfs.

Table 4.9: TSS Time Variations

Interval	Time	Influent	Effluent	Reduction
minute		mg/l	mg/l	%
15	09:15	66.4	11.2	83
30	09:30	16.8	25.2	
45	09:45	30.8	19.2	38
60	10:00	36.8	31.2	15
120	12:15	16.8	25.2	
180	13:15	7.0	18.4	

4.3.3 Nitrate Results

Generally, the results were fairly reasonable with respect to the concentration of nitrate decreasing over time and the concentration in the effluent being lower than the influent samples for each time interval. During the first flush there was 0.0 mg/l of nitrate in the influent and 0.0 mg/l detected in the effluent. The next round of sampling had the highest concentration of nitrate for the event. There was 11 mg/l of nitrate in the influent and 5.8 mg/l of nitrate in the effluent, a

48% reduction. The 45 minute interval had 0.0 mg/l of nitrate in the influent and 2.2 mg/l of nitrate in the effluent. The sampling results at the 60 minute interval had 5.8 mg/l of nitrate in the influent and 0.0 mg/l of nitrate in the effluent. With a flow rate of 0.07 cfs there was a 100% removal rate of nitrate from the runoff. The nitrate concentration decreased by 50% during the120 minute interval. The 180 minute interval had a 60% reduction in nitrate with a flow rate of 0.004 cfs (Table 4.10).

Table 4.10: Nitrate Time Variations

Interval	**Time**	**Influent**	**Effluent**	**Reduction**
minute		**mg/l**	**mg/l**	**%**
15	09:15	0.0	0.0	0.0
30	09:30	11.1	5.8	48
45	09:45	0.0	2.2	[redacted]
60	10:00	5.8	0.0	100
120	12:15	2.6	1.3	50
180	13:15	10	4.43	60

4.3.4 Phosphorus Results

Referring to the Table 4.11 the concentration of phosphorus during the first flush was relatively low with no reduction of phosphorus. The samples taken at the 45 and 180 minute interval were the only samples that showed a reduction in phosphorus. During the 45 minute sampling interval there was 1.9 mg/l of phosphorus in the influent and 0.0 mg/l in the effluent samples. At the beginning of the storm event, when the first flow peak of 0.14 cfs was observed, the reduction was 100% (45 minute interval). The 180 minute interval had an 80% reduction with a small flow rate of 0.004 cfs.

Table 4.11: Phosphorus Time Variations

Interval	Time	Influent	Effluent	Reduction
minute		mg/l	mg/l	%
15	09:15	0.0	0.6	■
30	09:30	0.8	1.0	
45	09:45	1.9	0.0	100
60	10:00	0.0	0.7	■
120	12:15	0.0	0.8	
180	13:15	1.0	0.2	80

4.3.5 Oil and Grease Results

Two water samples from the upstream and downstream site were sent to WST for oil and grease analysis for the 15 minute interval only. The results indicated that there was 6.8 mg/l of oil and grease in the influent and there was non-detection in the effluent, because there was less than 5 mg/l of oil and grease detected in the runoff. One half of the MDL was calculated, which resulted in a 63% reduction in oil and grease.

4.3.6 Lead Results

Four water samples were sent to WST to analyze for lead; two from upstream of the site and two from downstream of the site for the 15 and 60 minute interval. There was no detection of lead in all four samples that were analyzed. The non-detection value was manipulated to calculate a value by taking half of the MDL of 0.015 mg/l for lead which resulted in 0.0075 mg/l for each sample.

4.3.7 Zinc Results

Four water samples were delivered to WST for zinc analysis (two from upstream and downstream of the site). There were higher concentrations of zinc during the first 15 minutes of sampling, where the influent and effluent concentration was 0.166 mg/l and 0.031 mg/l. During the 60 minute interval of sampling the amount of zinc found in the runoff decreased from the initial start of sampling at the upstream site, which had 0.115 mg/l detected in the influent. Once that influent went through the Stormceptor for treatment the amount of zinc went from 0.115 to 0.088 mg/l, a 23% reduction (Table 4.12).

Table 4.12: Zinc Time Variations

Interval	**Time**	**Influent**	**Effluent**	**Reduction**
minute		**mg/l**	**mg/l**	**%**
15	09:15	0.166	0.031	81
60	10:00	0.115	0.088	23

4.4 Storm Event 4

The final sampling round was done on 09/28/2010 with a magnitude of 0.25 inches of rain and a peak flow rate of 1.3 cfs (Figure 4.4). This was not considered a qualifying storm event under EPA guidelines because it rained the day before so there was no antecedent dry period. Sampling was done every 15 minutes for the first hour and then every hour for a total of three hours of sampling lasting from 07:39 to 10:24. The water quality parameters that were analyzed from the water samples upstream and downstream of the site were E.coli, TSS, nitrate, phosphorus, oil and grease, lead, and zinc.

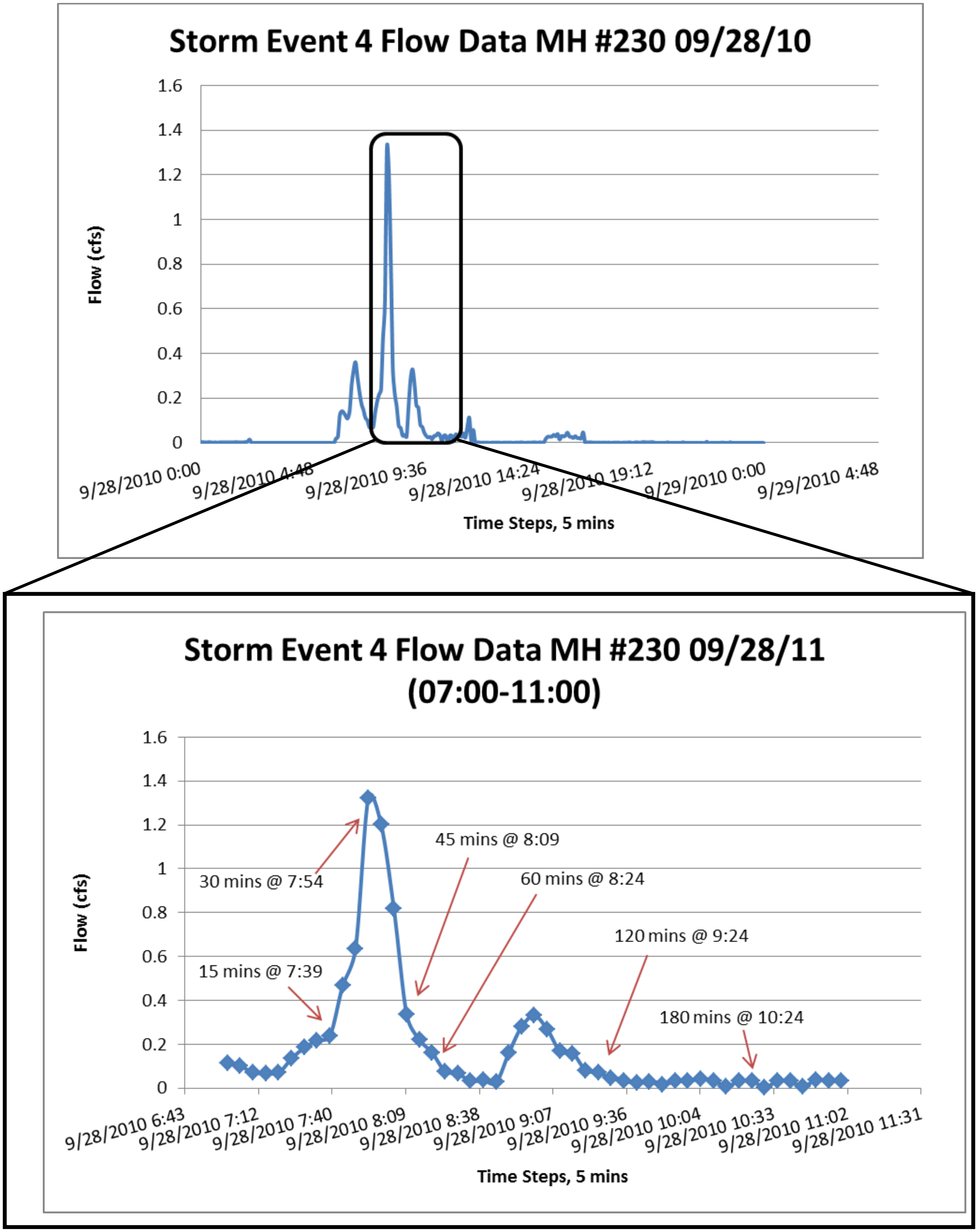


Figure 4.4: Flow data for Storm Event 4

4.4.1 E.coli Results

E.coli results are in Table 4.13. The first flush had 1,100 colonies/100 ml of E.coli in the influent and 600 colonies/100ml in the effluent, a 45% reduction with a flow rate of 0.22 cfs. The samples taken at the 30 minute interval had the highest levels of concentrations with 1,100 colonies/100 ml in the influent and 1,300 colonies/100 ml in the effluent, which had no reduction. After the 30 minute interval the E.coli levels subsided. There was a 12.5% reduction during the 45 minute interval and a 55% reduction at the 60 minute interval. During the 120 minute interval there was a slight increase of E.coli in the influent with a 55% reduction in the effluent. The levels of E.coli during the last sampling round decreased by 22% as the flow rate decreased to 0.032 cfs.

Table 4.13: E.coli Time Variations

Interval	**Time**	**Influent**	**Effluent**	**Reduction**
minute		**c/ 100 ml**	**c/ 100 ml**	**%**
15	07:39	1100	600	45
30	07:54	1100	1300	
45	08:09	800	700	12.5
60	08:24	900	400	55
120	09:24	1100	500	55
180	10:24	900	700	22

4.4.2 TSS Results

In Table 4.14 the TSS for the influent samples consistently decreased throughout the sampling period while the effluent results fluctuated. Of all the samples taken at each interval the 15 minute interval was the only one that had a reduction in TSS (50%). The sample taken at the 15 minute interval also had the highest concentration in the influent with 79.6 mg/l. The 30 minute sampling interval showed a slight decrease in concentration with 67.6 mg/l detected in the influent from the previous sample. There was a higher concentration in the effluent that had 74.4 mg/l than the previous sample which had 39.6 mg/l of TSS. The 30 minute interval also had a higher concentration in the effluent than in the influent, a 10% increase of TSS. The results for the 45 minute interval were 43.2 mg/l in the influent and 69.6 mg/l in the effluent samples. This shows that there was a 61% increase of TSS at the 45 minute sampling interval. The sample taken at the 120 minute interval resulted in 28 mg/l of TSS in the influent and 35.6 mg/l of TSS was in the effluent. The last sampling round had the lowest concentration in the influent with 10.4 mg/l and 53.6 mg/l in the effluent, which lead to an 80% increase of TSS.

Table 4.14: TSS Time Variations

Interval	**Time**	**Influent**	**Effluent**	**Reduction**
minute		**mg/l**	**mg/l**	**%**
15	07:39	79.6	39.6	50
30	07:54	67.6	74.4	
45	08:09	43.2	69.6	
60	08:24	38.8	58.4	
120	09:24	28	35.6	
180	10:24	10.4	53.6	

4.4.3 Nitrate Results

The results for nitrate showed favorable outcomes in terms of reduction rates. The influent samples seemed to have increased over time while the effluent samples decreased over time. The first flush had 0.0 mg/l of nitrate in the influent and the effluent had the highest concentration of all the samples taken, with 2.2 mg/l of nitrate. The 30 minute interval had a 50% removal rate of nitrate when the flow rate was 1.3 cfs. The samples taken at the 45, 60,120, and

180 minute interval all had a 100% reduction. The 60 minute interval sample had the highest concentration with 12.8 mg/l of nitrate in the influent. Sampling from 07:39 - 08:24 the concentrations appeared to increase in the influent, but managed to decrease during the 120 minute interval (Table 4.15).

Table 4.15: Nitrate Time Variations

Interval	**Time**	**Influent**	**Effluent**	**Reduction**
minute		**mg/l**	**mg/l**	**%**
15	07:39	0.0	2.2	
30	07:54	0.9	0.4	50
45	08:09	6.2	0.0	100
60	08:24	13	0.0	100
120	09:24	10.6	0.0	100
180	10:24	6.6	0.0	100

4.4.4 Phosphorus Results

For this particular storm the results for the phosphorus (Table 4.16) showed the Stormceptor was capable of removing phosphorus from the runoff (except during the 120 minute interval). The first flush contained the highest concentration in the influent sample with 1.4 mg/l and the concentration in the effluent sample had 0.1 mg/l, a 93% reduction. The 30 minute interval sample contained the second highest concentration with 0.8 mg/l of nitrate in the influent and 0.5 mg/l of nitrate in the effluent with a 38% reduction (the second lowest reduction rate). The samples taken at the 45, 60, and 180 minute interval had a 100% reduction in phosphorus while the 120 minute had a slight increase in concentration of phosphorus. Even with a flow rate of 0.07 cfs after the 60 minute interval the Stormceptor was still effective at removing the phosphorus. The concentration did decrease over time upstream of the Stormceptor, but the 60 minute interval sample showed an increase from the previous influent sample and then it decreased again at the 120 minute interval and slightly increased at the 180 minute interval.

