# Field Measurements of Non-Point Source Pollutant of Stormwater BMP's in the UD Experimental Watershed

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# Abstract

On the University of Delaware Campus student researchers sought to examine the pollutant removal efficiency of several installed stormwater Best Management Practices (BMPs). Stormwater BMPs are a candidate restoration strategy for the Christina Basin of northeastern Delaware and Southeastern Pennsylvania. This report seeks to obtain efficiency data for those stormwater BMPs already installed on the University of Delaware campus. Stormwater runoff was collected for three separate rainfall events at designated inflow and outflow stations in two stormwater BMPs—a bioretention site and a combination wetland swale. Results were mixed but promising. The conclusions drawn were that with continued maintenance and planting of native vegetation stormwater wetlands can be effective in protecting receiving waters.

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# Chapter One: Background and Justification

## *Introduction*

Managing stormwater runoff is an important aspect of ensuring the quality of our rivers, lakes and streams. Stormwater runoff replenishes our waterways. As the water flows over different types of surfaces it picks up particles, and chemicals that are sitting on the surface. Fertilizers, road salts and industrial pollutants are just a few of the things that can end up in streams this way. The variety of pollutants in urban stormwater runoff makes treatment very difficult. It is a mixture of many species of compounds that can change from season to season and during the storm (Sansalone, 2003)

The historical concern in stormwater management was to reduce downstream flooding. Little thought was given to the environmental impacts of practices geared towards quantity control. Quality of discharge has recently been added to the list of owner and operator responsibilities. The term 'BMP' (Best Management Practice) in relation to urban runoff was adopted in the 1970's to represent control measures and practices that could be applied to reduce runoff volumes and contaminant concentrations. Currently, most BMPs are pollutant management containments, not treatment facilities (Hird 2003). Many published studies have documented the efficacy of stormwater Best Management Practices (BMPs) in removing pollutants (Schuler, 2000).

Stormwater BMPs can be divided into three major categories:

- Source controls, which are intended to intercept the polluted runoff before it enters the stream
- Treatment based controls, which physically, chemically or biologically treat the water using a structural device
- Hydraulic controls to divert flows away from source areas (Hird et al, 2003)

This report focuses on vegetated BMPs, such as:

1. Vegetated Swales— A vegetated swale is a grassed water conveyance channel that removes pollutants by filtrating through grass and infiltration through soil.
2. Filter Strips— A filter strip is a vegetated strip of land that buffers a stream by accepting storm runoff as a sheet of overland flow and treating the water before releasing it to the receiving waters
3. Stormwater Wetlands— These can be man-made, natural, or modified natural. Pollutants are removed by sedimentation, plant uptake, sorption, infiltration, microbial decomposition, and ionic exchange (Field and Sullivan, 2003).

The BMPs under study are located on the University of Delaware campus in Newark, Delaware, mostly within the boundaries of the Experimental Watershed. Jennifer Campagnini created the Experimental Watershed in 2001 during an internship sponsored by the Delaware Water Resources Center. This report is part of phase three of the work within the University of Delaware Experimental Watershed. Tara Harrell conducted phase two in Spring 2002. Her report studied the link between land use and stream health. Judith Walker and Kristen Sentoff are also working on phase three by restoring Blue Hen Creek and Fairfield Run, two streams within the Experimental Watershed.

The Dickinson Bioretention area is behind the Dickinson Dormitories, along Hillside Drive. The Clayton Hall BMP is a manmade wetland and is located between Blue Hen Creek and Pencader Way. Figure 1 shows the locations of all BMPs on campus.

Retrofitting stormwater BMPs is currently considered as a restoration strategy in the Christina Basin of northern Delaware and southeastern Pennsylvania ( Kauffman et al.). This technique is intended for restoring developed watersheds that generally have poor water quality due to high amounts of impervious surfaces, low forested and open spaces, and higher densities of contaminant sources.

As reported in the *Watershed Restoration Action Strategy for the Delaware Portion of the Christiana Basin* the average grade for the Christina Basin is a ‘C’, with stream water quality receiving a ‘B-‘, Stream Habitat receiving a ‘C’, and watershed health receiving a ‘C-‘

(Kauffman 2003). The effort is to apply a restoration strategy in accordance with the Total Maximum Daily Loads under the Clean Water Act. This research is intended to gather information on the pollutant removal efficacy of the stormwater BMPs installed on the University of Delaware campus.

### *Objectives*

Project objectives were to test the levels of pollutants in the inflows and outflows of several stormwater BMPs. The BMPs were mapped using Geographic Information Systems (GIS). Using test kits, pollutant removal efficacy was tested as a ratio of inflow to outflow. The research was conducted with the following approach:

1. Compile literature review
2. Field Survey Stormwater BMPs
3. Map the BMPs using GIS
4. Create Methods for collecting samples
5. Sample stormwater during appropriate rain events
6. Compute pollutant removal efficiency
7. Prepare Research Report

### *Study Area*

The BMPs to be studied are situated on the University of Delaware Campus in Newark, Delaware. The Clayton Hall Stormwater Wetland is contained within the University of Delaware Experimental Watershed, established in 2001 by the UD Water Resources Agency. Student researchers selected the BMPs to be tested based on the following criteria.

1. Located on the University of Delaware campus.

Accessibility—The ability of researchers to get to the BMPs was a limiting

# Chapter Two: Methodology

***Literature Review***

Researchers conducted a literature review of available stormwater management data. Tables 1 and 2 display the results of this literature review. Table 1 is adapted from a manual published by the U.S. E.P.A. The pollutants displayed here are those most often studied and having readily available information.

*Table 1: Pollutant Removal Efficiency*

| BMP Type | Typical Pollutant Removal (percent) | | | |
|---|---|---|---|---|
| | **Suspended Solids** | **Nitrogen** | **Phosphorus** | **Metals** |
| Dry Detention Basins | 30-65 | 15-45 | 15-45 | 15-45 |
| Retention Basins | 50-80 | 30-65 | 30-65 | 50-80 |
| Constructed Wetlands | 50-80 | <30 | 15-45 | 50-80 |
| Infiltration Basins | 50-80 | 50-80 | 50-80 | 50-80 |
| Infiltration Trenches/ Dry Wells | 50-80 | 50-80 | 15-45 | 50-80 |
| Porous Pavement | 65-100 | 65-100 | 30-65 | 65-100 |
| Grassed Swales | 30-65 | 15-45 | 15-45 | 15-45 |
| Vegetated Filter Strips | 50-80 | 50-80 | 50-80 | 30-65 |
| Surface Sand Filters | 50-80 | <30 | 50-80 | 50-80 |
| Other Medial Filters | 65-100 | 15-45 | <30 | 50-80 |

