Field Report

Plan for Rocky Run Environmental Protection (PRREP)

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Chapter 1
The Rocky Run Watershed

1.1. Mission Statement

The purpose of this watershed management plan is to restore Rocky Run, a tributary to the Brandywine Creek that flows through New Castle County, Delaware, to support appropriate designated and desired uses while maintaining distinctive natural characteristics and aquatic biological communities. Rocky Run is currently listed on the Delaware Department of Natural Resources and Environmental Control (DNREC) Clean Water Act Section 303(d) List of Impaired Waters for habitat and biology. The goal of the Plan for Rocky Run Environmental Protection (PRREP) is to attain water quality levels appropriate to meet the fishable and swimmable goals of the Federal Clean Water Act and sustain ecological integrity and human uses, which would justify the removal of the stream from the 303(d) listing for the State of Delaware. The successful restoration of Rocky Run would ideally allow this watershed to serve as a model for integrated management efforts in small, mixed land use watersheds locally and in the larger region. While the exact time frame of this project depends on the solution alternatives chosen, we aim to implement the recommendations of this collaborative management plan by 2020.

1.2. Hydrology

As a tributary of the Brandywine Creek (Wilmington's primary source of public drinking water), the Rocky Run watershed spans 1,151 acres (1.8 mi^2) in northeastern New Castle County, Delaware. It is composed of three waterways, Hurricane Run in the west, Upper Rocky Run in the east, and the Rocky Run main stem below where the latter two streams converge. For the purposes of this analysis, these three small watersheds were further divided into 10 subwatersheds based on major land use coverage's. East Rocky Run contains subwatershed areas R1 through R6, the Rocky Run main stem consists of the R7 subwatershed, and Hurricane Run covers the H1 through H3 subwatersheds (Figure 1.1).

Table 1.1. Rocky Run subwatersheds

Watershed	Area (ac)	Subwatershed	Area (ac)
Hurricane Run	319	H1	83
		H2	133
		H3	103
East Rocky Run	679	R1	53
		R2	127
		R3	169
		R4	92
		R5	159
		R6	79
Rocky Run Main Stem	152	R7	152
Total	**1,150**	**Total**	**1,151**

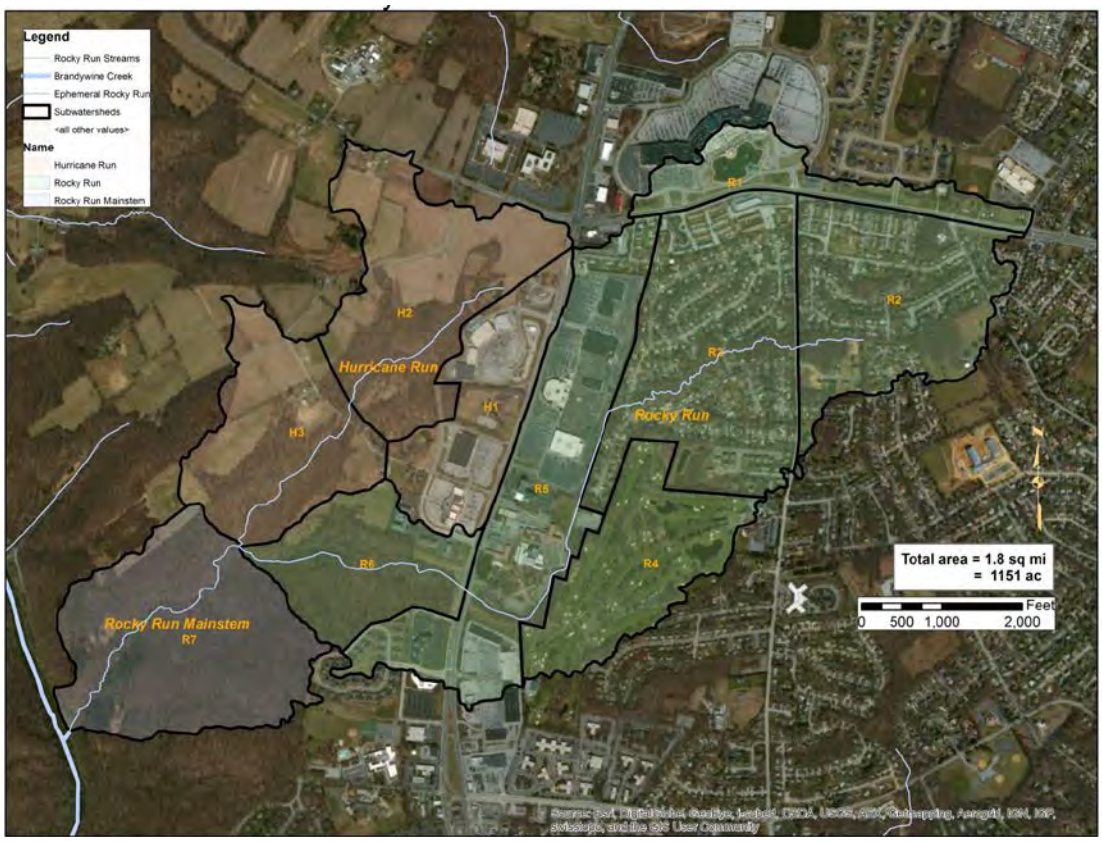

Figure 1.1. Rocky Run watershed

1.3. Physical and Natural Features

Climate: The Rocky Run watershed is within a temperate, humid continental climate zone. The mean annual temperature is 54.3°F, the highest annual temperatures are recorded in July with a mean of 72.2°F, and lowest annual temperatures are observed in January with a mean of 31.8°F (Office of the Delaware State Climatologist). Mean annual precipitation within the basin is 49.42 in. Most precipitation is produced by mid-latitude cyclones and tropical storms, nor'easters, and spring and summer severe thunderstorms.

Geology and Soils: The Rocky Run watershed consists primarily of gently sloping loam and silt loam soils. The small percentage of land that does not fit into this category is located in the areas of commercialized development where urban land is underlain by bedrock formations near the area surrounding Concord Mall. The majority of watershed soils (61%) are relatively well drained in hydrologic soil group B, 14.2% are moderately drained group C soils, 10.8% are low infiltration group D soils located primarily in the floodplain along the banks of Rocky Run and Hurricane Run, and 11.8% are classified urban soils (Figure 1.2).

Topography and Elevation: The headwaters of the watershed are located on top of the relatively flat Piedmont plateau at an approximate elevation of 400 ft. above sea level. The watershed extends southeast and ends at the confluence of Rocky Run with the Brandywine Creek, slopes steepen appreciably in the bottom reaches of the watershed as the elevation quickly decreases to approximately 140 ft. along the banks of the Brandywine Creek (Figures 1.3 and 1.4).

