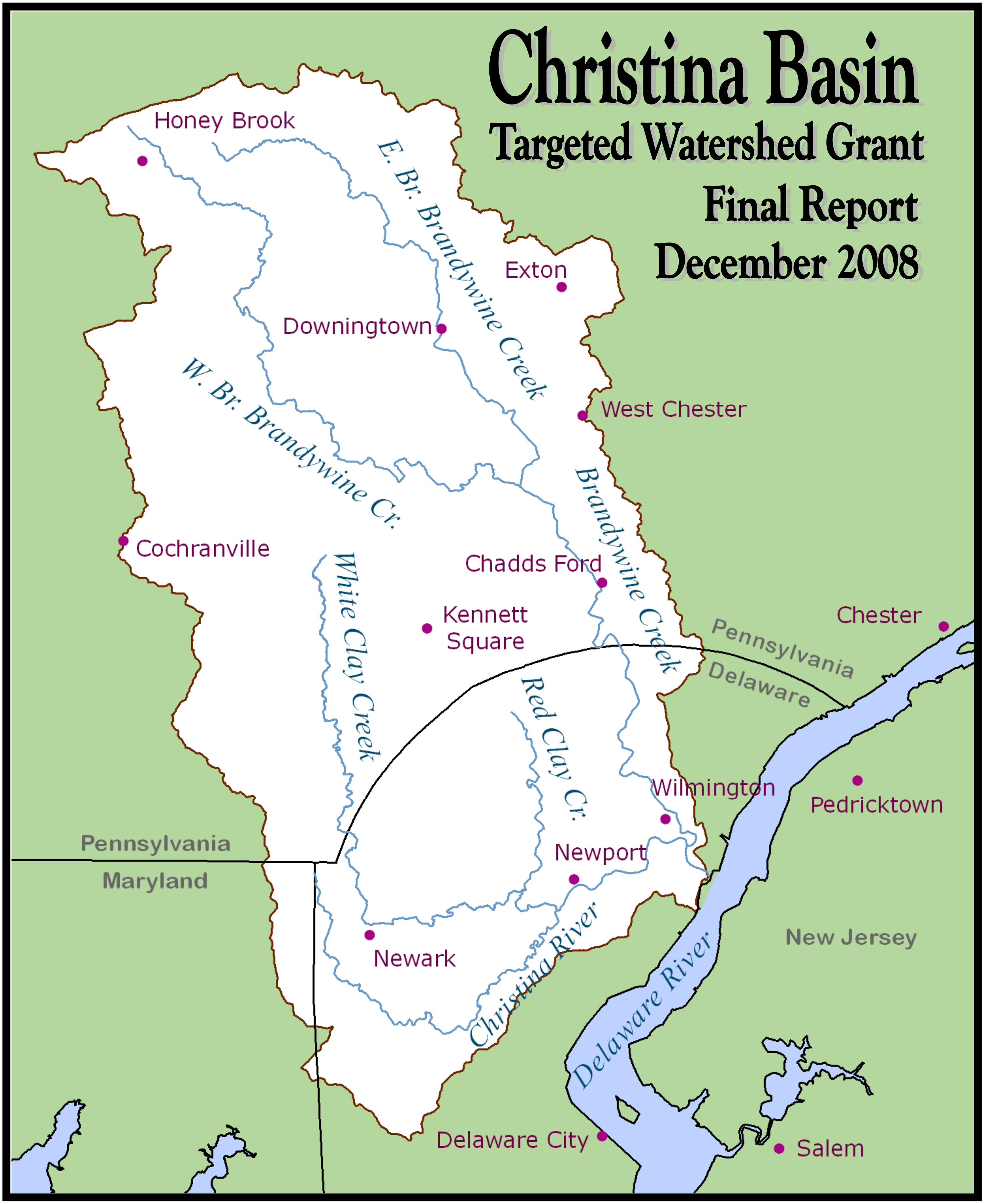
Christina Basin

Targeted Watershed Grant

Final Report

December 2008



Christina Basin Targeted Watershed Grant
Final Report

"A $1 million USEPA watershed restoration grant awarded to the Christina Basin in Delaware and Pennsylvania as the No. 1 rated application among 176 watersheds in the USA."

December 2008

Prepared by:

Pamela V'Combe
Delaware River Basin Commission
West Trenton, New Jersey

Edited by:

Martha Corrozi Narvaez
University of Delaware
Institute for Public Administration-Water Resources Agency
Newark, Delaware

On behalf of:

Christina Basin Clean Water Partnership

ACKNOWLEDGEMENTS

The Chester County Conservation District would like to acknowledge the following stakeholders who participated in watershed restoration projects in the Pennsylvania portion of the Christina Basin:

- Christian Fisher and Gary Westlake, who graciously provided property access to the Pennsylvania Department of Environmental Protection (DEP) for completion of this monitoring project.
- Southeast Region DEP Water Pollution Biologists Alan Everett and Allen Whitehead, who co-wrote this report.
- Pennsylvania DEP personnel who provided time and technical expertise to this monitoring project including: Alan Everett, Allen Whitehead, Mark Zolandz, Ed Filip, Joy Gillespie, Mike Boyer, and Dave Burke.

The Delaware Department of Natural Resources and Environmental Control would like to acknowledge the following stakeholders who participated in watershed restoration projects in the Delaware portion of the Christina Basin:

- Three Little Bakers Golf Course, specifically Nick and Hugo Immediato
- The Independence School
- Delaware River and Bay Authority
- USEPA
- Delaware Department of Transportation
- USDA Natural Resources Conservation Service
- Partnership for the Delaware Estuary
- New Castle Conservation District
- Judith Rizzo-Guest; Lucielle Herber; Gregg and Debra McCauley
- Meadowdale Civic Association
- The Sanford School
- Gwen Chen
- Jeffrey Thomas

EXECUTIVE SUMMARY

The Christina Basin is one of only two interstate watersheds in the Delaware River Basin, encompassing 565 square miles throughout Delaware, Pennsylvania, and Maryland. The Christina Basin includes four subwatersheds—the Brandywine, Red Clay, and White Clay Creeks, and the Christina River—that provide 100 million gallons per day (mgd) of drinking water to over 0.5 million people in three states. The mission of the Christina Basin Clean Water Partnership is to restore the waters of the Brandywine, Red Clay, and White Clay Creeks, and Christina River in Delaware and Pennsylvania to fishable, swimmable, and potable status by 2015.

Water quality concerns in the Christina Basin have a long history dating to just after the Second World War when the nation's first small watershed organization, the Brandywine Valley Association (BVA), was formed by concerned residents. The Christina Basin Water Quality Management Committee, comprised of multiple levels of government, private groups, and academia, was formed by the United States Environmental Protection Agency (USEPA) and the Delaware River Basin Commission (DRBC) in 1994 with the role of coordinating a scientific approach to improve the water quality in the basin and meet the region's water needs. The committee evolved into the Christina Basin Clean Water Partnership, which includes stakeholders co-coordinated by the University of Delaware's, Institute for Public Administration-Water Resources Agency (IPA-WRA) in Delaware and Chester County Water Resources Authority (CCWRA) and Chester County Conservation District (CCCD) in Pennsylvania. In January, 2001, the USEPA issued the low flow total maximum daily load (TMDL) for the Christina Basin. In April, 2005, the USEPA established the high flow TMDLs for the Christina Basin, and these were revised in September, 2006. The partnership is currently implementing pollution control strategies in both states to meet the TMDL targets.

In 2003, the USEPA launched the first national Targeted Watershed Grant (TWG) program and the Christina Basin Clean Water Partnership was selected as one of 20 community-based groups in the USA to receive federal funding. The Christina Basin Clean Water Partnership was selected to receive $1 million as the number one rated watershed grant out of 176 applications reviewed by the USEPA. The Christina Basin Clean Water Partnership developed a work plan designed to restore agricultural watersheds in Pennsylvania and reduce pollutant loads from urban/suburban watersheds in Delaware. The Christina Basin Targeted Watershed Grant work addressed nonpoint source TMDL reductions established by the USEPA and Delaware and Pennsylvania.

Federal TWG funds were leveraged utilizing funds from local and private sources by a two-to-one margin. The Christina Basin restoration budget was $3,679,778. Of that, $1,000,000 were provided by the USEPA Targeted Watershed Grant, $339,000 were provided by local match from Delaware and Pennsylvania stakeholders, and $2,340,778 were received in leveraged funds from other sources. For every federal dollar invested, over two dollars were raised from local match and leveraged sources to implement the watershed restoration projects.

Through leveraging and construction efficiencies, Christina Basin partners exceeded their original goals, some by more than 50 percent. For instance, 6,000 feet of stream reforestation in Pennsylvania was planned and over 9,000 feet were planted. About 5,000 feet of stream restoration in Delaware was planned and 8,900 feet were restored. The following list summarizes the on-the-ground best management practices that were completed with the Targeted Water Grant funds, including federal monies as well as match and leverage funds:

- PA Nutrient Management Control Plans — 10 Plans (1,067 acres)
- PA Nutrient Management Control Systems — 7 Systems
- PA Soil Conservation Practices — 728.5 Acres on 8 Farms
- PA Waterway Diversions — 2,250 Feet (1.29 acres) on 3 Farms
- PA Water Control Structures — 8 Structures on 6 Farms
- PA Stream Fencing — 8,025 Feet
- PA Stream Reforestation — 9,148 Feet
- DE Smartyard Landscaping/Rain Barrels — 150 Smartyards/204 Rain Barrels
- DE Stream Bank Restoration/Reforestation — 8,920 Feet
- PA Stream Bank Restoration — 1,200 Linear Feet
- PA Stormwater Outfall Retrofit — 1 Retrofit
- PA Stormwater Basin retrofits — 3 Retrofit
- DE Stormwater Wetland Retrofits — 5 Retrofits
- DE Stormwater Wetland Retrofit — 1 Rain Garden

In addition to supporting the installation of numerous on-the-ground projects the TWG funding supported: an annual conference, 12 meetings/conference calls, public outreach events and publications, storm drain stenciling, annual bus tours, and BMP site monitoring in Chester County, Pennsylvania, and New Castle County, Delaware.

The Partnership achieved many successes through the USEPA's Targeted Watershed Grant program. Most importantly, the bi-state collaboration led to enhancing funding sources and implementing BMPs throughout the entire 565 square mile watershed. The Partnership will continue to work together to achieve the fishable, swimmable, potable status in the Christina Basin by 2015. The Partnership will continue to implement state, county, and local water quality initiatives in Pennsylvania and Delaware, including the Christina Basin Pollution Control Strategy and the Chester County *Watersheds* Plan. In addition, as part of the Partnership's Phase VII implementation plan, the Partnership will begin to explore critical issues such as: a Christina Basin innovative governance structure, sustainable watershed financing, and water quality trading and watershed-based permitting.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

List of Terms

BMP – Best Management Practice
BVA – Brandywine Valley Association
CBOD5 – Chemical/Biological Oxygen Demand
CCCD – Chester County Conservation District
CCWRA – Chester County Water Resources Authority
CFU – Colony Forming Unit
CSOs – Combined Sewer Overflows
DNREC – Delaware Department of Natural Resources and Environmental Control
DNS – Delaware Nature Society
DO – Dissolved Oxygen
DRBA – Delaware River and Bay Authority
DRBC – Delaware River Basin Commission
FAA – Federal Aviation Administration
FGM – Fluvial Geomorphologic
GIS – Geographic Information Systems
IBI – Index of Biotic Integrity
IPA-WRA – Institute for Public Administration-Water Resources Agency
LSI – Land Studies, Inc.
MS4 – Municipal Separate Storm Sewer System
NH3-N – Ammonia Nitrogen
NPDES – National Pollutant Discharge Elimination System
NRCS – Natural Resources Conservation Service
PADEP – Pennsylvania Department of Environmental Protection
PCBs – Polychlorinated Biphenyls
PCS – Pollution Control Strategy
RBP – Rapid Bioassessment Protocol
RC&D – Resource Conservation and Development
RCVA – Red Clay Valley Association
SU – Standard Unit
TMDL – Total Maximum Daily Loads
TN – Total Nitrogen
TP –Total Phosphorus
TSS – Total Suspended Sediment
TWG – Targeted Watershed Grant
UD – University of Delaware
UD-CANR – University of Delaware College of Agriculture and Natural Resources
UNT – Unnamed Tributary
USDA – United States Department of Agriculture
USEPA – United States Environmental Protection Agency

Chapter 1 : Christina Basin

1.1 Setting

The Christina Basin is one of only two interstate watersheds in the entire Delaware River Basin, encompassing 565 square miles throughout Delaware, Pennsylvania, and Maryland (Figure 1.1). The Christina Basin includes four subwatersheds: Brandywine, Red Clay, and White Clay Creeks, and the Christina River (Figure 1.1). The Christina Basin is largely rural in Pennsylvania and urban/suburban in Delaware. Due to its pastoral quality in the headwaters and proximity to job centers in Philadelphia, Baltimore, and Wilmington, the basin is undergoing rapid development and is currently home to over 500,000 people.

The upper portion and headwaters of the Christina Basin are in Pennsylvania, accounting for two-thirds of the drainage area, while the basin's lower third is in Delaware, where it drains into the Delaware River at Wilmington. There are three primary land uses in the Christina Basin: urban/suburban (34 percent), agricultural (31 percent), and open space/forested lands (35 percent). The character of the watershed varies from urban areas such as Newark and Wilmington in the south, to mostly agricultural lands in the mid-western portion of the watershed, and a mixture of mostly wooded and agricultural areas to the north.

The Christina Basin provides over 100 million gallons of drinking water per day to over 500,000 residents of Chester County, Pennsylvania and New Castle County, Delaware. Streams and wells within the basin provide 70 percent of the water supply for New Castle County, Del. and up to 40 percent of the water supply for Chester County, Pennsylvania. The basin provides the only source of public surface water supply in Delaware, with the Brandywine Creek as the source of Wilmington's drinking water.

The Christina Basin's streams provide important habitat for wildlife, aquatic organisms, and plant species. The basin contains the only six trout streams in Delaware. Due to its idyllic setting, the Christina Basin provides an abundance of recreational opportunities, including fishing for rainbow and brown trout, smallmouth bass, and white perch, and opportunities for hikers and canoeists to enjoy wildlife, including wood ducks, bog turtles, and the graceful great blue heron.

The Christina Basin is found in the Piedmont physiographic province, a geographically "uplifted area" in northern Delaware and southeastern Pennsylvania where elevations reach to 1000 feet above sea level. This area of gently rolling hills causes the area's streams to flow at accelerated rates, especially during storm events. Pressures from development and increased volumes of water entering the stream system with each rain event have degraded numerous streams in the Christina Basin. The streams' degradation in the basin are caused by excess pollutants such as nutrients, toxics, bacteria, and sediment (Table 1.1).

Figure 1.1. Delaware River and Christina Basins.

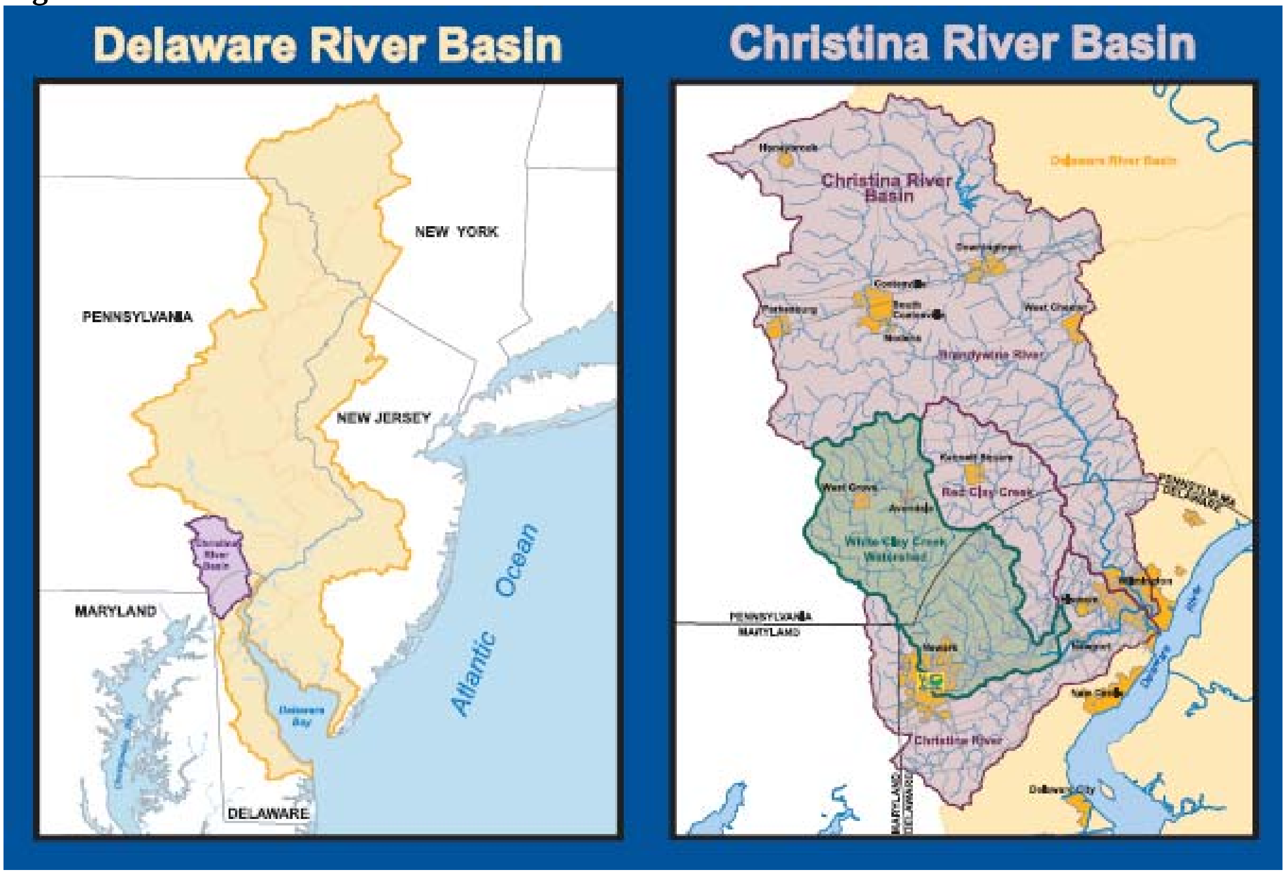


Table 1.1. Water quality concerns in the Christina Basin.

Water Quality Issue	Components
Nutrients	High levels of nitrogen and phosphorous loads, which deplete dissolved oxygen levels (160 stream miles).
Toxics (metals)	Elevated zinc levels (100 stream miles).
Bacteria (pathogens)	Concentrations exceed the primary recreation standards for swimming of 100 colonies per 100 milliliters (395 stream miles).
Fish Consumption Advisories	Health warnings advising against the consumption of fish due to polychlorinated biphenyl (PCB) contaminated sediment and high PCB levels in fish tissue (82 stream miles).
Sediment	High sediment loads between 300 to 1,000 pounds/acre annually.
Stream Habitat	Poor habitat due to the increased frequency and rate of runoff from urban/suburban development and rural activities.

Source: Christina Basin Water Quality Management Strategy, May 1999.

1.2 Christina Basin Clean Water Partnership

The mission of the Christina Basin Clean Water Partnership is to meet the goals of restoring the waters of the Brandywine, Red Clay, and White Clay Creeks, and Christina River in Delaware and Pennsylvania to fishable, swimmable, and potable status by 2015.

Water quality concerns in the Christina Basin have a long history and previous efforts have laid the groundwork for current remediation and protection projects. Just after the Second World War, the nation's first small watershed organization, the Brandywine Valley Association (BVA), was formed by concerned residents. As early as 1973, the U.S. Department of the Interior initiated an interdisciplinary Christina Basin Study that addressed the effects of urbanization on the water resources. In 1993, the United States Environmental Protection Agency (USEPA) recommended that the DRBC work with Delaware and Pennsylvania state agencies to address persistent water quality problems in the basin. In June 1994, the Christina Basin Committee was created to assess nonpoint source impacts on water quality in preparation of TMDL's for pollutants. The Christina Basin Water Quality Management Committee, comprised of government, private groups, and academia, formed in 1995 with the role of coordinating a scientific approach to improve the water quality in the basin and meet the region's water needs. The Christina Basin Water Quality Management Committee evolved into the Christina Basin Clean Water Partnership.

Within the Christina Basin Clean Water Partnership, a Policy Committee was designated to serve as an overall decision-making body, representing the secretaries of the environmental management agencies of both basin states (Delaware and Pennsylvania), DRBC's Executive Director, and USEPA. The Christina Basin Coordinating Committee was designated to coordinate local planning, project and program implementation, and stakeholder participation through the four local co-coordinators: the Chester County Water Resources Authority (CCWRA), the University of Delaware's Institute for Public Administration-Water Resources Agency (IPA-WRA), the Delaware Nature Society (DNS), and the CCCD. The Christina Basin Clean Water Partnership includes organizations that have been integral in providing critical technical assistance, agency resources, program implementation, shareholder engagement, and public participation (Table 1.2).

In 1994, the Christina Basin Clean Water Partnership developed a watershed wide multi-phased, five-year Clean Water Strategy. This strategy addresses water quality problems through voluntary watershed and water quality planning, management activities, and point and nonpoint source TMDL implementation, to achieve the long-term goal to restore the water quality of all streams and tributaries of the Christina Basin to their protected designated uses by 2015. The short-term goals of the strategy included four strategies to be completed in six phases (Table 1.3). The Christina Basin Clean Water Partners also developed six water quality goals:

1. Nutrients: Reduce nutrient pollutant loads to meet the fishable Delaware and Pennsylvania water quality standards in accordance with the Christina Basin TMDLs.
2. Toxics: Remediate the existing sources of zinc to reduce toxics loads in accordance with Delaware and Pennsylvania water quality standards and the Christina Basin TMDLs.

3. Bacteria: Reduce bacteria loads to the streams to meet the swimmable primary recreation water quality standards of both states.
4. Fish Consumption Advisories: Cleanup the hazardous waste sources of PCB's to reduce loads and ultimately lift the fish consumption advisories.
5. Sediment: Reduce total sediment loads from land and stream erosion sources by 50 percent to 200 pounds per acre annually.
6. Stream Habitat: Improve stream habitat to a "good" rating in Delaware and to the level of "good" biological diversity in the Pennsylvania portion of the basin.

Additional planning efforts were integrated into the Christina Clean Water Strategy. The Partnership also utilized the inter-jurisdictional and inter-agency coordination to identify priority areas. These concurrent efforts include the Chester County *Watersheds Plan*, the Delaware Department of Natural Resources and Environmental Control (DNREC) *Piedmont Whole Basin Assessment*, the Red and White Clay PL 566 Riparian Land Treatment Plan, and the *White Clay Creek Federal Wild and Scenic River Management Plan.*

Table 1.2. Christina Basin Clean Water Partnership.

GROUP	MEMBERS
Policy Committee	Delaware Department of Natural Resources and Environmental Control Delaware River Basin Commission Pennsylvania Department of Environmental Protection U.S. Environmental Protection Agency
Coordinating Committee	Chester County Water Resources Authority, Pennsylvania) Chester County Conservation District, Pennsylvania Delaware Nature Society Univ. of Delaware, Institute for Public Admin.-Water Resources Agency
Partners	Brandywine Conservancy Brandywine Valley Association Chester County Planning Commission Christina Conservancy City of Newark City of Wilmington New Castle Conservation District, Delaware Pennsylvania Department of Conservation and Natural Resources Red Clay Valley Association U.S. Department of Agriculture, Natural Resources Conservation Service U.S. Department of Interior, National Park Service U.S. Department of Interior, U.S. Geological Survey White Clay Creek Watershed Association White Clay Creek Wild and Scenic Watershed Management Committee

Table 1.3. Six phases of the Christina Basin Clean Water Strategy.

Phase	Goals	Timeline
I	DRBC/USEPA Mediation	1994-1996
I	GIS Watershed Mapping	1997-1998
III	Monitoring/Implementation	1999-2000
IV	TMDL Modeling/Implementation	2001-2003
V	TMDL Promulgation and Implementation	2004-2005
VI	Targeted Watershed Grant Implementation	2004-2007

1.3 New Castle County, Delaware's Christina Basin Pollution Control Strategy

In April 2005, the USEPA established the Christina Basin high flow TMDLs for nutrients and bacteria to improve the water quality of the rivers and tributaries that comprise the Delaware portion of the Christina Basin. DNREC and IPA-WRA formed and facilitated a Tributary Action Team for the Delaware portion of the basin and the team developed a Pollution Control Strategy (PCS) (Table 1.4). The PCS involved multiple stakeholders to develop feasible recommendations for reducing nonpoint source nitrogen, phosphorus, and bacteria loads in the waters of the Delaware portion of the Christina Basin to achieve the USEPA's targeted high flow TMDL levels.

The Tributary Action Team first met in February 2006 and held 13 meetings and a public forum over a 17-month period. Team members included representatives from nonprofit organizations, industry, water utilities, state and local government entities, private consultants, and residents of the basin. In December 2006 the group finalized 40 recommendations and began developing the PCS. The PCS contains voluntary and regulatory recommendations grouped according to five distinct sectors: stormwater, open space, wastewater, agriculture, and education. Each group of recommendations is intended to reduce the levels of nitrogen, phosphorus, and bacteria in the nonpoint source runoff in the Delaware portion of the Christina Basin. For each of the 40 recommendations the PCS details the specific recommendation, the organization(s) responsible for implementing the recommendation, the nutrient reductions that should result from implementing the recommendation, the source(s) of funding, the priority location for implementing the recommendation, the costs associated with implementing the recommendation, and the type of approach (regulatory or voluntary). The total estimated cost to implement the recommendations contained in the PCS is estimated at $31.3 million per year.

In November 2007, the *Christina Basin Pollution Control Strategy: A Watershed-based Strategy to Implement Total Maximum Daily Loads in the Brandywine, Red Clay and White Clay Creeks, and Christina River in Delaware, October 2007* was completed and presented for consideration to DNREC's Secretary John Hughes.

Table 1.4. Christina Basin Tributary Action Team members.

Committee Member	Organization
Jennifer Adkins	Partnership for the Delaware Estuary
Colleen Arnold	City of Wilmington, Public Works Department
Jessie Benjamin	Representing New Castle County Conservation District
Andrea Bennett	USEPA – Region 3
Jan Bowers	Chester County Water Resources Authority (Pennsylvania)
Laura Boyer	DNREC, Division of Water Resources, Watershed Assessment Section
Katherine Bunting-Howarth	DNREC, Division of Water Resources, Watershed Assessment Section
Kara Coats	City of Wilmington
Randy Cole	DelDOT
Martha Corrozi	University of Delaware, Institute for Public Administration-Water Resources Agency
Sarah Deacle	Delaware Center for Horticulture
Kelley Dinsmore	City of Newark
Maryanne Edwards	Citizen
Lorraine Fleming	Christina Conservancy
David Fournier	United Water Delaware
Jennifer Gochenaur	Delaware Nature Society
John Harrod	Delaware Nature Society
George Haggerty	New Castle County, Department of Land Use
John Hayes	Delaware Rural Water Association
Jerry Heisler	Reybold Group
Amie Howell	USEPA – Region 3
Stephen Johns	Vandemark & Lynch, Inc.
Jason Jones	Citizen
Lyle Jones	DNREC, Division of Water Resources, Watershed Assessment Section
Jim Jordan	Red Clay Valley Association
Francis Julian	Homebuilders Association of Delaware
Gerald Kauffman	University of Delaware, Institute for Public Administration-Water Resources Agency
Joel Karmazyn	Citizen
Jim King	Citizen
Carl Koch	Greeley and Hansen
Vikram Krishnamurthy	Delaware Center for Horticulture
Rich LaPointe	City of Newark
Stephen Lefebvre	Homebuilders Association of Delaware
Robert Lonsdorf	Brandywine Conservancy
Molly Mackil	VanDemark & Lynch, Inc
Karen Marshal	Greater Brandywine Village Revitalization
Stacey McNatt	New Castle County, Department of Land Use
Anne Mundel	DNREC, Source Water Assessment
Doug Nicol	Citrosuco
Ginger North	Delaware Nature Society
Bryan Pariseault	URS Corporation
Nancy Parker	Artesian Water Company
Frank Piorko	DNREC, Division of Soil and Water Conservation
Morgan Price	DNREC, Site Investigation and Restoration Branch
Alex Rittberg	DNREC, Division of Air and Waste Management
Bart Ruiter	DuPont
John Schneider	DNREC, Division of Water Resources, Watershed Assessment Section
Gary Schwetz	Delaware Center for Horticulture
Michael Sistek	City of Newark
Saurabh Srivastava	New Castle County, Department of Special Services
Linda Stapleford	White Clay Creek Wild and Scenic Program
John Stefferud	Natural Lands Trust
Martin Wollaston	University of Delaware, Institute for Public Administration, Planning Services
Lisa Wool	Partnership for the Delaware Estuary
Leslie York-Hubbard	University of Delaware, Department of Occupational Health and Safety
Jonathan Zangwill	Delaware River Basin Commission

1.4 Chester County, Pennsylvania's Watershed Action Plans

The *Brandywine Creek Watershed Action Plan, Red Clay Creek Watershed Action Plan,* and *White Clay Creek Watershed Action Plan* are part of 21 action plans developed for each of the 21 watersheds that are part of the *Chester County, Pennsylvania Water Resources Compendium* study area. According to the *Watersheds* Action Plans, the information provided in the plan summarizes key information on watershed characteristics, presents results from various analyses that were conducted and described in the *Compendium,* and develops a broad structure of goals and priorities that reflect the needs and challenges for the watershed consistent with the guidance and framework of the Chester County *Watersheds* Plan. The Brandywine, Red Clay, and White Clay Creeks' *Watersheds* Action Plans were published in December 2002.

The plans established priorities to help guide future efforts to the most important problems in each watershed in Chester County. Specifically these priorities will help to steer the efforts to the most important problems and will provide the greatest overall benefits while taking financial and human resources constraints into consideration. The overall goals of the Brandywine, Red Clay, and White Clay Creeks watersheds include:

- Engage and educate individuals, communities, and governments in watershed stewardship.
- Enhance recreational and cultural resources.
- Preserve natural resources.
- Improve water quality.
- Reduce stormwater runoff and flooding.
- Protect watershed water balances.
- Integrate utility and municipal planning to meet future water supply and wastewater needs.

According to the plans, in order to focus stewardship and restoration efforts within the overall goals for the watersheds, seven priority management objectives was developed for the Brandywine, White Clay, and Red Clay Creeks watersheds. These include:

1. Reduce stormwater runoff and flooding throughout the watershed.
2. Restore water quality of "impaired" streams and protect unimpaired streams from further degradation.
3. Protect and enhance vegetated riparian corridors, particularly for first order streams.
4. Increase public access to streams.
5. Undertake Integrated Water Resources Planning for growth areas to guide water supply and wastewater to meet future needs.
6. Implement other source water protection measures for water supply intakes, reservoirs and wells.
7. Protect and enhance the cultural and recreational resources of the watershed.

Cost information for implementing the practices that are necessary to meet these priorities and goals were gathered for each watershed. These costs are provided in the plans dated December

2002 and are intended only to provide an estimate and order of magnitude approximation of expected implementation costs. The costs associated with each watershed are provided below (Table 1.5). These costs do not include the cost of acquisition of easements or lands, or the costs for maintaining, modifying, or retrofitting built stormwater or other infrastructure systems.

A comparison of the specific actions outlined in Chester County's *Watershed* Action Plans for the Brandywine, Red Clay, and White Clay Creeks, and Delaware's Christina Basin Pollution Control Strategy is provided in Chapter 6 (Tables 6.1-6.7).

Table 1.5. Estimated costs for restoration in the Pennsylvania portion of the Christina Basin.

Watershed	Total Cost	Cost per Square Mile of Watershed	Cost per Stream Mile
Brandywine Creek	$219,814,200	$676,351	$387,679
	$69,814,200*	$198,336 *	$123,129*
Red Clay Creek	$14,002,900	$259,313	$137,283
White Clay Creek	$22,918,950	$12,213	$130,221

*Excluding the remediation of the combined sewer overflows (CSOs) for the City of Wilmington

1.5 Water Quality and TMDLs

Due to intense municipal, industrial, agricultural, and recreational demands the water quality and overall health of the Christina Basin is less than optimal. Nearly 50 percent of the 470 stream miles in the Christina Basin are listed as "impaired" by the Pennsylvania Department of Environmental Protection (PADEP) and DNREC (Figure 1.2). Both states' monitoring programs have identified impacts on aquatic life as a result of elevated nutrient levels, including low dissolved oxygen (DO) from regulated discharges. Nonpoint sources of pollution during low flows contribute to the high nutrients and low DO levels.

A 1998 watershed inventory indicated several potential pollution sources to the Christina Basin in Delaware, including 38 CSOs, National Pollutant Discharge Elimination System (NPDES) NPDES wastewater discharges (10 outfalls), roadways (2 percent of the watershed area), Solid/Hazardous Waste/Superfund Sites (135 identified), underground storage tanks (95 identified), and Urban/Suburban Runoff (53 percent of the watershed). In Pennsylvania, agriculture (40 percent of the watershed), NPDES wastewater discharges (82 outfalls), roadways (2 percent of the watershed), and Urban/Suburban Runoff (27 percent of the watershed) were all identified as potential pollutant sources. Fish consumption advisories are posted along reaches of the Brandywine and Red Clay Creeks, and Christina River. Impervious cover in developed watersheds exceeds the 10 to 15 percent threshold generally needed to protect stream habitat and fisheries. Despite the numerous potential sources of pollution, the Christina Basin waters are the cleanest they have been in over 100 years. Due to the Christina Basin Clean Water Partnership's efforts over the last 15 years, programs to improve water quality through the coordinated regulatory, physical, and educational initiatives have been successfully implemented.

To remediate water quality problems, a high flow and low-flow TMDL were necessary in the Christina Basin. Since each flow scenario has a distinct pollution profile, two TMDL scenarios were developed to address water quality problems at low- and high-flow conditions. The low flow TMDL was established in January, 2001 and the high flow TMDL was established in April, 2005. In September, 2006 the USEPA revised the Christina Basin low-flow nutrient/dissolved oxygen TMDLs, high flow nutrient/DO TMDLs, and high-flow bacteria TMDLs, in light of factors such as the availability of recent data and review of the computer model used to develop the original TMDLs.

Low Flow TMDL:
On January 19, 2001 (revised September, 2006), the USEPA issued the low flow TMDL for the Christina Basin. The TMDL calls for 8 wastewater dischargers to reduce chemical/biological oxygen demand (CBOD5), Ammonia Nitrogen (NH3-N), and Total Phosphorus (TP) loads (Table 1.6). Necessary reductions in pollutant loads will be included in the renewal of NPDES discharge permits.

Table 1.6. TMDL of nutrients and dissolved oxygen under low-flow conditions.

NPDES Facility	Flow	Level 1 and 2 Percent Reduction		
		CBOD5	**NH3-N**	**TP**
East Branch Brandywine Creek				
Broad Run Sewer Co. (PA0043982)	0.4	8%	0%	6%
Sonoco Products (PA0012815)	1.028	28%	28%	28%
Downingtown Area Reg. Authority (PA0026531)	7.134	36%	36%	36%
West Branch Brandywine Creek				
PA American Water Company (PA0026859)	3.85	28%	0%	28%
Sunny Dell Foods, Inc. (PA0044776)	0.6	10%	10%	10%
West Branch Red Clay Creek				
Kennett Square (PA0024058)	1.1	34%	34%	83%
Sunny Dell Foods, Inc. (PA0057720-001)	0.05	5%	5%	5%
West Branch Christina River				
Meadowville Utilities, Inc. (MD0022641)	0.7	0%	69%	0%

High Flow TMDL:
On April 8, 2005 (revised September, 2006) the USEPA established the high flow TMDLs for the Christina Basin. The U.S. Geological Survey prepared a high flow, nonpoint source TMDL watershed model for the Christina Basin using the Hydrologic Simulation Program-Fortran. The model is designed to simulate effects of nonpoint source loads for nutrients (Nitrogen and Phosphorus) and suspended sediment for the high flow TMDL.

TN reductions range from 0% in Burroughs Run at the PA-DE state line to 72.8% in the Christina River at the MD-DE state line. TP reductions range from 0% in Burroughs Run at the PA-DE state line to 72.6% in the Red Clay Creek at the PA-DE state line. Table 1.7 lists the percent reductions required for TN and TP at stream locations along the PA-DE and DE-MD state lines in the Christina Basin.

Bacteria reductions are required to meet the TMDL allocations for the Brandywine, Red Clay, and White Clay Creeks, and Christina River. The bacteria loads in the Christina Basin exceed the allocations and the reductions required range from 29% in Burroughs Run at the PA-DE state line to 93% in the Brandywine Creek at the PA-DE state line. Table 1.8 lists the percent reductions required at the PA-DE and DE-MD state lines to meet the bacteria allocations in the Christina Basin.

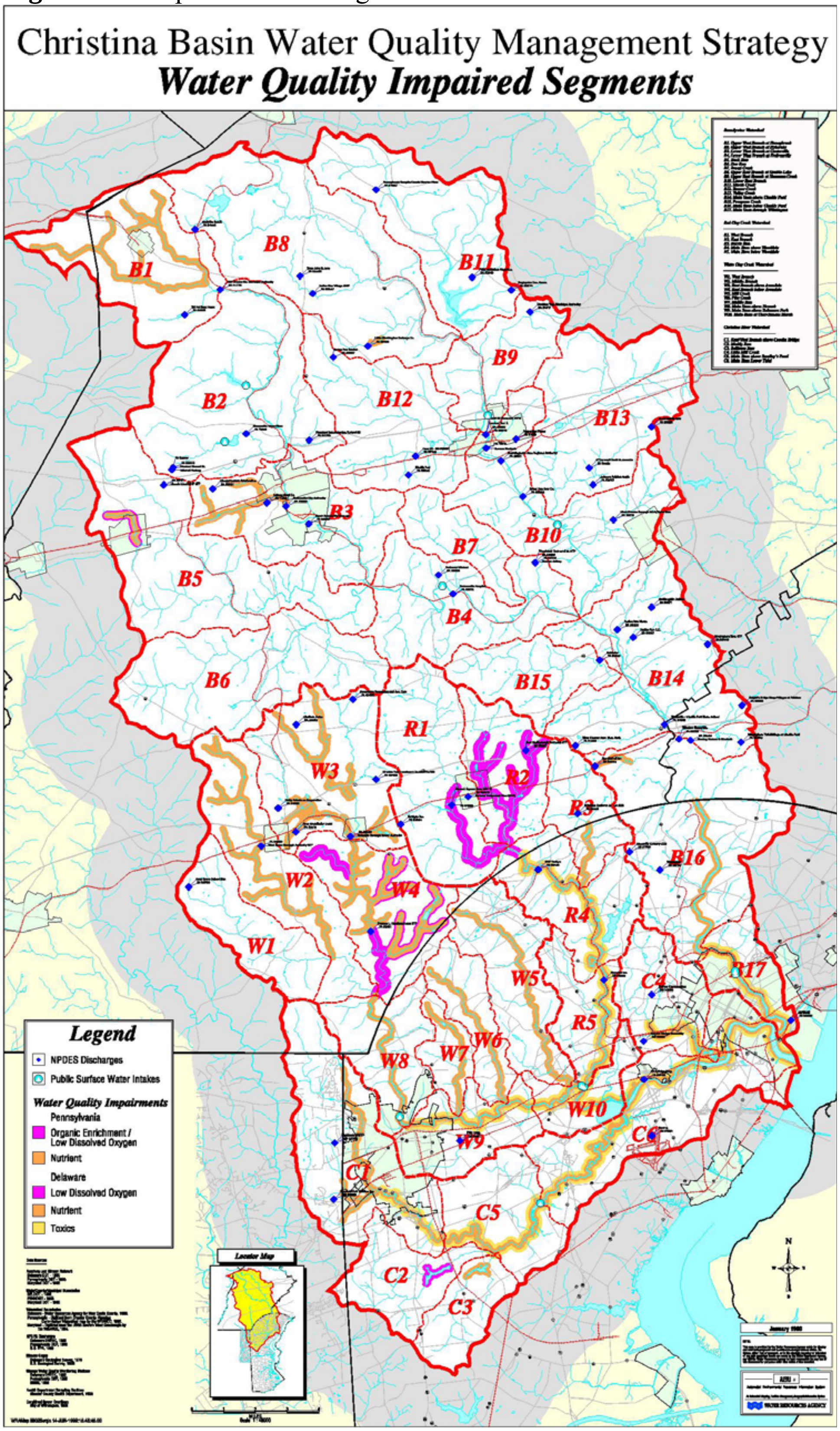
Table 1.7. High flow nitrogen and phosphorus TMDL allocations in the Christina Basin.

Location	Baseline Load (kg/day)	PA Allocation (kg/day)	Reduction
Total Nitrogen			
Brandywine Creek (at PA-DE Line)	6,849.8	3,663.8	46.5%
White Clay Creek (at PA-DE Line)	956.2	685.0	28.4%
Red Clay Creek (at PA-DE Line)	466.7	320.4	31.3%
Burroughs Run (at PA-DE Line)	43.4	43.4	0%
Christina River (at MD-DE Line)	68.7	26.2	72.8%
Total Phosphorus			
Brandywine Creek (at PA-DE Line)	423.8	250.8	40.8%
White Clay Creek (at PA-DE Line)	110.6	65.9	40.4%
Red Clay Creek (at PA-DE Line)	62.8	17.2	72.6%
Burroughs Run (at PA-DE Line)	0.8	0.8	0%
Christina River (at MD-DE Line)	3.8	2.0	47.5%

Table 1.8. High flow *enterococci* bacteria allocations in the Christina Basin.

Location	Baseline Load (cfu/yr)	PA Allocation (cfu/yr)	Reduction
Allocations at the Pennsylvania-Delaware State Line			
Brandywine Creek (at PA-DE Line)	3.12E+15	2.01E+14	93.56%
White Clay Creek (at PA-DE Line)	6.86E+14	2.06E+14	70.03%
Red Clay Creek (at PA-DE Line)	2.85E+14	1.08E+14	58.05%
Burroughs Run (at PA-DE Line)	1.85E+13	1.30E+13	29.32%
Allocations at the Maryland-Delaware State Line			
Christina River (at MD-DE Line)	1.86E+13	7.73E+12	58.40%

Figure 1.2. Impaired stream segments in the Christina Basin.



Chapter 2 : Targeted Watershed Grant

2.1 Christina Basin Scope of Work

In 2003, the United States Environmental Protection Agency (USEPA) launched the Targeted Watershed Grant (TWG) program, "to encourage successful community-based approaches to restore, preserve, and protect the nation's watersheds." The USEPA's goals for the Targeted Watershed Grant Program were to:

- Build on the successes of public and private watershed partnerships,
- Promote the achievement of tangible environmental results, and
- Encourage innovative approaches for watershed protection and restoration.

The USEPA conducted a national competition to determine the watersheds that most deserved funding through the Targeted Watershed Grant program. Grant recipients were selected from 176 nominations nationwide. The grants were reviewed by regional and national experts and the recipients selected were those applicants that best demonstrated their ability to achieve on-the-ground environmental results in a short period of time. Each one of the chosen watershed organizations exhibited strong partnerships, showed innovation, and demonstrated compatibility with existing government programs. The amount awarded through the Targeted Watershed Grant program ranged from $300,000 to $1 million. The Christina Basin Clean Water Partnership was one of 20 community-based groups to receive federal funding under the first national watershed grant program. The Christina Basin Clean Water Partnership was selected to receive $1 million as the number one ranked watershed application in the USA as ranked among the 176 reviewed by the USEPA.

The Christina Basin Clean Water Partnership developed a scope of work that included key actions such as: watershed coordination; monitoring and modeling; public education, outreach, and involvement; and implementing urban/suburban and rural best management practices (BMPs). This plan became the foundation for the Christina Basin Clean Water Partnership's scope of work submitted to and accepted by the USEPA's Targeted Watershed Grant program in 2003. The plan is comprised of 27 specific actions, implemented through bi-state, inter-jurisdictional policy coordination and provided a scope of work for the Targeted Watershed Grant funding. These tasks support the short- and long-term goals of the Christina Basin Clean Water Partnership; focus on the priority sub-basins identified in earlier phases of the Partnership's strategies; and implements high flow total maximum daily loads (TMDLs) under development for the Christina Basin.

The Targeted Watershed Grant funding enabled the Partnership to focus and accelerate their efforts in targeted areas in the basin to provide a sustained and measurable reduction in nonpoint source runoff from land areas and facilities throughout the Christina Basin. The following activities are included in the Partnership's goals and were achieved through funding from the Targeted Watershed Grant:

- Expand public participation and outreach;
- Study and demonstrate agricultural and urban stormwater BMPs;
- Improve residential landscape practices and reduce runoff;
- Install stream bank restoration;
- Install innovative stormwater runoff management techniques as pilot projects;
- Implement monitoring programs to document water quality improvements; and
- Continue inter-jurisdictional policy coordination to facilitate effective restoration strategies.

The implementation of these projects leads toward the Partnership's long-term goal of restoring "all waters of the streams and tributaries of the Christina Basin to achieve their designated protected uses by 2015."

2.2 Targeted Watershed Grant Budget and Schedule

Federal TWG funds were leveraged utilizing funds from local and private sources by a two-to-one margin. The Christina Basin restoration budget was $3,679,778. Of that, $1,000,000 were provided by the USEPA Targeted Watershed Grant, $339,000 were provided by local match from Delaware and Pennsylvania stakeholders, and $2,340,778 were received in leveraged funds from other sources. For every federal dollar invested, over two dollars were raised from local match and leveraged sources to implement the watershed restoration projects.

Through leveraging and construction efficiencies, Christina Basin partners exceeded their original restoration goals, some by more than 50 percent. For instance, 6,000 feet of stream reforestation in Pennsylvania was planned and over 9,000 feet were planted. About 5,000 feet of stream restoration in Delaware was planned, while 8,900 feet were restored. Table 2.1 summarizes the restoration work completed by the Christina Basin Clean Water Partnership and the total funds committed to each task. Table 2.2 provides the TWG proposed budget (2005), specifically allocating the TWG funds received and the organization's match for each grant task.

Table 2.1. Expended funds for the Christina Basin Targeted Watershed Grant (2008).

Contracted Tasks (Reporting Agency)	Planned 2003	Final Result 2008	Funds Received	Local Match	Leverage
1.1 Watershed Coordination and Oversight (IPA-WRA/CCCD)	Continuous	Continuous	$3,750	$3,750	$20,000
1.2 Grant Administration (DRBC)	8 Reports	8 Reports	$15,247	$3,750	$63,000
1.3 Annual Conferences (DRBC)	Conference	Conference	$5,000	$0	
1.4 Final Report (DRBC)	1 Report	1 Report	$5,000	$0	$2,400
2.1 GIS Clearinghouse and Website Maintenance (IPA-WRA)	Continuous	Continuous	$0	$15,000	
2.2 Watershed Stewardship and Education (CCCD/BVA)	12 Meetings/Conference Calls, 4 Tours, Public Event	12 Meetings/Conference Calls, 4 Tours, Public Event	$22,000	$0	
3.1A Project Administration (CCCD)	Continuous	Continuous	$27,000	$13,000	$300,000
3.1B PA Nutrient Management Control Plans (CCCD)	10 Plans	10 Plans (1,067 acres)	$7,500	$2,500	
3.1C PA Nutrient Management Control Systems (CCCD)	7 Systems	7 Systems	$229,662	$33,500	
3.1D PA Soil Conservation Practices (CCCD)	500 Acres	728.5 Acres on 8 Farms	$3,000	$1,000	
3.1E PA Waterway Diversions (CCCD)	2,000 Feet	2,250 Feet (1.29 acres) on 3 Farms	$3,000	$1,000	
3.1F PA Water Control Structures (CCCD)	4 Structures	8 Structures on 6 Farms	$9,000	$3,000	
3.1G PA Stream Fencing (CCCD)	2,700 Feet	8,025 Feet	$6,000	$2,000	
3.1H PA Stream Reforestation (CCCD)	6,000 Feet	9,148 Feet	$73,000		$33,000
3.2 DE Smartyard Landscaping/Rain Barrels (DNS)	150 Smartyards 150 Rain Barrels	150 Smartyards 204 Rain Barrels	$103,500	$16,500	$50,000
4.1 DE Stream Bank Restoration/Reforestation (DNREC)	5,000 Feet	8,920 Feet	$302,500	$101,500	$1,666,000
4.2 PA Stream Bank Restoration (PADEP)	1,200 Linear Feet	1,200 Linear Feet	$23,000	$100,000	$174,878
5.1A PA Project Administration (CCCD)	Continuous	Continuous	$10,000		
5.1B PA Stormwater Outfall Retrofit (CCCD)	1 Retrofit	1 Retrofit	$37,000	$13,000	
5.1C PA Stormwater Basin retrofits (CCCD)	2 Retrofits	3 Retrofit	$37,000	$13,000	
5.2 DE Stormwater Wetland Retrofits (DNREC)	5 Retrofits	5 Retrofits	$23,000	$10,000	
5.2 DE Stormwater Wetland Retrofit (IPA-WRA)	1 Rain Garden	1 Rain Garden	$22,000	$5,000	$20,000
6.1 Monitoring in Chester County, PA (PADEP)	Annual Data Summary	4 Data Summaries	$16,759	$0	$1,500
6.2 Monitoring in New Castle County, DE (IPA-WRA)	Annual Data Summary	4 Data Summaries	$10,082	$0	$10,000
6.2 Monitoring in New Castle County, DE (DNREC)	Annual Data Summary	1 Data Summary	$6,000	$1,500	
TOTAL			**$1,000,000**	**$339,000**	**$2,340,778**

Table 2.2. Christina Basin Targeted Watershed Grant proposed budget (2005).

