LINKING STREAM HEALTH AND LAND USE IN THE UNIVERSITY OF DELAWARE EXPERIMENTAL WATERSHED

by

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A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of
the requirements for the degree of Bachelor of Science in
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Glossary

Watershed – the sum of all land areas contributing runoff or drainage to a singular watercourse (Reimold, 7)

Riparian Buffers – vegetative buffers between the stream and the surrounding land use which aid in filtration, and dispersal of water flow; comprised of 3 zones

1) unmanaged forest of trees and shrubs to provide shade and habitat
2) managed forest maintained by land owner
3) tract of open land between managed forest and current land use

Impervious Surfaces – hard, packed land use which prevents the recharge of precipitation into ground water

GIS – Geographic Information Systems – a computer program which allows the user to analyze maps and highlight important information relating to the subject of interest

GPS – Global Positioning Systems – A satellite- conferencing hand-held unit which displays the exact Latitude and Longitude of the unit

Wild and Scenic River Legislation – federal legislation recognizing and protecting rivers of ecological importance (1968)

Abstract

Student researchers of the University of Delaware Water Resources Agency (UDWRA) have delineated an experimental watershed through the University of Delaware campus, which includes both the northern Piedmont Plateau and the southern Coastal Plain. The purpose of this project is to continue to research the link between stream health and certain types of land use and update the watershed report card for the Piedmont Plateau and the Coast Plain while exploring different methods and procedures. The land use in these areas is rapidly changing, and the amount of impervious services, such as roads and driveways, is increasing. A negative relationship between land use and stream health was found in the Piedmont Plateau, and a report card for establishing a user-friendly way of tracking watershed health through the years was developed. Stream sampling and chemical surveys were completed at each of the sampling stations through the watershed. The New Zealand National Institute of Water and Atmospheric Research (NZ-NIWA) donated a Stream Health Monitoring and Assessment Kit for research. The Overall Watershed Health Grade of the Piedmont Watershed was a **C+,** which has fallen from a **B-** in 2001. The stream in this watershed with the highest percentage of impervious cover had the lowest stream quality, in agreement with the hypothesis of this report. The Coastal Plain in 2002 received an Overall Watershed Report Card Grade of **C**, which is another decrease in total watershed health. The Coastal Plain Watershed received a **C+** in 2001. Tributary 3, which had the lowest percentage of impervious

cover, had the highest water quality grade. The stream with the lowest overall grade had the highest amount of negatively impacting land uses and highest percentage of impervious cover. Future researchers will be able to update and modify the Experimental Watershed Report Card to monitor temporal changes in the surrounding land.

Chapter 1

BACKGROUND AND JUSTIFICATION

Introduction

A watershed can be defined as the geographic area of land which contributes runoff or drainage into a specific body of water (Reimold, 1998). Watersheds connect waterways to their natural counterpart, the land. The land, its uses and its features affect the water flowing over them. Human use of the land changes the natural land features and the natural adaptations that have evolved to protect the quality of the water. The quality of the water is important because of its use as a drinking water source and a recreational area. Surface water and ground water are used as drinking water sources, but ground water is not as susceptible to contamination because of the filtration characteristics of soil.

The entire United States can be broken down into individual watersheds ranging in size from hundreds of thousands of square miles, such as the Mississippi-Missouri River System, to a few thousand square miles such as the Delaware River Basin, to just a few square miles for small streams and creeks, such as the White Clay Creek. Although the larger bodies of water may seem more significant, it is the compact watersheds where research can be focused.

Land use planning has been identified by the United States Environmental Protection Agency as perhaps the most important watershed protection tool (USEPA, 2000). Impervious surfaces can be defined as surfaces which do not allow water to recharge into the groundwater or soils, the process also known as infiltration. Some examples of impervious surfaces include roofs, roadways, sidewalks and parking lots. An increase in impervious surfaces is detrimental to stream health because it increases the amount of water that runs off the land into the stream. The stream has increased erosion and flooding due to the increase of flow. The runoff is usually higher in temperature, which degrades the aquatic biota, decreases the dissolved oxygen and increases algal blooms. In areas of natural landscape, precipitation is allowed to infiltrate the soil and recharge into the groundwater, thereby renewing water resources. Impervious surfaces prevent this cycle and so impair the surface and ground water resources humans require for existence (Center for Watershed Protection, 2000).

Description

The land area of the State of Delaware primarily drains into the Delaware Bay or the Chesapeake Bay, by way of either the Delaware River or smaller streams which flow into the Bay (Figure 1.1). The Newark Area primarily drains into the White Clay Creek which is within the Delaware River Watershed. The White Clay Creek Watershed encompasses two states, two counties and three cities. It drains 69,000 acres in southeast Pennsylvania and northwestern Delaware. Ninety-five thousand people live within the boundaries of the watershed but another hundred thousand live in close proximity (WCWA,1998). It is located in an area of rampant development, where the clash of agricultural tradition and suburbanization has led to land use disputes and regulation. Because of the precarious location of the watershed and its remarkable pristine condition, former President Clinton signed legislation designating the White Clay Creek as Delaware's first Wild and Scenic River (USNPS, 2001). This official federal legislation protects the watershed from development and recognizes its beauty.

The City of Newark community is a good example of a typical area in the watershed in terms of its growth and development. Because the city is uniquely situated on the fall line between the Piedmont Plateau and the Coastal Plain, Newark contributes an interesting case to the study of watersheds (Figures 1.2 and 1.3).

Previous Research

In 2001, student researchers of the UDWRA, funded by the Delaware Water Resources Center with a grant from the US Department of the Interior, delineated an experimental watershed through the campus of the University of Delaware (Campagnini, 2001). This was the first research of its kind at the University of Delaware. This initial research of the Piedmont Watershed resulted in the correlation of impervious surfaces with impaired stream health. In the prepared report, the stream with the highest stream health grade was the Lost Stream, with a **B** rating (on a scale from **A= excellent,** to **F= poor**). This grade incorporates the water quality, land use, impervious cover, and habitat analysis. The Lost Stream flows through the White Clay Creek State Park. Most of its sub-watershed is open space and forested. It had the best water quality and the highest habitat assessment rating. Conversely, Blue Hen Creek (the Pencader Creek) had the lowest stream health grade. This stream, which flows through the University of Delaware campus, had the highest percentage of impervious surfaces and the poorest water quality and habitat assessment rating. The overall Final Grade for the Piedmont Experimental Watershed was a **B-,** a **good** rating (Campagnini, 2001).

The conclusions of the preliminary Experimental Watershed report included the applicability to the Coastal Plain area of the Watershed. The Coastal Plain area of the UD campus has very different geography and land uses. It provides another example of the effects of land use on stream health. It also called for the continuation of the Watershed Report Card project in order to monitor stream health in the Experimental Watershed. Both of these suggestions have been taken into account to form the basis of this report.

The conclusions of the previous report were used to form the basis for this research. The prior research formed the basis for the watershed as an on-campus education and research tool for the University community. It will be available to serve as a classroom tool for future UD classes as well as a training ground for local educators to enhance their curriculum. The Watershed Mapping Process is easily taught to other professionals and educators in order to delineate watersheds in college and high school campuses. The relationship of Watershed Health to Land Use was found to be one of negative impact. For instance, the Lost Stream watershed with the largest areas of forest and open space, and lowest imperviousness, had a grade of **B (good)**, while the watersheds with higher levels of impervious cover, such as Blue Hen Creek (formerly Pencader Creek), had a grade of **C (fair)**. The Watershed Report Card is a user-friendly tool that will be able to track the health of the Experimental Watershed now and in semesters to come. The use of a standardized grading unit makes the report card more familiar to the public and easier to understand. The chart below summarizes the overall health grade each watershed received. The overall report card is shown in table 1.1.

	Watershed Health Grade	Health Rating
• Piedmont Experimental Watershed	**B -**	**Good**
▪ Blue Hen Creek (Pencader Creek)	**C**	**Fair**
▪ Fairfield Run	**C +**	**Fair**
▪ Lost Stream	**B**	**Good**

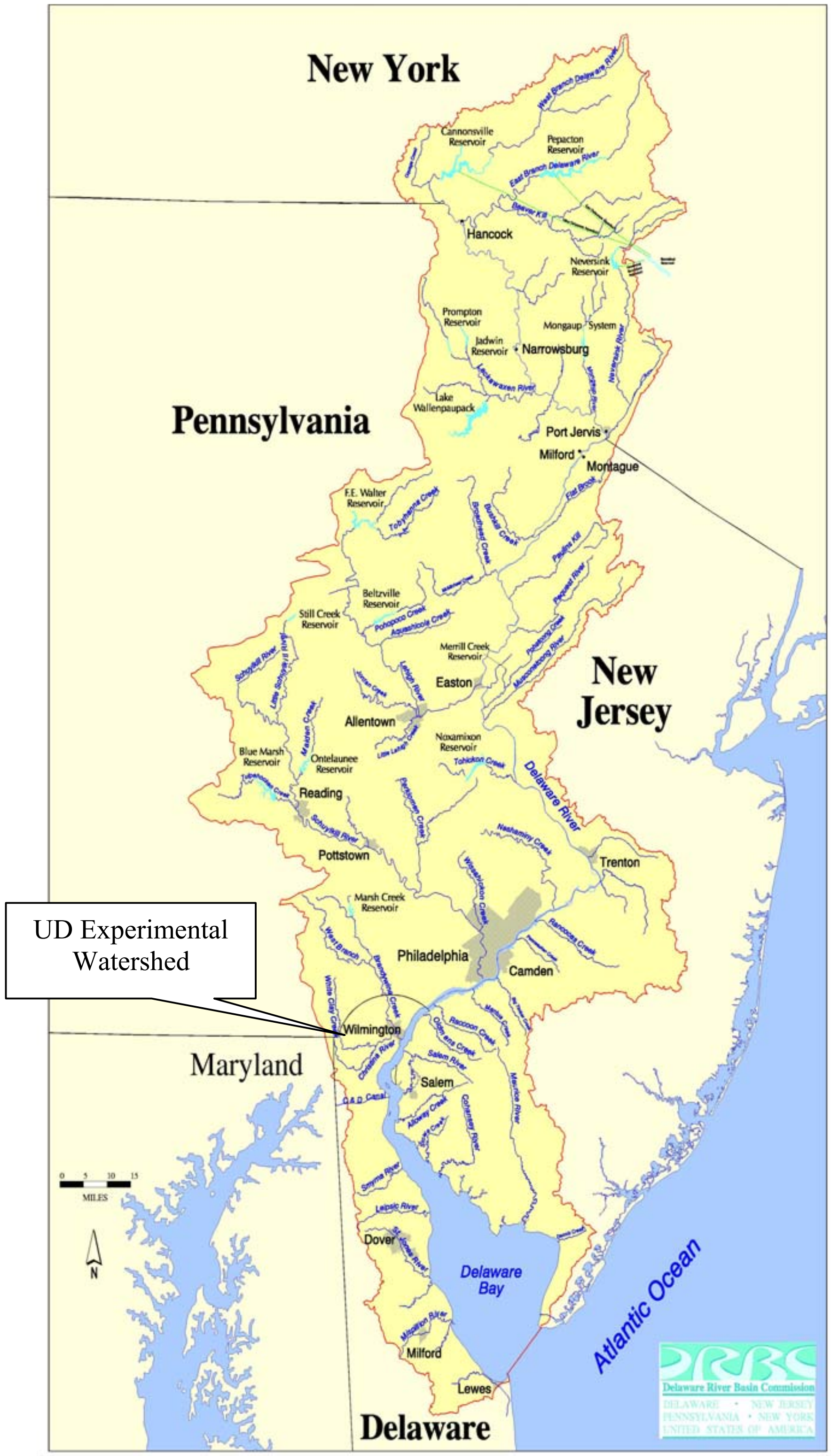
Table 1.1. 2001 Piedmont Watershed Report Card

PIEDMONT WATERSHED REPORT CARD					
STREAM	***WATER QUALITY***	***LANDUSE***	***IMPERVIOUS COVER***	***HABITAT ANALYSIS***	***FINAL GRADE***
PENCADER CREEK					C
P1PC	2.5	3.1	1.0	2.7	2.3
P2PC	2.6			2.9	2.4
P3PC	2.5			2.4	2.2
FINAL GRADE	**2.5**	**3.1**	**1.0**	**2.7**	**2.3**
FAIRFIELD RUN					C+
P5FR	2.8	3.3	1.0	3.1	2.5
P6FR	2.6			2.5	2.3
P7FR	2.6			2.7	2.4
FINAL GRADE	**2.7**	**3.3**	**1.0**	**2.8**	**2.4**
LOST STREAM					B
P9LS	2.9	3.8	3.0	3.0	3.2
FINAL GRADE	**2.9**	**3.8**	**3.0**	**3.0**	**3.2**
WATERSHED FINAL GRADE	**2.7**	**3.4**	**1.7**	**2.8**	**2.6**
WATERSHED FINAL LETTER GRADE*	**B-**	**B+**	**C-**	**B-**	**B-**

(Campagnini, 2001)

Figure 1.1. The Delaware River Basin

Delaware River Basin



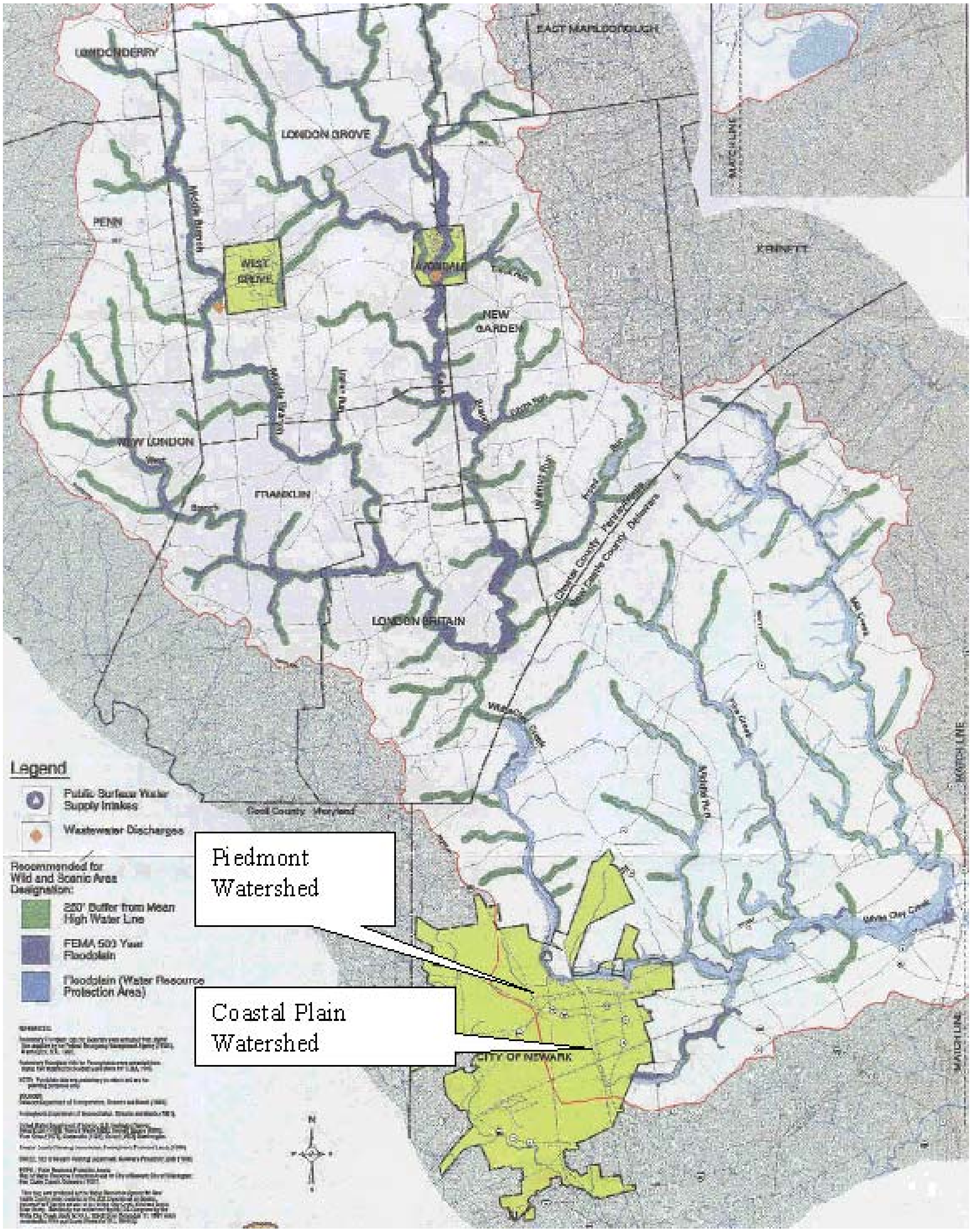


Figure 1.2. White Clay Creek Watershed (Campagnini, 2001)