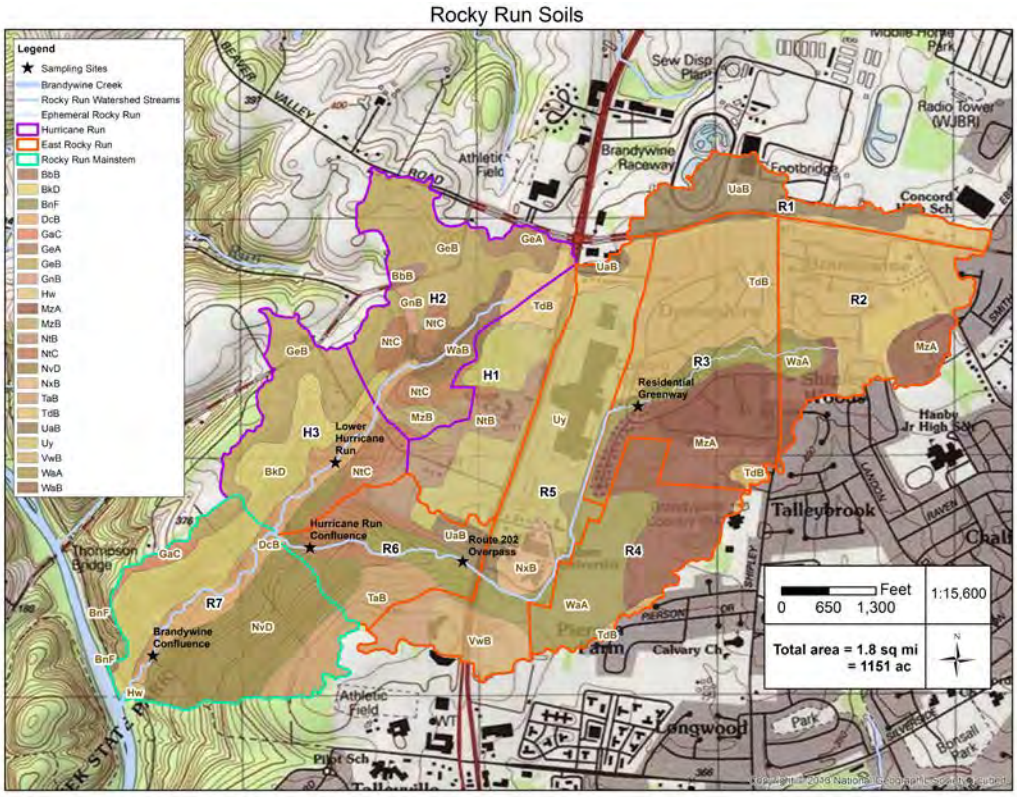

Figure 1.2. Rocky Run soils map

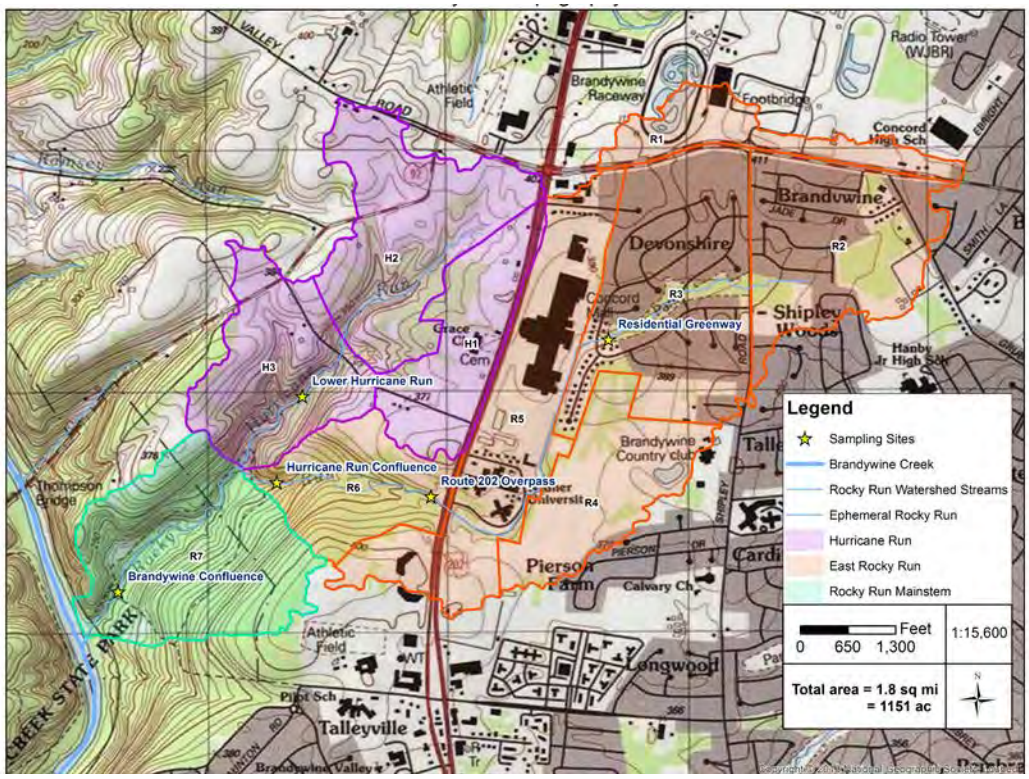

Figure 1.3. Rocky Run watershed topographic map

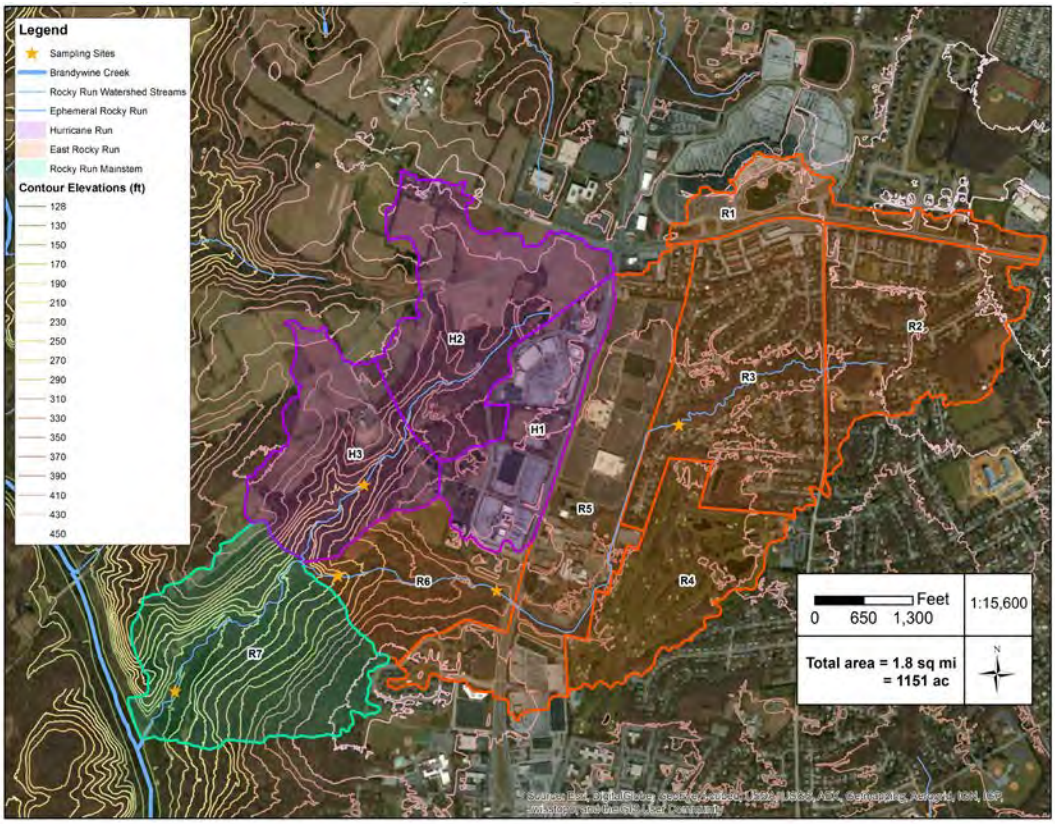

Figure 1.4. Rocky Run watershed aerial photography

Land Use: The Rocky Run watershed is nearly half urbanized in the residential and commercial neighborhoods primarily along and east of Concord Pike and half undeveloped covered by agriculture and the forested Brandywine Creek State Park in the steeply sloped downstream reaches west of Concord Pike (Table 1.2 and Figure 1.5). U.S. Route 202, also known as Concord Pike, bisects the Rocky Run watershed. The Route 202 corridor is comprised mostly of the Concord Mall and its adjoining strip malls, hotels, restaurant chains, and the Widener University Law School campus. Further east of the Route 202 corridor in R2 and R3 are residential areas with single and multi-family dwellings. The southeast corner of the Rocky Run watershed (R4) is covered by the 83-acre Brandywine Country Club. The steeply sloped downstream reach of East Rocky Run (R6) in Brandywine Creek State Park is largely forested. The northwest headwaters of Hurricane Run (H2) consist of agricultural and forested areas. The Rocky Run main stem is almost all forested in Brandywine Creek State Park, with some agriculture in the northwest corner.

Table 1.2. Land use in the Rocky Run watershed

Land Use	Area	(%)
Residential	273	24%
Urban	218	19%
Institutional	86	7%
Agriculture	163	14%
Forest/Park	412	36%
	1,151	**100%**

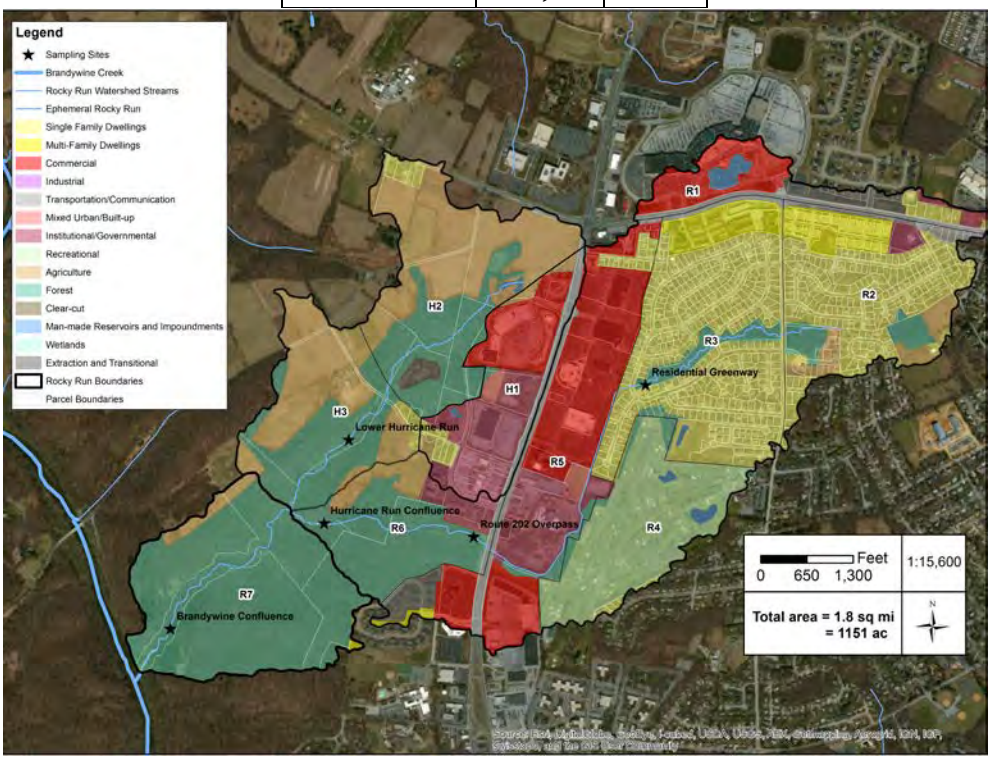

Figure 1.5. Rocky Run watershed land use

Impervious Cover: Although the distribution of land use types can be a predictor of watershed health, impervious cover may play a larger role in determining overall water quality. Impervious cover is defined as ground surfaces such as roads, parking lots, and buildings that do not allow water to percolate into the soil. Impervious cover for the Rocky Run watershed was determined through roadway and building footprint GIS data provided by New Castle County. Overall, the Rocky Run watershed has 27% of its surface area under impervious cover, the bulk of which is located in the highly commercialized Route 202 corridor. Subwatersheds with the largest amount of impervious cover were R5 with 72% and H1 at 60% along the commercialized Route 202 corridor and at the Concord Mall, Widener School of Law, and the hotel complex. The R7 subwatershed has no impervious cover along the steeply sloped Rocky Run in Brandywine Creek State Park.

Table 1.3. Rocky Run impervious cover

Subwatershed	Area (ac)	Imperv. (ac)	Imperv. (%)
H1	83	49	60%
H2	133	4	3%
H3	103	3	3%
R1	53	25	48%
R2	127	41	32%
R3	169	61	36%
R4	92	5	6%
R5	159	115	72%
R6	79	7	9%
R7	152	0	0%
Total	**1,151**	**309**	**27%**

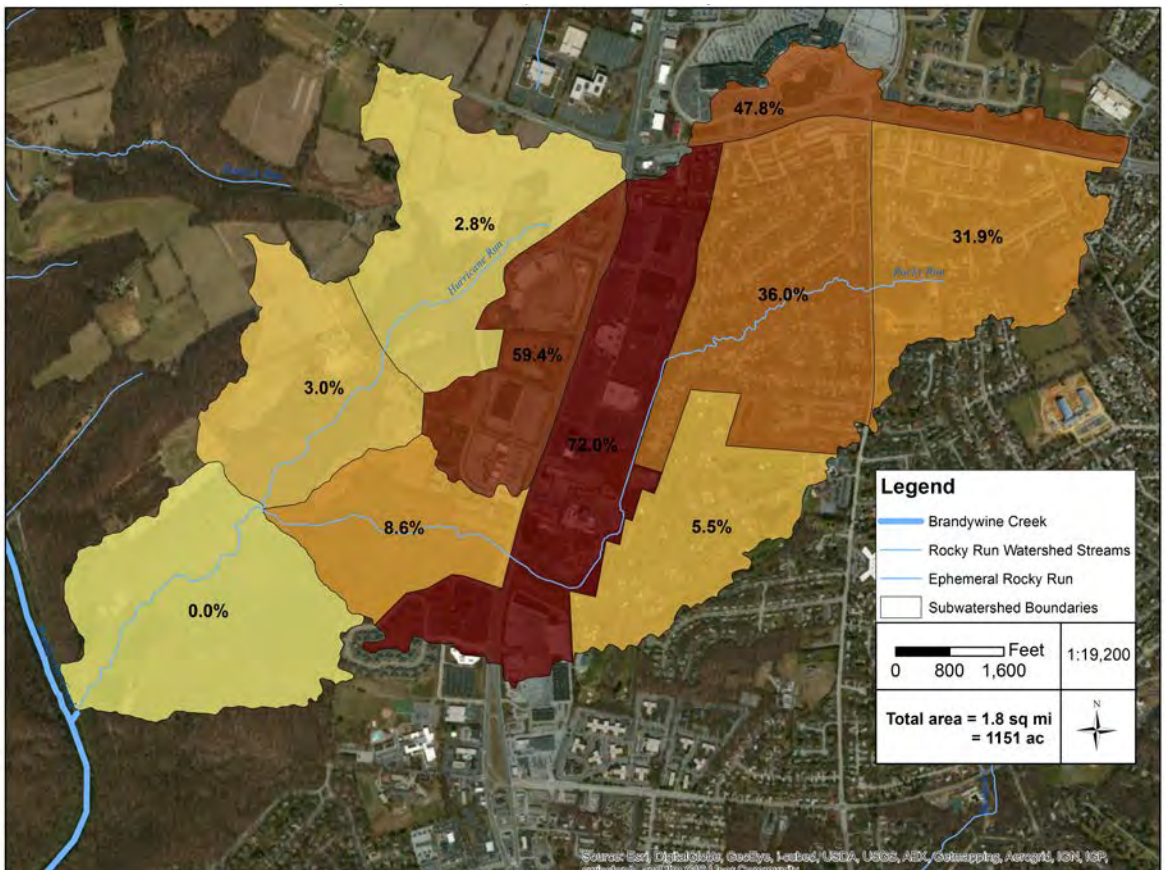

Figure 1.6. Rocky Run watershed impervious cover

Population: Approximately 2,320 people reside in the Rocky Run watershed, yielding a population density of 1,281 people per square mile. The U.S. Census defines areas as urban with a population density that exceeds 1,000 people per square mile. Median household income in the basin is $64,158, and the median home value is $254,400 (US Census Bureau).

1.4. Cultural Resources

Jester Park: The ephemeral headwaters of Rocky Run originate in Jester County Park, a twenty-five acre plot of land owned by New Castle County northwest of the Route 202 corridor that consists of mixed grasslands and forest. Located near Grubb Road in Wilmington, the Jester Farm farmhouse and barn are situated within the park on 1.1 acres of land. The historic farmstead is an example of early development in the Brandywine Hundred and the structure was built in two phases; the main house was constructed approximately 100 and 150 years ago, while an addition was constructed less than 100 years ago (New Castle County 2013). The farm was acquired by New Castle County from the Jester family in the mid-1970s. A portion of the land is leased to Hy-Point Dairy Farms for cattle grazing, a hobby and tradition of the creamery owners. These cows are not part of the dairy operation and are not grazed for beef. The remaining area of the park is currently available for lease through the County.

Route 202 Corridor: Known locally as Concord Pike, this highway is the southernmost reach of interstate U.S. Route 202, which extends from New Castle, Delaware north into Maine. The section of the highway that passes through the Rocky Run watershed was first constructed in 1811 as part of the Wilmington-Great Valley Turnpike and was a toll road up until the early 20th century. As local populations rose and more people began driving cars, traffic on Route 202 steadily increased and the road was widened into a divided highway in the 1950s. Today, this road is a heavily commercialized and extremely well traveled corridor. According to the Delaware Department of Transportation (2011), an average of 49,080 cars per day traveled along the 11.6-mile stretch of Route 202 between Woodlawn Drive and Route 92 (Naamans Road).

Concord Mall: Located along the Route 202 corridor in the heart of the Rocky Run watershed is the Concord Mall, Delaware's second largest commercial mall. The complex has nearly a million square feet in retail space and houses more than 90 stores. The first store was opened in 1965. Because of its location along a major highway and its proximity to the Pennsylvania border and New Jersey across the river, the Concord Mall draws local shoppers and visitors from nearby states that wish to take advantage of tax-free shopping in Delaware.

Brandywine Creek State Park: North of the City of Wilmington lies the Brandywine Creek State Park, 933 acres of forest and meadowlands open to the public for recreational enjoyment. Each year, the park receives roughly 80,000 visitors from near and far. The land on which the park currently sits was formerly owned by the DuPont family and operated as a dairy farm. The land was incorporated into the state park system in 1965 and contains the state's first nature preserves (Tulip Tree Woods and Freshwater Marsh). According to the Delaware State Park Service, the Brandywine Creek State Park was one of the first parks in the nation to be acquired using money from the U.S. National Park Service, Land and Water Conservation Fund.

First National Monument/Woodlawn Property: In March 2013, President Obama signed an executive order that designated the First State National Monument (as part of the National Park system) in Delaware. It is the first National Park in Delaware, which up until this point was the only state in the nation not represented in the national park system. The new National Monument includes three distinct locations: the Dover Green, the New Castle County Court House Complex, and the Woodlawn Property. The Woodlawn Property's designation as a part of First State National Monument highlights the importance of the Rocky Run watershed because the national park property occupies part of the watershed. Woodlawn is a 1,100-acre property along the Brandywine River. William Penn originally purchased it from the Duke of York in the 17th century. The property has been managed by the Woodlawn Trustees for over 100 years and has been preserved as an open space resource. The Conservation Fund acquired the property in 2012 with financial contributions from the Mount Cuba Center. The Conservation Fund in turn donated the Woodlawn property to the National Park Service as part of the First State National Monument.

