Edith J. Carrier Arboretum Stream Restoration and Storm Water Monitoring

A proposal submitted to the

Integrated Science and Technology Program

at James Madison University

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By

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1 Abstract

With over 75% of the United States population living in urban areas, large population centers have large areas of impermeable surfaces, which decrease infiltration, increase runoff, and alter the hydrology of the surrounding streams. This issue is termed urbanization and is happening to streams globally. Urban streams are usually highly modified from their natural, pre-urbanized state, with significant differences in stream and riparian habitat, streamflow, and water quality. Typically, streams in urban areas serve a variety of functions: habitat, urban drainage and flood management, and public and community amenity (including linkages to open space), and can include special cultural and community significance. These functions are often impaired in urban areas by altered hydrology and decreased water quality. Stream restoration projects that return the stream to more natural conditions can be effective in improving water quality and restoring the intended functions of these urban streams. At James Madison University specifically, the Edith J Carrier Arboretum has been chosen for restoration and been granted the funds to do testing and assessments to restore the stream back to a more natural state. Construction occurred from August-December 2015, to restore and stabilize the stream banks, reconnect the stream to the floodplain, and reestablish wetland areas. To assess whether this restoration improved water quality, a monitoring program was instituted. This program includes data collection at two sites, the inlet and the outlet of the arboretum, during the pre-construction, during the construction, and post construction. In five pre-construction storm events where samples were collected, all storm events had estimated mean concentrations that exceed the EPA recommended water quality criteria for total nitrogen, total phosphorus, total suspended solids, and turbidity. These results will provide a pre- construction baseline for water quality sampling that will continue post construction. These comparisons will assess the ultimate success of the arboretum restoration project.

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2 <u>Introduction</u>

2.1 Urbanization

In the United States 75% of the population lives in urban areas and the world wide percentage of people living in urban areas will continue to increase (Michael 2013). With large population centers growing in size and number problems arise when it comes to keeping our streams and waterways healthy. It is estimated that over 130,000 km of streams and rivers in the United States are ecologically impaired (Michael 2013). Large population centers have large areas of impermeable surface which decrease infiltration, in turn increase runoff, and alter the hydrology of the surrounding streams.

2.2 Ecological Effects of Urbanization

Biodiversity plays several important roles in urban environments. These roles include ecosystem services such as air and water purification (Bolund and Hunhammar, 1999) and amenity values such as aesthetic enjoyment and recreation (Miller 2006). Over 80% of most central (downtown) urban areas are covered by pavement and buildings (Blair and Launer, 1997), leaving less than 20% as vegetated area. Another negative impact on biodiversity is structural simplification of vegetation in many areas. Landscaping and maintenance of residential and commercial areas typically involves removal of shrubs and dead wood and an increase in grasses and herbs (Marzluff and Ewing 2001). These effects are changing the way animals and plants are living in urbanized areas and have to adapt to live.

2.3 Edith Carrier Arboretum and Restoration Project

The Edith J. Carrier Arboretum is a 125-acre urban botanical preserve located within the city of Harrisonburg and the campus of James Madison University. The Arboretum is named for Edith J. Carrier, the wife of JMU President Emeritus, Ronald E. Carrier, for her years of service to the university. It is a combination of naturalized botanical gardens and forest, a home to a diverse ecosystem. The Arboretum struggles with bank erosion and storm runoff that is becoming damaging to the Chesapeake Bay watershed it is located in.

The goal of the stream restoration was to restore about 1080 feet of tributary with an overall Master Plan. The Master Plan began in 2014 and stated that JMU will invest in stream best management practices as well as in propagation of specific plants over the course of the next couple of years. The second core area of focus, landscape infrastructure improvements, will tackle water and landscape limitations. This grant-funded plan, funded by the National Fish and Wildlife Foundation will help capture storm events and data in order to evaluate the construction and overall benefit of this plan. Best managements practices were incorporated to benefit the arboretum in this restoration process including, lowering of the stream banks so that flood waters can access the floodplain as well as planting along stream banks. To evaluate the success of the stream restoration project storm events were sampled pre-construction, during construction, and post-construction. Collection of data samples occurred at two locations, the two sampling sites where data was collected, the inlet, located on Neff Avenue, and the outlet, located within the JMU arboretum. Storms events were captured from April of 2105 until September of 2015 for pre-construction and construction, and this project will continue for post- construction data in the upcoming months.

2.4 Solar Heating

Urbanization brings large areas of impermeable surface, and with the increase of impermeable surfaces comes many ecological effects. Solar heating is the heating of surface water runoff. The increase in temperature of the surface water runoff brings ecological impairments in the stream systems. Many aquatic species have a tolerance level for water temperatures, so an increase in water temperature causes only the tolerant species to survive. Cold water can hold more oxygen, so with warmer waters comes a decreased capacity for oxygen.

2.5 Altered Morphology

When developing these large urban areas it has become a practice to alter the channel morphology to be more conducive for development. The altering of the morphology brings ecological effects including decreased infiltration, increased runoff, increased erosion, increased sediment loading, more frequent storm events, more powerful storm events, and flashier hydrographs (Walsh 1).

2.6 Sediment Loading

Most of life in the streambed lives in the bottom of the stream. The non-impaired stream bottom consists of cobble and rock, not mud. The increase in erosion and sediment loading smothers the benthic life that lives in the streambed. This smothering directly affects the food web by killing the benthic life. The increase in sediment also clouds the water and impairs fish from seeing prey. Ultimately, the effects of increased sediment completely changes which species can survive in the affected stream system.

2.7 Nutrient Loading

As previously stated, with urban development comes large areas of impervious surface which results in increased surface water runoff. Runoff carries with it large amounts of sediment and nutrients. Runoff carries sediment which yields nutrients, so with increase sediment loading comes increased nutrient loading. We typically associate nutrient loading with large amount of nitrogen and phosphorous. Nitrogen and phosphorous come from fertilizers, municipal waste, industrial waste, and fossil fuel emissions.

2.8 Eutrophication

Eutrophication is defined as “An increase in the rate of supply of organic matter to an ecosystem” (Nixon 2012). Eutrophication leads to an increased rate of algae growth due to the abundance of nutrients. Large amounts of algae cause a decrease in dissolved oxygen or hypoxia and reduced submerged aquatic vegetation. When algae die, the oxygen in the water is consumed, and if there is an abnormally large amount of algae then the oxygen is being depleted faster than it can be naturally re-oxygenated into the water. Algae reduced submerged aquatic vegetation by blocking the sunlight from reaching the vegetation on the streambed.

2.9 Social Implications of Urbanization

Across the globe human populations are becoming increasingly urban, with approximately fifty percent of the world's population currently residing in urban areas. Urban centers often develop among watersheds due to the capacity to provide drinking water and transportation. Over the last two centuries, urbanization has caused changes in watershed hydrology that include declines in the natural filtering capacity of river systems (e.g., channelization of headwater streams, loss of floodplains and wetlands) and regulation of flows due to the construction of dams and impoundments. Specifically at James Madison University and the Edith J Carrier Arboretum, we are part of the Chesapeake Bay watershed, a very large watershed extending over six states. The Chesapeake Bay over the last few decades has had many social practices and laws placed into effect to help restore the Bay back to the time before it was extremely polluted.