Table 4.16: Phosphorus Time Variations

Interval	Time	Influent	Effluent	Reduction
minute		**mg/l**	**mg/l**	**%**
15	07:39	1.4	0.1	93
30	07:54	0.8	0.5	38
45	08:09	0.1	0.0	100
60	08:24	0.3	0.0	100
120	09:24	0.0	0.1	[redacted]
180	10:24	0.1	0.0	100

4.4.5 Oil and Grease Results

Analysis for oil and grease for the influent and effluent samples was done for the 30 minute sample time only. The lab report (from WST) showed there was non-detection for oil and grease because it was less than 5 mg/l even with a peak flow of 1.3cfs. A calculation was done to get a value of 2.5 mg/l for each sample. Even though there was no detection, from visual inspection during sampling there was a thin film of grease on top of the water sample collected and there was an odor to it.

4.4.6 Lead Results

The water samples collected for lead analysis were taken at the 30 minute sample time and sent to WST. The lab report showed that there was a 40% reduction in lead. There was 0.048 mg/l of lead detected in the influent and 0.029 mg/l of lead in the effluent samples.

4.4.7 Zinc Results

Analysis for zinc in the water samples were delivered to WST for the 30 minute interval only (influent and effluent). The results for zinc were 0.162 mg/l at the influent and 0.142 mg/l in the effluent, a 12.3% reduction.

4.5 Summary of Event Concentrations

For legal compliance purposes for each storm event (1-4) the mean concentration was taken for all the analytes. To determine if the influent quality could be effectively improved by the Stormceptor a percent reduction was calculated for each storm event based on the averages. With different rainfall intensities and durations each storm event on 06/09/10, 07/09/10, 09/16/10 and 09/28/10 was treated separately instead of combined. For storm event 2, only the second peak event data was included instead of the first peak event due to insufficient amount of data.

4.5.1 Mean Concentration of E.coli

A geometric mean was used instead of arithmetic mean to represent accurately the level of E.coli. Figure 4.5 shows that during the first storm event E.coli levels were higher in the influent with 400 colonies/100 ml of E.coli and lower in the effluent with 2 colonies/100 ml of E.coli, a 99.5% reduction. This storm event had the lowest levels of E.coli of all the storm events. Storm event 2 shows that the influent had lower levels with 1,485 colonies/100 ml of E.coli and the effluent had 2,219 colonies/100 ml of E.coli with no reduction. Storm event 3 had the highest levels of E.coli with 5,597 colonies/100 ml of E.coli in the influent and 9,626 colonies/100 ml of E.coli in the effluent and there was no reduction. The last storm event that was sampled on 09/28/10 had a 33% removal rate of E.coli with 976 colonies/100 ml of E.coli in the influent and 651 colonies/100 ml of E.coli in the effluent.

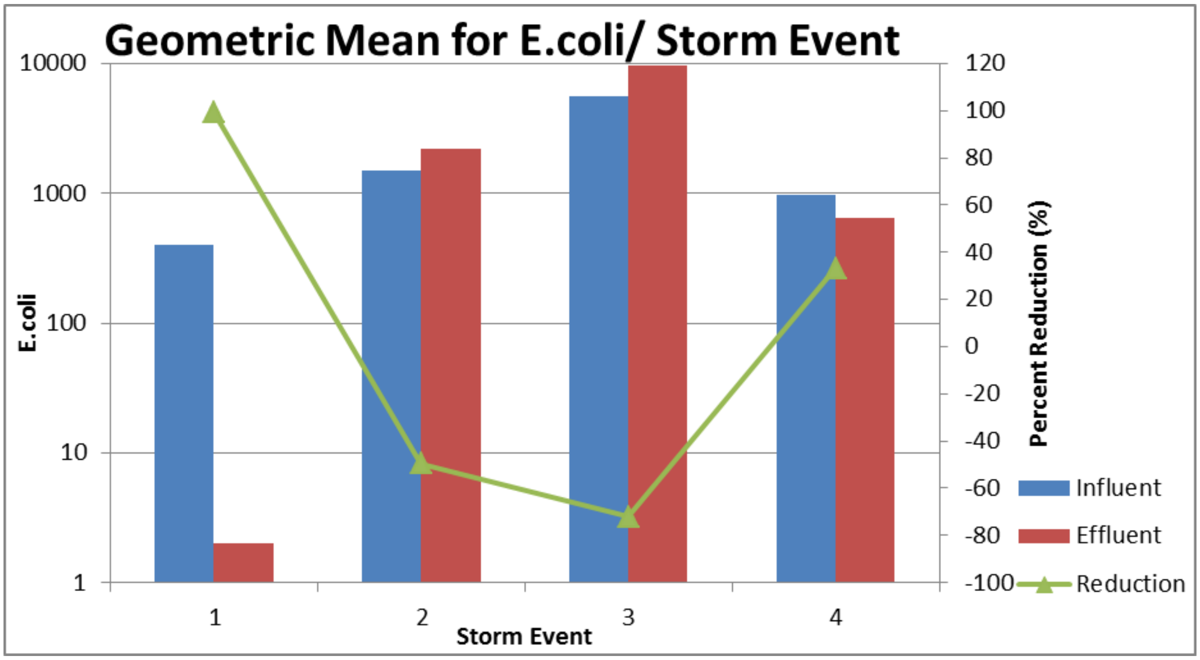


Figure 4.5: Percent Reduction for Geometric Mean E.coli Levels

4.5.2 Mean Concentration of Detergents

Only two storm events were used to collect water samples to analyze for detergents, 06/09/10 and 07/09/10. The arithmetic mean was calculated and the standard error to determine how much fluctuation there was in concentration during the sampling round. Both storm events showed a percent reduction in the effluent. Referring to Figure 4.6 storm event 1 had a mean concentration of 1.25 +/- 0.25 mg/l of detergents in the influent and 0.38 +/- 0.13 mg/l of detergents in the effluent. With these concentrations the percent removal of detergents from the runoff was 70%. Storm event 2 had fairly similar concentrations with 1.25 +/- 0 mg/l of detergents in the influent and 0.50 +/- 0 mg/l of detergents in the effluent, a 60% reduction.

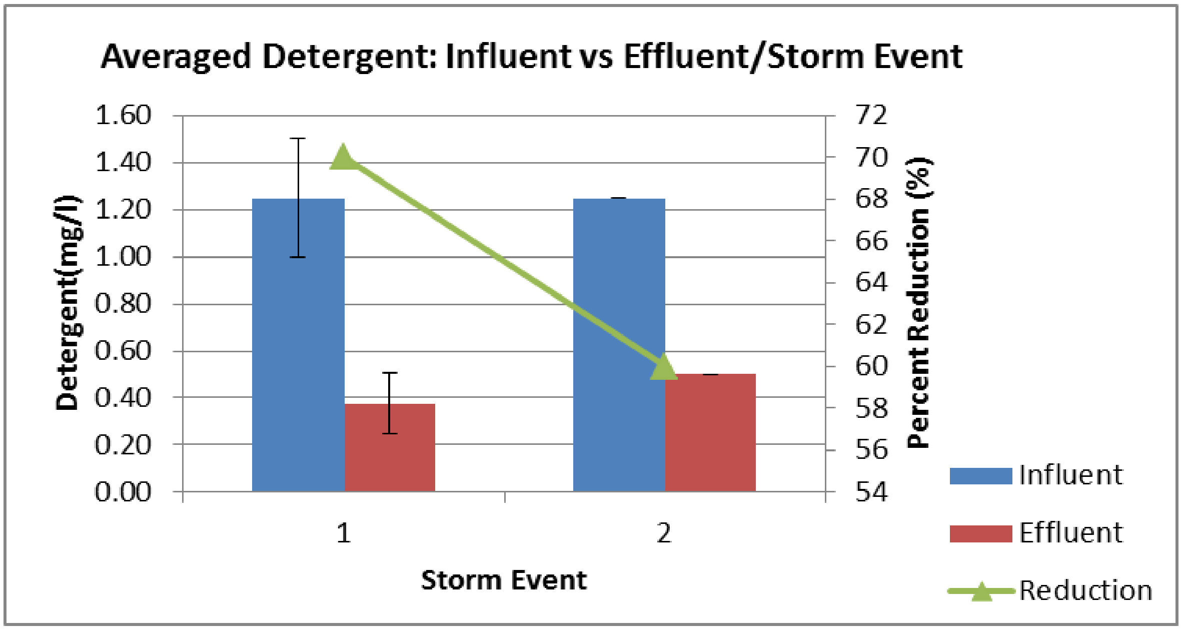


Figure 4.6: Percent Reduction for Mean Detergents Concentration

4.5.3 Mean Concentration of TSS

Water samples were collected for TSS analysis for all the storm events, but the first storm event was omitted due to lab error. The storm events shown in Figure 4.7 are for 07/09/10 (storm event 2), 09/16/10 (storm event 3) and 09/28/10 (storm event 4). Storm event 2 had the highest concentration of TSS. The mean of the five water samples were 59.9 +/- 32.3 mg/l in the influent and 193.4 +/- 134.3 mg/l in the effluent. Based on the 6 samples taken for storm event 3 this event had the lowest concentration of TSS with 29.1 +/- 8.6 mg/l in the influent and 21.7 +/-2.8 mg/l in the effluent. The last storm event there was 44.6 +/- 10.4 mg/l of TSS in the influent and 55.2 +/- 6.4 mg/l of TSS in the effluent. Even though storm event 3 had the lowest concentration of TSS it was the only event that had a reduction in TSS (25.5%).

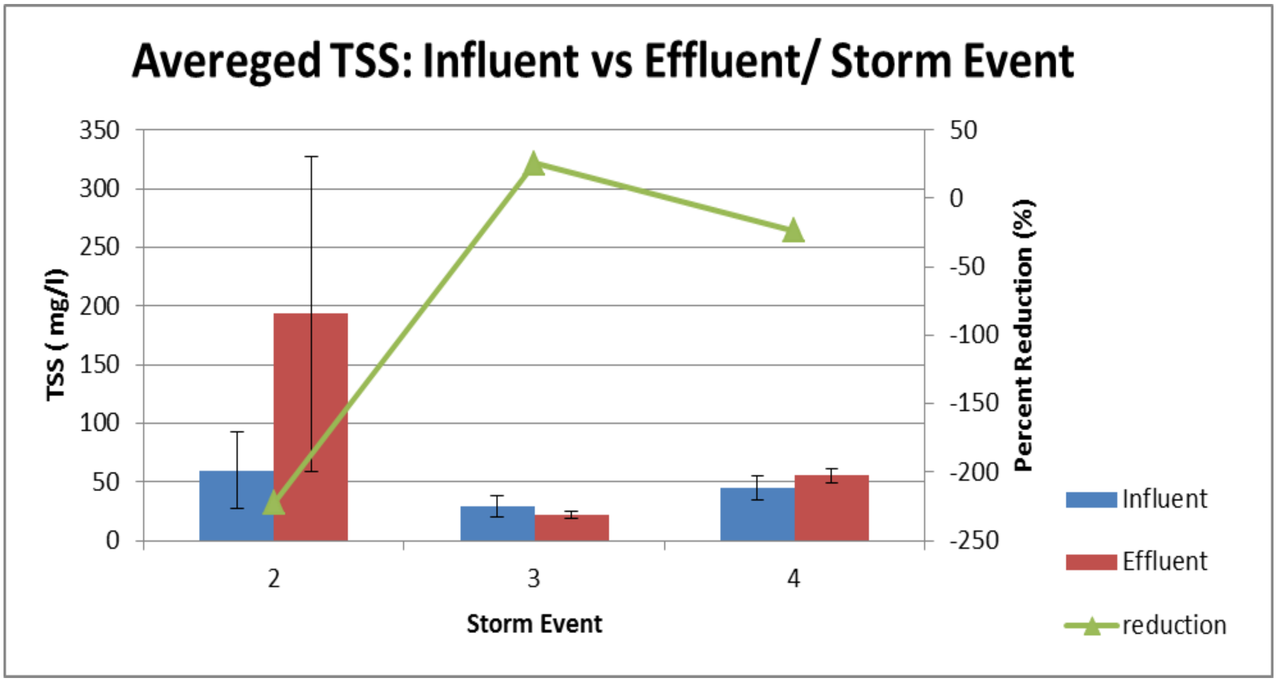


Figure 4.7: Percent Reduction for Mean TSS concentrations

4.5.4 Mean Concentration of Nitrate

Water samples were taken for all four storm events to analyze for nitrate. The water samples that produced an error where omitted from the mean concentrations calculations. The Stormceptor effectively removed the nitrate from the runoff during all four storm events (Figure 4.8). The minimum reduction rate was during the second storm event that removed 46% of the nitrate and the maximum removal rate was during the first storm event that had a 93% reduction rate. The second, third, and fourth storm event had comparatively similar mean concentrations in the influent, even though there were different rainfall intensities. The mean concentration for the first storm event was 4.0 +/- 0.8 mg/l in the influent and 0.3+/- 0.1mg/l in the effluent. There was 1.3+/- 0.6 mg/l of nitrate in the influent and 0.7 +/- 0.3 mg/l in the effluent during the second storm event. The samples that were collected on the third storm event had a mean concentration of 1.2 +/- 0.5 mg/l in the influent and a mean of 0.5 +/- 0.2 mg/l in the effluent. The fourth storm event samples in the influent had a mean concentration of 1.2 +/- 0.46 mg/l and the effluent had a mean concentration of 0.1 +/- 0.08 mg/l.