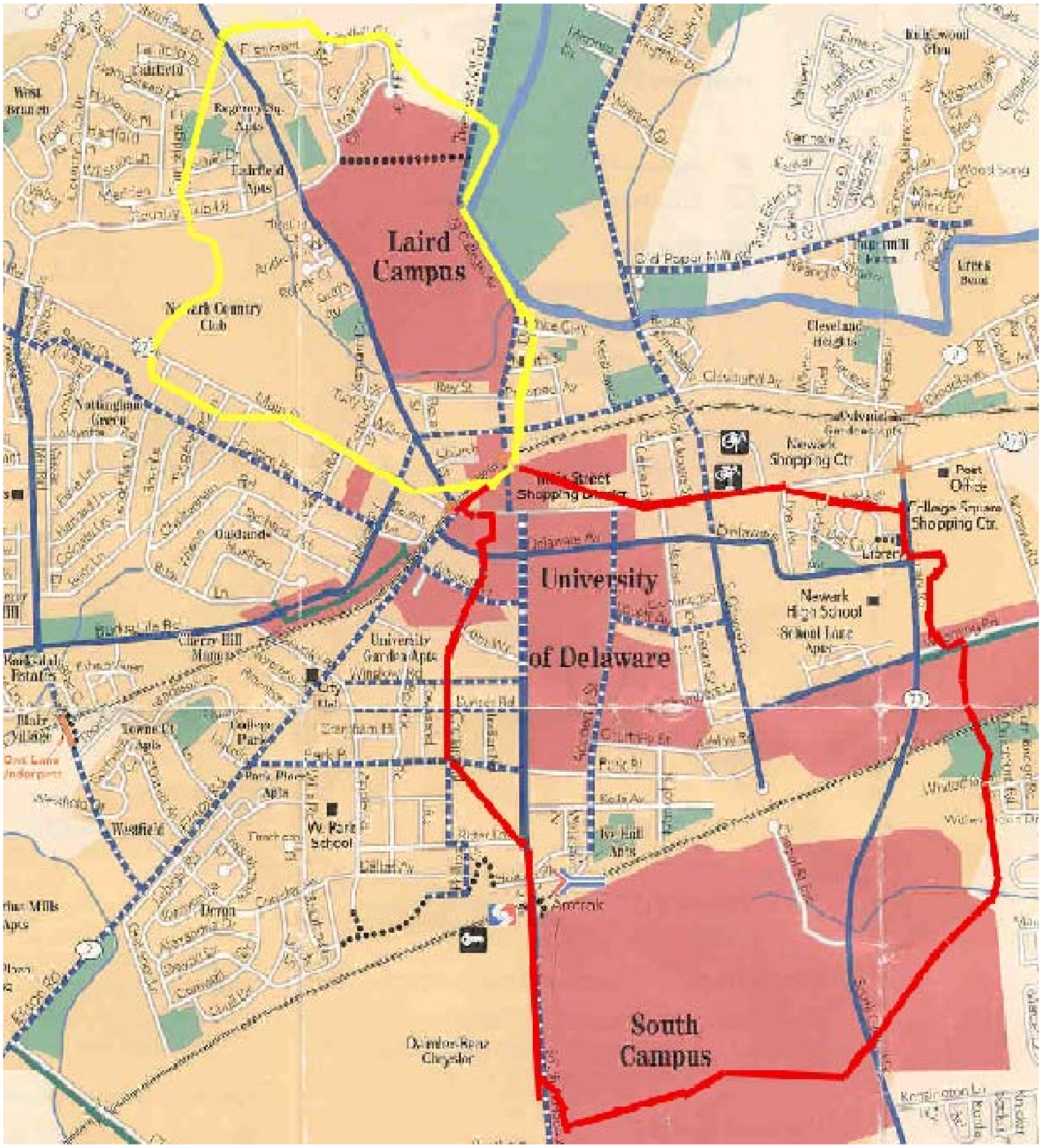


Figure 1.3. The University of Delaware Experimental Watershed over a Campus Map (Campagnini, 2001)

Chapter 2

RESEARCH OBJECTIVES

The goal of this research was to explore the link between land use, stream water quality and watershed health in the UD Experimental Watershed. In order to explore the link between water quality and land use, field inventories were conducted to update the existing watershed data. The inventories included locating 14 sampling positions with the Global Positioning System (GPS) and collecting data from water quality tests. Stream habitats and riparian buffers were also surveyed using the USEPA Rapid Stream Bioassessment procedure as well as a land survey. The University of Delaware Water Resources Agency (UDWRA) was fortunate enough to have contacts in New Zealand. The National Institute of Water and Atmospheric Research (NZ-NIWA) donated a Stream Health Monitoring and Assessment Kit to the WRA. A comparison between the two habitat assessment procedures illustrated the differences and perhaps calls for a modification of the current UD Experimental Watershed assessment technique. The NZ-NIWA assessment seems to be easier to come up with an actual quantitative value to compare the different areas' habitat quality. It may also be quicker to use (Biggs,1999). Urban nutrient surveys were conducted in streams with predominately commercial and residential land uses. This was done in September, November and February after precipitation events from storm water outfalls. The next task was to conduct chloride samples during the winter months to quantify the effect of road salt on streams in the Experimental Watershed.

The fifth task built upon the Watershed Report Card, which was created and implemented in the Fall of 2000. The data collected was compared to the previous data to analyze trends in land use and changes in stream health. In order to sample the streams and analyze stream health changes in areas, GIS was used to plot the exact location of sampling stations.

The last task, which was completed in order to fulfill the requirements of the Degree with Distinction, is the writing of the Senior Thesis. The methods of the study, the results and the corresponding conclusions will be discussed. Also included will be graphs, maps and charts to better illustrate the findings. Enclosed is a list of the task accomplished.

Task 1. Conducted Field Inventories – Conducted a series of field inventories to update the following databases within the Piedmont and Coastal Plain Experimental Watersheds:

- GPS Sampling Stations – With a Global Positioning System, located 14 sampling stations by latitude and longitude.
- Stream Quality – Assessed the links between land use and water quality, collect in-stream data for alkalinity, ammonia, chlorides, chlorine, chromium, copper, dissolved oxygen, biochemical demand, hardness, iron, nitrates, phosphates, pH, and hydrocarbons at 14 sampling stations.
- Stream Habitat – Characterized benthic health and stream substrate using an adaptation of the USEPA Rapid Stream

Bioassessment procedure and the NZ NIWA Stream Health Monitoring and Assessment Kit Stream Monitoring Manual.

Task 2. Conducted Urban Nutrient Surveys – Designed and carried out an urban nutrient survey in the field from residential and commercial land uses in the Piedmont Experimental Watershed. Levels of nitrogen and phosphorus were sampled in September, November and February after precipitation events at storm water outfalls from subdivisions in the watershed. This procedure was designed to be a "first-generation" attempt to quantify nutrient loading from typical New Castle County urban/suburban land uses.

Task 3. Conducted Chloride Surveys – Collected frequent chloride sampling data in the field during the winter months before and after snowmelt to quantify nutrient loading from typical New Castle County urban/suburban land uses.

Task 4. Updated Watershed Report Card – Updated the Watershed Report Card (based on letter grade or numerical index), which characterizes the health of the Experimental Watershed according to land use, impervious cover, stream water quality, stream habitat, and riparian buffer condition. Conducted an assessment that explores the link between land use and the stream and watershed health utilizing the sampled data. This report card assessment for 2001 in the experimental watershed will be compared to the assessment conducted in 2000 to monitor temporal trends and changes in stream health.

Task 5. Updated Watershed GIS Mapping – Using ARCVIEW GIS techniques, updated the UD Experimental Watershed base mapping using polygon or buffer techniques to include coverage of impervious cover, stream chemistry, riparian habitat, and watershed health. The location of sampling stations was plotted by latitude and longitude.

Task 6. Recorded Results – The advisor will supervise the student's project and assist in the preparation of a thesis. This will summarize the research project and will be submitted to the Undergraduate Research Center by May 24, 2002.

Chapter 3

EXPERIMENTAL METHODOLOGY

Sampling Stations

The previous researchers designated sampling sites based on criteria of accessibility, landmarks such as roads and location in relation to upstream land uses (Campagnini, 2001). The goal was to have the sampling sites on each stream represent the stream as a whole. The sampling sites are labeled as "**W**atershed, site number, **T**ributary **N**ame" (for example- **P**iedmont, 1, **P**encader **C**reek = P1PC). The original research designated seven sampling stations covering each stream of the Piedmont and Coastal Plain Watersheds. In figure 3.1, these stations are represented with yellow triangles. The watershed basins in this figure are outlined in brown. Due to the unusual drought conditions of the fall of 2001, the intermittent stream, known as the Lost Stream (P9LS) by the researchers, did not have a large enough flow to be sampled. The US National Weather Service recorded the least amount of rainfall at the Wilmington Airport in recorded history from July to December 2001. The Governor of Delaware, Ruth Ann Minner, enacted voluntary water restrictions on March 25, 2002 due to the low rainfall (USNWS, 2002). This weather anomaly brought the total number of sampling stations in the Piedmont region to six. The entrance of the Piedmont Streams into White Clay Creek was also surveyed for the Urban Nutrient and Chloride Surveys. These sites were used for Stream Health Assessments using the USEPA and NZ-NIWA, Urban Nutrient

Surveys and Chloride Surveys. A detailed look at the use of sampling stations is shown in table 3.1.

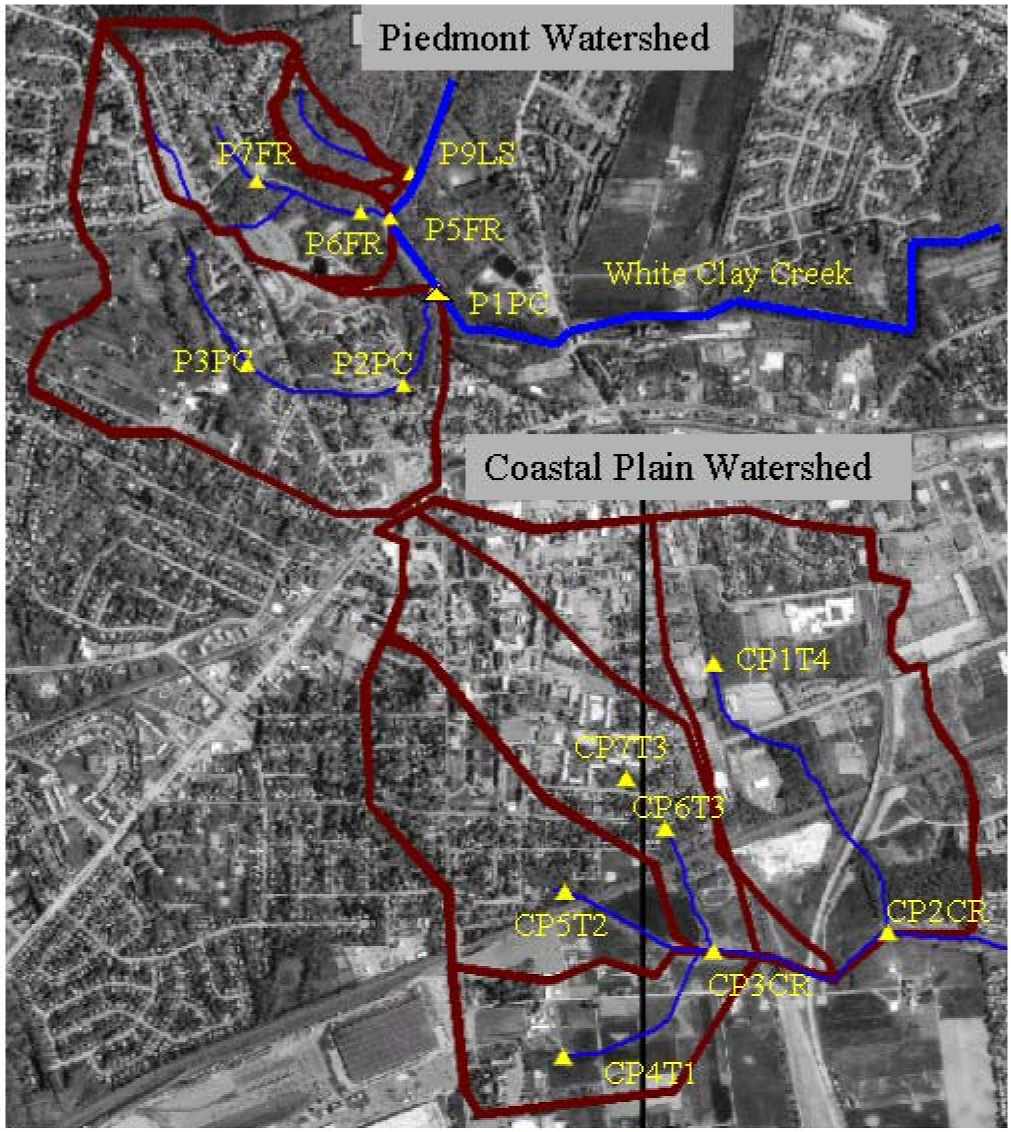


Figure 3.1 University of Delaware Experimental Watershed (with Sampling Stations)

Table 3.1. The Use of Sampling Stations in the UD Experimental Watershed for the Use of Assessing Watershed Health.

Sampling Sites	USEPA	NZNIWA	Urban Nutrient	Chloride
P1PC	X		X	X
P2PC	X		X	X
P3PC	X		X	X
WCC-PC			X	X
P5FR	X		X	
P6FR	X		X	
P7FR	X		X	X
WCC-FR			X	
CP1T4	X	X		
CP2CR	X	X		
CP3CR	X	X		
CP4T1	X	X		
CP5T2	X	X		
CP6T3	X	X		
CP7T3	X	X		

Chemical Water Quality Tests

Chemical Water Quality is important because it establishes the basic health of the water itself. Aquatic plants, microorganisms and microorganisms depend on the chemical properties of water to survive. Too much or not enough of any one chemical would be enough to change the ecology of the aquatic environment and stress the indigenous species (USEPA, 1999)

The Water Quality Parameters were established by the previous researchers of the Experimental Watershed due to their importance in assessing the general health of the stream. LaMotte Company Water Testing kits were used due to their user-friendly instructions and explanations. The Water Quality Rating Guidelines were established using the recommended, or daily, range of limits. These guidelines were then used to assign a grade of **1** to **4** to each individual chemical. A site receiving a grade of **1** would indicate that the stream was in excess of the recommended limit. A grade of **4** would indicate that the stream was within the recommended guidelines. Each subsequent grade less than 4 indicated a 25% decrease or increase in the amount of a pollutant. Please see table 3.2 for details of the recommended range for each chemical parameter. The Chemical Ratings were tabulated for each stream and then averaged. This result is the Water Quality Grade for each stream.

Table 3.2. Water Quality Grading by Parameter.

PARAMETER	4	3	2	1	Max. Limit
Alkalinity (ppm)	<20-50	50-100	100-150	>150	200
Ammonia (ppm)	<1	2-2.9	3-4	>5	10
Chloride (ppm)	<40	40-60	60-150	>150	250
Chlorine (ppm)	<0.1	0.1-0.2	0.2-0.4	>0.5	0.5
Chromium (ppm)	<0.003	0.003-.01	0.01-0.03	>0.04	0.05
Copper (ppm)	<0.03	0.03-0.3	0.3-0.6	>0.6	<1
Dissolved Oxygen (ppm)	5-6	4	3	<2	5-6
BOD (ppm)	5-6	4	3	<2	5-6
Hardness	<60	60-120	120-180	>180	180
Iron (ppm)	<0.1	0.1-0.15	0.5-0.2	>0.2	0.3
Nitrate (ppm)	<4	4-5	6-8	>8	40
pH	7	6.5-6.9 or 7.1-7.5	6.0-6.4 or 7.6-8.0	<6.0 or >8.0	5.0-8.5
Phosphate (ppm)	<0.01	0.01-0.02	0.02-0.03	>0.03	0.03
Turbidity	clear	slightly turbid	turbid	opaque	
Odor	no			yes	
Sheen	no	trace	some	thick	

Hydrocarbon	no	no		yes	
Conductivity	>50	50-100	100-150	>200	

(Campagnini, 2001)

Stream Habitat Assessments

Habitat assessment is critical for the evaluation of the stream health. Habitat is defined by the USEPA as the characteristics of the stream itself and the surrounding riparian habitat that influence the structure and function of the aquatic community in a stream. Habitat characteristics and water quality together determine the overall characterization of the stream habitat. Habitat Assessments were taken at each of the sampling stations on each stream as determined by latitude and longitude. Global Positioning Systems (GPS) units were used to locate each station.