Source: U.S E.P.A, 1999

*Table 2: Results of Stormwater BMP Literature Review*

| BMP Type | Description | Stormwater Treatment Median Pollutant Removal Percentage (parenthesis are first standard deviations where available) | | | | |
|---|---|---|---|---|---|---|
| | | Copper | Zinc | Sediment | Nitrate nitrogen | Phosphorus |
| Swale [2] | A grassed stormwater conveyance channel that functions by allowing the water to filter through grass and infiltrate through the soil [3] | 51 (40) [2] | 715 (36) [2] | 81 (14) [2] | 31 (49) [2] | 34 (33) [2] |
| Filter Strip 75 Feet [1] | Vegetated strips of land that act as a buffer. Accepts water as a sheet of overland flow. Low velocity flows, and vegetative cover enhance performance. [3] | N/a | N/a | 54 [1] | N/a | -25 [1] |
| Filter Strip 150 Feet [1] | | N/a | N/a | 84 [1] | N/a | 20 [1] |
| Stormwater Wetlands | Remove pollutants through sedimentation, plant uptake, microbial decomposition, sorption, filtration and ion exchange. Efficacy can be increased by addition of a forebay, meandering flow, bottom benching and pondscaping with multiple species of plants [3] | 40 (45) [2] | 44 (40) [2] | 76 (43) [2] | 67 (54) [2] | 49 (36) [2] |
| Dry detention ponds | Detain water for up to 48 hours. Adding a forebay can enhance performance. [3] | 26 [2] | 26 (37) [2] | 47 (32) [2] | 4 (23) [2] | 19 (13) [2] |
| Wet Ponds | Contain a permanent pool of water for treating runoff. Offer better removal and less maintenance than dry ponds. Addition of a forebay, and/or the use of a fringe wetland can increase efficacy. [3] | 57(22) [2] | 66 (22) [2] | 80 (27) [2] | 43 (39) [2] | 51 (21) [2] |
| Infiltration Trench | Shallow excavated trenches that are backfilled with stone to create an underground reservoir. Stormwater gradually exfiltrates from the trench into the soil. Clogging is the biggest problem. Grass filter strips can enhance performance. [3] | N/a | N/a | N/a | 42.3 [1] | 100 [1] |
| Infiltration Basin | Similar to a dry pond except for the presence of an emergency spillway, and standard outlet structure. [3] | N/a | N/a | 75 [1] | 55-60 [1] | 60-70 [1] |
| Porous Pavement | Permeable, asphalt-concrete mix, which allows stormwater to percolate through the pavement into a deep gravel storage base, or into a piping system. [3] | N/a | N/a | 95 [1*] | 82 [1*] | 65 [1*] |

[1] Stormwater Center Fact Sheets

[2] Pennington, et al., 2003

[3] Field and Sullivan, 2003

* Data based on fewer than 5 data points

As a result of the literature review, student researchers compiled a list of sources concerning the study of stormwater Best Management Practices. Table 3 displays these sources.

*Table 3: Stormwater BMP Sources*

| Reference | Author | Date | One Sentence Description |
|---|---|---|---|
| The Practice of Watershed Protection | Scheuler, Thomas R and Heather K. Holland | 2000 | A comprehensive book of techniques for protecting water quality. Detailed information about BMPs including case studies and published reports, |
| Wet Weather flow in the Urban Watershed | Field, Richard and Daniel Sullivan | 2003 | A compilation of 13 detailed studies of stormwater BMPs. |
| Preliminary Data Summary of Urban Stormwater Best Management Practices. | U.S. E.P.A. | 1999 | An extremely helpful guide to managing urban stormwater. Includes regulations, assessments of environmental problems associated with urban runoff, solutions and cost/benefit analysis. |

***Field Survey***

During field sampling surveyed the areas around the Dickinson Bioretention Basin and the Clayton Stormwater wetland the BMPs in order to assess accessibility. The BMPs were then mapped using GIS software and the 2002 Delaware aerial images.

Figure 2 displays the Dickinson Bioretention Basin and the area immediately surrounding it. Figure 5 displays the Clayton Hall stormwater wetland and its surroundings.

*Figure 1: Map of Stormwater Best Management Practices on and Adjacent to the University of Delaware Experimental Watershed.*