Task	DRBC	DRBC Match	CCCD	CCCD Match	IPA-WRA	IPA-WRA Match	PADEP	PADEP Match	DNS	DNS Match	DNREC	DNREC Match	Total
1.1 Watershed Coordination and Oversight			$7,500	$2,500	$3,750	$1,250							
1.2 Grant Administration	$11,250	$3,750											
1.3 Annual Conferences	$5,000	$0											
1.4 Final Report	$5,000	$0											
2.1 GIS Clearinghouse and Website Maintenance					$0	$15,000							
2.2 Watershed Stewardship Education & Involvement			$22,000	$0									
3.1A Project Administration			$27,000	$13,000									
3.1B PA Nutrient management Control Plans				$2,500									
3.1C PA Nutrient Management Control Systems installed			$255,500	$33,500									
3.1D PA Soil Conservation Practices			$3,000	$1,000									
3.1E PA Waterway Diversions			$3,000	$1,000									
3.1F PA Water Control Structures			$9,000	$3,000									
3.1G PA Stream Fencing			$6,000	$2,000									
3.1H PA Stream Reforestation			$50,000										
3.2 DE SMARTYARD Landscaping/Rain Barrels									$103,500	$16,500			
4.1 DE Stream Bank Restoration/Reforestation											$302,500	$101,500	
4.2 PA Stream Bank Restoration			$23,000					$100,000					
5.1A PA Project Administration			$10,000	$0									
5.1B PA Stormwater Outfall Retrofits			$37,000	$13,000									
5.1C PA Stormwater Basin Retrofits			$37,000	$13,000									
5.2 DE Stormwater Wetland Retrofits					$22,000	$5,000					$23,000	$10,000	
6.1 Chester County, PA Monitoring							$18,000						
6.2 New Castle County, DE Monitoring											$16,000	$1,500	
USEPA TWG	**$21,250**		**$490,000**		**$25,750**		**$18,000**		**$103,500**		**$341,500**		**$1,000,000**
Local Match		**$3,750**		**$84,500**		**$21,250**		**$100,000**		**$16,500**		**$113,000**	**$339,000**

Chapter 3 : Targeted Watershed Grant Projects

3.1 Watershed Coordination

The Christina Basin Clean Water Partnership's organizational structure provided the management framework necessary to coordinate the administrative and project oversight tasks necessary to meet the terms of the Targeted Watershed Grant. The Christina Basin Coordinating Committee had the primary responsibility for implementing the specific tasks defined in the grant scope. The Chester County Water Resources Authority (CCWRA), Chester County Conservation District (CCCD), and the University of Delaware's Institute for Public Administration-Water Resources Agency (IPA-WRA) provided local coordination and implementation of the projects. Additionally, the Delaware River Basin Commission (DRBC) served as the grant administrator and provided eight semi-annual reports to the Policy Committee and the United States Environmental Protection Agency (USEPA). A map of the on-the-ground projects that resulted from the coordinating committee's cooperation is provided below (Figure 3.1).

The administrative responsibilities related to the Targeted Watershed Grant included:

- Scheduling, chairing, hosting, follow-up and documentation for meetings of the Christina Basin Clean Water Partnership and Christina Basin Task Force and coordination of community participation and Christina Basin Task Force events;
- Preparing and assisting with presentations for and communications with the Christina Basin Policy Committee and local, regional, state, and federal officials;
- Coordinating and participating in periodic conference calls with other agencies involved in the Christina Strategy;
- Implementing and administering project contracts, adherence to budgets and schedules, and coordinating with other cooperators;
- Coordinating with other agencies (local, state, regional, federal) and entities (local government, civic, corporate, and non-governmental) to coordinate initiatives toward the goals and objectives of the Christina Basin Strategy.
- Scheduling meetings and conference calls of the Clean Water Partnership.

Grant administration and facilitation tasks undertaken by DRBC included:

- Adhering to project budgets and reporting schedules;
- Developing task line budget for agency invoicing,
- Receiving and administering grant funding, and invoice processing to partners;
- Coordinating and facilitating technical and planning meetings as appropriate;
- Tracking Phase VI as implemented through reports from local project coordinators;
- Compiling semi-annual reports to the USEPA on project studies' progress; and
- Providing other reports, as needed, to satisfy applicable federal funding requirements.

A major component of the success of the Targeted Watershed Grant implementation was a consistent series of Partnership meetings and conference calls for the Coordinating Committee, as well as special meetings and conference calls as needed (Table 3.1).

Figure 3.1. Christina Basin Targeted Watershed Grant projects.

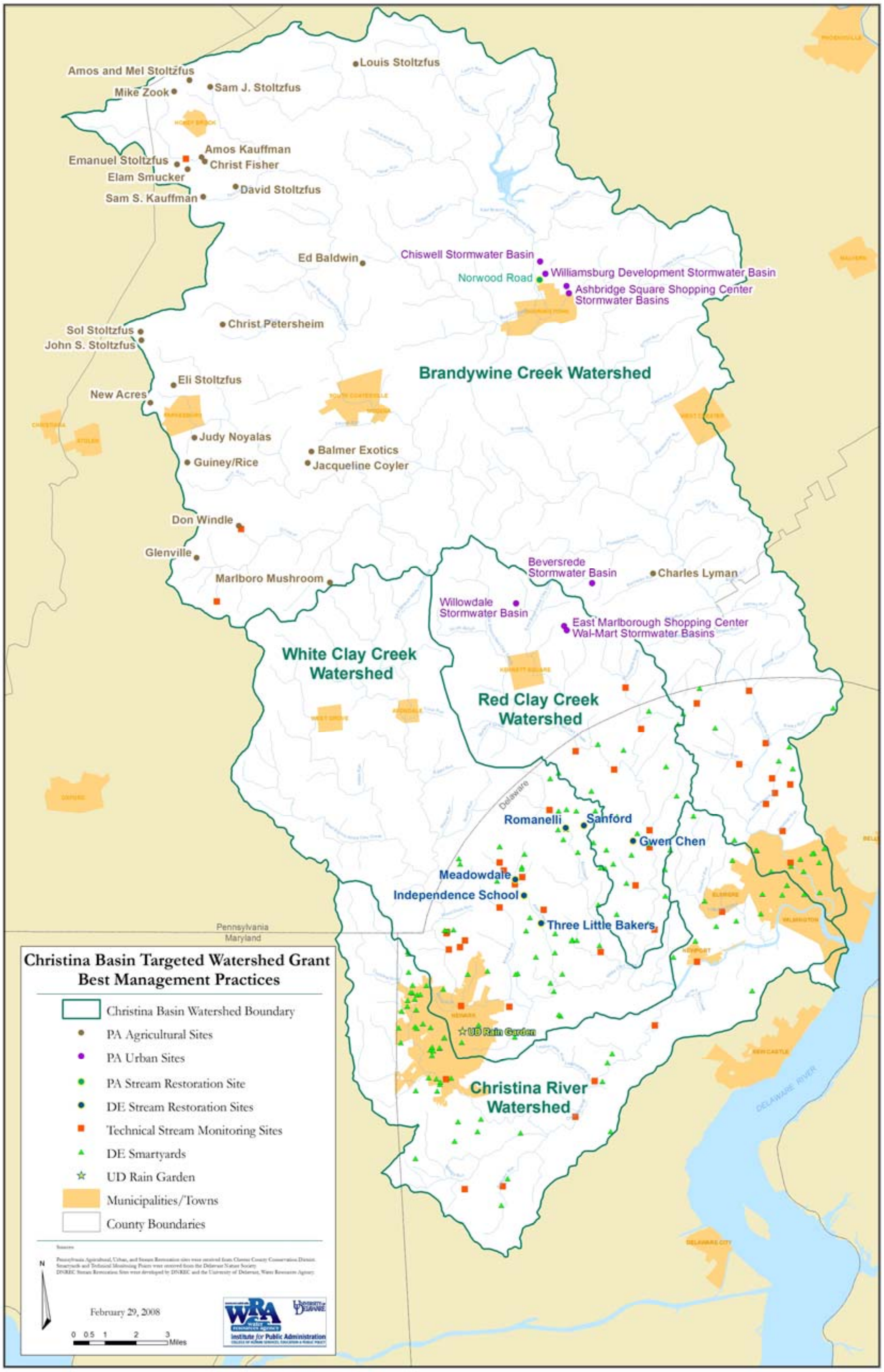


Table 3.1. Christina Basin Clean Water Partnership administrative meetings, 2003-2008.

Christina Basin Coordinating Committee	
Meetings	**Location**
June 11, 2004	BVA, West Chester, PA
October 28, 2004	Chester County, PA
June 3, 2005	West Chester, PA
August 12, 2005	UD, Newark, DE
October 14, 2005	West Chester, PA
May 19, 2006	CCWRA, West Chester, PA
October 26, 2006	UD, Newark, DE
Conference Calls	
August 11, 2004	
September 20, 2004	
November 16, 2004	
July 8, 2005	
September 9, 2005	
November 18, 2005	
June 20, 2006	
July 27, 2006	
August 25, 2006	
September 22, 2006	
March 28, 2007	
June 28, 2007	
October 25, 2007	
November 30, 2007	
December 13, 2007	
April 17, 2008	
Christina Basin Policy Committee	
Meetings	
December 3, 2004	West Chester, PA
December 9, 2005	Chadds Ford, PA
November 14, 2006	Wilmington, DE
December 14, 2006	Newark, DE
March 28, 2007	Newark, DE
Conference Calls	
August 26, 2004	
May 7, 2005	
Christina Basin Task Force Meeting	
June 3, 2005	West Chester, PA
TMDL Technical Meeting	
October 28, 2004	West Chester, PA
Special Meetings/Events	
October 13, 2004: The Historic Christina Basin Water Policy Forum, UD	Newark, DE
January 6, 2005: Christina Basin TMDL Public Meeting	Kennett Square, PA
February 10, 2005: Christina Basin TMDL Public Meeting, UD	Newark, DE
February 17, 2005: Christina Basin TMDL Public Meeting	West Chester, PA
June 7, 2007: TWG Partners Project Team Meeting	Philadelphia, PA

3.2 Community Participation and Education

Faced with the realization that the Christina Basin Clean Water Partnership's 2015 goal to restore all waters in the Christina Basin to their designated uses cannot be realized through government or nonprofit initiatives alone, education and outreach is an essential component of the water quality restoration effort. It is the goal of the Partnership to educate and influence individuals so that cumulatively their actions will have a discernable impact on many of the largest sources of nonpoint source pollution in the Christina Basin, individual property owners—urban, suburban, and agricultural. The Brandywine Valley Association (BVA), Red Clay Valley Association (RCVA), IPA-WRA, CCWRA, and Chester County Conservation District (CCCD) each played an active role in the community participation and education component of this grant funding.

BVA —the oldest small watershed organization in the nation—is a nonprofit organization that provides "water protection and environmental education for the Brandywine Valley." The BVA coordinates the Christina Basin Clean Water Partnership's public relations and outreach efforts through the delivery of community presentations and outreach opportunities designed to broaden the understanding that individual's can help maintain the integrity of the watershed systems. The Christina Basin public education and outreach programs, led by BVA, included:

- Developing educational materials for the general public, homeowners and property owners, as well as commercial interests;
- Developing various publications and reports for distribution; and an electronic newsletter. Printed materials include: a Christina Basin brochure, BasinScapes Homeowner Guides, and door hangers;
- Hosting public education and outreach efforts, in cooperation with CCCD, to inform the watershed community and landowners about the need to implement best management practices (BMPs) and enact better watershed stewardship in day-to-day activities.
- Providing cooperative outreach efforts regarding the ongoing development of the high flow total maximum daily load (TMDL) load allocations.

BVA and RCVA also led education programs with support and assistance from the Christina Basin Partnership organizations. In addition to the activities mentioned above there were several significant program areas that comprised the public education and outreach component of the Targeted Watershed Grant (TWG). These programs are summarized below.

Quarterly Meetings:
BVA coordinated quarterly meetings of the Christina Basin Task Force to involve the public, municipalities, watershed organizations, National Pollutant Discharge Elimination System (NPDES) dischargers, land developers, agricultural operators, water and wastewater purveyors, and other entities active in the watershed and in the decision-making and implementation processes of the Christina Basin Strategy.

Annual Bus Tour:
BVA organized an annual bus tour showcasing projects for stakeholders, decision-makers, and elected officials within the Christina Basin. The tour serves as a hands-on-experience for stakeholders to

understand the purpose, benefits, and challenges of implementing effective BMPs. The bus tour sites–locations of the projects implemented by the CCCD and the Delaware Department of Natural Resources and Environmental Control (DNREC)—emphasized the diversity of land use and BMPs throughout the Christina Basin and the Partnership's BMP implementation progress.

The bus tour occurred in September in 2004, 2005, 2006, and 2007 and a variety of sites were visited in Pennsylvania and Delaware (Table 3.2). One of the sites, located in Delaware and visited in September 2004, was a newly meandering stream at All Saints Cemetery in Delaware, this stream was restored to control erosion, prevent flooding in Balls Run Creek, and improve protection of the mausoleum shown in the background (Figure 3.2). A Pennsylvania site visit in September 2005 focused on a floodplain forest restoration project at the confluence of the Bucktoe and Red Clay Creeks (Figure 3.3).

Table 3.2. Annual Christina Basin bus tour sites.

Pennsylvania
Frienfield Farms Riparian Corridor Protection Plan
Hills of Sullivan Infiltration BMP
Pocopson Township Wetland BMP
Modern Mushrooms Tree Plantation
East Marlborough Wetland Project
Hy Tech Compost and Mushroom Farm
Beversrede Development
Meadowdale Development and Independence School
Norwood Road-Ludwig's Creek Stormwater Retrofit
Phillip's Mushroom Farm
Bucktoe/Red Clay Creek, Kennett Township
Buck and Doe Run Farms, Reforestation Project
Buck Run Farms Riparian Planting
Buck Run Riparian Planting
Willowdale Town Center
Balmer's Exotic Mushrooms
Sadsbury Township Stream Restoration
Delaware
City of Newark Bioengineering Project
USDA-NRCS Agricultural Conservation Projects
Three Little Bakers Golf Course/Pike Creek Stream Restoration
Newark Reservoir
Don Windle Dairy Farm
University of Delaware, IPA-WRA Rain Garden

Figure 3.2. All Saints cemetery restoration of Balls Run stream (DE).

Figure 3.3. Floodplain forest restoration, confluence of Bucktoe and Red Clay Creeks (PA).

Storm Drain Stenciling:

CCCD worked with local watershed associations on their Pennsylvania storm drain stenciling program. A fish stencil with the instructions "DON'T DUMP" was used on the drains. A fish-shaped door hanger was also distributed to residences within the towns to remind the public not to dump household chemicals, yard waste, and litter, and safely dispose of hazardous materials. The target areas were the City of Coatesville, Boroughs of South Coatesville, Modena, Avondale, West Grove and Downingtown, and the Exton area. Groups contacted for involvement in the program included school ecology clubs, Girl/Boy Scout troops, Indian Guides, and other civic organizations. Through these efforts over 300 storm drains were painted and 500 fish messages were distributed. The stenciling program attracted national attention and organizations from throughout the U.S. requested information on the program.

More specifically, the CCCD camp participants stenciled the storm drains in the Borough of Downingtown. Four groups of ten campers (a total of 40) stenciled 20 storm drains. The storm drains in the borough outlet to an underground waterway beneath the borough and to the East Branch of the Brandywine Creek, the campers' efforts educated the residents about the importance of water quality in their urban setting.

Website and Mapping:

IPA-WRA created and maintained the Christina Basin website *(http://www.wr.udel.edu/publicservice/cbstatus.html),* the geographic information system (GIS) watershed inventory, and continued to serve as the GIS clearinghouse for the Partnership. This effort enables IPA-WRA to respond to requests from agencies and the public for watershed mapping and digital data for water quality management purposes in the Christina Basin. As part of this effort IPA-WRA prepared GIS maps to support DRBC, DNREC, and the Pennsylvania Department of Environmental Protection's (PADEP) presentations on the TMDL results and in support of grant information presented to the public and elected officials.

IPA-WRA completed the updates for the 2002 land use and impervious cover GIS projections for the Christina Basin. The GIS watershed inventory includes existing geology, soils, land use, zoning, outfalls/intakes, and hazardous waste site data for the Christina Basin. This information was used to prioritize the watersheds, identify point and nonpoint source pollutants, provide inputs for the TMDL model, and develop graphics for the public education programs. The GIS watershed inventory includes an 18-map series which is available to the public in hard copy or digital format.

Stormwater Ordinance Inventory:
IPA-WRA developed a Stormwater Ordinance Inventory which includes a review of ordinances and zoning codes from over 60 municipal governments in the Christina Basin. The inventory determined that several ordinances need to be upgraded to provide minimum 100-year storm design criteria in order to reduce the stormwater impacts from new development. As a result of the inventory, IPA-WRA proposed recommendations to strengthen the stormwater ordinances to provide unified water quality criteria in the development codes.

Targeted Watershed Grant Completion Public Event:
On February 29, 2008 the Christina Clean Water Partnership held a legislative event to celebrate the success and conclusion of the TWG at the Red Clay Room, in Kennett Square, Pennsylvania. The Partnership presented awards to Christina Basin residents who, in coordination with the Partnership, implemented BMPs on their private property (Table 3.3). U.S. Representatives Joe Pitts (PA) and Mike Castle (DE), who have been supporters of the watershed program in the Christina Basin for many years, presented the awards to the recipients (Figures 3.4 and 3.5). The Legislative Event agenda is included below (Figure 3.6).

Table 3.3. Christina Basin Partnership Legislative Event awardees.

Property Owner	Type of Property/Location	BMP(s)
Pennsylvania		
The Laffey Family (Glenville Farms)	Houses 1,400 milking cows.	Comprehensive conservation plan (previously implemented), included installing: 3 animal crossings, 5,250 linear feet of stream fencing, 9,000 linear feet of total fencing, and 5 acres of riparian corridors.
Matt Balmer, M. Balmer Exotics	Mushroom Farm	Site owner installed a holding tank for the mushroom house runoff and used an irrigation system to apply the runoff to the fields. These hay fields then used to provide a crop for future mushroom compost.
Joseph and Dyanne Delaney	Ludwig's Creek near Downingtown	Project included improvements to 230 linear feet of Ludwig's Creek. This includes: realigning the stream channel, installing rock vanes, and stabilizing the stream bank with riparian grasses, trees, and shrubs. Personal involvement included contacting local officials, acquiring donated materials, and maintenance.
Delaware		
Nick and Hugo Immediato	Pike Creek	Two stream improvement projects, represented nearly 9,000 feet of stream restoration along Pike Creek in the White Clay Creek watershed.
The Independence School		
Mary Ann Capria	Smartyard	An active participant and promoter of Smartyards, the awardee implemented a backyard habitat program on several properties.

Figure 3.4. US Representative Mike Castle (DE) and Delaware award recipients.

Figure 3.5. US Representative Joe Pitts (PA) and Pennsylvania award recipients.

Figure 3.6. Christina Basin Clean Water Partnership Legislative Event agenda.

Christina Basin Clean Water Partnership Awards Ceremony:
A Celebration of Success
February 29, 2008
Red Clay Room • Kennett Square, Pennsylvania

10:00 AM **REGISTRATION**

COFFEE, TEA, AND JUICE WILL BE SERVED

10:30 AM **PROGRAM**

- MASTER OF CEREMONIES
  ROBERT STRUBLE, EXECUTIVE DIRECTOR, BRANDYWINE VALLEY ASSOCIATION AND RED CLAY VALLEY ASSOCIATION

WELCOME AND INTRODUCTIONS

- DELAWARE RIVER BASIN COMMISSION
  ROBERT TUDOR, DEPUTY EXECUTIVE DIRECTOR
- UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, REGION III
  JON CAPACASA, DIRECTOR, WATER PROTECTION DIVISION

RESULTS OF THE TARGETED WATERSHED GRANT

- CHESTER COUNTY CONSERVATION DISTRICT
  CHOTTY SPRENKLE, WATERSHED COORDINATOR/SPECIALIST
- DELAWARE DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL
  STEVE WILLIAMS, ECOLOGICAL RESTORATION COORDINATOR
- DELAWARE NATURE SOCIETY
  JOHN HARROD, BACKYARD HABITAT COORDINATOR

PRESENTATION OF AWARDS

- U.S. REPRESENTATIVE MICHAEL CASTLE (DELAWARE)

  DELAWARE AWARD RECIPIENTS:
  - NICK AND HUGO IMMEDIATO, THREE LITTLE BAKERS GOLF COURSE
  - THE INDEPENDENCE SCHOOL
  - MARY ANN CAPRIA

- U.S. REPRESENTATIVE JAMES GERLACH (PENNSYLVANIA)
- U.S. REPRESENTATIVE JOSEPH PITTS (PENNSYLVANIA)

  PENNSYLVANIA AWARD RECIPIENTS:
  - JOSEPH AND DYANNE DELANEY
  - MATT BALMER, M. BALMER EXOTICS
  - THE LAFFEY FAMILY, GLENVILLE FARMS

FUTURE PLANS

- PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL PROTECTION
  CATHY CURRAN MYERS, DEPUTY SECRETARY
- DELAWARE DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL
  DAVID SMALL, DEPUTY SECRETARY

ADJOURN AND ACKNOWLEDGEMENTS

- DELAWARE RIVER BASIN COMMSSION
  ROBERT TUDOR, DEPUTY EXECUTIVE DIRECTOR

12:00 PM **LUNCH**

3.3 Chester County, Pennsylvania Projects

The CCCD installed agricultural conservation BMPs in the headwaters of priority sub-basins of the Pennsylvania portion of the Christina Basin watersheds to control and reduce pollutant loads, improve water quality, protect stream bank stability, and engage local citizens in watershed stewardship while enhancing agricultural efficiency on project sites. CCCD utilized a suite of BMPs that included:

- Nutrient Management Control Plans (10) – 10 completed, covering 1,067 acres.
- Nutrient Management Control Systems (7) – 7 installed.
- Acres Treated (500 acres) – 728.5 acres completed on 8 different farms.
- Diversion (2,000 feet) – 2,250 feet (1.29 acres) installed on three different farms.
- Stream Bank Fencing (1,000 feet) – 8,025 feet erected on different farms.
- Water Control Structures (4) – 8 different structures installed on 6 farms.
- Stream Bank Restored (1,200 linear feet) – channel realigned, floodplain restored, planted.
- Stormwater Basin Retrofits (3) – 7 basins were naturalized (2 concrete channels removed, 2 HOAs, 5 shopping centers with high visibility of which 2 were Wal Mart sites).

Priority areas for installing these agricultural BMPs were selected based on: the results of the identified problems and priorities as described by CCCD; the Christina Basin short-term implementation strategy as presented to the Christina Basin Policy Committee; and the identification that sub-basins B1, B8, and B5 are stream segments listed on the PA 303(d) list of impaired streams. The priority areas include: Sub-basin B1 (West Branch Brandywine Creek, Honey Brook), Sub-basin B8 (Upper East Branch Brandywine), and Sub-basin B5 (Buck Run).

A critical component of installing the agricultural BMPs is to have willing landowners. These landowners were selected using two approaches: 1. Identifying individual farms or operations where BMP implementation would produce environmental results and 2. Using a ranking process that considered the following criteria:

- Priority subwatershed
- Pollution potential or loading
- Proximity to the stream
- Livestock
- Erodability of soils
- Location in tributaries near farmers that have previously participated in similar programs

A local committee comprised of CCCD staff and District directors ranked the projects and forwarded their recommendations to the Conservation District Board. Additional input from the local municipality and the watershed organizations was also considered. It is expected that for each land parcel, the agricultural BMPs will yield a 25% to 50% reduction in nonpoint source loads. Every landowner seeking cost incentive payments under the program is required to obtain and implement a Nutrient Management Plan or Nutrient Balance Sheet. Tables 3.4 and 3.5 outline the expected measurable nitrogen, phosphorus, and soil erosion benefits from BMP systems implemented by the

CCCD. The agricultural BMPs installed by the CCCD with Targeted Watershed Grant funds are described in detail in Sections 3.3.1-3.3.7.

Table 3.4. Expected measurable benefits from seven agriculture BMP systems.

	Total (gal/yr)	N (lbs./yr)*	P (lbs./yr)*
Total Manure Contained	1,813,634 (dairy)	—	—
Nutrient Runoff Reduction	1,813,634	50,782	23,577
Total Expected N and P Reduction (7 systems)	—	355,474	165,039

* Penn State Agronomy Guide

Table 3.5. Expected benefits of structural field BMPs.

Practice	Soil Loss Reduction Rate (tons/acre/year)*
Grassed Waterways	18
Terraces	10
Diversion	8

*Based on average estimates established by Chester County NRCS

3.3.1 Nutrient Management Control Plans

Nutrient management control plans, covering 1,067 acres, were developed to help producers apply the proper rates and types of inorganic and organic sources of nutrients at the proper times. The plans were prepared by Pennsylvania Act 6 Nutrient Management Program certified private consultants. Farm operations were, and will be, monitored every two years to evaluate the effectiveness of the nutrient management plans. Each nutrient management plan includes all fields on the farms to which manure is being applied. The ten nutrient management control plan sites are listed below (Table 3.6).

Table 3.6. Nutrient management control plan sites.

Landowner	Acres	Stream
Christ Fisher	70	Honey Brook
New Acres	371	Buck Run
Elam Smucker	69	Honey Brook
Amos and Mel Stoltzfus	140	West Branch
David S. Stoltzfus	102	Two Log Run
Emanuel Stoltzfus	68	Honey Brook
John S. Stoltzfus	70	Buck Run
Sam J. Stoltzfus	80	West Branch
Sol Stolztfus	25	Buck Run
Mike Zook	72	West Branch
Total Acres	**1,067**	

3.3.2 Nutrient Management Control Systems

Seven barnyard runoff control and/or manure storage systems were installed to prevent manure and other sources of nutrients from running off into storm ditches, creeks, and drainage ways. The specific types of BMPs installed include; waste storage structures (Figure 3.7), building gutters and downspouts, curbing, filter strips, drop boxes, underground drains and pipe conveyances and other system components necessary for nutrient management control. The nutrient management control systems installed are listed below (Table 3.7).

Figure 3.7. Nutrient management control system, M. Balmer Exotics Mushroom Farm.

Table 3.7. Seven nutrient management control systems.

Landowner	Stream	BMPs
Elam Smucker	Honey Brook Branch	2 Waste Storages, Heavy Use Protect, Roof runoff Management, Waste Transfer, Silage Leachate Runoff Collection
Amos Kauffman	Honey Brook Branch	Heavy Use Protection, Roof Runoff Management, Waste Transfer
Emanuel Stoltzfus	Honey Brook Branch	Waste Storage, Heavy Use Protection, Roof runoff management, Waste Transfer
Sam S. Kauffman	West Branch	Waste Storage, Heavy Use Protection, Roof runoff management, Waste Transfer
Sam J. Stoltzfus	West Branch Brandywine	Waste Storage, Roof runoff management
Ed Baldwin	West Branch	
Don Windle	Doe Run	Heavy Use Protection, Roof runoff management, Silage Leachate Collection, Waste Transfer
Marlboro Mushroom	Doe Run	Waste Storage, Waste Transfer, Wharf Runoff Controls
Christ Petersheim	Rock Run	Heavy Use Protection, Roof runoff management, Silage Leachate Collection, Waste Transfer

3.3.3 Cropland Treatment

CCCD implemented a total of 728.5 acres of cropland treatment (soil conservation practices). The initial goal of 500 acres was exceeded by an additional 228.5 acres, a 46% increase. The cropland treatment BMPs installed will prevent erosion and include: crop residue management, contour farming, contour strip cropping, conservation buffers, cover crops, and soil quality management. The landowners and cropland acres treated at each site is listed below (Table 3.8).

Table 3.8. Cropland treatment BMP sites and acres treated.

Landowner	Acres
Sam J. Stotlzfus	79.7
Eli Stoltzfus	57.7
Elam Smucker	75.3
Amos Kauffman	71.1
Emanuel Stoltzfus	66.9
Christ Petersheim	74.3
Louis Stoltzfus	225
Christ Fisher	78.5
Total	**728.5**

3.3.4 Waterway Diversions

The original proposal to install 2,000 feet of waterway diversions was exceeded by 13%, resulting in 2,250 feet of waterway diversions. Waterway diversions transform long slopes into a series of shorter slopes to reduce the rate of runoff and allow soil particles to settle out. The resulting cleaner water is carried off the field in a non-erosive manner. The benefits of this BMP include: reduced erosion, improved water quality, improved soil absorption, and reduced runoff to the structures below. Cross-slope channels are used on steep slopes where a terrace would be too expensive or difficult to maintain or farm. Diversions were also used on non-cropped land to protect farmsteads or barnyards from runoff. The waterway diversion sites and the total length installed are listed below (Table 3.9).

Table 3.9. Waterway diversion sites, acres and length installed.

Landowner	Acres	Length(ft)
Eli Stoltzfus	55	325
Judy Noyalas	1,904.64	475
Elam Smucker	12,716.80	1,450
Total	**14,676.44**	**2,250**

3.3.5 Stream Fencing

A total of 8,025 feet of stream fencing was installed on agricultural lands, almost three times the proposed 2,700 feet. The stream fencing installed will keep livestock out of the streams and therefore protect stream banks from erosion caused by animal access. The fencing will also establish buffer zones to filter pollution from stormwater runoff (Figures 3.8 and 3.9). The site locations and linear stream footage of stream fencing installed are listed below (Table 3.10).

Figure 3.8. Stream bank fencing at Glenville Farms.

Figure 3.9. Stream bank fencing at Glenville Farms.

Table 3.10. Stream fencing sites and linear stream footage.

Landowner	**Linear Stream Footage(ft)**
Christ S. Fisher	2,775
Glenville Farms	5,250
TOTAL	**8,025**

3.3.6 Water Control Structures

Eight different water control structures were installed at three farms. These BMPs protect animal stream crossings (to facilitate fencing projects) and protect waterways and diversion and pipe outlets for erosion and scour control as well as gully stabilization. The water control structure sites and the type of structures installed are listed below (Table 3.11).

Table 3.11. Water control structure sites and type of structure installed.

Landowner	Type of Water Control Structure
Eli Stoltzfus	Basin (to protect Diversion)
Eli Stoltzfus	Basin (to protect Waterway)
Eli Stoltzfus	700 Feet, Waterway
Christ S. Fisher	3 Stream Crossings
Christ Fisher	Watering Facility
Louis Stoltzfus	2 Storage Terraces

3.3.7 Agricultural Stream Reforestation

Exceeding greater than 50% of the project goals for this riparian corridor, 9,148 linear feet of agricultural stream reforestation was completed. Six thousand feet was originally required to fulfill CCCD's grant obligations. This reforestation effort will reduce sediment loads and improve biotic integrity. The agricultural stream bank reforestation sites and the linear stream footage of the stream reforestation are listed below (Table 3.12).

Table 3.12. Agricultural stream bank reforestation sites and linear stream footage.

Landowner	Linear Stream Footage(ft)
Christ S. Fisher	2,775
Jacqueline Coyler	1,123
Glenville Farms	5,250
Total	**9,148**

3.3.8 Norwood Road–Ludwig's Creek Stream Restoration

Norwood Road–Ludwig's Creek is a stream restoration project that took place in a subwatershed of the Brandywine Creek, contained in the Christina Basin. This urban stream valley was eroded by inadequate stormwater controls in older developments and the construction of large new developments with large amounts of paved surfaces in the upper watershed; building the new developments on steep slopes, and historical and record rainfall amounts in 2003 and 2004.

Norwood Road-Ludwig's Creek began as a restoration project involving three landowners. This project addressed flooding and instream erosion by expanding the floodplain, realigning the channel, and stabilizing the steep slopes. The emphasis was to expand the floodplain of the stream and to stabilize the eroding stream bank. After the hurricanes of September 2003 and September 2004 the stream valley was devastated, the creekside landowners on the lower section of Norwood Road had property damage, and the Williams Transco gas pipeline was exposed, causing a concern for public health and safety.

In an effort to address the overall flooding damage and the instream erosion and sedimentation that occurred from these intense rainfall events, the District decided to expand an existing stabilization and restoration plan to encompass as much of the lower stream valley as possible. The revised effort implemented a more comprehensive watershed approach, which provided additional stream bank restoration and stabilization, relocation of the stream channel, and restoration to the property of seven landowners in the Ludwig's Run watershed.

Three public meetings and several private meetings occurred and numerous emails were exchanged between October and December 2005 in order to inform and enlist the participation of the landowners. The revised plan included a timber cut to open the site, realign the channel, grade down and expand the floodplain on the lower section (five landowners) and move the gravel bar and reposition the channel to its previous alignment (November, 2004) in the upper section (two landowners), and stabilizing the banks and slopes with erosion control blankets, staples, and live stakes. PADEP issued an emergency permit in January 2005 to begin the work. The township bridge improvements and reconstruction design were changed to complement the design of the stream restoration.

Community involvement and interest was an important component of this restoration effort. The residents had two major concerns that needed action, the stream bank repair to their individual properties and a recurring flooding and erosion problem. For this reason, over 25 individuals came together to meet and discuss watershed flooding, erosion, and property damage issues with the intent of both short- and long-term stormwater resolution and solutions. Additionally a sign was placed overlooking the work zone to advertise the project. There was an obvious community interest, given the number of slowing and stopped cars on Norwood Road as well as questions from walkers on Struble Trail. Opportunities for communication about projects being done with Growing Greener Grant money also provided grassroots support and encouraged continued funding for the project.

The next section of Ludwig's Run, upstream from this project boundary, should also receive channel alignment in the valley and at its entry to the Township Bridge. The new channel should be able to reconnect with its floodplain, which also includes removing timber and grading to expand the existing and create additional floodplain. A locally led, long-term solution for stormwater management in this valley also needs to be addressed. A task force of residential representatives, municipal leaders from East Caln and Uwchlan townships, the Conservation District, and PADEP should be created to create a community-based and endorsed stormwater management plan. Photos of the restoration work at the Norwood Road-Ludwig's Creek site are included in Appendix A.

3.4 New Castle County, Delaware Projects

Delaware's DNREC, the Delaware Nature Society, and the University of Delaware, Institute for Public Administration's Water Resources Agency worked collectively to install best management practices to control and reduce pollutant loads to the Brandywine, Red Clay, and White Clay Creeks, and Christina River watersheds in the Christina Basin. More specifically, the following projects were installed in the Delaware portion of the basin:

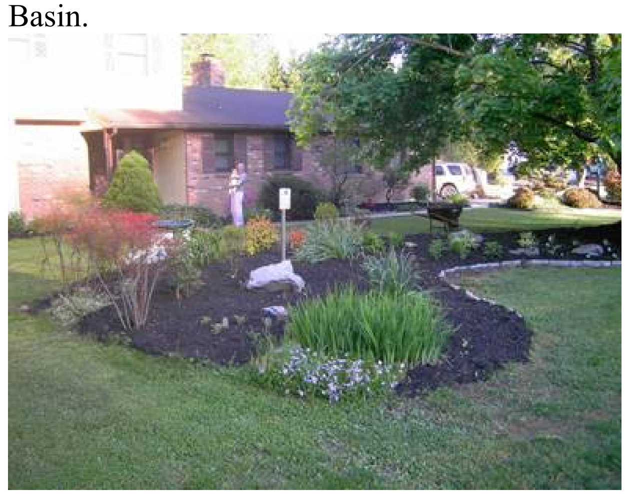
- Smartyard Landscaping/Rain Barrels — 150 Smartyards/204 Rain Barrels
- Stream Bank Restoration/Reforestation — 8,920 Feet
- Stormwater Wetland Retrofits — 5 Retrofits
- Stormwater Wetland Retrofit — 1 Rain Garden

Like their Pennsylvania counterparts, these Delaware organizations found that having a willing landowner is critical to installing BMPs. Engaging the local citizens in these projects was also a key component of the projects, for example: the Smartyards program required a dedicated commitment from the participating resident, DNREC's stream restoration and reforestation projects are serving as valuable outdoor education platforms, and UD's Rain Garden is a campus demonstration project and education and research tool for students and faculty at the University.

The BMPs installed in New Castle County, Delaware by DNREC, the Delaware Nature Society, and the University of Delaware, Institute for Public Administration's Water Resources, with the Targeted Watershed Grant funds, are described in detail in Sections 3.4.1 and 3.4.2.

3.4.1 Smartyards and Rain Barrels

Figure 3.10. A Smartyard site in the Christina Basin.



The Smartyards Landscaping program was initiated by the Delaware Nature Society (DNS) and IPA-WRA as part of the Christina Basin Clean Water Strategy. This program focused on the collective impacts that individual efforts can make towards achieving reductions in nitrogen, phosphorus, and bacteria in Delaware's waters. The Smartyards program is a unique expansion of the DNS's Backyard Wildlife Habitat ™ program. A Smartyard, which is designed to utilize local native plants, reduce stormwater runoff, filter pollutants, minimize watering maximize infiltration of precipitation to recharge groundwater, and provide habitat for wildlife, directly links domestic home maintenance to the watershed's water resources (Figure 3.10). DNS, an environmental nonprofit organization, was best suited to provide homeowners the education and tools necessary to implement this program. Through its affiliation with the National Wildlife Federation, DNS provides official certification for gardens and properties that implement resource conservation practices and meet the four criteria necessary for wildlife habitat; food, water, cover, and places to breed and raise young.

All residents within the Christina Basin were eligible for the Smartyards Landscaping packages, although community open spaces were not eligible for this project. Availability of the Smartyards Landscaping packages were promoted through a variety of sources, including: United Water billing insert; Artesian Water Company billing insert; University of Delaware native plant sale and Ag Day; DNS newsletter, website, native plant sale and seminar; Christina Basin Tributary Action Team; civic associations; Federation of Garden Clubs; and retail affiliates. Through this grant, DNS facilitated the installation of 150 Smartyards across the Basin. The map in Figure 3.12 shows the location of most of the Smartyards installed in the Christina Basin.

The Smartyards program is primarily a public education and outreach tool. It raises awareness of the individual's role in keeping water clean and encourages action to achieve TMDL reductions. As a condition of the program, the selected homeowners agreed to:

- Attend an introductory meeting where DNS staff provided an overview of the program, including information about the Christina Basin water quality initiative;
- Sign a voluntary 10-year agreement form modeled after those utilized in the Conservation District/Natural Resource Conservation Service (NRCS) cost-share programs, sample provided in Appendix B;
- Pick up their Smartyards materials at a central location;
- Provide mulch for plantings;
- Install all materials; and
- Complete the Backyard Wildlife Habitat ™ certification process.

Each Smartyard participant received approximately $500 in direct supplies and materials. Each Smartyard landscaping package included:

- A variety of native trees, shrubs, and perennials that provide habitat and reduce the need for watering and chemical applications;
- Birdfeeder, nesting box, and bird bath provided by Wild Birds Unlimited to enhance the property's wildlife value;
- Educational and how-to resources, including Delaware native plant list, local watershed information, habitat planning guide and design templates, tip sheets on attracting wildlife, application for Backyard Wildlife Habitat™ certification, and water quality checklist;
- Backyard Wildlife Habitat™ yard sign (9" x 12," metal) for public education and advertising (an illustration of the sign is provided in Appendix C);
- One-on-one, onsite technical assistance from Delaware Nature Society trained Habitat Stewards, that included planning and installation guidelines to ensure proper placement and maintenance of the plant materials; and
- A 55-gallon rain barrel to help conserve water resources and reduce stormwater runoff.

In addition to the $500 worth of materials and supplies that were provided each Smartyard participant received one-on-one, onsite technical assistance from DNS trained Habitat Stewards, including information on environmentally sensitive gardening practices, as well as recommendations for native plant selection and placement. For example, a tulip tree is among the list of native trees available to the Smartyard participants (Figure 3.11). Each Smartyard participant signed a 10-year agreement form pledging their "cost-share" via their labor for installation of the plant material and long-term care and maintenance, such as mulching. The evolution and installation of a Smartyard is described in detail in Appendix D. More specifically the Walck and Chambers properties are two Smartyard sites implemented through funding provided by the TWG grant. Photos and more detailed descriptions about these sites can be found in Appendix E.

Figure 3.11. A native tulip tree.

Figure 3.12. Christina Basin Targeted Watershed Grant Smartyards.

3.4.2 Stream Restoration and Reforestation

DNREC's Ecological Restoration Program housed in the Division of Soil & Water Conservation implemented several types of stream bank restoration projects within the Christina Basin. The overall goals were stabilization of the stream banks to reduce erosion; creation of habitat by putting in sequences of riffles and pools in the stream channel and planting the banks with a large number of native trees and shrubs; improving water quality; reducing the number of out-of-bank flooding events; and restoring and maintaining the natural features of the stream.

The projects were installed in the Piedmont Physiographic Province, where most of the Christina Basin lies. The topographical relief, combined with the impacts from development and increased volumes of water entering the stream system with each rain event, has degraded numerous streams. Several reaches of these streams were identified as excellent candidates to restore utilizing stream restoration construction techniques.

Through this grant, DNREC committed to restore 5,000 linear feet of stream. A summary of the stream restoration efforts that were accomplished through the TWG and other funding sources that the Department was able to leverage is provided in more detail below.

Sanford School Riparian Corridor Planting:
To enhance the riparian canopy of a 400-feet stream restoration project that was completed in 2002, students and staff at the Sanford School planted several hundred additional native trees and shrubs on April 8, 2006 along the banks of a tributary to Mill Creek. The USEPA TWG provided over $13,000 toward this effort. To enhance the riparian canopy, the planting of additional native trees and shrubs took place in the spring 2006 at the Sanford School restoration site (Figure 3.13).

Figure 3.13. Sanford School riparian corridor planting.

Pike Creek at Three Little Bakers Stream Restoration Project:
DNREC completed a 5,000 feet stream restoration project in the fall of 2005 along Pike Creek in northern New Castle County. The stream channel and adjacent banks were restored using numerous restoration techniques, including: rock toe and log toe protection; cross vanes; log vanes; root wads; riffle and pool sequences; and random bolder placement. This method of stream restoration measures the watershed inputs and valley type (e.g., size of drainage area, topographic relief, overland runoff) and provides a means to change the stream's pattern, profile, and dimension to accommodate for the effects caused from urbanization and restore stability, sediment transport, and biological functions. The restoration project also included the creation of three acres of wetlands and the planting of streamside vegetation that will further protect the banks, improve and maintain water quality, and provide wildlife habitat. Approximately five acres of the riparian corridor were enhanced with the planting of native trees and shrubs.

The Three Little Bakers site along Pike Creek was an excellent candidate for stream restoration because of its unique environmental and other related features, these include:

- Part of the White Clay Creek watershed, a designated National Wild and Scenic River System:
- A source for public drinking water;
- One of only six trout-stocked streams in the State;
- A habitat corridor in an area of dense development;
- A potential migratory corridor for the endangered bog turtle; and
- A single landowner that was very interested and willing to participate in a restoration project.

The goals that were accomplished by implementing this project include:

- Stabilizing the stream banks to reduce erosion;
- Creating habitat – putting in sequences of riffles and pools in the stream channel and planting the banks with a large number of trees and shrubs;
- Improving water quality;
- Reducing the number of out-of-bank flooding events; and
- Maintaining the natural look of the stream as nature would dictate.

A series of meander bends were introduced to the existing stream channel which will help reduce the flow velocity and return the stream to a more natural state. Several stream-side wetlands were also constructed, see Section 3.4.4. for more detailed information related to the wetlands. Construction work started in early March 2005; work (construction and riparian corridor planting) was completed by October 2005. The final phase of the project involved the planting of over 3,500 native trees and shrubs along both sides of the stream. These plantings will not only help hold the stream banks in place, but will eventually create a canopy over the stream. This will create better habitat and improve water quality by shading and cooling the water, resulting in increased levels of oxygen in the water column for fish and other aquatic species.

Post-biological monitoring will continue at the site to evaluate fish and macroinvertebrate communities and will be compared to pre-restoration data. This analysis will help determine the effectiveness of the restoration effort and will be considered when planning future projects.

The total design, construction, and oversight costs for this project totaled approximately $780,000; about $48,000 of this amount came from the USEPA TWG awarded to the Christina Basin Clean Water Partnership. The other funds came from the following partners on this project: Three Little Bakers, USEPA Nonpoint Source Program, Delaware Department of Transportation, United States Department of Agriculture Natural Resources Conservation Service, New Castle Conservation District, Partnership for the Delaware Estuary, and Delaware Department of Natural Resources and Environmental Control.

This project is serving as an excellent "outdoor classroom" as numerous site tours have been conducted with students, garden clubs, members of the general public, and a wide array of environmental professionals from the tri-state region including the Christina Basin Clean Water Partnership, the USEPA, and the American Water Resources Association (Figure 3.14). The project was also a topic in a series of environmental short-courses offered by the Delaware Nature Society on April 25, 2006. The site was also featured at the Red Clay Valley Association's annual meeting on April 27, 2006 where site tours were offered throughout the evening. An article about this project entitled "Stream Restoration Project Hits 'Hole in One' at Delaware Golf Course" was published in the September/October 2006 issue of the U.S. Golf Association's *Green Section Record*. The article featured the Three Little Bakers stream restoration project along Pike Creek. The magazine is circulated in all 50 states and approximately 40 countries worldwide. Steve Williams (DNREC) was invited by the U.S.G.A. to submit the article after making a presentation about the project at the Delaware State Golf Association Green Section's Sixth Annual Luncheon in January 2006.

Additionally, in October 2006 Mr. John VanStan, leader, and his 4-H group sponsored by the University of Delaware's Cooperative Extension, adopted the wetland site at Three Little Bakers through the Department's Adopt-A-Wetland Program. Pre- and post-biological monitoring is a component of this project; biologists from DNREC and a private environmental consulting firm performed post-restoration studies of macroinvertebrates and fish populations in October 2006.

Photos of the Three Little Bakers site are shown in Figures 3.15-3.19. The Three Little Bakers Site, at the pre-restoration stage, had a lack of streamside vegetation, which resulted in undercutting of banks and severe erosion (Figure 3.15). The site also had extensive rip-rap that was used to hold the stream banks in place (Figure 3.16). This same area has been restored using logs, tree stumps, boulders, and live-branch willow layering to stabilize the banks and create habitat for fish and macroinvertebrate species (Figure 3.17). There was a large disparity between the restored stream and the previous severely eroded stream banks, pre-construction the stream had a highly-eroded area with no main channel and banks that had been severely eroded and undercut (Figure 3.18). The restoration efforts stabilized the stream banks and removed the sharp bends in the stream channel (Figure 3.19).

Figure 3.14. Three Little Bakers restoration project serves as an excellent outdoor classroom.

Figure 3.15. Three Little Bakers site, pre-restoration.

Figure 3.16. Three Little Bakers Site, pre-restoration.

Figure 3.17. Three Little Bakers site, post-restoration.

Figure 3.18. Three Little Bakers site, pre-construction.

Figure 3.19. Three Little Bakers site, post-construction with stabilized stream banks.

Meadowdale Stream Restoration and Bank Stabilization Project:

The Meadowdale stream restoration project, located along upper Pike Creek, was accomplished through a cooperative effort with the Meadowdale Civic Association. The Meadowdale development has an asphalt walking path that follows Pike Creek. Severe bank undercutting along the toe of the stream caused a portion of the stream bank to collapse. This bank failure destroyed a portion of the walking path. In addition to the unstable banks, the stream was blocked with several large trees that had fallen into the stream (Figure 3.20).

This project called for the creation of a design plan that would stabilize the stream bank, provide for a more stable walking trail for the community, and reconnect the stream with a floodplain. This 500-feet project involved the installation of instream cross vanes, construction of a bank stabilization wall, relocating a walking path that was being eroded away by the stream, as well as improved backyards of the adjacent homeowners (Figure 3.21). Instream grade controls were also installed to reduce the down-cutting of the stream channel. After considering a great deal of input from the civic association, the construction phase was initiated in the fall 2006. The project was completed when native trees and shrubs were planted on January 12, 2007.