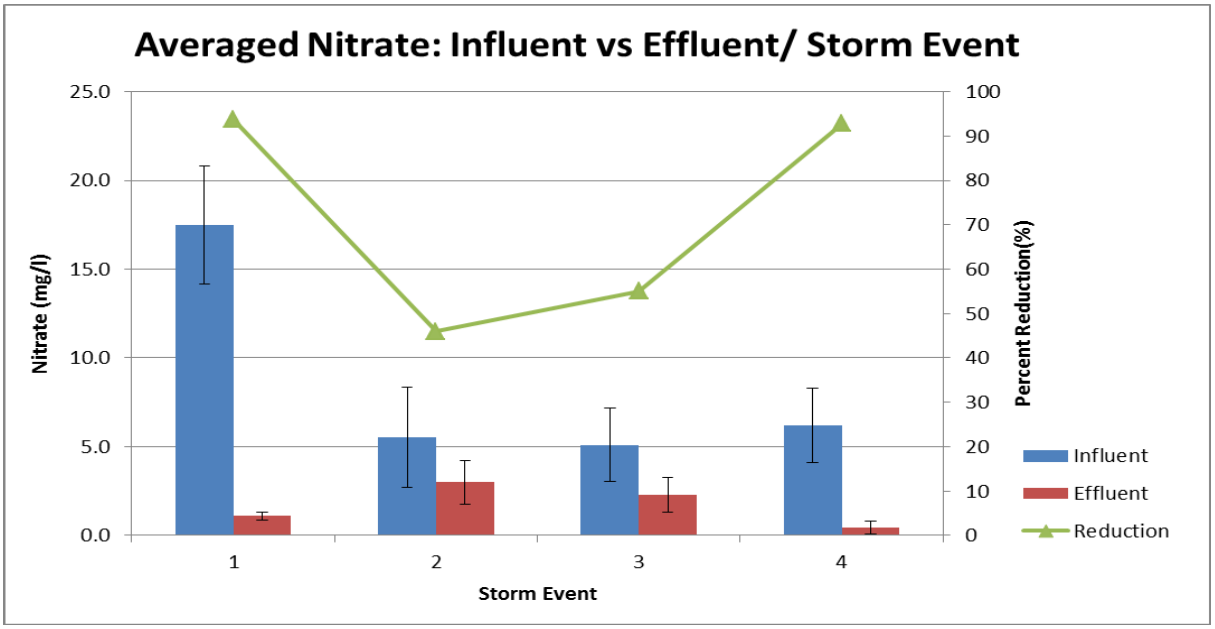


Figure 4.8: Percent Reduction for Mean Nitrate Concentrations

4.5.5 Mean Concentration of Phosphorus

Sampling during the first two storm events showed no reduction in phosphorus while the last two storm events showed the Stormceptor did remove the phosphorus from the runoff (Figure 4.9). For the first storm event the influent sample had a lower mean concentration of phosphorus at 0.3 +/- 0.2 mg/l than the effluent sample which had a mean of 1.15 +/- 1.15 mg/l, a -283 % reduction. The effluent for the first storm event had the highest mean concentration as compared to all other storm events, but also had a 1.63 mg/l standard deviation. The second storm event on 07/09/2010 had a mean concentration in the influent that once again was lower than the effluent; therefore there was a percent increase in phosphorus during this sampling period. The influent had a mean concentration of 0.4 +/- 0.13 mg/l and 0.85 +/- 0.35 mg/l in the effluent. The third storm event had an 11% reduction in phosphorus, as the mean concentration in the influent was 0.62 +/- 0.31 mg/l and the effluent sample had a mean of 0.55 +/- 0.15 mg/l. The water samples taken during the fourth storm event on 09/28/10 had a 73% reduction in concentration of phosphorus which was the highest of all the storm events. This storm event had approximately the lowest concentrations in the influent and effluent compared to the other storm event samples. The influent had a mean concentration of 0.45 +/- 0.22 mg/l and the effluent had a mean concentration of 0.12 +/- 0.08 mg/l.

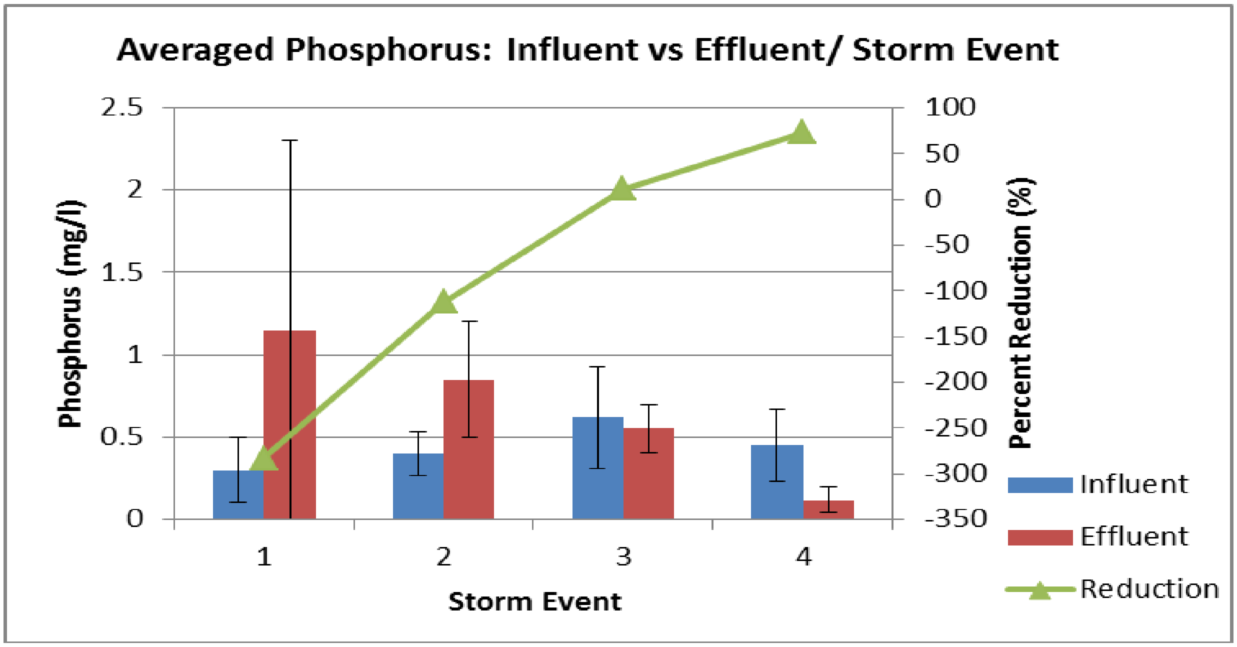


Figure 4.9: Percent Reduction for Mean Phosphorus Concentrations

4.5.6 Concentration of Oil and Grease

The water samples were analyzed using the EPA 1664A methods and showed that over 50% of the samples were less than the MDL of 5 mg/l in oil and grease. For each storm event only one set of samples were taken to analyze oil and grease. The first storm event samples had non-detections at both the influent and effluent sample. The second storm event on 07/09/10 had a 55% reduction of oil and grease (Table 4.17). This event had higher concentrations than any other storm event sample. The samples collected upstream and downstream of the Stormceptor had a concentration of 24.8 mg/l in the influent and 11.1 mg/l in the effluent. The third event on 09/16/10 had 6.8 mg/l of oil and grease detected in the influent and non-detection in the effluent. The last storm event had non-detections for both influent and effluent samples.

Table 4.17: Oil and Grease Concentrations

Date	Influent	Effluent
	mg/l	mg/l
06/09/2010	<5	<5
07/09/2010	24.8	11.1
09/16/2010	6.8	<5
09/28/2010	<5	<5

4.5.7 Lead Concentrations

Water samples were only analyzed for lead on 07/09/10 (storm event 2), 09/16/10 (storm event 3), and 09/28/10 (storm event 4) and one set (influent and effluent) of samples were taken for each storm event except for on 09/16/10 when two sets were collected. Using the EPA 6000/7000 Series Methods to analyze for lead there was a MDL of 0.015 mg/l and the majority of the samples taken had a non-detection of lead in the runoff as shown in Table 4.18.Except on 09/28/10 the Stormceptor was able to remove 40% of lead from the runoff.

Table 4.18: Lead Concentrations

Date	Influent	Effluent
	mg/l	mg/l
07/09/2010	< 0.015	< 0.015
09/16/2010	< 0.015	< 0.015
09/28/2010	0.048	0.029

4.5.8 Zinc Concentrations

Sampling for zinc in the runoff started on the second storm event that occurred on 07/09/10. Only one set of samples (influent and effluent) were taken for each storm event except on 09/16/10 when two samples were collected. Sampling that occurred during the second storm event had the lowest concentration of zinc as compared to other storm events (Figure 4.10). The influent concentration of 0.03 +/-0 mg/l was lower than the effluent concentration of 0.04 +/- 0 mg/l and had a -43% reduction rate. The third storm event had the highest percent reduction of 57%. The last storm event had a 12% reduction rate with 0.16 +/- 0 mg/l in the influent and 0.14 +/- 0 mg/l in the effluent.

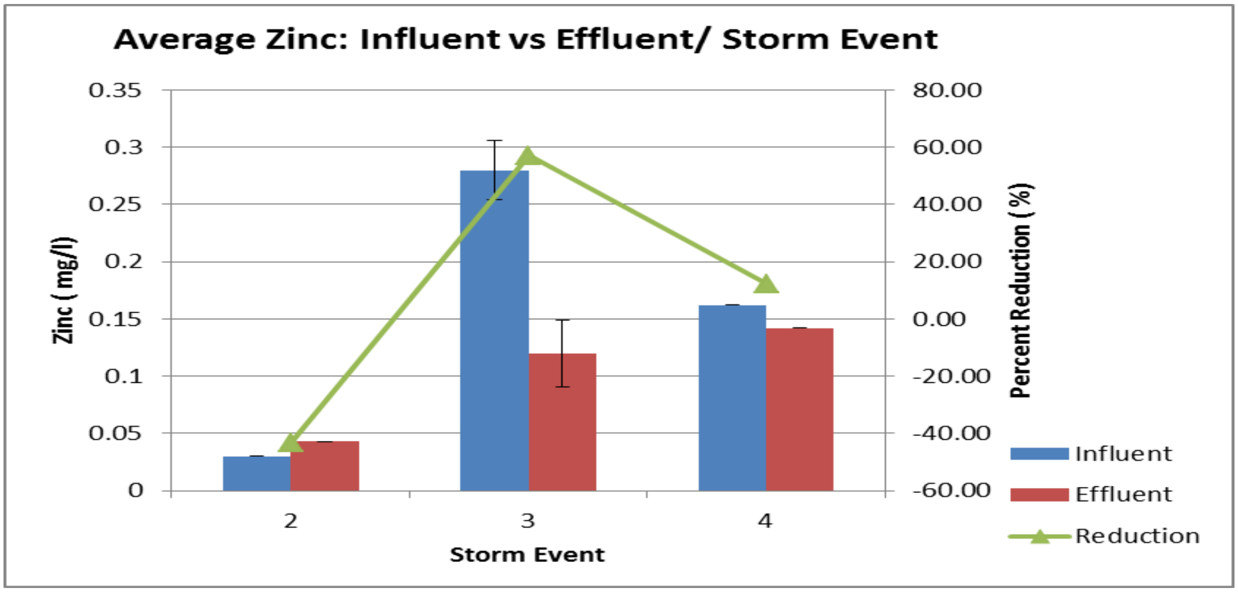


Figure 4.10: Percent Reduction for Mean Zinc Concentrations

4.6 Stormceptor Removal Efficiency

To determine if the stormceptor is an effective BMP at removing water pollutants a paired t-Test was used at a significance level of 0.05 for each average pollutant concentration combining all the storm events (t-Test were omitted for zinc, lead, oil and grease due to insufficient data). The efficiency was based on the pollution concentration before the runoff entered the Stormceptor (influent) and after the runoff exited the Stormceptor (effluent). The following two hypotheses were used to examine this theory:

HO: there is no difference between the average influent and effluent concentrations.