Chapter 2
Research Methods

2.1. Introduction

The Delaware Department of Natural Resources and Environmental Control declared the upper and lower branches of Rocky Run impaired in 1998. The upper half of the watershed was declared impaired for habitat while the lower half was declared impaired for both habitat and biology. The stream is not suitable for support of aquatic life (flora and fauna) as some chemical or physical characteristics of the stream may not consistently be within the range necessary to maintain an array of life forms. According to "Final Determination for the State of Delaware 1998 Clean Water Act Section 303(d) List of Waters Needing TMDLs", the probable source of impairment is nonpoint source pollution from land development. The Rocky Run TMDL implementation began in 2009. Hurricane Run is not listed as an impaired waterway.

This report sets out to develop a better understanding of the current conditions in the Rocky Run watershed, particularly in light of the DNREC declarations of impairment. For the purposes of this report, ecosystem health of the Rocky Run watershed was determined through the use of three parameters: (1) visual habitat assessment, (2) chemical assessment, and (3) biological assessment. Data on each of these parameters were collected at five sites throughout the watershed. These sites were chosen in order to represent the variety of land uses that are present in the Rocky Run watershed. All analyses were completed during the summer of 2013 during base flow (dry) conditions. Separately, these parameters serve as indicators of stream health, but together they paint a complete picture of the management plan for the watershed.

2.2. Visual Habitat Assessment

The visual habitat assessment was performed using "Chapter 5: Habitat Assessment and Physicochemical Parameters from Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macro invertebrates, and Fish (EPA 2011). The purpose of this assessment is to evaluate the Rocky Run watershed, both within the stream and along the stream banks, to provide adequate livable conditions for native wildlife species.

The visual habitat assessment evaluates ten stream characteristics including: (1) epifaunal substrate/available cover, (2) embeddedness of substrate material, (3) velocity/depth regime, (4) sediment deposition, (5) channel flow status, (6) channel alteration (7) frequency of riffles or bends, (8) bank stability, (9) vegetative protection of stream banks/riparian zones, and (10) riparian vegetative zone width. Each characteristic is scored from 0 to 20 points, a higher score indicates better habitat (Figure 2.1). The habitat scores are added to define four categories ranging from poor (0-50), marginal (51-100), suboptimal (101-150), and optimal (151-200).

To supplement the visual habitat assessment, measurements were taken to determine the width, depth, and shape of the stream channel and stream banks at designated points along the waterway. To assess Rocky Run's habitat, five segments per reach were visually assessed 100 feet apart beginning at least 50 feet from bridges, paths, and culverts. To reduce subjectivity, assessments were performed in pairs rotating the researcher performing the assessment.

HABITAT ASSESSMENT FIELD DATA SHEET—LOW GRADIENT STREAMS (FRONT)

STREAM NAME	LOCATION	
STATION #_____ RIVERMILE_____	STREAM CLASS	
LAT _____ LONG _____	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS		
FORM COMPLETED BY	DATE _____ TIME _____ AM PM	REASON FOR SURVEY

Parameters to be evaluated in sampling reach	Habitat Parameter	Condition Category			
		Optimal	**Suboptimal**	**Marginal**	**Poor**
	1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
	2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
	3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
	4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
	5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Figure 2.1. EPA habitat assessment field data sheets

HABITAT ASSESSMENT FIELD DATA SHEET—LOW GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

Figure 2.1. EPA habitat assessment field data sheets (con't)

2.3. Chemical Assessment

Water quality samples were collected at each study site along Rocky Run and Hurricane Run. All samples were collected during base flow/low flow stream conditions in the months of June and July. The samples were stored in sealed glass jars and transported to the Soil Testing Program Lab at the University of Delaware College of Agriculture and Natural Resources. Once the samples reached the lab, technicians analyzed each sample for the following parameters: pH; electrical conductivity (EC); aluminum (Al); boron (B); copper (Cu); iron (Fe); manganese (Mn); phosphorus (P); zinc (Zn); and nitrate (NO_3-N). The pH of each solution was measured using an Accumet pH meter and a SymPHony pH electrode. Electrical conductivity was measured using a VWR Model 1052 conductivity meter with a platinum dip cell. Nitrate-N was measured colorimetrically using a Bran&Luebbe AutoAnalyzer 3. Other parameters were measured through inductively coupled plasma optical emission spectroscopy using a Thermo Iris Interpid II XSP Duo View ICP.

All of the measured chemical concentrations have been compared to the relevant water quality standard to assess the chemical health of the stream at each site. The sources of the standards (or in the case of electrical conductivity, the suggested levels) are listed in the tables with the laboratory results. It should be noted that if the source of the standard is listed as EPA instead of the State of Delaware, this indicates that Delaware does not have its own standard for that parameter and instead defers to the EPA's ruling on acceptable concentration levels.

According to the draft Delaware Clean Water Act Section 303d list of impaired streams (DNREC 2014), the Brandywine Creek and Rocky Run are impaired (Table 2.1). For Brandywine Creek, bacteria was delisted in 2006 and relisted in 2008 and nutrients were listed in 1996 and delisted in 2014. The eastern tributary of the headwaters of Rocky Run is impaired for habitat in the upper half and for habitat and biology in the lower half.

Table 2.1. Draft Delaware Section 303d list of impaired streams (DNREC 2014)

WATERBODY ID	WATERSHED NAME	SEGMENT	Overall CALM Code	DESCRIPTION	SIZE	POLLUTANT OR STRESSOR	PROBABLE SOURCE(S)	YEAR LISTED	TARGET DATE FOR TMDL	TMDL DATE	Pollutant CALM Code	Year Changed from Category 5 Per 305(b) Assessment and Methodology	Notes
DE040-002	Brandywine Creek	Upper Brandywine	5	From State Line to Wilmington	9.3 miles	Bacteria	PS, NPS, SF	1996	2004	2005	4a		Bacteria, listed in 1996, delisted 2006 , relisted 2008
						Nutrients		1996		2000	1	2014	Nutrients, Listed 1996, Delisted 2014
						PCBs		1996	2003	2003	4a	2012	EPA TMDL for PCBS in Delaware River Zone 5 and tributaries
						Dioxin		2002	2017		5		Target date changed to 2017 in the 2012 Cycl, per the WATAR plan in the appendix
				From State line to the confluence with the Christina River	8.0 miles	Habitat	NPS	1998	2009		5		
DE040-003	Brandywine Creek	All tributaries on Brandywine Creek from the headwaters at PA-DE line to the confluence with the Christina River	5	Eastern tributary of Beaver Creek, from headwaters to the confluence with mainstem Beaver Creek	0.96 miles	Biology and Habitat	NPS	1998	2009		5		
				Tributary originating in Pennsylvania on the western side of Brandywine Creek	0.26 miles	Biology and Habitat	NPS	1998	2009		5		
				Tributary of Brandywine Creek, off Route 100 (near PA-DE border)	0.92 miles	Habitat	NPS	1998	2009		5		
				Tributary of Brandywine Creek just below Beaver Creek	0.85 miles	Habitat	NPS	1998	2009		5		
				Eastern tributary of the headwaters of Rocky Run(upper half)	1.16 miles	Habitat	NPS	1998	2009		5		
				Eastern tributary of the headwaters of Rocky Run(lower half)	1.16 miles	Biology and Habitat	NPS	1998	2009		5		
				From the confluence of the headwaters of Wilson Run to the next larger stream order (lower half)	0.64 miles	Habitat	NPS	1998	2009		5		

2.4. Biological Assessment

The methodology for the biological (macro invertebrate) assessment utilized in this study is based on a citizen monitoring protocol developed by Virginia Save Our Streams (VASOS). This methodology is the preferred assessment system of the local Brandywine Valley Association. It was chosen over the EPA's Rapid Bioassessment Protocols because the EPA protocols require identifying the specific taxa of each collected macro invertebrate, beyond the scope of this work.

This methodology requires the collection of 200 organisms (or no more than four kick net samples) at each site. The organisms are identified and counted, and scores for each site are assessed based on the type, quantity, and distribution of the sample. Specifically, the scores are calculated based on the percentage of each type of organism in the total sample. The presence of certain species of organisms indicates local stream health levels. For example, organisms like caddisflies, mayflies, and stoneflies are highly pollution intolerant, so their presence in the stream indicates low pollution and good ecosystem health. On the other hand, organisms like leeches, worms, and sowbugs are tolerant of pollution. When these species dominate the sample, ecological conditions are typically poor. The categories and their associated scores for the VASOS assessment are as follows: acceptable ecological condition (scores from 9-12), ecological conditions cannot be determined (a score of 8); and unacceptable ecological conditions (a score from 0-7). For more information on this scoring system, refer to the appendices for a copy of the VASOS scoring sheets.

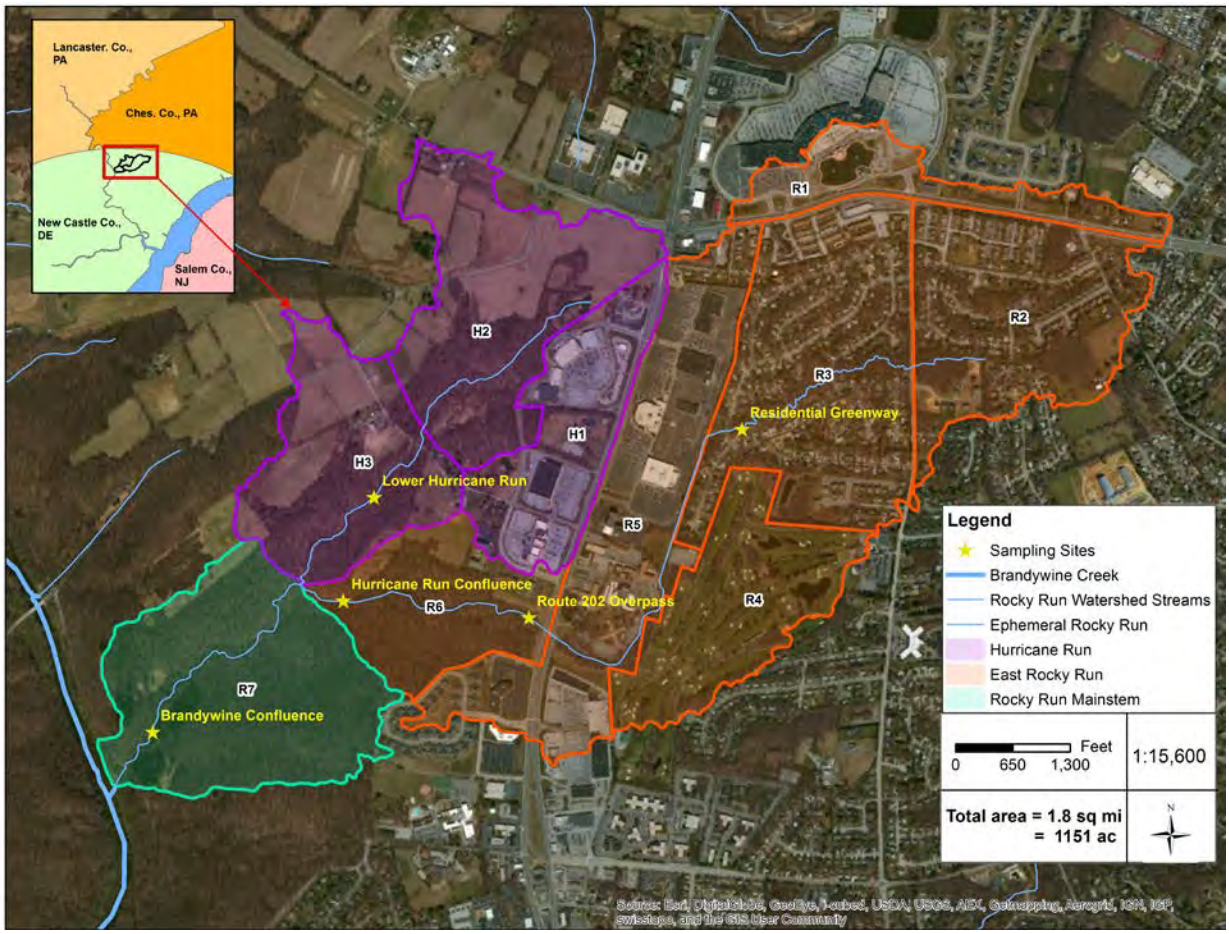

Figure 2.2. Rocky Run stream sampling sites

Chapter 3
Field Results

3.1. Introduction

This chapter details the results of the three ecosystem evaluations at each of the five sites throughout the Rocky Run watershed. The results are reported by watershed and include a site description along with the details of the habitat, chemical, and biological assessments. Although the assessments work together to form a more complete picture of the health of the stream at each site, they are independent of one another in their methodologies, assumptions, and results.

3.2. Rocky Run

Residential Greenway (R3): Located in a residential area near Devonshire Park behind the Concord Mall in subwatershed R3, this is the most upstream site in Upper Rocky Run. In this section of the stream, Rocky Run is a meandering creek following the typical riffle-run-pool sequence with highly eroded and undercut banks (Figure 3.1). On both side of the stream is a narrow forested buffer and in some areas there is evidence of ephemeral washes and small pipes that likely drain nearby residential yards and roadways.