Historically the Bay supported some of the most productive commercial fisheries in the world; it is a center of recreational and tourism activity; and it includes Hampton Roads and Baltimore, two of the largest ports in the United States. Over the last fifty years the environmental conditions of the Bay have deteriorated especially in the areas of submerged aquatic vegetation and shellfish, two of the Bay's largest profits (Dauer 2002). These declines have been credited to the increased sediment load and increased nutrient load all flowing into the Bay. In the 1980s with the implementation of the Clean Water Act, by the EPA, coordinated Bay-wide water quality and monitoring began. This included monitoring abundance, biomass, species diversity in regards to the benthic and plankton communities, and concentrations of dissolved oxygen and sediment loads in the Bay watershed.

Not only did the monitoring happen for within the Bay, but also the human activity outside the Bay was even more crucial for the future. Human activity in the watershed such as, population density, land use and loadings of nutrients and toxics all became a concern of the EPA. With the population increasing every day, not only around the Bay, more and more people must be provided for. With more housing, and jobs also comes the idea that more farming needs to be done to feed and sustain the life living near the Bay (Dauer 2002).

Human population is going to be forever growing, and in order to save the Bay, education and smart environmental choices by those living around the bay will need to be implemented. With the JMU Restoration projects, we can spread the knowledge to the community and other universities in hopes that they will implement these skills and take it to their communities. The Bay has improved greatly but there is always going to be more room for improvement.

2.10 Urban Stream Restoration

The health of stream ecosystems surrounding urban areas is a growing problem across the country. Awareness of the ecological effects of urbanization are increasing and the movement for urban stream restoration is growing, but yet the stream impairment problem is still growing (Walsh 2015). The goal for urban stream restoration is to return the stream to a more natural condition, improving water quality, and improved biotic composition (Walsh 2015). The movement is growing, but has not reached the large scale movement needed to reach the desired goals. Often many urban streams are so degraded that the chance of realizing the goals using only a local scale are low and a large scale approach is needed.

2.11 Restoration Methods

There are different approaches to take when undertaking a stream restoration project. Deciding on an approach is different considering the health state of the stream, geomorphology of the stream system, and the environment surrounding the stream. Common methods are detailed by the Journal of the North American Benthological Society (Walsh 2).

1. Reconstruction of eroding banks to lessen erosion
2. The redesign of pipe drainage systems and catchments to retain runoff from rain events for infiltration, evapotranspiration, or reuse.
3. Restoring riparian buffer zones to moderate temperature, reduce sediment, and stabilize stream banks

3 Project Overview

3.1 The Arboretum and the Restoration Project

The overall objective of the restoration project is to "Enhance a regional green infrastructure asset by stabilizing and reconnecting 1,080 linear feet of degraded stream with function-based stream restoration, including floodplain wetland treatment cells"(NFWF 1). Through this restoration, there is an expected reduction of 95 lbs Total Phosphorus, 280 lbs Total Nitrogen, and 217 tons Total Suspended Solids. The broader goal of the restoration is to progress toward meeting the Blacks Run Total Maximum Daily Load (TMDL).

3.2 Data collection

Monitoring and sample collection will begin before the restoration construction starts, continue during the restoration process, and finalize after the restoration is complete.

3.3 Monitored Pollutants

All of the following pollutants are concerning due to their relationships to ecological impacts detailed in section 1.2.

3.3.1 Nitrogen and Phosphorous

Nitrogen and phosphorous levels will be measured for each sample. Those levels are concerning due to the possibility of large amounts of nutrient loading leading to eutrophication and hypoxia.

3.3.2 TSS/Turbidity

Turbidity will be measured for each sample. TSS will be measured for the first samples and continue until a relationship can be made between TSS/Turbidity. TSS/Turbidity contribute to the potential eutrophication of the stream system.

3.3.3 Temperature

Temperature will be measured along with water flow rate by the installed flow probes. Taking temperature measurements can evaluate the solar heating of runoff.

3.3.4 Flow

Water flow rate will be measured by installed flow probes. Monitoring the flow will give insight to the effects of changing the geomorphology of the stream through the restoration construction. The estimated result would show less frequent and less powerful events.

4 Methodology

4.1 Overall Design

Major elements of the Stream Restoration Project and Design were to gather storm water samples prior to, during and after construction to determine the impact and success of the restoration project. Sampling statures were established upstream and downstream of the arboretum located at the two sampling sites listed earlier. The contribution that Matt and I will have to this project will be monitoring and analyzing samples. Three flow were placed on site for monitoring. One was located in Blacks Run Creek, and the other two were located within the tributary. One of the flow probes placed in the tributary is located in the tree, the data collected from this probe was used to determine the atmospheric pressure. The data from the other two probe samples gave results of the water flow and temperature. Using the program HOBOware, made available from the JMU computers in the lab, data collected in the field was downloaded and turned in graphs to more easily depict the data being read by the probes. The majority of data was focused on the effects temperature has to the stream, along with the measurements of nitrogen, phosphorus, and total suspended solids that were calculated. In addition a turbidity probe was added to the experiment a few months later, and recorded data for the project and the Arboretum site of the experiment. This design project will be continued out throughout the summer of 2016 to evaluate the post construction parameters.

4.2 Funding

Funding for this project was provided by the National Fish and Wildlife Foundation. Funding supported the cost of the restoration as well as monitoring and analysis conducted in this project. Monitoring and analysis cost included reagents and consumable supplies, recalibration of flow probes, and labor for sample collection and analysis.

4.3 Sample Collection

Five separate storm events were sampled from 6/8/15 to 9/10/15 (table 4.3). Four of these events were prior to restoration construction, and one was during construction. Additional post-construction sampling is planned for summer 2016. Samples were collected using the ISCO samplers that collected 24 bottles of sampled storm water per storm event. Each sample that was collected was between 400ml and 1000ml depending on the strength of the storm at the time or limitation of the size of the bottles in the samplers used. These samplers were programmed at timed intervals, to the best of knowledge to when a storm event was predicted to begin. In most cases students would have to enter the storm event to go and start the sampler to take intervals of the samples being collected. After samples were collected and brought to the lab for data analysis and testing composites were formed in order to better manage the amount of storm water gathered. Composites were made by taking sections of the storm event, for example from the baseline, rising limb, peak of the storm, receding limb and then the event mean concentration. These Composites were created for all the storm events excluding the 6/8/15 storm. For each sample collected Nitrogen, Phosphorus, Turbidity, and TSS testing was performed.

Table 4.3		
Sampled Storm Events		
Pre-Construction	Construction	Post-Construction
6/8/2015	9/10/2015	(To Come)
6/18/2015		
7/14/2015		
7/21/2015		

4.4 Nitrogen

Total nitrogen was measured using HACH Method 10071 (Hach, 2016), Total Nitrogen Persulfate Digestion Method. This method uses an alkaline persulfate digestion under heat to convert all forms of nitrogen to nitrate. Chromotropic acid is then added to react with nitrate and form a yellow complex with an absorption of 420 nm. Nitrate concentrations were determined using a spectrometer. Nitrate standards were prepared, and a five point calibration curve was used to determine nitrogen concentrations based on the absorbance of samples at 420 nm.