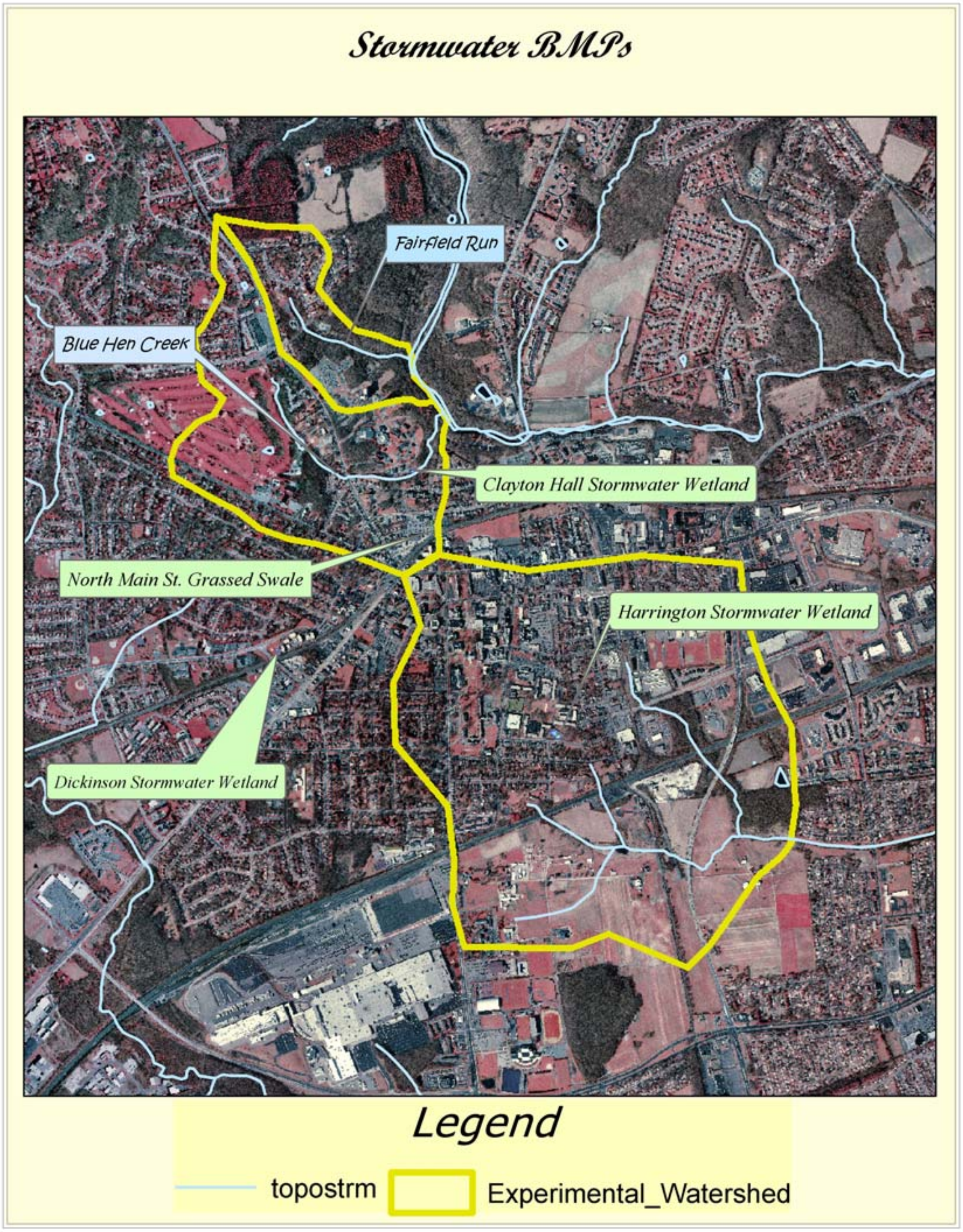


*Figure 2: Dickinson Dormitory Bioretention Area Map*

Location of Dickinson Stormwater Wetland

Source: datamil.udel.edu
Created by: Kathleen Cormier
February 3, 2004

In the summer of 2001 the University of Delaware Facilities Management built the Dickinson Stormwater wetland and then modified it in 2002. It was planted with a variety of wetland plants for aesthetic value, wildlife habitat and pollutant removal. Table 4 provides a listing of the plants used in the Dickinson Bioretention Area.

*Table 4: Plantings in the Dickinson Bioretention Area.*

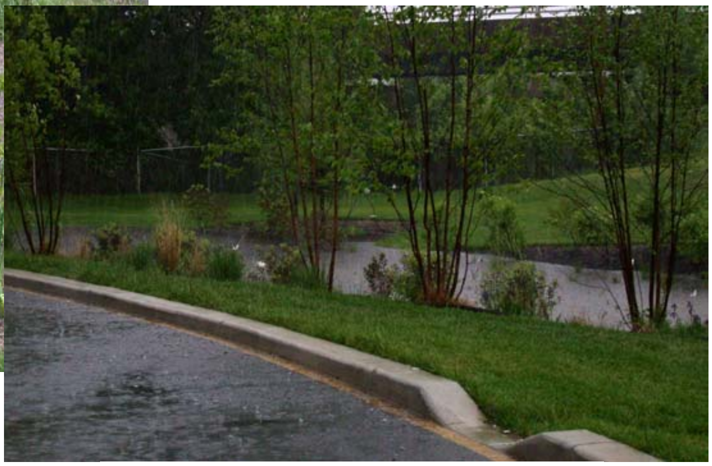
| Dickinson Stormwater BMP List of Plantings | |
|---|---|
| Common Name | Botanical Name |
| River birch | Betula nigra |
| Sweet Gum | Liquidambar styraciflua 'Moraine' |
| Bald Cypress | Taxodium distichum |
| Northern Bayberry | Myrica pesnylvanica |
| Chokeberry | Aronia arbutifolia 'brilliantissima' |
| Winterberry | Iles verticillata |
| Iris | Iris siberica |
| Slender Rush | Juncus tenius |
| Joe Pye Weed | Eupatorium purpeum |
| Cardinal Flower | Lovelia cardinalis |
| Goldenrod | Solidago graminifolia |
| Heavy Metal Switch Grass | Panicum virgatum |