H1: there is a difference between the average influent and effluent concentrations using the Stormceptor.

4.6.1 E.coli

A paired t-Test was performed to determine if the Stormceptor was effective at removing E.coli from the runoff .The mean reduction (N= 4) was not significantly different from 0, t Stat = 0.972, two tail p = 0.402 (Table 4-19), which provided evidence that the stormceptor is not effective at removing E.coli. Referring to Table 4.19 the t Stat (0.972) is less than t Critical two – tail (3.18) which also indicates there is a 95% certainty that after the runoff went through the stormceptor there was no significant reduction in pollution concentrations combining all the storm events together.

Table 4.19: E.coli Paired Two Sample t - Test

	E.coli Effluent	*E.coli Influent*
Mean	3124.5	2114.5
Variance	19,652,547	5,586,590
Observations	4	4
Pearson Correlation	0.998306707	
Hypothesized Mean Difference	0	
df	3	
t Stat	0.972052004	
P(T<=t) one-tail	0.201360424	
t Critical one-tail	2.353363435	
P(T<=t) two-tail	0.402720847	
t Critical two-tail	3.182446305	

4.6.2 Detergents

Detergents removal from the system was tested using a paired t- test was used to determine the two hypotheses. Using only the first and second storm event (second peak flow) to analyze detergents (N=2). Table 4.20 shows t Stat = 13 p = 0.049 and the p value calculated for the two tailed test (0.049) is smaller than the alpha (0.05) therefore HO is rejected. Furthermore, Table 4.20 shows the t Stat (13) is larger than the t Critical two- tail value of 12.7, therefore HO is rejected. The Stormceptor is reducing detergents, on average.

Table 4.20: Detergents Paired Two Sampled t-Test

	Detergent Influent	*Detergent Effluent*
Mean	1.25	0.4375
Variance	0	0.0078125
Observations	2	2
Pearson Correlation	#DIV/0!	
Hypothesized Mean Difference	0	
df	1	
t Stat	13	
P(T<=t) one-tail	0.024437252	
t Critical one-tail	6.313751514	
P(T<=t) two-tail	0.048874504	
t Critical two-tail	12.70620473	

4.6.3 TSS

Only three (N= 3) of the storm events (storm event 1 was omitted) were used to determine if the Stormceptor was significantly removing pollutants. The results for TSS using the paired t-Test showed that there was a 95% certainty that the Stormceptor is not effective at removing TSS from the system because there is no evidence to reject HO (fail to reject HO) as shown in Table 4.21 where: t Stat is 1.03, t Critical is 4.3, and P value > 0.05.

Table 4.21: TSS Paired Two Sample t-Test

	TSS Effluent	*TSS Influent*
Mean	90.1	44.53333333
Variance	8283.73	237.1633333
Observations	3	3
Pearson Correlation	0.941999527	
Hypothesized Mean Difference	0	
df	2	
t Stat	1.029228291	
P(T<=t) one-tail	0.205781542	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.411563085	
t Critical two-tail	4.30265273	

4.6.4 Nitrate

Table 4.22 shows the statistical analysis for all the nitrate water samples collected (N= 4) and the results are t Stat = 2.1and t Critical is 3.18 and P= 0.12. There is a 95% certainty that the Stormceptor does not effectively remove nitrate from the system (fail to reject HO because there is no strong evidence to reject it). However, the P value is 0.12, which is approaching a significant difference.

Table 4.22: Nitrate Paired Two Sample t - Test

	Nitrate Influent	*Nitrate Effluent*
Mean	8.583125	1.707395833
Variance	35.53333456	1.314118738
Observations	4	4
Pearson Correlation	-0.403564432	
Hypothesized Mean Difference	0	
df	3	
t Stat	2.112788773	
P(T<=t) one-tail	0.062517689	
t Critical one-tail	2.353363435	
P(T<=t) two-tail	0.125035379	
t Critical two-tail	3.182446305	

4.6.5 Phosphorous

Phosphorous was analyzed for all four storm events (N=4). The results from Table 4.23 shows there is no difference between the average phosphorous concentrations in the influent and effluent samples and we therefore fail to reject H0 t Stat = 0.85 and t Critical = 3.18 and P = 0.45.

Table 4.23: Phosphorous Paired Two Sample t- Test

	P Effluent	*P Influent*
Mean	0.6675	0.4425
Variance	0.193225	0.017891667
Observations	4	4
Pearson Correlation	-0.57528195	
Hypothesized Mean Difference	0	
df	3	
t Stat	0.852299223	
P(T<=t) one-tail	0.228341779	
t Critical one-tail	2.353363435	
P(T<=t) two-tail	0.456683558	
t Critical two-tail	3.182446305	

4.7 PCSWMM

PCSWMM was used to predict the rainfall-runoff surface flow rather than quality for four different storm events, all of which had different rainfall depths and durations. The model was calibrated using the observed flow data that was collected with the Sigma 910 flow meter from 06/09/10 – 10/01/10. The relationship between rainfall and observed flow for the entire period of record is shown in Figure 4.11, while the relationships between rainfall and observed flow for the four modeled events is shown in Figure 4.12

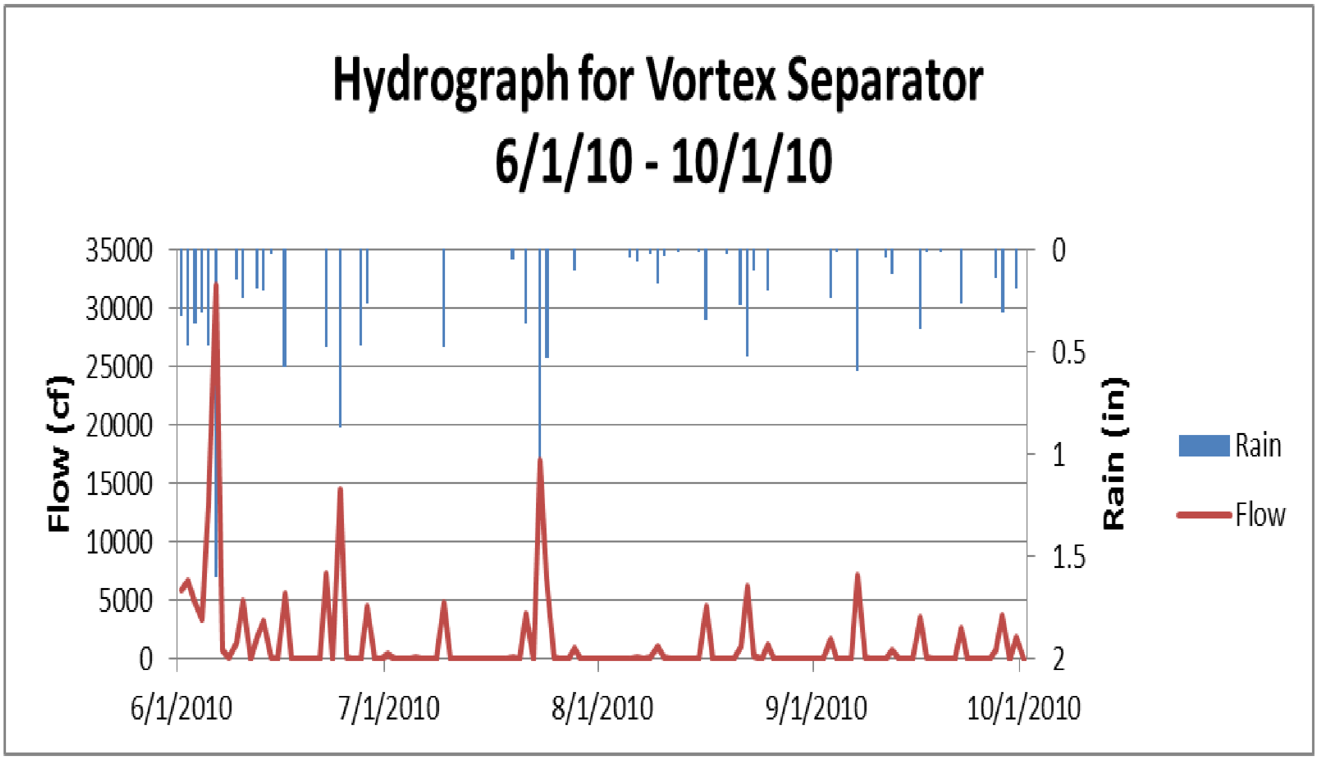


Figure 4.11: Hydrograph from all storm events

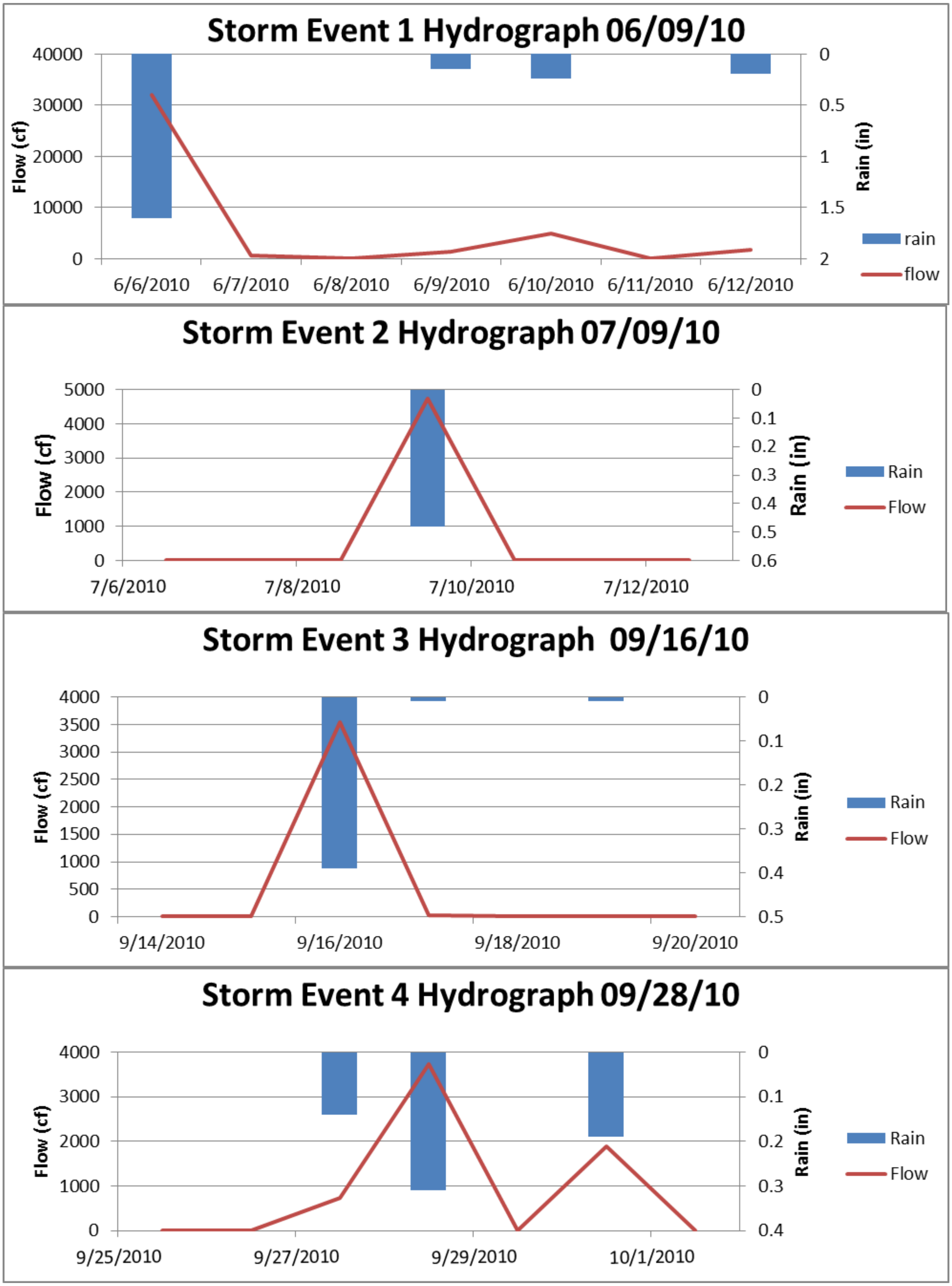


Figure 4.12: Hydrograph (rainfall-runoff) for individual storm events

To help ensure accuracy of the PCSWMM model predictions the model was calibrated to each of the storm events. Figure 4.13 shows a depiction of the PCSWMM model setup for the study area.