4.5 Phosphorus

Total Phosphorus was measured using HACH TNT 843 Phosphorus Reactive (ortho) Low Range Method. This method used pH of sample: 2-10 and the temperature of sample/ reagent: 15-25 °C. The principle is that phosphate ions react with molybdate and antimony ions in an acidic solution to form antimonyl phosphomolybdate complex, which is reduced by ascorbic acid to phosphomolybdenum blue in the 2.0mL samples. Phosphate standards were prepared as well and a calibration curve was used to determine phosphorus concentration based on absorbance of 0.2mL samples.

4.6 Turbidity

Turbidity was measured using the McVan Turbidity probe provided to us by the lab. The way that this probe works specifically is that is utilizes 90° optics and infrared light, the probe completely rejects fluctuating ambient light conditions to deliver clear, low-noise readings (INW 2016). The measurements were taken by holding the probe with the infrared light and optic end in the water and slowly rotating the probe around in the sample for a few second, while trying to keep a steady hand to get an accurate measurement. Again all measurements for the storm composites were recorded in the lab notebook and then backed up on the excel document.

4.6.1 Linear equation for standard Curve

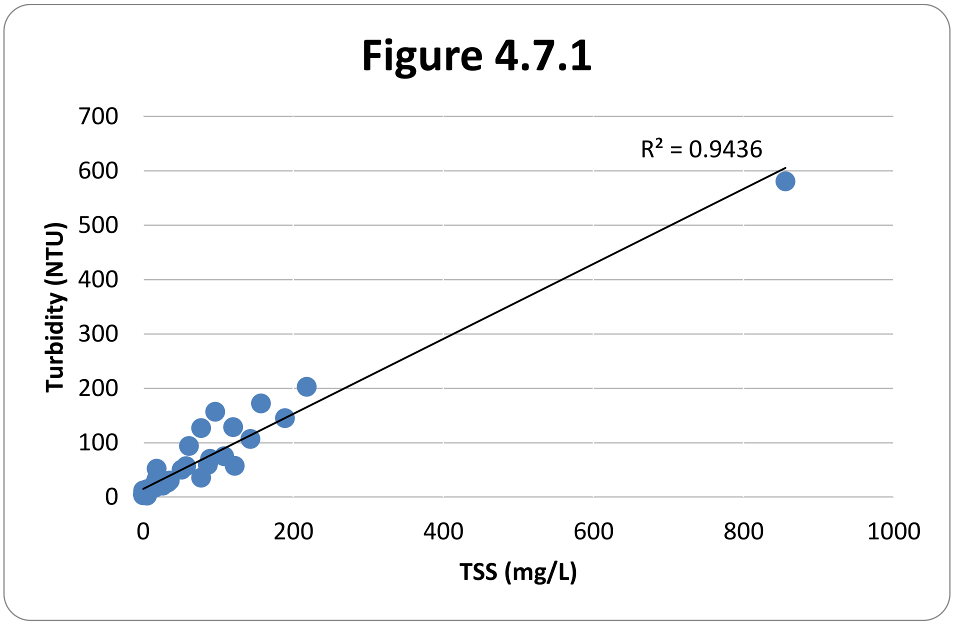

Figure 4.7.1 above shows the linear equation for the standard curve for Turbidity vs TSS, where turbidity is measured in (NTU) and TSS is measured in (mg/L). They show a positive correlation in the standard curve with one or two outliers that can be attributed to the storm data composites.

4.7 TSS

Total Suspended Solids (TSS) were measured using standard method 2540 D. dried at 103-105°C. Steps for this process are as followed. 100-200ml of a sample was filtered through pre-weighed 0.45 um membrane filters and then dried for one hour at 103-105°C. Following the drying of the samples they are transferred and cooled in a desiccator for at least 24 hours, and then weighed again. This process was repeated until weights did not change by more than 4%. Making note that each time samples were transported gloves and tweezers were used by all handling in the lab. All data was then recorded in the universal lab notebook as a hard copy as well as provided on an excel spreadsheet.

5 Results and Discussion

For all samples collected we tested for Phosphorus, Nitrogen, Turbidity, and Total Suspended Solids concentrations. Also included were total pollutant loads for each storm and summary comparisons of the sampled storm events. After all the samples were taken those sampled were flow weight composited. The following data included composite samples for each of the contaminants of concern and concentrations of those composite samples.

5.1.1 Storm Duration, Peak Flow Rate, and Total Volume

Table 5.1.1 gives a summary of the flow rates, peak flow, total volume and duration of the storm events. The peak flow rates and total volume are broken down into inlet and outlet.

Table 5.1.1					
Date	Duration (hrs)	Peak Flow (cfs)		Volume (Liters)	
		Inlet	Outlet	Inlet	Outlet
6/8/2015	4	16.40	0.00013	1.52E+06	3.04E+03
6/18/2015	7	13.96	2.17	3.95E+06	4.22E+05
7/14/2015	6.25	11.25	3.39	2.23E+06	8.23E+05
7/21/2015	7	37.77	33.79	5.87E+06	3.84E+06
9/10/2015	4	41.93	43.84	7.24E+06	7.25E+06

When looking at the flow data it can be seen as variability between different volumes and durations of storms. We had long storms which produce larger volumes and high flow rates, and smaller storms where not much volume actually reached the outlet sampling location.

5.2 Total Nitrogen

5.2.1 6/8/15 – Storm Event

For the 6/8/15 storm event only six samples were taken due to the short period of the storm. Due to the small sample size, the sample results were described by simply the average, and min and max values were detailed. Table 5.2.1 shows these results and Figure 5.2.1A and 5.2.1B show the hydrographs, inlet and outlet sampling locations, for this storm event.

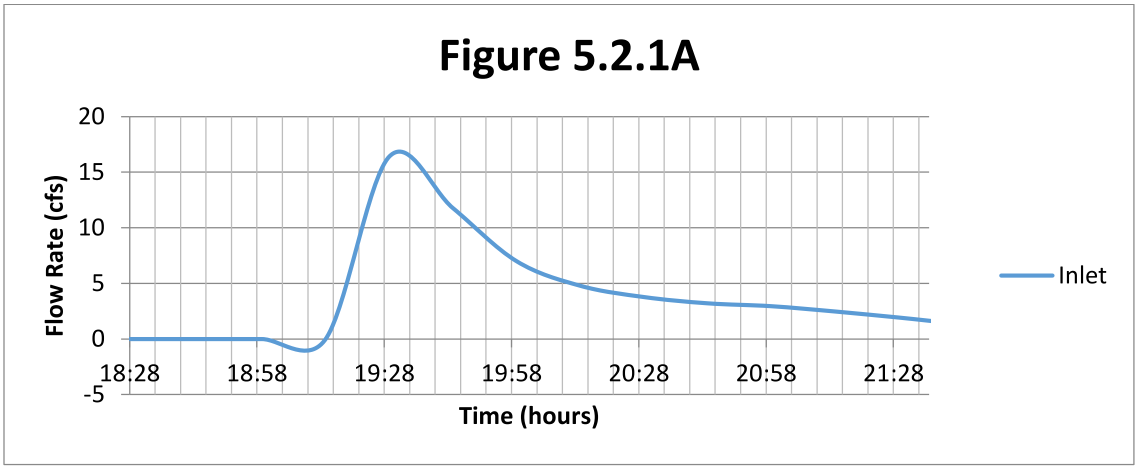

Figure 5.2.1A: Displays the Flow rate in cubic feet per second versus time for the 6/8/15 storm event at the inlet location. We saw a peak flow rate of 16.40 cfs at 19:30.