The previous researchers of the Experimental Watershed used the US Environmental Protection Agency's Rapid Bioassessment Protocol (please see the example in the Appendix) for several reasons. As the primary and largest environmental regulation and research institution in the United States, the USEPA is able to draw from a variety of resources and research to establish precedents and procedures. Also, the USEPA Rapid Bioassessment Protocol (RBP) is used nationally for the purpose of habitat assessment, so it is recognizable and familiar to many researchers in the field of watershed research. The USEPA RBP asks the surveyor to evaluate the physical characteristics and fill in the provided blanks, or assign a numerical value according to descriptive standards (USEPA, 1999). Based on the outlined parameters in the USEPA

RBP, a value from **1** to **4** was assigned to each feature indicating the relative health of the habitat (Table 3.3) The overall average was the stream habitat grade. The individual stream grades were averaged to give each stream and the entire watershed a grade.

Table 3.3. USEPA Rapid Bioassessment Protocol Grading by Parameter

PARAMETER	4	3	2	1
Litter (pieces)	0	1-10	11-50	50+
Manmade Structures	0/ site	1/ site	2-3 /site	4+ /site
Point Source Pollution	0/ site	1/ site	2-3 /site	4+ /site
NPS Pollution	0/ site	1 /site	2-3 /site	4+ /site
Erosion				
Epifaunal Substrate/Cover	Optimal	SubOptimal	Marginal	Poor
Characterization	Optimal	SubOptimal	Marginal	Poor
Pool Variablity	Optimal	SubOptimal	Marginal	Poor
Sedimont Deposition	Optimal	SubOptimal	Marginal	Poor
Channel Flow Status	Optimal	SubOptimal	Marginal	Poor
Channel Alteration	Optimal	SubOptimal	Marginal	Poor
Sinuosity	Optimal	SubOptimal	Marginal	Poor
Bank Stability	Optimal	SubOptimal	Marginal	Poor
Vegetative Protection	Optimal	SubOptimal	Marginal	Poor
Riparian Vegetative Zone	Optimal	SubOptimal	Marginal	Poor

In the fall of 2001, visiting scientists from New Zealand's National Institute of Water and Atmospheric Research (NZ-NIWA) brought one of their own Stream Health Monitoring and Assessment Kits as a gift of hospitality to the University of Delaware Water Resources Agency. The kit was designed to be used by farm families to monitor the health of local streams. The accompanying manual includes descriptions and explanations of all procedures used in the Stream Monitoring form. The kit includes the necessary instruments for collecting data as well as the Manual, forms and scoring sheets. The NZ-NIWA kit provides a good comparison to the USEPA Protocol because of its ease of use. It was designed to be used by laymen to record and report data and so is extremely quantitative. Every parameter has a standard to which a value is assigned. At the end of the form, the values are added together and compared to a graph in order to assign a classification to the overall health of the stream (Biggs, 2001). Below, table 3.4 illustrates the different parameters the NZ-NIWA SHMAK examined.

Table 3.4. NZ-NIWA Stream Health Monitoring and Assessment Kit Parameters

Categories
A. Recent Flow Conditions
B. Recent Catchment Cond.
Inputs/Disturbances
Activites w/in 500m
C.Habitat Quality
Flow Velocity (m/s)
Water pH
Water Temperature ('C)
Water Conductivity (mS/cm)
Water Clarity (cm)
Composition of Stream Bed
Deposits
Bank Vegetation

Urban Nutrient Surveys

The impact of fertilizer runoff affects Stream Health by damaging the water quality and impairing aquatic life habitat. In order to quantify the amount of nitrogen and phosphorus entering streams through the year, urban nutrient surveys were conducted. In order to compare comprehensive data, surveys were taken in November, March and April. In this way, seasonal variations can be compared. The streams of Blue Hen Creek Creek and Fairfield Run were used because of the high amount of drainage from commercial and residential land uses. Surveys were conducted after precipitation events and after a dry period in order to establish “normal” levels. The data was entered into a Microsoft Excel worksheet by month and stream. Nitrogen and phosphorus levels were tested as well as characteristic data to establish the overall condition of the stream, such as temperature, stream flow, turbidity and pH. Nutrients such as Nitrate and Phosphorus are commonly used in household fertilizers. Nitrogen also can be found in decaying organic matter as well as human and animal waste. Most of the Phosphorus in water comes from detergents. When nutrient levels are high, excessive plant and algae growth creates water quality problems in bodies of water (Campbell, 1992). This procedure is designed to be a “first-generation” attempt to quantify nutrient loading from typical New Castle County suburban land uses. Please see the Exhibits for an example survey.

Chloride Surveys

Road salting is a common practice during the winter months in order to treat icy and snowy roadways. High Chloride concentration in streams can poison aquatic life, just as a freshwater fish cannot live in a marine environment. Data was collected from Blue Hen Creek because of the major, state-owned Route 896 in its watershed, as well as the high acreage of University-owned land. In the original research proposal, the methodology prescribed “frequent” chloride sampling before and after snowmelt, in order to establish normal and elevated levels. Because of the unusual and mild weather this winter season, the chloride surveys will not be an important factor in the evaluation of stream quality. Surveys were only able to be taken after one frozen precipitation event.

A specific conductivity meter was used during the snowfall and snowmelt portions of the survey in order to test the viability of this method in the future. A conductivity and chloride relationship has been established by the United Water of Delaware Company, who kindly lent their Specific Conductance/ Chloride Concentration Correlation Chart to the UD Water Resources Agency.

GIS Analysis

The previous researchers of the UDWRA delineated the University of Delaware Experimental Watershed using Geographic Information Systems (GIS) Arc-View software. Using aerial photographs and data from the Delaware Geological Survey and the Delaware Department of Transportation, they were able to build a working map including streams, roads, topography and railroads. Below, figure 3.2 is an orthographic photograph of the Newark area. After using field reconnaissance methods and GIS mapping techniques, the researchers were able to delineate an Experimental Watershed, and choose sampling stations based on proximity to points of interest and accessibility (Campagnini, 2001).

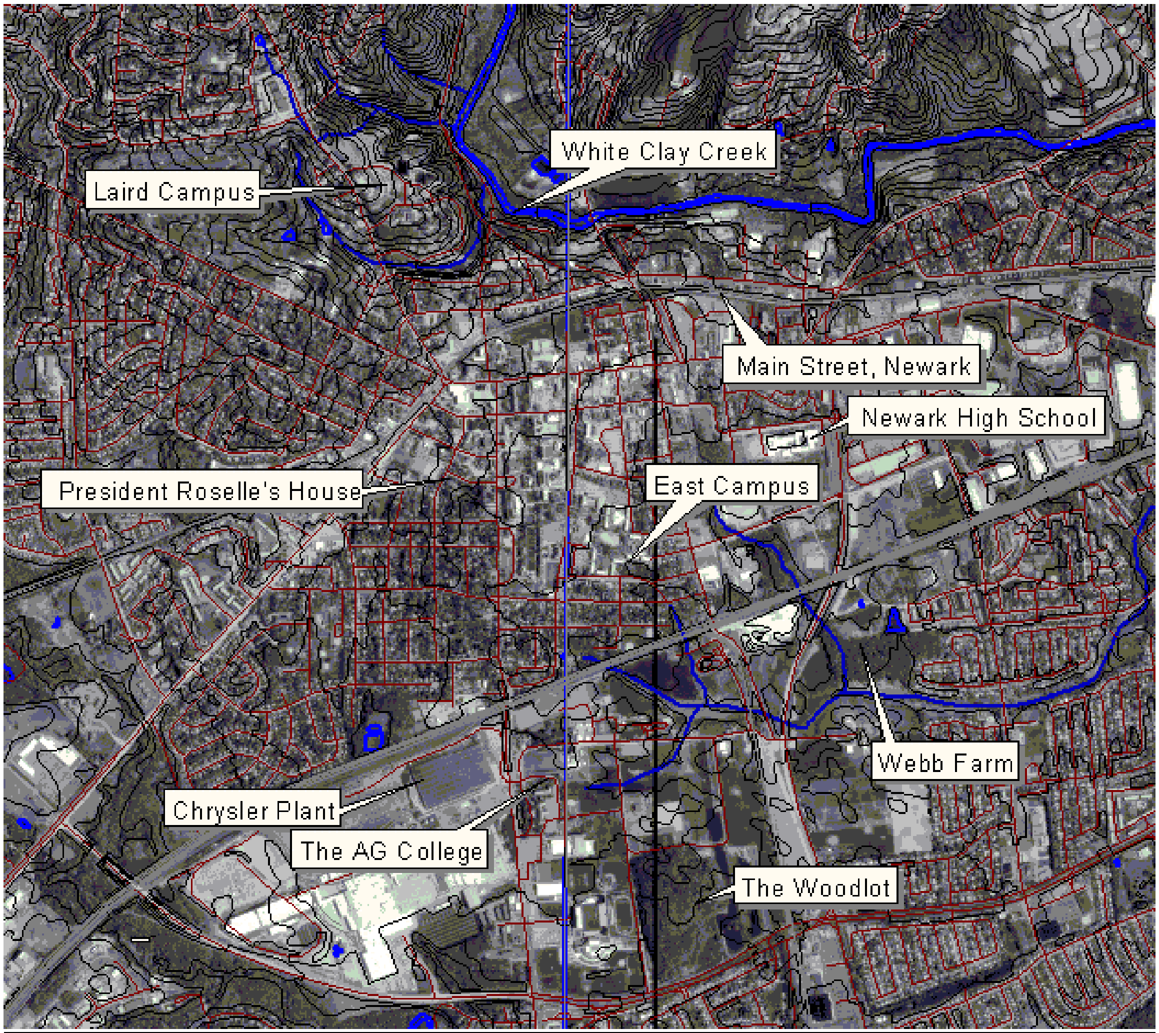


Figure 3.2. Newark Area Orthographic Photograph

Land use greatly impacts water quality. It is an essential indicator of the type and quantity of runoff that is destined for a stream. Generally, watersheds with low impact land uses such as protected open space and forests experience a higher water quality. Watersheds with a large amount of industrial and agricultural land uses usually experience lower water quality (Campagnini, 2001). A land use GIS file was obtained from the Delaware Department of Transportation and was used to establish base land uses in the Experimental Watershed. Land uses in the UD Experimental Watershed were extremely varied. Each land use was given a rating based on their impact to water quality. The higher the rating, the less impact the land use has towards water quality. Agricultural land uses include farm and pasture land. These are given a land use rating of **2** because of the affects of improper fertilizer and herbicide use on waterways. Commercial land uses are generally shopping centers or parking lots. It is because of these attributes that Commercial land uses receive a **2** rating. Single Family Residential refers to neighborhoods of detached dwellings whereas Multi-family Residential refers to apartment buildings and condominium complexes. Because Single Family Residential areas generally contain large spaces of lawn or woods, they are given a land use rating of **3**, which is higher than the Multi-Family Residential. Institutional land uses include university, religious and educational buildings. These also tend to large open spaces. Wooded areas are forested land parcels. Public and Private Open Space are those areas that are designated to be used for community or state parks or natural areas. Both of these areas have very little human impact and so are rated the highest. Table 3.5 illustrates the equations.

Table 3.5. Land Use Grade Equations

Land Use	Rating	Equation
Multi-family Residential	2	2 x (# multi-family acres/total # acres in sub-watershed)
Agricultural	2	2 x (# agricultural acres/total # acres in sub-watershed)
Commercial	2	2 x (# commercial acres/total # acres in sub-watershed)
Single Family Residential	3	3 x (# Single family acres/total # acres in sub-watershed)
Institutional	3	3 x (# institutional acres/total # acres in sub-watershed)
Wooded	4	4 x (# Wooded acres/total # acres in sub-watershed)
Public/Private Open Space	4	4 x (# open space acres/total # acres in sub-watershed)

(Campagnini, 2001)

Impervious Cover can be defined as the amount of pavement, concrete and other materials that do not allow precipitation to recharge into the groundwater. This creates runoff from the impervious surfaces into sewer systems, drainage ponds and natural streams and ponds. Each land use is assigned an impervious cover percentage factor due to the amount of impervious cover each land use generally has. The number of acres for each land use is multiplied by the percentage factor. All of these values are summed and then divided by the amount of total acres in the watershed to arrive at the percentage of imperviousness. Table 3.6 shows the factors of the land uses of the watershed.

Table 3.6. Impervious Cover Factors of Land Uses

Land Use	Impervious Factor (%)
Commercial	85
Multi-Family Residential	65
Institutional	55
Single Family Residential	30
Wooded	0
Agricultural	0
Public/Private Open Space	0

(Campagnini, 2001)

Anne Kitchell of the University of Delaware College of Marine Studies collaborated with the Water Resources Agency for her graduate research on the impacts of imperviousness on a watershed. The findings produced a scale of water quality to imperviousness cover percentage of the watershed. Watersheds with less than 10 percent impervious cover are generally extremely sensitive. The average water quality is very good. Watersheds with more than 25 percent imperviousness are not capable of supporting aquatic life (Kitchell, 2000). The scale in table 3.7 will be used to rate the watersheds in the Experimental Watershed and compare the results of the Stream health surveys.

Table 3.7. Impervious Cover Rating Scale

Rating	Watershed Imperviousness	Impact to Stream
4	**0%**	**No Impact**
3	**0-10%**	**Sensitive**
2	**10-25%**	**Impacted**
1	**> 25%**	**Non-Supporting of Aquatic life**

(Campagnini, 2001)

The Watershed Report Card

The purpose of the Watershed Report Card is to have a method of tracking watershed health through the years. By using the academic grading scale of **A** to **F** (representing **excellent** to **poor**), the watershed rating becomes more user-friendly. It is easier for the public to recognize the status of their local streams, but retains the scientific information that many scientists are interested in. The color coordination by grade adds to the ease of use by the public. This method is known as the "Stoplight Method", using the colors of green, yellow and red. Green is generally associated with "good", especially in terms of the environment. "Yellow" is generally considered an intermediate color and so will be used for those streams earning a transitional rating. For those streams that are in poor conditions, the color "red" is assigned.

The report card was generated using Microsoft Excel spreadsheets. The Chemical Parameters, Habitat Assessments, Land Use and Impervious Cover for each stream were placed in a Report Card, categorized by sampling station (each stream segment) and by parameter. The Coastal Plain Watershed was also used as the comparison of the New Zealand NIWA Stream Health Monitoring Kit. The results were placed in a separate report card because of the use of the NIWA grading scale. (Tables 3.8 and 3.9)

Table 3.8. Grading Scheme for the Watershed Report Card

Excellent			Good			Fair			Poor			
A+	A	A-	B+	B	B-	C+	C	C-	D+	D	D-	F
4	3.7	3.5	3.4	3.0	2.6	2.5	2.0	1.6	1.5	1	0.7	<0.7

Chapter 4

RESULTS AND DISCUSSION

Chemical Tests

In the analysis of water quality, 17 different chemical tests were used; alkalinity (the ability of water to neutralize acids), ammonia, chloride, chlorine, chromium, copper, dissolved oxygen (DO), BOD (biological oxygen demand), hardness, iron, nitrate, phosphate, pH, turbidity (clarity), odor, sheen and hydrocarbons. The hydrocarbon kit did not work properly, and the test was not used in the majority of the research.