This restoration project cost approximately $158,000. The USEPA TWG awarded to the Christina Basin Clean Water Partnership provided $65,000. The New Castle Conservation District provided the remainder of the funds and performed the construction oversight. Staff from DNREC's Division of Soil and Water Conservation prepared the site design plans.

Figure 3.20. Meadowdale stream restoration and bank stabilization project, pre-restoration.

Figure 3.21. Meadowdale stream restoration and bank stabilization project, post-restoration.

Hickory Spring Road Stream Restoration Project:

On March 28, 2006, Meadville Land Services completed a 350 feet stream restoration project along an unnamed tributary to Red Clay Creek along Hickory Spring Road just off of Lancaster Pike in the vicinity of the Delaware National Country Club. This project was initiated, designed, and overseen by members of the Department's Ecological Restoration Team. The USEPA TWG provided over $10,000 and DNREC directed almost $2,500 toward this project. The property owners provided the remainder of the funds which totaled over $7,000. Pre- and post-restoration photos of the Hickory Spring Road stream restoration project are shown in Figures 3.22 and 3.23. This project exemplifies that homeowners can participate in a small-scale restoration project.

Figure 3.22. Hickory Spring road stream restoration project, pre-restoration.

Figure 3.23. Hickory Spring road stream restoration project, post-restoration.

Pike Creek at Independence School and Private Landowners Stream and Wetland Restoration: DNREC Division of Soil and Water Conservation's Ecological Restoration and Protection Program, partnered with the Independence School and three landowners south of the school and completed a stream and wetland restoration project along Pike Creek in January 2008. Approximately 3,175 linear feet of Pike Creek (main stem) along with 496 feet of an unnamed tributary to the main stream channel and adjacent banks were restored using state-of-the-art restoration techniques. The restoration project also included the creation of 3.8 acres of wooded and emergent wetlands on the school property. The planting of over 4,800 native trees and shrubs in the wetland areas and along the stream was done to create a stream-side buffer which will improve water quality and provide wildlife habitat.

This is the third major stream restoration project in the upper Pike Creek Watershed (previous projects have been completed at Three Little Bakers Golf Course to the south and the Meadowdale development to the north). Like the project completed downstream at Three Little Bakers, the Independence School and private landowner sites were excellent candidates for stream restoration because of the same environmental reasons (refer to section entitled "Pike Creek at Three Little Bakers Stream Restoration Project").

The original plan was to utilize funding from various USEPA and other funding sources for the project at the Independence School. The design plans and some of the permits were secured in which the Independence School phase was combined with the Private Landowner phase located immediately downstream of the school. However during the course of planning this project an opportunity formulated where the school phase could be used as mitigation by the Delaware River and Bay Authority (DRBA). Because both phases were designed as one continuous project, a synergy was created whereby the phases can basically be considered one project. Therefore, a decision was made by the Independence School and the Department to take advantage of the funding being offered by the DRBA. Thus, the work done at the Independence School was entirely funded by the DRBA using funds received from the Federal Aviation Administration (FAA). The DRBA funded this project because the restoration work is serving as mitigation for stream and wetland impacts resulting for the New Castle County Airport runway expansion project. The DRBA was unable to find an area to restore near the airport because the area is so densely developed. The U.S. Army Corps of Engineers agreed that this would serve as an excellent mitigation site. The total funding provided by the DRBA for the work done at the Independence School was $641,361. The cost of the restoration work done on the three private properties immediately south of the school was $299,675 which was funded by DNREC's Ecological Restoration Program along with funds from the following USEPA grants: Targeted Watershed; Nonpoint Source; and Non-regulatory Wetlands. The photos in Figures 3.24-3.30 show the project pre- and post-restoration. Wooded and emergent wetlands have been created in what was once an open field at the Independence School restoration site (Figures 3.24-3.27). The flooding and undercutting of the stream banks posed a constant threat to several homes along Pike Creek (Figures 3.28) and the channel has been relocated to the east (Figure 3.29). The relocated stream channel contains a sequence of step pools (Figure 3.30).

Figure 3.24. Independence School Site, pre-restoration (left) and post-restoration (right).

Figure 3.25. Independence School Site, during restoration.

Figure 3.26. A degraded reach choked with debris blockage and sediment bars (before).

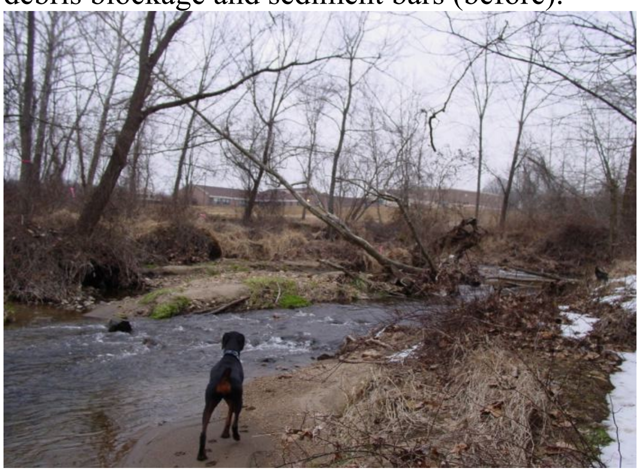


Figure 3.27. Establishment of floodplain and fringe wetlands (after).

Figure 3.28. Flooding and undercutting of stream banks along Pike Creek.

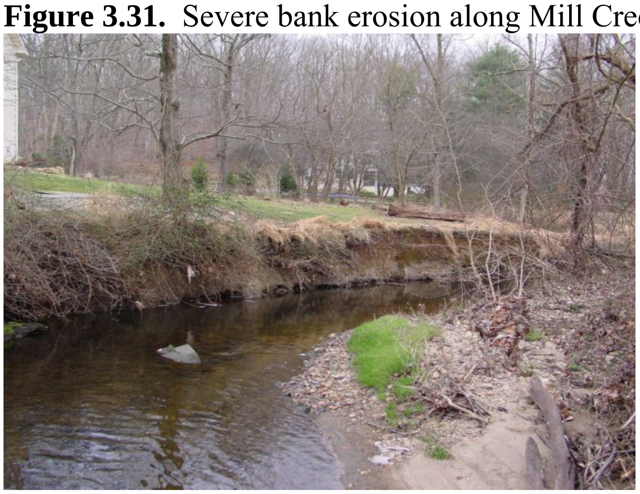
Figure 3.29. Channel relocation to the east of the original location.

Figure 3.30. Relocated stream channel displaying a sequence of step pools.

Mill Creek (Romanelli Site) Stream Restoration Project:

It was decided at the July 7, 2007, Christina Basin Clean Water Partnership Committee meeting to allocate $28,164 dollars from the Christina Basin Clean Water Partnership to pay for the design plans for a restoration project located along Mill Creek, a tributary to White Clay Creek. The site experienced severe stream bank erosion along Mill Creek and restoration and design plans are being prepared to address these problems (Figure 3.31). Field data was collected in December 2007 and final design plans will be completed in early May 2008.

Figure 3.31. Severe bank erosion along Mill Creek at the Romanelli site.



3.4.3 Stormwater Wetland Retrofits

Delaware committed to constructing six stormwater wetland retrofits within the Christina Basin drainage area. This task was completed through the restoration work done at the Pike Creek Three Little Bakers Golf Course and the University of Delaware Rain Garden projects.

Pike Creek Three Little Bakers Golf Course:
A total of five wetland cells were constructed as part of the Three Little Bakers project along Pike Creek, a tributary to the White Clay Creek. The wetlands were created adjacent to Pike Creek at the Three Little Bakers Golf Course restoration site (Figures 3.32 and 3.33). At this site stormwater runoff from upland developments and roadways is captured and filtered through a series of wetland cells before draining into Pike Creek.

Figure 3.32. Pike Creek created wetlands, pre-construction (left) and post-construction (right).

Figure 3.33. Pike Creek created wetlands, post-construction.

University of Delaware Rain Garden:

Wetlands created at the University of Delaware rain garden accounts for the final retrofit structure located at the headwaters of Cool Run that is also a tributary to the White Clay Creek. The UD Rain Garden, although small in stature, is part of a complex watershed system, ranging in increasing scale from the small Cool Run tributary, to the White Clay Creek watershed, to the Christina Basin, and finally to the Delaware River Basin. The UD Rain Garden is situated in the headwaters of Cool Run, a small, ephemeral stream that flows south past the UD Perkins Student Center and then under the Amtrak railroad tracks to the UD Agricultural Farm on its way to join White Clay Creek. As the UD campus developed, the stream has been manipulated and rerouted, sometimes into an underground pipe.

White Clay Creek, Delaware's only National Wild and Scenic River, is the first to be designated on a watershed basis instead of a single-river-segment basis. The 108-square-mile White Clay Creek watershed is an important source of drinking water for Newark's residents and is one of only six trout streams in Delaware. It is one of the four major streams in a larger watershed called the Christina River Basin. The White Clay Creek and sister watersheds Brandywine Creek, Red Clay Creek, and Christina River originate upstream in Pennsylvania before flowing through New Castle County, Delaware, on their way to the Delaware River. The Christina River Basin is, in turn, part of a larger watershed, the five-state Delaware River Basin, which includes parts of Maryland, Delaware, New Jersey, New York, and Pennsylvania.

Through funding received from the TWG a Longwood Graduate Fellow from the UD Longwood Graduate Program designed and installed the UD Rain Garden retrofit to treat and recharge stormwater flowing into the headwaters of the Cool Run tributary. The project served as a Master's Thesis research project designed by Elaine Grehl, Longwood Graduate Program, Class of 2005, with assistance from Jerry Kauffman and Carol Krawczyk.

The rain garden provides numerous benefits to the stakeholders in the area and to the local water quality in the region. Specific benefits include:

- Adds to the City of Newark's progress in meeting the city's NPDES Municipal Stormwater Phase II permit;
- Helps achieve the nutrient and bacteria reductions targeted for the White Clay Creek, as part of the USEPA's TMDL program; and
- Allows for groundwater recharge, flood control, and reduced sediment and nutrient loads to surface waters.

The rain garden site is located in a highly visible area on UD's campus along Academy Street (Figures 3.34 and 3.35). The rain garden demonstrates to the public and consultants that rain garden techniques are feasible retrofitting options. The restoration site also serves as an "outdoor classroom" for UD's College of Human Services, Education, and Public Policy, College of Engineering, and various other colleges throughout campus. A three-panel sign, which serves as an education tool, is installed on the rain garden's observation deck (Figure 3.36). This sign displays the rain garden's location and watershed drainage area, funding sources, and the benefits of a rain garden.

Figure 3.34. UD Rain Garden site, pre-construction.

Figure 3.35. UD Rain Garden site, after rain garden installation.

Figure 3.36. Three-panel rain garden sign at the UD rain garden.

Chapter 4 : Water Quality Monitoring

4.1 Chester County, Pennsylvania, PADEP Agriculture BMP Monitoring

Three Brandywine watershed dairy farms scheduled for agriculture best management practice (BMP) installation by the Chester County Conservation District (CCCD) were monitored by Pennsylvania Department of Environmental Protection (PADEP) to examine potential water quality and habitat improvements associated with the BMPs (Figure 4.1). Monitoring was performed in accordance with the Quality Assurance Project Plan approved by the United States Environmental Protection Agency (USEPA) on March 18, 2004 (PADEP, 2004, Appendix F). Fisher Dairy Farm is located on a second order tributary to the West Branch Brandywine (HQ-TSF, MF) near Honeybrook, Pennsylvania. Proposed BMP work on Fisher Farm included stream-fencing (cattle exclusion), cattle stream-crossings, and riparian reforestation. Windle Dairy Farm and Hicks Dairy Farm are located on first order tributaries to Doe Run (TSF, MF) near Cochranville, Pennsylvania. Proposed BMP work on Windle Farm provided for the separation of barnyard roof leaders and upgradient drainage from barn and barnyard areas utilized by the dairy herd. Proposed BMP work on Hicks Farm provided for fencing off headwater drainage and wetland areas from pasture lands. Monitoring data will be entered into STORET.

Fisher Farm monitoring is complete, whereas post-BMP monitoring at Windle and Hicks Farms has not been performed because BMP installation had not taken place prior to the 2007 monitoring season. The absence of post-BMP data for the two Doe Run Watershed farms precludes further discussion in this report. Pre-BMP data for Windle and Hicks Farms are included at the end of this report as baseline information for these two farms. PADEP is committed to completing post-BMP sampling and providing final farm monitoring reports as an addendum to this report in 2009. The monitoring activity completed as of January 15, 2008 is summarized below (Table 4.1). Detailed monitoring data for the Fisher Farm is included in Section 4.1.1.

Figure 4.1. Three dairy farms in the Brandywine Watershed, Chester County, PA.

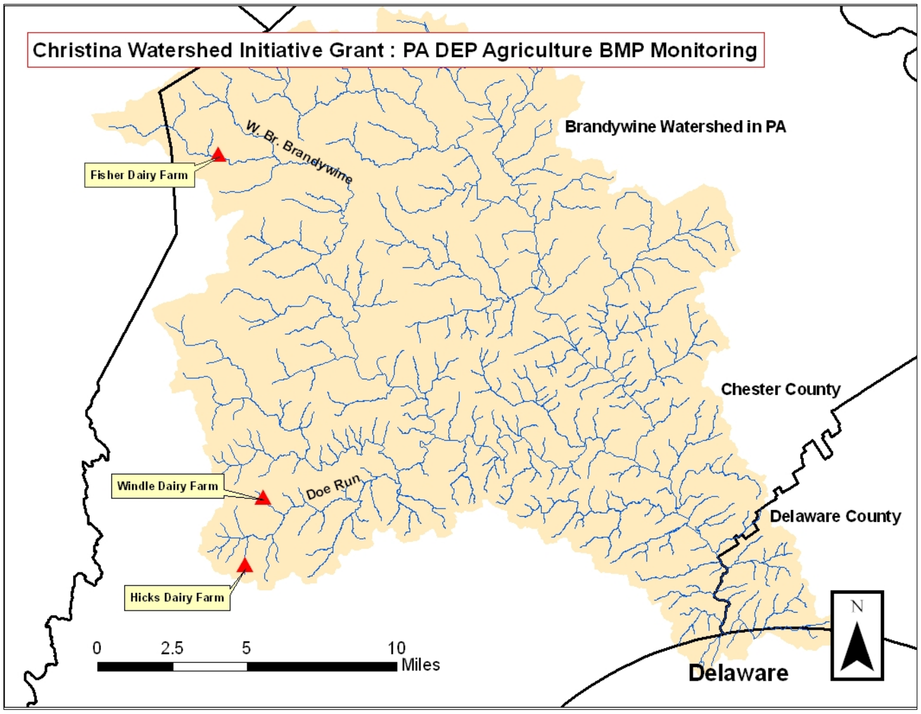


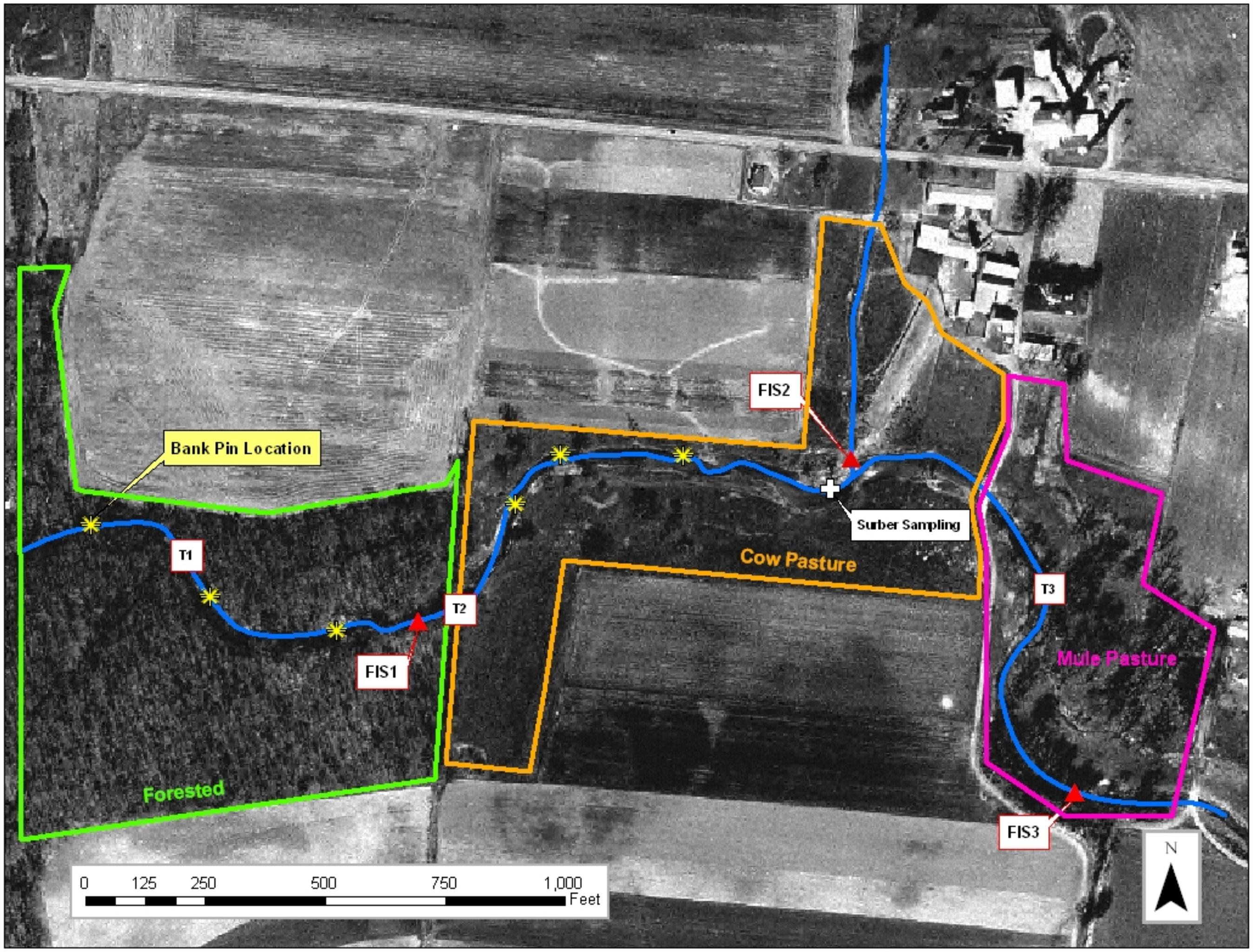
Table 4.1. Summary of agricultural BMP monitoring conducted by PADEP.

Farm	Stream	Agricultural BMP	Pre-BMP Monitoring Dates	Post-BMP Monitoring Dates
Fisher	UNT W.Br. Brandywine	Pasture Stream bank fencing/reforestation	May 25, 2004 July 8, 2005	7/5/2007 12/13/2007
Windle	UNT Doe Run	Barnyard Nutrient BMP	May 5, 2004 August 12, 2004	Not Available
Hicks	UNT Doe Run	Pasture Wetland Fencing	July 14, 2005 June 26, 2006	Not Available

4.1.1 Fisher Farm Monitoring Results

Riparian areas adjacent to the Unnamed Tributary (UNT) to West Branch Brandywine (W. Br. Brandywine) and a first order tributary on Fisher Farm were utilized as dairy herd and mule pasture prior to BMP installation (Figure 4.1). Stream-fencing, two dairy herd crossings, and one mule crossing were installed by Christian Fisher in 2006, effectively excluding animals from the streams and providing a small, variable-width herbaceous buffer (5 to 30 feet) for runoff filtration and improved bank stability.

Figure 4.2. Fisher Farm site map.



Visual Monitoring and Rapid Bioassessment Protocol Habitat Scoring:
Visual evidence of improved riparian conditions at Fisher Farm can be seen in photos taken along the channel before and after BMP installation of fencing and the development of an herbaceous riparian plant community (Appendix G, Figures 1-8). Photos downstream of the pasture, at the confluence of the first order tributary with the UNT West Branch Brandywine, show conditions prior to and following installation. Close cropped vegetation, unstable banks, un-vegetated instream sediment deposits and obvious cattle disturbance were noted in the pre-BMP photo, whereas, volunteer herbaceous vegetation provided good riparian coverage following fence installation. Figures 4.3-4.4 illustrate the Fisher Farm pre- and post-BMP installation. Figure 4.3 shows the lower Fisher Farm pasture, pre-BMP, on May 18, 2004 looking downstream near the confluence with the tributary (Station FIS2). Figure 4.4 shows the lower Fisher Farm pasture, post-BMP, on September 19, 2007 looking downstream near the confluence with the tributary (Station FIS2).

Figure 4.3. Lower Fisher farm pasture pre-BMP (May 18, 2004).

Figure 4.4. Lower Fisher farm pasture post-BMP (September 19, 2007).

Rapid Bioassessment Protocol (RBP) habitat scoring was conducted downstream of the herd pasture at Station FIS3, within the dairy herd pasture, and at Station FIS 1, an upstream wooded reach, before and after BMPs were installed. These locations are noted in Figure 4.2 above. RBP habitat scoring examines 12 instream and near-stream habitat parameters within a 100 meter channel reach. Each parameter scores on a 0 to 20 scale, with 20 being the highest (optimal habitat) and 0 being the lowest (poor habitat). The results found provided the following results:

- Overall, the total habitat scores prior to and following BMP installation were similar for all stations (Appendix G).
- Habitat downstream of the dairy herd pasture and within the mule pasture (stations FIS1 and FIS3) were suboptimal.
- The dairy herd station (FIS2) was considered marginal with regard to total habitat score. However, near stream habitat parameters associated with riparian areas, such as grazing pressure and riparian zone width, were

improved from poor to suboptimal in the dairy herd pasture(FIS2) and mule pasture (FIS3) following the installation of fencing.

- Surprisingly, bank condition did not show any improvement. This might be attributable to scoring subjectivity or the time of year the post-BMP habitat scoring was conducted (January).
- Additionally, the scorer noted that in many areas within the dairy herd pasture, high banks limited the ability of herbaceous vegetation to improve bank stability (see fluvial geomorphic study below). High vertical banks continued to erode below the herbaceous root zone and slump or collapse during storm events.

Water Quality:
Baseflow (grab-1 sample) and stormflow (grab-4 storm events) were collected at Stations FIS3, FIS2, and FIS1 both prior to and following installation of BMP and establishment of herbaceous riparian zone. Internet based Doppler radar was tracked to enable sampling of stream water quality on the rising hydrologic limb. Considerable variability of storm intensity and streamflow was encountered during stormflow sampling; however, no sampling biases were noted upon visual inspection of the data relative to pre- and post-BMP installation storm events. Parameters measured included:

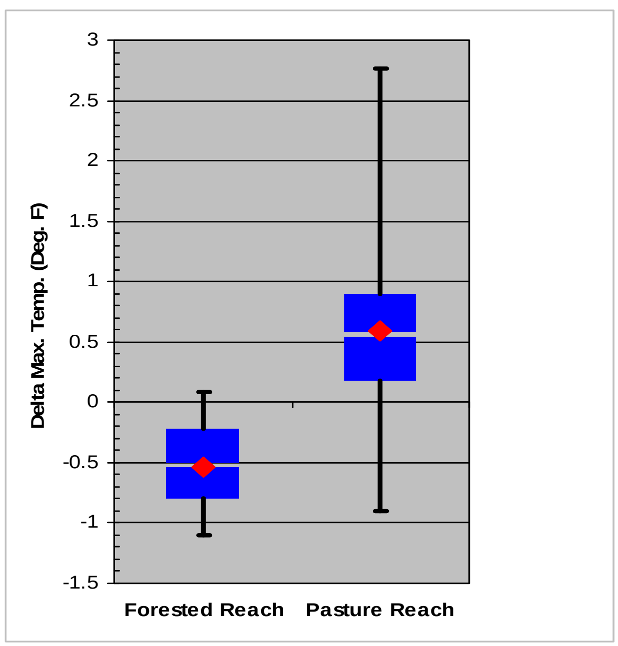
- Flow,
- Temperature,
- Dissolved Oxygen (DO),
- Specific Conductivity,
- pH,
- 5-day Carbonaceous Biological Oxygen Demand (CBOD5),
- Total Suspended Solids (TSS),
- Ammonia,
- Total Nitrogen (TN),
- Total Phosphorous (TP),
- Fecal Coliform, and
- *Enterococcus* Bacteria.

Statistical analysis (one-tailed t test) of intra-station comparisons revealed significant reductions (mean concentration) of several manure related water quality parameters at Station FIS2, which receives runoff from Fisher pasture lands in close proximity to the barn and upstream crop and pasture areas (Appendix G). Post-BMP storm event mean concentration for TN (43% reduction), ammonia (55% reduction), CBOD5 (71% reduction), fecal coliform (95% reduction) and enterococcus (92% reduction) were significantly less ($p<0.05$) than pre-BMP storm event mean concentrations. Noted reductions, corresponded with visual observations of trapped manure solids in riparian reed canary grass areas at the mouth of the tributary (FIS 2). Intra- and inter-station comparisons of downstream (FIS3) and upstream (FIS1) stations found no significant reductions for any water quality parameters tested. This may be attributed to the large agricultural drainage area (7.1 sq. miles) above Fisher Farm that limited the ability of the study to document reductions in the UNT West Branch Brandywine. Additionally, storm-flow sampling on November 15, 2007 coincided with cropland manure application and resulted in atypically high pollutant concentrations. TSS and TP concentrations were not reduced at any station. Because the study used grab sampling, event mean concentrations and storm loadings could not be estimated.

Water quality results were compared to state water quality criteria (pH, DO, ammonia toxicity, fecal coliform, and *enterococcus* bacteria (Delaware), and USEPA Recommended Criteria (TN and TP). Baseflow and stormflow samples never violated water quality criteria for pH (6 to 9 s.u.) or ammonia (pH and temperature dependent), either pre- or post-BMP installation. DO concentration (5.0 mg/l minimum) was violated only once (Station FIS2) during a pre-BMP stormflow sampling event. Fecal coliform (200 cfu/100ml – May to September, 2,000 cfu/100ml October to April) and *enterococcus* (100 cfu/100ml) standards were exceeded for all sample events at all stations. Pennsylvania's fecal coliform criteria is based upon the geometric mean of a minimum of 5 consecutive samples collected on different days during a 30-day period. Sampling conducted for this project did not follow this procedure. However, high baseflow fecal coliform concentrations and extremely high stormflow concentrations suggest manure is causing recreational impairment. USEPA recommended TP (37 ug/l) and TN (690 ug/l) levels for Nutrient Ecoregion IX were also exceeded for all sample events at all stations. Water quality results indicate poor water quality associated with agriculture land use in the watershed.

Water Temperature:
Temperature data loggers (Stowaway Tidbit®) were deployed at Station T1, T2, and T3 from July 29, 2004 to September 28, 2004 to examine potential benefits of forested riparian buffer shading. Mean daily delta maximum temperature (MΔT) for the forested reach (T2-T1) and pasture reach (T3-T2) were -0.53°F and 0.59°F, respectively (Figure 4.5). Forested reach MΔT was significantly lower than pasture reach MΔT (two tailed t-test, n=60, $p<0.05$). Although stream reach lengths were not standardized, data clearly show a cooling trend in the forested reach associated with shading and a warming trend in the pasture reach.

Figure 4.5. Mean daily delta maximum temperatures for forested and pasture stream reaches.



Pennsylvania Water Quality Rules (Chapter 93) for water temperature criteria were exceeded for only two of the 60 days examined (Appendix G). However, a greater number of exceedances probably would have resulted if the deployment period had been during the more stringent July Trout Stream Fishery temperature criteria. Forested riparian areas have an obvious beneficial impact on stream temperature. Temperature data supports the original BMP plan which included reforestation of riparian areas on Fisher Farm.

Fluvial Geomorphologic (FGM) Study:
Morphological characteristics of the unnamed tributary of West Branch Brandywine Creek at Fisher Farm where studied during the period from July 2004 to November 2007. The reach immediately upstream of the farm pasture, which has a mature forested floodplain, was also studied. The forested reach provided a contrast to the study reach, which has no forested buffer. The study of both reaches included surveying the longitudinal profile and several cross sections, as well as a characterization of the stream bed particle size distribution, measurement of bank erosion rates, and an overall semi-quantitative habitat evaluation. Most parameters were measured before and after the introduction of stream bank fencing and livestock exclusion.

The initial survey revealed differences between the two reaches that may be related to differences in riparian vegetation. The average depth of riffles at the bankfull, or channel-forming, discharge is nearly identical in both the pasture and forested reaches, but riffles in the pasture were, on average, 20% wider. This additional width may have resulted in reduced sediment carrying capacity in the pasture, which was observed when comparing the stream bed particle size distribution found in each reach. In the forest, the mean particle size (or "D50") was 27 mm, while in the pasture the D50 was 17 mm.

Pools were longer and shallower in the pasture than in the forest. In the forest, average pool depth at bankfull was 2.6 feet with an average length of 85 feet, while in the pasture's average pool depth was 1.8 feet, with a length of 150 feet. Relatively long, shallow pools are often the result of reduced sediment transport capacity and the excess accumulation of "fines"—particles less than 8 mm in diameter. Long, shallow pools, when combined with a lack of shading and instream cover, make poor fish habitat, and may prevent the development of a diverse, multi-trophic level fish community.

Monumented riffle and pool cross sections were established in both the forest and pasture reaches. These cross sections were each surveyed at least two times between 2004 and 2007. Metal rods ("bank pins") were also driven into the bank at each cross section at the point where erosion potential was greatest. There was a significant difference in the rate of erosion between the forest and the pasture (Figure 4.6). The differences in bank material being lost were determined by using the top of each bank as the point of comparison. The erosion rate for the pasture riffle was 0.8 feet/year, while the rate for the forest riffle was 0.3 feet/year. The difference between pools was even more striking. The bank at the pasture pool lost 2.4 feet/year, while the forested pool's rate of loss was virtually zero. An erosion rate greater than 0.2 feet/year on banks such as these can be cause for concern.

These differences can be explained in part by the type and rooting depth of vegetation found at the edge of each bank, and the relationship between rooting depth and the bankfull elevation. At the forest pool, with practically no discernable erosion in two years, the vegetation was mature forest. The rooting depth was three feet below bankfull, and one foot below the elevation of the base flow discharge. By contrast, the pasture pool, with a 2.4 feet/year erosion rate, had herbaceous vegetation at the edge of the bank with a rooting depth of only 0.6 feet (Appendix G). This depth is almost one foot *above* the bankfull elevation. A thick root/soil matrix, which can take years to develop, is an important factor in a bank's ability to resist erosive forces.

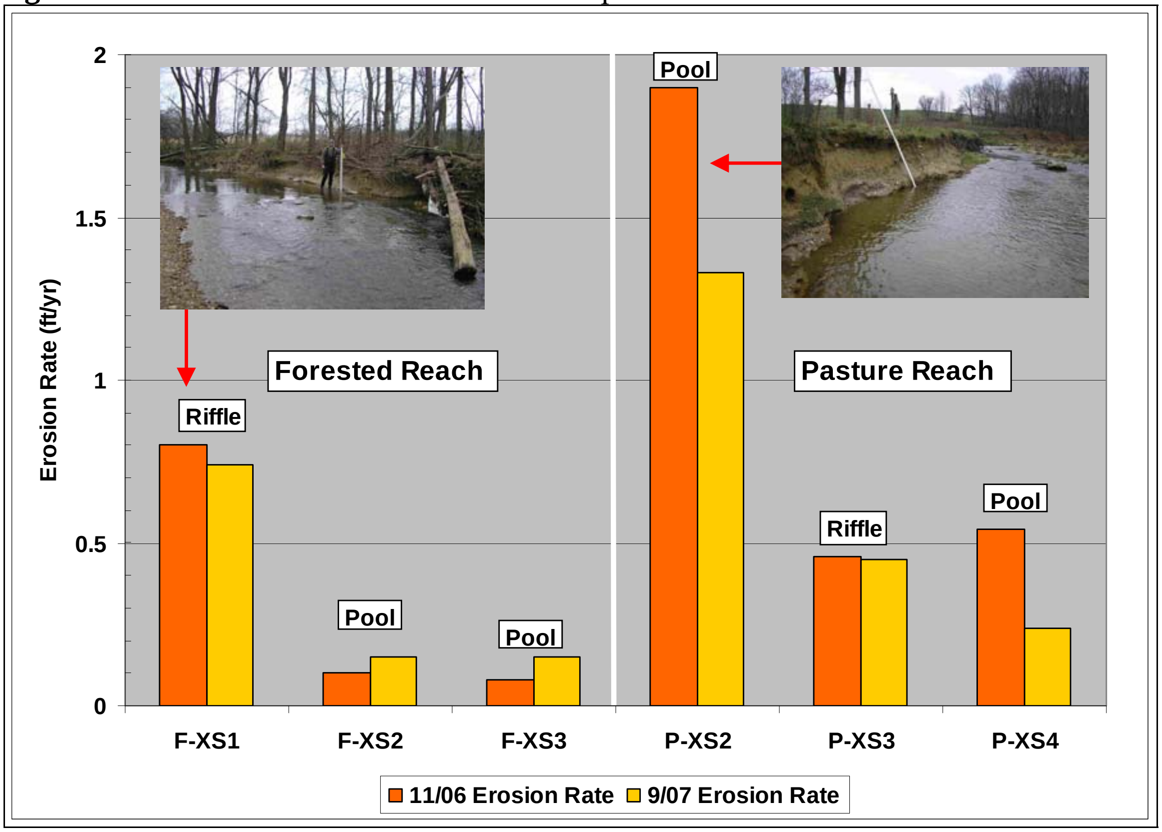
Riffles in the forest and pasture also differed in the bank protection offered by their resident vegetation. At the forest riffle cross section the rooting depth is 1.26 feet below bankfull, and the top of the bank lost one foot over a three year period. By contrast, the base of this same bank, which is almost one foot *below* rooting depth, lost 2.5 feet during the same period. At the pasture riffle the bank vegetation is all grass, and even though its rooting depth is 0.5 feet below bankfull, the top of the bank still lost 2.5 feet over three years. These results illustrate the fact that the root systems of most trees are superior to those of most grasses at reducing stream bank erosion.

The stream bed particle size distributions of the forest and pasture reaches, collected using the zigzag pebble count method, suggest an interesting trend. Every stream, depending on such factors as channel depth, slope, and the nature of the parent geological material, has an "ideal" size distribution. A healthy substrate in this watershed contains between 15% and 25% "fines". A higher percentage of fine material suggests accelerated erosion from banks and/or uplands. A lower percentage of fine material in channels such as this study reach could indicate scouring conditions and/or a low sediment supply. In 2005, the pasture reach sediment distribution contained 66% fine material, whereas in the forested reach, fines totaled 38%. By contrast, after one season of fencing and livestock exclusion, the 2007 numbers were 54% fines in the pasture reach and 43% in the forest, (Appendix G).

The reduction in fines in the pasture may be due to the more effective bank protection that resulted when the riparian vegetation was allowed to grow unimpeded. The more densely vegetated banks and floodplain may also have filtered out a significant volume of suspended fine sediment during flood events. The cross section plots do show that the rate of bank erosion in the pasture decreased between the 2005 and 2007 surveys. This could be in part due to the stream bank fencing, but differences in the volume and timing of flooding during the period may also be responsible. The cause of the increase in fines in the forested reach remains unknown. Rather than a trend, it may only be a temporary fluctuation due to rainfall patterns or other activities upstream.

Comparison of erosion rates in the forested and pasture reach provide evidence for the benefit of deep rooting depth (mature trees) on bank stability. Planting of trees in riparian pasture areas where the channel is connected to the floodplain (areas with lower bank height, channels not incised) would promote long-term bank stability.

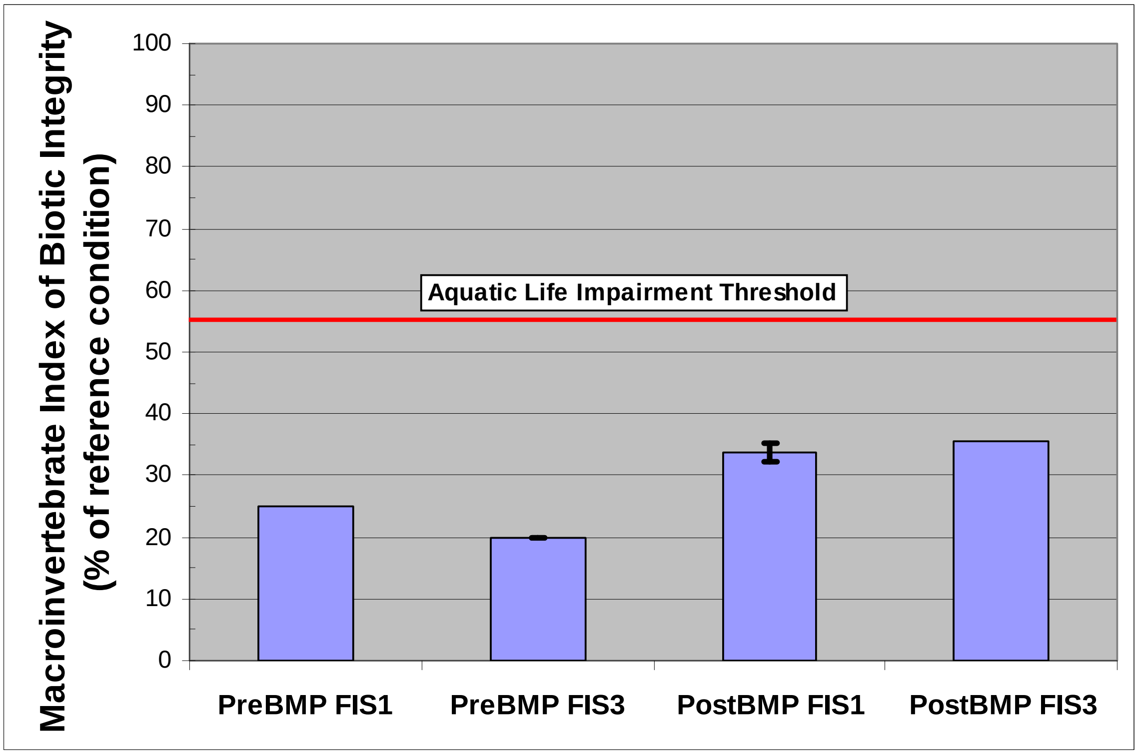
Figure 4.6. Bank erosion rates at forested and pasture reach FGM cross-sections.



Biological Monitoring/Macroinvertebrate Community:
Macroinvertebrate samples were collected upstream (FIS1) and downstream (FIS3) from the Fisher's dairy herd and mule pastures for pre- and post-BMP conditions. Following PADEP methods (2006), 2 D-frame composite samples were collected at each station and preserved in 70% ethanol. One hundred organism subsamples were identified to the lowest possible taxonomic level (typically genus) at the laboratory (Appendix G). Macroinvertebrate index of biotic integrity (IBI) scores were calculated by comparing samples with a reference condition for 5 metrics (Beck's Index, EPT taxa richness, pollution sensitive caddisfly taxa, Hilsenhoff organic pollution tolerance index, and filter/collector + predator + shredder taxa richness) and calculating a percent of reference macroinvertebrate community condition. Index of biotic integrity scores ranged from 20% to 35%, well below the aquatic life impairment threshold of 55%. Pre- and post-BMP macroinvertebrate IBI scores on the UNT W. Branch Brandywine Creek upstream (FIS1) and downstream (FIS 3) from the fencing/riparian areas were examined (Figure 4.7). Communities were dominated by relatively few organic pollution facultative and one tolerant taxa: the worm Naididae, the small minnow mayfly *Baetis*, the net spinning caddisflys *Cheumatopsyche* and *Hydropsyche*, the riffle beetle *Stenelmis*, and midges (Chironomidae). Inter-station comparisons between pre- and post-BMP communities revealed similar scoring, however, upstream and downstream station communities improved slightly in the post BMP sampling, due primarily to a reduction in pollution tolerant worm taxa. Because both the upstream and downstream community showed

similar improvement, the BMP installation was not considered to have any effect on macroinvertebrate communities in the UNT West Branch Brandywine.

Figure 4.7. Macroinvertebrate IBI Scores on UNT W.Branch Brandywine Creek.



Biological Monitoring/Fishery:

Fisher pasture reach electrofishing surveys were conducted on August 20, 2004 (pre-BMP) and November 9, 2007 (post-BMP). Reach length, start/end location, and sampling effort were similar for both dates. Fish were collected, identified, and enumerated in the field. Total lengths were recorded for the first 25 individuals of each species encountered (Appendix G). The fishery is characterized as a warm water fishery. Fish community composition was almost identical with respect to the number of pollution intolerant, intermediate, and tolerant species found in pre- and post-BMP conditions (Figure 4.8). Similarly, the number of piscivore, insectivore, and generalist feeder species showed little difference between the two surveys. The pasture fish community did show an increase in the percent pollution tolerant individuals and the percent of generalist feeder individuals (Figures 4.9 and 4.10). An increase in the number of White suckers (pollution tolerant, generalist feeder) from 11% of total number of individuals pre-BMP to 35% of total number of individuals post-BMP largely accounted for this community difference. A qualitative electrofishing survey of the upstream forested reach was conducted on August 20, 2004. Generally, community species composition was similar to the pasture fish community, however, because only relative abundances were recorded, further comparisons could not be made.

Overall, large numbers of pollution tolerant individuals, generalist feeders, and the rarity of game fish and piscivores suggests a poor fish community limited by both water quality and habitat (e.g. lack of cover, shallow pools). The study found no short-term fish community improvements associated with the riparian buffer and cattle fencing installed at Fisher Farm.

Quality Assurance/Quality Control:
Two blank and two duplicate samples were collected and analyzed for water quality parameters (Appendix G). Blank results showed TSS, ammonia, and total nitrogen concentrations slightly elevated above laboratory detection limits. Upon further investigation, blank contamination was attributed to the distilled water carboy maintained at PADEP's Southeast Regional Office. Following June 17, 2004 blank sampling, the SER carboy was cleaned, rinsed, and refilled with Central Office DI water. Duplicate samples collected on July 7, 2004 and June 26, 2006 showed good agreement except for one CBOD result, one ammonia result, and one fecal coliform result. The large coefficients of variation for these results are unexplained. In accordance with the Quality Assurance Project Plan, PADEP will include three additional duplicate samples during post-BMP monitoring of the two remaining farms.

Figure 4.8. Number of fish species, pre- and post-BMP conditions.

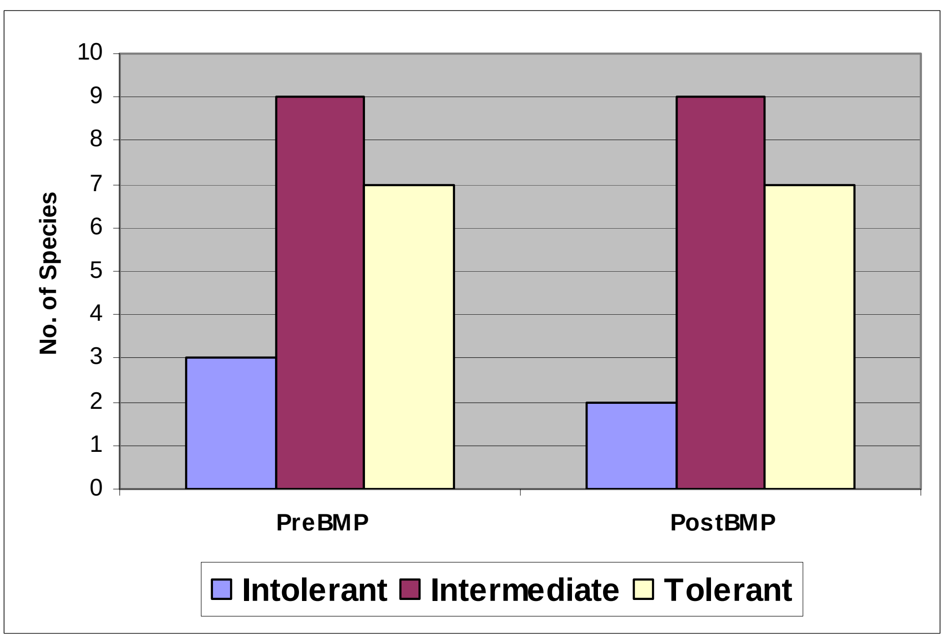


Figure 4.9. Fisher pasture fish species composition, by pollution tolerance designation.

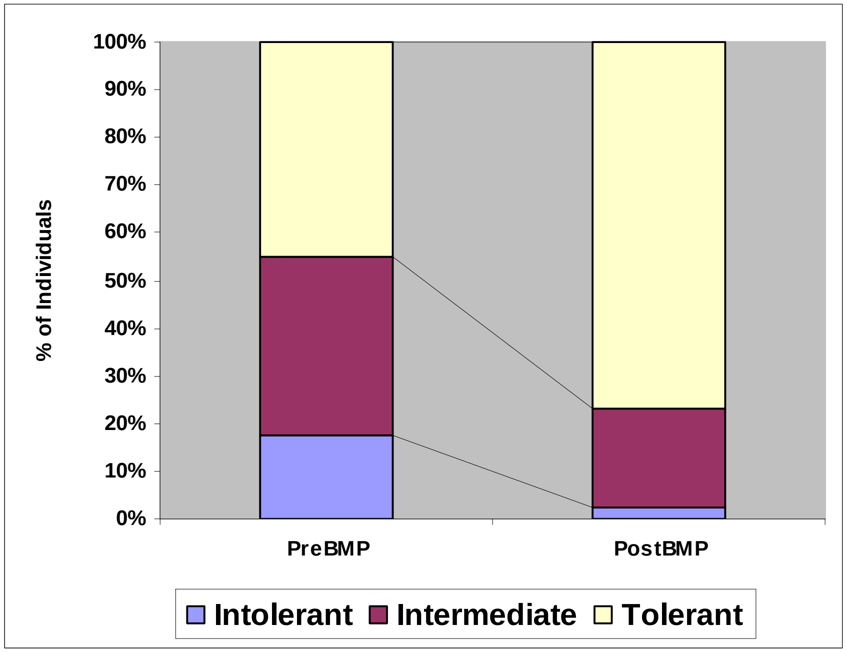
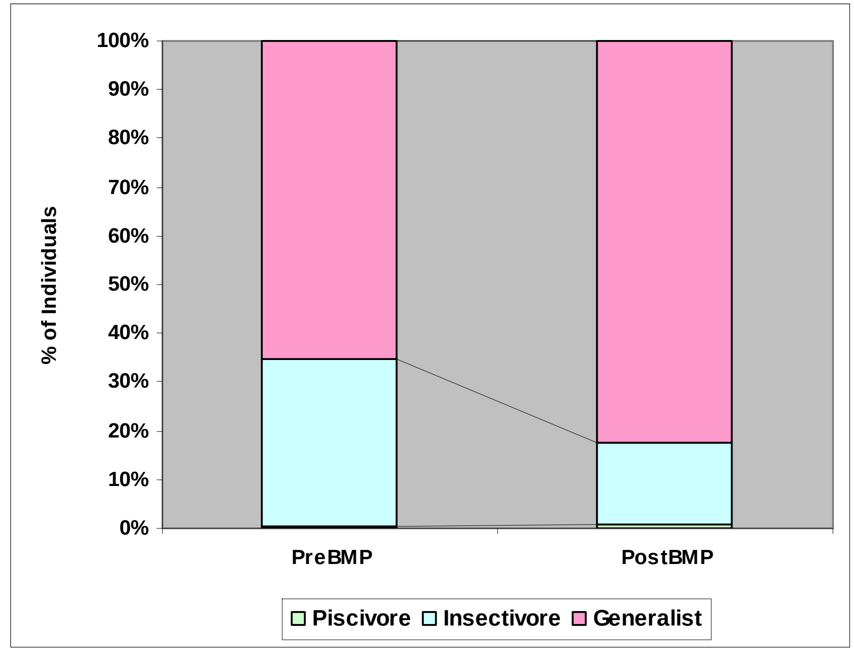


Figure 4.10. Trophic status designation by percent of total number of individuals.



Summary:
Seen in perspective, the stream bank fencing and development of herbaceous riparian areas at Fisher Farm is one small project in a relatively large watershed. The streams current high sediment load, nutrient load, and accelerated erosion rates are the legacy of past as well as present agricultural land use practices. Additionally, high bacteria and biological oxygen demand associated with current farming practices further contribute to recreational and aquatic life stream impairment. Degraded macroinvertebrate and fish communities suggest that the watershed will need considerable water quality and habitat improvements in order to attain designated protected uses.

The Fisher Farm stream fencing/riparian buffer project has provided improved water quality as evidenced by reductions of total nitrogen, ammonia, CBOD5, and bacteria at Station FIS2. Additionally, instream percent fine reductions, bank erosion rate reductions, and near-stream habitat improvements are encouraging trends which may be associated with BMP installation. Similar and even more ambitious projects throughout the watershed targeting nutrient/manure management, increasing bank stability, increasing riparian buffers, and restoring floodplain function will be critical for continued improvement.