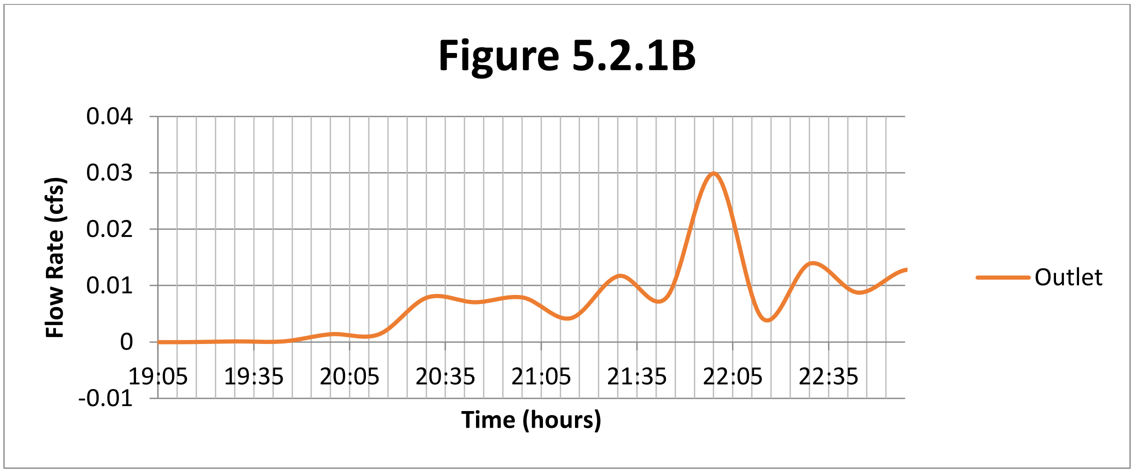

Figure 5.2.1A: Displays the Flow rate in cubic feet per second versus time for the 6/8/15 storm event at the outlet location. We saw a peak flow rate of 0.03 cfs at 22:00.

Table 5.2.1 shows the average, minimum, and max nitrogen concentrations sampled from the storm event on 6/8/15. The sample size of this storm event was small and is the reason we condense the few samples we had into average, min and max.

	Table 5.2.1 Nitrogen Concentration Summary (ppm)	
	Inlet	Outlet
Min	2.585	2.585
Max	2.857	4.761
Average	2.704	3.673

5.2.2 6/17/15 – Storm Event

We were able to get a full set of samples for both the inlet and out sample sites. Detailed below is the flow weighted composite concentration levels. Figure 5.2.2 shows the hydrographs, inlet and outlet sampling locations, for this storm event.

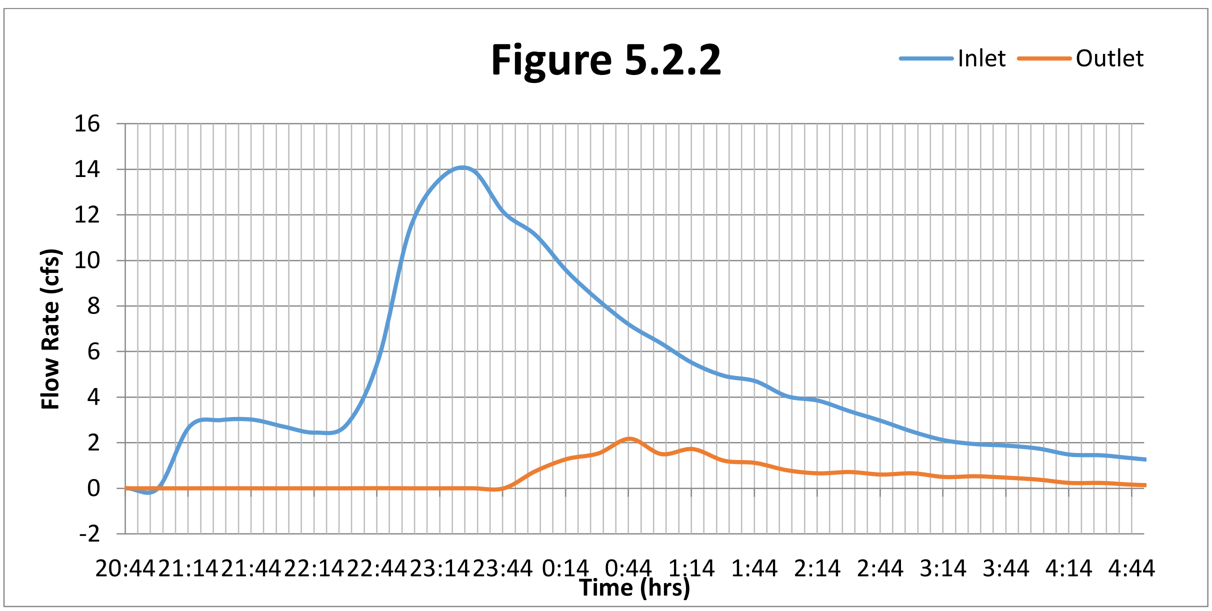

Figure 5.2.2: Displays the flow rate in cubic feet per second versus time for the 6/17/15 storm event. The figure includes both the inlet and outlet sampling locations. We saw peaks in the inlet at 23:30 and at 0:45 for the outlet locations.

Table 5.2.2 Shows the nitrogen concentration data for the composite samples of the storm event on 6/17/15. These concentrations were recorded in part per million (ppm).

	Table 5.2.2	
	Nitrogen Concentration Summary (ppm)	
	Inlet	Outlet
Baseline	0.750	1.139
Rising Limb	0.647	1.154
Peak	1.571	1.726
Receding Limb	0.400	2.285
EMC	0.678	2.062

5.2.3 7/14/15 – Storm Event

For the 7/14/15 Storm event there are some gaps in the data. This is due to complications in the sampling process. Figure 5.2.3 shows the hydrographs, inlet and outlet sampling locations, for this storm event.