Piedmont Watershed

Each sampling station in the Piedmont watershed received a grade in the **B** range. Fairfield Run had a slightly higher average score with a **B** (**3.02**), than Blue Hen Creek did with a **B-** (**2.83**). The entire watershed earned a grade of a high **B- (good)**, with an average of **2.93**. This grade is comparatively good. The basic land uses of the watershed are residential and institutional (UD). Blue Hen Creek runs through the Laird Campus of the University of Delaware and so may be more degraded. Fairfield Run is primarily forested though it does have its headwaters in the Fairfield Golf Course. This accounts for the poor grade received by the entire watershed in the nitrate and phosphate tests. Residential areas usually contain large areas of fertilized lawn or gardens. Some of the fertilizers, composed primarily of organic material, will eventually run off into the local streams and negatively affects the water quality. The watershed also received poor ratings for biological oxygen demand, which was extremely low. This could be because of the very low amount of biota living in the streams. The pH of both streams was a bit high as well. This could be due to alkaline soils in the land surrounding the streams (Campbell, 1992). Please see table 4.1 for the Water Quality Data of the Piedmont Watershed.

Table 4.1. Piedmont Watershed Water Quality Data

Stream	Blue Hen Creek						Fairfield Run							
	P1PC		P2PC		P3PC		P5FR		P6FR		P7FR		PARAMETER	
Parameter	Results	Grade	Results	Grade	Results	Grade	Results	Grade	Results	Grade	Results	Grade	Results	Grade
Alkalinity (ppm)	160	1	40	4	160	1	120	2	120	2	120	2	120	2
Ammonia (ppm)	0	4	0	4	0	4	0	4	0	4	0	4	0	4
Chloride (ppm)	60	3	40	3	40	3	60	3	60	3	60	3	53	3
Chlorine (ppm)	0	4	0	4	0	4	0	4	0	4	0	4	0	4
Chromium (ppm)	0	4	0	4	0	4	0	4	0	4	0	4	0	4
Copper (ppm)	0	4	0	4	0	4	0	4	0	4	0	4	0	4
Dissolved Oxygen (ppm)	6	4	4	3	3	2	3	2	4	3	4	3	4	3
BOD (ppm)	1	1	0	1	0	1	1	1	0	1	0	1	0	1
Hardness	320	1	120	3	240	1	80	3	120	3	120	3	167	2
Iron (ppm)	1	1	0.5	1	0	4	0	4	0	4	0	4	0.25	1
Nitrate (ppm)	15	1	5	3	20	1	3	4	5	3	10	1	10	1
Phosphate (ppm)	3	1	4	1	4	1	2	1	4	1	4	1	3.5	1
pH	8.0	2	8.0	2	8.0	2	8.0	2	8.6	1	8.25	1	8.1	1
Turbidity	clear	4	clear	4	clear	4	clear	4	clear	4	slightly	3	clear	4
Odor	No	4	No	4	No	4	No	4	No	4	No	4	No	4
Sheen	No	4	No	4	No	4	No	4	No	4	No	4	No	4
Hydrocarbon	n/a		n/a		n/a		n/a		n/a		n/a		n/a	
Overall Grade	B-	2.69	B	3.06	B-	2.75	B	3.13	B	3.06	B-	2.88		
Stream Grade	2.83						3.02							

Watershed Grade	B-	2.93

KEY
4 = Excellent
3 = Good
2 = Fair
1 = Poor

Grading Scale									
4.0 =	A+	3.4 =	B+	2.5 =	C+	1.5 =	D+	<0.7 =	F
3.9-3.7 =	A	3.3-3.0 =	B	2.4-2.0 =	C	1.4-1.0 =	D		
3.6-3.5 =	A-	2.9-2.6 =	B-	1.9-1.6 =	C-	0.9-0.7 =	D-		

Coastal Plain Watershed

The measure of conductivity, measured by the use of a specific conductivity meter, was added to the water quality tests for the Coastal Plain Watershed. This measures the overall amount of particles in the water. Tributaries 2 and 3 of the Cool Run stream received the highest grades of 2.88 and 2.76, both in the B- (good) range. Tributaries 1 and 4, as well as the main channel of Cool Run, received a grade in the C range. The lowest score was that of Tributary 4, which runs through a remediated brownfield as well as an industrial park. The sampling stations of Tributary 2 received the highest scores of 2.88. This branch runs through the University's main campus and nearby farm. Overall, the Coastal Plain Watershed earned a grade of C+ (fair) with a score of 2.6. In the individual tests, nitrate and phosphate were again a problem. This is most likely due to the fertilization of residential areas and farm areas. Biological oxygen demand was also very low. Iron and alkalinity were both very high. Soils and rocks are the most common sources of iron in the water. Industrial waste can contribute to elevated levels as well (LaMotte, 2000). Alkalinity refers to the ability of water to neutralize acids, or the buffering capacity of a stream. It helps to prevent drastic pH fluctuations. When the alkalinity of a stream is high, it could be due to acidic runoff from surrounding areas (Campbell, 1992). Please see table 4.2 for the Coastal Plain's Water Quality data.

Table 4.2. Coastal Plain Watershed Water Quality Data

Table 4.2. Coastal Plain Watershed Water Quality Data

Stream	Tributary 4		Cool Run				Tributary 1		Tributary 2		Tributary 3					
	CP1T4		CP2CR		CP3CR		CP4T1		CP5T2		CP6T3		CP7T3		PARAMETER GRADE	
Water Parameter	Results	Grade	Results	Grade	Results	Grade	Results	Grade	Results	Grade	Results	Grade	Results	Grade	Results	Grade
Alkalinity (ppm)	120	2	160	1	200	1	280	1	120	2	120	2	160	1	166	1
Ammonia (ppm)	0.5	4	0.5	4	2	3	4	2	0	4	0	4	0	4	1	3
Chloride (ppm)	60	3	80	2	60	3	0	4	100	2	100	2	100	2	71	2
Chlorine (ppm)	0	4	0	4	0	4	0	4	0	4	0	4	0.5	1	0.1	3
Chromium	0	4	0	4	0	4	0	4	0	4	0	4	0	4	0	4
Copper	n/a		0	4	0	4	1	1	0	4	0	4	0	4	0.14	2
Dissolved Oxygen (ppm)	6	4	4	3	5	4	8	4	2	1	6	4	6	4	5	4
BOD (ppm)	0	1	0	1	0	1	2	2	1	1	2	2	1	1	0.86	1
Hardness	200	1	280	1	280	1	240	1	200	1	200	1	80	3	211	1
Iron (ppm)	10	1	1	1	0	4	7	1	0	4	5	1	0	4	3	1
Nitrate (ppm)	0	4	15	1	10	1	0	4	2.5	4	15	1	5	3	7	2
Phosphate (ppm)	4	1	4	1	5	1	8	4	4	1	4	1	5	1	5	1
pH	5.5	1	6.5	3	8.0	2	7.0	4	6.5	3	6.0	2	7.0	4	6.6	3
Turbidity	slightly	2	slightly	3	turbid	2	opaque	1	clear	4	slightly	3	turbid	2	slightly	3
Odor	Yes	1	No	4	No	4	Yes	1	No	4	No	4	Yes	1	No	4
Sheen	Thick	1	No	4	No	4	Sheen	3	Little	3	No	4	No	4	No	4
Hydrocarbon	n/a		n/a		n/a				n/a		n/a		n/a		n/a	
Conductivity	n/a		980	1	730	1	1200	1	n/a		10	4	50	4	424	1
Overall Grade	C	2.27	C+	2.47	C+	2.59	C	2.47	B	2.88	B-	2.76	B-	2.76		
Stream Grade	2.28		2.53				2.56		2.88		2.76					

Watershed Grade	C+	2.60

KEY
4 = Excellent
3 = Good
2 = Fair
1 = Poor

Grading Scale				
4.0 = A+	3.4 = B+	2.5 = C+	1.5 = D+	<0.7 = F
3.9-3.7 = A	3.3-3.0 = B	2.4-2.0 = C	1.4-1.0 = D	
3.6-3.5 = A-	2.9-2.6 = B-	1.9-1.6 = C-	0.9-0.7 = D-	

Habitat Assessment

The parameters of the USEPA Rapid Bioassessment Protocol were outlined in the Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, published in 1999 by the USEPA. The survey looked for litter around and in the stream, manmade structures, point source and non-point source pollution, erosion, epifaunal substrate and cover (the amount and variety of natural structures in the stream), pool substrate characterization (type and condition of the bottom of streams), pool variability, sediment deposition, channel flow status (the amount of water in the channel), channel alteration, sinuosity (the amount of bends in the stream), bank stability, vegetative protection, and riparian vegetative zone (USEPA, 1999). For some of these characteristics, a comparison of each bank was needed, and so the scores were averaged together.

Piedmont Watershed

The overall grade of the Piedmont Watershed was a **C (fair)**, with an average score of **2.20**. Fairfield Run, again had the higher score of **2.37**, while Blue Hen Creek had a score of **2.04**. Fairfield Run had very poor bank stability, though most of the stations did have a partial riparian vegetative zone to protect the banks. Pool variability, or the amount of deep and shallow segments in the stream, was extremely poor in both streams, as was the amount of bends, or sinuosity. Streams without pool variability and low sinuosity, like Fairfield Run and Blue Hen Creek, do not have the diverse habitats to support aquatic life (USEPA, 1999). Blue Hen Creek also had very poor epifaunal substrate and cover. Epifaunal substrate is important because it provides habitat for the aquatic community. With more natural structures in a stream, the biota is able to find refuge and feeding areas, as well as spawning sites. Please see table 4.3 for the Habitat Assessment Data of the Piedmont Watershed.

Table 4.3. Piedmont Watershed Habitat Assessment Data

Stream	Blue Hen Creek						Fairfield Run							
	P1PC		P2PC		P3PC***		P5FR		P6FR		P7FR		PARAMETER GRADE	
PARAMETER	Results	Grade	Results	Grade	Results	Grade	Results	Grade	Results	Grade	Results	Grade	Results	Grade
Litter (pieces)	1-10.	3	1-10.	3	50+	1	11-50.	2	11-50.	2	11-50.	2	11-50.	2
Manmade Structures	3	2	4	1	7	1	3	2	0	4	1	3	3	2
Point Source Pollution	4	1	0	4	1	3	1	3	0	4	1	3	1	3
NPS Pollution	1	3	3	2	1	3	2	2	0	4	2	2	1.5	3
Erosion														
Epifaunal Substrate/Cover	Marginal	2	Marginal	2	P I S	1 I 3	Poor	1	Marginal	2	Marginal	2	Marginal	2
Pool Sub. Characterization	Marginal	2	Marginal	2	P I M	1 I 2	Marginal	2	Marginal	2	Marginal	2	Marginal	2
Pool Variablity	Poor	1	Marginal	2	Poor	1	Poor	1	Marginal	2	Poor	1	Poor	1
Sedimont Deposition	Marginal	2	Marginal	2	Poor	1	Poor	1	Marginal	2	Marginal	2	Marginal	2
Channel Flow Status	Marginal	2	Optimal	4	Poor	1	Marginal	2	Marginal	2	Marginal	2	Marginal	2
Channel Alteration	Marginal	2	Marginal	2	P I M	1 I 3	Marginal	2	Optimal	4	Optimal	4	Marginal	2
Sinuosity	Marginal	2	Poor	1	P I M	1 I 3	Suboptimal	3	Suboptimal	3	Marginal	2	Marginal	2
Bank Stability	Poor	1	Suboptimal	3	P I M	1 I 3	Poor	1	Marginal	2	M I P	2 I 1	Marginal	2
Vegetative Protection	Marginal	2	Suboptimal	3	M I S	1 I 3	Optimal	4	S I M	3 I 2	Marginal	2	Suboptimal	3
Riparian Vegetative Zone	Marginal	2	Marginal	2	P/M I S/M	1/2 I 3/2	Marginal	2	Optimal	4	S I O	3 I 4	Marginal	2
Site Grade	C-	1.93	C	2.36	C-	1.83	C	2.00	B-	2.80	C	2.31		
Stream Grade	2.04						2.37							

Watershed Grade	C	2.20

*** = Because the stream was so different on either side of the bridge, I analyzed each side separately (L I R) as well as each bank separately (L/R). Coloration= Average

KEY
4 = Excellent
3 = Good
2 = Fair
1 = Poor

Grading Scale				
4.0 = A+	3.4 = B+	2.5 = C+	1.5 = D+	<0.7 = F
3.9-3.7 = A	3.3-3.0 = B	2.4-2.0 = C	1.4-1.0 = D	
3.6-3.5 = A-	2.9-2.6 = B-	1.9-1.6 = C-	0.9-0.7 = D-	

Coastal Plain Watershed

The overall habitat assessment grade of the Coastal Plain Watershed was a **C (fair)**. Tributary 1 received the highest habitat score with a **2.64**. Tributary 3 received the lowest score, which was a **1.73**. In this watershed, the pool variability and epifaunal substrate were again parameters with poor ratings. These deficiencies are symptomatic of larger problems. Because many of these streams run through neighborhoods, many of them were channelized. Channelization is the process of enclosing a stream in a man-made ditch. Often the ditch is sided with concrete slabs. This action prevents flooding and stream wandering in times of rainfall, but it also inhibits habitat sustainability. The extremely low grades of Tributaries 2 and 3 reflect the channelization effect. Riparian vegetative buffers were not as protective as needed in this watershed. Since this area is located primarily on the University Farm, much of the streams are enclosed in fenced strips. The fences protect the streams from livestock intrusion, but the recent fences have not prevented the brush from being mowed. Over time, the vegetative buffers will be allowed to grow to a sustainable and protective area. Please see table 4.4 for the Habitat Data for the Coastal Plain Watershed.

Table 4.4. Coastal Plain Watershed Habitat Assessment Data (EPA)

Stream	Tributary 4		Cool Run				Tributary 1		Tributary 2		Tributary 3					
	CP1T4		CP2CR		CP3CR		CP4T1		CP5T2		CP6T3		CP7T3		PARAMETER	
PARAMETER	**Results**	**Grade**	**Results**	**Grade**	**Results**	**Grade**	**Results**	**Grade**	**Results**	**Grade**	**Results**	**Grade**	**Results**	**Grade**	**Results**	**Grade**
Litter (pieces)	1-10.	3	0	4	1-10.	3	0	4	11-50.	2	1-10.	3	1-10.	3	1-10.	3
Manmade Structures	2	2	0	4	2	2	1	3	3	2	2	2	1	3	2	2
Point Source Pollution	2	2	0	4	0	4	0	4	1	3	0	4	2	2	0.7	3
NPS Pollution	0	4	3	2	3	2	3	2	1	3	2	2	2	2	2	2
Erosion																
Epifaunal Subst./Cover	Poor	1	Sub.	3	Poor	1	Poor	1	Poor	1	Poor	1	Marginal	2	Poor	1
Pool Sub. Character.	Marginal	2	Sub.	3	Marginal	2	Marginal	2	Marginal	2	Marginal	2	Sub.	3	Marginal	2
Pool Variablity	Poor	1	Poor	1	Sub.	3	Marginal	2	Poor	1	Poor	1	Poor	1	Poor	1
Sedimont Deposition	Poor	1	Sub.	3	Poor	1	Marginal	2	Marginal	2	Poor	1	Marginal	2	Marginal	2
Channel Flow Status	Poor	1	Sub.	3	Sub.	3	Poor	1	Marginal	2	Poor	1	Sub.	3	Marginal	2
Channel Alteration	Marginal	2	Optimal	4	Marginal	2	Optimal	4	Marginal	2	Poor	1	Sub.	3	Marginal	2
Sinuosity	Poor	1	Marginal	2	Marginal	2	Sub.	3	Marginal	2	Poor	1	Marginal	2	Marginal	2
Bank Stability	M I P	2 I 1	S I P	3 I 1	Poor	1	Optimal	4	Marginal	2	n/a*		Sub.	3	Marginal	2
Vegetative Protection	Marginal	2	O I P	4 I 1	Marginal	2	Sub.	3	Poor	1	n/a*		Marginal	2	Marginal	2
Riparian Veg. Zone	Marginal	2	S I P	3 I 1	Poor	1	Marginal	2	Poor	1	n/a*		Marginal	2	Marginal	2
Site Grade	C-	1.80	B-	2.71	C	2.07	B-	2.64	C-	1.86	C-	1.73	C	2.36		
Stream Grade	1.80		2.39				2.64		1.86		2.04					
Watershed Grade	C	2.71														

*= Because this stream was channelized, the banks consisted of sharply sloping slabs of Concrete.