Fisher Farm Conclusions:
The following conclusions were drawn from this monitoring data:

1. Significant reductions in stormflow average concentrations of total nitrogen, ammonia, carbonaceous biological oxygen demand, and bacteria were found in the tributary which receives runoff from pasture areas in close proximity to the Fisher barn (FIS2).
2. Pasture bank erosion rates and pasture instream percent fines were lower following BMP installation suggesting improved bank stability and improved riparian filtration.
3. Comparison of forest and pasture riparian rooting depth and temperature monitoring suggest the proposed riparian reforestation would be beneficial to the stream and important to complete.
4. Poor upstream water quality and macroinvertebrate communities indicate that the UNT W.Br. Brandywine will require additional agriculture best management practices to restore impaired water uses and reduce loading to downstream reaches in the Christina Watershed.

4.2 New Castle County, Delaware BMP Monitoring

The monitoring for the Targeted Watershed Grant (TWG) BMPs implemented in New Castle County, Delaware included:

- Instream monitoring along the main stems of the Brandywine, Red Clay, White Clay Creeks, and Christina River
- Instream environmental monitoring at Pike Creek.
- Surface water quality monitoring at the University of Delaware's Newark Farm.
- Participant questionaires and Purdue's L-THIA water quality model for monitoring the Smartyards.

These monitoring efforts are discussed in more detail in Sections 4.2.1-4.2.3 and in Appendices H-J.

4.2.1 Main Stem Monitoring

In the Christina Basin in Delaware, water quality is monitored at DNREC stations to determine whether TWG and other Partnership restoration projects are working. The University of Delaware's Water Resources Agency plans to publish annual water quality monitoring reports at stations along the Brandywine, Red Clay, and White Clay Creeks, and Christina River. Since 1990, annual water quality monitoring reports indicate dissolved oxygen, phosphorus, and sediment levels have improved in the Brandywine and Red and White Clay Creeks, and Christina River. Bacteria levels remain high and unchanged or constant over time. Nitrogen levels are rising and continuing to degrade along three of the four streams. Water quality trends for dissolved oxygen, sediment, phosphorus, nitrogen, and bacteria in the Brandywine, Red Clay, White Clay Creeks, and the Christina River and the statistical analysis is summarized below (Tables 4.2 and 4.3). A more detailed analysis of water quality data and trends in the four subwatersheds is also provided below (Figures 4.11 and 4.12).

Table 4.2. Stream water quality change in the Christina Basin since 1990.

Subwatershed	DO	Sediment	Phosphorus	Nitrogen	Bacteria
Brandywine Creek	Improved	Constant	Improved	Degraded	Constant
Red Clay Creek	Improved	Constant	Improved	Degraded	Constant
White Clay Creek	Constant	Constant	Improved	Degraded	Constant
Christina River	Improved	Improved	Improved	Constant	Constant

Table 4.3. Seasonal Kendall statistics for Christina Basin water quality stations, 1990 to 2005.

Stream	DO				TSS			Bacteria			TKN			TP	
	p	slope	n	p	slope	n	p	slope	n	p	slope	n	p	slope	n
Brandywine Cr	**0.093**	0.086	91	0.108	0.275	89	0.347	8.3	90	0.225	0.018	75	0.858	-0.001	75
White Clay Cr	0.321	0.035	67	0.142	0.800	65	0.928	2.1	65	0.114	0.034	62	0.382	0.004	59
Red Clay Cr	0.142	0.112	80	**0.052**	0.400	75	0.690	8.4	78	0.530	0.010	75	0.147	-0.005	76
Christina River	**0.025**	0.146	99	0.893	0.000	98	0.225	3.8	100	0.775	-0.008	83	**0.098**	-0.002	83

p = probability ≤ 0.1 = statistically significant. Slope of Seasonal Kendall trend line. n = number of samples.

Figure 4.11. DO, TSS, TP, TN, and bacteria monitoring in the Christina Basin subwatersheds.

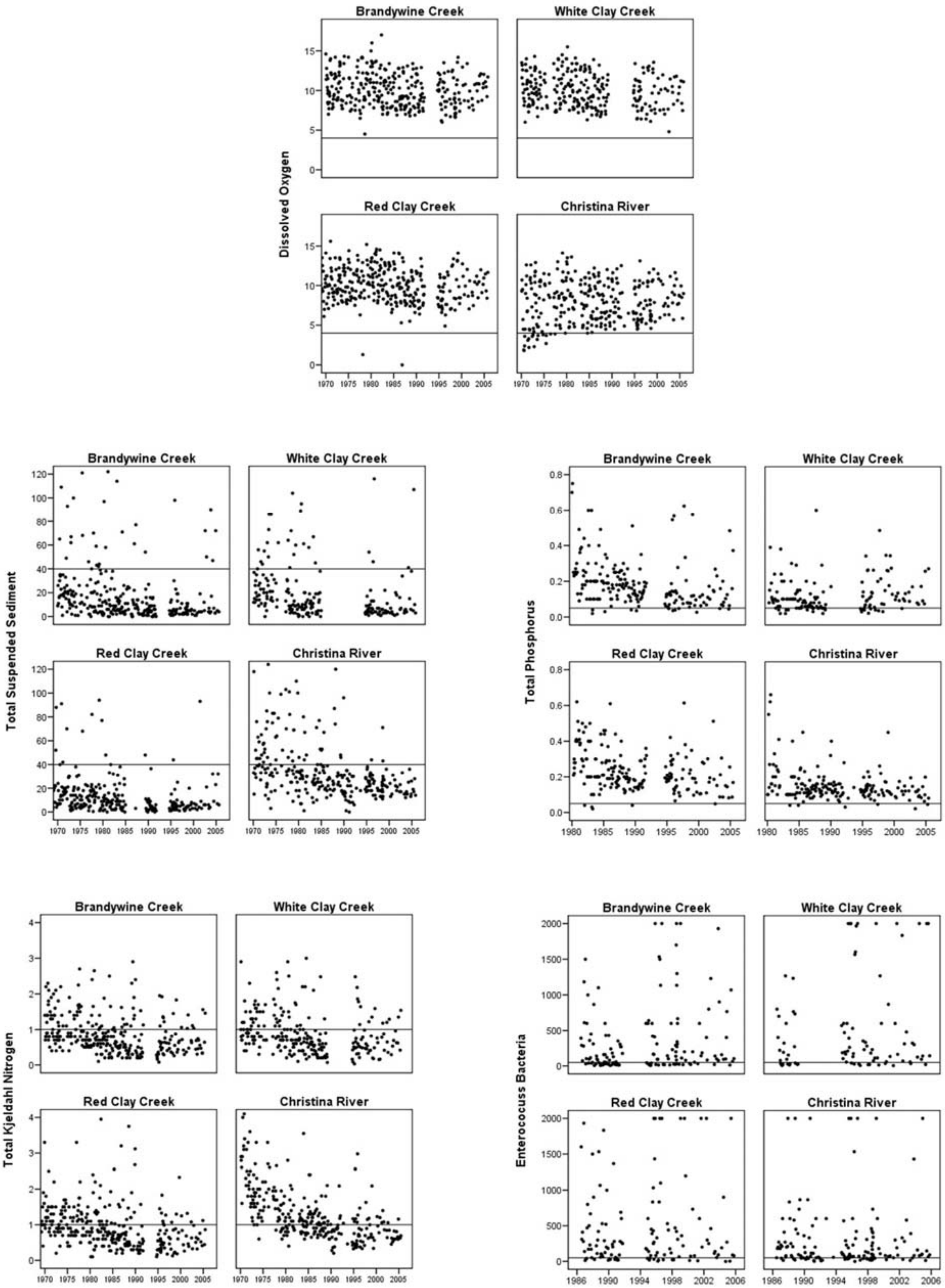
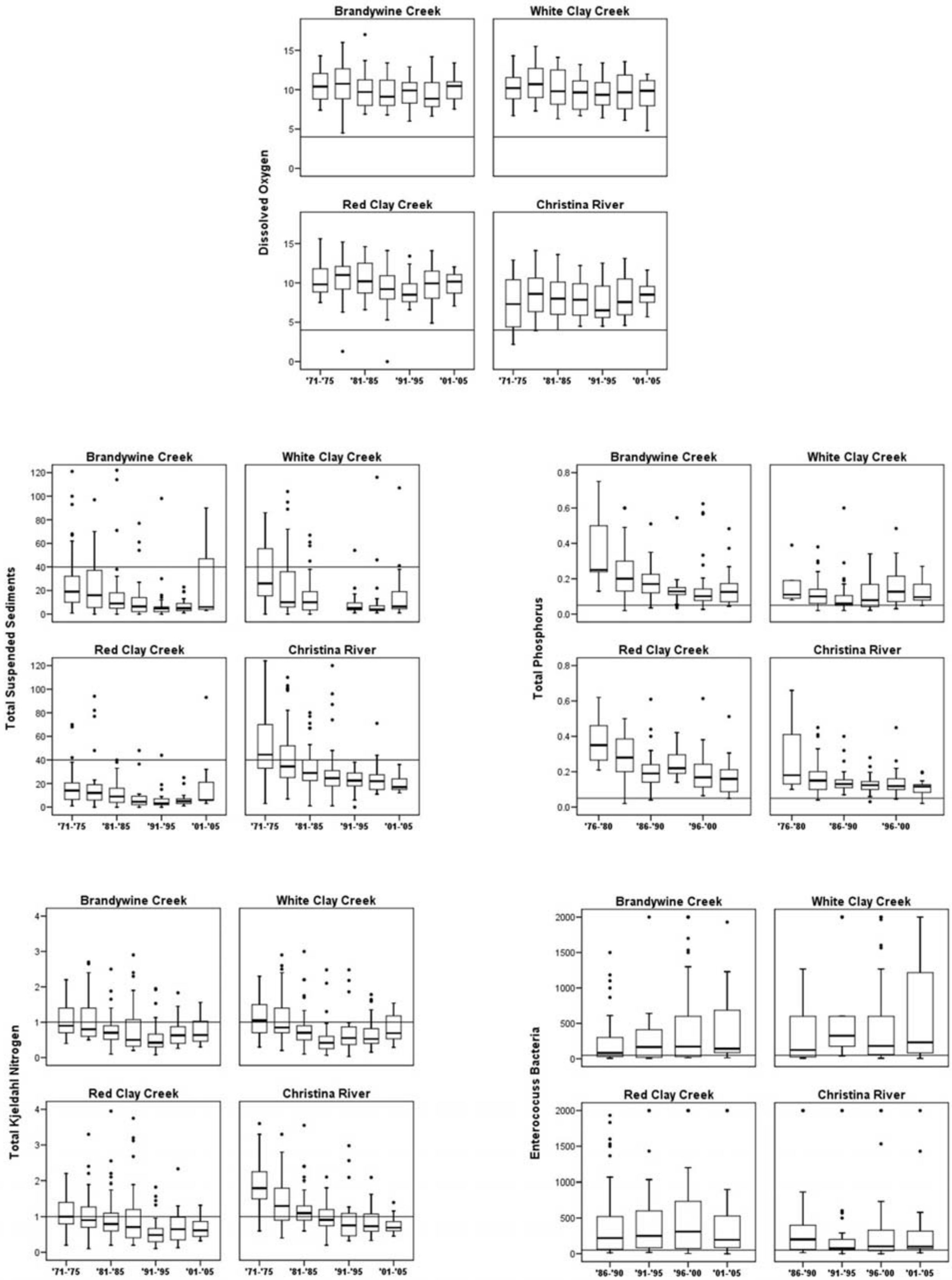


Figure 4.12. DO, TSS, TP, TN, and bacteria trends in the Christina Basin subwatersheds.



4.2.1 Pike Creek Instream Environmental Monitoring

A private consultant performed pre- and post-restoration macroinvertebrate sampling in October 2006 at several sites along Pike Creek. Benthic macroinvertebrates served as biotic indicators of stream health to assess the effects of stream restoration for Pike Creek. Four stream reaches were sampled in October 2006; three in the restoration area and one from a regional reference stream. The methods used for pre- and post-restoration sampling were the same as those used for pre-restoration data collected in 2002 at the Three Little Bakers site. The first section of stream sampled was a 5,000 linear foot restored reach located at the Three Little Bakers Golf Course in Newark, Delaware. This area was sampled to assess one-year post-restoration effects. Data are being compared to baseline data collected prior to the restoration in 2002 by scientists from the Delaware Department of Natural Resources and Environmental Control (DNREC), Division of Water Resources, Environmental Laboratory Section. The second stream reach is a 3,200 linear feet area located upstream of the restored section near Independence School. It was sampled to establish baseline data prior to restoration efforts scheduled to begin in the spring 2007. The third reach was approximately 500 linear feet located near the development of Meadowdale and was also sampled to establish pre-restoration baseline data. The fourth reach was the regional reference site at Middle Run, located within the same watershed (White Clay Creek). Monitoring will be entered into STORET.

Fish monitoring (pre- and/or post-restoration) was also done at these same sites by staff from the Division of Fish and Wildlife. Pre- and post-restoration monitoring was conducted to evaluate species size and types to determine the effectiveness of restoration efforts and collect baseline data prior to restoration.

The results of these studies were finalized and are contained in the separate reports (refer to Appendices H, I, and J) entitled: *Biological Assessment of Pike Creek (Macroinvertebrate and Habitat Survey)*; *Pike Creek Stream Restoration – 2006 Fish Monitoring Report*; and a *Summary of a Pre-restoration Fish Survey of Pike Creek in 2004*

Load Reductions:
Based on research conducted by Land Studies, Inc. (LSI) in their August 2005 publication entitled “Stream Bank Erosion as a Source of Pollution: Research Report,” for Piedmont streams in southeastern Pennsylvania, load reductions have been calculated for the stream restoration projects completed as part of the Christina Basin TWG. The following table shows sediment, phosphorus, and nitrogen load reductions using averaged load reduction rates derived from the report prepared by LSI (Figure 4.13).

Figure 4.13. Predicted load reduction for restored piedmont streams in the Christina Basin.

Annual Load Reductions Based on Land Studies' Research* on Piedmont Streams in Penna.

	Length of Stream (feet)	Annual Sediment Load (tons/yr)	Annual Total P Load (lbs/yr)	Annual Total N Load (lbs/yr)
Pike Creek - Independence School	3,671	1,946	1,762	4,699
Pike Creek - Three Little Bakers	5,000	2,650	2,400	6,400
Pike Creek - Meadowdale	500	265	240	640
Red Clay - Hickory Spring Road	350	186	168	448
TOTALS	9,521	5,047	4,570	12,187

* "Stream Bank Erosion as a Source of Pollution: Research Report" prepared by Land Studies, August 2005

4.2.2 Stormwater Retrofit Monitoring at the University of Delaware's Newark Farm

The Department entered into a Project Agreement with the University of Delaware in which the University will perform surface water quality sampling and analysis to evaluate ambient water quality and pre- and post-implementation pollutant loading in the Cool Run subwatershed within the White Clay Creek watershed.

Combined funding from the USEPA, DNREC, the White Clay Creek Watershed Association, and the University of Delaware College of Agriculture and Natural Resources (UD-CANR) has been dedicated to surface water quality monitoring at the University's Newark farm facility. The nearly 350-acre farm is located within the Cool Run subwatershed that drains to the White Clay Creek that, in turn, discharges to the Christina Basin. Most of the Cool Run headwaters are within the farm and UD main campus, with some residential land use mixed in. The intent of the monitoring is to compare surface water quality between residential and farm influences and to evaluate changes over time as BMPs are installed on the farm. Monthly monitoring was initiated in July, 2006 and styled to mirror the State ambient monitoring format so that data from this project can be evaluated in the context of other local state surface water quality monitoring. In addition to monthly surface water sampling, meters have been recently installed at two of the six sample sites to determine more precise flow measurements. The sample and flow data are currently under evaluation.

4.2.3 Smartyards Monitoring

Through questions posed to participants during the Backyard Wildlife Habitat™ certification process, the following changes in land management were indicated by the participants:

- 51 eliminated chemical fertilizer usage;*
- 60 eliminated chemical pesticide usage;*
- 150 controlled roof run-off;
- 136 reduced lawn size;
- 59 controlled invasive plant species; and
- 18 buffered their property when along a stream.

*These numbers do not reflect those who *reduced* chemical fertilizer and pesticide use.

In addition to improving each participant's landscaping practices, as shown in the responses above, community members took note of the Smartyards and its goals. Many participants in Phases II and III of the Smartyards program indicated that they learned about and were interested in the project as a result of a participant from a previous year.

Quantifying water quality changes based on 150 residential landscapes in the 159.67 square mile Delaware portion of the Christina Basin watershed was difficult due to the large number of variables in natural systems. Although the scale of 150 homes will limit the measurable direct effect on watershed health, the significant impact of this project was the qualitative benefits of education and grass-roots action as mentioned above.

The Delaware Nature Society (DNS) maintains information about all Smartyards participants/properties in an iMIS database that also houses records for the Backyard Wildlife Habitat™ program. This information is shared with the National Wildlife Federation and is stored in their Razor's Edge database. All Stream Monitoring data are stored in DNS's iMIS database and shared with DNREC.

Established in 1995, DNS's nationally recognized Technical Stream Monitoring program uses data gathered from citizen efforts for Delaware and USEPA. The program operates under an approved Quality Assurance Project Plan and adheres to Quality Assurance/Quality Control procedures. Data for dissolved oxygen, pH, alkalinity, nitrate nitrogen, phosphates, conductivity, temperature, and salinity (in tidal reaches) is collected every month at each Technical Monitoring site. There are 38 sites monitored in northern New Castle County, within the Christina Basin.

The data that the volunteers collect has been incorporated into a nonpoint source pollution water quality model used by DNREC's Division of Water Resources and the US Geological Survey for the Delaware-Pennsylvania total maximum daily load (TMDL) effort for the Upper Christina Watershed. In addition, the data has been published every year in DNREC's report on the statewide assessment of Delaware's surface and ground water resources that is required under Section 305 (b) of the Clean Water Act.

To determine if the installation of Smartyards had an impact on water quality, DNS analyzed the data from two Technical Monitoring sites. The criteria used to select sites was to identify those sites with the greatest number of Smartyards located directly upstream and those sites that had at least ten years of data. The two sites chosen for the Smartyards monitoring task were Christina River Site #8 (Rittenhouse Park) and White Clay Creek Site #4 (Mill Creek).

- Christina River Site #8 is located in a town park, where the Christina River is relatively small. Thirty-one Smartyards were installed upstream of the site. Five Smartyards were installed in 2005, fifteen in 2006, and eleven in 2007.
- White Clay Creek Site #4 is located on a tributary of the White Clay Creek and is in the coastal plain portion of the watershed. The site is upstream of the location where Mill Creek enters Delaware Park and is approximately one mile from the confluence of Mill Creek with the White Clay Creek. The White Clay Creek was designated a National Wild and Scenic River by an act of Congress in October 2000. This designation preserves its free flowing waters and highlights the importance of its natural resources to the public. Fourteen Smartyards were installed upstream of the site. Five were installed in 2005, four in 2006 and five in 2007.

DNS performed an analysis of data from these two established Technical Monitoring sites to determine if the Smartyards installation could affect the parameters tested in a measurable way. Data following Phase III of the Smartyards project in 2007 was not included, as the installation just occurred in May.

In each case, all parameters met or fell below State standards both before and after installation. The only exception was nitrates. The target level for total nitrogen (all forms of nitrogen combined) in Delaware freshwater is 1.0 to 3.0 mg/L. DNS volunteers measure nitrate-nitrogen, which is only one component of total nitrogen. Nitrate-nitrogen averages were within or below the target level for total nitrogen. In general, comparisons of all parameters show no significant changes due to Smartyards installation. Given more time to collect data it may be possible to see a change. Land use changes can take considerable time before they are able to show a measurable effect on water quality parameters.

It was difficult to monitor water quality changes resulting from the Smartyards installation, due to many factors including the size/scope of the installations versus the size/scope of the watershed. Rather than attempting to show measurable water quality improvements on this scale, pre- and post-surveys may prove a more effective evaluation tool in the future to determine if Smartyards was a motivational factor in starting residential watershed stewardship, and whether and how the participant relayed lessons and information learned to neighbors.

Purdue's L-THIA water quality model was also used to estimate the water quality and quantity benefits of planting Smartyards at 100 lawns assuming single family land use (¼ acre lots). Smartyards are a Delaware BMP that encourages homeowners to replace lawns with water-friendly native plants to reduce irrigation water use and reduce fertilizer and pesticide loads. Smartyards have similar water quality and quantity benefits as forests. The information used to run Purdue's L-THIA water quality model is provided below:

Given:
Existing: 100 lawns on ¼ acre single family residential lots = 25 acres
Future: Plant Smartyards on each lawn (40 ft x 25 ft = 1,000 sf x 100 = 100,000 sf) = 2.3 acres

Results:
Run the Purdue L-THIA water quality model. The results of the water quality model are provided below (Table 4.4).

According to the estimates provided by the model, Smartyards reduce runoff (and increase recharge); nitrogen, phosphorus, suspended solids, and bacteria loads; and irrigation water use.

Table 4.4. Purdue L-THIA model.

Parameter	Existing Lawns	Future Smartyards	Reduction
Runoff (million gallons)	2.90 in x 25 ac = 1.97 mg	2.71 x 25 ac = 1.84 mg	0.13 million gallons
Nitrogen (lb/yr)	30.0	27.3	2.7
Phosphorus (lb/yr)	9.0	8.0	1.0
Suspended Solids (lb/yr)	676.0	614.4	61.6
Fecal Coliform (millions)	1,500	1,362	138
Irrigation Water Use			(1 in/week)(12 week season)(2.3 ac Smartyards) (1ft/12 in)(43,560 sf/ac)(7.48 gal/cf) = 750,000 gal per year

Chapter 5 : Lessons Learned

5.1 Innovative Concepts

Stakeholders with the Christina Basin Clean Water Partnership have learned invaluable, on-the-ground lessons from the United States Environmental Protection Agency (USEPA) Targeted Watershed Grant (TWG). These lessons can be shared with watershed groups throughout the United States. This section discusses the innovative concepts learned from our projects, the strengths and weaknesses of the projects, and the successes and difficulties related to the work conducted for the grant. As is the case with most projects, upon completion of the Targeted Watershed Grant, the Partnership has had the opportunity to reflect on the implementation of this grant and has learned several lessons from the bi-state coordinated effort that occurred over the grant cycle. With this knowledge the Partnership has developed recommendations for future grant recipients and the USEPA Top 10 Watershed Lessons Learned provides a context for this discussion:

1. The best plans have clear visions, goals, and action items.

The mission of the Christina Basin Clean Water Partnership is to restore the water quality of the Brandywine, Red Clay, White Clay and Christina Creeks in Delaware and Pennsylvania to fishable, swimmable and potable status by 2015. Goals are to reduce sediment, phosphorus, and nitrogen loads by 50% to 90% in accordance with total maximum daily loads (TMDLs) set by the USEPA and the two states. The Partnership implemented measurable actions during the Christina Basin TWG. In the Pennsylvania portion these include: nutrient management control plans (10), nutrient management control systems (7), soil conservation practices (>725 acres), waterway diversions (2,250 feet), water control structures (6), stream fencing (8,025 feet), stream reforestation (9,148), stormwater outfall retrofit (1), and stormwater basin retrofits (2). In the Delaware portion these include: Smartyards and rain barrels (204), stream bank restoration (8,920), and stormwater wetland retrofits (6).

2. Good leaders are committed and empower others.

The Christina Basin is an interstate watershed in Delaware and Pennsylvania, one of only two watersheds in the entire Delaware River Basin that flows through two states. Therefore, project implementation presented significant institutional challenges inherent in organizing stakeholders from two states, five counties, and 60 municipalities. The Partnership sought to overcome intergovernmental cooperation barriers by employing the following leadership concepts:

- Gubernatorial Cooperation – Governor Ruth Ann Minner from Delaware and Governor Tom Ridge from Pennsylvania co-signed the original TWG application as a commitment to watershed restoration at the highest levels in State government. In the Partnership's experience, watershed restoration is highly difficult, if not impossible, without commitment from the States and their Chief Executives. The Partnership received commitment from both Governors in a nonpartisan way, a notable act given that the former Governor from the Commonwealth is a Republican and the Governor from the First State is a Democrat.

- Legislative Endorsement – The Partnership received legislative support for the Christina Basin TWG from U.S. Senators Joe Biden and Tom Carper from Delaware and Arlen Specter from Pennsylvania; and Congressmen Mike Castle from Delaware and Joe Pitts from Pennsylvania. Even though they may not agree on some issues, the Senators and Congressmen all agreed on the need for clean water for over 0.5 million of their constituents and came together to support this project on both sides of the State line. The Partnership held special legislative briefings for elected officials in the epicenter of the Christina Basin in Kennett Square, Pennsylvania in November 2003 and February 2008. These legislative briefings each drew over 200 stakeholders and were notable events in the Christina Basin Partnership's TWG project history.

- Local Buy-In – The Partnership received local buy-in by dedicating funds to local stakeholders such as schools, farms, and homeowners. One of the largest obstacles was gaining permission from willing property owners to build watershed restoration projects on their land. The group formed partnerships with local landowners who were motivated to restore the streams that flow through their property. The funding from the Christina Basin TWG provided economic incentive to landowners, particularly farmers, who were at first reluctant to participate in the program.

3. Having a coordinator at the watershed level is desirable.
Full time watershed co-coordinators from each state led the Christina Basin effort. Since 1994, the University of Delaware's Institute for Public Administration-Water Resources Agency has been the Delaware Coordinator and the Chester County Conservation District and Chester County Water Resources Authority have been the Pennsylvania coordinators for the Christina Basin Clean Water Partnership. Since these local coordinators are nonprofit, nonregulatory, and locally based, each one can effectively reach across state and municipal lines to cooperate in implementation. Since the local coordinators have a decade-and-a-half history in the Partnership, the commitment and dedication to the Partnership is strong. Additionally, these local coordinators drink the water from Christina Basin streams, the ultimate personal commitment toward watershed restoration.

4. Environmental, economic, and social goals are compatible.
The original TWG scope provides measurable project goals, for example, restoring 5,000 feet of streams. As discussed previously, the Partnership over-achieved on project goals by looking for cost efficiencies and leveraging funds. For instance the stream restoration contractor on Delaware's Pike Creek saved money on his contract and was able to restore more stream footage (8,920 feet) than planned (5,000 feet). In several of the Christina Basin TWG projects there was a greater final result than the initial required deliverable (Table 5.2).

Table 5.1. Christina Basin TWG implementation values as compared to required deliverables.

Task	Action	Required Deliverable	Final Result
3.1C	PA Soil Conservation Practices	500 Acres	>725 Acres
3.1D	PA Waterway Diversions	2,000 Feet	2,250 Feet
3.1E	PA Water Control Structures	4 Structures	6 Structures
3.1F	PA Stream Fencing	1,000 Feet	8,025 Feet
3.1G	PA Stream Reforestation	6,000 Feet	9,148 Feet
3.2	DE Smartyards and Rain Barrels	150 Rain Barrels	204 Rain
4.1	DE Stream Restoration/Reforestation	5,000 Feet	8,920 Feet

The clean up of the Christina Basin meets environmental, economic, and social goals. The streams provide drinking water for over 0.5 million people in both states. The economic value of the Christina Basin approaches $270 million per year with net present benefits up to $5.4 billion over 30 years (Table 5.2). Significant investments are needed protect this invaluable resource.

Table 5.2. Economic value of the Christina Basin.

Benefit	***Present Value ($ million/yr)***	***Net Present Value ($ million) n = 30 yrs, i = 3%***
Drinking Water Supply	36.1	744.0
Warm Water Fishery	6.2	127.3
Recreation (Boating)	6.6	135.3
Ecotourism (kayaking)	0.8	16.5
Trout Fishing	4.3	88.9
Motor Boating	10.5	217.1
Wetlands	10.0-38.1	206.9-784.9
Forest	159.7	3,290.1
Total	**224.2-262.3**	**4,619.2-5,404.0**

*This economic valuation does not include ecosystem services.
Source: *Christina Basin Pollution Control Strategy (PCS): A Watershed-based Strategy to Implement Total Maximum Daily Loads in the Brandywine, Red Clay, and White Clay Creeks, and Christina River in Delaware*, November 2007.

5. Plans only succeed if implemented.
Both states have developed watershed restoration plans. The Christina Basin TWG provided major incentive to implement the Christina Basin TMDLs. Delaware is implementing a Christina Basin Pollution Control strategy which includes components for:

- Stormwater
- Open Space
- Wastewater
- Agriculture
- Education

6. Partnerships equal power.

Since 1994, the Christina Basin has had a committed interstate partnership of Federal, State, and local governments and nonprofits mediated by USEPA and the Delaware River Basin Commission. Given the intergovernmental complexity of the interstate Christina Basin, a hybrid watershed partnership was formed under the umbrella of the Delaware River Basin Commission who oversees the work. The Partnership employed a "middle-in" approach whereby technical staff from the states and local government partners dedicate in-kind services to structure the grant scope (top-down) and then projects are implemented with buy-in from the public (bottom-up). The Christina Basin Clean Water Partnership acts as a flexible network of interested parties from government and the public to prioritize funding from existing sources (such as the TWG grant) to restore the streams. Refer to Table 1.2 for the structure of and the organizations involved in the Christina Basin Clean Water Partnership.

7. Good tools are available.

The University of Delaware employed a geographic information system (GIS) as a tool to map and track watershed restoration efforts. The GIS map in Figure 5.1 is an example of the GIS mapping tools developed and used for the TWG. Figure 5.1 shows the TWG projects throughout the Christina Basin, including a brief description of some of these projects. The maps developed have been used in multiple reports and presentations related to the Christina Basin Clean Water Partnership and TWG.

8. Measure, indicate, and account for progress.

The Partnership touted water quality improvements as a sign that the restoration projects are working and will motivate future work. As discussed in Chapter 4 of this report, annual water quality monitoring reports indicate dissolved oxygen, phosphorus, and sediment levels were improving in the Brandywine, Red and White Clay Creeks, and Christina River. Bacteria levels remain high and unchanged. Nitrogen levels are rising and continuing to degrade. Evidence that water quality is improving provides impetus to move forward with often complex and expensive watershed restoration projects.

9. Education and involvement drive action.

In the Christina Basin, the Brandywine Valley Association (BVA) leads a substantial public education and outreach program in the Christina Basin. The major public education and outreach programs BVA has conducted throughout the TWG are outline below (Table 5.3).

10. Build on small successes that fuel future, larger ones.

The Partnership tried to move quickly with project implementation to demonstrate successes using the following techniques.

- Watershed Funding – Since the Christina Basin lies in two states, a single entity was needed to distribute TWG funds to the projects across state lines. Therefore, the Partnership partnered with the Delaware River Basin Commission (DRBC), an interstate agency that represents Delaware, Pennsylvania, New Jersey, and New York, as a watershed banker to distribute funds to projects in both states.
- Incentives – The TWG funds provided financial incentives for farmers to cooperate in the program. Many of the cooperating farms in Chester County, Pa are owned by

Mennonite and Amish farmers who are sometimes reluctant to participate in work sponsored by the government. The Chester County Conservation District (CCCD) provided incentives by working with the church elders who advised the CCCD that the Partnership's clean water goals are supportive of the farmers' beliefs. Also, the CCCD let it be known that checks would be mailed immediately to the farmers who chose to participate in the agricultural conservation projects. Once word got out that checks were available, the farmers became motivated.

- Leveraging – The Partnership leveraged the funds received from the TWG. In one instance, stream restoration funds for Pike Creek in Delaware were pooled with wetland mitigation funds provided by the Federal Aviation Administration for runway construction work in the Christina Basin. The Delaware Department of Transportation contributed funds to restore streams along the Pike Creek Road right-of-way. The TWG funding served as a prestigious watershed restoration "magnet" that attracted funds from other places to restore the Christina Basin streams. The estimates that the total leveraged funds exceeded the $1 million TWG funds by over a 2:1 margin.

Table 5.3. Christina Basin public education and outreach programs.

Project	Description	Deliverable/Unit of Measure
Community Participation Events	Quarterly Christina Basin Task Force meetings to involve stakeholders.	12 meetings over 3 years.
Annual Bus Tour	Visit BMP implementation sites to foster understanding of the purpose, benefits, and challenges of implementing effective BMPs.	3 bus tours over 3 years.
Publications	Updated, published, and distributed to enhance public awareness, education, and involvement. Examples include: *Christina Basin brochures* and *BasinScapes* Homeowner's Guides.	Number of publications distributed.
General Outreach and Education	Evening meetings, educational forums, regional workshops, or conferences.	Number of forums held, number of attendees.
E-Newsletters and Press Releases	Describe accomplishments of the Partnership and stakeholders to media outlets such as local and regional newspapers, and television/radio stations.	Number of press releases, estimated audience reached.
Website and GIS Clearinghouse	Establish and maintain a website and GIS Clearinghouse for the Christina Basin Strategy.	Number of website/linked webpage visits.
Storm Drain Stenciling	Continue working with the watershed associations on the Pennsylvania storm drain stenciling program.	Listing of locations stenciled and groups or individuals involved.

Figure 5.1. Christina Basin Targeted Watershed Grant project locations and BMPs.

5.2 Strengths

Beyond the nutrient management systems, stream crossings, Smartyards, rain gardens, wetlands, and numerous other best management practices (BMPs) implemented on-the-ground the Christina Basin Clean Water Partnership identified several strengths of the TWG program. The strengths of the TWG program include:

- A conscientious mission to meet fishable, swimmable, and potable standards in the Christina Basin by 2015.
- Leadership from governors and congressmen from Delaware and Pennsylvania.
- A commitment from local watershed co-coordinators from Delaware and Pennsylvania, dating as far back as 1994.
- Through leveraging and economic efficiencies the Partnership exceeded goals for implementation.
- A locally based, interstate partnership is in place to implement projects using the "middle-in" approach.

5.3 Obstacles and Challenges

There were several challenges that were realized throughout the grant process. These include:

- It took time, sometimes up to three years, to secure willing property owners to implement projects on their land.
- A major constraint is the lack of staff, particularly at the conservation districts, to implement projects in-the-ground.
- The interstate nature of the Christina Basin made fund disbursement to states more complex. DRBC assumed the role of interstate banker to disburse funds to the states.

Through these challenges the grantees identified several recommendations for future grantees. These include:

- Secure property owner commitments immediately, in year one of the project.
- Streamline the grant reimbursement process using a standard progress report form as recommended by the DRBC.
- Schedule more frequent progress report meetings or conference calls between the USEPA and grant recipients.
- Look for more opportunities to leverage funds from other sources, although the Partnership leveraged funds exceeded the $1 million grant by a 2:1 margin.
- Monitoring was a challenge in Delaware as it was difficult to set up monitoring stations at the outlet of the BMPs. Differences in monitoring approach across state boundaries make it difficult to assess complete trends in water quality.
- Several projects were relocated due to lack of land owner participation.

5.4 Lessons Learned

Invaluable lessons were learned throughout the implementation of projects funded through the TWG. Several clear lessons related to the Pennsylvania agricultural BMPs, the Pennsylvania urban stormwater BMPs, the Smartyards, and the University of Delaware (UD) Raingarden are discussed in detail below.

Pennsylvania Agricultural BMPs:
In any and every watershed effort, education is an important component to success. Educating the landowners and residents on the intent of the project, the benefits to the watershed, the funding source(s), and requirements was necessary for complete participation in the project.

Financial investment and/or cost share by the landowner should be required in all BMP installation projects. CCCD requires agriculture operators to cost share 20% of the improvement. However, urban residents are not asked the same and should be. A financial investment by every property owner is fair, instills ownership, and will nearly insure long-term maintenance of the BMP.

Although there is little that can be done to remedy this, grantors need to understand that timelines, contractor workloads, and the weather can not be accurately predicted and do not always meet the grant timeline and end date.

Next Steps for Pennsylvania Agricultural and Urban BMPs in the Christina Basin:
The effort continues to acquire funding for continued urban and agriculture projects in the watershed. The upper watershed is predominately agriculture with Plain Sect (Amish) farmers and BMP installation is critical to protect the downstream waters of the Brandywine Creek. State and federal cost-share programs allow groups like the CCCD to continue cooperator sign up.

The effort continues with the third year of the successful horse drawn no-till equipment rental program to agriculture operators in all watersheds. The District has acquired two horse drawn no-till corn planters with United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) funds (Conservation Innovation Grant) and with a donation from BVA. A no-till vegetable planter was also on loan from Resource Conservation and Development. The District was and is responsible for scheduling the equipment, delivery to operators, and maintenance.

The effort also continues to acquire funding for urban stormwater retrofits. The municipalities of the watershed need education on proper and effective stormwater BMPs and retrofits, as well as the engineers they employ or contract. The Conservation District promotes and requires developers and engineers to incorporate the recommendations of the Pennsylvania Department of Environmental Protection (PADEP) Stormwater BMP manual (2007) and meet infiltration requirement in all plans submitted for review and approval.

The effort continues to educate landowners on individual conservation measures the landowners can perform to minimize the impact of stormwater runoff. In August 2008, 354 rain barrels were sold to residents of Chester County for installation and collection. The project was partially funded ($2,000) with a grant from the Pennsylvania Association of Conservation Districts.

The effort continues to partner with willing and interested conservation organizations on education, grant writing, grant administration, BMP implementation, watershed organization development and projects i.e. stream clean-ups, fairs, displays, planting riparian buffers using Tree Vitalize funding through the Pennsylvania Department of Conservation and Natural Resources and the PA Horticultural Society.

Pennsylvania Stream Restoration:
The Ludwig Creek-Norwood Road project addressed the impacts of flooding and instream erosion by expanding the floodplain, realigning the channel, and stabilizing the steep slopes along Ludwig's Creek in the Williamsburg housing development. Severe erosion due to inadequate stormwater controls upstream and runoff from upstream construction of pavement on steep slopes threatened building stability. In addition, a Transco gas pipeline was exposed, causing concern for public health and safety.

Over 25 local individuals cooperated in this project. The project site had a public information sign advertising the project. This helped generate community support for stream restoration projects. Daily and weekly personal and e-mail communications from CCCD and the consultants were an effective way to keep landowners, the utility company, Pennsylvania Representative Schroder, and the public informed. In response to the project, township bridge improvements and reconstruction design were changed to complement the design of the stream restoration.

Challenges in the project included six bridges and two gas pipeline crossings that had to be negotiated with proper authorities before work could begin. The utility company was resistant to the restoration project and did not offer any financial assistance, and project managers believed that there was stalling throughout the project. Eventually, Transco Williams was removed as a partner from the project.

Individual landowners were hesitant to sign their Grantee/Landowner Agreements. Some individual landowners were unprepared to make a financial contribution toward the watershed because the farmer's focus was on his or her personal property. There was resistance to making a commitment to providing conservation practices, especially for the lifespan of the project, e.g. ten years.

1. *Landowners will focus only on personal property, at first:* Initially, Landowners were only focused on their own properties and did not fully embrace the watershed management concepts. However, over time, as the shock and distress from the damages were rectified by the reconstruction efforts, and the BMPs stabilized, they became 'converts," to watershed principles and understand the upstream/downstream relationships.

2. *Clear the air early:* At times, different parties involved in the processes had separate agendas regarding funding and repairs. Identifying all individual issues early in the

outreach process allows for these to be addressed so that no misunderstandings arise after the project is complete. Project managers are now familiar with what these problems are and can anticipate some of these issues, should a similar occasion arise in Chester County.

3. *If something is wrong, it needs to be corrected*: Due to the public health risks arising after the hurricanes in 2003 and 2004, there was a sense of urgency to move quickly. Qualified professionals were put in the position of delaying the project when project designs had to be resubmitted. By not going against "better judgment" the project will succeed and will not need to be repaired.

4. *When there are disagreements with a project design, get a third party:* Recently acquired knowledge should not be more open to question simply because it is untested by personal experience. Instead, weigh both sides of an argument based on the sources and the evidence presented by both sides.

5. *NEVER violate the well-documented relationship between stream type and valley type:* A stream channel must be built with the appropriate dimension, pattern, and profile for its landscape. If there is a mismatch between stream channel design and the existing landscape, only trouble can result.

6. *Advance a set of attributes for Applied Fluvial Geomorphology practitioners:* Attributes will include: a broad and deep knowledge of fluvial processes, an understanding of which restoration technique is best-suited to a particular set of conditions, and a willingness to learn and appropriately use new techniques once they are proven to work.

7. *Be humble:* Acknowledge that any one school of thought may not have all of the answers.

Delaware Smartyards:
The basic framework/concept for Smartyards is for the private homeowner to make a transition from traditional lawn maintenance practices to landscaping practices with native plants to reduce water usage and fertilizer/pesticide application and to provide better wildlife habitat. This framework is entirely transferable to other watershed groups, with only the specific local information about appropriate native plants for the region, key water quality issues, and local wildlife being substituted. The nonpoint source pollution checklist included general BMPs and could be tailored to focus on any watershed. The Delaware Nature Society (DNS) has conducted Smartyard projects in the Pike Creek subwatershed and Appoquinimink watershed in Delaware, and the White Clay watershed in Pennsylvania utilizing this same general framework. Based on the amount of available funding, the direct materials/supplies (plant material, habitat enhancements, etc.) could be reduced or provided at a cost-share to participants.

The Smartyards project had multiple strengths, including:

- Smartyards is easily duplicated. The principles and framework are always the same. The program can be altered (specifically native plant selection) to fit any region or area of the

country. DNS has conducted Smartyards projects in other watersheds in Delaware and nearby Pennsylvania.
- Smartyards is complementary to regulatory approaches to improve water quality. It is difficult to regulate and enforce nonpoint source pollution. Smartyards is a good hands-on, voluntary way to approach TMDLs when regulatory approaches are impractical. For example, it is impractical for regulators to go out into a neighborhood and cite homeowners for improper application of lawn fertilizer.
- Smartyards connects people to the watershed. Participants must know their “watershed address” to know if they qualify for the project.
- Smartyards provides individuals with one-on-one consultation and site specific information through visits by Habitat Stewards.
- Smartyards has broad appeal. The public loves “free stuff.”
- Smartyards participants will have ongoing learning and involvement opportunities through DNS and the National Wildlife Federation.

The project also had several challenges:

- Although drafted to engender commitment from the participants, the Smartyards agreement form is essentially non-binding. The project is done in good faith producing qualitative benefits through education. If participants revert to poor property management, the materials they received can not be repossessed.
- The project received great community response primarily due to its free materials. For future projects, less plant material could be given to each participant so that more homeowners could be reached. Care would need to be taken to determine the appropriate amount given to the participants. If the amount is too small, participants may not feel the need to ask for an in-depth site visit and these one-on-one site visits are strength of the project.

University of Delaware Rain Garden:
A valuable lesson learned was that obtaining property owner approval is a time consuming task and it is helpful to get landowner permission as soon as possible. Design of the rain garden took one month and the installation and planting of the rain garden took two weeks. Securing the paper work for grant funding through the TWG process took several months. Yet, securing permission from the property owner, the University of Delaware, took nine months.

The most important accomplishment resulting from the installation of the rain garden on the UD campus is that as a demonstration project it provides education and outreach to thousands of visitors annually to the Christina Basin. The rain garden demonstrates progressive ways to infiltrate and conserve water by utilizing native plants instead of fertilizer and pesticide intensive lawn. The UD rain garden is an innovation and has led to the construction of more rain gardens both within the Christina Basin and adjacent watersheds. The rain garden sign posted on the observation deck illustrates the importance of the Christina Basin as an interstate watershed within the greater context of the Delaware River Basin.

The most helpful aspect of the TWG grant to this part of the overall project was the partnership and support from USEPA, the three-year timeframe of the grant to secure property owner permission, and the ability to distribute the grant to both states in the Christina Basin. On the other hand, the paperwork and overhead in administering the grant can be burdensome leaving less time to actually implement the grant projects.

Even more benefits could be obtained by the Christina Basin Partnership if the USEPA increased the TWG funding nationally to $100 million per year. The TWG is a very successful program, this is exemplified by the facts that 176 watersheds throughout the USA applied during the first year for a pool of $20 million and only approximately 20 watersheds received funding.

Delaware Stream Restoration:
A success of the TWG includes the grant's intent to promote and focus restoration and monitoring activities in a specific watershed and/or subwatershed within the Christina drainage basin. This targeted initiative allowed practitioners to direct their efforts to specific areas, such as the Pike Creek subwatershed in Delaware. Instead of doing a fragmented restoration effort, which is typically done in many instances through various funding programs, Delaware was able to implement almost two miles of stream and fringe wetland cells in almost a continuous reach of stream along Pike Creek because of the TWG. This type of approach makes a significant contribution to overall improvements to a watershed when compared to the traditional "Band-Aid" approach.

The innovative funding approaches and partnership opportunities resulting from the TWG enabled the Delaware Department of Natural Resources and Environmental Control (DNREC) to team up with the Federal Aviation Administration (FAA) through the Delaware River and Bay Authority (DRBA) and implement a stream and wetland mitigation project along Pike Creek. The DRBA funded this project because the restoration work is serving as mitigation for stream and wetland impacts resulting for the New Castle County Airport (operated by the DRBA) runway expansion project. This unique partnership allowed for the creation of 3.8 acres of wooded and emergent wetlands and 2,100 linear feet of stream on the school property using state-of-the-art restoration techniques. Over 4,800 native trees and shrubs were planted in the wetland areas and along the stream to create a stream-side buffer which will improve water quality and provide wildlife habitat. This project is between the Pike Creek Independence School Private Landowner phase and the Three Little Bakers Golf Course project to the south and the Meadowdale development project to the north.

Although Delaware was aware of the strength that exists through strong partnerships because of its involvement with the Christina Basin Clean Water Partnership since the mid-1990s, the TWG strengthened that belief. The take-home message is that strong and committed partnerships at varying levels (local, state, and federal) can really accomplish things if everyone is committed and that is the case with the Christina Basin Clean Water Partnership.

It would be productive if the USEPA can promote the concept of bi-state and/or local/state/federal partnerships throughout the county. Unfortunately there is never a guarantee that these partnerships will work, one can bring a group of professionals together, but that does not necessarily create success. Yet, the Delaware/Pennsylvania partnership is comprised of several very talented and thoughtful professionals that work very well together. This is a unique organization in which the Christina Basin reaps the many benefits.

Chapter 6 : Christina Basin Next Steps

6.1 Swimmable, Fishable, Potable by 2015

The Christina Basin Clean Water Partnership proposes to reinvigorate the partnership to meet the goals of restoring the waters of the Brandywine, Red Clay and White Clay Creeks, and the Christina River in Delaware and Pennsylvania to fishable, swimmable, and potable status by 2015. To do this, the Partnership will:

1. Implement the Christina Basin Pollution Control Strategy in Delaware
2. Continue implementation of the Chester County *Watersheds* Plan and local and county water quality improvement projects.

The major initiatives outlined in the Pennsylvania and Delaware plans and a comparison of the plans are provided in Tables 6.1-6.7.

In addition, the Partnership will explore the following initiatives:

1. Employing a permanent watershed partnership structure.
2. Raising funds for restoration through sustainable watershed financing.
3. Researching the feasibility of a water quality trading bank and watershed based permitting.

The Christina Basin Clean Water Partnership employs the following phased approach:

Phase	Tasks	Milestones
I	DRBC/USEPA Mediation/Problem Assessment	1994 - 1996
II	GIS Watershed Characterization	1997 - 1998
III	Water Quality Monitoring/Implementation	1999 - 2000
IV	TMDL Modeling/Implementation	2001 - 2003
V	TMDL Promulgation and Implementation	2004 - 2005
VI	Targeted Watershed Grant Implementation	2004 - 2007
VII	Implementation of Pollution Control Strategy	2008 - 2015

Although significant water quality improvements have been achieved over the past 15 years, significant impairments still remain from agricultural, urban/suburban, and industrial runoff. The Christina Basin is an extremely valuable natural resource and the economic value of the Christina Basin approaches $270 million annually, yet estimates of at least $80 million will be needed over the next ten years to achieve total water quality restoration from nonpoint pollutant sources in Delaware alone. In order to build upon the current progress and achieve the water quality goals, the Christina Basin Clean Water Partnership continues to pursue sources of long-term funding for Phase VII.

The University of Delaware's Institute for Public Administration-Water Resources Agency (IPA-WRA) presented the Christina Basin Clean Water Partnership's Policy Committee with future scenarios in the basin for consideration to meet their goal of all waters being fishable, swimmable, and potable by 2015. The Partnership may continue their interstate collaboration through Memorandums of Understandings while continuing a broad application of best management practices (BMPs) to address the goal of achieving restored water quality by 2015.

Phase VII Implementation could involve the development of a scope of work and additional funding, focusing on six key areas of action:

- Stormwater
- Open Space
- Wastewater
- Agriculture
- Education
- Land Use Planning

1. Stormwater

Stormwater best management practices for the Christina Basin include many actions that require a coordinated effort to engage local municipality participation in the Christina Basin Clean Water Strategy as well as the potential of expanding the role of non-government collaboration through numerous community groups. Examples of the types of projects considered include:

- Increasing urban tree canopy.
- Design and implementation of stormwater BMPs in line with TMDLs.
- Limiting addition of new impervious cover.
- Advance Low Impact Development practices.
- Creating consistency within stormwater ordinances.
- Convene a Christina Basin group to review new development applications.
- Implement a stormwater utility.
- Retrofit stormwater BMPs.