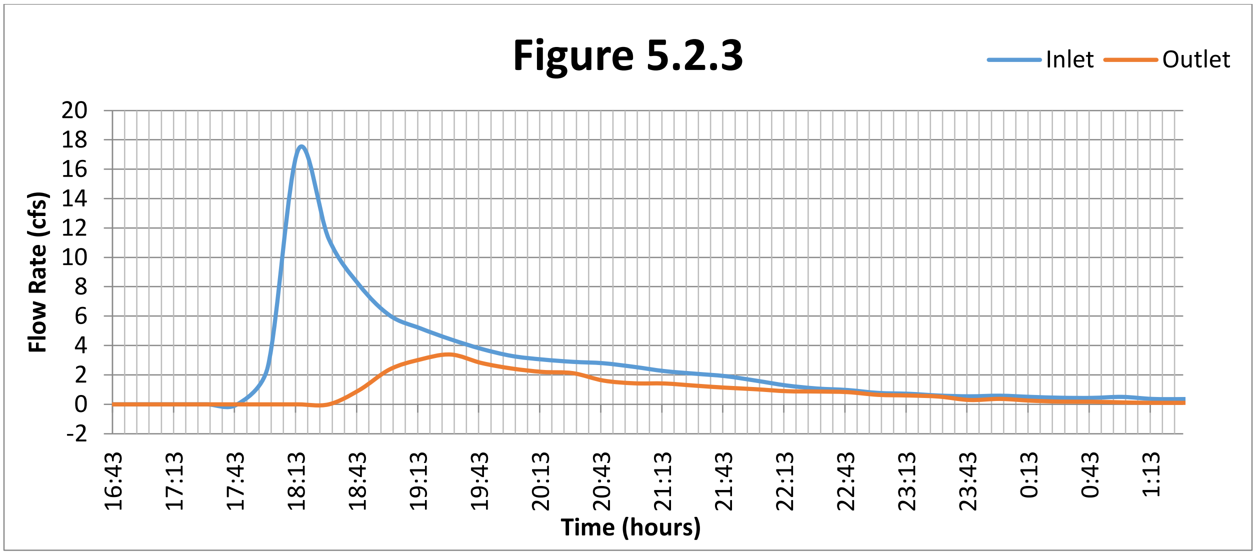

Figure 5.2.3: Displays the flow rate in cubic feet per second versus time for the 7/14/15 storm event. The figure includes both the inlet and outlet sampling locations. We saw peaks in the inlet at 18:15 and at 19:30 for the outlet locations.

Table 5.2.3: Shows the nitrogen concentration data for the composite samples of the storm event on 7/14/15. These concentrations were recorded in part per million (ppm). The missing data is due to complications in the sampling process.

	Table 5.2.3 Nitrogen Concentration Summary (ppm)	
	Inlet	Outlet
Baseline	1.290	-
Rising Limb	4.000	2.194
Peak	5.742	2.903
Receding Limb	1.548	-
EMC	4.861	-

5.2.4 7/21/15 – Storm Event

In the 7/21/15 Storm Event we had a small error in the sampling process indicated by the gap in concentration data for the outlet sampling site. Figure 5.2.4 shows the hydrographs, inlet and outlet sampling locations, for this storm event.

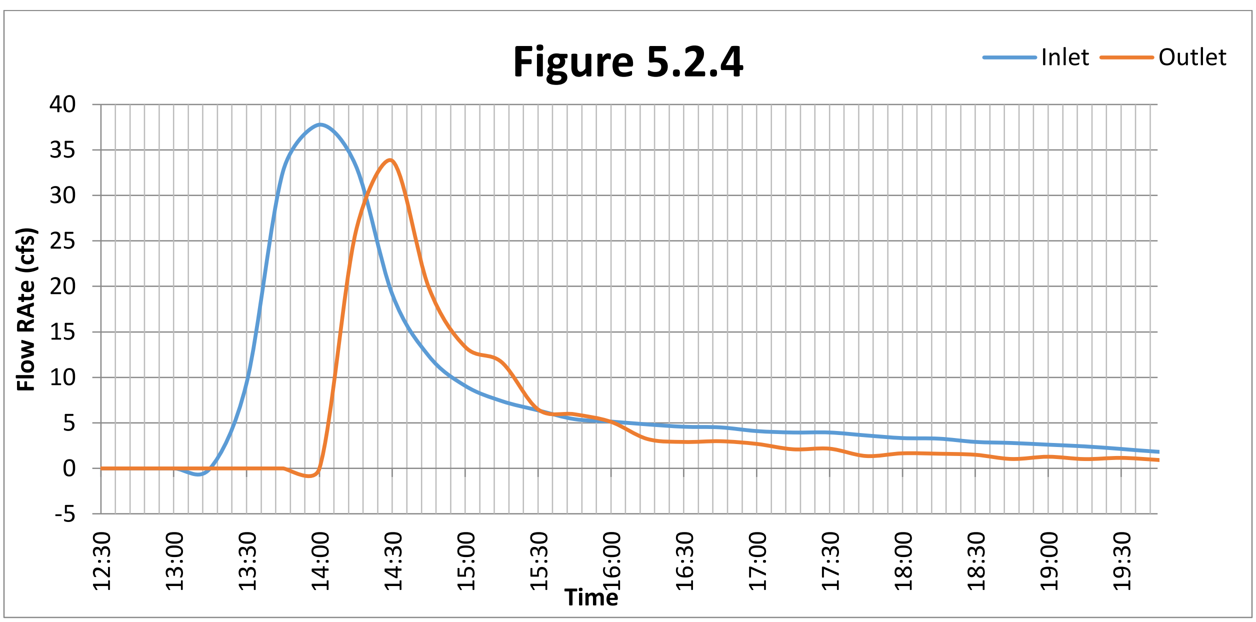

Figure 5.2.3: Displays the flow rate in cubic feet per second versus time for the 7/21/15 storm event. The figure includes both the inlet and outlet sampling locations. We saw peaks in the inlet at 14:15 and at 14:30 for the outlet locations.

Table 5.2.4: Shows the nitrogen concentration data for the composite samples of the storm event on 7/21/15. These concentrations were recorded in part per million (ppm). The missing data is due to complications in the sampling process.

	Table 5.2.4 Nitrogen Concentration Summary (ppm)	
	Inlet	Outlet
Baseline	<0.07	-
Rising Limb	3.986	2.753
Peak	1.666	1.666
Receding Limb	<0.07	0.652
EMC	0.434	0.0724

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5.2.5 9/10/15 – Storm Event

For the 9/10/15 Storm Event the small gaps in sampled data was due to complications in the sampling process. Figure 5.2.5 shows the hydrographs, inlet and outlet sampling locations, for this storm event.

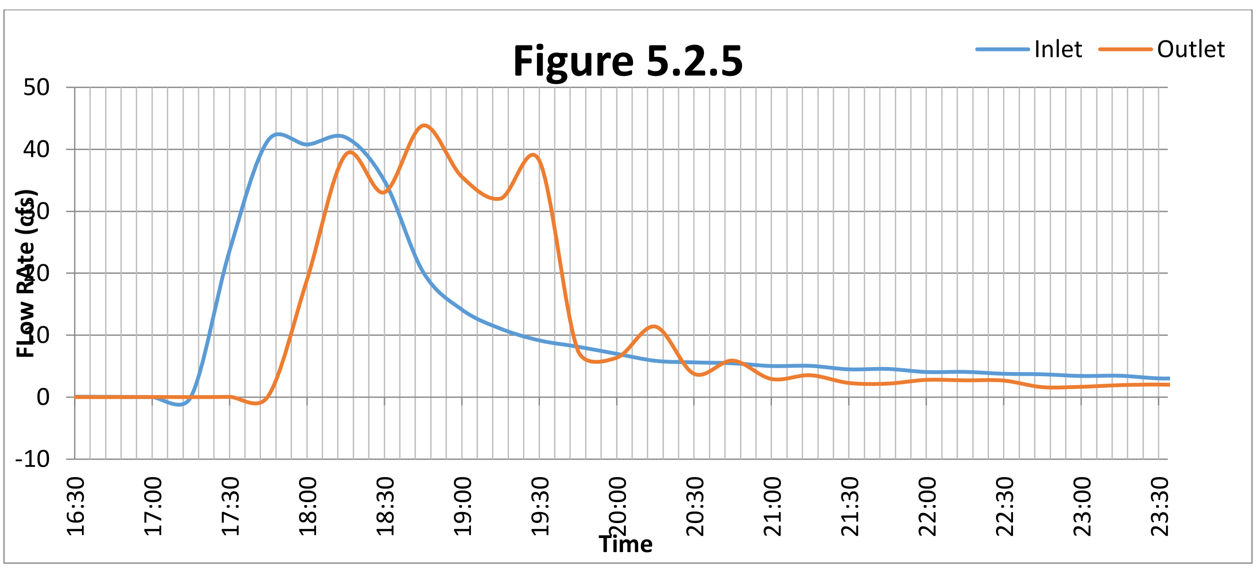

Table 5.2.5: Shows the nitrogen concentration data for the composite samples of the storm event on 9/10/15. These concentrations were recorded in part per million (ppm). The missing data is due to complications in the sampling process.