Therefore, I could not describe these parameters.

KEY
4 = Excellent
3 = Good
2 = Fair
1 = Poor

Grading Scale				
4.0 = A+	3.4 = B+	2.5 = C+	1.5 = D+	<0.7 = F
3.9-3.7 = A	3.3-3.0 = B	2.4-2.0 = C	1.4-1.0 = D	
3.6-3.5 = A-	2.9-2.6 = B-	1.9-1.6 = C-	0.9-0.7 = D-	

A Comparison

When comparing the two Watersheds, they share many of the same problems. Table 4.5 illustrates the grades by parameter. For instance, the streams in both watersheds only received a marginal grade in sediment deposition, channel flow status, sinuosity, bank stability and riparian vegetative zone. This indicates the streams are extremely susceptible to erosion. Without adequate vegetative zones, the banks cannot remain stable during a period of heavy flow. This causes the stream to have large deposits of sediment and stretches of heavily eroded bank. Pool variability in both watersheds was given a **poor** rating. This is probably also due to the extreme erosion and consequent sediment deposition. This sediment will fill in the natural deeper and shallower areas (known as pools and riffles), and the stream is less adequate to sustain aquatic life (USEPA, 1999). Both streams did score well on the point source pollution parameter, though there were a number of non-point source pollution influences in both watersheds.

Table 4.5. Comparison of the Watershed's Habitat Assessment Data by Parameter

	Piedmont		Coastal plain	
	PARAMETER GRADE		PARAMETER GRADE	
PARAMETER	**Results**	**Grade**	**Results**	**Grade**
Litter	11-50 pieces	2	1-10pieces	3
Manmade Structures	3	2	2	2
Point Source Pollution	1	3	0.7	3
NPS Pollution	1.5	3	2	2
Erosion				
Epifaunal Substrate/Cover	Marginal	2	Poor	1
Pool Sub. Characterization	Marginal	2	Marginal	2
Pool Variablity	Poor	1	Poor	1
Sedimont Deposition	Marginal	2	Marginal	2
Channel Flow Status	Marginal	2	Marginal	2
Channel Alteration	Marginal	2	Marginal	2
Sinuosity	Marginal	2	Marginal	2
Bank Stability	Marginal	2	Marginal	2
Vegetative Protection	Suboptimal	3	Marginal	2
Riparian Vegetative Zone	Marginal	2	Marginal	2

NZ-NIWA SHMAK

The New Zealand National Institute for Water and Atmospheric Research (NZ-NIWA) uses a Stream Health Monitoring and Assessment Kit (SHMAK) to monitor the health of its streams. The kit was originally designed for use by farm families in order to determine whether land use practices were affecting waterways. The kit is extremely explanatory, concise and quantitative. All the needed equipment can be found within a foot-high plastic container, including a 10 meter long rope that is used to delineate the sample area. Each question has a scoring scale which assigns a score to each measurement value. For instance, if the pH was measured at 7, the monitor would find that the score for all measurements between 6.5 and 7.5 is a **10**. This is the highest score possible because 7 is the optimal pH for a stream. At the end of the habitat survey (a stream bed life survey was also included in the kit), all the scores are added together for a Total Score. The higher the score, the healthier a stream is. In order to determine the precise classification of a stream, the kit provides a graph with the habitat score and invertebrate score on the X, Y axes. There are multiple graphs depending on the composition of the streambed. By matching up the scores, the monitor can arrive at the classification of "Very Poor, Poor, Moderate, Good, Very Good" for their stream. The overall NZ-NIWA Stream Monitoring Data can be found in table 4-6. This method was used in the Coastal Plain Watershed in order to compare the ease of use and repeatability, time to completion and overall stream habitat evaluation to the USEPA method.

Table 4.6. Coastal Plain Watershed Stream Monitoring Data (New Zealand-NIWA)

Stream	Tributary 4		Cool Run				Tributary 1		Tributary 2		Tributary 3			
	CP1T4		CP2CR		CP3CR		CP4T1		CP5T2		CP6T3		CP7T3	
Categories	**Results**	**Grade**	**Results**	**Grade**	**Results**	**Grade**	**Results**	**Grade**	**Results**	**Grade**	**Results**	**Grade**	**Results**	**Grade**
A. Recent Flow Conditions	Low Flow	**1**	Stable Flow	**5**	Stable Flow	**5**	Low Flow	**1**	Low Flow	**1**	Stable Flow	**5**	Stable Flow	**5**
B. Recent Catchment Cond.														
Inputs/Disturbances	1		4		6		5		2		3		3	
Activites w/in 500m	2		0		1		2		2		0		2	
C.Habitat Quality														
Flow Velocity (m/s)	<0.1	**1**	0.3	**10**	<0.1	**1**	<0.1	**1**	0.1	**8**	0.21	**8**	0.3	**10**
Water pH	5.5	**5**	6.5	**10**	8.0	**5**	7.0	**10**	6.5	**10**	6	**5**	7	**10**
Water Temperature ('C)	16	**8**	11	**10**	12.5	**10**	11	**10**	17.8	**8**	21	**5**	28	**1**
Water Conductivity (mS/cm)	n/a		980	**1**	730	**1**	1200	**1**	n/a		10	**10**	50	**16**
Water Clarity (cm)	65	**5**	62.5	**5**	35.5	**3**	18	**1**	90	**10**	58.5	**5**	36.7	**3**
Composition of Stream Bed	-900	**-9**	-120	**-1.2**	-600	**-6**	-2000	**-20**	-120	**-12**	-1050	**10.5**	100	**1**
Deposits	Thick	**-10**	Fine	**5**	Moderate T	**-5**	Thick	**-10**	Moderate	**0**	Moderate T	**-5**	Thick	**-10**
Bank Vegetation	670	**6.7**	70	**0.7**	-1600	**-16**	280	**2.8**	710	**7.1**	0	**0**	480	**4.8**
Total Score	**Poor**	7.7	**Good**	45.5	**Poor**	-2	**Poor**	-3.2	**Mod.**	**32.1**	**Good**	43.5	**Good**	40.8
Stream Grade	7.7		21.8				-3.2		32.1		42.15			
Watershed Grade	**Mod.**	**23.5**												

Grading Scale			
100-60 = Very Good	60-40= Good	40-20= Moderate	20- -50= Poor

In the NZ-NIWA method, all of the measurements are highly quantitative. Each parameter asks the monitor to take a measurement in order to complete the scoring. The two exceptions to this generalization are the Streambed Composition and Bank Vegetation parameters. For both of these, the monitor is required to estimate a percentage of cover; either the streambed cover of rock, sand, silt or vegetation or the bank cover of native trees, grasses, scrubs and bare ground. It is comparatively easy for a monitor to estimate these percentages as s(he) is on the ground, investigating the stream. The score for these parameters was calculated by adding the total percentage of each stream bank and multiplying it by the value of each vegetation type and dividing by one hundred. In this way, the maximum possible score was twenty if both banks had 100% native trees and wetland vegetation ({100% + 100%} x 10]/ 100= 20). It is easy to see where the stream has its parameters of poor quality and what are the healthiest parameters.

In contrast, the USEPA method was extremely subjective. The monitor is asked to estimate percentages and evaluate status based on personal viewpoint. There are four classifications of Optimal, Suboptimal, Marginal and Poor. Each has a range of 5 grades (max. 20- min. 0) and a description to follow. The monitor bases his/her assessment on the comparison between the description and his/her perception of the stream characteristics. The description may be based on percentages or generalizations, and occasionally an actual measurement or comparison. The score of the habitat assessment is for the benefit of the monitor and is not used for an overall measurement of the total stream health. Once all the parameters have been considered, the monitor must refer to all the scores and count the score of each condition category to get a feeling for the overall health of the stream. The more Optimally scored conditions, the better the stream health must be, and of course, the reverse. The USEPA method is very user-friendly when comparing parameters. Obviously, a stream that is rated Optimal for channel flow status is in better shape than one rated Marginal.

When comparing the USEPA RBP and the NZ-NIWA SHMAK total scores of each sampling site, it was found that both scores were very similar in most cases. The sites CP2CR and CP5T2 received the same score with both methods. CP2CR, located on Cool Run, was scored a **3**, or Suboptimal rating, by both the USEPA and NZ-NIWA. The site on Tributary 2 of the Coastal Plain, CP5T2, received a grade of **2** by each of the assessment methods. The overall, averaged Watershed score for both methods was a Moderate Score of **2**. This indicates that although individual streams may have been scored differently, overall, the habitats of the Coastal Plain Watershed are only intermediate in their ability to sustain aquatic life. It is interesting to note that the lowest score of the USEPA method was a **2**, while the NIWA method did score some sites at a **1**, indicating extremely poor habitat. Table 4.7 illustrates the different scores between the USEPA and NZ-NIWA.

Table 4.7. A Comparison of the Total Score of the Coastal Plain Sampling Sites between the USEPA and NZ-NIWA Method

Site	US-EPA	NZ-NIWA
CP1T4	2	1
CP2CR	3	3
CP3CR	2	1
CP4T1	3	1
CP5T2	2	2
CP6T3	2	3
CP7T3	2	3
WATERSHED	2	2

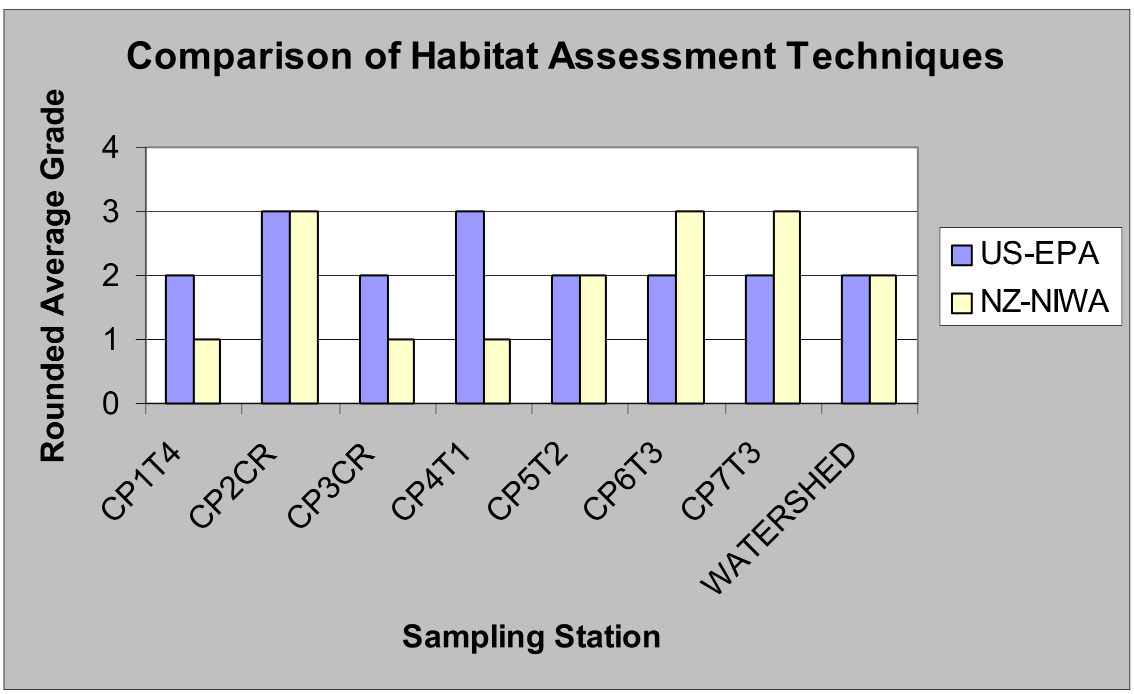


Figure 4.1. A Comparison of the Total Score of the Coastal Plain Sampling Sites Between the USEPA and NZ-NIWA Method

Table 4.8. Comparison of Scoring Techniques for Selected USEPA and NZNIWA Attributes of Streams in the Coastal Plain Watershed

Bank Veg Comparison	4	3	2	1
Vegetative Protection (US)	Optimal	SubOptimal	Marginal	Poor
Bank Vegetation (NZ)	20-10	10-5	5-0	<0

Clarity Comparison	4	3	2	1
Turbidity (US)	clear	slightly	turbid	opaque
Clarity (NZ)	70-100	55-69	35-54	<35

In order to illustrate the difference between the two habitat assessment methods, two similar parameters from each method were compared with each method. Please see table 4.8 for the comparison of scoring each parameter. The parameters chosen had different names in each method, but were basically measuring the same characteristic. The first example is the Riparian Vegetative Zone Width, which is used to measure the width of natural vegetation from the edge of the stream bank out through the riparian zone by the USEPA. The monitor is asked to estimate the riparian vegetative zone width and how much human activities have impacted the zone on each bank of the stream. The monitor has four basic choices to assign, an Optimal, Suboptimal, Marginal and Poor description. The Poor category has the fewest points, while the Optimal has the highest.

The Stream Health Monitoring and Assessment Kit used by NZ-NIWA, has a section devoted to Bank Vegetation. The score is found by estimating the percentage of each category of vegetation types in a strip five meters wide on either side of the water's edge. The choices of vegetation types range from trees, wetland vegetation, scrub, rock, and grassland to human induced vegetation, such as pastures and roads. Each category has a score that the vegetation percentage of each side is multiplied by. The native trees and wetland vegetation have the highest score, with 10 being the multiplication factor. Conversely, human influences were given the lowest value with –10 being the multiplication factor. After the total percentage multiplied by the score for each vegetation category is totaled, this large number is divided by 100 to leave the final overall score for bank vegetation. Comparing these two assessment techniques was not easy. The report card system previously established helped to categorize the four conditions of the USEPA method into a scorecard from **1** to **4**, from Poor to Optimal. The NZ-NIWA method was divided up based on the maximum possible score and the minimum possible score. In order to account for the destructive characteristics of man-made land forms and the benefits of native vegetation, the grading is not equally divided between the scorecard. A **1** grade is designated to those values under 0, while a score between 10 and 20 is a **4**.

The comparison between the two water clarity measurements was extremely illustrative of the overall difference between the USEPA and NZ-NIWA method. The USEPA method was called Turbidity and asked the monitor to estimate how clear the water was with the option of four choices: clear, slightly turbid, turbid, and opaque. The assumption is made that cleaner, healthier streams will have clearer water, so the scoring system works from **4** for clear to **1** for opaque. This is a highly subjective method and relies heavily on the amount of light available, the clearness of vision as well as the particular placement of the test.

The NZ-NIWA method uses a plastic tube to measure the actual distance a monitor can see through the water. The process begins with the filling of a Clarity Tube made of clear plastic with each centimeter marked off on one side. Only stream water is used to fill the tube to the top of one end. A magnet with a black disc is placed inside the tube with its partner facing it from the outside. The tube is sealed with the bung and the magnets are moved to the clear window end of the tube. While holding the tube horizontally close to the monitor's eye, move the magnet back along the tube until the black disk just disappears in the water. Record this distance as the first measurement and repeat several times. The average of these readings is the Water Clarity. The score works on a scale of **1-10**. If the water was clear to the bottom of the tube (100cm), the score awarded was a **10**. If the monitor could not see over 35cm, the score was a **1**. This method is extremely quantitative and measurable. It is totally objective and does not allow for any outside influences to interfere with the actual, mathematical measurement.

Below, in table 4.9, the final grades are given for each method and each category. It is interesting to note in the Bank Vegetation Scoring that only two of the scores from the USEPA or the NZ-NIWA method were the same. The largest difference came on Tributary 2, with site CP5T2. The NZ-NIWA method gave the site a **3**, whereas the USEPA method scored the site with a **1**. This site was given a **2** for overall Habitat Assessment by both methods. This discrepancy between methods may be explained by the emphasis the USEPA placed on percentage of vegetative cover, whereas the NZ-NIWA placed more emphasis on the type of cover. The New Zealand method also scored the largest number of high scores and low scores, with two of each. The Water

Clarity measurements were extremely close in their measurements. In fact, only Tributary 4 had two different scorings. This is particularly unexpected because it would be assumed that the subjective evaluation would not give the same answers as an exact, precise measurement. These scores were the same in every category- whether poor or good. From this, it can be said that the human eye can be used as a discretionary tool. Figures 4.2 and 4.3 also illustrate the scores in a graph form.