2. Open Space

Open Space tasks would include not only agency and nonprofit actions, but private interests. Open space projects that enhance water quality and are conductive to passive water quality management practices include:

- Mapping and inventory existing open space areas.
- Prioritizing high value water resource areas for protection.
- Installing vegetated buffers.
- Requiring open space management plans for community and Homeowners Associations.
- Implementing new stream restoration plans.
- Acquiring open space and easements.
- Introducing conservation programs for existing open space.
- Reforesting watersheds and headwaters.

3. Wastewater

Wastewater BMPs would need to address complex regulatory, engineering, and enforcement programs, along with municipal, utility, and private sector coordination. The high costs of wastewater BMPs would require serious consideration to the establishment of a formal revenue generating mechanism that can handle the complex nature of wastewater related strategies. Targeted actions would include:

- Installation of performance standards, and conduct inspections and pump-outs of onsite wastewater treatment systems.
- Elimination of cesspools and seepage pits.
- Connection of onsite wastewater treatment systems to existing wastewater treatment plants.
- Elimination of combined sewer overflows.
- Continued inspection, repair, and elimination of unpermitted discharges.
- Remediation of contaminated waste sites.

4. Agriculture

Agricultural best management practices currently being implemented should be continued. The existing programmatic and project institutional "know how" allows for effective and efficient on-site installation. Appropriate pre-and post-monitoring would provide accurate records to be kept on the following practices:

- Nutrient management plans
- Cover crops
- Pasture stream fencing
- Grassed filter strips and buffers
- Grassed waterways
- Riparian forested buffer
- Pasture and hay planting

5. Education

Education and outreach efforts are essential for a broad range of practices that impact water quality through individual behavior. Individual efforts to improve water quality and conserve water resources can result accumulatively in a measurable improvement in a watershed's water quality plus strengthen popular support for water quality programs and policies. Education and outreach efforts that can enhance the efforts of the Christina Basin Clean Water Partnership include:

- Targeting individual behavior change through social marketing.
- Highlighting alternative stormwater management practices (i.e. nutrient management plans for turf fields at education facilities).
- Encourage golf course managers to decrease nutrient application and stormwater runoff and erosion.
- Educate pet owners on cleaning up pet waste.
- Educate homeowners on residential stormwater BMPs.

- Integrate education into state and local permitting processes.
- Encourage corporate environmental stewardship programs.
- Coordinate nonprofit organizations throughout the Basin.
- Support water conservation to reduce nutrients leaving a site.
- Provide education programs on lawn and garden BMPs.

6. Land Use Planning
Comprehensive and responsible land use planning is a critical component of improving water quality and decreasing the pollutant loads entering the tributaries of the Christina Basin watershed. Key land use planning priorities that can have a positive impact on water quality include:

- Continue to work with local governments on comprehensive plans.
- Improve local land use practices.
- Develop coordinated and progressive stormwater ordinances throughout the watershed.
- Reduce the impact of land development on water resources.

6.2 Watershed Governance

During 2009, the Christina Basin Clean Water Partnership proposes to reenergize and reinvigorate in order to restore the streams to fishable, swimmable, and potable status by 2015. A full-time watershed governance structure will be employed. This structure will be coordinated by the University of Delaware's IPA-WRA in Delaware and the Chester County Conservation District/Chester County Water Resources Authority/Brandywine Valley Association in Pennsylvania. The IPA-WRA proposes to contribute a level of funding to this effort for the next six years. Additional proposed partnership initiatives include:

- Holding bimonthly progress meetings in West Chester, Pennsylvania and Newark, Delaware.
- Developing quarterly progress reports from stakeholders on implementation of reforestation, restoration, agriculture conservation, and pollution control projects.
- Increasing public education and outreach programs.
- Finalizing an interstate watershed restoration plan merging the Delaware Pollution Control Strategy and the Chester County watershed plans.
- Signing an interstate watershed MOU between Delaware and Pennsylvania.
- Hosting a Christina Basin Caucus for chief executives from over 60 municipal, county, and states governments in the Christina Basin.
- Coordinating the Christina Basin Clean Water Partnership with the structure of the Partnership for the Delaware Estuary.

6.3 Sustainable Watershed Financing

Sustainable watershed financing for the Christina Basin is critical and translates to obtaining dedicated annual financing to fund watershed restoration projects. Dedicated financing is needed to replace the grant-to-grant approach that has worked reasonably well over the last 15 years but will not get the Christina Basin to the finish line in 6 years. The annual goal for this sustainable funding is approximately $1,000,000, but more or less than the funding goal is acceptable. A variety of funding options may be considered, however all have large regulatory, political, logistical concerns due to the fact that Delaware has a county-based form of government while Pennsylvania has a municipal-based local government. The municipal storm sewer system (MS4) permit program is municipal-based and TMDLs are watershed-based both of which further complicates funding strategies (Figure 6.1). The Partnership will explore and evaluate options to determine what will be most feasible and acceptable to the community at large.

6.4 Water Quality Trading and Watershed-based Permitting

Water quality trading and watershed-based permitting are important considerations to achieve success in meeting the Clean Water Act goals. Establishing a formal Christina Basin water quality trading bank whereby stakeholders may fund upstream improvements could create a tool to achieve the goals in a cost-effective approach. Governments may choose to fund improvements in other portions of the watershed in lieu of spending less cost-effective funds on projects within their own boundaries. Currently, the City of Wilmington, Delaware is participating with upstream farms in Chester County, Pennsylvania as part of their source water program.

The National Academy of Sciences recently released a report that recommended that the USEPA base stormwater discharge and wastewater permits on watershed boundaries instead of political boundaries. The revised watershed-based permitting structure includes market-based trading of credits among stormwater dischargers to achieve compliance. A pilot program is recommended that will allow the USEPA to work through the watershed-based permitting approach. The Christina Basin Clean Water Partnership will consider the NAS recommendations and explore the potential opportunities of such an approach in the Christina Basin.

Table 6.1. Interstate comparison of PA and DE's stormwater recommendations.

Recommended BMP	DE	PA	Recommended Implementer(s)
Stormwater			
Complete development, promulgation, and implementation of high flow TMDLs.		X	USEPA, DRBC, PADEP, DNREC
Require urban tree canopy.	X		DNREC (Watershed Assessment Section), NCC, municipalities, Delaware Center for Horticulture, developers, citizens
Require stormwater BMPs be designed to reduce nutrients according to the TMDLs.	X		DNREC (Division of Water Resources and Division of Soil and Water Conservation)
Limit addition of new impervious cover to less than 20 percent of the watershed above public water supply intakes.	X		Developers, City of Wilmington, City of Newark, NCC
Promote LID in new construction and redevelopment.	X		Developers
Implement comprehensive stormwater management ordinances.	X	X	Local engineers, White Clay Creek Wild and Scenic Management Committee, Christina Basin Clean Water Partnership, RCVA, BVA, City of Wilmington, City of Newark, NCC, CC Planning Agencies, CCWRA, CCCD
Expand the role of RPTAC to create a Christina Basin group responsible for reviewing new development applications.	X		NCC
Implement a stormwater utility.	X		Municipalities, NCC, DNREC
Maintain BMPs.	X		Municipalities, NCC, DNREC
Reduce and manage existing impervious cover.	X		Municipalities, NCC, DNREC
Identify areas where stormwater retrofits would effectively reduce sediment and nutrients.	X		NCC, NC Conservation District
Implement pilot urban stormwater runoff improvement projects within or downstream of developed areas to reduce impacts of urban runoff (2 RC, 4 BC, 4 WC).		X	Kennett Square, Kennett Township, RCVA, Chester County municipality where project is located, CCCD, PADEP, NCC municipality where project is located, UD IPA-WRA, NCCD, DNREC
Implement suburban runoff retrofit projects to reduce peak rate and/or volume of runoff and reduce nonpoint source pollutant runoff (2 RC, 4 BC, 2 RC).		X	Kennett Square, Kennett Township, RCVA, Chester County municipality where project is located, CCCD, PADEP, NCC municipality where project is located, UD IPA-WRA, NCCD, DNREC
Establish an expanded Watershed Watch program throughout the watershed.		X	BVA
Implement NPDES Phase II requirements in regulated PA municipalities.		X	PA municipalities, conservation districts, PADEP

Table 6.2. Interstate comparison of PA and DE's open space recommendations.

Recommended BMP	DE	PA	Recommended Implementer(s)
Open Space			
Map, inventory, and prioritize existing wooded open space areas.	X		UD IPA-WRA, nonprofit and government organizations in the Basin with existing data
Protect existing wooded/vegetated open space areas.	X		NCC, DNREC (Division of Parks and Recreation), municipalities, private and nonprofit conservancies
Require management plans for community and HOA open space areas.	X		DNREC (Watershed Assessment, Urban Nutrient Management)
Require forested riparian buffers of adequate and proper widths sufficient to reduce or eliminate nonpoint source pollution for all new development abutting all waters of the state—including private/state/county land. Encourage establishing and restoring forested riparian buffers on existing development abutting all waters of the state—including private/state/county land. (PA, specifically first order streams with 15%of streams goal (for new buffers) and protection for 30% of streams (for existing buffers) and an overall priority on establishing buffer networks).	X	X	USDA NRCS, nongovernmental land conservancies, county conservation districts, RCVA, municipalities, county agencies, land conservancies,
Implement stream restoration projects.	X		DNREC (Division of Soil and Water Conservation)
Implement pilot geomorphology based stream restorations for several degraded stream reach to restore instream flow regime and habitats (1 RC, 6BC, 2 WC).		X	Chester County, municipalities, BVA, NCCD, DNREC, CCCD
Acquire/conserve additional open space and retain conservation easements.	X		DNREC (Division of Parks and Recreation), State of Delaware Open Space Council, NCC (Department of Special Services), City of Newark (Department of Parks)
Focus open space land preservation in the drainage areas of first order streams and water supply reservoirs and intakes; wellhead protection zones; woodlands; and floodplains.		X	Nongovernmental land conservancies, land owners, developers, County planning agencies
Reforest watersheds and headwaters.	X		Delaware Department of Agriculture, Delaware Nature Society, NCCD

Table 6.3. Interstate comparison of PA and DE's agriculture recommendations.

Recommended BMP	DE	PA	Recommended Implementer(s)
Agriculture			
Nutrient management plans.	X		USDA-NRCS, NCCD, Delaware Department of Agriculture, PA USDA-NRCS, UD IPA-WRA,
Cover crops.	X		USDA-NRCS, NCCD, Delaware Department of Agriculture, PA USDA-NRCS, UD IPA-WRA,
Pasture stream fencing and cattle crossings.	X	X	USDA-NRCS (PA and DE), NC and CC Conservation Districts, Delaware Department of Agriculture, UD IPA-WRA, agriculture land operators
Grassed filter strips.	X		USDA-NRCS, NCCD, Delaware Department of Agriculture, PA USDA-NRCS, UD IPA-WRA,
Grassed waterways.	X		USDA-NRCS, NCCD, Delaware Department of Agriculture, PA USDA-NRCS, UD IPA-WRA,
Forested riparian buffers.	X	X	USDA-NRCS (PA and DE), NC and CC Conservation Districts, Delaware Department of Agriculture, UD IPA-WRA, agriculture land operators
Pasture and hay planting.	X		USDA-NRCS, NC Conservation District, Delaware Department of Agriculture, PA USDA-NRCS, UD IPA-WRA,
Prepare, update, and implement soil and water conservation plans and practices on all crop farm lands.		X	USDA-NRCS (PA), CC Conservation Districts, Delaware Department of Agriculture, UD IPA-WRA, agriculture land operators
Implement manure management plans and facilities to eliminate runoff from barnyards to streams or infiltration to groundwater and to avoid winter spreading of manure (10 WC, 20 BC, 5 RC).		X	NRCS, NC and CC Conservation Districts, agricultural land operators

Table 6.4. Interstate comparison of PA and DE's education recommendations.

Recommended BMP	DE	PA	Recommended Implementer(s)
Education			
Educate Christina Basin stakeholders on nonpoint source pollution and their role in reducing it, specifically targeting behavior change.	X		Nonprofit, private, government entities
Encourage nutrient management plans for turf fields at education facilities.	X		Nonprofit, private, government entities
Encourage golf course managers to decrease nutrient application, stormwater runoff, and erosion.	X		Nonprofit, private, government entities
Educate pet owners on cleaning up pet waste.	X		Nonprofit, private, government entities
Educate homeowners and implement programs for residential stormwater BMPs, BMP maintenance, and nutrient reduction.	X	X	Nonprofit, private, government entities, NC and CC Conservation districts, BVA, UD IPA-WRA
Integrate education into state and local permitting processes.	X		Nonprofit, private, government entities
Encourage corporate environmental stewardship programs.	X		Nonprofit, private, government entities
Coordinate nonprofit organizations throughout the basin.	X		Nonprofit, private, government entities
Support and encourage water conservation and water quality measures to reduce nutrients leaving a site.	X		Nonprofit, private, government entities
Work with organizations to provide education programs on lawn and garden BMPs.	X		Nonprofit, private, government entities
Advise DNREC to research nutrient reductions related to bacteria counts and BMPs.	X		Nonprofit, private, government entities

Table 6.5. Interstate comparison of PA and DE's monitoring commendations.

Recommended BMP	DE	PA	Recommended Implementer(s)
Monitoring			
Establish a Long-Term Water Quality and BMP monitoring program to monitor progress and identify problems in the watershed.	X	X	PADEP, DNREC, USGS, DRBC, CCWRA, NC and CC Conservation Districts

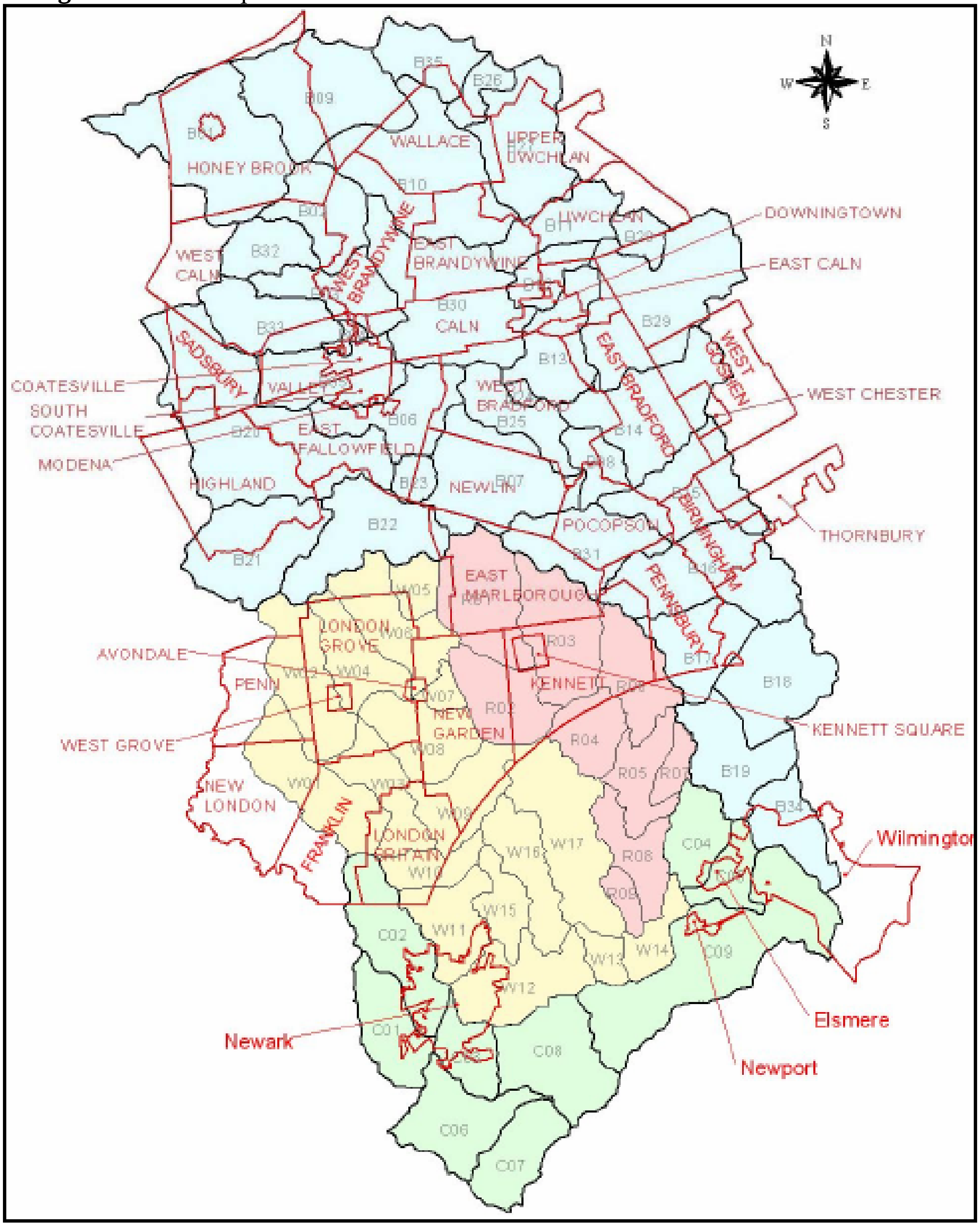
Table 6.6. Interstate comparison of PA and DE's wastewater recommendations.

Recommended BMP	DE	PA	Recommended Implementer(s)
Wastewater			
Require OWTS performance standards, and conduct inspections and pump-outs.	X		DNREC (Division of Water Resources and Groundwater Discharges Section)
Eliminate cesspools and seepage pits.	X		DNREC (Division of Water Resources and Groundwater Discharges Section), NCC (Department of Special Services)
Remove OWTS through connection to centralized WWTP.	X		NCC (Department of Special Services)
Prohibit new OWTS drainfields within 100 feet of wetlands, tidal waters, perennial streams and ditches, and ponds in-line with perennial watercourses.	X		DNREC (Division of Water Resources and Groundwater Discharges Section), NCC (Department of Special Services)
Implement City of Wilmington CSO Remediation Plan.	X	X	State of Delaware, City of Wilmington, USEPA
Continue sewer repair projects and conduct regular inspections.	X		NCC (Department of Special Services), City of Newark (Water and Wastewater Department), City of Wilmington (Public Works Department)
Eliminate runoff from and remediate contaminated substance sites.	X	X	DNREC (Division of Air and Water Management), USEPA, property owners, UD IPA-WRA

Table 6.7. Water supply/wastewater planning and protection recommendations.

Recommended BMP	DE	PA	Recommended Implementer(s)
Water Supply/Wastewater Planning and Protection			
Prepare and implement Integrated Water Resources Plans (IWRPs) (for Chester County portion of watershed (RC), 3 growth regions including: E. Br. Brandywine Creek above Downingtown, Honey Brook, W. Br. Brandywine below Coatesville).		X	Municipalities, county agencies, purveyors
Complete Source Water Assessment underway for surface water intake, and prepare Source Water Protection Plan (6 in BC).		X	PADEP, DNREC, water suppliers, county agencies, UD IPA-WRA
Complete wellhead protection plans for groundwater based public water supply systems in PA (4 RC, wells addressed in Rivers Conservation Plan in BC, 5 WC).		X	Utilities, public water supply well owner, municipality where well is located, county agencies, BVA, RCVA
Complete wellhead protection plan for Honey Brook Borough Water Authority.		X	Honey Brook Borough Water Authority, Honey Brook Township, PADEP
Develop and implement lake management plan and water quality monitoring program (if they do not exist) (for Hoopes Reservoir in RC, 4 water supply reservoirs in BC).		X	Reservoir owners, City of Wilmington
Provide groundwater budget information/data to municipalities.		X	CCWRA, BVA, RCVA
Protect stream water quality and ground water recharge through conversion of point source discharges of treated effluent to land application systems.		X	PADEP, County agencies, BVA, RCVA

Figure 6.1. Municipalities with MS4 Permits in the Christina Basin.



REFERENCES

Section 4.1, Pennsylvania Water Quality Monitoring

American Public Health Association, 1995, Standard Methods for the Examination of Water and Wastewater, 19th edition, American Public Health Association, Washington D.C.

Barbour M.T., J. Geritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for use in Streams and Wadeable Rivers : Periphyton, Benthic Macroinvertebrates and Fish, Second Edition, EPA 841-B-99-002. U.S. Environmental Protection Agency ; Office of Water; Washington D.C.

PADEP, 2004. Quality Assurance Project Plan : Upper Christina Watershed Initiative Grant, Chester County Water Quality Monitoring. Available from DEP SERO.

PADEP, 2006. Standardized Biological Field Collection and Laboratory Methods. Pennsylvania Department of Environmental Protection. Available form DEP Central Office.

Fishman, M.J., et.al. 1989. Methods for Analysis of Inorganic Substances in Water and Fluvial Sediments. U.S. Department of the Interior, Techniques of Water-Resource Investigations of the U.S. Geological Survey, Denver, CO.

Harrelson, C.C., C.L. Rawlins, and J.P. Potyondy. 1994. Stream Channel Reference Sites: An Illustrated Guide to Field Technique. USDA Forest Service, General Technical Report RM-245.

USEPA, Ambient Water Quality Criteria Recommendations : Information supporting the development of state and tribal nutrient criteria : Rivers and Streams in Nutrient Ecoregion IX, US Environmental Protection Agency; Office of Water; Washington D.C.

USEPA, 2002. Guidelines Establishing Test Procedures for Analysis of Pollutants Under the Clean Water Act. Final Rule, Part II 40CFR, Part 136, Volume 56, No. 195, US Government Printing Office, Washington D.C.

APPENDICES A-J

APPENDIX A

Norwood Road-Ludwig's Creek Stream Restoration

Figure 1. Norwood Road-Ludwig's Creek stream restoration, pre-Restoration.

Figure 2. Norwood Road-Ludwig's Creek stream restoration, post-restoration.

APPENDIX B

Delaware Nature Society
Smartyards' Program Commitment Form

DELAWARE NATURE SOCIETY

ABBOTT'S MILL NATURE CENTER • COVERDALE FARM • ASHLAND NATURE CENTER • COOCH-DAYETT MILLS

EDUCATING TODAY
PRESERVING FOR TOMORROW

www.delawarenaturesociety.org

Administrative Offices
Ashland Nature Center
PO Box 700
Hockessin, DE 19707
(302) 239-2334 Tel
(302) 239-2473 Fax

SMARTYARDS PROGRAM PARTICIPATION AGREEMENT

I/we ________________________________ acknowledge participation in the Smartyards component of the Backyard Habitat Program™ being co-sponsored by the Delaware Nature Society and the Christina Basin Clean Water Partnership, and supported by the Environmental Protection Agency. Participation in the program will help improve the surface water quality in the Christina River Basin. In exchange for plant materials, bird bath, bird feeder, nesting box, and rain barrel I/we will agree to do the following:

1. Have my/our property certified by the Delaware Nature Society as part of their Backyard Wildlife Habitat™ program. All necessary materials and assistance will be provided by the Society.
2. Provide all labor necessary for the installation of plants in one contiguous area for optimum value and care thereafter in accordance with furnished installation guidelines. I/we understand that there will be no replacement guarantees associated with the plants.
3. Place a sign in my/our front yard. The sign will be furnished by the Society. Its intent will be to raise public awareness and encourage others to do the same.
4. Pick up all plant materials at the Delaware Nature Society native plant sale in Hockessin, Delaware in the spring of 2006.
5. Provide mulch after initial installation and at least once annually thereafter in accordance with furnished installation guidelines.

I/we agree to abide by this agreement for 10 years from the date of signing. This agreement is non-transferable and will not apply to a new homeowner if you should sell your property.

____
Signature(s) and date

____
Street

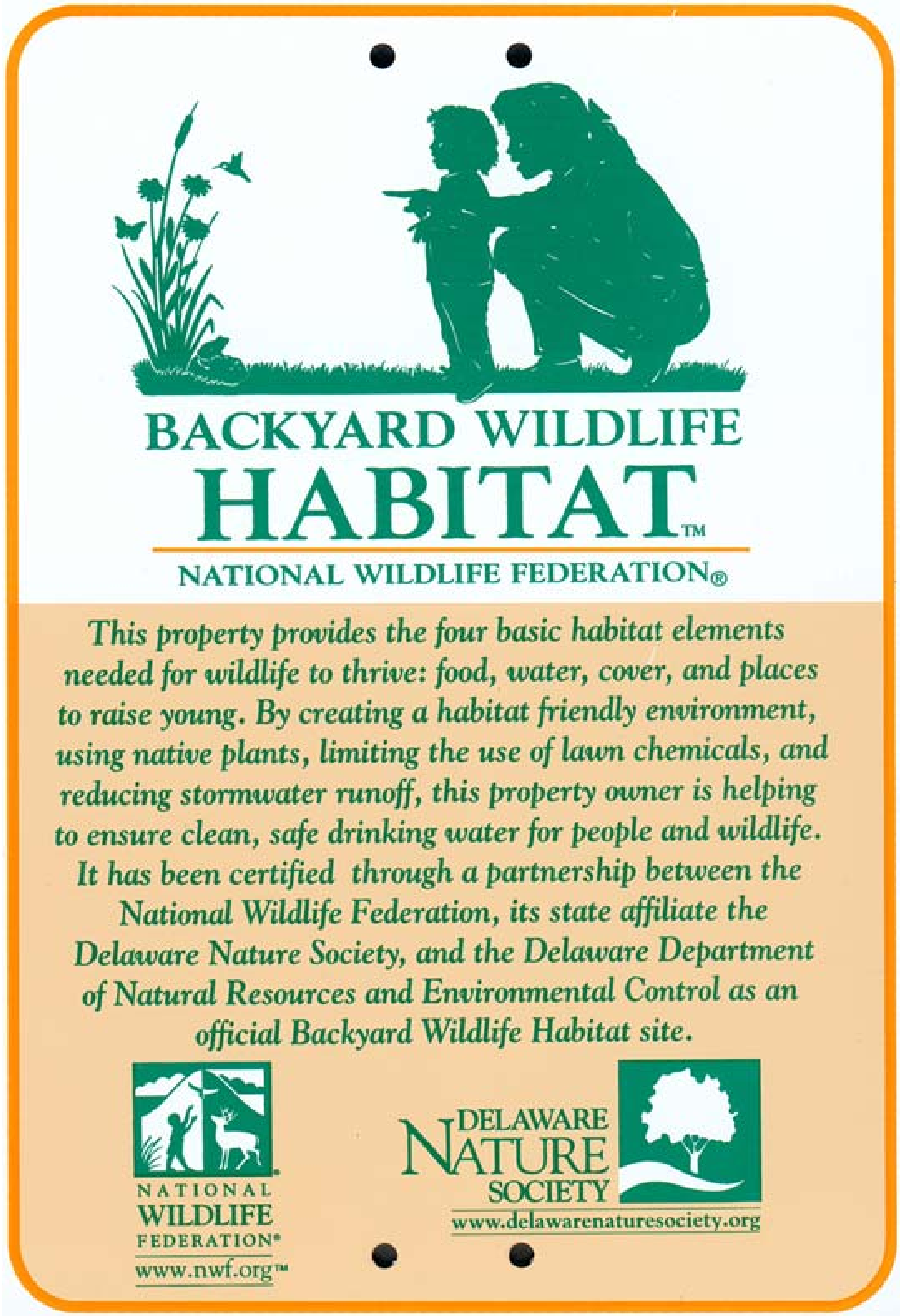
____
City, State, and Zip Code

____
Phone number

____
Email address

APPENDIX C

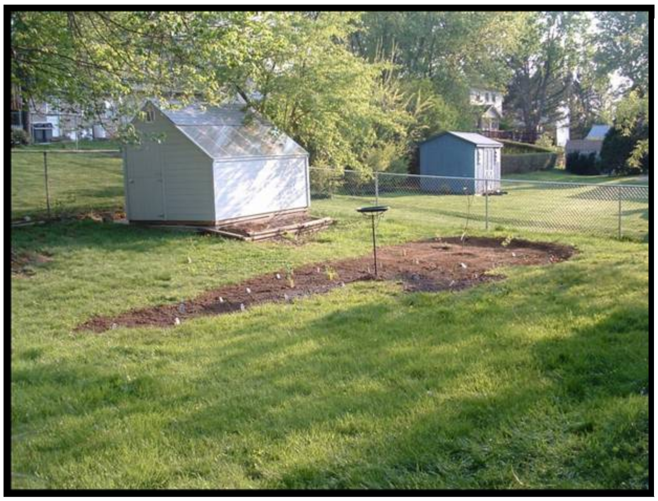
Delaware Nature Society
Smartyard Backyard Wildlife Habitat ™ Sign


BACKYARD WILDLIFE
HABITAT™
NATIONAL WILDLIFE FEDERATION®
This property provides the four basic habitat elements needed for wildlife to thrive: food, water, cover, and places to raise young. By creating a habitat friendly environment, using native plants, limiting the use of lawn chemicals, and reducing stormwater runoff, this property owner is helping to ensure clean, safe drinking water for people and wildlife. It has been certified through a partnership between the National Wildlife Federation, its state affiliate the Delaware Nature Society, and the Delaware Department of Natural Resources and Environmental Control as an official Backyard Wildlife Habitat site.
NATIONAL WILDLIFE FEDERATION®
www.nwf.org™
DELAWARE NATURE SOCIETY
www.delawarenaturesociety.org

APPENDIX D

Evolution of a Smartyard

The Smartyard was strategically located to replace a portion of the lawn and to intercept the flow of water across the property, allowing it to percolate more slowly into the ground.

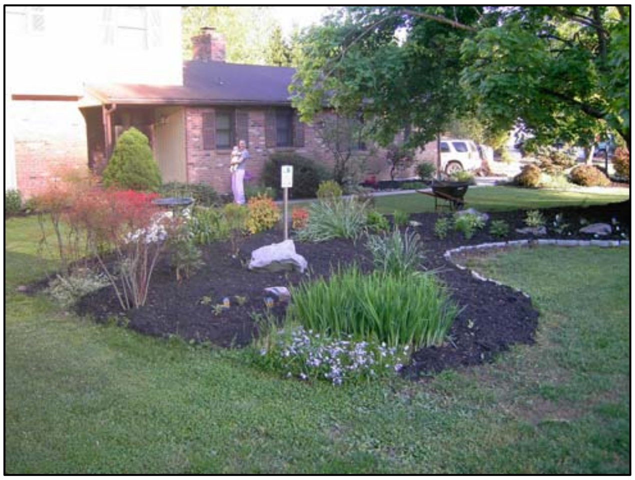


Prior to installation of the Smartyard, the property was primarily covered by lawn with a few larger trees along the property border. Stormwater runoff from adjacent lawns sheet-flowed across the site.

Because the Smartyards plants are regionally and locally native species, they are adapted to the soil and climatic conditions, thereby providing improved habitat and requiring less maintenance and inputs including fertilizer, pesticides, and water.

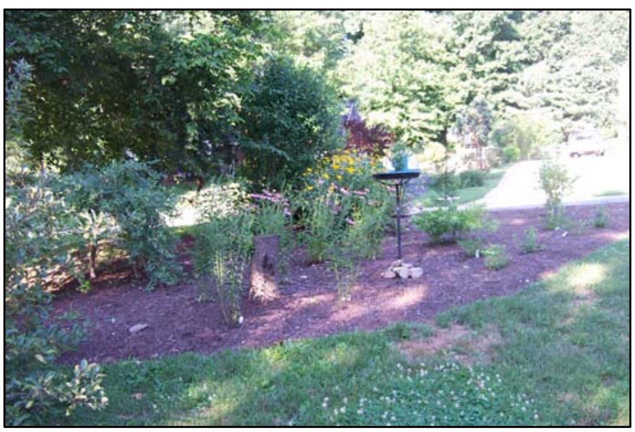
APPENDIX E

Smartyards Landscaping:
The Walck and Chambers Sites



Walck site **Walck site**

The Walck property represents a traditional suburban site predominated by lawn and a few large trees. Through the Smartyards initiative, the Walck's expanded and enhanced an existing flower bed with native perennials and shrubs to reduce the size of the lawn and associated maintenance/environmental impacts (fertilizer/pesticide application, water use, etc.). The site now provides food, shelter, and places to raise young for a variety of backyard birds, butterflies, and other wildlife (the Backyard Wildlife Habitat™ sign can be seen in the photos above).



Chambers site **Chambers site**

The Chambers site represents a property where lawn area was reduced and replaced with a Smartyard landscape bed composed of native trees, shrubs, and perennials. The Smartyard supplements adjacent plantings and habitat within the neighborhood. The Backyard Wildlife Habitat™ sign was placed in a prominent location on this residential street for all passers-by to see.

APPENDIX F

Pennsylvania Quality Assurance Project Plan

Quality Assurance Project Plan

Upper Christina Watershed Initiative Grant
Chester County Water Quality Monitoring

January 22, 2004

Project Officer's Signature	
Project Officer	**Larry Merrill, US EPA Region 3**
Project Quality Assurance Officer's Signature	
Project Quality Assurance Officer	**Patricia Iraci, US EPA Region 3**
PA DEP SERO Water Management Operations Chief's Signature	
PA DEP SERO Water Management Operations Chief	**Steve O'Neil**

Revised QAPP approved by EPA on March 18, 2004.

Table of Contents

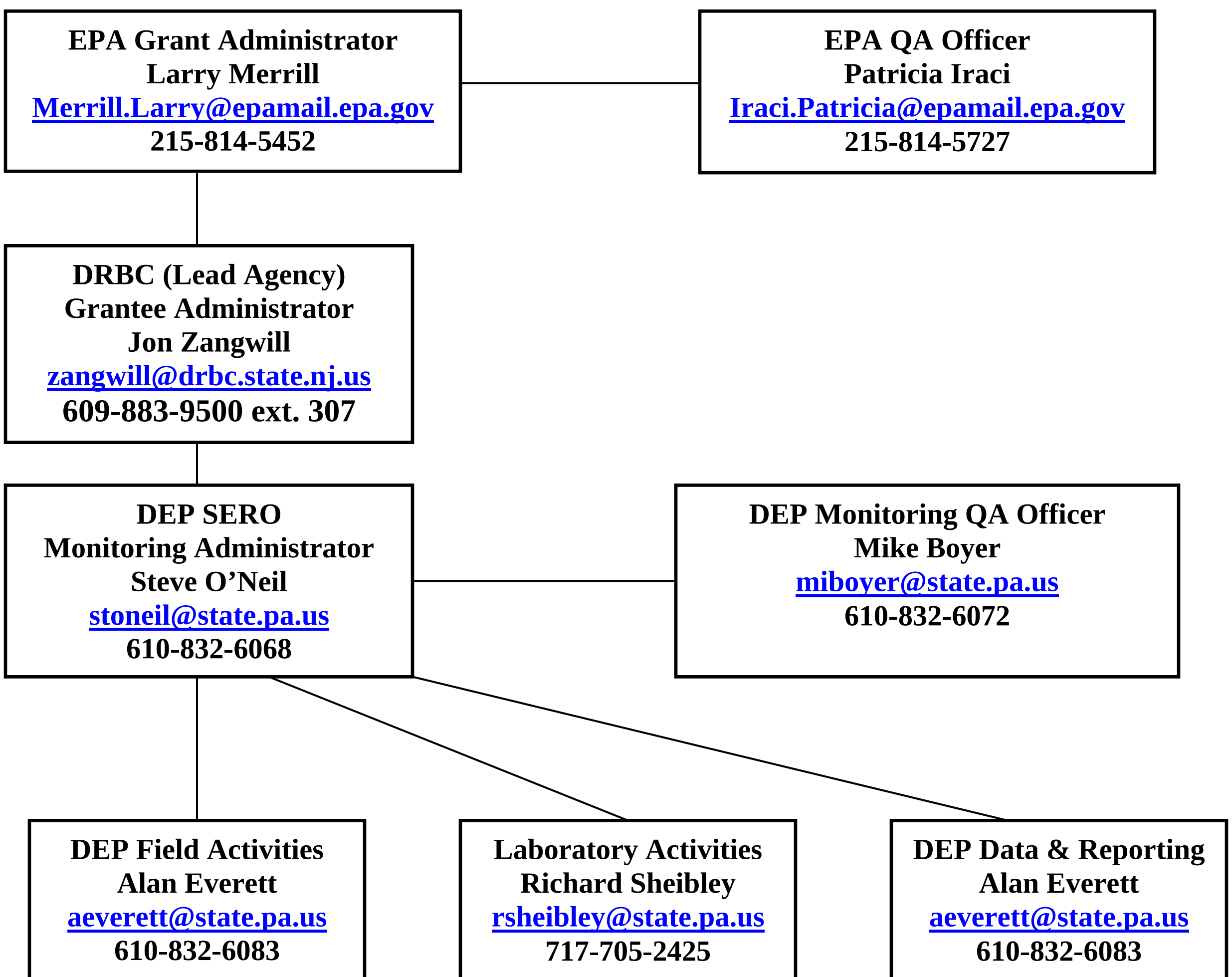
Project Management

A3 Distribution List

The following is a list of individuals who will receive an electronic copy of the approved QA Project Plan and any subsequent revisions:

Name	Agency
Jon Zangwill	DRBC
Jan Bowers	CCWRA
Dan Greig	CCCD
Larry Merrill	US EPA Region 3
Patricia Iraci	US EPA Region 3
Steve O'Neil	PA DEP, SERO
Donna Suevo	PA DEP, SERO
Alan Everett	PA DEP, SERO
Mike Boyer	PA DEP, SERO
Allen Whitehead	PA DEP, SERO
Richard Sheibley	PA DEP, Laboratory
Tony Shaw	PA DEP , Central Office

A4 Project Organization



A5 Problem Definition and Background

As part of the EPA Christina Watershed Initiative Grant, Chester County Conservation District will be implementing agricultural BMPs within 3 Brandywine Creek Subbasins (West Branch Brandywine Creek, Upper East Branch Brandywine Creek, and Buck Run). Three agricultural BMP locations will be monitored to examine and document in-stream biological, chemical, and physical changes associated with BMP installation. Nutrients and sediment are prioritized pollutants in the Christina Basin that will be targeted by the watershed initiative grant. BMP derived reductions in nutrients and sediment will be monitored. BMP pollutant reduction findings associated with this monitoring effort can then be incorporated into continuing restoration strategies in the Christina Basin.

A6 Project Description

Two nutrient management control sites and one stream bank reforestation/stream fencing site will be monitored. The three specific monitoring sites will be chosen from the total Chester County BMP installation sites included in the grant. The monitoring plan may be altered based upon site conditions encountered during reconnaissance of BMP sites, however, the primary components described below will be included in the study.

Table 1. Project Schedule Time Line

Activity	Anticipated Date of Initiation	Anticipated Date of Completion	Deliverable	Deliverable Due Date
Monitoring Site Selection	12/1/2003	3/31/2004	3 BMP Monitoring Sites	3/31/2004
Pre-BMP Site Monitoring	4/1/2004	8/1/2005	na	na
Post-BMP Site Monitoring	4/1/2005	8/1/2006	na	na
Monitoring Report / Data Analysis	8/1/2006	12/31/2006	Final Report	12/31/2006

Monitoring Components:

1. **Chemical Monitoring** (all sites) **–** Water quality monitoring for instantaneous flow, dissolved oxygen, pH, specific conductivity, temperature, total phosphorus, total nitrogen, ammonia, total suspended solids, fecal coliform and Enterococcus will be conducted upstream,downstream and at one direct runoff site. One baseflow (stream samples) and 4 highflow (stream and runoff) grab samples will be collected prior to and following BMP installation (total samples per site = 28, upstream samples = 10, downstream samples = 10, direct runoff samples = 8. Pre and post instantaneous pollutant concentrations will be compared. Flow measurements will be used to qualitatively compare the magnitude of runoff

events. Event mean concentrations and storm event loading will not be calculated because of the lack of composite sampling.

2. **Biological Monitoring:**

   a. Macroinvertebrate Sampling (all sites) – Macroinvertebrate sampling, utilizing PA DEP's RBPIII sampling procedures will be conducted upstream and downstream from BMP locations before and after BMP implementation. Pre-BMP and Post-BMP sampling will be conducted during the same season (fall or spring).
   b. Rapid Periphyton Survey (all sites) – Rapid periphyton surveys will be performed upstream and downstream before and after BMP implementation. This survey will consist of a semi-quantitative visual assessment that examines percent macroalgae coverage and maximum length of filamentous algae.
   c. Periphyton Standing Crop and Diatom Assemblage (one nutrient management site) – Periphyton standing crop (Chl-a) and diatom assemblages will be sampled upstream and downstream. Pre-BMP and post-BMP periphyton samples will be conducted in summer.
   d. Fishery Survey (reforestation/fencing site) – A fishery survey (species,abundance, and size) will be conducted before and after BMP installation in the summer.

   Pre and post-BMP in-stream biological condition will be compared to document effects of BMP installation on flora and fauna.

3. **Physical Monitoring:**

   a. Visual Habitat Assessment and Photography (all sites) – EPA's Visual Habitat Assessment Form, riffle substrate characterization and photography will be performed at upstream and downstream sites before and after BMP installation to document habitat differences between reference (upstream) and potential impact (downstream) sites. Additionally, photography will be used to document farm management changes and visual impacts on water quality.
   b. Fluvial Geomorphic Characterization (reforestation/fencing site) – A fluvial geomorphic characterization including pre-BMP and post-BMP erosion rate predictions and validation will be performed. Benefits of reforestation/fencing on bank stability are likely to occur over a longer time scale than the grant because of the length of time required for establishment of woody vegetation. It may be possible to reexamine the site after the grant is completed.

A7 Data Quality Objectives :

Accuracy – Accuracy is determined by routine laboratory protocol that requires random spiking of samples as described in the Laboratory Quality Manual. One matrix spike per nine samples is analyzed for Total Phosphorous, Total Nitrogen,and Ammonia. Accuracy is considered acceptable and meeting established criteria when results are within +/- 10% of a known concentration. Laboratory accuracy for the chemical parameters is listed in Table 2.

Table 2. Data Quality Assessments

STORET	Parameter	Precision	Accuracy
530	Total Suspended Solids	±15.0% at 15.2 mg/L ± 8.2% at 72.0 mg/l	96.2% at 15.8 mg/L 90.5% at 79.6 mg/l
00610A	Ammonia nitrogen	± 16.3 % at 0.022 mg/L ± 1.9% at 1.00 mg/l	111.3% at 0.02 mg/L 98.7% at 1.00 mg/l
00665A	Total Phosphorus	± 12.5% at 0.009 mg/L ± 1.6% at 0.5 mg/l	91.2% at 0.01 mg/L 100.4% at 0.5 mg/l
00600A	Total Nitrogen	± 8.1% at 0.073 mg/L ± 3.0% at 10.00 mg/l	113.4% at 0.064 mg/L 99.8% at 10.00 mg/l
31616	Fecal Coliform	Not applicable	Not applicable
	Enterococcus	Not applicable	Not applicable

Precision – Precision is determined by collecting one laboratory duplicate per 20 samples. An acceptance criterion of +/- 20% relative percent difference for concentrations greater than or equal to five times the laboratory quantitation limit is recommended for laboratory duplicates. For concentrations less than five times the laboratory quantitation limit, an acceptance criteria of + or – the laboratory quantitation limit is recommended. Laboratory precision for the chemical parameters is shown in Table 2 above.

Sensitivity

Table 3. Parameter Method Detection Limits

Parameter	Analytical Method Reference	Reporting Limit	Detection Limit
TSS	EPA 160.2	2 mg/L	not applicable
NH_3-N	EPA 350.1	0.020mg/L	0.0114 mg/L
Total Phosphorus	EPA 365.3 Modified (autoclave)	0.010 mg/L	0.0036 mg/L
Total Nitrogen	Std. Methods 4500-Norg D	0.064 mg/L	0.019 mg/L
Fecal Coliform	Std. Methods 9222D	1 cfu[1] per 100mls	not applicable
Enterococcus	Std. Methods 9230C	1 cfu[1] per 100mls	not applicable

[1] cfu = colony forming unit
Standard Methods, 19th edition

Data Representativeness – Chemical grab samples collected in the thalweg at mid-depth represent instantaneous water quality conditions. Environmental variables associated with high flow sampling (ea. storm intensity, storm duration, season) can cause water quality variability. Comparison of upstream and downstream water quality should reduce the importance of storm related variables on in-stream sampling. Runoff grab samples will be representative of water quality collected during storm events.

Data Comparability – Comparability of data collected during the monitoring project is assured though standardized sample collection requirements, standardized field and laboratory analyses and standardized reporting.

Data Completeness – A cursory examination of sample size and power analysis with concentration estimates revealed that four high flow runoff measurements should provide enough valid data to show large effect pollutant reductions (>50%) that are statistically significant. For in-stream samples, the magnitude of the effect will be dependent upon the overall watershed size relative to the BMP restoration area. If statistically significant reductions are not found in-stream, trends can be evaluated using upstream and downstream water quality and biological data.

A8 Special Training / Certification

No special training or certification is required for this project. Water Pollution Biologists and Water Quality Specialists from PA DEP's Southeast Regional Office routinely collect chemical, biological, and physical field data as part of routine duties. A biologist within the region has recently complete four of David Rosgen's FGM courses (1-4) and is trained for completing the fluvial geomorphic characterization. Laboratory technicians routinely analyze the water quality parameters that will be included in this monitoring project.

A9 Documents and Records

- The most recent QAPP will be distributed to project staff by e-mail.
- Field log books, field data sheets, field instruments, calibration logs, and raw data will be maintained at DEP's Southeast Regional Office.
- Records will be maintained for a period of 3 years following the completion of the project.
- Analytical log books and laboratory instrument calibration information will be maintained at the DEP Laboratory.
- Macroinvertebrate and algal samples will be maintained at DEP's SERO for a period of 3 years following completion of the project.
- The final report will be sent by e-mail to individuals included on the QAPP distribution list and a hard copy will be placed in DEP's SERO Stream File.

Data Generation and Acquisition

B1 Experimental Design
Specific design elements are not included here because monitoring sites will be chosen after BMP installation sites have been determined. Preference will be given to headwater agricultural sites that are more likely to have a significant adverse impact on the stream (i.e. larger BMP area to watershed area ratio). Additionally, and attempt will be made to locate a monitoring site in each of the Brandywine Sub-basins described in Task 3 of the grant application.

This monitoring project utilizes a judgmental sampling design that will examine in-stream pre and post-BMP chemical, biological and physical conditions as well as pollution runoff reduction associated with BMP instillation. The design has spatial (reference and potential impact stations) and temporal (pre and post-BMP) components.

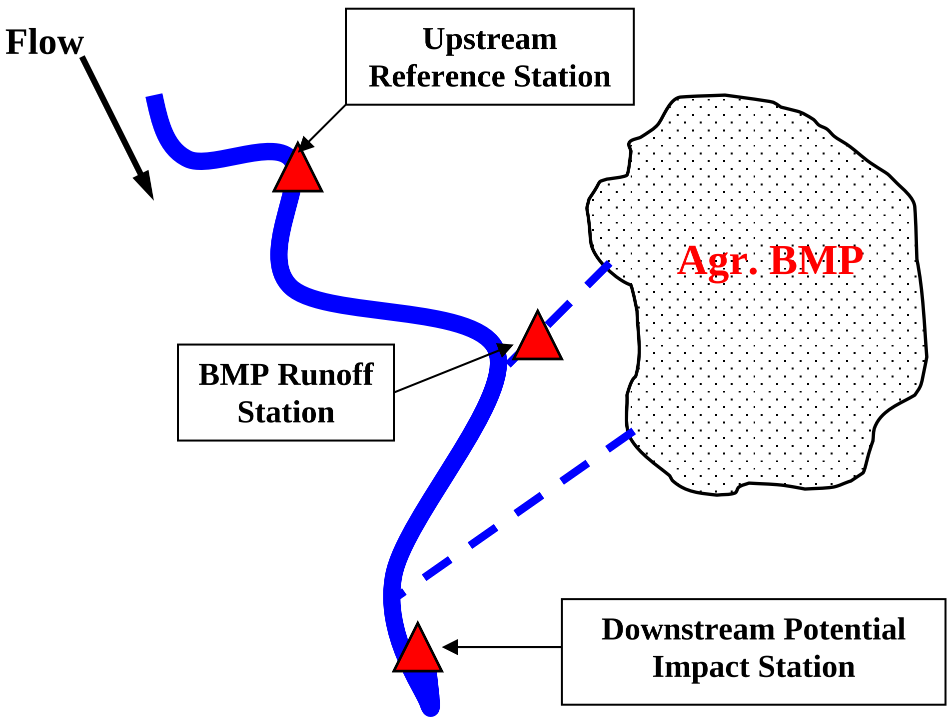


Figure 1. Idealized Agriculture BMP Monitoring Site

Interstation comparisons (reference and impact stations) and intrastation comparisons (pre and post-BMP) of chemical, biological and physical parameters will be made during data analysis. Chemical and bacterial concentrations will be compared to adopted and recommended water quality criteria (Table 4)

Table 4. Water Quality Criteria

Parameter	Water Quality Criteria	Reference
pH	6 to 9 su	PA Code Title 25 Chapter 93.7
DO	Dependent on aquatic life protected use (see Appendix 2)	PA Code Title 25 Chapter 93.7
Specific Conductance	none	na
Temperature	Dependent on aquatic life protected use and season (see Appendix 2)	PA Code Title 25 Chapter 93.7
TSS	none	na
NH_3-N	Dependent on pH and Temperature (see Appendix 2)	PA Code Title 25 Chapter 93.7
Total Nitrogen	690 ug/l	EPA Recommended Criteria (Nutrient Ecoregion IX
Total Phos.	37 ug/l	EPA Recommended Criteria (Nutrient Ecoregion IX
Fecal Coliform	200cfu/100ml (May-Sept) 2000 cuf/100ml (Oct-April)	PA Code Title 25 Chapter 93.7
Enterococcus	100 cfu/100ml	Delaware Water Quality Standards (1999)

Number of Samples

The number of chemical, biological, and physical samples, including Quality Control samples is shown in Table 5.