	Table 5.2.5	
	Nitrogen Concentration Summary (ppm)	
	Inlet	Outlet
Baseline	-	0.699
Rising Limb	-	2.307
Peak	<0.07	0.909
Receding Limb	<0.07	0.349
EMC	0.629	2.447

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5.2.6 Nitrogen Summary

When analyzing the nitrogen concentration data from the sampled storm events we look to compare the numbers in a few different ways to provide context. We compare the data to the EPA Water Quality Recommended Standards for Nutrients. For nitrogen that standard is 0.31 ppm. We also compared the differences from Inlet to Outlet in the way of a percent difference. When looking at those differences we want to see negative differences meaning that nutrients were getting taken out by the water system before reaching the outlet point. For much of our comparisons we use the calculated Event Mean Concentration (EMC) as our representative concentration for each storm event. Table 5.2.6 gives a summary of the nitrogen data for all five sampled storm events.

Table 5.2.6: Shows the Estimated Mean Concentrations (EMC) for each of the five sampled storms and their respective percent differences from inlet to outlet. The EMC was used as a representative estimation for total storm concentration data.

Table 5.2.6				
Treatment	Date	Nitrogen - EMC (ppm)		
		Inlet	Outlet	% Different
Pre-Construction	6/8/2015	2.704	3.673	36%
	6/18/2015	0.678	2.062	204%
	7/14/2015	4.861	-	-
	7/21/2015	0.434	0.072	-83%
Construction	9/10/2015	0.629	2.447	289%

By comparing the data to the EPA standards, it can be seen that all of the storm events exceeded the standards in both the inlet and outlet with the exception of the outlet result during the 7/21/15 storm event. Next when looking at the percent differences between the inlet and outlet, it can be seen that the results are highly variable from one storm event to the next. Large percent increases which exhibited in the 6/18/15 and 9/10/15 storm events, which indicates excess nutrients reaching the outlet. In the 7/21/15 storm event, however we see a negative percent difference between the inlet and outlet which we attribute to the fact the storm did not produce as much flow as in other storms, so less flow was able to travel from the inlet to the outlet. During smaller storm events, the arboretum can absorb nutrients and act as a nutrient sink. In larger storms, however erosion throughout the Arboretum can act as a source of nutrients to the downstream watershed.

Based on our data we can see that due to the urbanization and large agricultural area that resides in the watershed leading to the arboretum that there is a nutrient loading problem. In addition, not only is there a large amount of nutrients flowing into the arboretum but the arboretum is not able to absorb much if any of those nutrients. This non-absorption indicated is the major factor to consider. High entry level concentrations could be attributed to factor greater than just the local urbanization or agricultural areas, but the fact that the data shows no absorption by the arboretum indicates a problem.

5.3 Total Phosphorus

Section 5.3 includes the phosphorus concentrations results for each of the five sampled storm events.

5.3.1 6/8/15 – Storm Event

Table 5.3.1: Shows the average, minimum, and max phosphorus concentrations sampled from the storm event on 6/8/15. The sample size of this storm event was small and is the reason we condense the few samples we had into average, min and max.

	Table 5.3.1 Phosphorus Concentration Summary (ppm)	
	Inlet	Outlet
Min	0.118	0.240
Max	0.187	0.376
Average	0.153	0.3085

5.3.2 6/17/15 – Storm Event

Table 5.3.2: Shows the phosphorus concentration data for the composite samples of the storm event on 6/17/15. These concentrations were recorded in part per million (ppm).

	Table 5.3.2 Phosphorus Concentration Summary (ppm)	
	Inlet	Outlet
Baseline	0.0500	0.0397
Rising Limb	0.0175	0.1333
Peak	0.0170	0.1204
Receding Limb	0.0567	0.0594
EMC	0.0864	0.0788

5.3.3 7/14/15 – Storm Event

Table 5.3.3: Shows the phosphorus concentration data for the composite samples of the storm event on 7/14/15. These concentrations were recorded in part per million (ppm). The missing data is due to complications in the sampling process

	Table 5.3.3 Phosphorus Concentration Summary (ppm)	
	Inlet	Outlet
Baseline	0.0111	0.0143
Rising Limb	0.1853	0.1821
Peak	0.5116	-
Receding Limb	0.2550	-
EMC	0.4490	-

5.3.4 7/21/15 – Storm Event

Table 5.3.4: Shows the phosphorus concentration data for the composite samples of the storm event on 7/21/15. These concentrations were recorded in part per million (ppm). The missing data is due to complications in the sampling process.

	Table 5.3.4 Phosphorus Concentration Summary (ppm)	
	Inlet	Outlet
Baseline	0.0350	-
Rising Limb	0.2862	0.1297186
Peak	0.3425	0.2423
Receding Limb	0.1174	0.1325
EMC	0.1929	0.1856

5.3.5 9/10/15 – Storm Event

Table 5.3.5: Shows the phosphorus concentration data for the composite samples of the storm event on 9/10/15. These concentrations were recorded in part per million (ppm). The missing data is due to complications in the sampling process

	Table 5.3.5	
	Phosphorus Concentration Summary (ppm)	
	Inlet	Outlet
Baseline	-	0.2515
Rising Limb	-	1.4270
Peak	0.1533	0.864828514
Receding Limb	0.0955	0.6415
EMC	0.0863	0.11835

5.3.6 Phosphorus Summary

When analyzing the Phosphorus concentration data from the sampled storm events we look to compare the numbers in the same way we compared the nitrogen concentrations. We compared the data to the EPA Water Quality Recommended Standards for Nutrients. For Phosphorus that standard is 0.01 ppm. Table 5.3.6 gives a summary of the Phosphorus data for all five sampled storm events.

Table 5.2.6: Shows the Estimated Mean Concentrations (EMC) for each of the five sampled storms and their respective percent differences from inlet to outlet. The EMC was used as a representative estimation for total storm concentration data.

Table 5.3.6				
Treatment	Date	Phosphorus - EMC (ppm)		
		Inlet	Outlet	% Different
Pre-Construction	6/8/2015	0.154	0.309	100%
	6/18/2015	0.086	0.079	-9%
	7/14/2015	0.449	-	
	7/21/2015	0.193	0.186	-4%
Construction	9/10/2015	0.086	0.118	37%

When comparing to the EPA standards it can be seen that all of the storm events event mean concentrations exceed the standard of 0.01 ppm. Next when looking at the percent differences between the inlet and outlet sample locations we only see small difference between the storm events. The storm event on 6/8/15 had a sizable difference of 100 percent increase from inlet to outlet, but due to this storm having a small sample size there is nothing we can attribute this difference to, just variability in the storms.