Figure 3.1. Residential greenway site (R3) along Rocky Run

Habitat/Physical Assessment: This reach of the Rocky Run scored a total 117 of 200 in the EPA rapid habitat assessment, a score that measures on the low end of the suboptimal range. Scores for the subcategories in this assessment show suboptimal conditions for epifaunal substrate and available cover, pool substrate characterization, pool variability, sediment deposition, channel flow status, and channel alteration. Channel sinuosity was rated as marginal, owing largely to

the fact that the stream is channelized in the most downstream reaches of this study site. Due to severe undercutting, bank stability is only marginally rated in this location (although it is not entirely clear whether this undercutting is natural, the result of anthropogenic stormwater runoff, or some combination of the two). Short vegetation along the banks of the river provide a suboptimal rating vegetative protection, while the relatively close proximity to residential development yields a narrow riparian buffer and thus poor rating with respect to the vegetative riparian zone width.

Chemical Assessment: Table 3.1 summarizes the results of the water quality analyses at the residential greenway along Rocky Run. The results from this site show that, at the time these samples were taken, there is no chemical impairment present in the waters at the Residential Greenway.

Table 3.1. Water quality analysis at residential greenway along Rocky Run subwatershed(R3)

Parameter	Result	Units	WQ Standard	Source
pH	7.5	-	6.5-8.5	**DE** Fresh Water Quality Standards
EC	280	µhos/cm	150-500	**EPA** Suggestion for Freshwater Habitat[3]
Al*	0.081	mg/L	0.75[1]	**DE** WQ Criteria for Aquatic Life Protection
B	0.018	mg/L	0.75	**EPA** "Gold Book" Criteria
Cu*	0.001	mg/L	0.0134[1]	**DE** WQ Criteria for Aquatic Life Protection
Fe*	0.106	mg/L	1.0[2]	**DE** WQ Criteria for Aquatic Life Protection
Mn	0.001	mg/L	0.50	**EPA** "Gold Book" Criteria
P	0.105	µg/L	200.0	**EPA** Ecoregional Nutrient WQ Critera
Zn*	0.000	mg/L	0.117[1]	**DE** WQ Criteria for Aquatic Life Protection
NO_3-N	0.96	mg/L	10.0	**DE** WQ Criteria for Human Health Protection

1. Values calculated by Kiliszek (2010) assuming pH of 7.0 and hardness of 100mg/L $CaCO_3$.

Biological Assessment: Two hundred and nine organisms were collected from this site. Of those macro invertebrates, 158 fell into the pollution tolerant category. The most abundant taxa collected were flat worms and worms at 90 and 40 sites, respectively. Because the majority of organisms identified in this survey were highly pollution tolerant, this site was given a VASOS index of 6, which indicates that the water quality in the Residential Greenway is in an unacceptable ecological condition to support healthy, diverse aquatic life.

Route 202 Overpass: Route 202 crosses Rocky Run as a six-lane highway surrounded by stores, strip malls, and hotels. This particular stretch of Rocky Run is located just downstream of the Route 202 overpass. This site is at the end of a mile long concrete channel through which the stream flows. Some areas of that channel are in serious disrepair, and natural stream conditions begin to reemerge. In other areas, the channel remains eroded and impaired, supporting minimal or no aquatic flora and fauna. At this site there was a noticeable amount of litter, which is likely related to the site's proximity to the highway as well as a major strip mall and two large hotels.

Habitat/Physical Assessment: The EPA rapid habitat assessment results in this section of Rocky Run led to a suboptimal habitat rating with a score of 125/200. Suboptimal scores were given for the epifaunal substrate/available cover, pool substrate characterization, pool variability, sediment deposition, bank stability, and vegetative protection along this reach. Channel sinuosity was found to be marginal, given that this site location is just downstream of Rocky Run's concrete

channelized reach. Riparian vegetative protection was found to be poor, as a major strip mall and two hotels are located within approximately 30 feet of the stream at this location. Undercutting of the stream banks was observed. However, most of the undercutting was observed on one side of the stream rather than both sides in the cross section measurements.

Figure 3.2. Route 202 overpass along Rocky Run

Chemical Assessment: Table 3.2 summarizes the results of the chemical analyses performed at the Route 202 overpass along Rocky Run. The results from this site show that, at the time these samples were taken, there is no chemical impairment present in the waters at the Route 202 overpass.

Table 3.2. Site #2 chemical assessment results

Parameter	Result	Units	WQ Standard	Source
pH	7.6	-	6.5-8.5	**DE** Fresh Water Quality Standards
EC	610	µhos/cm	150-500	**EPA** Suggestion for Freshwater Habitat[3]
Al*	0.090	mg/L	0.75[1]	**DE** WQ Criteria for Aquatic Life Protection
B	0.037	mg/L	0.75	**EPA** "Gold Book" Criteria
Cu*	0.003	mg/L	0.0134[1]	**DE** WQ Criteria for Aquatic Life Protection
Fe*	0.059	mg/L	1.0[2]	**DE** WQ Criteria for Aquatic Life Protection
Mn	0.001	mg/L	0.50	**EPA** "Gold Book" Criteria
P	0.085	µg/L	200.0	**EPA** Ecoregional Nutrient WQ Critera
Zn*	0.001	mg/L	0.117[1]	**DE** WQ Criteria for Aquatic Life Protection
NO_3-N	0.91	mg/L	10.0	**DE** WQ Criteria for Human Health Protection

1. These are acute water quality standards; values were calculated by Kiliszek (2010) assuming a pH of 7.0 and a hardness of 100mg/L $CaCO_3$. 2. The only water quality standard for iron is for chronic contaminant levels.
3. This is not a standard; it is merely a suggested healthy level for EC. According to the US EPA, "Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µhos/cm.

Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macro invertebrates." http://water.epa.gov/type/rsl/monitoring/vms59.cfm

Biological Assessment: As in Site #1, there was minimal biodiversity at site #2 and the majority of the organisms represented in the sample were pollution-tolerant flatworms (141 out of a total of 169 organisms). The second most abundant organisms were midges (16 identified individuals). Though the goal of this biological assessment is to collect and document 200 individual organisms, researchers completed the four kicknet samples (the maximum number allowed by this protocol) and were still no able to reach the desired sample size. With a Va. SOS index of 4, the water quality at Route 202 was labeled as being in an unacceptable ecological condition to support healthy, diverse aquatic life.

Hurricane Run Confluence: Site #3 is located just upstream of Upper Rocky Run's confluence with Hurricane Run. Below this point the two streams merge to form the Rocky Run main stem. This segment of the stream is characterized by a large boulder field, both within the stream channel and along the banks. So numerous were the boulders that it was difficult to discern the boundaries of the stream banks. A wide forested riparian buffer lines both sides of the stream in this area. Some street litter was found among the boulders at this site, and the researchers believe it is likely that this litter was washed downstream from the more urbanized headwaters during storm/flooding events.

Figure 3.3. Hurricane Run confluence in R6

Habitat/Physical Assessment: This study site received an overall rating of 146 of 200 using the EPA rapid habitat assessment method. This value is in the high end of the suboptimal range and

is just below the minimum score of 150/200 needed for optimal classification. A marginal rating was given for channel sinuosity, which ultimately lowered the overall score. Additionally, minimal vegetation along the stream's banks and the presence of large boulders in the stream channel significantly reduced pool substrate characterization and channel flow status, yielding suboptimal ratings in these categories. On the other hand, epifuanal substrate/available cover, pool variability, sediment deposition, bank stability, and riparian vegetative protection width were rated optimally for this stream reach.

Chemical Assessment: The results of the chemical analyses performed on water quality samples from Site #3 are reported in Table 3.3. The results from this site show that, at the time these samples were taken, there is no chemical impairment present in the waters at the Hurricane Run Confluence.

Table 3.3. Site #3 chemical assessment results

Parameter	Result	Units	WQ Standard	Source
pH	7.7	-	6.5-8.5	**DE** Fresh Water Quality Standards
EC	0.42	µhos/cm	150-500	**EPA** Suggestion for Freshwater Habitat[3]
Al*	0.037	mg/L	0.75[1]	**DE** WQ Criteria for Aquatic Life Protection
B	0.011	mg/L	0.75	**EPA** "Gold Book" Criteria
Cu*	0.001	mg/L	0.0134[1]	**DE** WQ Criteria for Aquatic Life Protection
Fe*	0.045	mg/L	1.0[2]	**DE** WQ Criteria for Aquatic Life Protection
Mn	0.000	mg/L	0.50	**EPA** "Gold Book" Criteria
P	0.052	µg/L	200.0	**EPA** Ecoregional Nutrient WQ Critera
Zn*	0.001	mg/L	0.117[1]	**DE** WQ Criteria for Aquatic Life Protection
NO_3-N	0.69	mg/L	10.0	**DE** WQ Criteria for Human Health Protection

1. These are acute water quality standards.
2. The only water quality standard for iron is for chronic contaminant levels.
3. This is not a standard; it is merely a suggested healthy level for EC. According to the US EPA, "Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macro invertebrates." http://water.epa.gov/type/rsl/monitoring/vms59.cfm*These values were calculated by Kiliszek (2010) assuming a pH of 7.0 and a hardness of 100mg/L $CaCO_3$.

Biological Assessment: Because of the large number of boulders located within this site, there were few stream riffles in which the researchers could collect samples of macro invertebrates. From 4 kicknet samples (the maximum allowed in under the Va. SOS protocol), only 10 organisms were collected: 4 caddisflies, 3 common netspinners, 2 craneflies, and 1 sowbug. These numbers indicate a proportionally high number of pollution intolerant species and rendered a Va. SOS index of 9, meeting acceptable ecological conditions. It should be noted that the small number of macro invertebrates collected is less indicative of the quality of the natural habitat at this site and more indicative of the difficulty that the site presented for sampling techniques. Maneuvering the kicknets around the boulder system and finding riffle sections of the stream to survey was hampered by the dense boulder system. However, the researchers believe that the Va. SOS findings, despite being based on a small sample size, are accurate in their description of the overall quality of the ecological habitat at this site given the types of organisms collected.

3.3. Hurricane Run

Lower Hurricane Run: The Lower Hurricane Run site is located within a heavily forested area of the Hurricane Run subwatershed. With its extensive trail system, hikers, runners and horseback riders often utilize this area. Much of this stream segment has eroded and undercut banks but perhaps the most defining characteristic is the large step-like topography of the underlying bedrock.

Figure 3.4. Lower Hurricane Run in H1

Habitat/Physical Assessment: The Lower Hurricane Run study site received a rating of 147.6/200 using the EPA rapid habitat assessment method, a value which is just below the minimum score (150/200) needed for an optimal rating. Score reductions were the result of erosion and undercutting along the stream's right bank (which yielded low suboptimal observations for bank stability) and lack of channel sinuosity (which produced only marginal ratings in this category). Lower Hurricane Run's epifaunal substrate/available cover, pool substrate characterization, pool variability, and channel alteration were all found to be optimal. Sediment deposition, channel flow status, vegetative protection, riparian vegetative zone width were all rated on the high end of the suboptimal range. As in Sites #1 and #2, the Lower Hurricane Run site also had noticeably steep and undercut riverbanks.

Chemical Assessment: The results of the chemical analyses performed on water quality samples from Site #4 are reported in Table 3.4. The results from this site show that, at the time these samples were taken, there is no chemical impairment present in the waters at the Lower Hurricane Run site.

Table 3.4. Site #4 chemical assessment results

Parameter	Result	Units	WQ Standard	Source
pH	7.8	-	6.5-8.5	**DE** Fresh Water Quality Standards
EC	280	µhos/cm	150-500	**EPA** Suggestion for Freshwater Habitat[3]
Al*	0.061	mg/L	0.75[1]	**DE** WQ Criteria for Aquatic Life Protection
B	0.010	mg/L	0.75	**EPA** "Gold Book" Criteria
Cu*	0.000	mg/L	0.0134[1]	**DE** WQ Criteria for Aquatic Life Protection
Fe*	0.056	mg/L	1.0[2]	**DE** WQ Criteria for Aquatic Life Protection
Mn	0.000	mg/L	0.50	**EPA** "Gold Book" Criteria
P	0.003	µg/L	200.0	**EPA** Ecoregional Nutrient WQ Critera
Zn*	0.000	mg/L	0.117[1]	**DE** WQ Criteria for Aquatic Life Protection
NO_3-N	2.20	mg/L	10.0	**DE** WQ Criteria for Human Health Protection

1. These are acute water quality standards. These values were calculated by Kiliszek (2010) assuming a pH of 7.0 and a hardness of 100mg/L $CaCO_3$. 2. The only water quality standard for iron is for chronic contaminant levels. 3. This is not a standard, it is merely a suggested healthy level for EC. According to the US EPA, "Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macro invertebrates." http://water.epa.gov/type/rsl/monitoring/vms59.cfm*

Biological Assessment: Only 36 organisms were collected in the four kicknet samples taken, which is likely because there were more runs and pools at this specific site than riffles (the ideal sampling condition). However, of those 36 individuals, 26 were caddisflies, stoneflies, and mayflies at 18, 5, and 3, respectively. These organisms are highly intolerant of pollution and their presence indicates good quality habitat. As such, with a Va. SOS index of 10, Lower Hurricane Run was at an acceptable ecological condition. It should also be noted that Hurricane Run is not listed as an impaired waterway on the 303(d) list put forth by DNREC and the EPA.