Source: Taylor, 2004

*Figure 3: Dickinson Bioretention Wetland after Completion*

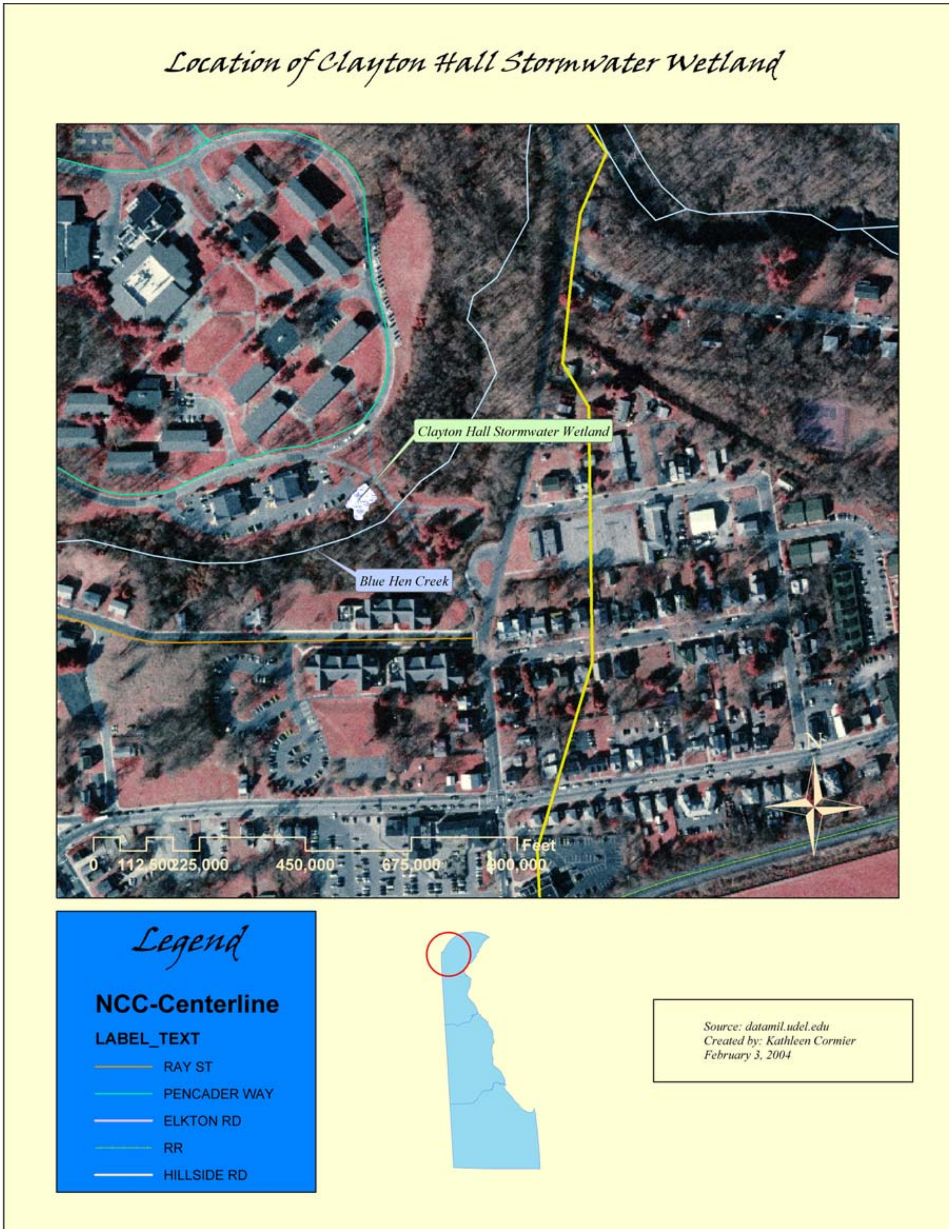
*Source: Taylor, 2004*

*Figure 4: Dickinson Bioretention Basin in the Rain*



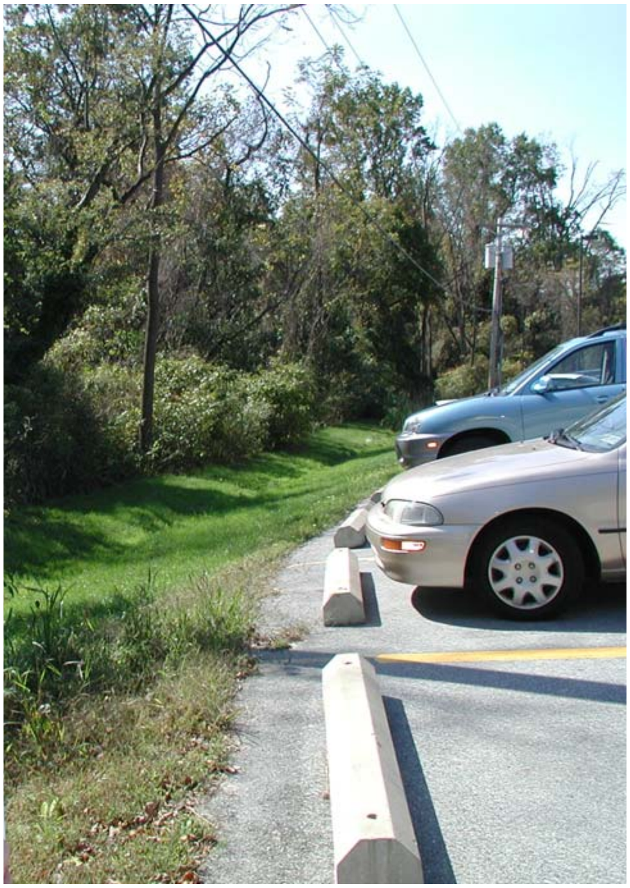
*Source: Taylor 2004*

*Figure 5: Clayton Hall Stormwater Wetland Map*



Source: datamil.udel.edu
Created by: Kathleen Cormier
February 3, 2004

*Figure 6: Image of Clayton Hall Stormwater Swale Running along the Alpha Sigma Alpha Parking Lot.*



### *Sampling Methods*

Researchers grabbed samples of stormwater runoff using the following methods

*Dickinson Bioretention Basin*

Task 1: Monitor rainfall totals as measured at the State Climatologist's office at Pearson Hall on the University of Delaware Main Campus.

Task 2: Grab samples at inflow and outflow sites. Inflowing water was collected in a glass collection jar as it ran off the adjacent Dickinson complex parking lot. Researchers modified a plastic graduated cylinder with fishing line to gather outflow water from the underground outflow pipe, accessible via an above ground grate.

Task 3: Return to UD WRA office to complete water quality tests, using Lamotte Student test kits.

*Clayton Hall Stormwater Wetland*

Task 1: Monitor rainfall totals as measured at the State Climatologist's office at Pearson Hall on the University of Delaware Main Campus.

Task 2: Grab samples at inflow and outflow sites. Collect inflowing water flowing in the swale running parallel to Blue Hen Creek and the Alpha Sigma Alpha parking lot. . Researchers modified a plastic graduated cylinder with fishing line to gather outflow water from BMP, collecting water as close to the outflow pipe as possible. Clogging of the outflow pipe presented a problem for sampling.

Task 3: Return to UD WRA office to complete water quality tests, using Lamotte Student test kits.

### *Analysis*

Researchers analyzed the following pollutants in the inflow and outflow water:

- Temperature
- pH
- Ammonia
- Chloride
- Chlorine
- Copper
- Dissolved Oxygen
- Iron
- Nitrate
- Phosphate
- Conductivity