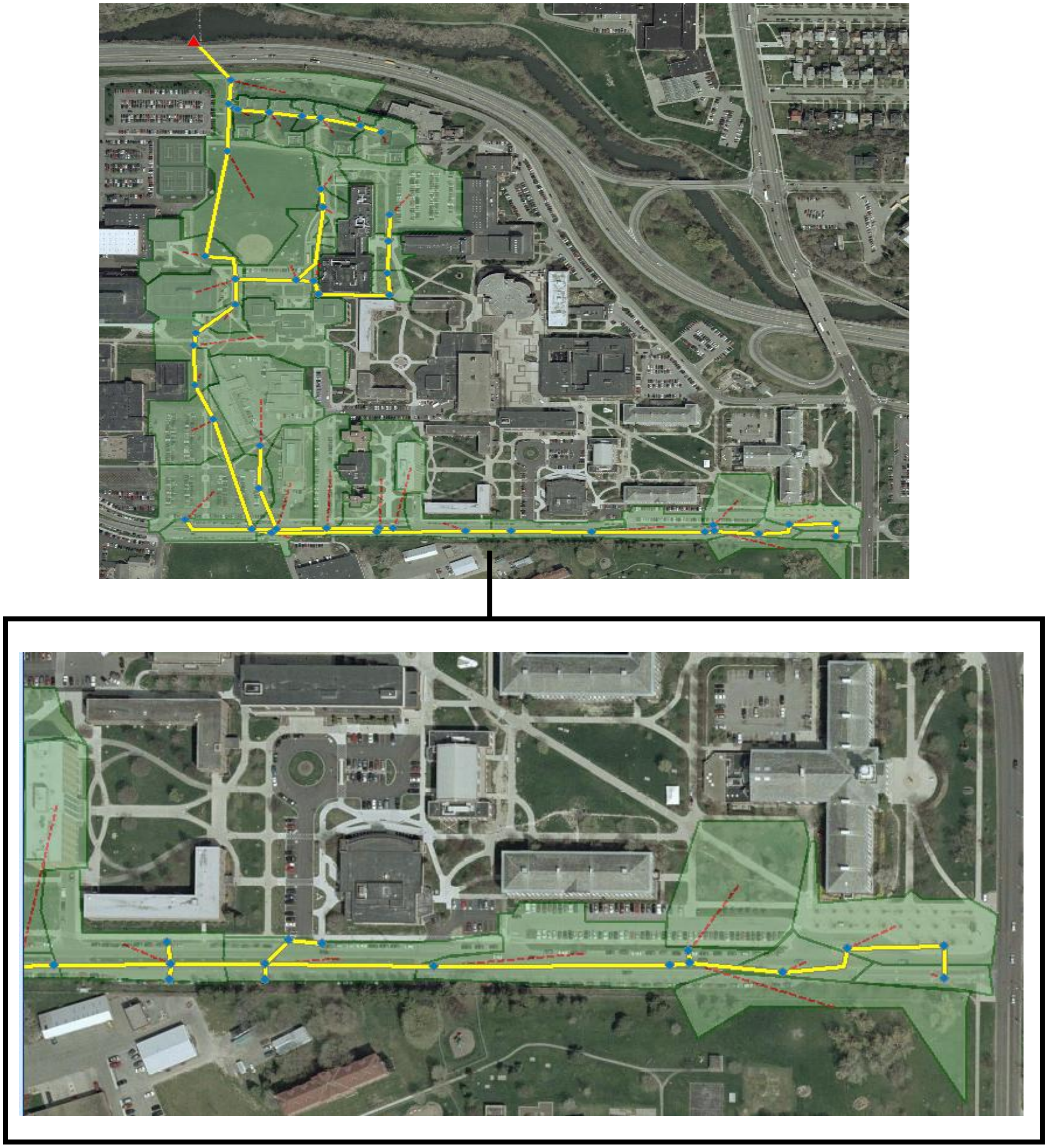


Figure 4.13: PCSWMM version of study area. The red lines show the subcatchment areas that drain into the appropriate catchbasins (blue dots) which are all located on the main trunk line.

For each storm event the various attributes of the subcatchments were calibrated within a 30% range to better represent the observed flow. Mainly the impervious areas, depression storage, and zero impervious area was adjusted (Figure 4.14). For each subcatchment either by visual or field inspection the attributes can be defined for PCSWMM. Adjustments were made for the time series due to the fact that the rain gauge data used hourly intervals and the flow meter collected data in five minute intervals and as such there was a two hour time lag when running the model. The data in the time series had to be set back by two hours to account for the time lag. Overall the storm events produced relatively small amounts of flow. To evaluate model performance, statistical analysis was used to assess the calibration by visual inspection of scatter plots and the coefficient of determination value for each storm event. A computer model that has higher than a 60% correlation is considered excellent. Three out of the four storm events showed strong correlations, which indicates overall that PCSWMM is a good indicator for predicting future flows (Figures 4.15 - 4.18).

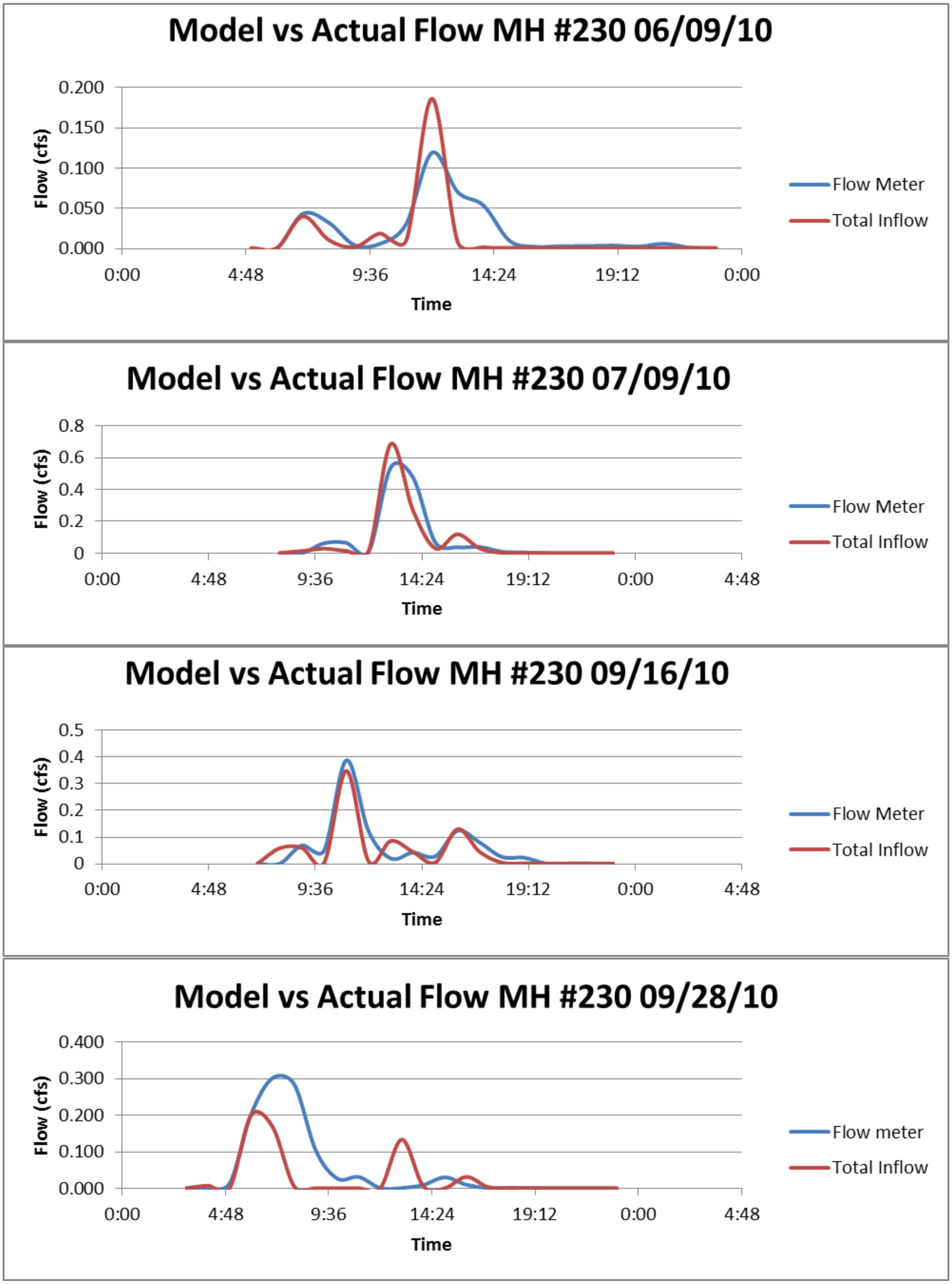


Figure 4.14: Calibrating Model

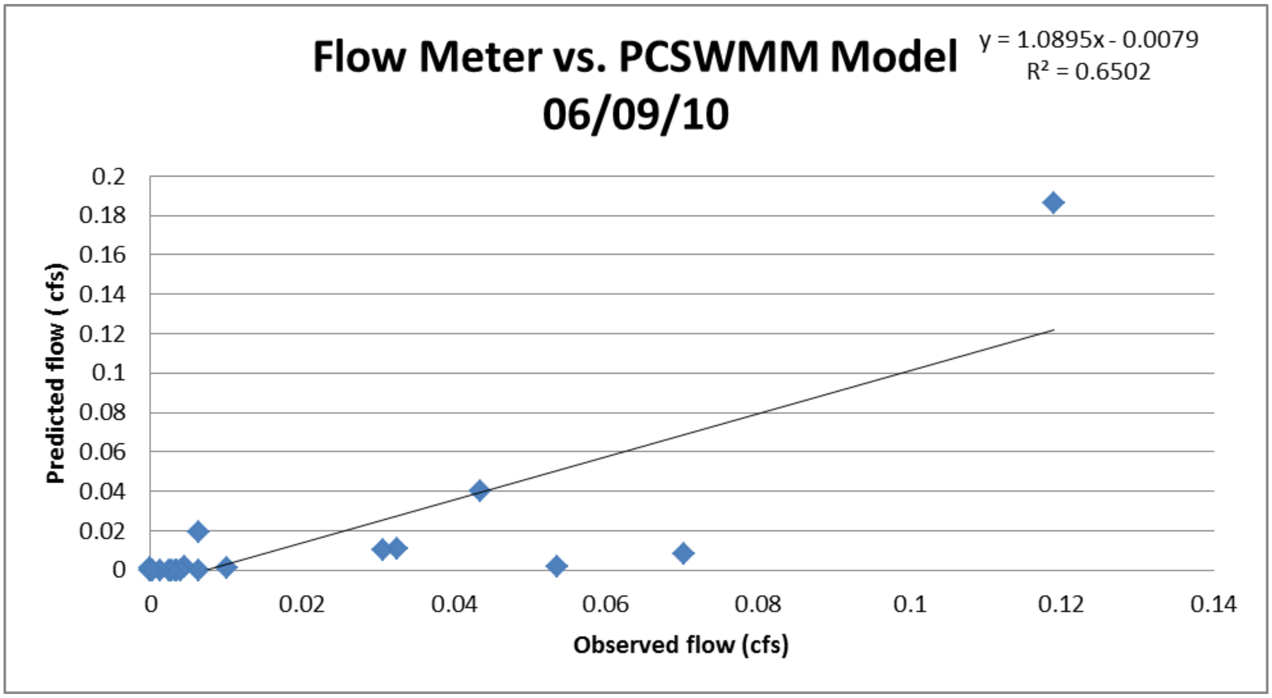


Figure 4.15: Storm Event 1 correlation between predicted and observed flow, 65% positive correlation.