3.4. Rocky Run Main Stem

Brandywine Confluence: The fifth site just above the confluence of the Brandywine Creek and the Rocky Run main stem was reached by a trail through the Brandywine Creek State Park. This segment of Rocky Run also contained a great number of boulders and stones, but not to the magnitude of Site #3. There were also what appeared to be the remnants of a stone dam or mill located on the western stream bank at this site.

Habitat/Physical Assessment: The Rocky Run at Brandywine Creek confluence study site received an overall rating of 153/200, which is considered to be optimal. This was the highest ranking received of the five study sites. The high rating is the result of the optimal ratings given for the subcategories of epifaunal substrate/available cover, pool substrate characterization, pool variability, channel flow status, and channel alteration. Both sediment deposition and riparian vegetative zone width were ranked on the high end of the suboptimal range. Channel sinuosity and bank stability were rated as suboptimal along this reach of the river. As in some of the upstream sites, Site #5 showed signs of bank undercutting and steepness.

Figure 3.5. The Brandywine confluence with Rocky Run in R7

Chemical Assessment: The results of the chemical analyses performed on water quality samples from Site #5 are reported in Table 3.5. The results from this site show that, at the time these samples were taken, there is no chemical impairment present in the waters at the Rocky Run main stem site.

Table 3.5. Site #5 chemical assessment results

Parameter	Result	Units	WQ Standard	Source
pH	7.6	-	6.5-8.5	**DE** Fresh Water Quality Standards
EC	300	µhos/cm	150-500	**EPA** Suggestion for Freshwater Habitat[3]
Al*	0.082	mg/L	0.75[1]	**DE** WQ Criteria for Aquatic Life Protection
B	0.010	mg/L	0.75	**EPA** "Gold Book" Criteria
Cu*	0.001	mg/L	0.0134[1]	**DE** WQ Criteria for Aquatic Life Protection
Fe*	0.063	mg/L	1.0[2]	**DE** WQ Criteria for Aquatic Life Protection
Mn	0.000	mg/L	0.50	**EPA** "Gold Book" Criteria
P	0.036	µg/L	200.0	**EPA** Ecoregional Nutrient WQ Critera
Zn*	0.000	mg/L	0.117[1]	**DE** WQ Criteria for Aquatic Life Protection
NO_3-N	1.08	mg/L	10.0	**DE** WQ Criteria for Human Health Protection

1. These are acute water quality standards. These values were calculated by Kiliszek (2010) assuming a pH of 7.0 and a hardness of 100mg/L $CaCO_3$. 2. The only water quality standard for iron is for chronic contaminant levels. 3. This is not a standard, it is merely a suggested healthy level for EC. According to the US EPA, "Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macro invertebrates." http://water.epa.gov/type/rsl/monitoring/vms59.cfm.

Biological Assessment: Site #5 was particularly notable for the great number of caddisflies present. So numerous were the caddisflies that one could see them resting on the rocks without having to pick them up. Of the total 146 organisms sampled, 116 were caddisflies. These organisms are highly pollution intolerant and can only survive, especially in such large populations, in high quality habitats with minimal contamination. Thus, the Va. SOS index was 10, meeting acceptable ecological conditions.

3.5. Summary of Field Results

The following table outlines the findings from the field assessments at the five study sites throughout the Rocky Run watershed.

Table 3.6. Summary of sampling and assessment results

Subwatershed	No.	Site	Habitat	Chemical	Biological
Upper Rocky Run	#1	Residential Greenway	Suboptimal (117/200)	No identified chemical impairment	Unacceptable Va. SOS = 6
	#2	Route 202 Overpass	Suboptimal (125/200)	No identified chemical impairment	Unacceptable Va. SOS = 4
	#3	Hurricane Run Confluence	Optimal/Suboptimal (146/200)	No identified chemical impairment	Acceptable Va. SOS = 9
Hurricane Run	#4	Lower Hurricane Run	Optimal/Suboptimal (147/200)	No identified chemical impairment	Acceptable Va. SOS = 10
Rocky Run Main Stem	#5	Brandywine Confluence	Optimal (153/200)	No identified chemical impairment	Acceptable Va. SOS = 10

Chapter 4 Hydrologic Modeling

4.1. Hydrologic Modeling with TR-55

Technical Release 55 Urban Hydrology for Small Watersheds (TR-55) is a hydrologic computer-modeling program developed by the USDA Soil Conservation Service (now Natural Resources Conservation Service or NRCS) in 1975. Using equations and data inputs, TR-55 models and produces hydrographs, charts that illustrate a waterway's water discharge over time during user-defined rain events). In other words, TR-55 predicts how much water is flowing through a waterway during rainstorms. The hydrographs depict these flows over the course of a rainfall event and estimate both the maximum amount of water and how fast that water is flowing.

Recently, officials at the Brandywine State Park have expressed concern regarding the erosion of hiking trails near the mouth of the Rocky Run stream during large storm events. The heavily urbanized landscape upstream of this point has the potential to impact water flow during rain events as paved areas prevent water from seeping into the ground, thereby creating higher velocity and greater volume runoff than in natural areas. Though Rocky Run is typically considered to be a low flow stream during dry or base flow conditions, the TR-55 models afford a better understanding of what happens in the watershed during a storm, particularly as the stream moves from the urbanized, upstream portion of Rocky Run to the downstream portion near its mouth at the Brandywine Creek State Park.

4.2. TR-55 Process

The Natural Resources Conservation Service (NRCS) has streamlined TR-55 into a computer program through which the user enters specific inputs to produce stream hydrographs. Minimum data requirements for the TR-55 model include state, county, and storm data, subwatershed area(s), soil data, land use, and cross-sectional areas of the waterway, among others.

This set of data is used to determine each subwatershed's weighted curve number (the area's runoff potential during a storm event) and time of concentration (the time it takes for water to travel from the remotest part of the watershed to the waterway outlet). For more details on these assumptions and parameters involved with the TR-55 model, visit the NRCS TR-55 website: http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/hydrology/?cid=stelprdb1042901.

State, County, and Storm Data: For the analysis of the Rocky Run watershed, the following assumptions were entered into the TR-55 model: the state and county were input as Delaware and New Castle Coastal Plain DMVC respectively, and the Delmarva dimensionless hydrograph with a Type II rainfall distribution was input as the storm type.

Subwatersheds: The subwatersheds used in this model were the same as the original subwatersheds outlined in the first chapter excluding those in Hurricane Run (since Hurricane Run is not listed as an impaired waterway). This left subwatersheds R1 through R7, which were organized such that each flowed into a downstream subwatershed as an outlet: R1 and R2 flowed into R3; R3 and R4 flowed into R5, R5 into R6, and R6 into R7.

Weighted Curve Number: Soil Data and Land Use: Using ESRI ArcGIS software, a soil type map was created for the Rocky Run watershed. Using the USDA Web Soil Survey, the hydrologic soil groups (HSG) were determined for each soil type. These are groups defined by a soil's runoff potential when thoroughly wet. There are four HSG categories:

Group A soils have the lowest runoff potential when thoroughly wet as water moves freely within it. Soils in this group tend to have less than 10% clay and more than 90% sand or gravel.

Group B soils have moderately low runoff potential when thoroughly wet, having between 10% to 20% clay with 50% to 90% sand and may have sandy loam or loamy sand textures.

Group C soils have a higher runoff potential than Group B soils at 20% to 40% clay to and less than 50% sand. These soils also have loamy textures: loam, silt loam, clay loam, and sandy clay loam, among others.

Group D soils have the highest runoff potential with highly restricted water movement through the soil. These soils are generally greater than 40% clay and less than 50% sand and are generally clayey in texture.

There was no Group A soils in the Rocky Run watershed. The watershed was mostly characterized by Group B soils, with some Group C and D. Table 4.1 on the following page illustrates the types and distributions of the different soil types that can be found in the Rocky Run watershed.

Table 4.1. Soil types in the Rocky Run watershed

Map Unit	Soil Type	HSG	Acres	%
BbB	Baile-Glenville complex, 0-8% slopes	D	2.7	0.2
BkD	Brinklow Channery Loam, 15-25%	B	67.4	5.9
BnF	Brinklow-Blocktown complex, 25-65% slopes	B	0.4	0.0
DcB	Delanco-Cdorus Hartboro, 0-8% slopes, flooded	C	38.2	3.3
GaC	Gail loam, 0-3% slopes	B	5.0	0.4
GeA	Glenelg loam, 0-3% slopes	B	9.0	0.8
GeB	Glenleg loam, 3-8% slopes	B	104.2	9.1
GnB	Glenville silt loam, 3-8% slopes	C	2.5	0.2
Hw	Hatboro-Codorus complex, 0-3% slopes, frequently flooded	D	1.7	0.1
MzA	Mount Lucas silt loam, 0-3% slopes	C	135.5	11.8
MzB	Mount Lucas silt loam, 3-8% slopes	C	7.2	0.6
NtB	Neshimany silt loam, 3-8% slopes	B	31.7	2.8
NtC	Neshimany silt loam 8-15% slopes	B	58.6	5.1
NvD	Neshimany Monalto silt-loam 15-25% very stoney	B	81.5	7.1
NxB	Neshimany urban land complex, 0-8% slopes	B	13.0	1.1
TaB	Talleyville Silt Loam. 3-8%	B	44.1	3.8
TdB	Talleyville-Monalto urban land complex	B	216.2	18.8
UaB	Udorthents, bedrock substratum, 0-8%	B	57.7	5.0
Uy	Urban land, bedrock substratum	D	127.4	11.1
VwB	Urban land-Wheaton complex, 0-8% slopes	D	23.0	2.0
WaA	Watchung silt loam, 0-3% slopes	D	105.6	9.2
WaB	Watchung silt loam, 3-8% slopes	D	17.0	1.5

Once hydrologic soil groups were identified, the next step was to approximate the area (ac) of each HSG by land use category: commercial and business, residential, pasture/grassland, woods, paved parking lots, and streets and roads. Together, the soil data, land use data, and area were used by the program to calculate the weighted curve number.

Time of Concentration: Several inputs were needed to calculate time of concentration, or the time it takes for water to travel from the point furthest away from the waterway to the waterway. These inputs were equal to the length and slopes of sheet flow, shallow concentrated flow, and channel flow. Sheet flow is defined as 100 ft. from the point furthest away from the waterway towards the waterway. Slope was determined using the 10 ft. contours from the US Topography map and is formulated as length (ft.) over elevation (ft.). The second calculation, shallow concentrated flow, is the length from the sheet flow end point to the waterway. Slope was again calculated using the 10 ft. contours from the US Topography map. The channel flow calculation was the length of the waterway from the shallow concentrated flow to its outlet. Again, slope is defined as length (ft.) over elevation (ft.). Other inputs for channel flow not required of sheet flow and shallow concentrated flow were cross-sectional area (determined through the stream bank cross sections measured at the study sites) and the wetted perimeter (the amount of surface area in the stream bank and bed that is submerged in water during flood events calculated as the lengths of the bank walls and streambed). Once the data were properly input, the TR-55 program calculates velocity and time of concentration for each subwatershed.

4.3. Modeling Results

Together, the weighted curve number and the time of concentration along with geographical and rainstorm data were used by the program to estimate peak volume and time during a storm event. Table 4.2 summarizes the peak volume in cubic feet per second (cfs), the time into the storm at peak volume, and the volume per acre. Conventional wisdom dictates that an urbanized stream with greater impervious surfaces in its land uses would have a greater volume per acre than its more natural counterparts where more water can infiltrate the soils. Figures 4.1-4.3 depict the peak volumes and times for 2 year, 10 year, and 100 year storm events respectively.