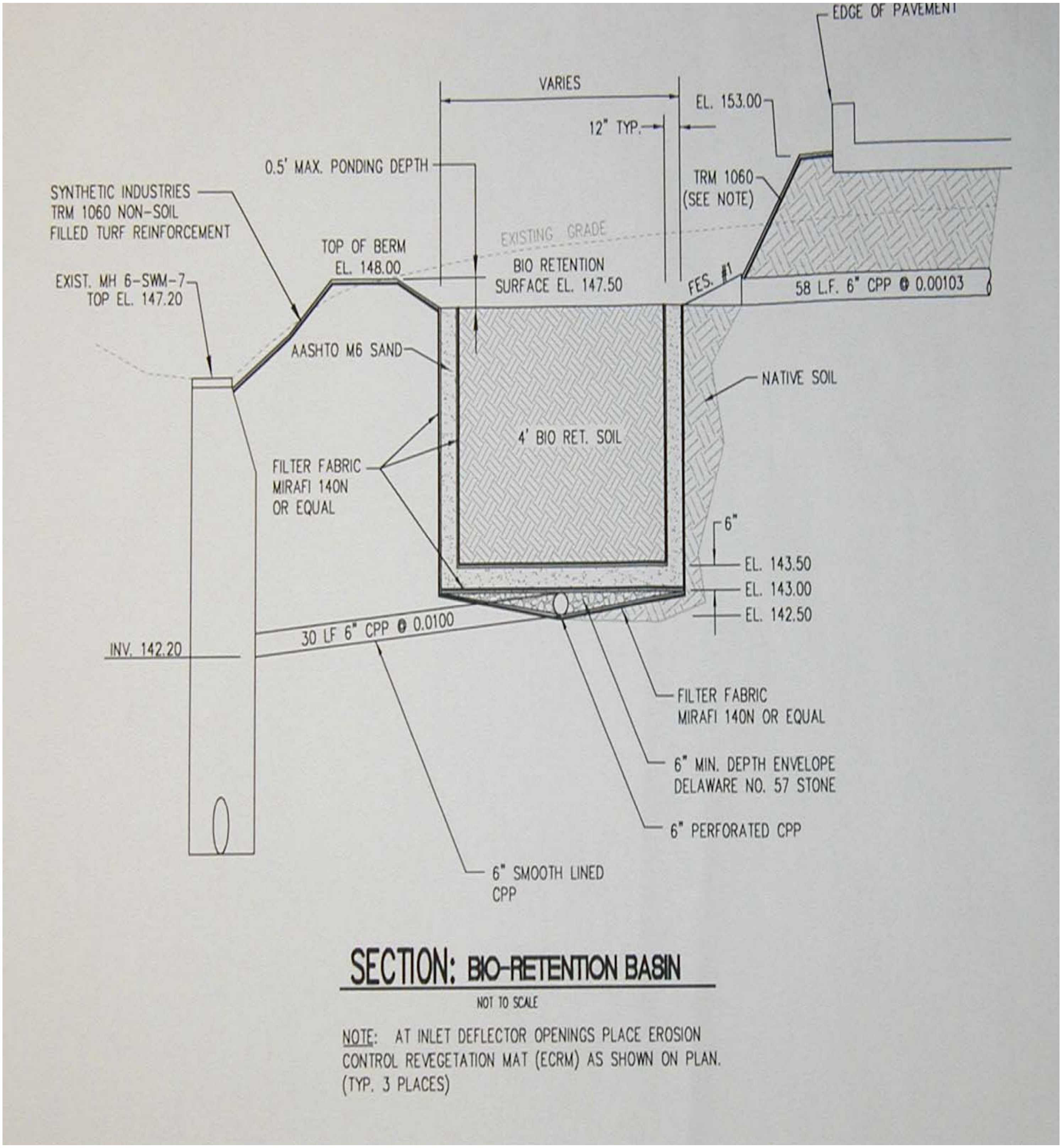
Water samples were collected in the field and then brought back to the UD WRA office and tested using the Lamotte Water Quality test kits. The kits contain test tablets that react with pollutants in water. Water is measured into a test tube and then the appropriate tablet is added. A color change occurs, and that color compared to a chart. It is in this manner that pollutant concentrations are determined.

# Chapter Three: Results and Discussion

## *Dickinson Bioretention Area*

The University of Delaware Facilities Management built this Bioretention basin in 2001. The original design of the wetland called for a sandy bottom. However the sand did not permit the wetland to drain fast enough, and in 2002 the sand was replaced with a layer of coarse gravel. It has a 0.5 feet ponding depth and a bottom surface area of 2,500 square feet, and is designed to hold runoff for a period of 24-48 hours. The original reason for building the wetland was to control the volume of flow, running off of the adjacent parking lot and surrounding field. (Taylor, 2004). Figures 7 and 8 display the installation plans for this wetland, including underground pipes.

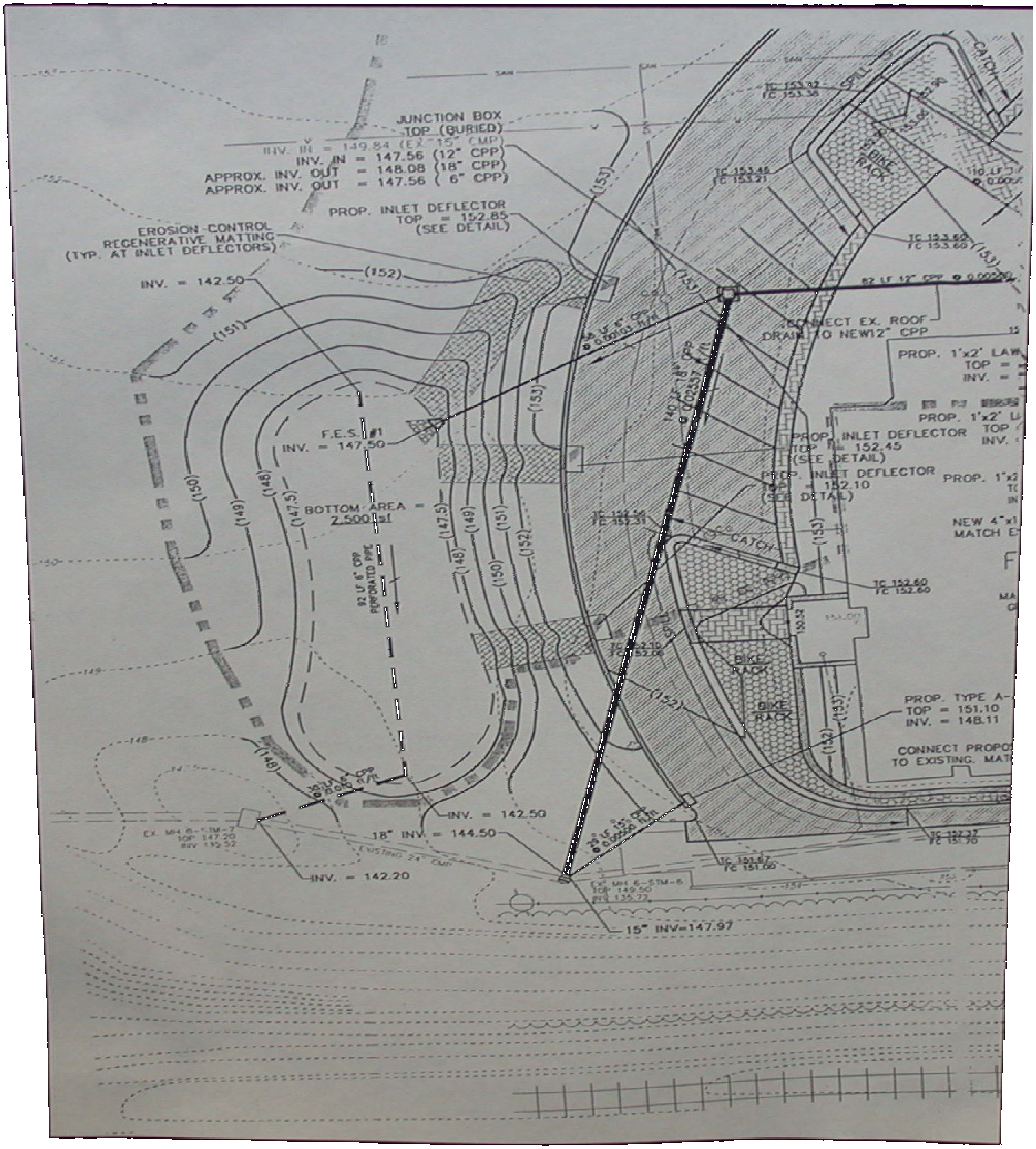
*Figure 7: Design Plans for Dickinson Stormwater Wetland.*