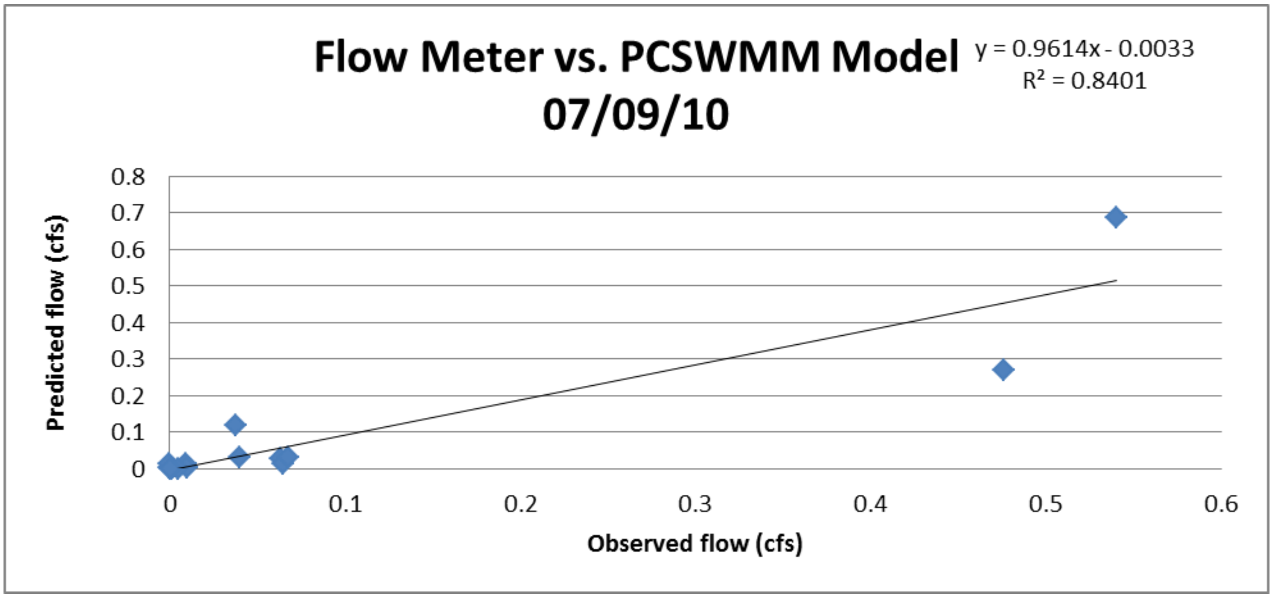


Figure 4.16: Storm event 2 correlation between predicted and observed flow, 84% positive correlation.

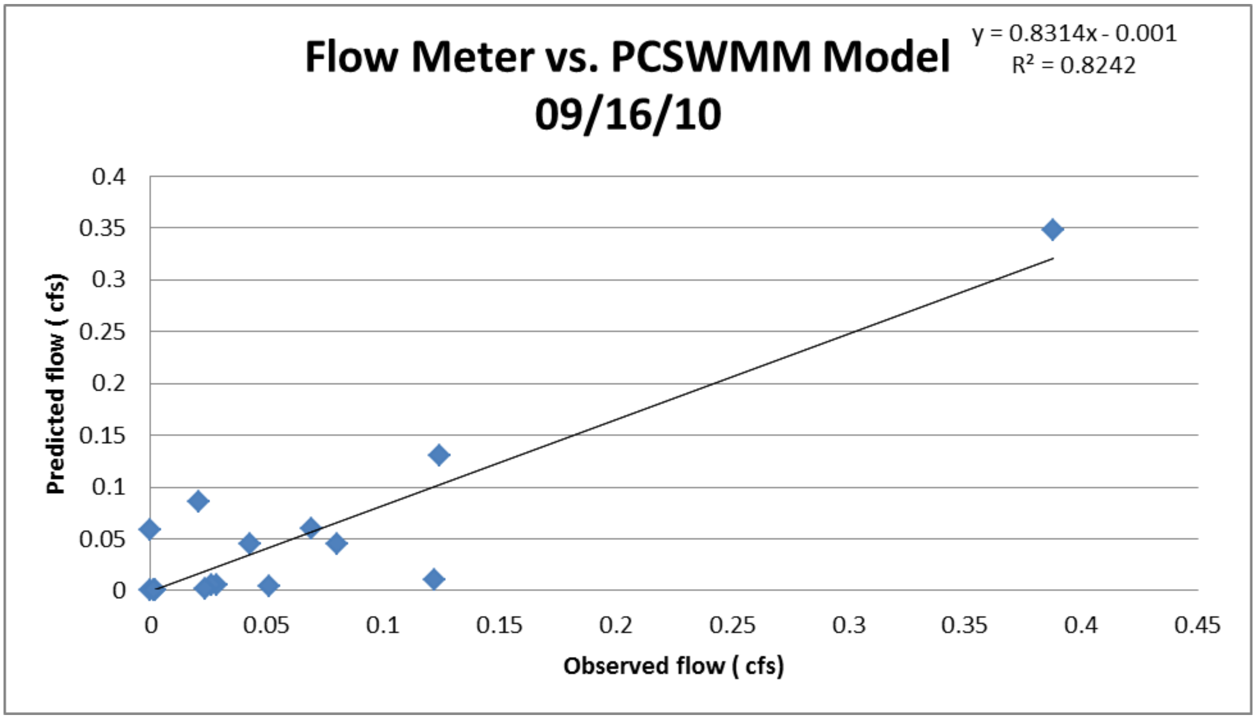


Figure 4.17: Storm event 3 correlation between predicted and observed flow, 82% positive correlation.

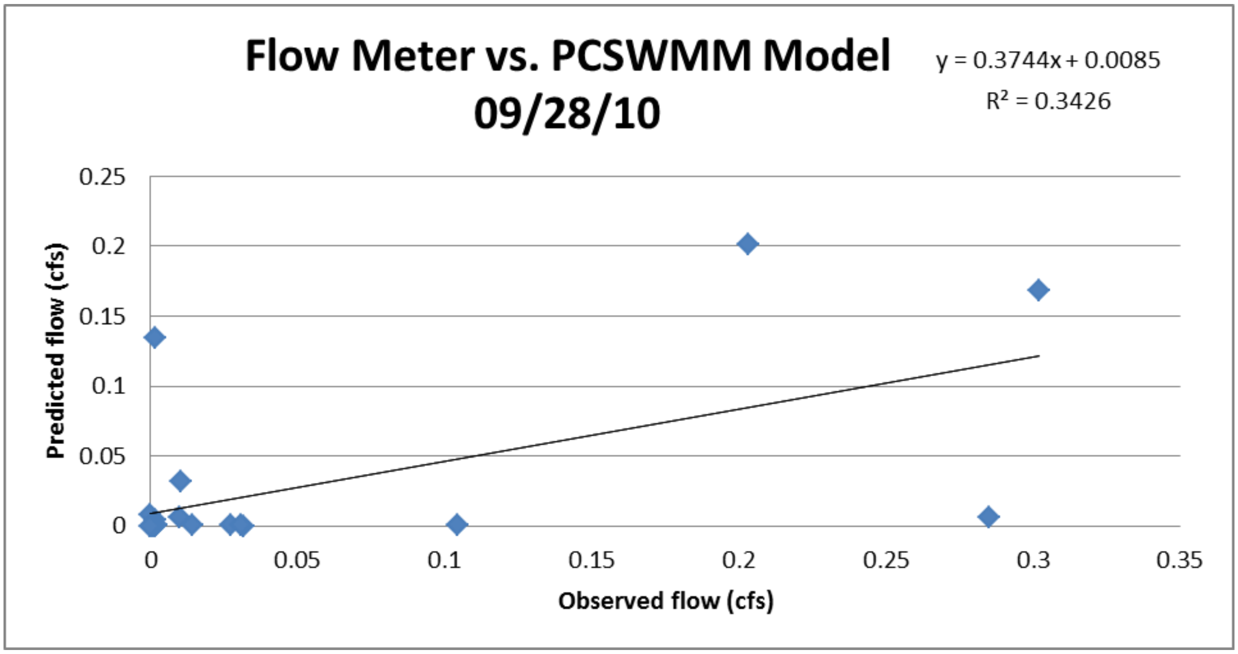


Figure 4.18: Storm event 4 correlation between predicted and observed flow, 32% positive weak correlation.

4.8 Quality Assurance and Quality Control

Quality assurance and quality control was done during random sampling intervals and for different parameters by taking duplicate samples for phosphorus, nitrate, lead, zinc, oil and grease (no duplicates for E.coli and TSS). This was to assure that the original samples taken were defensible samples. As a control measure the relative percent difference (RPD) was calculated to determine if the outcomes were the same. Ideally calculating a RPD of 0% indicates that the original and duplicate sample were the same. A RPD of 20% or greater will indicate that the two samples varied too much. A total of 13 duplicate samples were collected upstream (InOrg and InDup) and 6 duplicates were collected downstream (EffOrg and EffDup) of the stormceptor (Table 4.25A and 4.25B)

Table 4.25A: Duplicate Influent Samples

Date	Pollutant	Time interval	InOrg	InDup	InAvg
		minute	mg/l	mg/l	mg/l
07/09/2010	Nitrate	90	1.9	0.9	1.4
07/09/2010	Nitrate	90	1.9	0.25	1.075
07/09/2010	O&G	90	24.8	6.4	15.6
07/09/2010	Lead	90	0.0075	0.0075	0.0075
07/09/2010	Zinc	90	0.03	0.03	0.03
09/16/2010	Nitrate	15	0.25	1	0.625
09/16/2010	Phosphorus	15	0.15	0.9	0.525
09/16/2010	Phosphorus	60	0.15	0.2	0.175
09/16/2010	Phosphorus	180	1	0.5	0.75
09/28/2010	Phosphorus	60	0.3	0.15	0.225
09/28/2010	Nitrate	30	0.2	0.25	0.225
09/28/2010	Nitrate	60	2.9	0.25	1.575
09/28/2010	Nitrate	120	2.4	0.25	1.325

InOrg = original influent sample
InDup = duplicate influent sample
InAvg = average influent sample

Table 4.25B: Duplicate Effluent Samples

Date	Pollutant	Time interval	EffOrg	EffDup	EffAvg
		minute	mg/l	mg/l	mg/l
09/16/2010	Nitrate	60	0.25	1.3	0.775
09/16/2010	Phosphorus	15	0.6	0.15	0.375
09/16/2010	Phosphorus	60	0.7	0.2	0.45
09/28/2010	Phosphorus	30	0.5	0.1	0.3
09/28/2010	Nitrate	60	0.25	0.25	0.25
09/28/2010	Nitrate	120	0.25	0.25	0.25

EffOrg = original effluent sample
EffDup = duplicate effluent sample
EffAvg = average effluent sample

Half the analyte MDL was used if the concentrations were 0 mg/l or below detect. Table 4.26A and 4.26B shows the RPD for each duplicate sample. There were only two samples that had a RPD of 0% which was lead and zinc. The phosphorus sample taken on 09/16/10 and the nitrate sample taken on 09/28/10 both had a RDP value less than 50%. The samples taken for nitrate on 09/28/10 had the highest variation of 168% and 162% consecutively. The rest of the samples had values greater than 50%. The two effluent samples for nitrate had RPDs that were 0% and the rest of the samples had RPDs greater than 50%. On 09/16/10 the nitrate sample had a RPD of 136%. During the 15 minute sampling interval on that day phosphorus had 120% RPD and at the 60 minute interval the RPD was 111%. A duplicate sample for phosphorus was taken on 09/28/10 and had a RPD of 133%. Half the MDL of 0.3 mg/l of phosphorus was used to calculate the RPD for some of the samples. This includes samples taken during the third storm event at the 15 minute interval in the influent and effluent and at the 60 minute interval in the influent. Half of the MDL was also used during the fourth storm event at the 60 minute sampling interval in the influent.

Table 4.26A: Relative Percent Difference of Influent Samples

Date	Analyte	Interval	InRPD
		minute	%
07/09/2010	Nitrate	90	71.4
07/09/2010	Nitrate	90	153.5
07/09/2010	O&G	90	117.9
07/09/2010	Lead	90	0.0
07/09/2010	Zinc	90	0.0
09/16/2010	Nitrate	15	120.0
09/16/2010	Phosphorus	15	142.9
09/16/2010	Phosphorus	60	28.6
09/16/2010	Phosphorus	180	66.7
09/28/2010	Phosphorus	60	66.7
09/28/2010	Nitrate	30	22.2
09/28/2010	Nitrate	60	168.3
09/28/2010	Nitrate	120	162.3

InRPD = influent relative percent difference

Table 4.26B: Relative Percent Difference of Effluent Samples

Date	Analyte	Interval	EffRPD
		minute	%
09/16/2010	Nitrate	60	135.5
09/16/2010	Phosphorus	15	120
09/16/2010	Phosphorus	60	111.1
09/28/2010	Phosphorus	30	133.3
09/28/2010	Nitrate	60	0
09/28/2010	Nitrate	120	0

EffRPD = effluent relative percent difference

5. DISCUSSION

5.1 Generalization for Each Storm Event

The Stormceptor operates based on the drainage area and rate of flow rather than volume (Clayton 1999). Flow rate was taken into consideration for each sampling interval to determine how the In- Line Stormceptor STC - 2400 ® performed at removing pollutants from the runoff during different storm events. The flow rate varied for each time interval and for each storm event. The Stormceptor is located on the main trunk line of the sewer system in a small drainage area and based on Rinker manufacturer standards the Stormceptor should be connected latterly from the trunk line. This is to prevent by-pass overflow from larger rainfalls. The Stormceptor has a patent (Number 4985148) to prevent scouring, but the results indicate that scouring could be one of the reasons why the effluent concentrations are higher than the influent concentrations.