Table 4.2. Peak volume and time results for storm events

Subareas	Area (ac)	2-year Storm			10-year Storm			100-year Storm		
		Peak (cfs)	Peak (hr)	cfs/ac	Peak (cfs)	Peak (hr)	cfs/ac	Peak (cfs)	Peak (hr)	cfs/ac
R1	52.8	149	11	2.8	242	11	4.5	424	12	8.0
R2	127.1	127	12	2.4	254	12	4.8	523	12	9.9
R3	168.9	137	12	2.6	304	12	5.7	677	12.	12.8
R4	92.0	101	12	1.9	198	12	3.7	401	12	7.6
R5	162.8	336	12	6.3	538	12	10.1	936	12	17.7
R6	79.0	24	12	0.5	71	12	1.3	189	12	3.5
R7	152.4	13	12	0.3	58	12	1.1	201	12	3.8

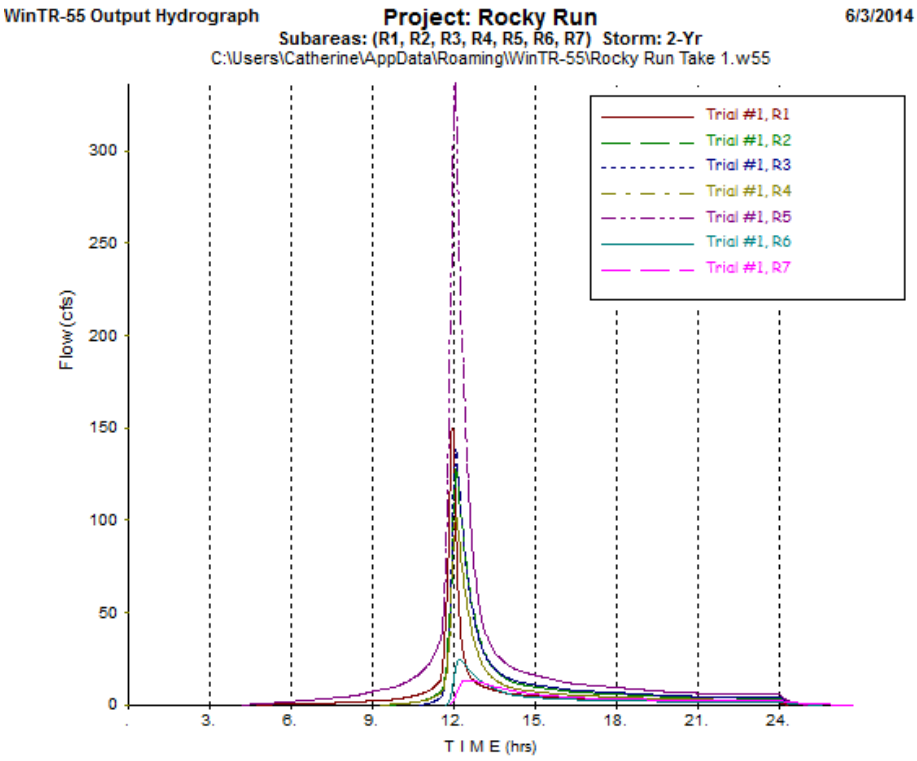

Figure 4.1. 2-year storm hydrograph along Rocky Run

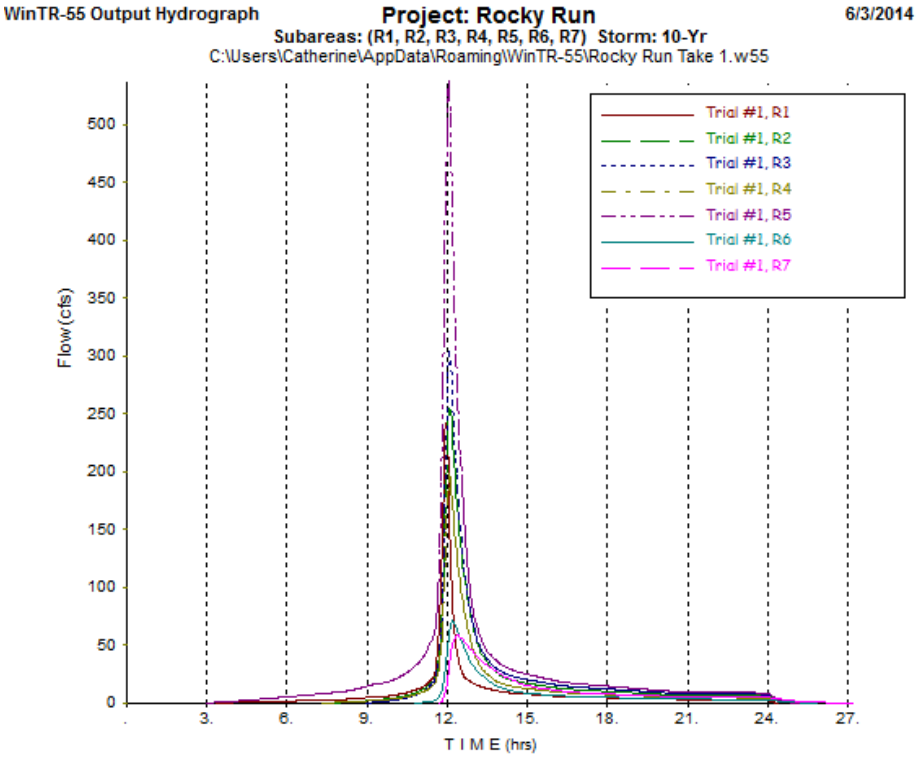

Figure 4.2. 10-year storm hydrograph along Rocky Run

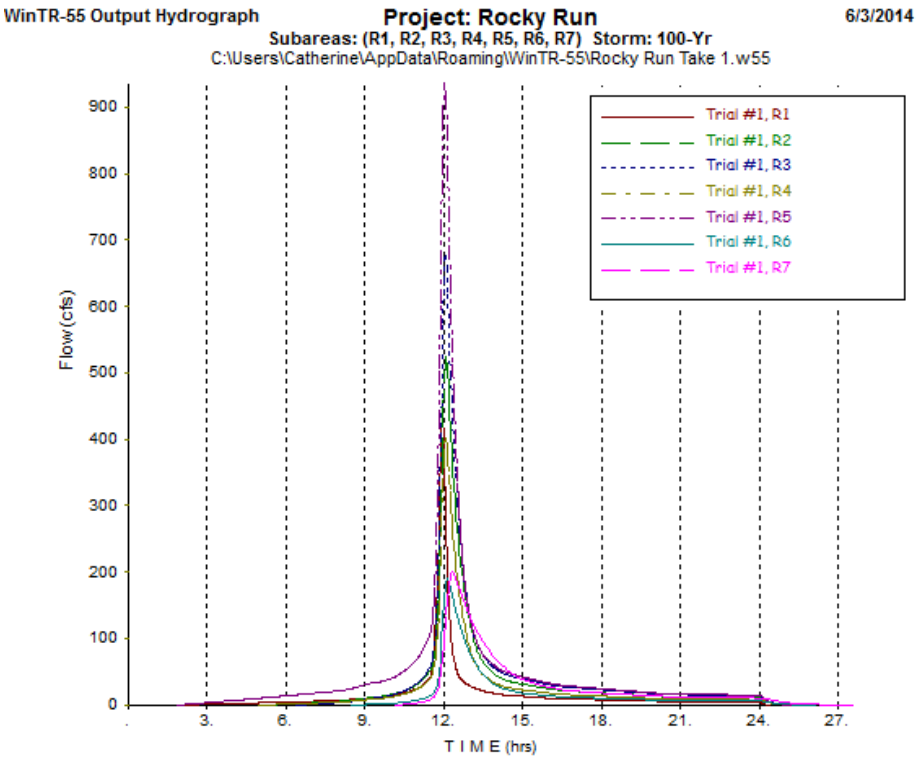

Figure 4.3. 100-year storm hydrograph along Rocky Run

As expected, the subwatersheds with the highest peak flows were those with the most urbanized landscapes farther up in the watershed, regardless of the size of storm event. R1 (in a residential area) and R5 (the subwatershed containing the Concord Mall) had the greatest discharges. R6 and R7, the most forested subwatersheds, had the lowest peak discharges despite being furthest downstream subwatersheds (which receive the elevated stream discharges from the more urbanized areas to the northeast).

The implications of these results are that the magnitude of water flow from the upstream, urbanized portion of the watershed is over 25 times that of the downstream, forested portion of the watershed. Future HECRAS modeling is recommended for more detailed peak flow estimations and for estimations in water holding capacities of the current waterway, particularly in the subwatersheds with high discharge rates during storm events and around the channelized section of the stream.

Chapter 5
Policies Applicable to the Watershed

5.1. Federal Regulations

There are two major federal laws that aim to protect water quality in streams like Rocky Run. They are the Clean Water Act and the Safe Drinking Water Act (USEPA 2012).
The major applicable provisions of each act are described below.

The Clean Water Act: The Clean Water Act (CWA) of 1972 establishes the basic structure for regulating discharges of pollutants into the waters of the United States and protecting the quality standards for surface waters. Several major Clean Water Act statues apply directly to the Rocky Run watershed and the larger Brandywine Creek watershed. They are:

§301: Establishes effluent limitations, which effectively prohibits any pollutant discharges into waters of the United States unless authorized via a permit from the US Environmental Protection Agency.

§303: Requires states to identify waters within their boundaries that are “impaired” or that do not meet water quality standards for their designated uses.

§304: Requires the EPA to provide assistance to the states so that they may develop their own water quality standards that protect the quality of waters within their boundaries and the ability of those waters to fulfill their designated uses. These standards ultimately inform and control the regulation of pollutant discharges into waterways.

§319: Gives the EPA authority to issue grant money to states and local governments that are in the process of developing plans and practices to handle nonpoint source pollution-related water quality problems.

§402: Establishes the National Pollutant Discharge Elimination System (NPDES), which is the permit program, to be run either by the EPA or by a delegated state agency that all effluent dischargers must obtain before they can discharge into waters of the United States. This may include municipal sources like publicly owned treatment works (POTWs) that process both sewer and storm water. Delaware operates its own NPDES permit program with authority from the EPA.

Safe Drinking Water Act: The Safe Drinking Water Act (SDWA) of 1974 is the primary federal law that ensures the quality of Americans' drinking water. Under SDWA, the EPA sets standards for drinking water quality and oversees the states, localities, and water suppliers who implement those standards. Rocky Run is a tributary of Brandywine Creek, which serves as the main source of drinking water for the City of Wilmington. The major provisions of the Act that apply specifically to the Rocky Run watershed are:

§1412: Requires the development of a National Primary Contaminant List by the EPA in order to identify the types and acceptable concentrations of certain physical and chemical contaminants in public drinking water supplies.

§1413: Establishes the principle of state primacy, which allows states to assume responsibility for operating their own drinking water standards programs, provided that their standards are at least (if not more) stringent than the federal standards.

§1453: Requires the states to complete Source Water Assessments in order to identify the quality of, as well as threats to, the natural sources of drinking water for the public supply.

5.2. Delaware Regulations

The Delaware Constitution can be found online at http://delcode.delaware.gov/. Title 7 of this Code outlines Conservation practices for Delaware and several chapters within this Title relate to water management and policy (State of Delaware, Code, 2013). Typically, the requirements in these chapters are managed by two state divisions: the Division of Water, whose mission is to manage and protect water resources by providing technical assistance, laboratory services, regulatory guidance and implementation, educational services; and the Division of Watershed Stewardship, whose mission is to preserve and protect Delaware's soil, water, and coastal resources by managing Delaware's shoreline, coastal zone and navigable waterways through the regulation of coastal and urban land use and construction activities, and by promoting smart agricultural and urban land management practices. Both of these divisions operate out of the Department of Natural Resources and Environmental Control.

Chapter 40: Erosion and Sediment Control: Designed to foster the improved management of erosion and sedimentation issues throughout Delaware. The policy of Chapter 40 is to strengthen and extend erosion and sediment control activities and programs of the state for both rural and urban lands and to provide for control and management of stormwater runoff consistent with sound water and land use practices. As set forth by the regulations in this chapter, no person (barring certain exceptions) shall engage in land disturbing activities without submitting a sediment and stormwater management plan to the appropriate plan approval authority and obtaining a permit to proceed.

Chapter 44: Flood Mitigation Standards: Seeks to promote the public health, safety and general welfare, and to encourage the utilization of appropriate construction practices in order to prevent or minimize flood damage in the future. Though flooding can be a natural phenomenon, it is often caused or exacerbated by human development and activities, and must be minimized by maintaining natural drainage and by constructing effective flood prevention mechanisms.

Chapter 60: Environmental Control (Subchapter VI: Source Water Protection): The state law dedicated to protecting the natural sources of public drinking water supplies throughout the state, including surface and groundwater supplies. This law requires municipalities with year-round populations greater than 2,000 people (and encourages municipalities with smaller populations) to incorporate the findings of the local federally mandated source water assessment into their codes and ordinances. Some of the protective ordinances put in place by local

governments may include wellhead and wetland buffers, impervious surface limitations, graduated riparian buffer zones, etc.

Chapter 66: Wetlands: Much of the wetlands within the state of Delaware have been lost or destroyed by dredging, dumping, and filling, and that the remaining wetlands in Delaware are also in jeopardy. This chapter highlights the state's commitment to the idea that the preservation of wetlands in Delaware is crucial. As a result, the regulations go beyond the mandatory federal permitting system to require that a permit must be obtained from the appropriate county or municipal government before any activity that may alter or impact a wetland can occur.

Section 7400: Watershed Assessment Section: Establishes water quality standards for surface waters along with designated uses for watersheds across the state. There are chronic and acute water quality standards for dozens of contaminants in both fresh water and marine environments. The designated uses vary from those dedicated to the water's end use as a potable or industrial supply, or they focus more on human interactions with the water while it is still in the stream (acceptable for primary or secondary human contact). Still other types of designated uses focus more on the waterway's capacity to support fish and wildlife.

According to DNREC's Delaware surface water quality standards, Brandywine Creek is designated for several uses (State of Delaware, 2011). The following uses are to be protected throughout the entire stream basin: industrial water supply, primary contact recreation, secondary contact recreation, fish, aquatic life, and wildlife. The following uses are designated for the freshwater segments only: public water supply source and agricultural water supply.

Exceptional Recreational or Ecological Significance (ERES) waters are designated from the PA/DE line to the Wilmington city line. Cold-water fish (put-and-take) is designated from March 15 to June 20 on Beaver Run from PA/DE line to Brandywine and from Wilson Run Route 92 through Brandywine Creek State Park.

Senate Bill 64: Passed in response to growing concerns regarding flooding and drainage problems in the Delaware from rising sea levels and extreme storms. Governor Jack A. Markell signed Senate Bill 64 on August 17, 2011 establishing a Floodplain and Drainage Advisory Committee that recommended that the 57 municipalities and 3 counties in Delaware adopt the following minimum floodplain and drainage standards by code or ordinance (Cruz-Ortiz, 2013).