NOTE: AT INLET DEFLECTOR OPENINGS PLACE EROSION CONTROL REVEGETATION MAT (ECRM) AS SHOWN ON PLAN. (TYP. 3 PLACES)

***Source: Taylor, 2004***

*Figure 8: Image of Dickinson design plans (aerial view)*



**Source: Taylor, 2004**

### *Clayton Hall Stormwater Wetland*

The University of Delaware Facilities Management constructed the Clayton Hall stormwater wetland in 1996 (Taylor, 2004). This wetland was not intensively planted—only river birch was manually planted. All other plants living in the wetland are volunteer, the predominant plant being multiflora rose. This thorny invasive species has spread from the nearby Blue Hen Creek (Taylor, personal communication). This wetland catches runoff from the University of Delaware's Laird Campus. This is entirely institutional land use. This type of land use has an imperviousness factor of 55% (Campagnini, 2001). Design Plans for this wetland were unavailable.

### *Pollutants of Urban Runoff*

Given the areas in which these BMPs are located, they should be held accountable to the types of pollutants most often found in urban runoff. According to the U.S. E.P.A. Pollutants most commonly associated with urban runoff are:

- Suspended Solids
- Nitrogen
- Phosphorus
- Lead
- Zinc
- Copper
- Bacteria

The tests conducted were not sensitive to all of these pollutants but did test for important components of urban runoff. The sources of these pollutants are varied, but all have their origins in urban infrastructure. While these indicators are important, factors such as temperature and salinity must also be considered

### *Solids and Floatables*

Solids are extremely common in urban stormwater Solids come from many different sources- erosion of roadways, dust and litter. They contribute to the increased turbidity of water, which makes it difficult for sunlight to penetrate to the bottom of a pool of water. Water quality, wildlife habitat and aesthetic problems all follow from this issue. Settled sediments alter and can destroy fish habitat and bottom dwelling organisms. They also can play a role in holding pollutants in a water body by binding the particle to the solids' surface (U.S. E.P.A., 1999)

### *Oxygen Demanding Substances*

Urban stormwater can contain many different types of living organisms that need oxygen to survive. It is important for the habitat quality of a receiving stream that the dissolved oxygen levels stay high enough to support a variety of fish and other aquatic organisms. Typically, levels are comparable to that of water being released from wastewater treatment facilities and therefore are not a concern. The levels of dissolved oxygen do become an issue when nutrient enrichment and the needs of bottom dwelling organisms are considered (U.S. E.P.A, 1999). It is here that our dissolved oxygen tests become important

### *Nitrogen and Phosphorus*

Nitrogen and phosphorus are the main nutrients of concern when dealing with urban runoff. The major sources are fertilizers, detergents, plant debris, atmospheric deposition, old septic systems and animal wastes. When excess nutrients are in a water body, primary biological activity tends to increase, which causes excessive algal growth. Eutrophication and nuisance algal blooms can follow. A study conducted by the EPA between 1978 and 1983 concluded that nutrient levels found in urban runoff are high when compared to other possible discharges (U.S. E.P.A., 1999).

### *Ammonia*

Ammonia is a source of Nitrogen. Typically it is non-toxic except at extremely high levels. Sources of this chemical can include animal wastes and cleaning products.

### *Chlorine*

Chlorine is not naturally present in waters. High levels of this chemical can be toxic to aquatic life.

### *Chloride*

Chlorides in urban runoff usually have their sources in road salting. High levels can be toxic to aquatic life

### *Metals*

Metals found in urban stormwater are typically from automobiles and industry. Lead, copper and zinc are the most prevalent priority pollutant found in urban runoff (NURP qtd in U.S. EPA, 1999). Copper is usually found in industrial effluent, and on surfaces coming form the corrosion of pipes and fittings. Iron is present in most natural waterways. The most common sources are soil and rocks. It can also come from rusting automobiles. High levels are usually traced to industrial effluent (Campagnini, 2001)

### *Temperature*

Water holds less oxygen as the temperature increases, therefore decreasing its ability to support life. As urban runoff flows over rooftops, parking lots and roadways, the water can be heated. If it then flows directly into a receiving body of water, the temperature will increase in that body and alter the spectrum of organisms able to live there. A study described in the August 1999 Preliminary Data Summary of Urban Stormwater Best Management Practices found that for every one percent increase in watershed imperviousness, base flow water temperature increased by 0.14 °F.

### *pH*

Fish and other aquatic organisms are very sensitive to changes in pH. Urban areas tend to have higher pH levels in runoff due to the lack of a buffering capacity found in natural soils and landscapes. (U.S. E.P.A, 1999)

### ***Pollutant Removal Methods***

Stormwater BMPs use a variety of different methods to remove pollutants from urban runoff. The BMPs in this study used a combination of sedimentation, biological uptake, filtration, and infiltration.

#### *Sedimentation*

Gravitational settling is the major mechanism in ponds and constructed wetlands. Metals, hydrocarbons, nutrients and oxygen demanding substances can be adsorbed to particulate matter, especially clay soils. Sometimes a coagulant is needed for fine particulate matter (U.S. E.P.A, 1999).

#### *Biological Uptake*

Urban runoff typically contains significant amounts of nutrients. Aquatic plants, algae and microorganisms can use these nutrients for growth. If the plant matter is removed at the end of the growing season, then these nutrients can be permanently removed. However, if the plants are left to decompose in the BMP the nutrients can be re-released into the water column (U.S. E.P.A, 1999).

#### *Filtration*

When water is passed through a porous material such as soil, sand, gravel, peat or compost or a combination of materials particulates can be separated and therefore removed. However, the success of this removal practice depends upon a wide variety of variables such as particle shape, size and chemical charge and the velocity of the water (U.S. E.P.A, 1999).

#### *Infiltration*

Infiltration reduces the runoff volume discharged into receiving waters, making it the most effective way to control runoff. It also is an effective method of pollutant control, removing contaminants as water infiltrates into the ground (U.S. E.P.A, 1999).

### ***Results***

The results for both stormwater BMPs were mixed, making it difficult to draw any strong conclusions. Overall, the water collected from the inflowing runoff was free of the pollutants analyzed in this study. Ammonia, chlorine, and copper were never detected in inflowing water in either BMP.