Similarly to the Nitrogen results, not only is there a large amount of nutrients flowing into the arboretum but the arboretum is not able to absorb much if any of those nutrients. This non-absorption indicated is the major factor to consider. High entry level concentrations could be attributed to factor greater than just the local urbanization or agricultural areas, but the fact that the data shows no absorption by the arboretum indicates a problem.

5.4 Total Suspended Solids

Section 5.4 includes the Total Suspended Solid Results for each of the five sampled storm events.

5.4.1 6/8/15 – Storm Event

Table 5.4.1: Shows the average, minimum, and max TSS concentrations sampled from the storm event on 6/8/15. The sample size of this storm event was small and is the reason we condense the few samples we had into average, min and max.

	Table 5.4.1 TSS Concentration Summary (ppm)	
	Inlet	Outlet
Min	92.74	241.40
Max	173.21	497.81
Average	127.86	369.61

5.4.2 6/17/15 – Storm Event

Table 5.4.2: Shows the TSS concentration data for the composite samples of the storm event on 6/17/15. These concentrations were recorded in part per million (ppm).

	Table 5.4.2 TSS Concentration Summary (ppm)	
	Inlet	Outlet
Baseline	26.4	3.5
Rising Limb	33.1	142.7
Peak	69.5	120
Receding Limb	29.4	32.3
EMC	37.7	60.6

5.4.3 7/14/15 – Storm Event

Table 5.4.3: Shows the TSS concentration data for the composite samples of the storm event on 7/14/15. These concentrations were recorded in part per million (ppm). The missing data is due to complications in the sampling process

	Table 5.4.3	
	TSS Concentration Summary (ppm)	
	Inlet	Outlet
Baseline	<5	16
Rising Limb	108	89
Peak	218	-
Receding Limb	57	-
EMC	177.5	-

5.4.4 7/21/15 – Storm Event

Table 5.4.4: Shows the TSS concentration data for the composite samples of the storm event on 7/21/15. These concentrations were recorded in part per million (ppm). The missing data is due to complications in the sampling process.

	Table 5.4.4	
	TSS Concentration Summary (ppm)	
	Inlet	Outlet
Baseline	6.5	-
Rising Limb	122	856
Peak	189	157
Receding Limb	35.5	33
EMC	77	86

5.4.5 9/10/15 – Storm Event

Table 5.4.5: Shows the TSS concentration data for the composite samples of the storm event on 9/10/15. These concentrations were recorded in part per million (ppm). The missing data is due to complications in the sampling process

	Table 5.4.5	
	TSS Concentration Summary (ppm)	
	Inlet	Outlet
Baseline	-	58.7
Rising Limb	-	1632.5
Peak	92.7	916.5
Receding Limb	27.2	570.1
EMC	34.09	894.7

5.4.6 Total Suspended Solids Summary

To analyze the data for total suspended solids there was no EPA recommended standard for comparison. We then looked to compare percent differences between the inlet and outlet for each storm event. Table 5.4.6 gives a summary of the Total Suspended Solids concentration for the five sampled storm events.

Table 5.4.6: Shows the Estimated Mean Concentrations (EMC) for each of the five sampled storms and their respective percent differences from inlet to outlet. The EMC was used as a representative estimation for total storm concentration data.

Table 5.4.6				
Treatment	Date	TSS - EMC (mg/L)		
		Inlet	Outlet	% Different
Pre-Construction	6/8/2015	127.8	369.6	189%
	6/18/2015	37.7	60.6	60%
	7/14/2015	177.5	-	-
	7/21/2015	77	86	12%
Construction	9/10/2015	34.09	894.7	2524%

It can be see what can be considered typical variation in the Pre-Construction Storms, but in the Construction storm event 9/10/15 we see a major increase in the percent difference. The 2524 percent increase in from the inlet to the outlet in the 9/10/15 storm event is attributed to that during construction there was large amounts of dirt and soil being moved around which cause there to an abnormal amount of lose soil that could be transported downstream by storm events.

High TSS readings indicate another problem inside the arboretum, one that can be visually seen along the banks of the stream. The bank of the arboretum was heavily eroded, with large concave bank that could have easily collapsed in the near future. Our data collaborates the visual erosion that could be seen throughout the arboretum such as the eroding banks and cloudy water. Considering that the Arboretum is generally a source of sediment prior to restoration, during restoration it was a major source.

5.5 Turbidity

Section 5.5 includes the Turbidity results for each of the five sampled storm events.

5.5.1 6/8/15 – Storm Event

Table 5.5.1: Shows the average, minimum, and max Turbidity concentrations sampled from the storm event on 6/8/15. The sample size of this storm event was small and is the reason we condense the few samples we had into average, min and max.

	Table 5.5.1 Turbidity Concentration Summary (NTU)	
	Inlet	Outlet
Min	68	177
Max	127	365
Average	93.7	271

5.5.2 6/17/15 – Storm Event

Table 5.5.2: Shows the Turbidity concentration data for the composite samples of the storm event on 6/17/15. These concentrations were recorded in part per million (ppm).

	Table 5.5.2 Turbidity Concentration Summary (NTU)	
	Inlet	Outlet
Baseline	19.36	8.32
Rising Limb	24.33	106.57
Peak	51.00	128.30
Receding Limb	21.62	29.14
EMC	27.70	56.49

5.5.3 7/14/15 – Storm Event

Table 5.5.3: Shows the Turbidity concentration data for the composite samples of the storm event on 7/14/15. These concentrations were recorded in part per million (ppm). The missing data is due to complications in the sampling process

	Table 5.5.3	
	Turbidity Concentration Summary (NTU)	
	Inlet	Outlet
Baseline	3.8	-
Rising Limb	75	17.1
Peak	203	70
Receding Limb	57	-
EMC	162.9	-

5.5.4 7/21/15 – Storm Event

Table 5.5.4: Shows the Turbidity concentration data for the composite samples of the storm event on 7/21/15. These concentrations were recorded in part per million (ppm). The missing data is due to complications in the sampling process.

	Table 5.5.4	
	Turbidity Concentration Summary (NTU)	
	Inlet	Outlet
Baseline	7.9	-
Rising Limb	57.5	581
Peak	145	172
Receding Limb	30.1	27
EMC	35.6	59.3

5.5.5 9/10/15 – Storm Event

Table 5.5.5: Shows the Turbidity concentration data for the composite samples of the storm event on 9/10/15. These concentrations were recorded in part per million (ppm). The missing data is due to complications in the sampling process

	Table 5.5.5	
	Turbidity Concentration Summary (NTU)	
	Inlet	Outlet
Baseline	-	43.1
Rising Limb	-	1197
Peak	68	672
Receding Limb	20	418
EMC	25	656

5.5.6 Turbidity Summary

When analyzing the Turbidity concentration data from the sampled storm events we look to compare the numbers in the same way we compared the nitrogen and phosphorus concentrations. We compared the data to the EPA Water Quality Recommended Standards for Nutrients. For Phosphorus that standard is 2.3 NTU. Table 5.4.6 gives a summary of the Turbidity data for all five sampled storm events.