Table 5. Number of Samples

Chemical

	BMP Locations	Pre-BMP Samples (base/high)	Post-BMP Samples (base/high)	Total Samples	QC Dup./Blks
Water Quality	**3**	**6 / 36**	**6 / 36**	**84**	**5 /2**

Table 5. Number of Samples (cont.)

Biological

	BMP Locations	Pre-BMP Samples	Post-BMP Samples	Total Samples	QC Dup.
Macroinvertebrate	**3**	**6**	**6**	**12**	**2**
Fish	**1**	**1**	**1**	**2**	**0**
Rapid Periphyton	**3**	**6**	**6**	**12**	**1**
Chl-a* / Diatom	**1**	**2**	**2**	**4**	**1**

Physical

	BMP Locations	Pre-BMP Samples	Post-BMP Samples	Total Samples	QC
FGM / Bank Erosion	**1**	**1**	**1**	**2**	**0**
Visual Habitat Assessment	**3**	**7**	**7**	**14**	**0**

B2 Sampling Methods

1. Chemical Sampling Methods

Table 6. Chemical Sampling Methods

Parameter	Sample Matrix	Container	Analytical Method	Sample Preservation	Holding Time
pH	water	in-stream	Std. Methods (Potentiometric)	none	analyze in field
DO	water	in-stream	Std. Methods 4500-O	none	analyze in field
Specific Conductance	water	in-stream	Std. Methods 2510	none	analyze in field
Temperature	water	in-stream	Std. Methods 2550	none	analyze in field
TSS	water	HDPE, 500 ml	USGS 1-3765-85	cool to 4^oC	7 days
NH_3-N	water	HDPE, 500 ml	EPA 350.1	cool to 4^oC, H_2SO_4 pH<2	28 days
Total Nitrogen	water	HDPE, 500 ml	Sts. Methods 4500-Norg D	cool to 4^oC, H_2SO_4 pH<2	28 days
Total Phos.	water	HDPE, 500 ml	EPA 365.1	cool to 4^oC, H_2SO_4 pH<2	28 days
Fecal Coliform	water	PP, 125 ml	Std. Methods 9222 D	dechlorination	30 hours
Enterococcus	water	PP, 125 ml	Std. Methods 9230 C	dechlorination	30 hours

Standard Methods, 19^{th} edition.
USGS 1989 Methods for Analysis of Inorganic Substances in Water and Fluvial Sediments.

Grab samples will be collected at mid-depth in the thalweg of the stream or swale (runoff sample). Nutrient sample bottles will be triple rinsed with 1% HCL and deionized water. Duplicate samples will be collected using an acid rinsed 2 liter plastic bottle retrofitted with a nozzle, tubing and clamp for subsamping.

2. Biological Methods

Macroinvertebrate and fish sampling methods will follow methods described in DEP's Standardized Biological Field Collection and Laboratory Methods (Shaw 2002). Macroinvertebrates will be collected from riffles using 500 um mesh D-frame net. Two D-frames will be composited for each station. A 100-count subsample will be removed form a gridded tray by randomly picking grids until 100 (+/-20) macroinvertebrates are removed. Macroinvertebrates will be identified to the lowest taxonomic level possible (typically Genus).

Fish will be collected over a 100 meter reach (one pass) at each station using a Smith-Root DC Electrofisher. Species and total length will be recorded in the field for each fish captured.

Periphyton work will follow methods described in EPA's Rapid Bioassessment Protocols for use in Wadable Streams and Rivers (EPA 841-B-99-002). Periphyton Standing Crop Periphyton will be performed under stable base flow conditions. Boulder, cobble, or large gravel substrates will be randomly sampled from the left, center, and right 1/3 of the channel along each transect and composited prior to analysis. Periphyton will be collected by pressing a 2-inch diameter (20.3 cm^2) PVC pipe section, fitted with a foam gasket (collar), against the substrate. With the PVC pipe section firmly pressed against the rock's surface, the rock will be removed from the stream and attached algae removed with a modified hard bristle toothbrush. The algal slurry is transferred to a plastic container with a cooking baster or wide-bore pipette. Samples are sieved (800um X 900 um mesh) to remove moss from the sample. Moss was gently brushed and shaken to remove entangled or epiphytic algae. Filamentous algae collected on the sieve is segmented with a razor blade on a glazed tile and rinsed back into the sample. A total sample volume was recorded for each transect.

Well-mixed subsamples are taken for Chlorophyll-a and Phaeophytin-a analysis, and diatom identification and enumeration. Chl-a samples are field filtered onto glass fiber filters (Gelman A/E, 1um). $MgCO_3$ slurry (1gm/100ml) was added to the filtered Chl-a sample for buffering and stabilization. Samples are stored on dry ice in the field (-20^{o}C), in a conventional freezer at the DEP field office, shipped to Harrisburg (DEP Laboratory) on dry ice and stored in deep freeze (-30^{o}C) prior to analysis.

Analysis and calculation of Chl-a (mg/l) and phaeophytin (mg/l) at DEP's Bureau of Laboratories will follow spectrophotometric methods (Method 10200 H) described in Standard Methods for the Examination of Water and Wastewater (19^{th} edition, 1995). Chl-a and phaeophytin concentrations per unit substrate surface area (mg/m^2) are calculated by multiplying the laboratory determined concentration (mg/l) by the total sample volume (l) and dividing by the total surface area (0.00608 m^2).

A 15 to 20 ml subsample will be transferred to a scintillation vial and preserved with glutaraldehyde (2% diluted concentration) for diatom identification and enumeration.

The Rapid Periphtyon Assessment will utilize semi-quantitative visual assessments to estimate the maximum length (mm) and percent coverage of macroalgae (typically filamentous green algae). Three random locations along each transect, in the left, center, and right 1/3 of the channel, will be examined using a viewing bucket with 49 equi-spaced dots organized in a 7" X 7" grid. Percent macroalgae coverage is estimated for each location by counting the dots where macroalgae was present. Maximum macroalgae length found within the grid will be measured and recorded. Average percent coverage and average maximum length for each transect are considered one sample. Transect results for each station are then averaged for the mean station score.

3. **Physical Monitoring**

Visual habitat assessments will follow methods described in EPA's Rapid Bioassessment Protocols for use in Wadeable Streams and Rivers (EPA 841-B-99-002). Fluvial geomorphic characterization will follow methods described in Stream Channel Reference Sites: An Illustrated Guide to Field Technique (USDA Forest Service, General Technical Report RM-245).

B3 Sample Handling and Custody

Water quality samples preserved in the field will be transported in coolers on ice (4^0C) to DEP's Southeast Regional Office. Each sample will be labeled with 4-digit collector number, 3-digit field sample sequence number, station ID, date, and preservation information. Sample submission sheets (Appendix 1) are submitted to the laboratory with each sample. A courier service transports the samples overnight to DEP's Laboratory in Harrisburg. At the laboratory coolers are checked for the presence of ice to document proper holding temperature and a laboratory sample ID is assigned to each sample. The collector enters Field data for each chemical sample into DEP's Sample Information System (SIS). As laboratory analyses are completed, results are entered into the Laboratory Information Management System (LIMS) by the analyst. When complete, the results are transferred electronically from the LIMS to SIS. Completed reports will be retrieved from SIS and a hardcopy will be maintained at DEP's SERO.

B4 Analytical Methods

Analytical methods are referenced in section B2 (Sampling Methods). Chemical analytical methods are referenced in Table 5 (Chemical Sampling Methods) and will not described further.

B5 Quality Control

1. Field duplicates will be performed for the following parameters: total suspended solids, total nitrogen, total phosphorus, fecal coliform, Enterococcus, chl-a, and macroinvertebrates. Percent differences between duplicate samples will be calculated, reported, and precision will be discussed in the final report. The numbers of duplicates are found in Table 4 (B1- Experimental Design).
2. Field blanks will be performed for total suspended solids, total nitrogen, total phosphorus, fecal coliform, and Enterococcus. Field blank data will be reported and discussed in the final report. Two field blanks will be performed during the study.
3. DEP's Laboratory QC procedures (e.g. spikes, % recovery) are described in the Laboratory's Quality Manual. The U.S. EPA conducts a laboratory audit every three years, which in part examines laboratory QC.

B6 Instrument/Equipment Testing Inspections and Maintenance

Field meters (flow, dissolved oxygen, pH, specific conductivity, and temperature) will be examined visually at the beginning of each field day to ensure they are in working order (batteries, membranes, connectors, etc…). Spare field meters are available at DEP SERO for use if any of the primary meters fail to work. Spare meters will not be taken in the field, but will be used as backup for future sampling.

Laboratory instrument testing, inspection and maintenance procedures are described in the Laboratory's Quality Manual.

B7 Instrument/Equipment Calibration and Frequency

Field meter calibration and frequency are outlined in Table 7. DO calibration checks will be performed throughout the day and a one point pH calibration check will be performed following sampling.

Table 7. Field Meter Calibration

Parameter	Meter	Accuracy[1]	Resolution[1]	Calibration	Calibration Frequency
Dissolved Oxygen	YSI 556 MPS	0.2 mg/l	0.01 mg/l	water-saturated air	daily
pH	YSI 556 MPS	0.2 SU	0.01 SU	two point (7-10)	daily
Specific Conductivity	YSI 556 MPS	1uS/cm	1uS/cm	KCL Calibration Standard (1000 uS/cm	daily
Temperature	YSI 556 MPS	0.15^0C	0.01^0C	Calibration Check (NIST Thermometer)	annual
Flow	Marsh-McBirney 201D	2% of reading	0.1 ft/sec	Advanced Devices (5/11/2002)[2]	

[1] Manufacturers Specification
[2] Date of latest factory calibration

Laboratory instrument calibration and frequency are described in the Laboratory's Quality Manual. EPA performs an triennial laboratory inspection, which in part examines the adequacy of instrument calibration procedures.

B8 Inspection/Acceptance of Supplies and Consumables

Field and laboratory supplies used for this project are routinely used in water quality sampling and analyses performed by DEP. Field supplies at SERO, including sample bottles and fixatives, are maintained by Bob Bauer (Water Quality Specialist Supervisor). Fixatives are supplied by Eagle Picher in single use ampules/vials to limit potential contamination. Bottles are not certified for cleanliness, however cleanliness will be monitored using blanks.

B9 Non-direct Measurements

Spatial data, including geology, topography, soils, physiographic provinces, and streams, may be used in the project report. The source for all spatial data will be the Pennsylvania Spatial Data Access (PASDA, www.pasda.psu.edu) . Precipitation data from NOAA weather stations may be used to summarize storm information (intensity, duration). Non-direct measurement water quality data will not be contained in the results section of the final report. Ancillary data from the scientific literature and DEP stream files may be used for comparison purposes in the final report's discussion section. Peer-reviewed literature sources known to the investigators will be used. A literature search will not be performed.

B10 Data Management

All completed field data, chemical data reported by DEP's Sample Information System (SIS), and biological data (identification and enumeration) will be kept in DEP SER Water Management's Operations Section. Field calibration logs and laboratory calibration logs will be maintained at the field office laboratory and the main laboratory respectively. Prior to transcribing into electronic format, field data will be maintained in a hardcopy file. Transcribed data will be spot-checked for errors. Laboratory chemical data will be maintained in hardcopy and electronic format.

Excel and SAS will be used for data transformation and reduction. Created data files will be maintained on a PC hard-drive. Backup files will be maintained on a regional server.

Data will be reported in Excel generated tables and figures within the final report (Word). Following completion of the final report, chemical and macroinvertebrate data will be entered onto EPA's STORET database.

Assessment and Oversight

C1 Assessments and Response Actions

Prior to the first sampling event, DEP's SERO will conduct a readiness review for field staff to assess project planning and preparation. Mike Boyer, DEP Southeast Region QA Officer, will conduct the readiness review in March 2004. A memo itemizing deficiencies and remedies will be sent to individuals included on the QAPP Distribution List (A3) in April 2004.

Laboratory assessments are described in the Laboratory's Quality Manual.

C2 Reports to Management

1. Quarterly Project Status Reports (PSR) will be sent to individuals included on the QAPP Distribution List (A3). The reports will briefly discuss project progress and any problems encountered during selection of monitoring sites, monitoring, data analysis or final report writing. Alan Everett, DEP SER Water Pollution Biologist, will be responsible for project status reports.

2. A Final Report will be sent to individuals included on the QAPP Distribution List (A3). The report will include introduction, methods, results from each BMP monitoring site, discussion and conclusions. Alan Everett, DEP SER Water Pollution Biologist, will be responsible for the final report.

Data Validation and Usability

D1 Data Review, Verification, and Validation

Water quality data analyzed by DEP's Laboratory is routinely reviewed for quality objectives (holding time, pH, spike recovery etc..). If quality objectives are not met, chemical data is not reported or flagged (depending upon quality objective) in LIMS by the analyst. Quality objectives are discussed in the Laboratory's Quality Assurance Work Plan. Field blanks and duplicates will be reviewed by field personnel to determine if significant contamination was present and estimate sample variability. Field bland contamination or extreme variation in field duplicates will be flagged and reflected in the final monitoring report.

D2 Verification and Validation Methods

Laboratory data will be validated in accordance with the Laboratory's Quality Manual. Field blank and field duplicate data will provide additional validation of chemical data. Field blank and field duplicate data will be provided to Richard Sheibley at the laboratory. Field form data entry and electronic transcription will be visually checked to ensure that transcription of recording errors did not occur. Alan Everett, DEP SER Water Pollution Biologist, will be responsible for data analysis and validation. Any validation issues will be discussed with Mike Boyer (SER QA Officer).

D3 Reconciliation with User Requirements

In the final report, monitoring results will be examined within the context of how well data quality objectives were achieved. Quality control data (ea. blanks, duplicates) and achievement of quality objectives (ea. calibration, preservation, spike recovery) will be discussed. A statement about data validity will be made based upon a qualitative review of compliance with the Quality Assurance Project Plan.

References

American Public Health Association, 1995, Standard Methods for the Examination of Water and Wastewater, 19th edition, American Public Health Association, Washington D.C.

Barbour M.T., J. Geritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for use in Streams and Wadeable Rivers : Periphyton, Benthic Macroinvertebrates and Fish, Second Edition, EPA 841-B-99-002. U.S. Environmental Protection Agency ; Office of Water; Washington D.C.

Fishman, M.J., et.al. 1989. Methods for Analysis of Inorganic Substances in Water and Fluvial Sediments. U.S. Department of the Interior, Techniques of Water-Resource Investigations of the U.S. Geological Survey, Denver, CO.

Harrelson, C.C., C.L. Rawlins, and J.P. Potyondy. 1994. Stream Channel Reference Sites: An Illustrated Guide to Field Technique. USDA Forest Service, General Technical Report RM-245.

Shaw, T. 2003. Standardized Biological Field Collection and Laboratory Methods. Pennsylvania Department of Environmental Protection. Available form DEP Central Office.

U.S. EPA, 2002. Guidelines Establishing Test Procedures for Analysis of Pollutants Under the Clean Water Act. Final Rule, Part II 40CFR, Part 136, Volume 56, No. 195, US Government Printing Office, Washington D.C.

Appendix 1. Laboratory Sample Submission Sheet

…0-FM-WC0012   8/98

Fixed:

DEP Sample Information System
Sample Submission Sheet

LAB USE ONLY

Lab Number:

Date Received:

Received By:

Collector ID | Sequence No. | Date Collected (MM. DD. YY) | Time Collected (HH MM)

Reason Code: | Cost Center Code: | Program Code: | STD Analysis Code:

SPN | Matrix Code: | Residual Chlorine: Yes / No | pH less than 2.0? Yes / No

Additional Analysis: (from list on back)

Legal Seal Number | How Shipped | Check If Broken ☐ ☐ ☐ ☐

Collectors Name: ______________________ Phone: ____________

Facility Number | Facility Name ______________

Permittee ______________________

Permit Number

Discharge Point or Sampling Location ______________________

Stream Code | River Mile Index

Stream Name ______________________

Latitude | Longitude

FIELD RESULTS:

Chlorine (mg/l)	(50060)	________
Temp.(°c)	(00010)	________
pH (units)	(00400)	________
D.O. (mg/l)	(00300)	________
Sp. Cond. (μmhos)	(00094)	________
Gage (ft)	(00065)	________
Flow (cfs)	(00061)	________
Flow (mgd)	(50051)	________

Comments:

Appendix 2. Pennsylvania Code Title 25 Chapter 93 – NH3-N, Dissolved Oxygen, and Temperature Water Quality Standards.

Ammonia Nitrogen	Am	The maximum total ammonia nitrogen concentration at all times shall be the numerical value given by: un-ionized ammonia nitrogen (NH_3-N) $\times$ ($\log^{-1}[pK_T - pH] + 1$), where:

un-ionized ammonia nitrogen = $0.12 \times f(T)/f(pH)$

$f(pH) = 1 + 10^{1.03(7.32 - pH)}$

$f(T) = 1,\ T \geq 10°C$

$$f(T) = \frac{1 + 10^{(9.73 - pH)}}{1 + 10^{(pK_T - pH)}},\ T < 10°C$$

and

$$pK_T = 0.090 + \left[\frac{2730}{(T + 273.2)}\right]$$, the dissociation constant for ammonia in water.

The average total ammonia nitrogen concentration over any 30 consecutive days shall be less than or equal to the numerical value given by: un-ionized ammonia nitrogen (NH_3-N) $\times$ ($\log^{-1}[pK_T - pH] + 1$), where:

un-ionized ammonia nitrogen = $0.025 \times f(T)/f(pH)$

$f(pH) = 1,\ pH \geq 7.7$

$f(pH) = 10^{0.74(7.7 - pH)},\ pH < 7.7$

$f(T) = 1,\ T \geq 10°C$

$$f(T) = \frac{1 + 10^{(9.73 - pH)}}{1 + 10^{(pK_T - pH)}},\ T < 10°C$$

The pH and temperature used to derive the appropriate ammonia criteria shall be determined by one of the following methods:

1) Instream measurements, representative of median pH and temperature—July through September.

2) Estimates of median pH and temperature—July through September—based upon available data or values determined by the Department.

For purposes of calculating effluent limitations based on this value the accepted design stream flow shall be the actual or estimated lowest 30-consecutive-day average flow that occurs once in 10 years.

Dissolved Oxygen	DO_1	Minimum daily average 6.0 mg/l; minimum 5.0 mg/l. For lakes, ponds and impoundments only, minimum 5.0 mg/l at any point.	CWF, HQ-WWF, HQ-TSF
	DO_2	Minimum daily average 5.0 mg/l; minimum 4.0 mg/l. For the epilimnion of lakes, ponds and impoundments, minimum daily average of 5.0 mg/l, minimum 4.0 mg/l.	WWF
	DO_3	For the period February 15 to July 31 of any year, minimum daily average of 6.0 mg/l, minimum 5.0 mg/l. For the remainder of the year, minimum daily average of 5.0 mg/l, minimum 4.0 mg/l. For lakes, ponds and impoundments, the criteria apply to the epilimnion.	TSF
	DO_4	Minimum 7.0 mg/l.	HQ-CWF
Temperature		Maximum temperatures in the receiving water body resulting from heated waste sources regulated under Chapters 92, 96 and other sources where temperature limits are necessary to protect designated and existing uses. Additionally, these wastes may not result in a change by more than 2°F during a 1-hour period.	See the following table.

SYMBOL: CRITICAL USE: PERIOD	*$TEMP_1$ CWF*	*$TEMP_2$ WWF TEMPERATURE °F*	*$TEMP_3$ TSF*
January 1-31	38	40	40
February 1-29	38	40	40
March 1-31	42	46	46
April 1-15	48	52	52
April 16-30	52	58	58
May 1-15	54	64	64
May 16-31	58	72	68
June 1-15	60	80	70
June 16-30	64	84	72
July 1-31	66	87	74
August 1-15	66	87	80
August 16-30	66	87	87
September 1-15	64	84	84
September 16-30	60	78	78
October 1-15	54	72	72
October 16-31	50	66	66
November 1-15	46	58	58
November 16-30	42	50	50
December 1-31	40	42	42

APPENDIX G

Fisher Farm Data

Fisher Farm Photographs and Data

Figure 1. Lower Fisher Farm Pasture Pre-BMP (May 18, 2004).

Figure 2: Post-BMP (September 19, 2007) looking upstream from Ford.

Figure 3: Lower Fisher Farm Pasture Pre-BMP (May 14, 2004)

Figure 4: Post-BMP (September 19, 2007) looking downstream near confluence with UNT.

Figure 5: Middle Fisher Farm Pasture Pre-BMP (May 18, 2004).

Figure 6: Post-BMP (September 19, 2007) looking downstream.

Figure 7: Upper Fisher Farm Pasture Pre-BMP (September 3, 2004).

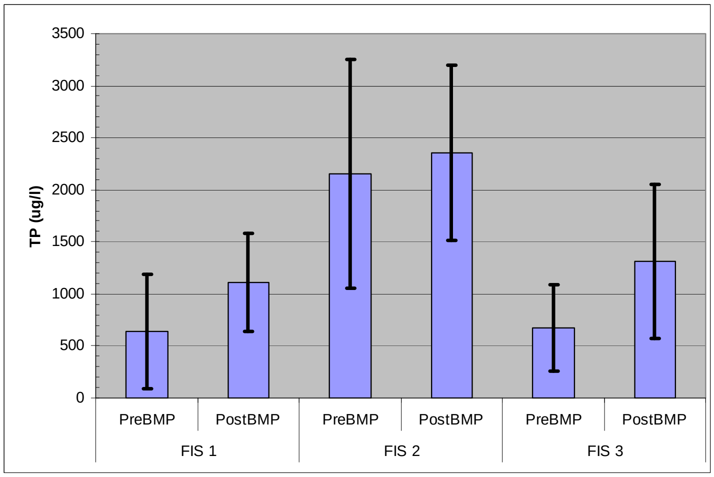
Figure 8: Post-BMP (September 19, 2007) looking upstream towards woodlot.

Habitat Data

Table A1-1. Pre & Post BMP EPA RBP Habitat Scoring.

	FIS3		FIS Pasture		FIS 1	
	PreBMP	Post PMP	PreBMP	Post BMP	PreBMP	Post BMP
	9/2/2004	1/7/2008	9/2/2004	1/7/2008	9/2/2004	1/7/2008
Habitat Parameters						
Instream Cover	15	14	7	6	9	10
Epifaunal Substrate	16	15	10	7	8	10
Embeddedness	11	9	12	8	11	11
Velocity/Depth Regimes	15	15	14	13	14	15
Channel Alteration	16	16	15	16	17	16
Sediment Deposition	14	13	5	3	4	8
Frequency of Riffles	15	15	12	11	11	14
Channel Flow Status	16	16	16	16	16	17
Condition of Banks	12	12	9	8	8	12
Bank Vegetative Protection	12	11	7	9	10	10
Grazing or Other Disruptive Pressure	2	11	2	8	17	17
Riparian Vegetative Zone Width	3	6	2	6	16	16
Near-Stream Habitat total	29	40	20	31	51	55
Habitat Total	147	153	111	111	141	156
Habitat Category	**Suboptimal**	**Suboptimal**	**Marginal**	**Marginal**	**Suboptimal**	**Suboptimal**

Water Quality Data



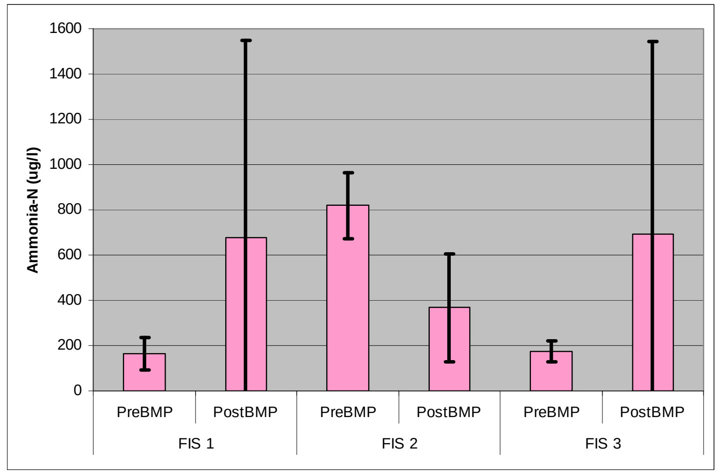
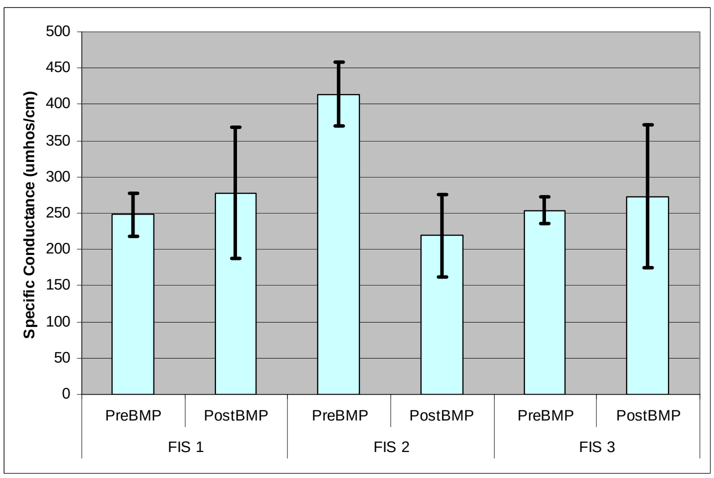


Figure A1 -1. Storm-flow Total Phosphorous and Ammonia concentration at FIS1,FIS2, and FIS3. Post BMP mean ammonia concentration is less than pre BMP mean ammonia concentration at FIS2 ($p<0.05$, one tailed test).



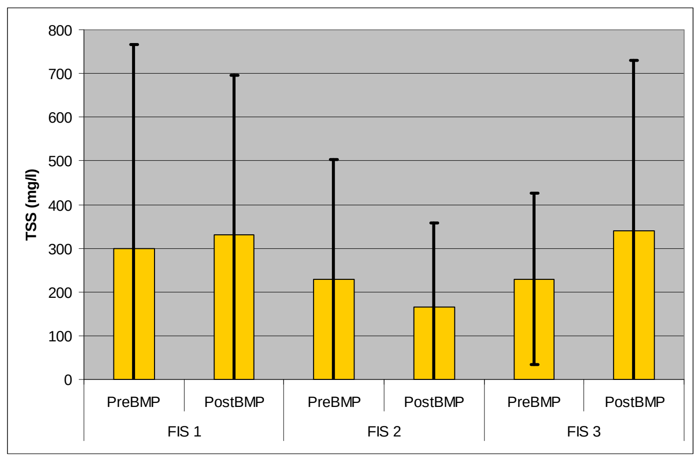
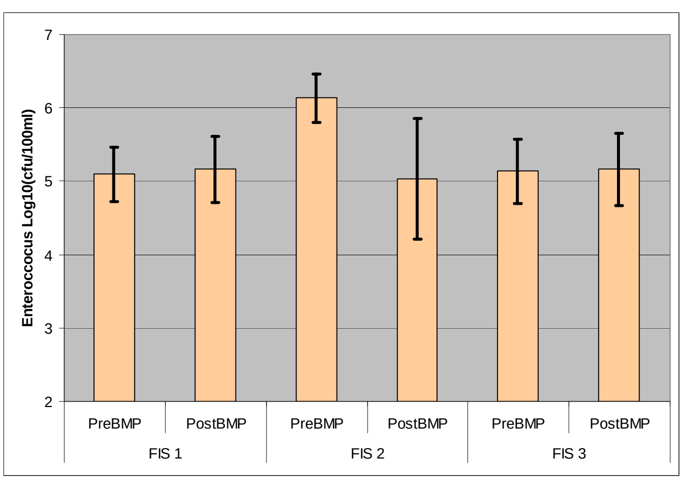


Figure A1-2.. Storm-flow Specific Conductance and Total Suspended Solids at FIS1,FIS2, and FIS3. Post BMP mean Specific Conductance is less than pre BMP mean Specific Conductance at FIS2 ($p<0.05$, one tailed test).



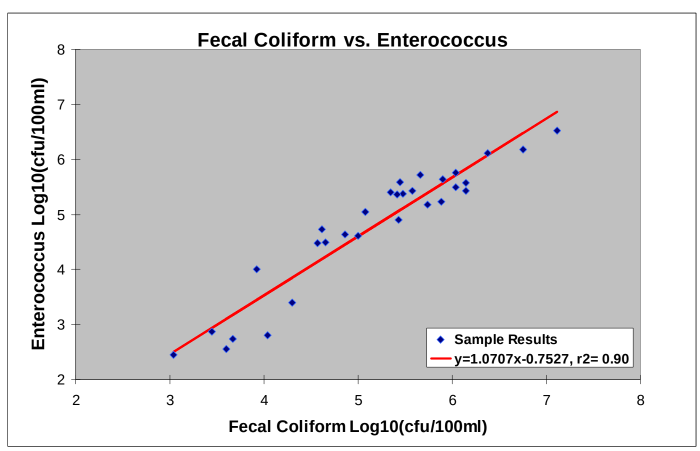


Figure A1-3. Storm-flow Enteroccocus concentration and the relationship between log transformed Enteroccocus concentration and Fecal Coliform concentration at all Fisher Farm sites and sampling dates. Post BMP mean Enteroccocus concentration is less than pre BMP mean Enteroccocus concentration ($p<0.05$, one tailed test).

Temperature Monitoring – Forested Reach vs. Pasture Reach

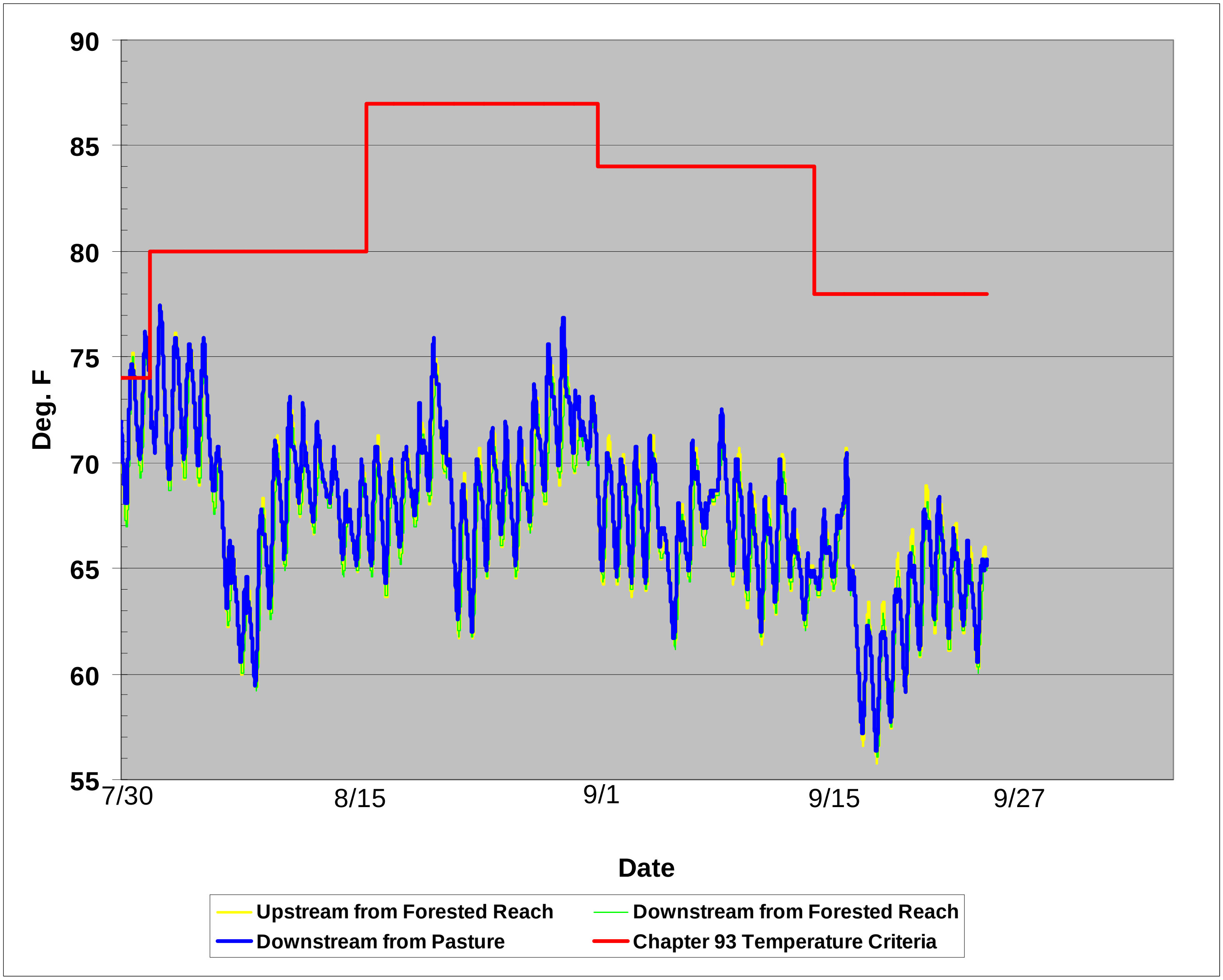


Figure A1-4. Continuous Temperature Monitoring compared to Chapter 93 Temperature Criteria.

Pre BMP Sampling

Station	FIS3	FIS2	FIS1	FIS3	FIS2	FIS1	FIS3	FIS2	FIS1	FIS3	FIS2	FIS1	FIS3	FIS2	FIS1
Sample #	109506	109507	109508	109522	109523	109524	109525	109526	109527	109530	109528	109529	109530	109529	109528
Baseflow/Stormflow	B	B	B	S	S	S	S	S	S	S	S	S	S	S	S
Date	5/25/2004	5/25/2004	5/25/2004	7/12/2004	7/12/2004	7/12/2004	9/28/2004	9/28/2004	9/28/2004	10/14/2004	10/14/2004	10/14/2004	7/8/2005	7/8/2005	7/8/2005
Time	1316	1400	1430	1711	1545	1800	1720	1555	1633	1110	1045	1200	800	700	725
Flow (cfs)	6.16	0.14	5.43	90.6	0.91	135.59	**94.5**	2.58	ns*	17.92	0.35	14.05	30.9	0.48	17.3
Temperature (oC)	22.53	25.74	20.44	19.57	19.29	19.66	19.09	19.54	18.84	12.34	12.95	12.37	18.79	18.58	18.96
DO (mg/l)	10.52	9.74	9.26	8.24	7.19	7.75	7.23	6.13	7.43	9.7	8.16	9.63	7.48	4.75	7.42
%DO	121.7	119.5	102.9	90	78.1	84.5	78.1	66.9	79.8	90.3	77.4	90.1	80	50.8	79.9
Sp. Cond. (us/cm)	276	274	272	239	403	205	238	415	248	272	367	275	267	472	262
pH (su)	8.24	7.67	7.63	7.53	7.35	7.23	7.24	7.24	7.06	7.22	6.96	7.04	7.44	7.3	7.39
BOD5 Inhibited	ns	ns	ns	4.5	14.5	5.5	6.2	31	7.2	2.5	30.1	3.1	5.3	15.6	3.9
TSS (mg/l)	<2	20	10	474	596	996	270	284	120	4	<2	4	174	38	80
NH3-N (ug/l)	50	40	50	200	850	270	160	1000	110	120	650	120	220	780	160
TN (ug/l)	7510	10860	7340	6830	11800	7520	5060	10530	4980	7920	10880	6840	4930	7310	4920
TP (ug/l)	80	78	65	1057	3227	1415	949	2296	599	146	627	153	550	2471	386
Fecal Coliform (cfu/100ml)	4000	11000	4700	1400000	5700000	1100000	1400000	13000000	760000	73000	460000	100000	270000	2400000	120000
Enteroccocus (cfu/100ml)	360	640	550	270000	1500000	310000	370000	3300000	170000	44000	530000	41000	80000	1300000	110000

* not sampled because Marsh McBirney velocity meter would not callibrate. Following field work it was determined that the waterproof meter housing was compromised (leaked). A plastic covering will be needed for future rain sampling.

Post BMP Sampling

Station	FIS3	FIS2	FIS1	FIS3	FIS2	FIS1	FIS3	FIS2	FIS1	FIS3	FIS2	FIS1	FIS3	FIS2	FIS1
Sample #	109915	109914	109913	109879	109878	109877	109897	109896	109895	109925	109924	109923	109929	109928	109927
Baseflow/Stormflow	B	B	B	S	S	S	S	S	S	S	S	S	S	S	S
Date	9/19/2007	9/19/2007	9/19/2007	7/5/2007	7/5/2007	7/5/2007	8/21/2007	8/21/2007	8/21/2007	11/15/2007	11/15/2007	11/15/2007	12/13/2007	12/13/2007	12/13/2007
Time	1330	1400	1430	1930	1800	1830	1230	1250	1320	1205	1050	1115	1700	1550	1630
Flow (cfs)	2.22	0.05	2.44	225.2	13.83	156.1	28.3	0.32	28.4	49.1	2.4	43.6	**65.4**	3.18	62.8
Temperature (oC)	18.12	17.01	14.88	20.25	20.1	20.47	15.91	16.31	15.93	10.1	9.69	10.26	3.24	2.69	3.26
DO (mg/l)	12.8	7.26	10.91	7.92	7.34	7.83	9.65	6.75	9.44	10.88	11.43	10.79	15.46	15.65	15.3
%DO	135.7	75.3	108	87.7	80.9	87	97.7	69	95.5	96.7	100.7	96.3	115.7	115.5	114.6
Sp. Cond. (us/cm)	257	306	294	142	147	173	268	285	245	305	229	311	378	214	383
pH (su)	7.65	6.68	7.00	ns	7.04	6.77	6.9	6.63	6.83	6.94	6.75	6.92	6.89	6.78	6.89
BOD5 Inhibited	2.2	2	0.3	8.1	9.8	8.7	3.5	4.35	3.8	21.5	7.7	27.7	8.2	4.7	7.2
TSS (mg/l)	<2	46	<2	924	450	876	134	28	136	138	64	172	168	120	146
NH3-N (ug/l)	40	140	50	250	590	210	220	550	200	1970	120	1980	330	210	320
TN (ug/l)	7770	8270	8070	5310	6580	5480	4980	7280	4130	9370	4680	9550	5040	4480	4810
TP (ug/l)	69	594	58	2355	3516	1648	735	2208	669	1337	2204	1357	831	1490	765
Fecal Coliform (cfu/100ml)	1100	20000	2800	550000	790000	380000	220000	1100000	300000	280000	41000	260000	37000	8400	45000
Enteroccocus (cfu/100ml)	280	2500	750	150000	430000	270000	250000	570000	240000	390000	54000	230000	30000	10000	31000

Fishery Data			**Fisher Pasture, PreBMP Sampling (8/20/04)**	**Wooded Upstream Reach (8/20/04)**	**Fisher Pasture - PostBMP Sampling (11/9/07)**

Species	Trophic Guild	Pollution Tolerance	Count	Avg. Length (mm)	Max. Length (mm)	Min. Length (mm)	Relative Abundance	Count	Avg. Length (mm)	Max. Length (mm)	Min. Length (mm)
Cyprinidae											
Rosyside dace, *Clinostomus funduloides*	I	I	10	67(13)	85	40	Present	1	81	81	81
Satinfin shiner, *Cyprinella analostana*	I	T	14	58(5)	66	50	Absent	0	na	na	na
Spotfin shiner, *Cyprinella spiloptera*	I	T	0	na	na	na	Absent	1	63	63	63
Cutlips minnow, *Exoglossum maxillingua*	I	I	139	70 (16)	105	50	Common	24	69(19)	102	48
Common shiner, *Luxilus cornutus*	G	M	147	82(13)	114	65	Common	58	60(23)	120	22
Spottail shiner, *Notropis hudsonius*	G	M	15	100(14)	125	72	Absent	51	65(17)	100	45
Swallowtail shiner, *Notropis procne*	I	M	60	57(5)	65	49	Present	24	54(11)	71	32
Bluntnose minnow, *Pimephales notatus*	G	T	213	67(7)	78	54	Common	163	55(13)	100	41
Blacknose dace, *Rhinichthys atratulus*	G	T	168	62(8)	82	47	Present	178	52(13)	70	30
Longnose dace, *Rhinichthys cataractae*	I	M	102	69(10)	85	45	Present	20	60(17)	85	42
Creek chub, *Semotilus atromaculatus*	G	T	34	84(44)	170	40	Common[+]	89	97(43)	200	40
Catostomidae											
White sucker, *Catostomus commersoni*	G	T	122	146(77)	260	60	Present	400	128(60)	220	60
Creekchub sucker, *Erimyzon oblongus*	G	I	1	161	161	161	Absent	0	na	na	na
Ictaluridae											
Margined madtom, *Noturus insignis*	I	M	21	106(17)	130	78	Present	12	101(19)	133	75
Esocidae											
Redfin pickerel, *Esox americanus americanus*	P	M	1	126	126	126	Rare	0	na	na	na
Cyprinodontidae											
Banded killifish, *Fundulus diaphanus*	I	T	7	73(9)	86	64	Absent	50	68(18)	100	42
Centrarchidae											
Rock bass, *Ambloplites rupestris*	P	M	1	66	66	66	Present	7	90(23)	115	46
Redbreast sunfish, *Lepomis auritus*	G	M	39	72(32)	138	40	Present	5	118(37)	162	60
Green sunfish, *Lepomis cyanellus*	G	T	4	97(24)	115	70	Present	1	136	136	136
Pumpkinseed sunfish, *Lipomis gibbosus*	G	M	0	na	na	na	Absent	1	115	115	115
Largemouth bass, *Micropterus salmoides*	P	M	0	na	na	na	Rare	0	na	na	na
Percidae											
Tesselated darter, *Etheostoma olmstedi*	I	M	43	58(8)	73	44	Present	61	58(6)	70	45
Total Count			1141				na	1146			
Total Taxa or Count			19				16	18			

Macroinvertebrate Data

Taxa	Pre-BMP FIS1	Pre-BMP FIS3	Pre-BMP FIS3 Dup.	Post-BMP FIS1	Post-BMP FIS1 Dup.	Post-BMP FIS3
Ancylidae	0	0	0	0	0	1
Dugesia	1	2	0	0	0	0
Nematoda	0	7	13	0	0	0
Oligochaeta	0	0	0	0	1	0
Tubificidae	0	3	5	0	0	0
Naididae	14	20	23	0	0	0
Asellus	0	1	1	0	0	0
Baetis	16	27	14	5	5	4
Leuchotrichia	0	0	0	0	0	1
Cheumatopsyche	3	2	2	27	21	25
Hydropsyche	7	5	6	16	18	18
Chimarra	0	0	0	6	7	6
Nigronia	1	0	0	0	0	0
Psephenus	1	0	0	1	0	0
Optioservus	0	0	0	2	7	2
Ancyronyx	0	0	0	0	1	0
Stenelmis	22	12	8	26	33	21
Bezzia	1	0	1	0	0	0
Ephydridae	0	0	0	1	0	0
Chironomidae	31	21	32	19	14	27
Antocha	4	6	4	0	0	3
Simulium	0	3	6	0	4	4
Total Count	101	109	115	103	111	112
Beck's Index	3	1	1	3	3	3
EPT Taxa Richness	3	3	3	4	4	5
Modified Caddisfly Taxa	0	0	0	1	1	1
FC+PR+Sh Taxa Richness	4	3	4	3	4	4
Hilsenhoff Index	6.12	6.77	7.09	5.42	5.29	5.44
Total Biological Score	25.0%	20.0%	20.0%	32.6%	34.7%	35.5%
Collection Date	5/25/2004	5/25/2004	5/25/2004	6/8/2007	6/8/2007	6/8/2007

Channel Morphology - Bank Pin Cross-Sections

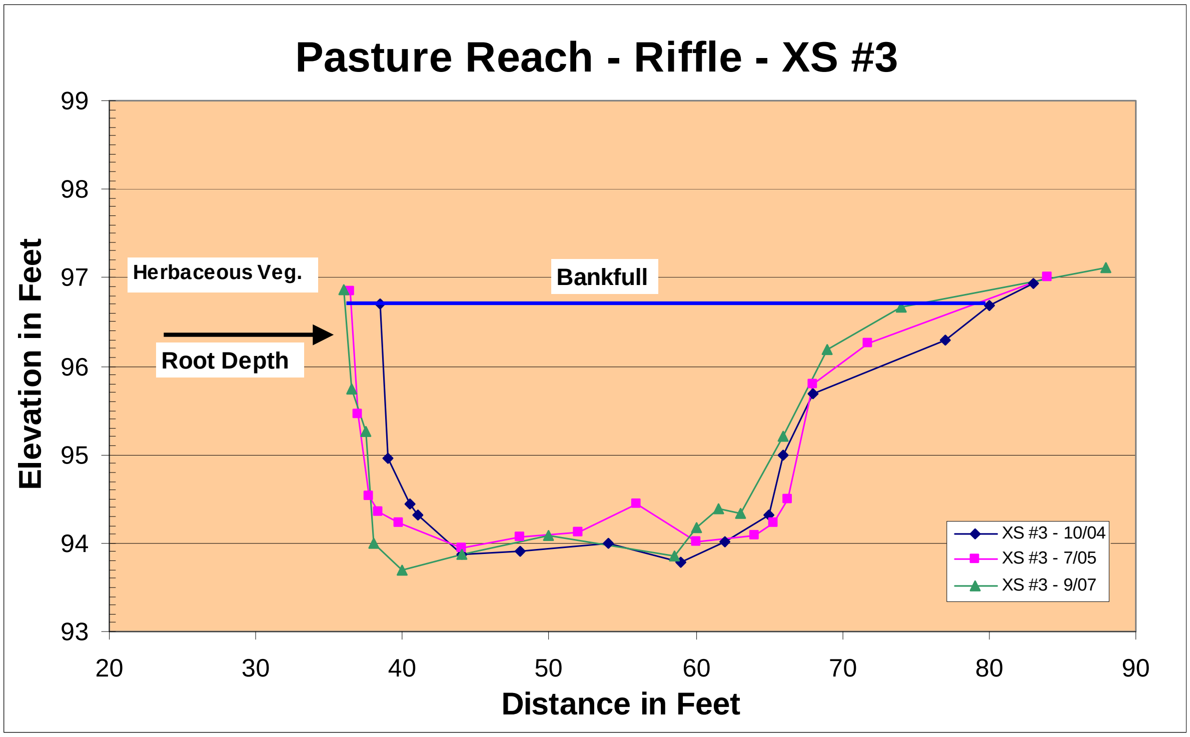


Figure A1-5. Riffle Cross-section in pasture reach.