Table 4.9. Comparison of Data Results for the Coastal Plain Streams Using USEPA and NZNIWA Methods of Grading

	Bank Vegetation			Water Clarity	
Site	US-EPA	NZ-NIWA	Site	US-EPA	NZ-NIWA
CP1T4	2	3	CP1T4	2	3
CP2CR	2	2	CP2CR	3	3
CP3CR	2	1	CP3CR	2	2
CP4T1	3	2	CP4T1	1	1
CP5T2	1	3	CP5T2	4	4
CP6T3	0	1	CP6T3	3	3
CP7T3	2	2	CP7T3	2	2

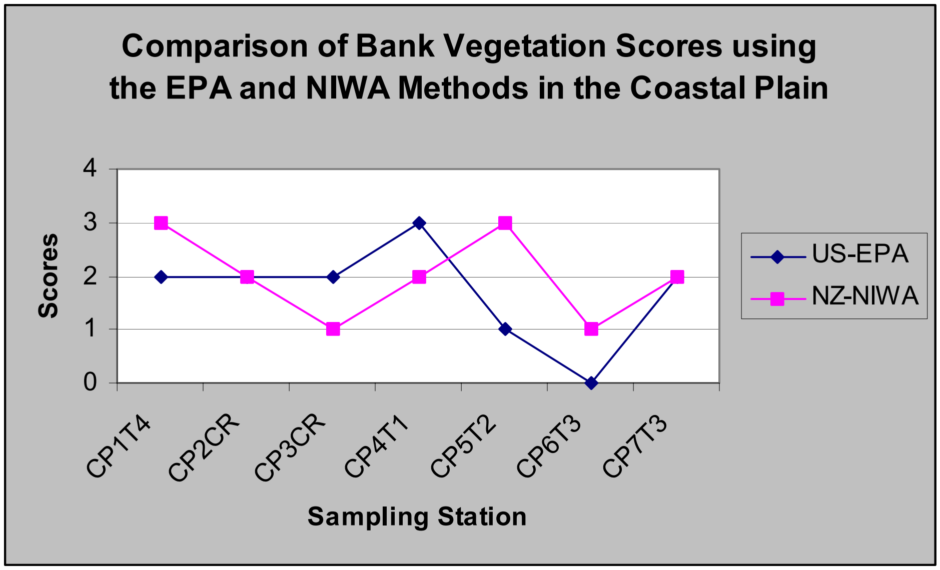


Figure 4.2. Comparison of Bank Vegetation Scores using the USEPA and NZ-NIWA Methods in the Coastal Plain Watershed.

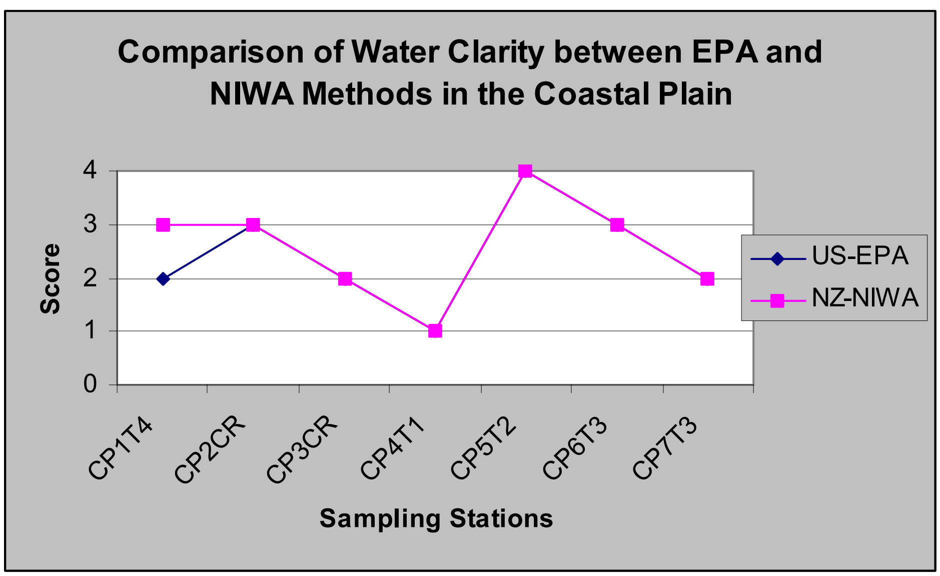


Figure 4.3. Comparison of Water Clarity between the USEPA and NZ-NIWA Methods in the Coastal Plain Watershed.

Urban Nutrient Surveys

When designing the research for this project, it was determined that Urban Nutrient Surveys would be conducted throughout the year. In this way, it would be possible to compare the seasonality of the water chemistry of the streams in the Piedmont Watershed. The surveys would be conducted after a rain event and after a period of no precipitation in order to also compare the effect of recent runoff. Unfortunately, due to the timing of a drought and the loan of the kits to a high school biology program, the only results available to be published in this report are the wet and dry samples from November, dry samples from March and wet samples from April. The dry samples were taken November 16, 2001 and March 29, 2002. The wet samples were taken November 30, 2001 and April 10, 2002 (Table 4.10).

At each site, the temperature, conductivity, water odor, turbidity, pH, Nitrates and Phosphates were measured. The results were placed in a chart using Microsoft Excel. When comparing the temperature of the dry samples to those of the wet in each season's samples, it is easy to see that the temperature increases. This could be explained by rainfall and the influx of water in the streams. The water odor and turbidity of the streams did not change on most of the sites on the Blue Hen Creek. The pH increased with a precipitation event at all of the sites except for the White Clay Creek in the autumn sampling set, and on most of the sites in the spring sampling set. This is interesting to note because if the Newark area had a problem with acid precipitation, the pH of the streams would be expected to drop after a precipitation event. Since the pH rose, it's safe to assume Newark does not have a problem with acid rain.

Since the first surveys were taken in November, many people were fertilizing their lawns and gardens. It is because of this that the differences in dry and wet results are not extremely dramatic, with the exception of the White Clay Creek site and P2PC. The dry results show a higher level of nitrate than the wet results at most of the sites. This is because of the impact of dilution, or the increase of water in the streams. A larger amount of water dilutes the amount of nitrates. The units for nitrate measurements are in parts per million, which stands for parts of nitrate per million parts of water. With an increase of water, the relative amount of nitrates would decrease, especially in the smaller streams. On the White Clay Creek, though, the wet level of nitrates was the highest in the fall. The White Clay Creek, which gathers dozens of smaller streams in its watershed, the combined amount of nitrates causes an elevated level. When reviewing the spring levels of nitrates, the wet and dry surveys do not have a noticeable decline or increase. This could be due to the continuing drought and voluntary water restrictions on Delaware households or the cold, unseasonable spring weather. When considering water quality, any nitrate reading under 5ppm would be considered healthy. The several readings of 15ppm in Blue Hen Creek would be considered a symptom of extremely poor water quality. Please see figure 4.4 for an illustration of the results.

The phosphate results showed an increase in wet levels, especially at the downstream and upstream ends of the Blue Hen Creek. The site P3PC had the largest increase in levels, from 2 ppm to 6ppm. The two stations in the middle did not change the amount of phosphate at all from dry to wet in the fall surveys. In the spring surveys, the dry levels were less than both of the fall surveys for the middle two sampling stations, but were above the dry surveys at the extreme ends of the Blue Hen Creek. The wet samples were the lowest and most stable levels of the surveys. This could be a result of voluntary water restrictions which discourage homeowners from watering and fertilizing their lawn. All of the phosphate readings would be indicative of poor water quality. The recommended level of phosphate is 0.03ppm. Please see figure 4.5 on page 57.

Table 4.10. Blue Hen Creek Urban Nutrient Survey Data

November	P1PC	P1PC	P2PC	P2PC	P3PC	P3PC	WCC-PC	WCC-PC
Parameters	**11/16/01**	**11/30/01**	**11/16/01**	**11/30/01**	**11/16/01**	**11/30/01**	**11/16/01**	**11/30/01**
Temperature ('C)	11	14.5	11	14	10	15	8	13
Conductivity (mS/cm)	500	n/a	340	n/a	350	n/a	300	n/a
Water Odor	None	Musky	None	None	None	None	None	None
Turbidity	Clear	Clear	Clear	Clear	Clear	Cear	Clear	Clear
pH	5.5	6.0	5.5	6.0	5.0	6.0	6.5	6.0
Nitrate (ppm)	5	4	15	5	5	2	3	15
Phosphate (ppm)	4	4	6	6	2	6	0.5	4

March	P1PC	P2PC	P3PC	WCC-PC
Parameters	**3/29/02**	**3/29/02**	**3/29/02**	**3/29/02**
Temperature ('C)	13	12	14	9
Conductivity (mS/cm)	390	330	320	210
Water Odor	None	None	None	None
Turbidity	Clear	Clear	Clear	Clear
pH	6.0	6.5	6.0	6.0
Nitrate (ppm)	0	0	2	5
Phosphate (ppm)	4	4	5	3

RED=a dry sample (no rain within 76 hours)
BLUE=a wet sample (rain within 24 hours)

April	P1PC	P2PC	P3PC	WCC-PC
Parameters	**4/10/02**	**4/10/02**	**4/10/02**	**4/10/02**
Temperature ('C)	17	16	15	16
Conductivity (mS/cm)	380	340	380	260
Water Odor	None	None	None	None
Turbidity	Clear	Clear	Clear	Clear
pH	6.5	6.5	6.5	6.0
Nitrate (ppm)	0	0	0	5
Phosphate (ppm)	2	2	1.5	2

The Fairfield Run Urban Nutrient Survey also contained 4 sampling stations. Only the wet surveys were taken here in November, but the full complement of wet and dry surveys were taken in the spring. Please see Table 4.11 for the data from Fairfield

Run. There was no difference between the stations in terms of temperature, water odor, turbidity or pH, but the nitrate and phosphorus results were interesting. The highest nitrate survey in the fall came from P5FR, which is located right before the stream meets the White Clay Creek. The accumulation of all the inputs into the stream at this end point could account for the unusually high results. The phosphate fall surveys show the same results, with the P5FR site having the highest levels. The White Clay Creek also had a high reading. This is probably due to the accumulation of runoff going into the White Clay Creek from not only the UD Experimental Watershed, but the surrounding land areas as well.

The temperature of Fairfield Run and the specific conductivity both rose with the influx of precipitation in the spring. The rain did not change the clarity of the water or the odor. The nitrate levels dropped from 10 to 0 at the center sampling site, P6FR. At the White Clay Creek, the nitrate levels diminished from 5 to 2.5 after a rain event. The highest level of nitrates after rain was found at P7FR, which is the destination for runoff from Fairfield Run Golf Course as well as a residential area. This may be because spring is the typical season for fertilization, and an increase in poorly applied fertilizer would result in an increase of nitrate runoff. The phosphate levels were relatively stable and consistent from the dry to wet period. There was a decrease from dry to wet samples, but it was not drastic. The nitrate and phosphate schedules are included in figures 4.6 and 4.7.

Table 4.11. Fairfield Run Urban Nutrient Survey Data.

November	P5FR	P6FR	P7FR	WCC-FR
Parameters	**11/30/01**	**11/30/01**	**11/30/01**	**11/30/01**
Temperature ('C)	13	13	13	13
Conductivity	n/a	n/a	n/a	n/a
Water Odor	Musky	None	None	None
Turbidity	Clear	Clear	Clear	Clear
pH	6.0	6.0	6.0	6.5
Nitrate (ppm)	8	0.5	0.5	4
Phosphate (ppm)	6	4	4	6

March	P5FR	P6FR	P7FR	WCC-FR
Parameters	**3/29/02**	**3/29/02**	**3/29/02**	**3/29/02**
Temperature ('C)	9	15	12	12
Conductivity	300	300	330	230
Water Odor	None	None	None	None
Turbidity	Clear	Clear	Clear	Clear
pH	5.5	5.5	5.5	6.5
Nitrate (ppm)	20	10	n/a	5
Phosphate (ppm)	4	4	4	4

April	P5FR	P6FR	P7FR	WCC-FR
Parameters	**4/10/02**	**4/10/02**	**4/10/02**	**4/10/02**
Temperature ('C)	14	14	14	16
Conductivity (mS/cm)	310	340	330	250
Water Odor	None	None	None	None
Turbidity	Clear	Clear	Clear	Clear
pH	6.5	6.0	6.0	6.0
Nitrate (ppm)	5	0	10	2.5
Phosphate (ppm)	4	2	2	2