Table 5.5.6: Shows the Estimated Mean Concentrations (EMC) for each of the five sampled storms and their respective percent differences from inlet to outlet. The EMC was used as a representative estimation for total storm concentration data.

Table 5.5.6				
Treatment	Date	Turbidity - EMC (NTU)		
		Inlet	Outlet	% Different
Pre-Construction	6/8/2015	93.7	271	189%
	6/18/2015	27.7	56.4	104%
	7/14/2015	162.9	-	-
	7/21/2015	35.6	59.3	67%
Construction	9/10/2015	25	656	2524%

Table 5.5.6

When comparing to the EPA standards it can be seen that all of the storm events event mean concentrations exceed the standard of 2.3 NTU. Next when looking at the percent differences between the inlet and outlet sample locations in a similar fashion to the TSS data we see variability in the pre-construction storm data but a major increase in the percent difference in the 9/10/15 storm event. This increase is attributed to the same factor as the TSS, during construction there was much soil and dirt being moved around which cause an abnormal amount of soil to get washed downstream which in turn caused the massive percent difference we see.

Similarly to the TSS results, high turbidity readings indicate a problem of heavy bank erosion indicated by the condition of the stream banks pre-construction.

5.5.7 Total Sediment Load

Total sediment loading along with the flow data can give us some better context when concerning Total Suspended Solids and Turbidity. Tables5.5.8A-C give summaries of total load calculations for Sediment, Nitrogen, and Phosphorus.

Table 5.5.8: Shows the Total Sediment Loading for each storm, broken down into inlet and outlet sediment loading. Total Sediment loading was calculated by multiplying the Total Suspended Solids data versus the total volume recorded by each storm.

Table 5.5.8A		
Date	Total Sediment Load (tons)	
	Inlet	Outlet
6/8/2015	0.21	0.001
6/18/2015	0.16	0.03
7/14/2015	0.44	-
7/21/2015	0.50	0.36
9/10/2015	0.27	7.15

Table 5.5.8B: Shows the Total Nitrogen Loading for each storm, broken down into inlet and outlet sediment loading. Total Nitrogen loading was calculated by multiplying the Nitrogen EMC data versus the total volume recorded by each storm.

Table 5.5.8B	
Total Nitrogen Load Load (tons)	
Inlet	Outlet
0.00452	0.00001
0.00296	0.00096
0.01197	-
0.00281	0.00031
0.00502	0.01957

Table 5.5.8C: Shows the Total Phosphorus Loading for each storm, broken down into inlet and outlet sediment loading. Total Phosphorus loading was calculated by multiplying the Phosphorus EMC data versus the total volume recorded by each storm.

Table 5.5.6C	
Total Phosphorus Load (tons)	
Inlet	Outlet
0.000257	0.000001
0.000376	0.000037
0.001106	-
0.001249	0.000786
0.000688	0.000946

To analyze the sediment loading the flow data also had to be considered. We see comparable sediment load for the inlet of all five storm events, but when looking at how much was washed downstream or eroded from the stream we see that during the storm event in the midst of construction, 9/10/15, 7.15 tons of sediment was eroded downstream. This can attributed to the same reasons as the massive increase in turbidity and TSS.

Total sediment loading calculations shown some interesting indicators of the problems in the arboretum. We found pre-construction average of 0.131 tons of sediment per storm event were being passed through the arboretum through the outlet sampling location. Also during the construction period there was a calculated 7.15 tons of sediment passing through the arboretum outlet sampling location. A pre-construction problem can be seen through the average of 0.131 tons per storm event. This corroborates the previously stated issues of erosion through the stream inside the arboretum.

5.5.8 Storm Comparison Contaminant EMC by Treatment

During this stream restoration project there were three designated treatment period, pre-construction, construction, and post-construction. The current data only includes the first two treatment periods but comparing these two can give more insight into the problem inside the arboretum and why this project needed to occur. The contaminant EMC's were broken down into the two treatment periods and compared to each other. Table 5.5.9 gives the summary of this comparison.

Table 5.5.9: Shows a treatment comparison of EMC's for each contaminant. Pre-Construction treatment numbers come from averaging all storm events sampled during that treatment period. The construction treatment period numbers, due to only have data on one storm during that period are a product of the storm event on 9/10/15.

	Table 5.5.9			
	Contaminant EMC Comparison by Treatment			
	Pre-Construction		Construction	
	Inlet	Outlet	Inlet	Outlet
Phosphorus (ppm)	0.22	0.19	0.086	0.118
Nitrogen (ppm)	2.16	1.93	0.629	2.44
TSS (mg/L)	105.04	172	34.09	894.7
Turbidity (NTU)	79.9	128	25	656
Total Sediment Load (tons)	0.32	0.131	0.27	7.15

To give this comparison true context we will need the post-construction sampling that will occur in the coming months, but even without we can see the high levels of contaminants when referring back to the EPA standards. The nutrient levels (TP and TN) show some variability from pre-construction to construction, but not major change. When looking at the TSS, Turbidity, and Total Sediment Loading we see large increases in all three from pre-construction to construction treatment period. When comparing the storms by treatment periods we saw an expected variability, and major changes in previously discusses contaminants of concern (TSS, Turbidity). A major indicator when looking at this comparison is how pre-construction concentrations don't change much from inlet to outlet. We would hope to see once the post-construction sampling is finished those concentrations to show major decreases from inlet to outlet.

6 Conclusion

6.1 Future of the Arboretum

Unfortunately, this overall experiment, at this time, is not able to evaluate the complete success of the project. With construction just coming to an end in the past months with spring planting and grass laying, it was not possible to capture storms post construction for this thesis. This is not the end though for this project, as the post construction storm and data collection will be picked up by current students working this summer. To truly evaluate the success of the restoration, post-construction sampling/monitoring will need to continue years past the completion of the project. Anticipation for the results of this experiment is going to come in the next months as this design experiment is put to the test. With the placement of the new tributary and the creation of the riparian buffer and stream banks lowered, the belief is that the arboretum is going to flourish and benefit the watershed it is located in. Data collection and analysis will continue as well and follow the same arrangements that have already been put in place, to get to most accurate representation of what will come out of this experiment.

6.2 Significant Results

After analyzing and interpreting the data above, it is very clear to acknowledge that the Edith J. Carrier Arboretum, as to be expected from urbanization, was continuing to add to the pollution of the watershed. The arboretum restoration project was set to manage restoration of the watershed by implementing best management practices, including creating a riparian buffer, planting grass around the bank, and dredging the pond to lower the stream banks. These practices and physical changes will benefit the overall watershed to have a large scale positive impact. Looking at the sediment and nutrient loads, referring back to section five of this thesis, the Edith J. Carrier Arboretum is performing a function of overall reducing the loads that leave the arboretum. It is clear in the data that the arboretum is doing what it is supposed to do by absorbing most of the sediments and loads and not allowing it to leave and enter the watershed. This is true for all cases except for the storm during construction, which is again to be expected. It will be very interesting to see as this project continues how further sediments and nutrient loads will be reduced after construction. As this project continues the data from storm events will conclude the benefits of the overall stream restoration project.

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9 Appendix 1: Procedure

1. **Total Nitrogen (printed version)PDF**
2. **Total Phosphorous (printed version) PDF**

10 Appendix 2: Data