#### *Dickinson Bioretention Area*

The results of the analysis of the inflowing and outflowing waters of the Dickinson Bioretention Area are as follows:

- Conductivity increased dramatically.
- Chlorides always increased
- Dissolved Oxygen stayed constant unless inflowing concentrations were high
- Iron was removed
- Phosphorus was detected in all outflowing concentrations, even when absent in inflowing waters. One possible explanation could be the occasional presence of waterfowl in the BMP. Another reason could be an internal production of phosphorus by microbes living in the BMP (Thomas et al, 2000)

#### *Clayton Stormwater Wetland*

The results of the analysis of the inflowing and outflowing waters collected at the Clayton Hal Stormwater Wetland are as follows:

- Conductivity in this BMP always increased.
- Chlorides were increased when inflowing concentrations were low but were slightly reduced in the other 2 samples.
- Dissolved Oxygen stayed level except in the instance where inflowing concentrations were low (2ppm), in which case the DO level increased.
- Iron addition was observed in one instance
- Phosphates were removed on one occasion, and remained untreated from another storm.

The following tables display the data collected on each storm event. Table 5 displays the results of the first analysis. Table 6 and Table 7 show the results of the water quality analysis of runoff from a combination of rainwater runoff and snowmelt event. Pollutant loads in snowmelt are much higher than that of rain runoff (Hird et al, 2003). This can be attributed to the fact that snow tends to sit on the ground and gather pollutants from passing cars, atmospheric deposition and such. Also because the ground is frozen, not as much water infiltrates into the soil. Pollutants are then more likely to be carried into waterways by overland flow.

*Table 5: Results of Water Quality Tests for the Storm of January 5, 2004*

| Parameter (ppm) | Dickinson 1/5/04 | | | Clayton 1/5/04 | | |
|---|---|---|---|---|---|---|
| | Inflow | Outflow | Removal Ratio | Inflow | Outflow | Removal Ratio |
| Temperature (°C) | 12.0 | 11.0 | 8.4% | 12.0 | 12.5 | 4.0% |
| PH | 6.0 | 6.0 | 0.0% | 6.0 | 6.0 | 0.0 |
| Conductivity | 50.0 | 470.0 | -840.0% | 400.0 | 750.0 | -87.5% |
| Ammonia | 0.0 | 0.0 | N/A | 0.0 | 0.0 | N/A |
| Chloride | -72.8 | 44.8 | 161.4% | 25.2 | 123.2 | -388.9% |
| Chlorine | 0.0 | 0.0 | N/A | 0.0 | 0.0 | N/A |
| Copper | 0.0 | 0.0 | N/A | 0.0 | 0.0 | N/A |
| Dissolved Oxygen | 4.0 | 4.0 | 0.0% | 3.0 | 3.0 | 0.0% |
| Iron | 0.0 | 0.0 | N/A | 0.0 | 0.0 | N/A |
| Nitrate | 0.0 | 0.0 | N/A | 0.0 | 0.0 | N/A |
| Phosphate | 0.0 | 0.5 | 0.0% | 0.5 | 0.0 | 100.0% |
| Time | 12:00 PM | 12:15 PM | | 12:30 PM | 12:45 PM | |

*Table 6: Results of Water Quality Tests of the February 3, 2004 Rainfall and Snowmelt Runoff.*

| Parameter (ppm) | Dickinson 2/3/04 | | | Clayton 2/3/04 | | |
|---|---|---|---|---|---|---|
| | Inflow | Outflow | Removal Ratio | Inflow | Outflow | Removal Ratio |
| Temperature (°C) | 8.0 | 8.0 | 0.0 | 6.0 | 6.5 | -8.4 |
| PH | 5.5 | 6.0 | -9.1 | 5.5 | 5.5 | 0.0 |
| Conductivity | 880.0 | 1990 | -126.14% | 1630.0 | 1540.0 | 5.4% |
| Ammonia | 0.0 | 0.0 | N/A | 0.0 | 0.0 | N/A |
| Chloride | 159.6 | 470.0 | -194.74% | 369.6 | 344.4 | 6.7% |
| Chlorine | 0.0 | 0.0 | N/A | 0.0 | 0.0 | N/A |
| Copper | 0.0 | 0.0 | N/A | 0.0 | 0.0 | N/A |
| Dissolved Oxygen | 6.0 | 4.0 | 33.2% | 2.0 | 6.0 | -200.0% |
| Iron | 1.0 | 0.0 | 100.0% | 1.0 | 1.0 | 0.0% |
| Nitrate | 0.0 | 2.0 | 0.0% | 0.0 | 0.0 | N/A |
| Phosphate | 4.0 | 1.5 | 0.5% | 0.0 | 0.0 | N/A |
| Time | 3:00 PM | 3:00 PM | | 3:25 PM | 3:30PM | |

*Table 7: Results of Water Quality Tests of the February 6, 2004 Rainfall and Snowmelt Runoff.*

| Parameter (ppm) | Dickinson 2/6/04 | | | Clayton 2/6/04 | | |
|---|---|---|---|---|---|---|
| | Inflow | Outflow | Removal Ratio | Inflow | Outflow | Removal Ratio |
| Temperature (°C) | 11.0 | 10.0 | 9.1 | 11.0 | 10.0 | 9.1 |
| PH | 6.5 | 6.0 | N/A | 5.5 | 5.5 | N/A |
| Conductivity | 660.0 | 1990.0 | -201.4% | 450.0 | 290.0 | 35.6% |
| Ammonia | 0.0 | 0.0 | 100% | 0.0 | 0.0 | N/A |
| Chloride | 98.0 | 470.4 | -380.0% | 39.2 | -5.6 | 114.3% |
| Chlorine | 0.0 | 0.0 | 100.0% | 0.0 | 0.0 | N/A |
| Copper | 0.0 | 0.0 | 100.0% | 0.0 | 0.0 | N/A |
| Dissolved Oxygen | 2.0 | 2.0 | 100.0% | 6.0 | 6.0 | 100.0% |
| Iron | 1.0 | 0.0 | 100.0% | 0.0 | 1.0 | 0% |
| Nitrate | 0.0 | 0.0 | N/A | 0.0 | 0.0 | N/A |
| Phosphate | 0.0 | 2.0 | 0.0% | 1.0 | 1.0 | 100.0% |
| Time | 12:45 PM | 12:45 PM | | 1:10 PM | 1:10 PM | |

An expected result of the snowmelt runoff is the extreme spike in conductivity of the water, both inflowing and out flowing. It also seems that conductivity is increased as the water flows through the BM P. This could be from the road salts in the runoff flowing into the wetland, concentrating in the BMP and then being flushed out by the incoming rainwater.