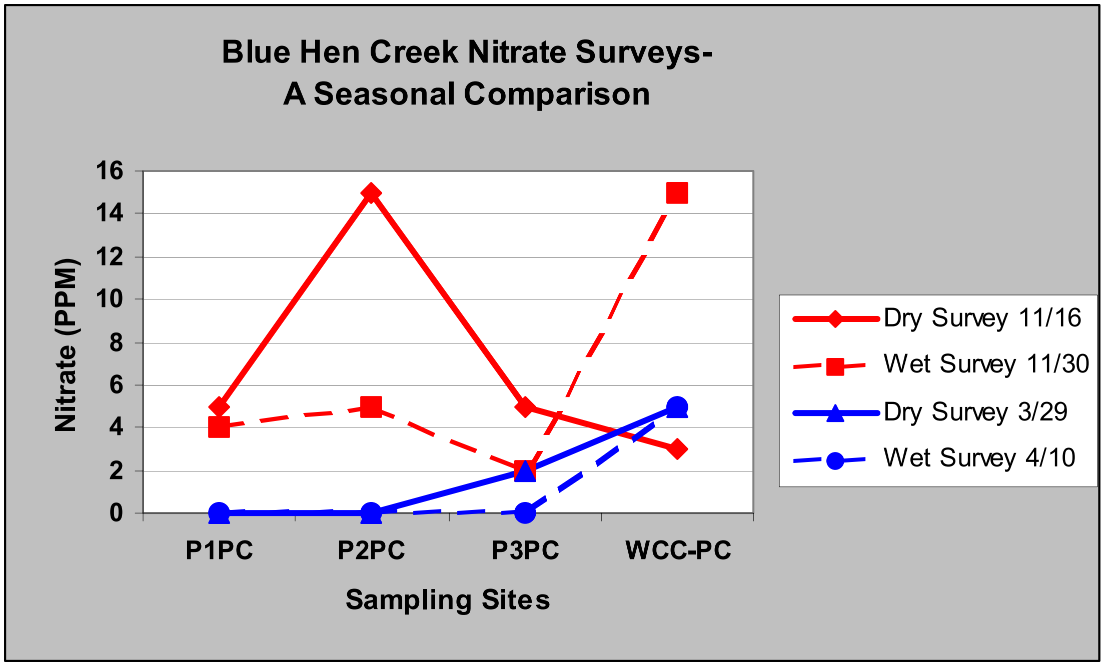


Figure 4.4. Blue Hen Creek Nitrate Surveys- A Seasonal Comparison

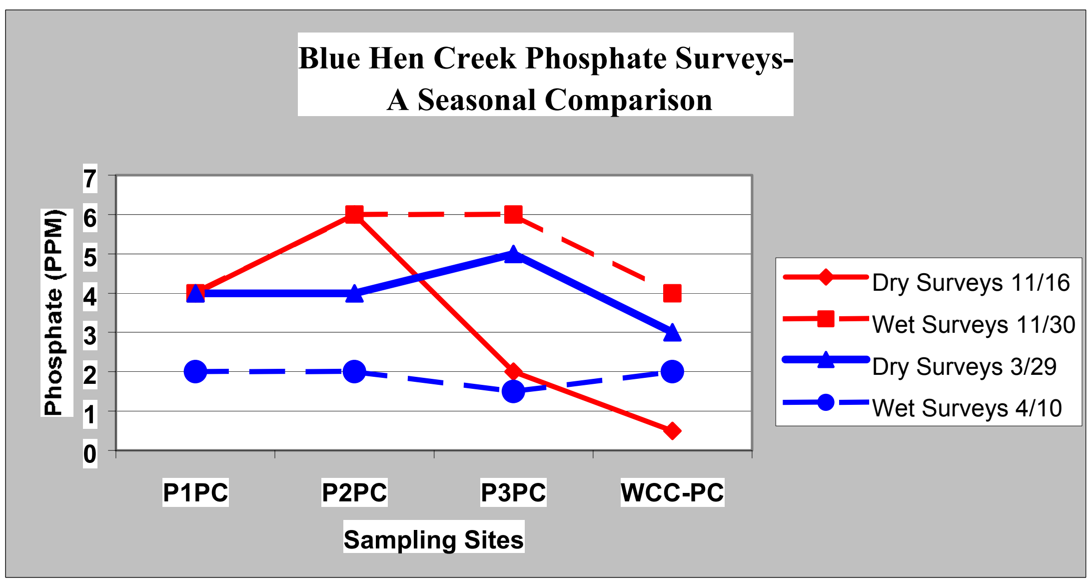


Figure 4.5. Blue Hen Creek Phosphate Surveys- A Seasonal Comparison

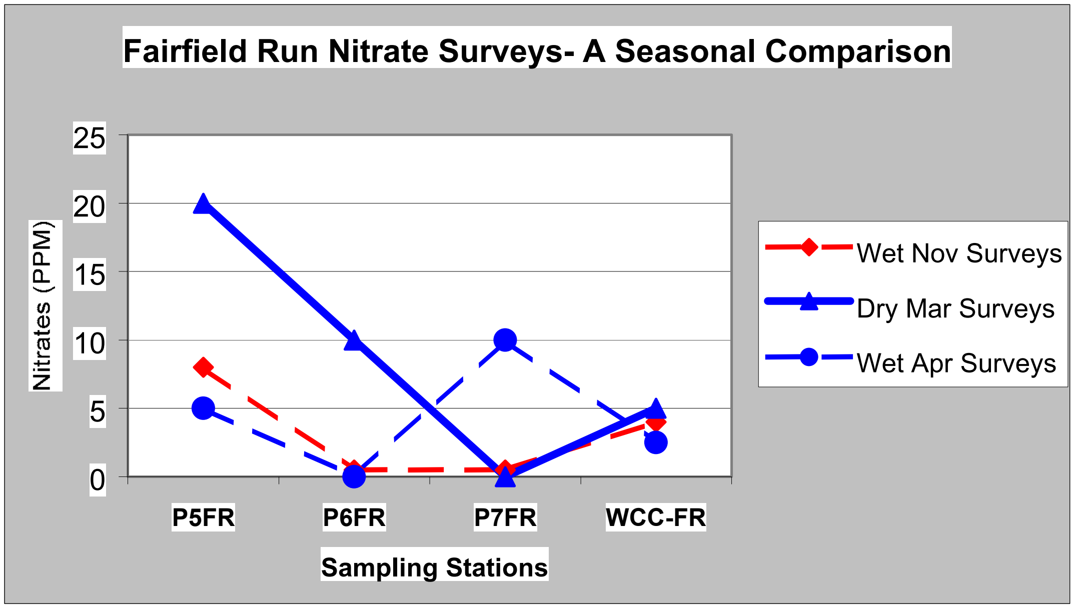


Figure 4.6.Fairfield Run Nitrate Surveys- A Seasonal Comparison.

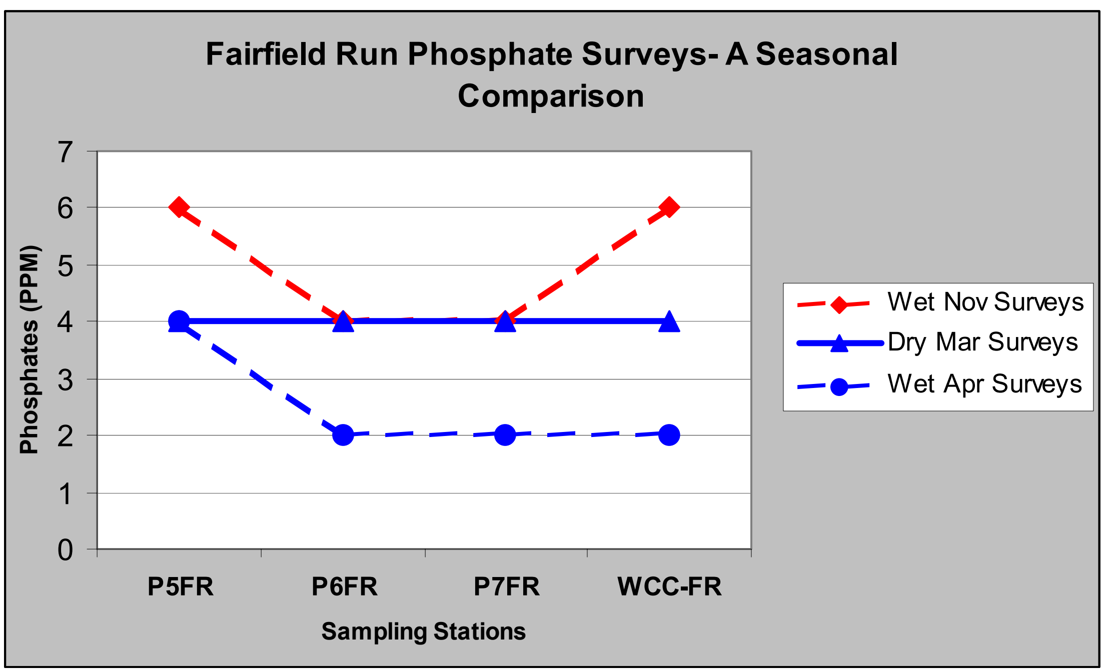


Figure 4.7. Fairfield Run Phosphate Surveys- A Seasonal Comparison.

Chloride Surveys

The purpose of the Chloride Surveys was to set a precedent for the study of the effects of road salt on streams in the UD Experimental Watershed. Surveys were to be taken after three separate snow events and before the snow season began, establishing a base line. Unfortunately, the winter of 2001-2002 was unusually warm and it only snowed enough to need road salt once in Newark, Delaware. Though the results are not repetitive, they do produce results that are within the expected range. The Baseline measurements of the Blue Hen Creek, taken on December 11, 2001, were all in the excellent range in terms of water quality. The day after snowfall, January 22, 2002, the measurements were extreme. Four out of the five sampling stations had measurements that were above the range of the Specific Conductivity meter. These are denoted by a maximum reading of 450 ppm. The only site that did not have a maximum score was the White Clay Creek, where the Chloride could be diluted. Two days after snowfall, on January 24, 2002, when the snow began to melt, another measurement was taken. These readings were significantly less than the Snowfall measurements, but high nonetheless. The readings from each of the Blue Hen Creek stations were approximately the same throughout the snowfall and melt. P7FR, the only site on the Fairfield Run, had an extraordinary reading two days after snowfall of 277.2 ppm. This site was specifically chosen for its proximity to county roads where salt was likely to be distributed during a snow event. The continuing runoff from the road likely perpetuated high Chloride levels (Figure 4.8).

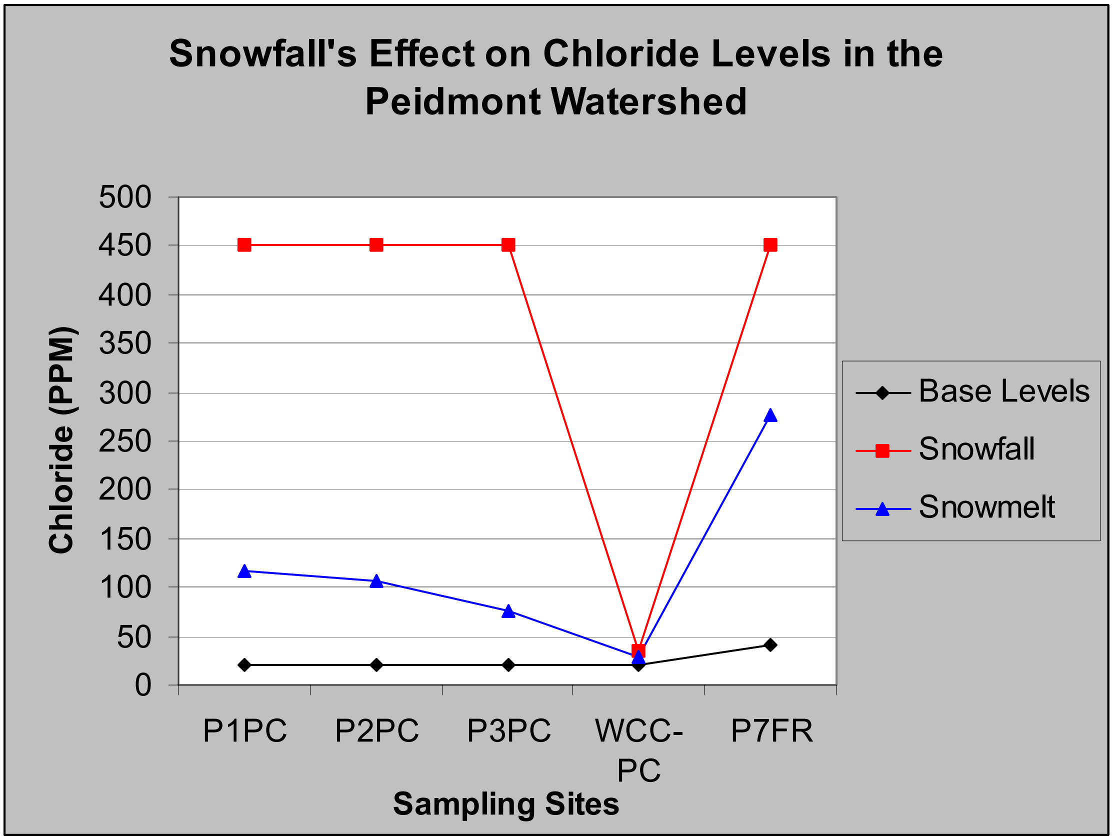


Figure 4.8. Snowfall's Effect on Chloride Levels in the Piedmont Watershed.

GIS Analysis

The GIS data for this project is from Jennifer Campagnini's paper Development of the University of Delaware Experimental Watershed Project which was written to fulfill the requirements of the Delaware Water Resources Center's Undergraduate Internships in Water Resources program. Please see figure 4.9 for a picture of the land use survey composed by the Arc-View GIS Software. The orange triangles detonate the sampling stations along the blue-colored streams. The distinctive light blue colors represent institutional land uses. The University of Delaware owns most of these areas inside the brown outlines of the watershed. The predominate yellow and dark red land uses are residential areas, both single family and multi-family. The green land uses, both dark and light, are open space. The dark represents wooded and forested areas, whereas the light green represents public or private open space.

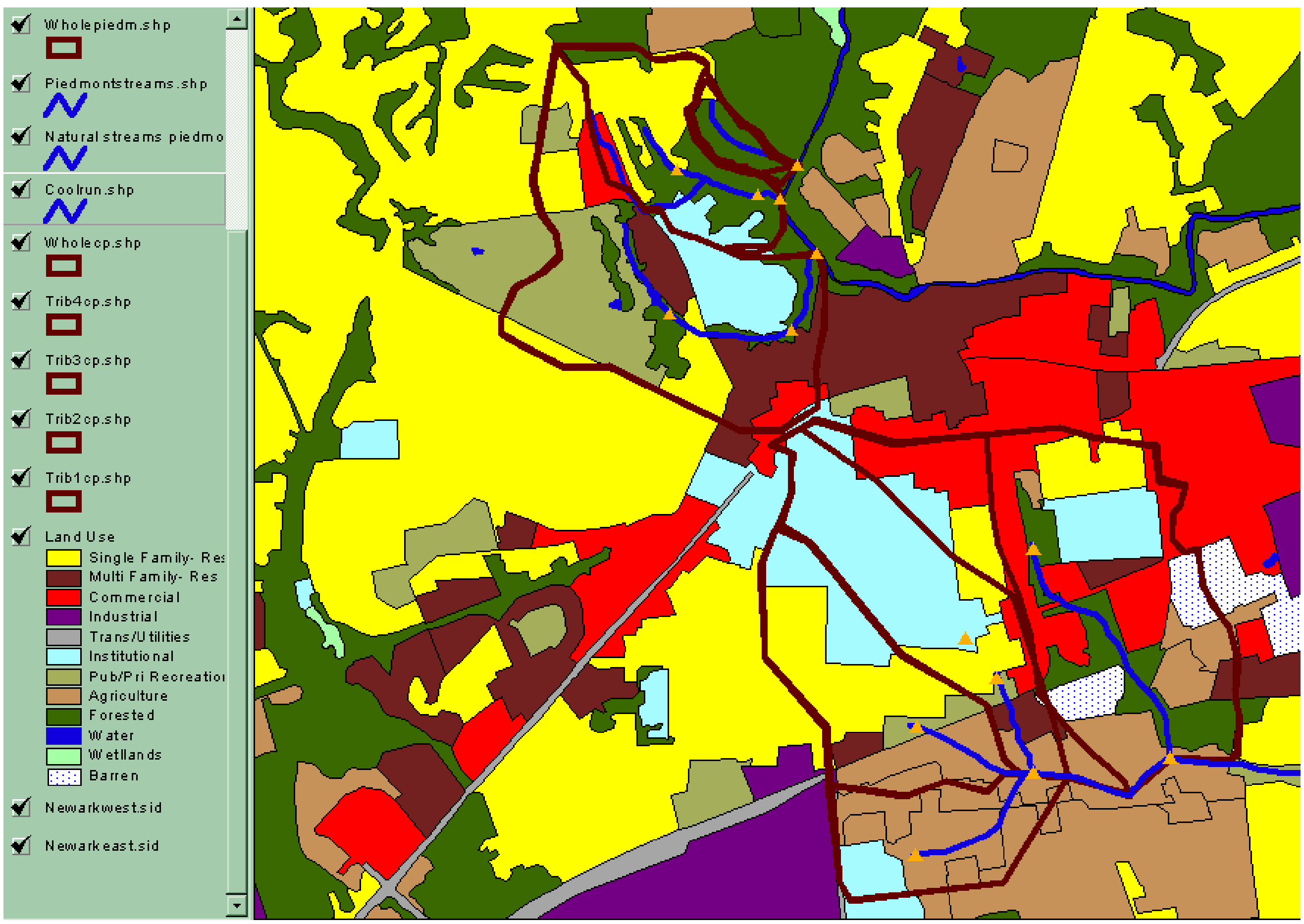


Figure 4.9. A GIS Layout of the UD Experimental Watershed Land Uses

Land Use in the Piedmont Watershed

The area of the Piedmont Watershed totals 427.2 square acres, or 0.65 square miles. Blue Hen Creek has the largest area with 281.6 square acres whereas the Lost Stream has the smallest drainage basin with only 25.6 square acres. The amount of land in each land use was divided by the total amount of land in each sub-watershed to reach the percentage of each land use. Multi-family residential is the largest land use in the watershed, followed closely by single-family residential, with 94.4 and 92.8 square acres respectively. Fairfield Run has the largest amount of forested land, but the Lost Stream has the largest percentage of forested land. No agricultural land uses were present in this watershed. Grades were calculated using table 3.5, Land Use Grading Equations. The percentage of a particular land use was multiplied by the land use score. The grades were added together for each stream and compared to the Watershed Report Card Grading Scheme (table 3.8). The Lost Stream had the highest grade out of the Piedmont Watershed. This is due to the large percentage of wooded land use and lack of commercial and residential land uses. The largest sub-watershed, Blue Hen Creek had the lowest grade with a **3.06**. Though this is the lowest grade comparatively, it is still a very good rating. The overall Piedmont Watershed grade was a **B** as well (Table 4.12).