5.1.1 Storm Event 1 Trends

For the first storm event on 06/09/10 there was a 48 hour antecedent period. The event had an average flow of 0.030 cfs during the sampling times and an accumulation rainfall of 0.15 inches for that entire day with a runoff volume of 1,448 ft^3. The rain event started Wednesday at 6:00 am and there was not enough rainfall to produce a great enough flow to collect samples to do analysis. Samples were collected in the first 15 minutes during the second wave of rainfall which started around 11:40 am with a temperature of 54 degrees Celsius a wind speed of 9 mph South East and the rainfall reached 0.02 inches. The rain event did not last long enough to do all six time intervals (15, 30, 60, 120, 180, 300 minute) for each type of sample. For this particular rain event only E.Coli, detergents, nitrate, total phosphorus, oil and grease were collected at 15 and 30 minute intervals along with the pH which was neutral at 7.44.

With a normal flow rate the majority of the pollutants were able to be effectively removed by the Stormceptor except for phosphorus. This storm event had the highest mean concentration of pollutants removed as compared to the other three sampled events. Going into further detail for this event the flow rate fluctuated between the two sampling intervals (15 and 30 minute). When the flow rate was 0.048 cfs during the first flush the amount of pollutants were higher and when the flow rate was 0.013 cfs the pollutant concentrations were lower.

There was a time delay at the upstream and downstream site because the team could not deploy fast enough for each time interval. Water samples were collected to analyze for TSS, but there were technical issues with the Tyson oven not being set to the appropriate temperature and the TSS apparatus was malfunctioning so analysis was not completed. Nitrate concentrations decreased over time in the effluent. Phosphorus had similar concentrations in the influent (0.3 mg/l) as is normally found in runoff where the average is 0.26 mg/l (Center for Watershed Protection 2007) or 0.33 mg/l (EPA 1983)

5.1.2 Storm Event 2 Trends

For the second storm event on 07/09/10 there was a 72 hour antecedent period, but it was an infrequent high flow event with an average flow rate of 0.73 cfs during the sampling period and 0.48 inches of rainfall for the entire day with a runoff volume of 1,165 ft^3. Since this was a high flow event the runoff managed to by-pass the weir and go straight into the outlet with no treatment or scouring could have prevailed. Therefore, the effluent concentrations were higher than the influent samples for majority of the pollutants.

The first peak flow event at 10:25 am (0.175 cfs) had a higher concentration for E.coli and detergents than the second peak flow event which had a higher flow rate of 0.852 cfs while zinc and oil and grease were lower than the second peak flow. The E.coli concentration for the first peak flow event was 4,300 colonies/ 100 ml in the effluent, which was higher than all the samples taken during the second peak flow event. The results for the detergents collected during the first peak was 7.5 mg/l in the influent and was higher than the first storm event samples and the other sample taken during the second storm event. Since this was a 72 hour antecedent period the first flush had the highest amount of pollutants at a flow rate of 0.852 cfs because the pollutants were able to build up. The 30 minute interval had the highest flow rate of 1.006 cfs and had the second highest concentration of pollutants. The first flush washed or diluted the pollutants which reduced the amount of pollutants during the 30 minute sampling interval. The last interval had the lowest flow rate of 0.179 cfs and had the lowest concentration of pollutants. On average there was no pollutant removal for E.coli, TSS, zinc and phosphorus.

False start rain events are problematic for a sampling program as it was for this case. For the most part, storm events are unpredictable and when sampling began it quickly came to a halt where only one sample could be collected, but it was ideal to collect samples that represented the storm event that is why there is a first and second peak sampling round.

E.coli in the effluent was higher than in the influent, as was the case with the TSS. There is a possibility that the high flow could have scoured the E.coli and TSS. Detergents were analyzed for this storm event but not the previous due to shortage of supplies. The first peak showed a high concentration of detergents in the influent, but no downstream sample was collected because the team would not have been able to deploy fast enough. Detergents were visibly noticeable on the surface during the storm event. Analyzing for nitrate was slightly problematic due to the inaccuracy of the Hannah Multiparameter meter that was used to test the water samples therefore the results are not conclusive. The results showed lower nitrate coming into the system and higher nitrate leaving the system. The assumption is as the rainfall dissipates so should the amount of pollutant concentration in the runoff. In this case at the 60 minute interval there were higher levels of nitrates found in the runoff than during the start of the rainfall, with 2.4 mg/l in the influent and 1.3 mg/l in the effluent. Triplicate samples were taken at the last interval for the influent and resulted in 1.9, 0.9, and 0.0 mg/l and then averaged to get 0.93 mg/l. A triplicate sample was also done for the effluent sample and resulted in errors each time.

5.1.3 Storm Event 3 Trends

There was a 72 hour antecedent period for the third storm event on 09/16/10 and it had a very low flow rate with an average of 0.08 cfs during the sampling period and 0.39 inches of rainfall for the entire day with a runoff volume of 3,814 ft^3. The sampling started as soon as it started raining and sample times were as follows: 15, 30, 45, 60, 120, and 180 minutes, which is slightly different from the previous two rain events of samples. The alteration of time intervals is due to the duration of the rain event itself. The majority of the mean concentrations were lower in the effluent except for E.coli. It was observed that the E.coli levels during most of the sampling intervals in the effluent were higher than the influent concentrations. There was an outlier in the effluent sample during the 30 minute interval that was approximately 20 times higher than the influent and had the highest levels in the effluent, possibly due to scouring.

Considering this was a 72 hour antecedent period, the first flush concentrations were relatively low compared to the other sampling intervals. There was only one exception; TSS had a higher concentration during the first flush. This storm event had the highest flow rate at 0.191

cfs during the 120 minute sampling interval which was right after the peak flow. There was no large increase in concentration of any pollutants during this time. The flow rate of 0.191 cfs may have been the highest sampled for this event, but the flow rate is still relatively low. Zinc showed detection amounts in the runoff with a higher concentration during the first 15 minutes of sampling upstream that had 0.166 mg/l in the influent as compared to 0.031 mg/l in the effluent. Once the runoff went through the Stormceptor the amount of zinc went from 0.115 to 0.088 mg/l. During the 60 minute interval of sampling the amount of lead found in the runoff drastically decrease from the initial start of sampling in the influent to 0.115 mg/l. The results for phosphorus in the runoff were variable when samples were taken for each time interval. Phosphorus in the influent sample fluctuated from concentrations at the beginning of the rain event (0.9 mg/l) to increasing even higher (1.9 mg/l) then decreasing again (0.2, 0.0 mg/l respectively) to increasing again to 0.75 mg/l over a period of time. Comparing the effluent to the influent water samples by time intervals 50% of the time the runoff coming through the outlet of the Stormceptor did decrease in concentration and the other 50% of the time there was an increase in concentration in the effluent.

5.1.4 Storm Event 4 Trends

The fourth storm event on 09/28/10 was a frequent low flow event that had a 24 hour antecedent period and an average flow rate of 0.34 cfs during the sampling period and there was an accumulation of 0.31 inches of rainfall for the entire day with a runoff volume of 3,037 ft^3. The majority of the pollutants were removed by the Stormceptor except for TSS. TSS had higher concentrations for all the effluent samples than the influent samples except during the first flush. The highest flow rate was at 1.32cfs during the 30 minute interval and this also was peak flow for the event. The pollutant concentrations seemed to be higher when the flow rate was high.

Concentration generally was higher in the effluent than in the influent samples. E.coli and TSS results for the 30 minute interval showed that the effluent was higher than the influent concentrations. The effluent sample for nitrate had a higher concentration than the influent including the duplicate sample. Phosphorus had the highest concentration in the effluent and the influent had the second highest concentration during the 30 minute interval.

5.1.5 Overall Trends

There seemed to be little to no detection for lead and zinc in the runoff, but higher zinc concentrations were collected than lead. As noted by Warren (1981) lead and zinc are insoluble and zinc is more abundant than lead on roads. The zinc detected in this study could be associated with the galvanized roofs, which have numerous down spouts that drain directly into catchbasins that eventually flow into the inlet of manhole # 230 upstream of the Stormceptor. It is possible that concentrations were low for heavy metals because BSC employs a street sweeper to remove street sediment on a monthly basis.

The Stormceptor is known to remove oil, grease, and TSS and it also has the capabilities of removing hydrocarbons and particle-bound pollutants. The Stormceptor indeed removed a large percentage of E.coli, detergents, and nitrate, but often it was not statistically significant. Nitrate soil concentration was consistently high for every storm event because nitrate is known to leach out. The concentration of phosphorus seemed to be relatively low for each storm event. There was a trend with phosphorus throughout each sampling event. Phosphorus consistently had higher concentrations in the effluent than in the influent samples for almost each time interval except during storm event 4. E.coli, nitrate, and detergents are not common monitoring pollutants so there are no standard removal rates for these pollutants. These pollutants were chosen because of the characteristics of the land use. Taking half of the MDL for lead, oil and grease (when there was a non- detection in the sample) to calculate the mean concentration was not done, because it would of lead to misleading results due to small number of samples. Non – detection means there was not enough concentration to produce a reading, therefore that could mean there is 0 mg/l or some concentration remaining.

Each pollutant had a MDL for analysis (except for TSS, E.coli, and detergents). If the pollutant did not meet the MDL then it was consider non-detected in the runoff. Some pollutants did not meet the MDL so a calculation was done to get a value to determine other parameters (i.e. percent removal reduction). The MDL using the Hanna Multiparameter meter for nitrate and phosphorus analysis for was 0.5 mg/l and 0.3 mg/l respectively. Using the EPA 6000/7000 for metals the MDL for lead and zinc was 0.015 mg/l and 0.013 mg/l respectively. The MDL for oil and grease using the EPA 1664A methods was 5.0 mg/l (Table 5.1). There is no MDL for E.coli using the Coliscan Easygel method or for TSS using a flask apparatus.

Table 5.1: Method Detection Limit for Pollutants

Nitrate	Phosphorous	Lead	Zinc	Oil and Grease
mg/l	mg/l	mg/l	mg/l	mg/l
0.5	0.3	0.015	0.013	5.0

The pollutant concentrations were compared to the DEC National Median Concentrations and the EPA Nationwide Urban Runoff Program typical concentrations of pollutants found in urban runoff. This was to ensure BSC was not contributing to the excess amount of the typical pollutant concentrations found in urban runoff (i.e. by not over fertilizing the campus, on - going construction work, urbanized campus), especially considering that this is a small drainage area. Table 5.2 provides the typical pollutant concentrations found in stormwater runoff by three different entities. The Department of Environmental Conservation (Center for Watershed

Protection 2007) used the average concentrations to obtain the national median concentration. The EPA’s National Urban Runoff Program used the event mean concentrations (EMC) to determine the typical pollutant concentrations. The influent concentrations were averaged to determine how well it compared to the other two entities concentrations.

Table 5.2: Typical Pollutant Concentrations found in Stormwater Runoff

Entity	TSS	TP	TN	Lead	Zinc	F. Coli
	mg/l	mg/l	mg/l	mg/l	mg/l	1000c/ml
National Median Concentration (DEC)	54.5	0.26	2.00	0.0507	0.129	1.5
NURP (EPA) EMC	100	0.33	N/A	0.144	0.160	N/A
Stormceptor (Influent)	Avg=44.5	Avg=0.44	Avg=1.9	*Avg=0.048	Avg=0.15	**Avg=2114.5

*Not enough data to compute an average for lead
** E.coli was tested and units are colonies/100 ml

In the study area the land uses are rooftops, streets, lawns, and a parking lot and source specific typical concentrations are shown in Table 5.3. Due to insufficient data for E.coli; fecal coliform was used instead because E.coli typically can be found in fecal coliform, but generally are lower in number. The mean concentrations for TSS in the influent was less than the typical concentrations found in stormwater (54.5 mg/l), but exceeded the amount found in parking lots which can help explain why there was no reduction. There was an outlier for the TSS during the first flush in the effluent with 719.6 mg/l and the rest of the concentrations in the effluent were under 200 mg/l. The mean concentration of 0.44mg/l exceeded the typical amount of phosphorous in runoff (0.26 mg/l) and what is normally found in parking lots (0.15 mg/l). The mean concentrations of nitrate detected in parking lots is1.9 mg/l and typical nitrate concentration is 2.0. The influent average concentration was in the range of expectation. Mean zinc concentrations fell well below the typical concentrations detected in stormwater as well as what is detected in parking lots and rooftops.