Floodplain standards:

1. For all new development activities that exceed 50 lots or 5 acres in locations contiguous to streams <u>without</u> a FEMA-delineated floodplain, a floodplain study shall be conducted.

2. For all new development that exceed 50 lots or 5 acres in Zone A FEMA floodplains, a flood study shall be submitted to FEMA for approval prior to record plan approval.

3. Only FEMA approved floodplain and BFE data shall be shown on record plans and development documents.

4. Only base flood elevation data approved by the appropriate county or municipal agency or FEMA may be used in building permit application documents.

5. Floodplain information must be included on permitting documentation.

6. Require use of FEMA elevation certificate and flood-proofing certificate.

7. Require 18 inches of freeboard for all new construction and substantial improvements or require 12 inches of freeboard for all new construction and substantial improvements.

8. Require 18 inches of freeboard for manufactured homes.

9. Fill placed in the floodplain which results in land having an elevation less than 18 inches above base flood elevation will not result in a relaxation of floodplain standards.

Drainage Standards:

1. Easements of an adequate width shall be required over drainage conveyance systems within any proposed subdivision.

2. Drainage conveyance systems within proposed subdivisions shall meet the minimum 10-year storm event.

3. Lot grading shall ensure adequate drainage away from buildings and accessory structures without creating an adverse impact to adjacent structures or lands.

4. A topographic plan submittal shall be required for all construction activity greater than 5,000 square feet.

5. An as-built submittal shall be required for any construction with an approved topographic plan.

5.3. New Castle County Regulations

The New Castle County Code of Ordinances consists of various chapters that extensively discuss water management and water policy (Municode, County of New Castle, 2013). The Code can be found online here http://library.municode.com/index.aspx?clientId=14845.

Chapter 12 Drainage: Looks closely at sediment and stormwater management (Article 5), stormwater management facility and watercourse maintenance (Article 6) and drainage improvement by New Castle County (Article 7).

Chapter 31 Utilities (Article 2 - Sewers and Sewage Disposal): Outlines information on wastewater discharge permits.

Chapter 40 Unified Development Code: Contains many of the environmental regulations put forth by the county that pertain to water resources. The major provisions of this chapter that relate to the Rocky Run watershed are listed below.

§40.10.310: Establishes floodplain and floodway protections in order to prevent (or at the very least, strictly regulate) construction and development in identified floodplains.

§40.10.330: Requires the establishment of riparian buffer zones along both public water supply and non-public water supply waterways. Development, activities, and the amount of permitted impervious surface cover are limited in these zones.

§40.10.340: Limits development on steep slopes where the gradient is greater than or equal to 15% in order to promote safety and minimize erosion.

§40.10.380: Establishes Water Resource Protection Areas (WRPAs) in karst areas like the Cockneysville Formation, around public water supply wellheads, and recharge areas. As in the riparian buffer zone, development and activities are regulated, and the permissible amount of impervious surface cover is limited to 20% of the total area.

§40.22.210: Covers the management of stormwater and storm drainage, including the installation of green infrastructure technologies and other best management practices in order to reduce the negative impacts associated with flooding and runoff with a particular emphasis on new development.

Chapter 6
Discussion and Recommendations

6.1. Discussion

The major findings of this report generally support the findings of the Delaware Department of Natural Resources and Environmental Control's findings that sections of Rocky Run are impaired for biology and habitat. The analyses presented in this report demonstrate, based on the data available, the most impaired sections of the stream are in the upper reaches of the Rocky Run watershed near Concord Pike and Concord Mall in the areas of significant urbanization. The habitat and biological assessments indicate the forested, natural areas farther down in the watershed exhibit the characteristics of healthier ecosystems.

The chemical assessments completed as a part of this analysis indicate that there are little or no chemical impairments in the Rocky Run watershed. These findings are consistent with the Delaware Clean Water Act Section 303d list of impaired streams, as DNREC officials were also unable to identify specific chemical sources of impairment. However, water quality sampling ought to be repeated over various hydrologic and seasonal conditions to verify these findings, considering that the sampling conditions studied in this report are fairly limited. Generally, the researchers would expect to see higher chemical concentrations in the heavily urbanized areas of the watershed in the headwaters, particularly downstream from residential neighborhoods, Concord Mall, and shopping centers along the Route 202 corridor.

Hydrologic modeling using TR-55 indicated the reaches of the stream that are the most "flashy" during storm events are found in the headwater region where development (and subsequently, impervious surface cover) is the greatest. During storm events, these high velocity large quantity stream flows can lead to increased erosion and sediment transport, which disrupt the benthic habitat system by replacing gravel/cobble substrate with silt and sediment (Missouri Department of Natural Resources, 2009). This theory is supported by the rapid visual assessments completed in the upper reaches of the stream, where researchers observed heavily eroded banks and stream channels, silty streambed habitat, and few natural riffles. Large tracts of impervious surface cover may contaminants into the stream, which are detrimental to local aquatic life.

Ultimately, DNREC confirmed that the main reason Rocky Run appears on the Delaware 303(d) List as an impaired waterway for biology and habitat is because roughly a mile of the stream flows through a trapezoidal concrete channel behind Concord Mall that is capable of supporting minimal (if any) aquatic life. In his work on the ecological impacts associated with channelization, Brooker (1985) states that directing a stream through a channel like the one present in the Rocky Run watershed has the potential to negatively affect the stream and the aquatic life that lives there in a variety of ways. Among them are increases in flow velocity; increases in water temperature, the disturbance or removal of natural habitat and cover, increased sediment transport, and an alteration of natural stream depth. Further study would be required to confirm the extent of such problems, but visual observations confirm the complete removal of natural habitat and benthic substrate in large stretches of the channelized area.

In addition to the channelized portion of the stream, reaches farther upstream in the residential area of the watershed (Site #1) were also found to be ecologically compromised under the rapid habitat and biological assessments. The flashiness during storm events predicted by the hydrologic models could explain some of this degradation. However, the absence of pollution intolerant macro invertebrates could signal impairments not accounted for in this research. For example, measurements for water temperature and dissolved oxygen were not taken as a part of this study, and there are a variety of chemicals not tested for by the laboratory that may be present in an urbanized watershed. More frequent sampling in various weather conditions is needed to identify chemical impairments. If pollution were being carried into the stream by runoff during storm events, it would be beneficial to sample during or shortly after rainstorms.

6.2. Recommendations

Based on the current ecological conditions identified in the Rocky Run watershed, there are a variety of recommendations the researchers would like to suggest for managing the impaired waterways. This section outlines those recommendations, which will include both structural and non-structural remediation techniques, and they will be presented by watershed. Table 6.1 depicts the recommendations presented in this chapter by subwatershed.

Table 6.1. Executive summary of recommendations

Subwatershed	Structural Recommendation	Non-Structural Recommendation
Upper Rocky Run	Channel removal Storm basin retrofit (feasibility study)	Downspout disconnection Rain barrel installation Rain garden installation in parking lots Reforestation
Hurricane Run	No recommendations, unimpaired waterway	No recommendations, unimpaired waterway
Rocky Run Main Stem	Bioengineering to restructure boulder system (feasibility study)	Reforestation

Structural Recommendations: The primary recommendation to restore the impaired waterways in the Upper Rocky Run subwatershed is to remove the trapezoidal concrete channel that stretches from the north end of the Concord Mall to the Route 202 overpass. The previous chapter details the negative impacts on ecology and habitat associated with stream channelization, and the best way to improve this section of the stream is to remove the concrete channel and restore natural benthic and stream bank conditions. However, this method would likely be a costly venture that would require a significant financial commitment from interested parties as well as the cooperation of the local landowner (Concord Mall Management). Regardless, it may be worth the effort to complete a feasibility study on channel removal.

Because channel removal may be cost prohibitive, other structural techniques ought to be considered in the reaches of the stream around the Concord Mall. In this area behind the restaurant Red Lobster, there is a large stormwater retention basin that is meant to capture some of the water from an adjacent strip mall before it enters the stream. The researchers recommend studying the feasibility of retrofitting stormwater basins along the Concord Pike commercial corridor to increase its water storage and infiltration capacity to mitigate the effects of large

storm and flood events on the lower Rocky Run as it cascades down through the forested State Park and First State National Park to the Brandywine Creek.

Some areas of the Rocky Run Main Stem display significant erosion and undercutting. Researchers recommend that a feasibility study be conducted on the potential to use bioengineering techniques to restructure and reposition the natural boulder system that exists within the stream to stabilize heavily eroded portions of the stream bank.

Non-Structural Recommendations: There are a variety of non-structural techniques that may be employed in the Upper Rocky Run subwatershed, particularly to decrease the amount of runoff from impervious surfaces reaching the stream. This is especially important in the residential and commercial areas of this subwatershed, where hydrologic models indicate elevated flashiness during storm events that can lead to erosion and compromise aquatic habitat.

In the residential areas, downspout disconnection and installation of neighborhood rain gardens and rain barrels can minimize the runoff contribution from housing infrastructure. Educational programming for local residents on the issue of stormwater runoff and steps they can take to mitigate its impact would be crucial to successful implementation. Local residents can also become more engaged in their watershed through stream cleanups in the areas where litter and debris were identified by the researchers.

Runoff from the parking lot of the Concord Mall and other local strip malls could be mitigated through the installation of small rain gardens or other vegetated islands in parking areas. These areas would serve to slow and absorb stormwater as it moves across the impervious surface, minimizing the amount of water that reaches the stream.

Finally, reforestation around the stream channel floodplain is recommended for several reasons. Bank stabilization will be beneficial in areas where erosion has been identified and there is little or no existing riparian buffer. Trees also have the capacity to absorb water and encourage infiltration into the soil, which can reduce runoff into the stream, and they provide shade over the stream, which can help regulate temperature and provide organic material (leaves and other plant debris) that serves as a base source of energy for the stream's food chain. Currently, the most feasible area for reforestation in the near future is just above the beginning of the channelized section of the stream upstream from Concord Mall. This parcel of land is owned and controlled by the New Castle County government, and government officials have expressed interest in participating in the process of restoring Rocky Run.

The Main Stem of Rocky Run appears to be fairly healthy according to the results of this study. However, there are some basic recommendations that could serve to further improve this area's overall quality in terms of ecosystem and aquatic life habitat. Although the majority of the Rocky Run Main Stem is well vegetated, there are some areas where reforestation efforts may be beneficial, particularly to stabilize stream banks in areas where they are currently eroded and vulnerable. However, researchers recommend that reforestation efforts should first be directed in the areas where they are most needed, particularly in the Upper Rocky Run subwatershed, before limited financial and capital resources are allocated to improving the fairly healthy downstream reaches.

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Appendix A
Macroinvertebrate Assessment Sheets

Monitors checklist for the Va. SOS modified method

1) Choose a site (riffle) that is accessible (public property or with landowner permission) and that has the stream water bubbling over cobblestone sized rocks (3"-10" at the widest part of the particle). We strongly encourage monitors to avoid DEQ monitoring sites and the mixing zone of permitted wastewater discharges.

2) Use a Va. SOS seine net. This mesh is important for quality assurance purposes.

3) Approach the riffle from downstream (so as not to disturb potential collection areas) and position the net just below a spot with maximum bubbling action and a predominant number of cobbles. (approx. 45 degree angle) The net should be spread as widely as possible and set to allow a direct flow of water into the center of the net.

4) The monitor that will do the rubbing should take some cobbles from OUTSIDE the area to be sampled and rub them underwater (and outside of the "net zone")before gently laying them on the bottom of the net to anchor the net to the stream bottom.

5) The person holding the net will then time the other monitor to allow the rubbing of rocks for twenty seconds immediately upstream of the net. The final five seconds will be announced and for that time the "rubber" will scratch the stream bottom with their fingers or a garden cultivator type tool to collect any organism that live in the substrate.

6) Rub the "anchor" stones to remove any critters that may have attached themselves and with a forward and scooping motion remove the net from the stream. Examine the net for any organisms that are not macroinvertabrates (minnows or salamanders) and return them to the stream.

7) Take the net to the streamside and place it on a sheet that will allow for identification of any organisms that may pass through the mesh. Use ice cube trays and dishes to pick ALL organisms. Examine both sides of the net and the sheet beneath to obtain a rigorous count of all aquatic macroinvertabrates that were caught.

8) Repeat this procedure until a composite of all nets yields a total of organisms in excess of 200. Remember to thoroughly pick each net and add the total to the previous total. The time devoted to rubbing can be modified according to the judgment of the monitors but can not exceed 90 seconds per "dip". Also, no more than 4 "dips" can be made in pursuit of exceeding 200 organisms. If the monitors fail to find 200 organisms in 4 "dips" the calculation shall be made with the total that is obtained. Special note of this fact should be made in reporting the data.

9) With the individual counts of the organisms according to the categories as listed on the Va. SOS identification sheet and the total of all categories, calculate the six percentages (metrics) and combine them into one index value using the Va. SOS field calculation sheets. Be sure to report your results to Va. SOS ASAP.

Do this four times a year (every 3 months). Thank you for being a Va. SOS monitor!!!