Table 4.12. Land Use Data for the Piedmont Watershed

Land Use	Blue Hen Creek			Fairfield Run			The Lost Stream			PIEDMONT WATERSHED		
	Acres	Ratio	Grade	Acres	Ratio	Grade	Acres	Ratio	Grade	Acres	Ratio	Grade
Multi-family Residential (Score = 2)	89.6	31.8%	0.64	4.8	4.0%	0.08	0	0.0%	0.00	94.4	22.2%	0.44
Agricultural (Score =2)	0	0.0%	0.00	0	0.0%	0.00	0	0.0%	0.00	0	0.0%	0.00
Commercial (Score=2)	1.6	0.6%	0.01	6.4	5.3%	0.11	0	0.0%	0.00	8	1.9%	0.04
Single Family Residential (Score=3)	41.6	14.8%	0.44	44.8	37.3%	1.12	6.4	25.0%	0.75	92.8	21.7%	0.65
Institutional (Score =3)	40	14.2%	0.43	19.2	16.0%	0.48	0	0.0%	0.00	59.2	13.9%	0.42
Wooded (Score=4)	25.6	9.1%	0.36	38.4	32.0%	1.28	19.2	75.0%	3.00	83.2	19.5%	0.78
Public/Private Open Space (Score =4)	83.2	29.5%	1.18	6.4	5.3%	0.21	0	0.0%	0.00	89.6	21.0%	0.84
Totals	281.6	100.0%	3.06	120	100.0%	3.28	25.6	100.0%	3.75	427.2	100.1%	3.17
Stream Grades	B	3.06		B	3.28		A	3.75		B	3.17	

Land Use in the Coastal Plain Watershed

The Coastal Plain Watershed is almost twice as large as the Piedmont Watershed. Its land uses differ greatly as well. The largest land use in the watershed is institutional, as expected. The main campus of the University as well as the College of Agriculture and Natural Resources is in the watershed's catchment. The second largest land use is agriculture. This is not surprising because the Cool Run flows through both the University Farm and Webb Farm. In contrast to the Piedmont Watershed, forested land occupies the least amount of land. In terms of individual stream grades, Tributary 4 had the lowest grade with a **2.61**. This is barely considered a **B-**. This stream's basin includes a former brownfield, a previously industrial, now barren site and a residential area. The stream with the majority of "good" land uses was Tributary 1, with a grade of **3.09**. This stream also had the smallest land area, though it did include some of the College of Agriculture and Natural Resources' buildings. It had a very small amount of commercial or residential land uses. The overall Watershed grade was a **B-** with a **2.80** (Table 4.13).

Impervious Cover Data

The results of the Land Use Survey were used to determine Impervious Cover Data as well. Impervious Cover was determined using Table 3.6 Impervious Cover Factors. The Impervious Factor percentage was multiplied by the amount of each land use in the sub-watershed. The Impervious Factors for each stream sub-watershed were totaled and divided by the total acreage. This gave the total Watershed Impervious Percentage, which was compared to table 3.7, Impervious Cover Rating Scale. The data was put into an Excel spreadsheet.

The Piedmont Watershed had an overall rating of **Poor** for the Impervious Cover Survey. The percentage of impervious cover for the entire watershed was **30.09%**. This falls above the 25 percentage cutoff for Impacted Stream Health, and is officially Non-Supporting of Aquatic Life. Both the Blue Hen Creek and Fairfield Run had Non-Supporting health ratings as well. The Lost Stream had a sensitive rating. By referring back to table 4.12, the Land Use Data, it is easy to see the causes of these ratings. Blue Hen Creek and Fairfield Run both have high amounts of multi-family residential and institutional land uses, which have very high impervious cover percentages. The Lost Stream has extraordinary percentages of forested land, which is extremely pervious. table 4.14 demonstrates the Impervious Cover results.

Table 4.14. Impervious Cover Data for the Piedmont Watershed

Land Use	Impervious Factor (%)	Blue Hen Creek		Fairfield Run		Lost Stream		Piedmont Watershed	
Commercial	85	1.6 x 85 =	136	6.4 x 85 =	544	0 x 85 =	0	8 x 85 =	680
Multi-Family Residential	65	89.6 x 65 =	5824	4.8 x 65 =	312	0 x 65 =	0	94.4 x 65 =	6136
Institutional	55	40 x 55 =	2200	19.2 x 55 =	1056	0 x 55 =	0	59.2 x 55 =	3256
Single Family Residential	30	41.6 x 30 =	1248	44.8 x 30 =	1344	6.4 x 30 =	192	92.8 x 30 =	2784
Wooded	0	25.6 x 0 =	0	38.4 x 0 =	0	19.2 x 0 =	0	83.2 x 0 =	0
Agricultural	0	0 x 0 =	0	0 x 0 =	0	0 x 0 =	0	0 x 0 =	0
Public/Private Open Space	0	83.2 x 0 =	0	6.4 x 0 =	0	0 x 0 =	0	89.6 x 0 =	0
TOTAL		9408	33.41%	3256	27.13%	192	7.50%	12856	30.09%
		Non-Supporting of Aquatic life		Non-Supporting of Aquatic life		Stream Health Sensitive		Non-Supporting of Aquatic life	

Rating	4	3	2	1
Imperviousness	0%	0-10%	10-25%	> 25%
Impact to Stream	No Impact	Sensitive	Impacted	Non-Supporting of Aquatic life

The Coastal Plain had the worst ratings for Impervious Cover. Tributaries 3 and 4 both had scores of **50%**. This is directly due to the large amount of Commercial and Residential land uses in these sub-watersheds. Cool Run had the best rating with a **2.26%** impervious rating. The land in this watershed is primarily Agricultural, which relies on the entrance of water into the soil and groundwater. Tributary 1 received an **Impacted** rating because of the amount of institutional land uses, though it does have a good deal of agriculture and open space in its basin. Overall, the Coastal Plain Watershed received a rating of **35.42%**, which is classified as Non-Supporting of Aquatic

Life. Most of the Impervious Cover percentage came from commercial land uses. Table 4.15 demonstrates the details of the Impervious Cover Survey.

Comparison of Watershed Report Cards

In Jennifer Campagnini's report Development of the University of Delaware Experimental Watershed Project, a proposal for the continuation of the Watershed Report Card was made. This report has been completed with that goal in sight. With the completion of the four parameters; Water Quality, Habitat Analysis, Land Use and Impervious Cover, the report card can be completed and compared to the previous one. Of course, some variation will exist due to the unusual weather conditions of this fall and winter. That is out of the control of the researchers, and hopefully, in the continuation of the project, the outlying years will be absorbed by the overall average (Campagnini, 2001).

In the year 2001, the Overall Watershed Health Grade of the Piedmont Watershed was a **B-**. Each stream in the watershed received no lower than a **C** for total health. The weakest parameter overall was Impervious Cover, with a **C-** grade. Land Use had the highest grade with a **B**. Water Quality and Habitat Analysis both received **B-** grades. Please see table 4.16 (Campagnini, 2001).

The year of 2002 brought about changes for the Piedmont Watershed. The Overall Watershed Health Grade of the Piedmont Watershed was a **C+**. The lowest individual Stream Health Grade was a **C**, but both the Blue Hen Creek and Fairfield Run received this grade. Blue Hen Creek had the lowest score for land use as well as water quality and habitat assessment. The Lost Stream was not able to be tested for Water Quality or Habitat Assessment, so its grade is not reflective of its overall condition.

Impervious Cover is still the lowest scoring parameter, but the Habitat Analysis Grade dropped as well. Please see table 4.17 for more details

Table 4.16. Piedmont Watershed Report Card for 2001

Stream	Water Quality		Habitat Assessment		Land Use		Impervious Cover		TOTAL	
	Results	Grade	Results	Grade	Results	Grade	Results	Grade	Results	Grade
Blue Hen Creek	C+	2.5	B-	2.7	B	3.1	D	1	C	2.1
Fairfield Run	B-	2.7	B-	2.8	B	3.3	D	1	C+	2.5
Lost Stream	B-	2.9	B	3.0	A	3.8	B	3.0	B	3.2
PIEDMONT WATERSHED	B-	2.7	B-	2.8	B	3.4	C-	1.7	B-	2.7

Table 4.17.Overall Piedmont Watershed Report Card for 2002

PIEDMONT WATERSHED REPORT CARD					
STREAM	WATER QUALITY	HABITAT ANALYSIS	LANDUSE	IMPERVIOUS COVER	FINAL GRADE
BLUE HEN CREEK					C
P1PC	2.69	1.9	3.1	1.0	2.2
P2PC	3.1	2.4			2.4
P3PC	2.8	1.8			2.2
FINAL GRADE	2.8	2.0	3.1	1.0	2.2
FAIRFIELD RUN					C
P5FR	3.1	2.0	3.3	1.0	2.4
P6FR	3.1	2.8			2.6
P7FR	2.9	2.3			2.4
FINAL GRADE	3.0	2.4	3.3	1.0	2.4
LOST STREAM					B+
P9LS	n/a	n/a	3.8	3.0	3.4
FINAL GRADE	n/a	n/a	3.8	3.0	3.4
WATERSHED FINAL GRADE	2.9	2.2	3.2	1.7	2.5
WATERSHED FINAL LETTER GRADE*	B-	C	B	C	C+

The Coastal Plain Watershed Report Card was not available for publishing at the time of Development of the University of Delaware Experimental Watershed Project, but it was later completed. One sampling station was left out of the results for Tributary 3. The Overall Watershed Health Grade of the Coastal Plain Watershed was a **C+** in 2001. The weakest parameter was Impervious Cover, as it was in the Piedmont Watershed. Habitat Analysis and Land Use both received grades of **B**. Water Quality was graded a **C**. Please see table 4.18 (Campagnini, 2001).

The Coastal Plain in 2002 received an Overall Watershed Report Card Grade of **C**, which is another decrease in total health. The highest grade was awarded in Land Use, which was a **B-**, a decrease from the previous grade of **B**. Habitat Analysis was awarded a **C**, which was a fall from the **B** of 2001. Impervious Cover, once again, received the lowest grade with a **C-.** There was an improvement in Water Quality from a **C** to a **C+** in the Coastal Plain. Cool Run, which had the lowest percentage of impervious cover, had passable water quality grades. The stream with the lowest overall grade had the highest amount of negatively impacting land uses and highest percentage of impervious cover, which was Tributary 4 (Table 4.19).

Table 4.18. Summary Coastal Plain Watershed Report Card Data for 2001

	WATER QUALITY	*IMPERV. COVER*	*HABITAT ANALYSIS*	*LAND USE*	*FINAL GRADE*
TOTAL SCORE	**2.57**	**1.60**	**2.14**	**2.85**	**2.29**
FINAL GRADE	**C+**	**C-**	**C**	**B-**	**C**

Table 4.19. Overall Coastal Plain Watershed Report Card For 2002

COASTAL PLAIN WATERSHED					
	WATER QUALITY	IMPERV. COVER	HABITAT ANALYSIS	LAND USE	FINAL GRADE
TRIBUTARY 4					C
CP1T4	2.27	1.00	1.80	3.09	2.04
COOL RUN					B-
CP2CR	2.47	3.00	2.71	2.90	2.77
CP3CR	2.59		2.07		2.64
TRIBUTARY 1					C+
CP4T1	2.47	2.00	2.64	2.96	2.52
TRIBUTARY 2					C
CP5T2	2.88	1.00	1.86	2.61	2.09
TRIBUTARY 3					C
CP6T3	2.76	1.00	1.73	2.69	2.05
CP7T3	2.76		2.36		2.20
TOTAL SCORE	2.57	1.60	2.14	2.85	2.29
FINAL GRADE	C+	C-	C	B-	C

Chapter 5

CONCLUSIONS AND IMPLICATIONS

The results of this research indicate that there is a link between land use, stream water quality, and watershed health at the University of Delaware Experimental Watershed. The watersheds with higher levels of urban and suburban and built land uses have lower watershed grades than the watersheds with higher amounts of forested and open space. The watershed report card grading system developed here for the University of Delaware Experimental Watershed may have applications to other watersheds in the Piedmont and Coastal Plain regions of the Northeastern and Mid-Atlantic USA.

Conclusions/Implications

1. **Watershed Health** - The Piedmont Watershed generally had better watershed health as reflected in the following grades.

Watershed	Grade	Rating	Dominant Land Use
Piedmont	**C+**	**Fair**	**Multi-Family Residential**
Blue Hen Creek	**C**	Fair	Multi-Family Residential
Fairfield Run	**C**	Fair	Single Family Residential
Lost Stream	**B+**	Good	Wooded
Coastal Plain	**C**	**Fair**	**Agriculture**
Tributary 1	**C**	Fair	Open Space
Tributary 2	**C**	Fair	Single Family Residential

Tributary 3	**B-**	Good	Institutional
Tributary 4	**C**	Fair	Commercial
Cool Run	**C**	Fair	Agriculture

2. **Temporal Changes in Watershed Health** – The change in the health of the watershed from 2001 to 2002 could be a result of human impacts, the conditions of the drought, or the change in primary monitors. The watershed report card will be updated every fall semester to establish a more precise trend line.

Watershed	Grade 2001	Grade 2002
Piedmont	**B- (Good)**	**C+ (Fair)**
Blue Hen Creek	**C (Fair)**	**C (Fair)**
Fairfield Run	**C+ (Fair)**	**C (Fair)**
Lost Stream	**B (Good)**	**B+ (Good)**
Coastal Plain	**C+ (Fair)**	**C (Fair)**
Tributary 1	**C (Fair)**	**C (Fair)**
Tributary 2	**C (Fair)**	**C (Fair)**
Tributary 3	**C- (Fair)**	**B- (Good)**
Tributary 4	**C (Fair)**	**C (Fair)**
Cool Run	**C- (Fair)**	**C (Fair)**

3. **USEPA vs. NZ-NIWA Method** - The two stream habitat sampling methods compare favorably in their results. The NZ-NIWA method takes less time and is more

efficient and replicable in the field and is the recommended method for stream habitat sampling in the UD Experimental Watershed

Coastal Plain Station	USEPA Method	NZ-NIWA Method
CP1T4	C- (Fair)	Poor
CP2CR	B- (Good)	Good
CP3CR	C (Fair)	Poor
CP4T1	B- (Good)	Poor
CP5T2	C- (Fair)	Moderate
CP6T3	C- (Fair)	Good
CP7T3	C (Fair)	Good

4. **Urban Nutrient Surveys**- Urban and suburban land uses in the UD Experimental Watershed emit relatively high levels of Nitrogen and Phosphorus although the level did not exceed the standard. Nitrogen levels were generally higher for the dry condition and Phosphorus levels higher for the wet conditions. A lawn care management program should be considered to work with homeowners to reduce fertilizer use and minimize runoff of Nitrogen and Phosphorus into the streams.

Station	N-DRY	N-WET	P-DRY	P-WET	Dominant Land Use
P1PC	5ppm	4ppm	4ppm	4ppm	Wooded/ Inst.
P2PC	15ppm	5ppm	6ppm	6ppm	Inst./Mult.Res.
P3PC	5ppm	2ppm	2ppm	6ppm	Open Space
WCC-PC	3ppm	15ppm	0.5ppm	4ppm	Mult. Res.

5. **Chlorides** - Application of road salt during winter deicing activities results in higher chloride levels in the Piedmont streams of the UD experimental watershed. Chloride levels as measured in the streams are higher during snowfall and snow melt conditions than during pre-snow conditions. The Delaware Department of Transportation and City of Newark should consider alternative roadway de-icers and/or reduce the application of road salt in the watersheds that feed drinking water streams.

Station	PreSnow	Snowfall	Snow Melt
P1PC	20ppm	450ppm	117ppm
P2PC	20ppm	450ppm	107ppm
P3PC	20ppm	450ppm	75.6ppm
WCC-PC	20ppm	35ppm	29.7ppm
P7FR	40ppm	450ppm	277.2ppm

6. **Flowering Dates** - We have initiated a record of flower on dates at the UD Experimental watershed as a measure of potential long-term climate change. The

dates of flower on during 2002 were 2 to 4 weeks earlier than in 2001 possibly due to the unseasonably warm winter of 2002 and the drought conditions.

Location	Flower On 2001	Flower On 2002
Crocuses (Park Place/College Avenue)	Feb 27	Feb 21
Crab grass (UDWRA Building)	Mar 19	Mar 9
Forsynthia (DGS Building)	Apr 3	Mar 5
Cherry Tree (Main St. Parking)	Apr 5	Mar 10
Daffodil (DGS Building)	Apr 3	Mar 13
Pear Trees (Main St)	Apr 10	Mar 26
Azaleas (Academy Street)	Apr 10	
Dogwood (Penny Hall)	Apr 24	
Rhododendrum (Allison Hall)	May 12	

7. **Recommendations for the Future** -- Though the streams in the Piedmont Watershed have been named, there are still 4 tributaries of the Cool Run in the Coastal Plain that have not yet been named. This could provide a method of recognition for the Experimental Watershed. To expand public outreach, plans are currently underway with the UD Facilities Management Department to erect signs to educate the faculty, students, and community about watersheds and implications of land use. The placement of these signs would be along highly trafficked walkways and roads on the University Campus. Many stream health experts recommend using biological

indicators in stream assessment. These include macro-invertebrates, insect larvae, amphibians, and fish. The researchers would educate themselves about these topics and use them as a separate parameter for stream health. Both NZNIWA and USEPA have programs to incorporate these into a stream health assessment.

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