Table 5.3: Site Specific Typical Pollutant Concentrations in Stormwater Runoff (Center for Watershed Protection 2007)

Site	TSS	TP	TN	Lead	Zinc	F.Coli
	mg/l	mg/l	mg/l	mg/l	mg/l	1000c/ml
Comm Rooftops	N/A	N/A	N/A	0.017	0.256	N/A
Parking Lots	27	0.15	1.9	0.139	0.028	1.8
Street	468	N/A	N/A	0.17	0.45	N/A

5.2 Pollutant Removal

The percent reduction and t –test for each pollutant was calculated to address the objective of how effective the stormceptor is at removing pollutants. The percent reduction was compared with five different previous studies and or testing laboratories that had already determined the percent removal rate for each pollutant using the Stormceptor (Table 5.4).

Table 5.4: Stormceptor Verified Percent Removal Rate

Testing Company	TSS	O & G	Lead	Zinc
	%	%	%	%
Rinker Manufacturer	80	95		
EPA	50 - 80			
CETV	76 - 94			
NJCAT	75			
Private Study Canada	52.7	43.2	51.2	39.1
Stormceptor (Effluent)	0[2],25.5[3],0[4]	0[1],55[2],0[3],0[4]	N/A	0[2],57.1[3],12.3[4]

[1] = Storm event 1,[2] = Storm event 2,[3] =Storm event 3, [4] =Storm event 4

5.2.1 TSS Pollutant Removal

TSS showed no reduction for the second and fourth storm event, but the third storm event showed a 25.5% reduction which did not meet any of the percent standard reduction and overall there is no significant reduction in TSS.

5.2.2 Phosphorus Pollutant Removal

The first two storm events showed no reduction for phosphorus, but the last two storm events had an 11.3% and 73.3% reduction. However, there was no significant reduction in EMC. There is no standard reduction for phosphorous using a Stormceptor. For the first storm event there were only two samples taken and there was a large standard error in the effluent sample. The second storm event showed reliable results and for the majority of the time the concentrations were higher in the effluent than in the influent samples. For the third storm event there was an 11.3% reduction but that is because there was an outlier in the influent sample that skewed the results; the majority of the time the effluent was higher than the influent sample. The fourth storm event showed favorable results.

5.2.3 Nitrate Pollutant Removal

For all four storm events the Stormceptor effectively removed nitrate from the runoff, but statistically showed no significant reduction in the EMC (at alpha = 0.05, although it was significant at P = 0.12 even though the percent removal was extremely high (94, 43, 55, 94%)). There is no standard percent reduction for nitrate using the Stormceptor.

5.2.4 Lead Pollutant Removal

The percent reduction rate was only calculated for the second, third, and fourth storm event for lead. The samples were below the MDL for the second and third event, but for the fourth storm event lead was detected and there was a 40% reduction rate. A case study conducted in Canada showed there was a 51.2% removal of lead using the Stormceptor. There was no t-test calculated because the majority of the samples were non-detected.

5.2.5 Zinc Pollutant Removal

Zinc was reduced for the third and fourth storm event. There were no water samples collected for zinc during the first event and the second event showed no reduction. The third storm event had the highest removal rate of 57% and this exceeded the standard removal rate of 39.1% established in Edmonton, Alberta Canada. There were two samples taken during the third event and one was during the first flush whereas only one sample was taken for the other storm events. The fourth event had a 12.3% reduction rate and this was during the highest flow rate. The reduction rate was low overall because only one sample was taken.

5.2.6 E.coli Pollutant Removal

The Stormceptor exhibited a reduction in E.coli during the first (95%) and fourth storm event (35%), but there was no significant reduction overall. This could be due to the fact that the second and third storm events had negative reductions. It is evident why the mean concentration in the effluent was higher than the influent samples by reviewing the results for storm event 2, at each 15 minute interval. There were two outliers at the 45 minute and especially at the 60 minute interval that negatively impacted the outcome. The 60 minute interval had 500 c/100ml of E.coli in the influent and 3500 c/100 ml in the effluent. For storm event 3 the effluent sample had double the amount of E.coli present as compared to the influent sample during the first 15 minutes.

5.2.7 Oil and Grease Pollutant Removal

The EMC t –Test for oil and grease was not done, because there were a few samples that had non-detections. The first and fourth storm event showed no reduction in oil and grease. The second and third storm event had a 55% and 63% removal rate although Rinker manufacturers claim that the Stormceptor can remove 95% of oil and grease. A case study in Canada has concluded that the Stormceptor can remove 43.2% of oil and grease. Oil and grease in this case seems to be dependent on the antecedent period and first flush. The first storm event had no reduction because there was only a 48 hour antecedent period and had a low flow rate of 0.048 cfs. As observed the fourth storm event had no reduction, but it had the highest flow rate of 1.3 cfs as compared to the rest of the oil and grease samples during that sampling interval. This is because there was no antecedent period, it rained the day before. The second and third storm event had a 72 hour antecedent period, but the third storm event had a lower flow rate (0.009 cfs) and a higher percent reduction than the second storm event which had a flow rate of 0.21 cfs.

5.2.8 Detergents Pollutant Removal

Detergents were only analyzed during the first and second storm event because supplies were limited. There was a 70% and 60% reduction for these two storm events and there was a significant reduction in the EMC using the Stormceptor. The results suggested that the percent removal rate is in fact based on the magnitude of the storm i.e. the flow rate, but also the antecedent period.

5.3 First Flush

It was important to collect a first flush sample for each storm event because this is the time when the highest amounts of concentrations may be observed (Saget et al. 1996) and this is important information for the design of future stormwater pollution controls. If the first flush is frequent then maybe more BMPs needs to be implemented (Saget et al. 1996).

The first flush seems to be defined by the volume of rainfall. From the results storm events 3 and 4 failed to exhibit a first flush. Storm Event 3 had a first flush flow rate of 0.009 cfs. Storm event 3 and 4 most likely did not have a first flush because the pollutants were not mobile due to a low flow rate; if there is not a strong flush the pollutants are immobile (Environment and Heritage 2012). E.coli during the first flush did not have the highest concentration compared to the rest of the sampling intervals. TSS during the first flush in the influent was higher than the rest of the concentration, but the effluent sample had the lowest concentration compared to the rest of the results in the effluent. Nitrate and phosphorus were unaffected by the first flush. There were 6.8 mg/l of oil and grease during the first flush and there was none detected in the effluent. Oil and grease was only sampled twice during the first flush for the first and third storm event and there was not enough data to determine if this concentration was significantly high to be considered a first flush. Most oil and grease samples taken at different time intervals and rain events resulted in non-detection except for one that had 24 mg/l that was not during a flush first. Zinc had high concentration during the first flush and a low concentration in the effluent compared to the other samples taken during that storm event. Storm Event 4 only had a 24 hour antecedent period so there was not a first flush for this event. Even though the Stormceptor is designed to handle the first flush (this is if the Stormceptor is on a lateral line, but this Stormceptor is located on the trunk line) Charbeneau et al. (2004) stated that the first flush can be treated if diverted off the main trunk line and held until it can be slowly released back into the pipe system.

5.4 QA/QC

Duplicates were taken for the majority of storm events to determine if there were any inconsistencies with the original results. TSS and E.coli were the only two pollutants that did not have any duplicates. The EPA has established an acceptable RPD range for duplicate samples to be 20% while Irvine et al. (1996) used a RPD of 35%. Any value above this will be flagged as having is too much variability between the original and duplicate sample. Ideally this paper aims to calculate an RPD of 0% for all thirteen duplicate samples to represent that this data as defensible. Technically calculating the RPD of a value that is 0 mg/l does not produce a logical answer. To replicate a more reliable RPD value one-half of the MDL was calculated for the analytes when the results were 0 mg/l or non-detected. Only four out of the 19 duplicate samples had an RPD of 0%. Lead and zinc duplicate samples taken in the influent during the second storm event had an RPD of 0%.The other two analytes that had an RPD of 0% was nitrate that was collected downstream of the site during the fourth storm event. Duplicate samples were taken during the 60 minute and 90 minute interval and the results were 0 mg/l for both the effluent and duplicates.

Overall there were no other analytes that had an RPD value of less than 20% but two samples were under 35%; phosphorus (29%) was taken during the third storm event and nitrate (22%) taken during the fourth event. The rest of the RPD values were above 100%. The main analytes that contained duplicates were the nitrate and phosphorus samples. Both these samples were tested using a Hannah Multiparameter meter (which was not done by a third party) and had large variabilities between the original and duplicate samples. This particular meter had precision errors because it was an old instrument. The oil and grease duplicate taken upstream of the site during the second storm event was analyzed at WST and the RPD was 118%. The duplicates either analyzed by a non-third party or by WST show that there is still quite some variability with the samples.

5.5 PCSWMM

Before the model was calibrated the original model in PCSWMM was only slightly off from the observed flow for each storm event. The most distinct difference in the model vs. the observed flow was that the flow was offset by two hours, which was easily fixable by calibrating the model two hours early. The downside to PCSWMM was hourly rainfall data was used due to the fact that the rain gauge is set up to collect rainfall in hourly intervals. There needs to be smaller rainfall intervals and if need be the smaller increments can be added up to complete a one hour interval of rainfall. The other major flaw of the model was the flow peak volume did not match the size of the observed peak flows, which was amended by either decreasing or increasing certain attributes. For example if the model peak flows was higher than the observed peak flows, decreasing the impervious area attribute to a certain percentage (by using a method of trial and error) would decrease the model peak flows. Even the measured field data that was collected and used into the PCSWMM model had to be modified to fit the observed data. Field data can be subjected to human error and trying to justify the following attributes: Mannings N, depression storage, zero impervious. Some attribute values are based on referencing a table which can be inaccurate. Since each storm event had different rainfall amounts, each storm event had to be calibrated by manipulating different attributes. From looking at the previous Figure 4.14 the model flow is supposed to overlap on the observed flow data to indicate that the predicted flow matches exactly to the observed flow. From visual inspection the calibrated model matches fairly close to the observed flow data. To verify how closely they match the correlation was calculated referring back to Figures 4.15- 4.18 For the most part all four graphs showed positive trends. As the observed flow increased so did the predicted flow throughout the storm event.

6. CONCLUSION AND RECOMMENDATIONS

The BSC Stormceptor is designed to work in a parking lot area to capture and remove pollutants that are typically found in stormwater runoff, which are: TSS, oil and grease (hydrocarbons, heavy metals, and nutrients. BSC has a NPDES permit which requires water pollution discharge to be kept to a minimum and the Stormceptor was installed (retrofitted) for preventive measures to improve the water quality discharge from a 2.69 acre area. The results obtained from the water quality samples were pertinent to determine if the Stormceptor was effectively removing the pollutants from the runoff. Statistically the Stormceptor did not significantly reduce the EMC for the majority of the water pollutants analyzed in the 2.69 acre area, but with all BMP's there are variabilities.

There were some limitation to this study that included not taking triplicate samples for each analyte and not collecting enough samples for oil and grease, lead, and zinc because of budget constraints. The samples taken for oil and grease, lead, and zinc did not represent the entire storm event nor could a realistic comparison be made. The Hannah Multiparameter meter presented a lot of variability in the results. This was evident in the QA/QC section for the nutrients. Another limitation was sampling upstream of the Stormceptor in the inlet of manhole #230 because the location of the Stormceptor's inlet was not accessible. Also, there were three incoming pipes leading into the inlet of manhole #230 producing a greater amount of volume and possibly dilution which could help explain the higher concentration in the effluent samples than in the influent samples. Catching the ideal storm event is difficult (amongst other conditions). Another point of consideration is that in 2009 Rockwell Road was being reconstructed, and to cut down on cost the Stormceptor was retrofitted in this area on the main trunk line with no pre-treatment BMP prior to the Stormceptor. Manufacturers advise, against installing the

Stormceptor on the main trunk line of the MS4, but instead be placed on the lateral trunk line. Overall the results showed that PCSWMM is a good predictor for quantity of flow. This particular Stormceptor has a by-pass flow rate of 8.37 cfs and PCSWMM can be used to calculate the frequency of by-passes. PCSWMM can also be used for calculating the pollutant load using EMC. This was more of a preliminary study for BSC because the Stormceptor was recently installed in 2009 and future performance test needs to be conducted.

For future studies, more than four rain events need to be sampled and perhaps collecting water samples that have the same rainfall amount for each storm event, so there could be a better comparison. There should be a pre-treatment BMP installed upstream from the Stormceptor and there should also be another Stormceptor installed downstream from the original Stormceptor, so the whole 37 acre area sewereshed would be treated before discharging into Scajaquada Creek. The treated sediment that is stored in the sedimentation chamber should be analyzed and sieved as a different way to calculate the removal rate. This way would determine how much of a pollutant the Stormceptor is actually removing without the by-pass being a factor.

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