Individual Metrics

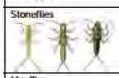
Metric Number	Metric Organism Group	Number of metric organism		Total number of organisms in the sample		Percent (This is your value for this metric)
1	Mayflies + Stoneflies + Most Caddisflies		÷		Multiply by 100	%
2	Common Netspinners		÷		Multiply by 100	%
3	Lunged Snails		÷		Multiply by 100	%
4	Beetles		÷		Multiply by 100	%

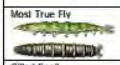
Metric 5 - % Tolerant

Taxon	Number
Worms	
Flatworms	
Leeches	
Sowbugs	
Scuds	
Dragonflies and Damselflies	
Midges	
Black Flies	
Lunged Snails	
Clams	
Total Tolerant	
Total Tolerant divided by the total number of organisms in the sample	
Multiply by 100 **This is your Value for Metric 5**	

Metric 6 - % Non-Insects

Taxon	Number
Worms	
Flatworms	
Leeches	
Crayfish	
Sowbugs	
Scuds	
Gilled Snails	
Lunged Snails	
Clams	
Total Non-Insects	
Total Non-Insects divided by the total number of organisms in the sample	
Multiply by 100 **This is your Value for this Metric 6**	

Macroinvertebrate	Tally	Count
Worms 		
Flat Worms 		
Leeches 		
Crayfish 		
Sowbugs 		
Scuds 		
Stoneflies 		
Mayflies 		
Damselflies and Dragonflies 		
Hellgrammites, Fishflies, and Alderflies 		

Macroinvertebrate	Tally	Count
Common Netspinner 		
Most Caddisfly 		
Beetles 		
Midges 		
Blackflies 		
Most True Fly 		
Gilled Snail 		
Lunged Snail 		
Clams 		
Other Subsurface Invertebrates		
TOTAL NUMBER OF ORGANISMS IN SAMPLE		

Save Our Streams Multimetric Index

Write your metric value from the previous page in the 2nd column (Your Metric Value). Determine whether each metric should get a score of 2,1, or 0 – depending upon the range of your metric value. Put a check in the appropriate box for your metric value under 2,1, or 0. Count the total number of 2's, 1's, and 0's. Follow the multiplication at the bottom of the chart to determine your Save Our Streams Multimetric Index score and determine whether the site has acceptable or unacceptable ecological condition.

Metric Number	Metric Organism	Your Metric Value	2	1	0
1	% Mayflies + Stoneflies + Most Caddisflies		Greater than 32.2	16.1 – 32.2	Less than 16.1
2	% Common Netspinners		Less than 19.7	19.7 – 34.5	Greater than 34.5
3	% Lunged Snails		Less than 0.3	0.3 – 1.5	Greater than 1.5
4	% Beetles		Greater than 6.4	3.2 – 6.4	Less than 3.2
5	% Tolerant		Less than 46.7	46.7 – 61.5	Greater than 61.5
6	% Non-Insects		Less than 5.4	5.4 – 20.8	Greater than 20.8
			Total # of 2s:	Total # of 1s:	Total # of 0s:
		Subtotals:	Multiply by 2:	Multiply by 1:	Multiply by 0:

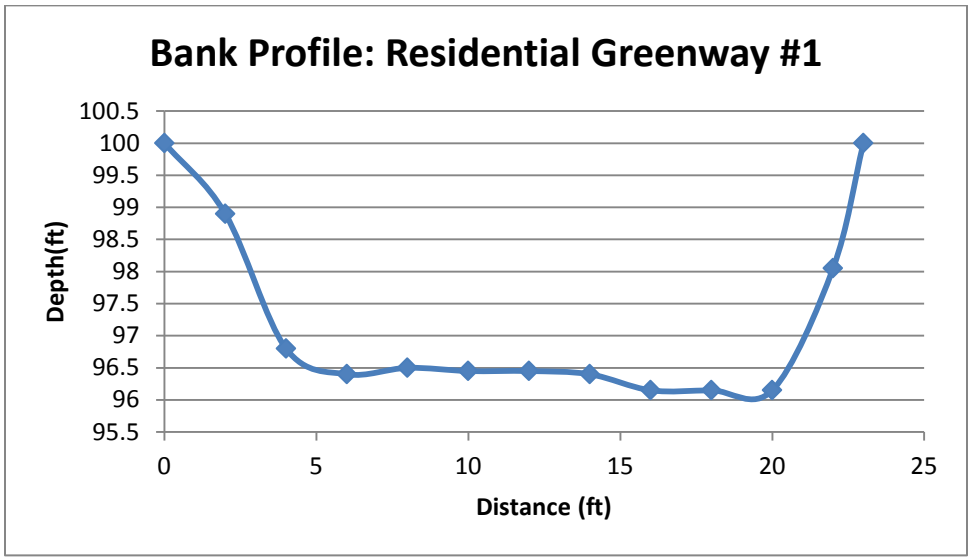
Now add the 3 subtotals to get the Save Our Streams Multimetric Index score:_____

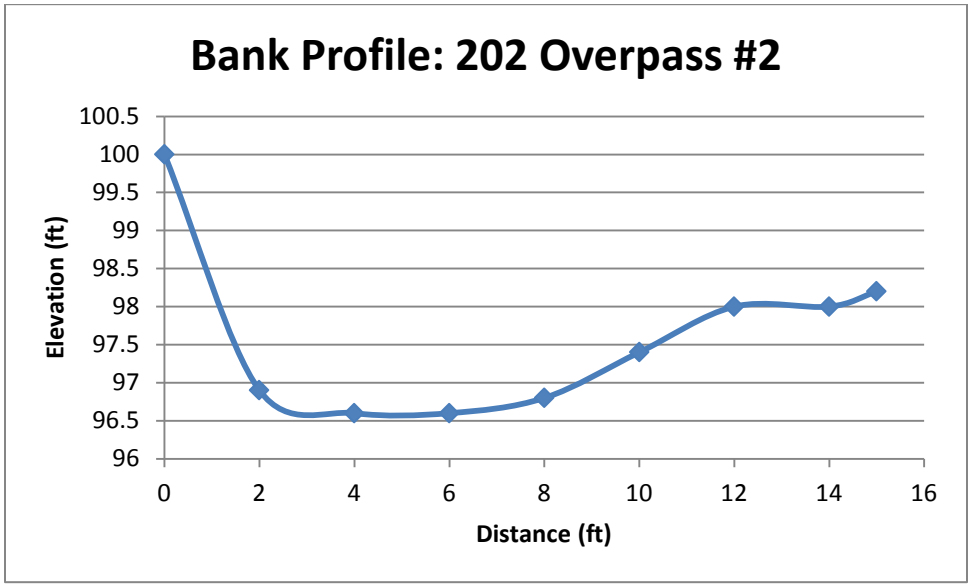
_____Acceptable ecological condition (9 to 12)

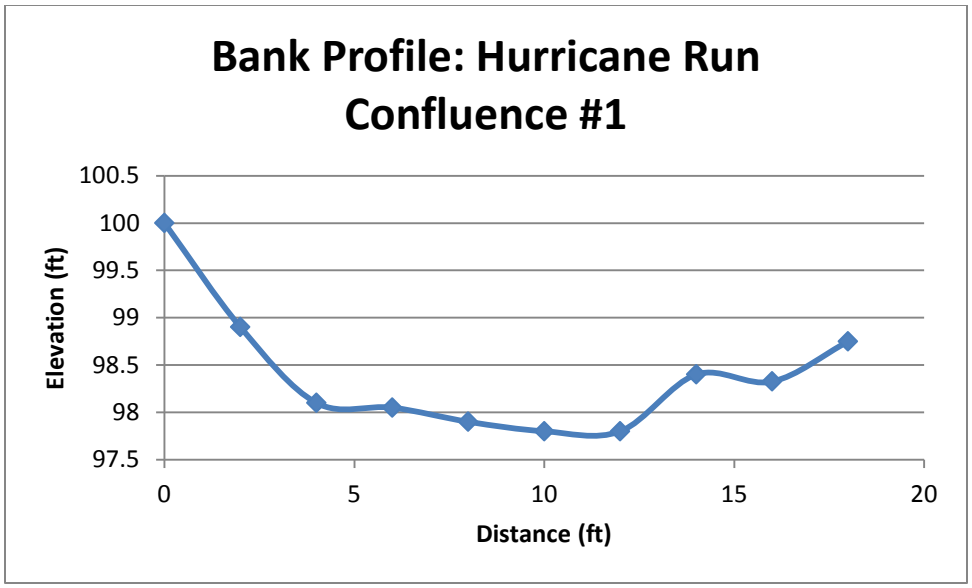
_____ Ecological conditions cannot be determined at this time (Gray Zone) (8)

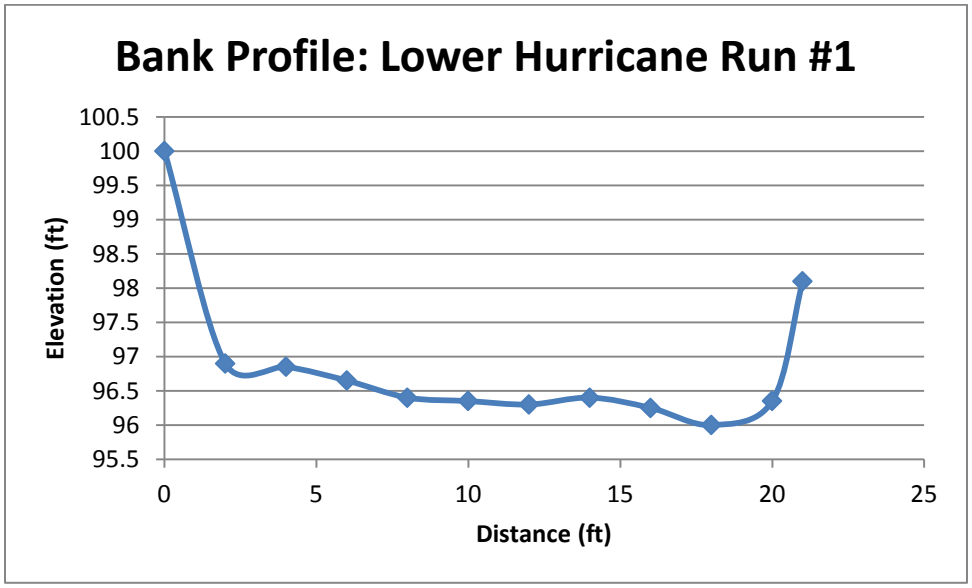
_____Unacceptable ecological condition (0 to 7)

Appendix B
Stream Cross Sections






Bank Profile: Hurricane Run Confluence #1
Elevation (ft)
100.5
100
99.5
99
98.5
98
97.5
0
5
10
15
20
Distance (ft)


Bank Profile: Lower Hurricane Run #1
Elevation (ft)
100.5
100
99.5
99
98.5
98
97.5
97
96.5
96
95.5
0
5
10
15
20
25
Distance (ft)

Appendix C
Stakeholders in the Rocky Run Watershed

Government
National Park Service
Delaware Department of Natural Resources and Environmental Control
Delaware State Parks Service
Delaware Department of Transportation
New Castle County Conservation District
New Castle County Government
City of Wilmington
City of Wilmington Public Water Supply
New Castle County Chamber of Commerce

Nonprofits
The Nature Conservancy
The University of Delaware Water Resources Agency
The Delaware Nature Society
Delaware Audubon
Delaware Chapter of the Sierra Club
Partnership for the Delaware Estuary

Homeowners Associations
Country Gates
Presidential Estates
Village of Rocky Run

Other
Widener Law School
Brandywine Country Club

Businesses
Concord Mall
Concord Mall Management
AB Sports
Aeropostale
American Eagle Outfitters
American Greetings
AT&T Wireless
Auntie Anne's Hand-Rolled Soft Pretzels
Barnes & Noble
Bath & Body Works
Best Buy
Body Central
Boscov's
Cafe Riviera

Champs
Chick-fil-A
The Childrens Place
China Express
Christopher & Banks
Claire's Boutique
Coffee Beanery
Concord News Stand
Customer Service
Dakota Watch Co
Del Haven Jewelers
Dream Fragrance
Eastern Mountain Sports
Express
Famous Footwear
Fast Feet Shoe Repair
Foot Locker
FYE (For Your Entertainment)
GameStop
GNC Live Well
Gordon's Jewelers
H&M
Hallmark
Hollister Co.
Hot Topic
Hugs & Yogurt
Journeys
Justice
Kay Jewelers
Kids Foot Locker
Kitchen Kapers
Lady Foot Locker
Lane Bryant
LensCrafters
Lids
LOFT
Macy's
Macy's Home Store
Mall Management*
Mall Security
New Images
New York & Company
Noodles & Company
Pac Sun
Payless ShoeSource
Piercing Pagoda

Piercing Pagoda Plus
RadioShack
Red Lobster
Regis Salon
Retro Fitness
Ruby Tuesday Restaurant
rue21
Sbarro Italian Eatery
Schuylkill Valley Sports
Sears
Sears Auto Center
Spencer's
Sprint
Subway
Sunglass Hut
Things Remembered
T-Mobile
ULTA Beauty
Verizon (We R Wireless)
Verizon FiOS
Victoria's Secret
Wet Seal
Yankee Candle
Zales
Zumiez

Brandywine Commons II
Sports Authority
Raymour & Flannigan
The Tile Shop
ShopRite

Other
Applebees
Brandywine Country Club
DoubleTree by Hilton
Inn at Wilmington
Kohls
Homewood Suites
Courtyard Wilmington-Brandywine
Grace Episcopal Church