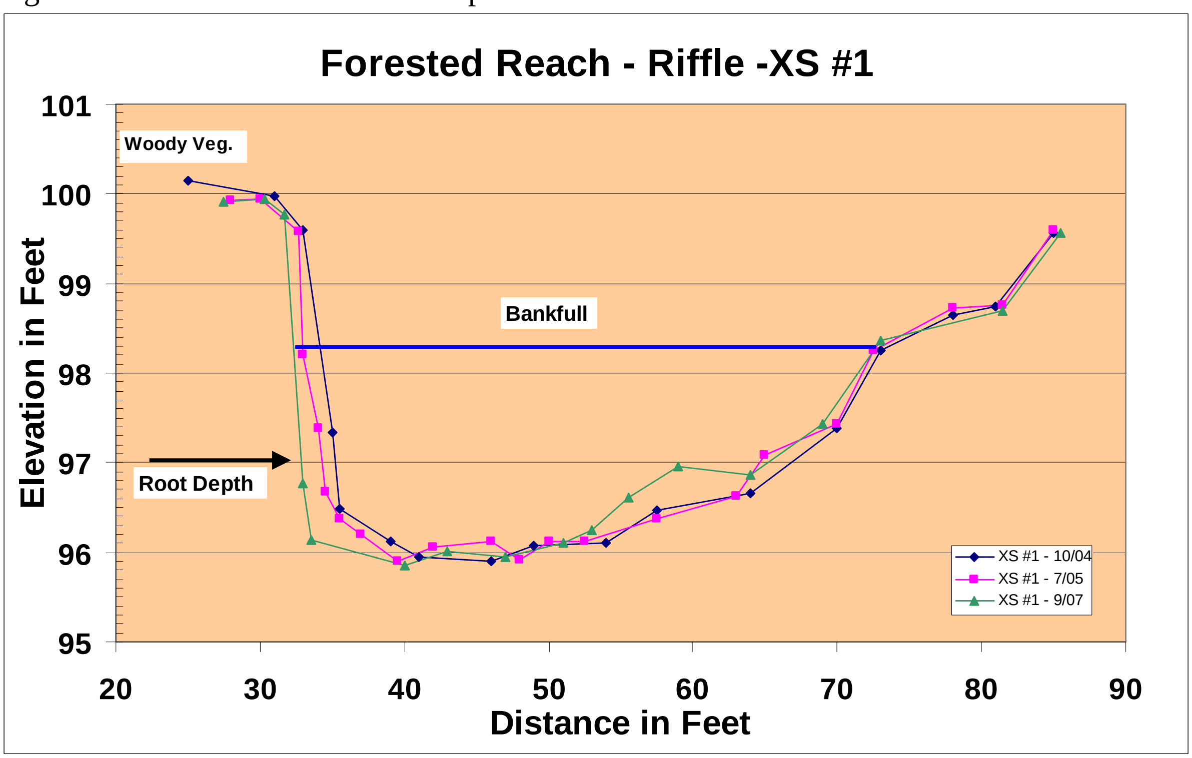
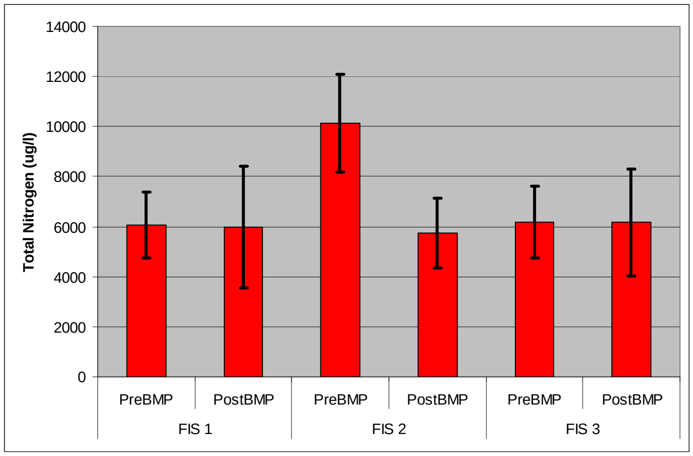
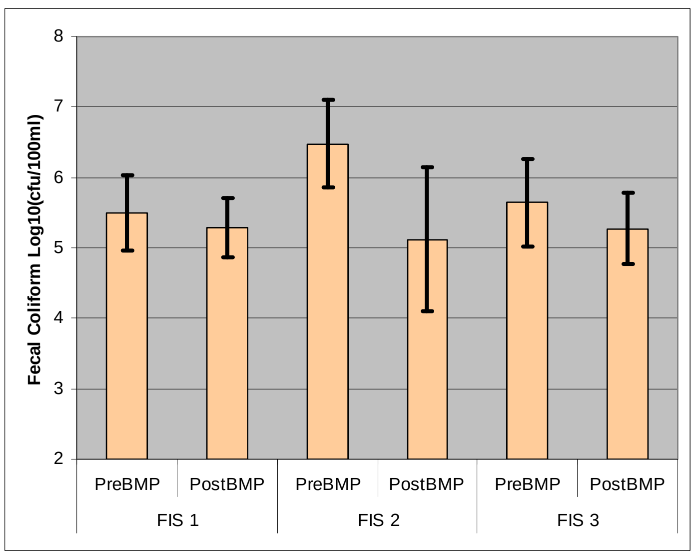


Figure A1-6. Riffle Cross-section in forested reach.

Figure **Error! No text of specified style in document.**.1 Storm-flow Total Nitrogen, Fecal Coliform, and CBOD5 at FIS1, FIS2, and FIS3. Post-BMP mean total nitrogen concentration, fecal coliform numbers, and CBOD5 concentration are less than pre-BMP means at FIS2 (n= 4, one tailed t-test, $p<0.05$).





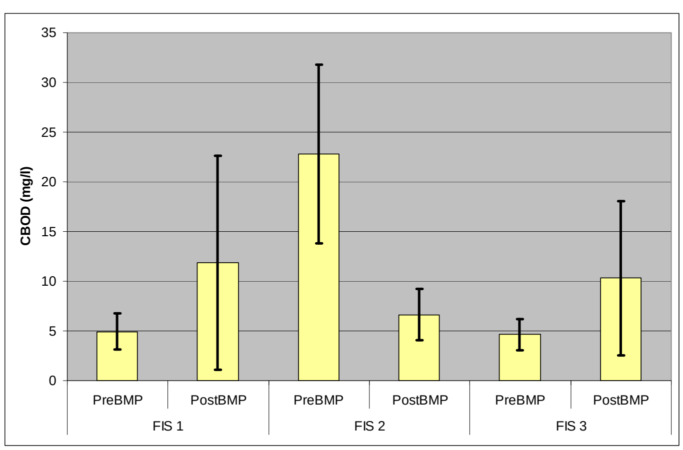


Figure 1 Pasture reach pool cross-section changes throughout study showing bankfull elevation relative to rooting depth.

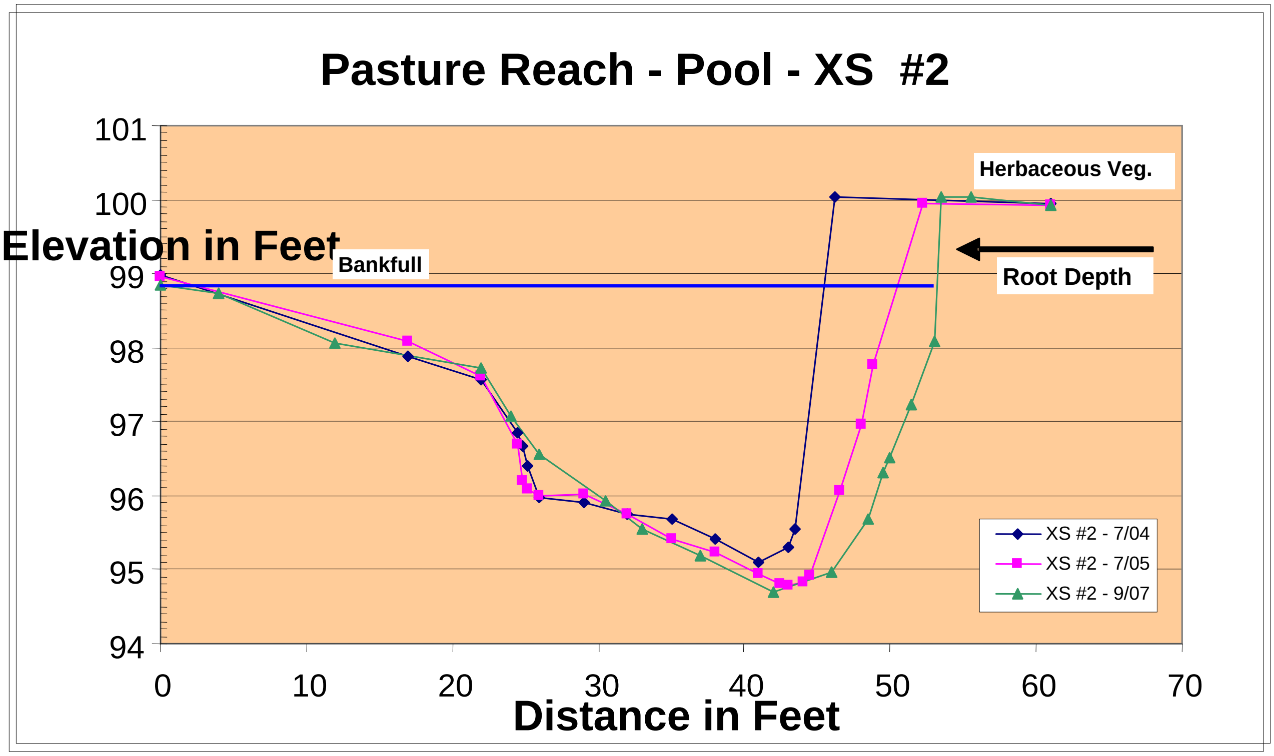


Figure 2 Forested reach pool cross-section changes throughout study showing bankfull elevation relative to rooting depth.

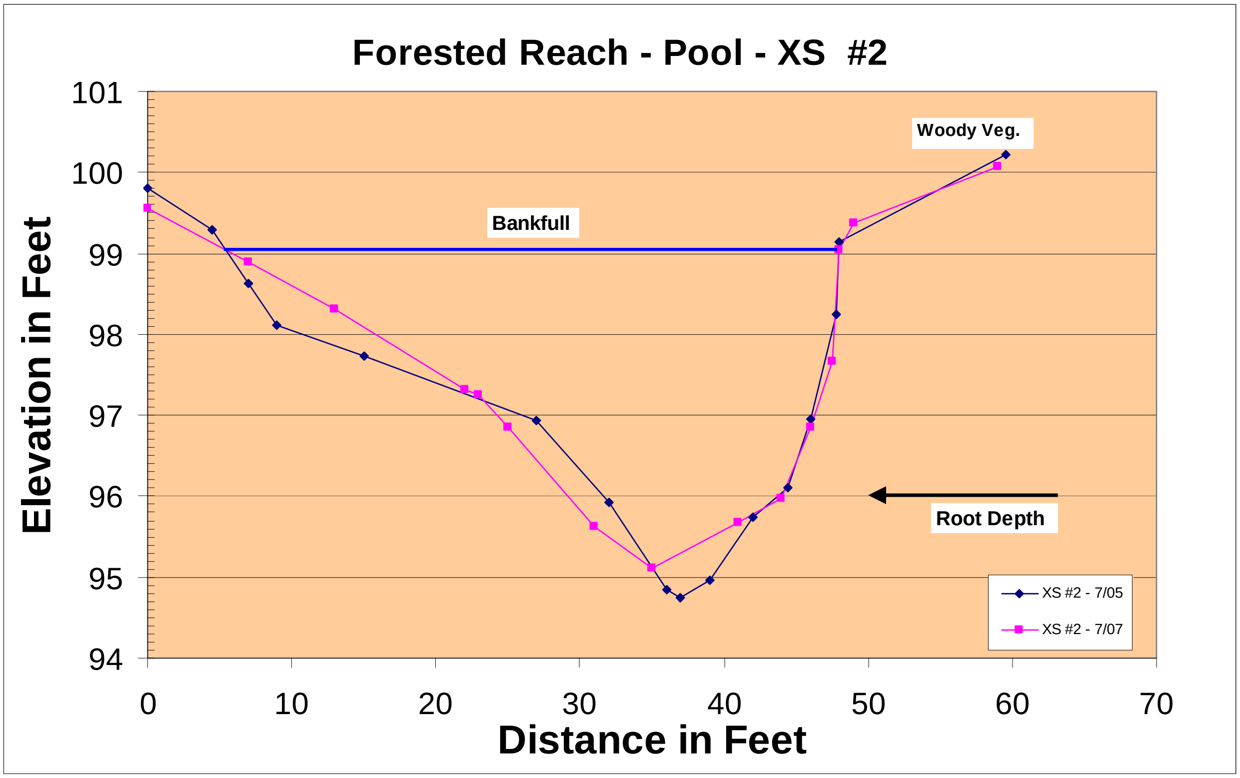
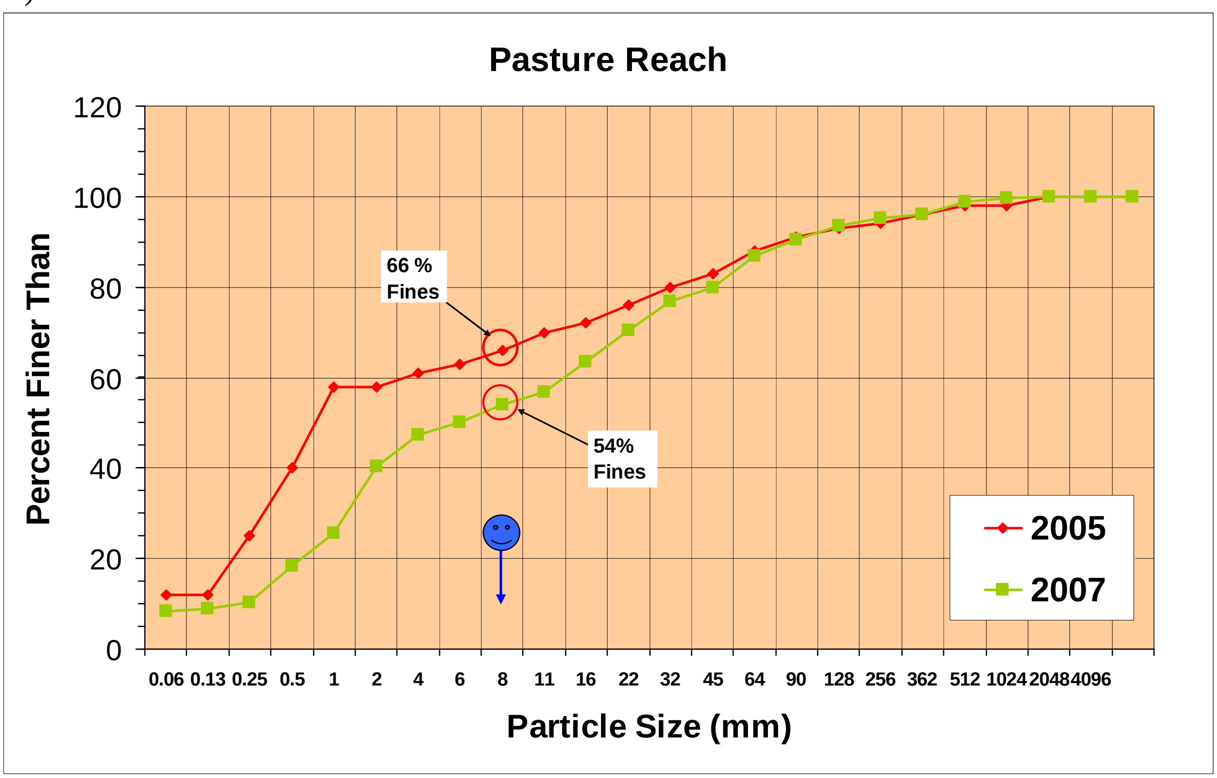
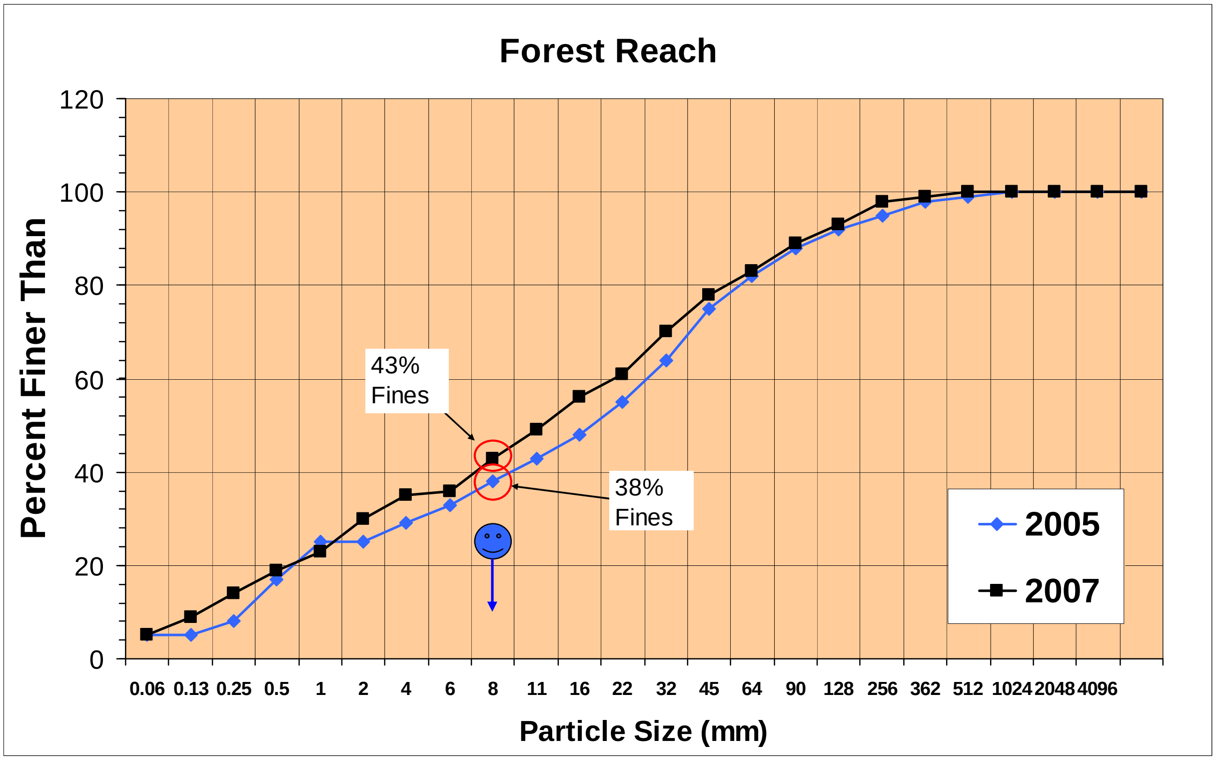


Figure 3 Stream bed particle size distribution in the pasture reach prior to (2005) and following (2007) BMP installation.



.

Figure 4 Stream bed particle size distribution in the forested reach prior to (2005) and following (2007) BMP installation.



APPENDIX H

BioAssessment Pike Creek Stream Restoration

Biological Assessment

Pike Creek Stream Restoration
(Macroinvertebrate and Habitat Survey)

Prepared for:

The Delaware Department of Natural Resources and Environmental Control, Ecological Restoration and Protection Program
89 Kings Highway
Dover, DE 19901

Prepared by:

JM Environmental Consultants
7845 Terrace Drive
El Cerrito,CA 94530
(510) 495-7515

April 2007

TABLE OF CONTENTS

FIGURES AND TABLES

FIGURES

TABLES

1.0 Executive Summary

The purpose of this Biological Assessment (BA) was to determine the effects of stream restoration on the habitat and benthic macroinvertebrate community assemblages in Pike Creek, an urban/suburban piedmont stream located in northern Delaware. Three stream reaches in the Pike Creek Watershed were chosen for restoration due to impaired physical conditions and degraded aquatic habitat. The goals of the restoration project were to improve water quality, fish and benthic invertebrate habitat, stabilize banks, and to restore the natural hydrologic regime.

The success of the project will be measured by implementing a long-term monitoring program, which will keep track of the stream morphology (shape and position) along with assessing the biological health. We conducted the first post-restoration biological assessment of the restored reach as part of the long-term monitoring plan. In addition, we conducted a pre-restoration biological assessment of the upstream, unrestored segments scheduled for restoration in 2007 to establish baseline data.

Benthic macroinvertebrates were used as biotic indicators of stream health to assess the effects of stream restoration for Pike Creek. Rapid Bioassessment Protocols were used to collect habitat data and benthic invertebrate samples. Water quality data was collected with a YSI 650 datasonde. Three stream reaches in the restoration area were sampled during September 2006. The first section of stream sampled was a 5000 linear feet restored reach located at the Three Little Bakers Golf Course in Newark, Delaware. This area was sampled to assess one-year post-restoration effects. Data was compared to baseline data collected from the same reach prior to the restoration in 2002 by scientists from the Delaware Department of Natural Resources and Environmental Control (DNREC), Division of Water Resources, Environmental Laboratory Section. The second and third stream reaches were 3200 and 400 linear feet sections located upstream from the restored reach near the Independence School and the residential subdivision at Meadowdale. Samples were also collected from a regional reference stream (Middle Run) within the same watershed.

Results from field data indicated that overall habitat quality in the restored reach was improved, although the mean taxonomic richness decreased 10%, and the mean number of sensitive families belonging to the orders Ephemeroptera, Plecoptera and Trichoptera (EPT) decreased 3% one year post-restoration. This indicated that one year post-restoration was likely not enough time for the benthic biological community in the restored reach to fully rebound and for riparian vegetation to establish itself and improve ecological processes. The upstream, unrestored reaches had moderately degraded habitat, primarily suffering from bank erosion and resulted with mean taxonomic richness equal to the reference site, and mean abundance greater than both the reference and restored reaches. It is probable that restoring the upstream reaches, will further improve the overall habitat and water quality throughout Pike Creek, thereby providing greater potential for re-establishing ecosystem processes and colonization by a more diverse assemblage of benthic organisms.

2.0 Introduction

The process of designing a natural stream restoration is a complex endeavor. There are several steps and calculations involved in the process of returning a disturbed system to a more functional and natural state. Moreover, the difficulties increase for stream catchments in urban settings mainly due to the many constraints and range of stressors in the environment. A stream suffering from urbanization has several indicators such as elevated concentrations of nutrients and contaminants, flashier hydrographs (flashy flows), altered channel morphology, and reduced biotic richness including increased abundance of pollution tolerant and/or invasive species (Walsh et al. 2005). Other constraints such as utility crossings, property boundaries, lack of reference reaches and problems with isolating diverse stressors can contribute to the difficulties involved with reversing disturbed conditions.

Stream processes, to some extent, are influenced by all the factors that can influence hydrologic cycles in a watershed; upland, overland, upstream, downstream, subsurface and groundwater flow (Ward and Trimble 2004). In urban systems however, the main reason why so many streams are being degraded is from anthropogenic influences, primarily poor land stewardship. Urbanization degrades physical and biological conditions by changing the hydrology i.e., altering flow patterns (Booth 2005). The change of flow patterns in urbanized areas indicates that a primary goal for successful and effective restoration is reestablishing the natural hydrologic regime. However, simply reconfiguring channels or stabilizing banks in an effort to restore natural flow patterns may not address all the issues that are affecting biotic health. Thus, what is important to any restoration goal is to attempt to restore the *entire* stream ecosystem processes i.e., the hydrologic, geomorphic, and ecological processes (Palmer and Wilcock pers. comm. June 2006). This means that a combination of both physical and ecological methods for restoration must be incorporated into the restoration design. In order to effectively do this, a thorough understanding of the stream's history and context is essential (Palmer and Wilcock pers. comm. June 2006). It is important to understand that the area to be restored isn't solely being impacted by its immediate, surrounding area but rather by the entire watershed. Furthermore, the entire watershed's functions and activities are the result of both human and natural influences, understanding this is an integral part of restoration projects. For example, the Pike Creek restoration goals are to improve water quality and habitat for fish and benthic invertebrates, and to stabilize banks and restore balanced sediment transport. The project design incorporates geomorphologic and ecological principles to target the underlying processes of the stream dynamics by restoring natural flow for sediment transport through engineering meanders and bends and stabilizing banks for redirection of water. It also increases habitat quality by replanting riparian buffers, creating wetlands and adding instream features such as riffle-pool complexes and large woody debris/rootwads. The aim is to restore both the physical *and* biological processes.

3.0 BACKGROUND

3.1 Study Site

Pike Creek is located in Northern New Castle County, Delaware (see Figure 9, Appendix A). Pike Creek is a second order stream, 9.4 miles in length, with a watershed of approximately 6.6 square miles, dominated by residential developments. Pike Creek is a tributary of White Clay Creek, which is part of the National Wild and Scenic River system. White Clay Creek is a subbasin of the Christina River basin, and is part of the piedmont ecoregion.

Approximately 50 percent of the streams in the Christina River Basin have impaired water quality due to the combined impacts of sewage treatment plants, industry, agricultural runoff and urban/suburban runoff. Point and non-point source pollution problems include excess nutrients, bacteria, toxic chemicals and metals, fish consumption advisories, habitat loss, and excess sediment (Partnership for the Delaware Estuary 2006). An assessment of the piedmont basin conducted by the DNREC in 2000 resulted with 100 percent of the White Clay Creek watershed failing to meet water quality standards (DNREC 2000).

A Riparian Corridor Stream Inventory Study conducted by the DNREC's Whole Basin Piedmont Team in 1998-99 and a Christina River Watershed Restoration Study conducted in 1999 identified the upper Pike Creek as a segment in need of restoration. The stream was shown to have significant bank erosion that contributed to heavy sediment loads and degraded aquatic habitat. Deep entrenchment with nearly vertical eroding banks (Figs. 1 and 2) was evident in several segments and numerous mid-channel bars had formed from the heavy sedimentation (DNREC 1999).

Figure 1. Pre-restoration photo: Severe bank erosion along the Pike Creek mainstem at the Three Little Bakers Golf Course (Source: DNREC 2002)

Figure 2. Pre-restoration photo: Bank erosion and slumping along Pike Creek at the Three Little Bakers Golf Course (Source: DNREC 2002).

Three stream reaches in the upper section of the Pike Creek watershed were chosen for restoration based upon these reasons and several other factors that supported its candidacy for restoration. Pike Creek serves as a public drinking water source-water stream. It is also one of the few trout put-and-take stocked streams in Delaware, and provides habitat and aesthetic value in a rapidly growing urban/suburban environment. Furthermore, due to its proximity to local parks, golf courses, and schools it provides an excellent opportunity for public awareness and educational programs. In recent years, it has become evident that having an active community involvement in urban stream restorations increases the potential for overall project success (Riley 1998). Neighborhood participation can increase a communities sense of pride and in many instances further protect the restored stream by educating the public and creating teams of volunteers that collect valuable data on a regular basis and monitor the stream's condition. Community involvement may also prevent opposition to the project as local property owners are not left out of the decision making process, which could hinder project implementation.

3.2 Restoration Goals and Strategies

For the purposes of this research, the definition of stream restoration is " the repairing of a waterway that no longer performs ecological and social functions such as supporting biotic communities, transporting sediment and removing excessive nutrients and contaminants from land runoff, or providing clean drinking water" (Palmer and Allan 2006).

The project area is located in the upper portion of the Pike Creek watershed with a drainage area of approximately 4 square miles. The restoration project uses stream restoration methods that measure the watershed inputs and valley type and provide a means to change the stream's pattern, profile and dimension to a more "natural" form, one that would accommodate input changes (e.g., inputs from urbanization) and restore stability, improve sediment transport and ecological function.

DNREC implemented the Pike Creek restoration project at Three Little Bakers Golf Course in 2002. This phase of restoration was completed in the summer of 2005 (Table 1). The goal of this project was to stabilize 5000 linear feet of stream channel using natural channel design geomorphologic techniques (DNREC 1999, Rosgen 1996). These techniques attempt to return a stream or stream reach to morphological equilibrium by reducing bank erosion and restoring sediment transport and turbidity levels to those that would occur under stable stream conditions comparable to pre-urbanization conditions. Reduction in sediment loads to the stream will serve to reduce suspended solids in the stream, thereby improving water quality and aquatic habitat, and controlling aggradation and degradation. The project also attempted to stabilize the streambed and bank, by introducing rock, log and cross vanes, meandering bends, and creating riffle-pool sequences (Figs. 3 and 4). Streamside wetlands and riparian wetland and upland plantings (Figs. 5, 6 and 7) were also included to further stabilize the banks, improve and maintain water quality, provide shade, riparian habitat and organic matter for ecological processes.

Figure 3. Post-restoration photo: Log vane (lower right corner) installed for hydrologic directional control and bank stabilization (Source: DNREC 2005).

Figure 4. Post-restoration photo: Rock toe and vane, cross vane, and rootwad installed for bank stabilization, and hydrologic direction and grade control (Source: DNREC 2005).

Figure 5. Post-restoration photo: Live riparian willow sprigs (*Salix sp.*) and coir matting installed for bank stabilization and to establish a riparian buffer (Source: DNREC 2005).

Figure 6. Post - restoration: Willow plantings one year post-restoration (same area pictured in Fig. 5 above)(Source: J. Meyer 2006).

Figure 7. One year post-restoration at the Three Little Bakers Golf Course (same area depicted in Fig. 1). Log, rock and cross vanes, rootwads, and willow plantings were used to stabilize the bank, control the flow of water, and improve habitat (Source: J. Meyer 2006).

Figure 8. Pre-restoration photo: Bank erosion along the upstream, unrestored reach near the Independence School. Gabion baskets have been installed by homeowners in and attempt to stabilize the banks (Source J. Meyer 2006).

After the first phase of restoration was completed in 2005, additional upstream segments were identified as restoration candidates. These segments include a 3200 linear feet segment located upstream from the restored site that flows through private residential properties and near the Independence School elementary (Table 1), and a 400 linear feet segment located near the residential development of Meadowdale. These impaired stream reaches exhibited similar degraded conditions as the pre-restored Three Little Bakers reach, such as eroding banks, sedimentation problems and degraded aquatic habitat. Property losses for the nearby landowners are also primary concerns (Fig. 8). Similar natural channel-design techniques will be implemented for these next phases of the restoration. The Pike Creek restoration will be the largest (8600 linear feet) stream restoration project in Delaware's history.

As previously mentioned, the success of the project will be determined via a long-term monitoring program, intended to keep track of the morphological and biological conditions of the stream. We conducted the first post-restoration biological assessment of the restored reach, and a pre-restoration biological assessment of the upstream segments scheduled for restoration in 2007 to establish baseline data.

Table 1. Pike Creek Restoration Phases and Sampling Schedules	Phase I. Restored Reach at the Three Little Bakers Golf Course	Phase II. Unrestored Reach at the Independence School and Meadowdale
Length of reach	5000 linear feet	3600 (3200 and 400) linear feet
# 2006 Sampling Sites*	6	4
# Pre-restoration 2002* Sampling Sites	5	N/A
Restoration Start Date	2002	2007
Restoration Completion Date	August 2005	N/A
Date of Pre-restoration Sampling	December 2002	September 2006
Date of post- restoration sampling	September 2006	N/A

***See Figures 9 and 10 in Appendix A for site map and sampling locations**

3.3 Bioassessments and the Use of Benthic Macroinvertebrates as Biotic Indicators

The use of benthic macroinvertebrates as biotic indicators of stream health has been well documented (Barbour et al. 1999, Brooks et al. 2002, Cardinale et al. 2002, Covich et al. 1999, Karr 1991, Klemm et al. 2003, Merritt and Cummings 1996, Moore and Palmer 2003, Morley and Karr 2002, NCDENR 2004, Palmer et al. 2000, Paul and Meyer 2001, Plafkin et al. 1989, Roy et al. 2003, Smith et al. 2005, Walsh et al. 2001). There are many advantages to using benthic macroinvertebrates in bioassessments. Benthic invertebrates are abundant and diverse in most streams and rivers, and are relatively easy to sample and identify for analysis. Benthic invertebrates are a direct or definitive measure of biotic integrity, not an indirect (or predictive) measure, as are physiochemical parameters. Benthic invertebrates can be used as a barometer of overall biodiversity in aquatic ecosystems. Research on the effects of urbanization on invertebrates has shown that as urban land use increases, there is a decrease in invertebrate diversity (decreased richness); especially in the more pollution sensitive orders such an Ephemeroptera, Plecoptera, and Trichoptera. Furthermore, increased urbanization and increased pollutants generally results in invertebrate communities dominated by the more pollution tolerant organisms such as Diptera (e.g. chironomidae) and oligochaetes (i.e. decreased evenness) (Moore and Palmer 2003, Roy et al. 2003, Walsh et al. 2001).

Invertebrate communities respond to changes in water and habitat quality, and integrate impacts over time because of their extended residency period in the stream. Therefore, they can give a picture of the past as well as the present health of the stream. Moreover, they are relatively immobile and cannot avoid "events" or "pulses" of pollutants or other forms of stress often missed by conventional water or habitat quality sampling. It may be difficult to identify stream pollution with water analysis, which can only provide information for the time of sampling. A macroinvertebrate sample may thus provide information about pollution that is not present at the time of sample collection. This differs from other organisms such as fish, which are more mobile and can move away to avoid polluted water and return when conditions are more favorable. Therefore, the presence of fish may not provide information about a pollution problem that an aquatic invertebrate can. The presence or absence of specific taxa can also be indicative of specific environmental and habitat factors. Benthic invertebrates are classified according to their level of pollution sensitivity. For instance, a high abundance of pollution tolerant taxa (e.g., Chironomidae) is indicative of poor water quality conditions.

Benthic taxa are also organized by their habit and functional feeding group (FFG). A benthic macroinvertebrates habit is the way in which it can maintain position and move around in the aquatic environment (i.e. clingers, swimmers, burrowers, sprawlers and climbers), each adapted to a particular habitat. Therefore, a stream's physical properties can determine the biotic richness or community diversity because benthic substrates differ in each habitat and can support different species. Heterogeneous habitat therefore, is more desirable as it can support a more diverse biotic community. While benthic species are not strictly restricted to one type of habitat such as a depositional (pool) or erosional (riffle) habitat, many species are more common in one than the other. The functional feeding group is determined by their feeding strategy e.g., shredders, scrapers, filterers and collectors or gatherers. A balanced assemblage of the various groups is indicative of stable environmental conditions and diversity of habitat. A dominance of any group can be indicative of stressed environmental conditions. Species can be lost from degraded systems when food sources are eliminated, such as those that occur through the removal of riparian buffers, or when water scouring or sedimentation decreases habitat heterogeneity. Therefore, both the type of food and habitat availability can determine what the benthic community assemblage is in each stream reach.

Finally, benthic macroinvertebrates serve as the primary food source for many fish species in freshwater systems. They are an important link in the aquatic food chain. In most streams, the energy stored by plants is available to animal life either in the form of leaf litter that falls into the water or in the form of algae that grows on the stream substrate. The leaves and algae are eaten by benthic macroinvertebrates, which in turn are consumed by fish, thereby providing an energy source for larger animals such as reptiles, birds, mammals and humans.

4.0 Methods

4.1 Site Selection

Due to the long length of stream within the Pike Creek restoration project area (approximately 1.6 miles), 10 sites were selected from the restoration areas and one reference site was chosen (Fig. 10, Appendix A). The Three Little Bakers site had 6 sites (restored sites TPCR 1-6) sampled from 100 meter restored segments (see Figure 11 for sampling schematic). The Independence School segment had 3 sites (unrestored sites IPCR 1-3) sampled from 100 meter sections, and the Meadowdale site (unrestored site MPCR 1) had one sample collected from a 100 meter segment.

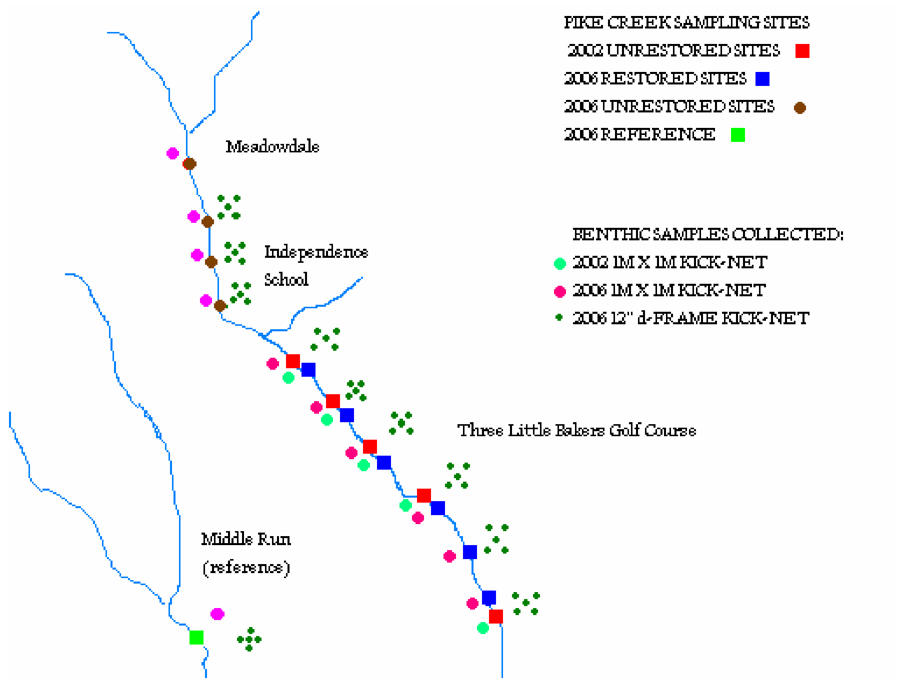


Figure 11. Pike Creek sampling site locations with method type and number of benthic samples collected for 2002 and 2006.

<u>4.2 Data Collection and Analysis</u>

Water Quality

Field measures for water quality parameters e.g., dissolved oxygen, temperature, pH, and specific conductance were collected at each site using a YSI 650 datasonde.

Benthic Macroinvertebrates

Benthic macroinvertebrates were collected in September 2006 using USEPA Rapid Bioassessment Protocols (RBP II) from the restoration project areas, and one sample from the regional reference site (Middle Run) for comparison. Fifty multi-habitat composite samples were collected for semi-quantitative analysis (Table 2). The same methodologies were used to collect data for both pre and post-restoration segments (except for the multi-habitat composites which will be discussed in detail later). The first stream segment sampled from the restoration area was the 5000 linear feet restored reach located at the Three Little Bakers Golf Course (restored sites TPCR 1-6). This area was sampled to assess one-year post-restoration effects. Data is compared to the baseline data collected by DNREC scientists prior to the restoration in 2002 (pre-restoration sites PCR 3-7). Data was not collected for a reference site in 2002, the only data available for a reference site was collected by DNREC in October 1997. Due to the time difference (5 years), and several extreme weather events, such as a regional drought in 2002 followed by extreme flooding in 2003, it was determined that the reference data available would not be suitable to make accurate biological comparisons of the pre-restoration data. Comparisons were made between the

2002 pre-restoration segments and 2006 post-restoration segments. Comparisons were also made between the reference, post-restoration and pre-restoration data collected in 2006.

The second section of stream sampled was the 3200 linear feet area located upstream of the restored section near Independence School (unrestored sites IPCR 1-3). The last section sampled was the 400 linear feet Meadowdale site, at the uppermost boundary of the restoration area (unrestored site MPCR 1). The reaches located at Independence School and Meadowdale were sampled to establish baseline data prior to restoration efforts scheduled to begin in 2007. Site PCR3 of the 2002 pre-restoration samples is located upstream of the restoration area at the Three Little bakers Golf Course (Fig. 9, Appendix A). This site was sampled to track changes to Pike Creek that may occur as a result of the restoration activities, as it is situated between the restored and unrestored reaches of Three Little Bakers Golf Course and Independence School and Meadowdale. In order to match sampling efforts, a post-restoration sample (site TPCR 1) was collected in 2006 in a similar location for comparisons (Fig. 10, Appendix A).

Table 2. Pike Creek Restoration Sampling Methods	**Restored Reach, Three Little Bakers Golf Course**	**Unrestored Reaches, Independence School and Meadowdale**	**Reference Reach, Middle Run Natural Area**
Length of reach	5000 linear feet	3600 (3200 and 400) linear feet	328 linear feet
# Sampling Sites	**6**	**4**	**1**
Kick-nets	2 square meters from each 100m segment	2 square meters from each 100m segment	2 square meters from each 100m segment
D-frame nets	1.5 square meters from random habitat types (pools, riffles, rootwads, vegetated banks, etc.) in each 100m segment	1.5 square meters from random habitat types (pools, riffles, rootwads, vegetated banks, etc.) in each 100m segment	1.5 square meters from random habitat types (pools, riffles, rootwads, vegetated banks, etc.) in each 100m segment

Two kick-net (1m x 1m, 500µm mesh) samples were collected from two square meters in riffle areas and composited from each site in both the restored and unrestored stream reaches (Table 2). Samples were bottled and preserved in 95% ethanol in the field and transported to the lab. The samples were picked, sorted, enumerated and identified to family level in a lab[1]. A Caton subsampler was used to obtain ~100 organism subsamples. Organisms were compared to the reference, and a Biotic Comparison Index (BCI) was calculated using 6 metrics and reported as a level of impairment of the biological community compared to the reference. The metrics and scoring criteria are presented in Table 3. Statistical summaries were calculated for the mean taxonomic richness (TR) and mean EPT.

[1] All organisms were identified to family level except for aquatic worms and mites (Oligochaeta, Nematoda, and Acariformes) which were identified to class, phylum or order.

Table 3. Biological Metrics for Biotic Comparison Index (Mitchell and Dickey 2004)
TR- Taxonomic richness: the number of families in the subsample. Higher numbers indicate good water quality
EPT – EPT richness: the number of families representing the most pollution sensitive orders of aquatic insects (Ephemeroptera **(**mayflies); Plecoptera (stoneflies); Trichoptera (caddisflies). Higher numbers indicate good water quality
%EPT - % EPT abundance: the percentage of individuals in the sample that belong to EPT orders. Higher numbers indicate good water quality
%C - %Chironomidae: the percentage of individuals in the sample belonging to the Chironomidae family (as a whole, one of the most pollution tolerant families of aquatic insects). Higher numbers indicate poor water quality
%DT - % Dominant taxa: the percent contribution of numerically dominant taxa (family) in the sample. Lower numbers indicate good diversity within the community, hence good water quality
FBI – Family Biotic Index: the measure of the sensitivity of the benthic community to organic pollution. The pollution tolerance of each family sample is used to calculate this index. Tolerance values range from 0 to 10, with 10 being the most pollution sensitive. A low FBI indicates good water quality.
BCI Classification and Scoring percentages (percent of reference): <34% = Severely degraded conditions with a severe (S) level of impairment; 34-66% = moderately degraded conditions, level of impairment is moderate (M); 67-99% = good conditions, level of impairment is none (N); ≥100% is excellent conditions, no impairment.

Additional samples were randomly collected from multiple habitat types (e.g. pools, riffles, runs, undercut banks and rootwads) using a D-frame kick-net (12 inch, 500µm mesh) for semi-quantitative analysis (Table 2)[2]. Habitat types were selected based upon presence and frequency within each 100m segment. Approximately one and one-half square meters were sampled at each segment and the collected specimens were preserved in 95% ethanol. Five multi-habitat samples were collected from each site, each composed of 3 habitat types. Organisms were sorted, enumerated and identified to family level[1] in the lab.

Habitat

RBP II methods were used to collect habitat data at each sampling site. A Habitat Comparison Index (HCI) was calculated and reported as a percent comparison to the reference. The HCI is a regional index developed by DNREC for the piedmont ecoregion, and uses 11 parameters scored on a scale of 0-20. Habitat quality in each stream segment was classified according to the degree in which it can support a healthy biological community as severely degraded, moderately degraded, good condition, or excellent; then given a final rating for the ability to support biota as Comparable to the reference (C), Supporting (S), Partially Supporting (PS), or Non-supporting (N) (Mitchell and Dickey 2004).

[2] Additional habitat samples were not collected from the uppermost Meadowdale segment. This site was a last-minute addition, only two one 1m x 1m kick-net samples were collected for baseline data.

The habitat parameters and classification categories are presented in Table 4. The mean HCI was calculated by taking the average of the site habitat scores for each reach, 2002 pre-restored reach (pre-restoration sites PCR 3-7), 2006 restored reach (restored sites TPCR 1-6), and the 2006 unrestored upstream reach (unrestored sites IPCR 1-3 and MPCR1).

Table 4. Habitat Parameters for Habitat Comparison Index (Mitchell and Dickey 2004)
CM – Channel Modification: stream is rated on whether or not it has been modified by man, e.g., channelized, and the extent to which it meanders
BSAC – bottom substrate/available cover: rates the amount and variety of available habitat throughout the stream segment
E- Embeddedness: the degree to which the substrate is surrounded by fine sediment
RQ – Riffle quality: rates the dominant substrate in the riffle where the sample was collected, cobble being desirable.
FR – Frequency of riffles: rates the abundance of riffle areas in the stream segment
SD – Sediment deposition: the degree to which sediment is deposited in the stream channel. Rating is based on the presence of islands and point bars, or sediment deposited among the substrate
V/D – Velocity/depth: rates the absence or presence of four categories of water, i.e., slow & deep; slow & shallow; fast and deep; fast & shallow
BS – Bank stability: measures erosion of the stream bank
BVT – Bank vegetative type: rates the dominant vegetation on the stream bank, shrubs being the most desirable
S – Shading: rates the percent of the stream surface that is shaded throughout the day
RZW – Riparian zone width: measures the amount of natural vegetation along the edge of the stream. The riparian zone is measured outwardly from the top of the stream bank
HCI – Habitat Comparison Index (expressed as a percent of reference score 175): 0-59% = severely degraded conditions, non-supporting classification (NS); 60-89% = moderately degraded conditions, partially supporting classification (PS); 90-99% = good condition, supporting classification (S); ≥ 100% = excellent conditions, comparable to the reference (C).

5.0 Results

5.1 Water Quality

Water quality data for Pike Creek and the regional reference site are presented in Table 5. All parameters were within acceptable water quality limits. Temperatures ranged from 4.92-15.29 °C for the 2002 pre-restoration sites (PCR 3-7), 16.56-20.13 °C for the 2006 restored sites (TPCR 1-6), and 13.18-16.22 °C for the 2006 unrestored sites (IPCR 1-3, MPCR 1). The differences in temperatures between the lower pre-restoration values and the higher 2006 values are likely due to the time of sampling. The pre-restoration data was collected in December 2002, and the post-restoration was collected in September of 2006. The regional reference temperature was 19.32 °C. Dissolved oxygen ranges were higher than the reference of 8.94 mg/L, ranging from 9.49-10.65 mg/L for the 2006 restored sites, and 11.63-13.09 for the 2006 unrestored sites. The 2002 pre-restoration sites ranged from 9.8-16.33 mg/L, similar to the 2006 post-restoration and unrestored site ranges. pH levels ranged from 6.7-7.95 for the 2002 unrestored sites, 7.56-8.32 for the 2006 restored sites, and 6.93-7.74 for the 2006 unrestored sites. The regional reference pH was 7.33. Specific conductance ranged from 99-290.33 *μmhos* for the 2002 unrestored sites. All of the 2006 segments had higher specific conductivity levels ranging from 273-288 *μmhos* for the 2006 restored sites and 257-259 *μmhos* for the 2006 unrestored sites, compared to the regional reference site of 166 *μmhos*.

Table 5. Pike Creek Water Quality Data

Site	Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Specific Conductance (µmhos)
Pre-restoration 2002 PCR3	4.92	16.33	7.14	288.0
Pre-restoration 2002 PCR4	10.2	9.8	6.7	99
Pre-restoration 2002 PCR5	18.34	10.10	7.95	262.33
Pre-restoration 2002 PCR6	15.04	12.44	7.41	290.33
Pre-restoration 2002 PCR7	15.29	12.62	7.08	257
Reference 2006 RREF*	19.32	8.94	7.33	166
Post-restoration 2006 TPCR1	17.39	9.49	7.96	288
Post-restoration 2006 TPCR2	18.48	9.49	8.2	287
Post-restoration 2006 TPCR3	16.56	10.11	7.56	285
Post-restoration 2006 TPCR4	20.13	10.65	8.32	274
Post-restoration 2006 TPCR5	19.62	10.63	8.04	273
Post-restoration 2006 TPCR6	17.87	10.2	7.63	276
Pre-restoration 2006 IPCR1	13.18	13.09	6.93	259
Pre-restoration 2006 IPCR2	15.72	11.63	7.55	310
Pre-restoration 2006 IPCR3	16.22	12.6	7.74	302
Pre-restoration 2006 MPCR1	15.29	12.62	7.08	257

*** Reference data was not collected in 2002**

5.2 Biological Assessment

Results for the biological assessment data are displayed in Table 6. The Biotic Comparison Index (BCI) calculated for the 2006 restored segments and the 2006 unrestored segments indicated that Pike Creek is moderately degraded at 4 sites (restored sites TPCR 2-5) and in good condition at 2 sites (restored sites TPCR1 and TPCR6). Restored sites TPCR1 and TPCR6 in the restored stream reach resulted with BCI scores of 82% and 73% comparable to the regional reference. This indicated a level of impairment of “none” (N) to the biological community in these segments. The remaining restored sites (TPCR 2 - 5) all resulted with BCI scores indicating moderately degraded conditions, with a moderate (M) level of impairment. Both restored sites TPCR 4 and TPCR 5 scored the lowest, 45%

comparable to the reference; with moderate impairment (M). Restored sites TPCR 3 and TPCR 4 scored the same BCI, 64% comparable to the reference, which indicated a moderate level of impairment. The upstream unrestored reaches received BCI scores between 73-100%. Unrestored sites IPCR 1 and IPCR 2 both had BCI scores of 73%. Unrestored sites IPCR 2 and MPCR 1 had the highest BCI scores of 91% and 100%, respectively. These percentages indicated good conditions with levels of impairment as "none".