The results of the water quality tests were used to calculate pollutant removal percentages. Table 8 displays these percentages which were calculated using the following formula

$$\frac{\text{(Inflow Concentration- Outflow Concentration)}}{\text{Inflow Concentration}} *100 = \%\text{Removal}$$

*Table 8: Removal Ratios*

| Parameter (ppm) | Dickinson ratios 1/5/04 | Dickinson ratios 2/3/04 | Dickinson ratios 2/6/04 | Clayton ratios 1/5/04 | Clayton ratios 2/3/04 | Clayton ratios 2/6/04 |
|---|---|---|---|---|---|---|
| Temperature | N/A | N/A | N/A | N/A | N/A | N/A |
| PH | N/A | N/A | N/A | N/A | N/A | N/A |
| Conductivity | -840.0% | -126.1% | -201.5% | -87.5% | 5.5% | 35.6% |
| Ammonia | N/D | N/D | N/D | N/D | N/D | N/D |
| Chloride | 161.5% | -194.7% | -380.0% | -388.9% | 6.8% | 114.3% |
| Chlorine | N/D | N/D | N/D | N/D | N/D | N/D |
| Copper | N/D | N/D | N/D | N/D | N/D | N/D |
| Dissolved Oxygen | 0.0% | 33.3% | 0.0% | N/D | -200.0% | 0.0% |
| Iron | N/D | 100.0% | 100.0% | N/D | 0.0% | 0.0% |
| Nitrate | N/D | 0.0% | 0.0% | N/D | N/D | N/D |
| Phosphate | 0.0% | 62.5% | 0.0% | N/D | 0.0% | 0.0% |

N/D means that particular pollutant was not detected, and a negative removal ratio indicates addition by the BMP.

# Chapter Four: Conclusions and Implications

1. Pollutant Removal Efficiencies

Overall, the water entering the wetlands is free of the pollutants analyzed in this study. When pollutants are present in the inflowing water, they are not removed with a high level of efficiency. Concerns are the additions of phosphorus in the Dickinson BMP, the presence of invasive plant species in the Clayton Hall BMP and the consistent increase in the conductivity of the water in both BMPs.

The Dickinson wetland consistently adds phosphorus to the out flowing water, except in the case of extremely high inflowing concentrations (table 2). This suggests that there is a background level of phosphorus in the BMP at all times. Also, nutrients could be coming from decomposing plant matter, as there is no end of season detritus removal schedule by the University of Delaware, or from microbes living in the BMP.

2. Maintenance

Both Stormwater BMPs are in need of cleaning. Regularly scheduled maintenance would aid in the performance of both wetlands.

This issue is addressed specifically in a published study conducted on an area known as Lake McCarrons. A researcher returned to a pond/ wetland system 12 years after conducting an initial study. The original study had been conducted during the first 2 years of the wetland's existence, and was very intense. The results indicated that the wetland was highly effective. In both winter and summer it functioned at 15-20% above the national average (Schueler et al, 2000).

Ten years later the system was again studied using the same sampling and testing techniques. Over that 10-year period the system had changed quite a bit, there were 100 new acres of drainage area added to the system, flow along the system had begun to channelize and the wetland species had been taken over by invasives. As a result of the lack of maintenance and upkeep of the system, performance declined drastically. The primary factor leading to the decline of the system results from the fact that the system became 'leaky', meaning that during base flow conditions it would export pollutants, and not absorb as much as it used to during storm events. These results point to the importance of keeping up with the maintenance of stormwater wetlands (Schueler et al, 2000).

Currently plans are under way to clean out the outflow pipe at the Clayton wetland. The Dickinson Bioretention BMP does not have any planned maintenance schedule at this time ( Taylor, 2004). A schedule may be needed to remove the decomposing vegetation. This alone could aid in the removal of phosphorus from the out flowing water.

3. Vegetation

The fact that the Clayton wetland was not planted with any vegetation except river birch leaves room for improvement. As observed in a study conducted in Maryland, over a period of years a ‘volunteer’ wetland in a Washington D.C. Business Park not planted with any species was overtaken by common reeds and cattails. A seasonal wetland observed in the study had an interesting growth pattern. Created in Queen Anne, Maryland it was originally planted with 4,000 individuals from 3 species. The planted species did very well, however the emergent zone was invaded by cattails and spike rush and other sedges. However, the entire wetland was not overtaken by these species (Schueler et al, 2000).

Both wetlands appeared to function very well, even though the Washington Business Park volunteer wetland presented some obstacles to testing. The Queen Anne Stormwater Wetland was extremely effective at removing Phosphorus and Suspended Solids. Perhaps most interesting is that this wetland’s plant community formed a “structural matrix” that was exploited by many other species (Schueler et al, 2000).

Currently the Clayton wetland is being taken over by multiflora rose. This invasive is extremely difficult to remove and a highly efficient invader of any open space. The Clayton wetland would benefit from some plantings of native perennial wetland plants. However adding plants must be followed by a maintenance schedule, as illustrated by the phosphorus problem found in the Dickinson Bioretention Basin.

*Recommendations for the Future*

Based on the research conducted during this study and the results of the tests conducted, I recommend that several tests be added to the methodology. To detect pollutants that are commonly found in urban stormwater. The additional tests would provide a more accurate portrait of how well the BMPs are functioning as well as a more complete picture of what is entering the BMPs. Testing should be added for:

    a. Suspended Solids
    b. Hydrocarbons
    c. Zinc
    d. Lead

Stormwater BMPs do help to remove pollutants from the water cycle. Those studied here are small in scale; other studies conducted on larger BMPs have shown to bring significant improvements to polluted water. All BMPs require several steps to keep them in working order:

1. Monitor the BMP immediately after installation—this allows for any temporal changes to be documented and keeps a running record of efficiency.
2. Develop a Maintenance Schedule—keeping the pipes clean and dead plant matter out of the system could be two of the most important aspects of BMP functionality. Without water flow stagnation can occur; flow over dead plant matter simply puts nutrients back into the system
3. Establish Suitable Vegetation—This provides soil stabilization, nutrient removal and prevents invasives from taking over the BMP.

The BMPs installed here appear to function below the average for pollution removal, but do provide flood and erosion control. The area where the Dickinson BMP is now located had very poor drainage prior to the installation of the BMP. After a rain the area was constantly under an inch of water. The Clayton Hall stormwater wetland diverts much rainwater from the eroded slopes of the Blue Hen Creek. While it does not do much for pollutant removal, it does help to maintain the integrity of the stream below. Additional care would only serve to improve the functions of these man made wetlands.

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# Exhibits

*Exhibit 1: Chemical Data Sheet*

## Chemical Data Sheet

Date: _____________ Recorder: ________________ Time: _____________

Site Number: _________________ Temperature:______

BMP

Location/ Number:___________________ pH__________________

| Parameter | Results | Comments/Grade |
|---|---|---|
| Ammonia | | |
| Chloride | | |
| Chlorine | | |
| Copper | | |
| Dissolved Oxygen* | | |
| Iron | | |
| Nitrate | | |
| Conductivity | | |
| Phosphate | | |