The mean taxonomic richness (TR) was calculated for pre and post restoration reaches. Comparison results between pre and post sites indicated a 10% decrease in the number of different benthic taxa one-year post-restoration (Figure 12). The mean number of families for the 2002 pre-restoration sites (PCR 3-7) was 10 (± 1.79), within the 95% confidence interval. The mean number of families one year post-restoration for sites (TPCR 1-6) was 9 (± 1.72), at the 95% confidence interval which was 90% comparable to pre-restoration conditions, and 69% comparable to the regional reference site of 13 families. The upstream, unrestored sites near the Independence School (IPCR 1-3) and Meadowdale (MPCR 1) resulted in a mean number of 10 (± 2.22) families, within the 95% confidence interval, which was 111% comparable to the restored sites, and 77% comparable to the regional reference.

The number of sensitive families belonging to the orders Ephemeroptera, Plecoptera and Trichoptera (EPT) for the 2002 pre-restoration sites (PCR 3-7) ranged from 2-5. The range of EPT post-restoration (TPCR 1-6) was 3-4. The 2006 unrestored, upstream sites (IPCR 1-3, MPCR1) had a range of EPT from 3-6. The regional reference site had the highest number of EPT with 5 families.

Statistical means for the pre and post restoration reaches resulted in a 3% decrease of the mean number of EPT families for the post-restoration sites compared to pre-restoration. The pre-restoration sites had a mean of 3.40 (±1.14) at 95% confidence, and the post-restoration sites had a mean of 3.33 (± .52), with 95% confidence. The post-restoration sites had a 32% lower EPT mean than the regional reference. The upstream, unrestored sites at IPCR 1-3 and MPCR1 resulted with a mean number of EPT of 4.75 (± 1.50), within the 95% confidence interva1, which indicated a 30% greater mean difference between the upstream, unrestored reaches and the restored sites downstream. Unrestored sites IPCR 1-3 and MPCR 1 resulted in a 5% lower EPT difference compared to the reference.

EPT percentages of individuals per site ranged from 24 - 60% pre-restoration, and 49 -92% post-restoration, this indicated an overall increase in percent EPT individual abundance post-restoration. The EPT percent for the regional reference was 56%. The unrestored, upstream sites (IPCR 1-3, MPCR1) resulted with percentage ranges of 80-93% EPT.

The percentage of Chironomidae for pre-restoration (pre-restoration sites PCR 3-7) conditions ranged from 3 – 31%. The post-restoration sites (restored sites TPCR 1-6) ranged from .82 – 35% Chironomidae. The upstream, unrestored sites (IPCR 1-3, MPCR 1) had ranges of 1-6%. The regional reference site (RREF) consisted of 5% Chironomidae.

The percent dominant taxa per reach ranged from 28-59 % pre-restoration, and 31-84% post-restoration. The regional reference had 33% dominant taxa. The upstream, unrestored sites IPCR 1-3 and MPCR 1 had 41-50% dominant taxa. The regional reference site had 33% dominant taxa. The taxa from the pre-restoration sites of PCR 3 and PCR 5-7 were dominated by caddisflies belonging to the family Hydropsychidae. Pre-restoration site PCR 4 was dominated by riffle beetles in the family Elmidae. All of the taxa from the post-restoration sites except for TPCR 1 were also dominated by Hydropsychidae, which supports the result for the overall increase in EPT abundance percentages for the post-restoration sites. TPCR 1 was dominated by caddisflies belonging to the family Philopotamidae. The upstream, unrestored sites (IPCR1-3, MPCR 1) were also dominated by taxa from Hydropsychidae.

The family biotic index (FBI) scores ranged from 3.79-4.53 for sites the 2002 pre-restoration sites (PCR 3 -7). The 2006 post-restoration FBI scores ranged from 3.5 - 4.87 for sites TPCR 1-6, and from 3.50 – 3.96 for the 2006 unrestored sites IPCR 1-3 and MPCR1. The regional reference FBI was 3.93. Lower values of FBI are indicative of the presence of more sensitive taxa, and better water quality conditions.

Table 6. Pike Creek Biological Assessment

Sites	TR	EPT	% EPT	% C	% DT	FBI	BCI – (Impairment)
Pre-restoration 2002 PCR3	13	5	41	3	33	3.79	
Pre-restoration 2002 PCR4	10	4	36	22	33	4.21	
Pre-restoration 2002 PCR5	10	3	37	25	28	4.53	
Pre-restoration 2002 PCR6	8	2	24	31	32	4.34	
Pre-restoration 2002 PCR7	10	3	60	9	59	3.98	
Reference 2006 RREF*	13	5	56	5	33	3.93	
Post-restoration 2006 TPCR1	10	4	81	2	31	3.50	81.82 (N)
Post-restoration 2006 TPCR2	10	3	49	26	35	4.45	45.45 (M)
Post-restoration 2006 TPCR3	10	4	83	8	78	4.16	63.64 (M)
Post-restoration 2006 TPCR4	7	3	92	5	84	4.07	63.64 (M)
Post-restoration 2006 TPCR5	7	3	49	35	40	4.87	45.45 (M)
Post-restoration 2006 TPCR6	11	3	79	.82	76	4.19	72.73 (N)
Pre-restoration 2006 IPCR1	7	3	93	3	50	3.67	72.73 (N)
Pre-restoration 2006 IPCR2	11	6	80	6	55	3.96	90.91 (N)
Pre-restoration 2006 IPCR3	9	4	87	4	53	3.63	72.73 (N)
Pre-restoration 2006 MPCR1	12	6	91	1	41	3.50	100.00 (N)

***Reference data was not collected in 2002, therefore the BCI could not be calculated for that year.**

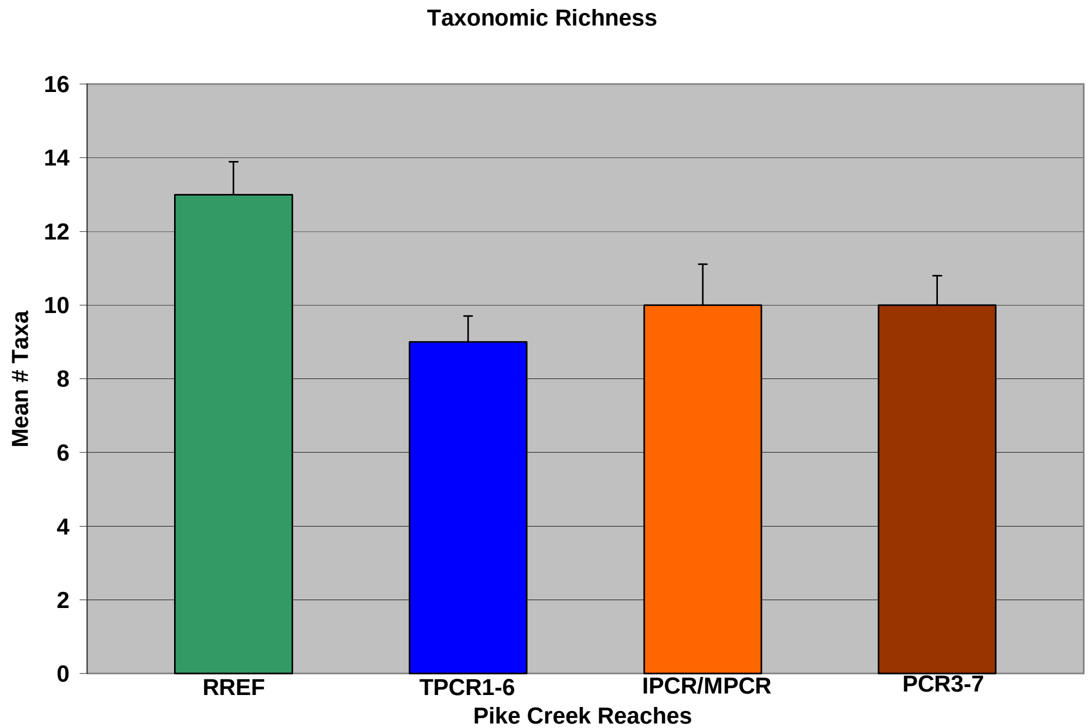


Figure 12. Mean number of taxa per unrestored and restored reaches at Pike Creek. The mean number of taxa decreased 10% one year-post restoration. The 2006 restored sites also had 10% less TR than the 2006 upstream, unrestored reaches. The 2006 regional reference is indicated in green. The blue column represents the 2006 restored reach at the Three Little Bakers Golf Course (TPCR 1-6). The orange column represents the 2006 unrestored, upstream segments at Independence School (IPCR 1-3) and Meadowdale (MPCR1). The brown column represents the 2002 unrestored reach (PCR 3-7) at the Three Little Bakers Golf Course (± SE).

The multi-habitat biotic assessment results are presented in Table 7. The five individual samples from each site were composited into one sample for calculations and comparisons. The Biotic Comparison Index (BCI) calculated for the 2006 restored segments and the 2006 unrestored segments indicate that Pike Creek is moderately degraded and impaired at 6 sites (restored sites TPCR 2-6 and unrestored site IPCR 2) and in good condition with no impairment at 3 sites (restored site TPCR1 and unrestored sites IPCR1 and 3). The downstream restored section (sites TPCR 1 – 6) resulted with BCI scores between 45-82%; these percentages falling under the category of moderately degraded and impaired conditions. The 3 unrestored upstream reaches resulted in 55-73% comparability to the reference. This indicated a moderate level of impairment (unrestored site IPCR2) and no impairment (unrestored sites IPCR1 and 3) to the biological community in these segments.

Table 7. Pike Creek Biological Assessment - Multi-habitat Composites							
Sites	**TR**	**EPT**	**% EPT**	**% C**	**% DT**	**FBI**	**BCI – (Impairment)**
Reference 2006 RREF	29	12	61	3	44	4.02	
Post-restoration 2006 TPCR1	29	9	43	8	31	4.47	82 (N)
Post-restoration 2006 TPCR2	28	7	54	19	44	4.53	55 (M)
Post-restoration 2006 TPCR3	27	8	72	12	66	4.25	55 (M)
Post-restoration 2006 TPCR4	23	7	55	19	48	4.63	64 (M)
Post-restoration 2006 TPCR5	21	4	52	27	48	4.77	45 (M)
Post-restoration 2006 TPCR6	22	8	56	2	51	4.72	55 (M)
Pre-restoration 2006 IPCR1	27	8	68	4	36	3.79	73 (N)
Pre-restoration 2006 IPCR2	30	7	70	8	55	4.13	55 (M)
Pre-restoration 2006 IPCR3	30	8	67	11	32	3.86	73 (N)

The mean abundance of organisms varied throughout the sites. Mean abundance was calculated for the 5 samples from each site and is presented in Figure 13. The regional reference mean abundance was 140 (± 149). The highest values for mean abundance were found at the unrestored, upstream sites IPCR1-3. Unrestored site IPCR1 had the highest abundance mean of 274 (± 164), unrestored IPCR2 was 233 (± 131), and unrestored IPCR3 was 190 (± 127), all within the 95% confidence interval. The downstream restored segments had mean abundances ranging from 61 – 156. Restored site TPCR3 had the highest mean abundance of organisms for the restored reach with 156 (± 129). For the restored sites: TPCR4 was the lowest mean of 61 (± 47). TPCR2 was 133 (± 119), TPCR1 was 84 (± 49.3), TPCR5 was 94 (± 90) and TPCR6 was 95 (± 61), all within the 95% confidence interval. All of the sites were dominated by the caddislfy from the family Hydropsychidae except for the unrestored site IPCR3 which was dominated by the caddisfly in the family Philopotamidae.

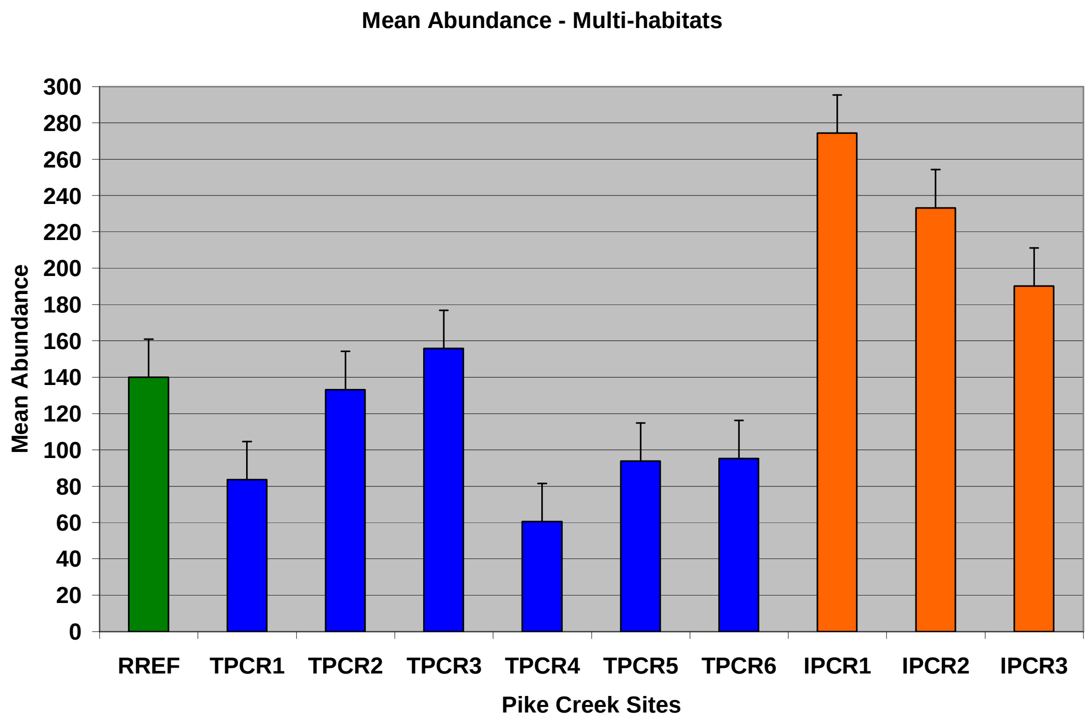


Figure 13. Mean Abundance for Pike Creek Multi-habitat Samples. The regional reference (RREF) had a mean abundance of 140 organisms, indicated in green. The restored reach (TPCR 1-6) had lower abundances overall ranging from 61-156, indicated in blue. Mean abundance was highest at the unrestored reaches ranging from 190-274, indicated in orange (± SE).

Mean taxonomic richness (TR) values were calculated for the 5 samples taken from each site. The data is presented in Table 8 and Figure 14. In the restored segment, site TPCR 1 had the same TR as the regional reference with 15 families. Restored sites TPCR 2 and 3 had 12 families, resulting in 20% less benthic organism diversity than the regional reference. Restored sites TPCR4 and 6 each had 10 families, which was 33% less diverse than the regional reference. Restored site TPCR5 had the lowest diversity of 9 families, resulting with 40% less diversity than the reference. The upstream, unrestored sites had higher TR than the lower, restored sites. The TR for unrestored sites IPCR 1 – 3 ranged from 13-16 families. Unrestored site IPCR1 had 6% less diversity than the regional reference. Unrestored sites IPCR2 and 3 were 100% and 106% as taxonomically rich as the regional reference.

Table 8. Mean Taxonomic Richness for Multi-habitat Assessment						
Sites	Mean TR	SD	Confidence Interval	Median	*P* =	*F* =
Reference 2006 RREF	15	± 4.93	95%	13	.009	2.933
Post-restoration 2006 TPCR1	15	± 3.42	95%	14	.009	2.933
Post-restoration 2006 TPCR2	12	± 3.29	95%	14	.009	2.933
Post-restoration 2006 TPCR3	12	± 3.77	95%	12	.009	2.933
Post-restoration 2006 TPCR4	10	± 2.55	95%	9	.009	2.933
Post-restoration 2006 TPCR5	9	± 3.21	95%	9	.009	2.933
Post-restoration 2006 TPCR6	10	± 2.59	95%	9	.009	2.933
Pre-restoration 2006 IPCR1	14	± 1.82	95%	14	.009	2.933
Pre-restoration 2006 IPCR2	15	± 4.60	95%	14	.009	2.933
Pre-restoration 2006 IPCR3	16	± 2.30	95%	16	.009	2.933

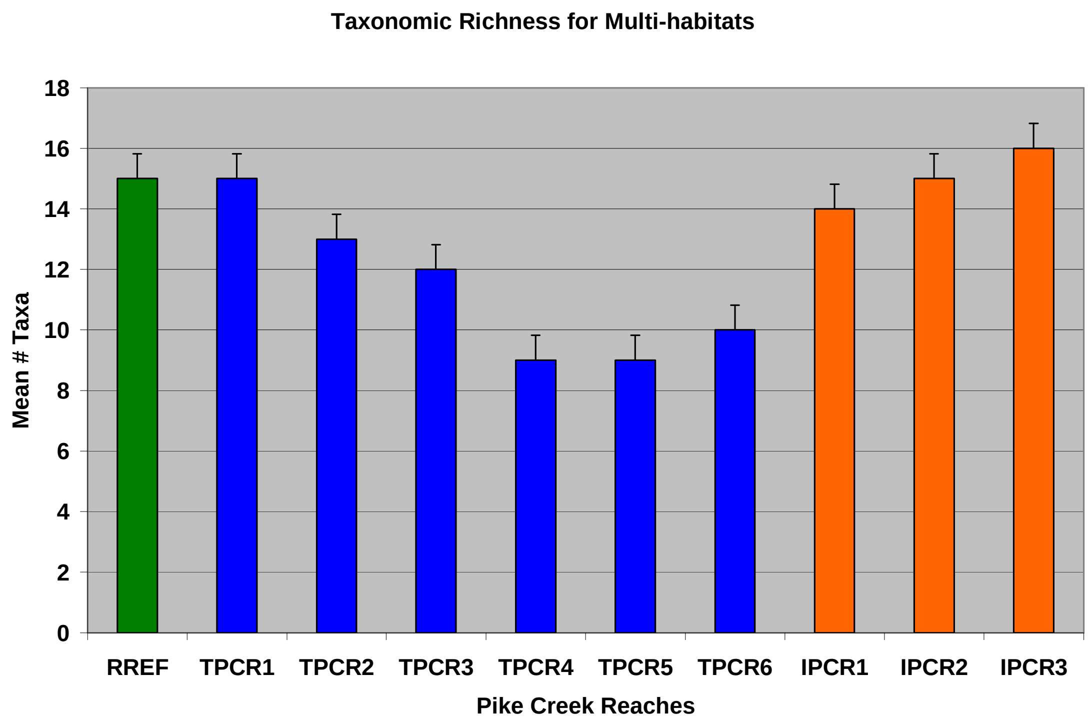


Figure 14. Mean Taxonomic Richness for multi-habitat types from Pike Creek. Taxonomic richness was less than the regional reference in the restored sites (TPCR 1-6 in blue bars) and equaled or exceeded the regional reference (RREF green bar) for the unrestored sites (IPCR 1-3, orange bars) ± SE.

Benthic Habit and Functional Feeding Group (FFG) percentages were calculated for each site composite. Habit percentages are presented in Figure 15 and Functional Feeding Group data is presented in Figure 16.

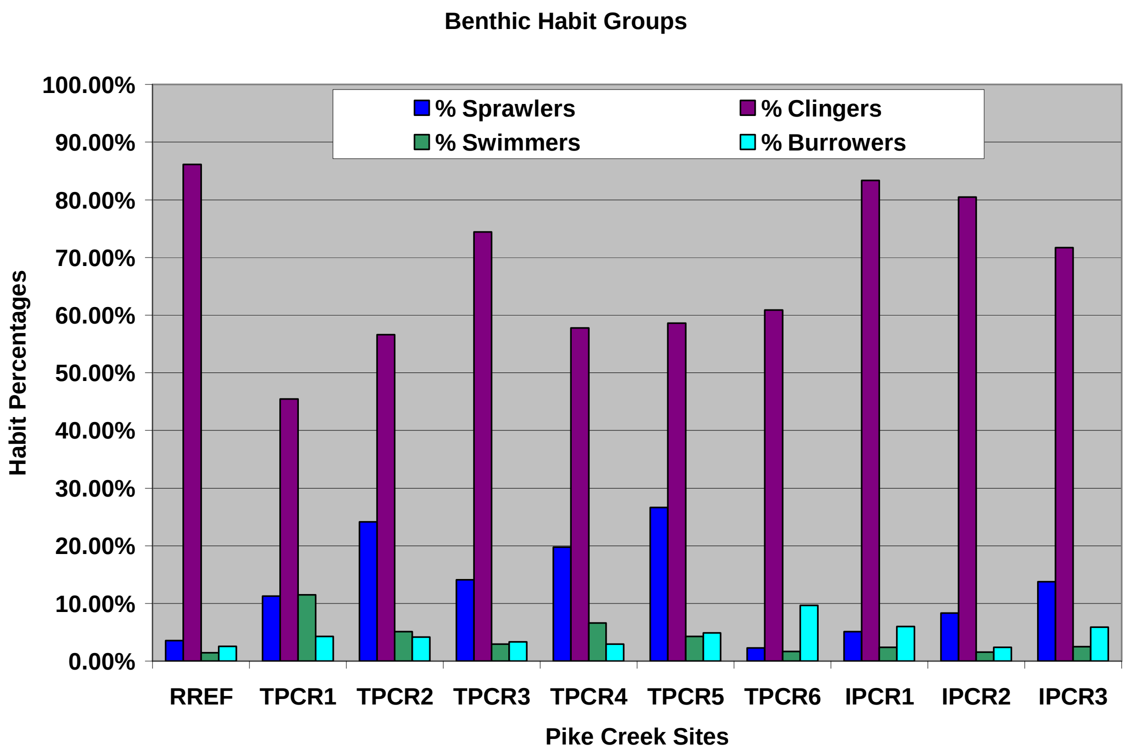


Figure 15. Percentages of Benthic Habit Groups for Pike Creek. Pike Creek is dominated by clingers. The 2006 restored sites are TPCR 1-6. The 2006 upstream, unrestored sites are IPCR 1-3. The 2006 regional reference is RREF.

The benthic community of the regional reference was dominated by organisms from the FFG of filterers (56%) and by the habit group of clingers (86%). The restored reach sites were similarly dominated by filterers and clingers, although one site, TPCR1 had a higher percentage of predators compared to the other sites. The restored reach site TPCR1 had 35% filterers and 45% clingers; restored site TPCR2 had 47% filterers and 57% clingers; restored site TPCR3 had 68% filterers and 58% clingers; restored site TPCR4 had 50% filterers and 59% clingers; restored site TPCR5 had 50% filterers and 59% clingers. The last site in the restored reach, TPCR6 had 53% filterers and 60% clingers. The upstream sites had similar distributions, unrestored site IPCR1 had 69% filterers and 84% clingers; unrestored sites IPCR2 and IPCR3 had 69% and 63% filterers and 80% and 72% clingers, respectively.

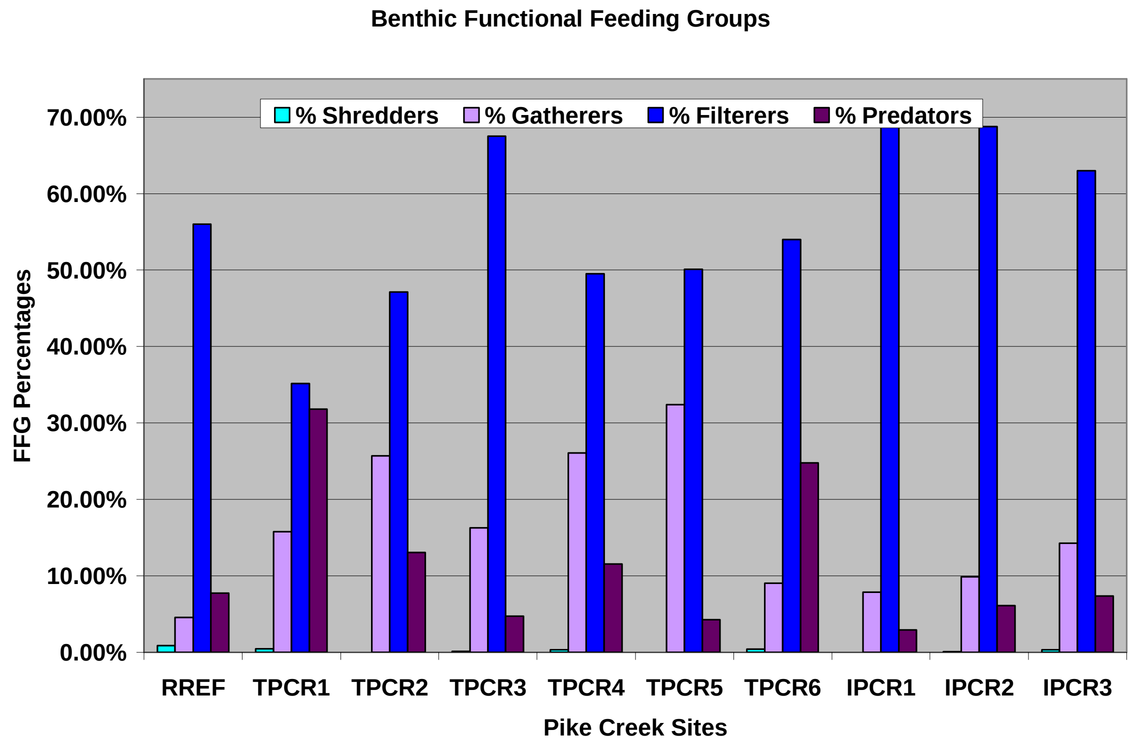


Figure 16. Percentages of Benthic Functional Feeding Groups (FFG). Pike Creek is dominated by filterers. Site RREF is the 2006 regional reference. Sites TPCR 1-6 are the 2006 restored sites. Sites IPCR 1-3 are the 2006 upstream, unrestored sites.

5.3 Habitat Assessment

Results for habitat data are presented in Table 9. The Habitat Comparison Index is reported as a percent comparison to the regional reference value. For eastern piedmont streams, DNREC uses a set reference score of 175 for comparison calculations. Therefore, calculations for the 2002 pre-restoration sites were completed without 2002 reference habitat data. The HCI was calculated by adding 11 habitat parameter metrics. Scores for each parameter range from 0-20, with 0-5 = Poor, 6-10 = Fair, 11-15 = Good and 16-20 = Excellent. The 2002 pre-restoration sites (PCR 3-7) resulted in habitat scores ranging from 70-90% comparability to the regional reference. These scores indicated moderately degraded conditions, capable of partially supporting biota (PS) for all of the sites, and good condition in one site (PCR6). The 2006 post-restoration sites (restored sites TPCR 1-6) show some habitat improvement, particularly sites TPCR2, TPCR4, and TPCR6 with HCI scores between 91-99% comparable to the reference. This range of scores was indicative of good habitat condition, capable of supporting (S) a diverse and abundant biotic community. The sites with lower HCI scores were restored sites TPCR1, TPCR2 and TPCR5, with HCI percentages ranging from 72-86%. These scores indicated moderately degraded conditions, capable of partially supporting (PS) a healthy biotic community. It should be mentioned that the pre-restoration site PCR3 and restored site TPCR1 are the upstream sites outside the boundaries of the construction area. TPCR1 resulted with 6% improvement, 86% comparable to the reference compared to the pre-restored condition of 80%. The upstream, unrestored sites near Independence School (unrestored sites IPCR 1-3) and Meadowdale (unrestored site MPCR1) had HCI ranges between 76-85%. Unrestored sites IPCR2 and IPCR3 scored the lowest with HCI percentages of 76 and 79%. These scores fell within the range of moderately degraded conditions, only partially capable of supporting the biotic community. The uppermost, unrestored sites of Pike Creek at IPCR1 and MPCR1 scored slightly higher percentages at 85% and 82%, respectively. These scores also indicated moderately degraded conditions, only partially capable of supporting a healthy assemblage of biota.

The mean reach HCI scores were 145 (± 13.9), within 95% confidence for the 2002 pre-restoration reach, 83% comparable to the reference and 151 (± 18.4), within 95% confidence for the 2006 restored reach, 86% comparable to the reference indicating a 3.6% improvement in overall reach habitat quality post-restoration. The upstream, unrestored 2006 reach mean was 141 (± 6.60); 81% comparable to the reference and had lower habitat quality then both the 2002 unrestored and 2006 restored reaches at Pike Creek.

Table 9. Pike Creek Habitat Assessment

Site	CM	BSAC	E	RQ	FR	SD	V/D	BS	BVT	S	RZW	TOTAL	HCI - Class
Pre-restoration 2002 PCR3	13	16	10	13	18	8	17	11	7	17	10	140	80 (PS)
Pre-restoration 2002 PCR4	13	17	12	14	18	11	13	14	6	5	0	123	70 (PS)
Pre-restoration 2002 PCR5	17	18	13	18	11	12	19	9	11	17	9	150	86 (PS)
Pre-restoration 2002 PCR6	12	18	10	19	17	8	19	15	11	18	10	157	90 (S)
Pre-restoration 2002 PCR7	12	19	10	18	13	15	15	12	16	19	11	155	89 (PS)
2006 REFERENCE	15	18	15	17	19	17	15	17	9	18	20	187	
Post-restoration 2006 TPCR1	10	14	14	10	19	16	14	18	18	17	8	151	86 (PS)
Post-restoration 2006 TPCR2	15	15	13	15	14	11	18	17	10	5	18	159	91 (S)
Post-restoration 2006 TPCR3	16	11	11	18	13	10	14	12	11	3	15	135	77 (PS)
Post-restoration 2006 TPCR4	17	16	15	15	16	17	17	19	11	5	15	163	93 (S)
Post-restoration 2006 TPCR5	17	13	13	15	11	11	13	5	8	3	17	126	72 (PS)
Post-restoration 2006 TPCR6	15	18	16	18	17	19	18	14	11	17	11	174	99 (S)
Pre-rest oration 2006 IPCR1	17	19	11	14	19	6	17	4	6	17	18	148	85 (PS)
Pre-restoration 2006 IPCR2	12	16	11	12	18	10	15	1	8	18	12	133	76 (PS)
Pre-restoration 2006 IPCR3	16	17	10	18	16	12	15	0	9	16	9	138	79 (PS)
Pre-restoration 2006 MPCR1	13	18	10	15	16	10	18	8	7	18	11	144	82 (PS)

6.0 Discussion

Although the habitat quality improved from pre-restoration conditions of 70-90% comparable to the reference and moderately degraded conditions, to 72-99% comparable to the reference ranging from moderately degraded to good conditions, the overall taxonomic richness of organisms declined from pre-restoration conditions. These results were not unexpected and likely due to several factors. First, the amount of rebound period for the post-restoration reach was only one year. This short duration has not allowed the full ecological processes to become re-established. An important goal of successful restoration should be to wait for the habitat to re-establish a new equilibrium, in other words to be patient with nature and don't try to force outcomes (of success) more quickly than nature allows. This reasoning is supported by the individual habitat scores for the 100m segments. Many of the restored sites scored lower in the habitat parameters of bank vegetative type (BVT) and Shading (S). Although the restoration project included the replanting of native riparian vegetation, one year is not a sufficient enough time for the plants to grow and establish themselves in the riparian zone. Conversely, the upstream, unrestored reaches scored higher in the shading category and also had higher taxonomic richness and abundance, including higher percentages of sensitive EPT taxa.

Second, the upstream, unrestored reaches scored the lowest out of all the sites in the habitat parameters for bank stability (BS). These reaches were suffering from severe bank erosion in several segments. The upstream reaches did have lower habitat scores, but water quality parameters were similar to the downstream reaches. It is possible that the increased sediment loads coming from the upstream reaches and subsequently deposited further downstream in the restored section are contributing to an impaired biotic community. This would be an important factor to monitor in future assessments, especially once the upstream reaches have been restored.

Third, the restored reach sites had lower scores in the bottom substrate/available cover (BSAC) parameter. This is partially due to an immature riparian zone as well as the lack of well established instream features such as large woody debris, rootwads and undercut banks and shaded pools. These components were included in the restoration, however, they have not had a chance to become sufficiently colonized by benthic organisms, therefore important ecosystem functions have not been established. Once the riparian trees and plants mature, they will deliver more organic matter, contributing to instream features as well as available food sources. A mature riparian corridor will also more effectively filter pollutants and excess nutrients entering the watershed from the surrounding landscape. The stream is likely suffering from increased nutrient inputs from fertilizers and dissolved solids. The restored reach flows alongside the Three Little Bakers Golf Course, and the unrestored, upstream reaches are bordered by the Independence School and housing developments such as Meadowdale, all of which have extensive grass lawns and impervious surface coverage.

Other indicators of negative effects from high nutrient input as well as effects from poor shading in the restored reach on the BSAC were the amount of algae that was observed in many of the reaches and the dominant taxa group. Large amounts of algae were present throughout the restored segments, especially the centrally located restored sites TPCR2 – 5. These sites had the lowest shading scores, higher temperatures and high DO levels. This is possible due to increased algal photosynthesis rates, and immature trees and shrubs. Furthermore, all of the sites had higher specific conductance rates than the regional reference, also indicative of a greater amount of ions (dissolved solids) in the water.

The dominant taxon found throughout the reaches, both pre and post restoration was the caddisfly belonging to the family Hydropsychidae. The only sites that were not dominated by this family in 2002 was site PCR4, dominated by riffle beetles in the family Elmidae and for 2006, site TPCR1 which was dominated by another caddisfly belonging to the family Philopotamidae. As discussed previously, a dominance of any group can be indicative of stressed environmental conditions. The Hydropsychidae caddisfly's habit is that of a clinger, and belongs to the FFG of filterer-collector. The large abundance of this group is responsible for the results of habit and FFG for each site. This caddisfly is commonly known as the net-spinning caddisfly, and constructs a fixed retreat that filters nutrients from the water. The Hydropsychids as a group are facultative, i.e. more pollution tolerant (although some genera are somewhat sensitive) compared to other members in the same order Trichoptera (Voshell 2002, Merritt and Cummins 1996). Many genera in this family like warm, sunny areas and are often abundant in streams suffering from moderate levels of pollution from organic wastes and nutrients, especially streams with high concentrations of algae and a lot of fine detritus suspended in the water (Voshell 2002). The dominance of Hydropsychid caddisflies throughout the reaches further supports the conclusion that both the pre and post restoration sites are suffering from moderate levels of impairment partially caused by lack of a mature riparian zone, high nutrient inputs and large amounts of algae.

7.0 Conclusion

Once the upstream reaches have been restored, and the hydrologic regime progresses toward a more natural cycle, it is probable that habitat and water quality will continue to improve in the downstream reaches and throughout Pike Creek. In conjunction with re-establishing more natural hydrology and morphology, the ecological functions provided by a mature riparian zone will further contribute to the success of the restoration and increase potential for colonization by a more diverse assemblage of benthic organisms. There is very limited information regarding the "rebound" period post-restoration that is required to detect positive effects to the biological assemblages, especially for "hard" restorations. With continued monitoring, the detection of shifts to the biological community will provide valuable information regarding temporal requirements for re-establishing ecosystem processes for Pike Creek, thereby providing restoration managers and stakeholders with the information necessary to effectively plan future restoration efforts throughout the watershed.

8.0 Literature Cited

Barbour, M.T., Gerritson, J., Snyder, B.D. and J.B. Stribling. 1999. Rapid Bioassessment Protocols or Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Booth, D. 2005. Challenges and prospects for restoring urban streams: a perspective from the Pacific Northwest of North America. J.N. Am. Benthol. Soc. 24(3):724-37.

Brooks, S.S., Palmer. M.A., Cardinale, B.J., Swan, C.M., and S. Riblett. 2002. Assessing Stream Ecosystem Rehabilitation: Limitations of Community Structure Data. Restoration Ecology 10(1): 156-68.

Cardinale, B.J., Palmer, M.A., and S.L. Collins. 2002. Species diversity enhances ecosystem functioning through interspecific facilitation. Nature 415:426-29.

Covich, A.P., Palmer, M.A., and T.A. Crowl. 1999. The Role of Benthic Macroinvertebrate Species in Freshwater Ecosystems. Zoobenthic species influence energy flows and nutrient cycling. BioScience 49(2): 119-27.

Dickey, E. 2000. Pike Creek Restoration Project Biological Monitoring Component. Ecological Assessment Branch, Environmental Laboratory Section, Division of Water Resources. Delaware Department of Natural Resources and Environmental Control

DNREC. 1999. Christina River Watershed Stream Restoration Study. Delaware Department of Natural Resources and Environmental Control. Division of Water Resources.

DNREC. 2000. Piedmont Basin Assessment Report. Delaware Department of Natural Resources and Environmental. Whole Basin Management Team.

DNREC. 2003. Pike Creek Watershed Plan. Delaware Department Of Natural Resources and Environmental Control. Division of Soil and Water Conservation.

Karr, J.R. 1991. Biological Integrity: A Long-Neglected Aspect of Water Resource Management. Ecological Applications 1(1): 66-84.

Klemm, D.J., Blocksom, K.A., Fulk, F.A., Herlhy, A.T., Hughes, R.M., Kaufmann, P.R., Peck, D.V., Stoddard, J.L., Thoeny, W.T., and M.B. Griffith. 2003. Development and Evaluation of a Macroinvertebrate Biotic Index (MBII) for Regionally Assessing Mid-Atlantic Highland Streams. Environmental Management 31(5): 656-69.

Merritt, R.W., and K.W. Cummins. 1996. An Introduction to the Aquatic Insects of North America. Third Edition. Kendal Hunt Publishing Company.

Mitchell, G.M., and E. Dickey. 2004. The Biological Assessment of Mill Creek, November 2002. Ecological Assessment Branch, Environmental Laboratory Section. Division of Water Resources, Delaware Department of Natural Resources and Environmental Control

Moore, A.A., and M.A. Palmer. 2003. Invertebrate biodiversity in agricultural and urban headwater streams: implications for conservation management. Ecological Applications.

Morley, S.A. and J.R. Karr. 2002. Assessing and Restoring the Health of Urban Streams in the Puget Sound Basin. Conservation Biology 16(6): 1498-1509.

NCDENR. 2004. Ecological Functions of Restored Stream Systems Benthic Macroinvertebrates. Division of Water Quality (DWQ) North Carolina.

Palmer M.A. and J.D. Allan. 2006. Restoring Rivers. Issues in Science and Technology. Winter 2006. 40-48.

Palmer, M.A., Swan, C.M., Nelson, K., Silver, P., and R. Alvestad. 2000. Streambed landscapes: evidence that stream invertebrates respond to the type and spatial arrangement of patches. Landscape Ecology 15:563-76.

Partnership for the Delaware Estuary. 2006. [Online] 8/2006 URL: www.delawareestuary.org

Paul M.J. and J. Meyer. 2001. Streams in the Urban Landscape. Annu. Rev. Ecol. Syst. 32:333-65.

Plafkin, J.L., Barbour, M.T., Porter, K.D., Gross, S.K., and R.M. Hughes. 1989. RapidBioassessment Protocols or Use in Streams and Rivers: Benthic Macroinvertebrates and Fish. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, D.C. EPA 440-4-89-001.

Riley, A.L. 1998. Restoring Streams in Cities: A guide for planners, policy makers, and citizens. Washington D.C., Island Press.

Roy, A.H., Rosemond, A.D., Paul, M.J., Leigh, D.S., and J.B.Wallace. 2003. Stream Macroinvertebrate response to catchment urbanization (Georgia, U.S.A.) Freshwater Biology. 48:329-46.

Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, Colorado.

Smith, J.G., Beauchamp, J.J., and A.J. Stewart. 2005. Alternative approach for establishing acceptable thresholds on macroinvertebrate community metrics. J.N. Am. Benthol. Soc. 24(2): 428-40.

Voshell, J.Reese Jr., 2002. A Guide to Freshwater Invertebrates of North America. The McDonald & Woodward Publishing Company, Blackburg, VA.

Walsh, C.J., Roy, A.H., Feminella, J.W., Cottingham, P.D., Groffman, P.M. and R.P. Morgan II. 2005. The Urban Stream Syndrome: current knowledge and the search for a cure. J.N. Am. Benthol. Soc. 24(3): 706-23.

Walsh, C.J., Sharpe, A.K., Breen, P.F., and J. Sonneman. 2001. Effects of urbanization on streams of the Melbourne region, Victoria, Australia. I. Benthic macroinvertebrate communities. Freshwater Biology. 46:535-51.

Ward, A.D., and S.W. Trimble. 2004. Environmental Hydrology. Second Edition. Lewis Publishers.

Personal Communications

Palmer, M. June 2006. Professor of Entomology and Biology. University of Maryland Center for Environmental Sciences. College Park, MD.

Wilcock, P. June 2006. Professor. Department of Geography and Environmental Engineering. Johns Hopkins University. Baltimore MD.

APPENDIX A: Site Sampling Maps

Figure 9. 2002 Pre-restoration Sampling Sites (PCR 3-7) at the Three Little Bakers Golf Course.

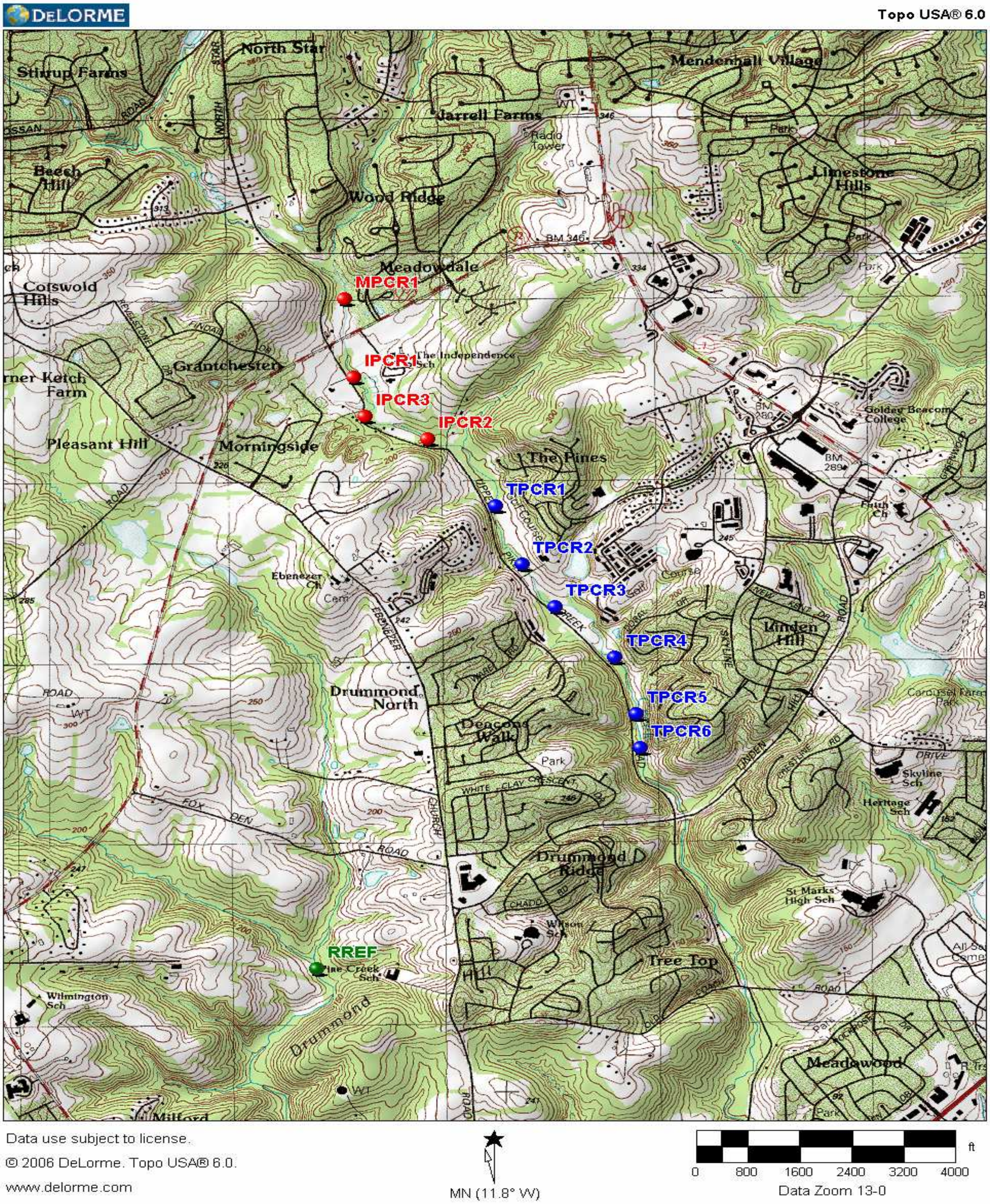


Figure 10. 2006 Pike Creek Restoration Sampling Sites. The 5000 linear feet restored segment sites (TPCR 1-6) are indicated in blue. The 3200 and 400 linear feet unrestored reach sites (IPCR 1-3 and MPCR 1) are indicated in red. The 2006 regional reference (RREF) is indicated in green.

APPENDIX I

Pike Creek Stream Restoration – 2006 Fish Monitoring Report

Pike Creek Stream Restoration – 2006 Fish Monitoring Report

Kevin Kalasz
Delaware Natural Heritage and Endangered Species Program
Division of Fish and Wildlife
5 March 2007

Introduction

Three sections of Pike Creek have been identified for restoration. These include the Three Little Bakers Country Club, Independence School, and Meadowdale. Three Little Bakers Country Club was the first site to be restored with work having taken place during 2005. The other two sites are to be restored in 2007. One of the intended benefits to stream restoration is to improve habitat conditions for aquatic species. Monitoring species' response to restoration activities is critical to measuring the success of restoration. Fish are one of the most important biotic elements to stream systems and need to be monitored to determine the impacts of restoration. To measure restoration success, surveys must be conducted prior to work to establish baseline fish community as well as after to detect fish community response to restoration work. This report summarizes fish monitoring in Pike Creek to date to help evaluate the effectiveness of restoration work.

Methods

The Independence School and Meadowdale restoration sites are adjacent to each other with Meadowdale being just upstream from Independence School. Both sites are assumed to have similar habitats and aquatic communities and should be restored in similar ways. Improvements to conditions upstream should translate to improvements in water quality downstream. Therefore, because of their spatial proximity, only one section located at the downstream end of Independence School (Ind Sch) was chosen to monitor restoration at both sites (Figure 1). This should provide a measure of the effectiveness of restoration at that site as well as benefit from improvements to water quality from work conducted upstream. The Three Little Bakers (TLB) is more than 1 km downstream from Ind Sch (Figure 1).

Sampling took place during the low-flow stream conditions present in the fall. TLB was surveyed prior to restoration on 16 September 2004. Post-restoration surveys were conducted nearly a year after restoration work ended so fish could recolonize the newly created habitat. The post-restoration survey at TLB took place on 3 October 2006. Pre-restoration surveys of Ind Sch to determine the baseline fish community was conducted on 16 Oct 2006.

Data collection was standardized to provide spatial and temporal comparability between years and sites. Stream surface area (Paller, 1995) or volume (Angermeier and Schlosser, 1989) has been suggested to standardize sites and increase the probability of sampling all representative habitats for a given size of stream. In restoration monitoring, it is important to both identify the representative fish community as well as increase the probability of detecting rare species as rare species may be more sensitive to disturbance and habitat change. A length-to-width ratio was used to standardize the sample site based on stream width. A length of 5-105 times stream width captured 95% of the species in Wisconsin streams (Angermeier and Smogor, 1995) and 60-120 times stream widths in South Carolina Coastal Plain streams was required to capture maximum species richness (Paller, 1995). The regional variation in species and streams that occurs between streams in these studies and Delaware streams limits the applicability of their results but provides some guidelines. Delaware likely has an overall lower species richness than Midwest or Southern Coastal Plain streams given different geologic histories. Therefore, for Delaware, sample sites are standardized by sampling a length of stream that is 60 times the downstream width of the survey sites.

A direct current backpack electroshocker adjusted to output levels that maximize effects while minimizing mortality given varying levels of conductivity was used to collect fish. To maximize the probability of detecting rare species at a survey site, a 2-pass deletion method was used. Block nets were placed at both the upstream and downstream ends of the survey site to inhibit immigration or emigration. Fish from the first pass were held in a large holding tank and processed prior to the next pass. Processing fish collected during the first pass prior to the second pass enabled the water clarity to return to base levels which maximized sampling efficiency during the second pass. Fish processed prior to the second pass were released outside of the survey site to recolonize the survey site when the block nets were removed.

Each species recorded was categorized based on its feeding guild (trophic designation) and its tolerance to human-induced stream conditions (Barbour et al. 1999). Relative abundance based on catch per unit effort (CPUE: number of individuals caught per minute) was calculated by species and site.

Results and Discussion

Three Little Bakers Country Club

Several metrics are commonly used to evaluate stream condition and biotic integrity. Examples include species richness, number of intolerant species, feeding guild, relative abundance, and dominance. One might expect a short-term decrease in species richness and/or abundance after the disturbance activities associated with instream restoration work. Results from pre- and post-monitoring at TLB indicates there was little change in the community composition (both species and their associated overall trophic and tolerance designations) and no change in species richness, number of native species, and number of intolerant species (Table 1). While *Lampetra appendix* and *Oncorhynchus mykiss* were lost after restoration, *Lepomis macrochirus* and *Notropis procne* were gained. The biggest difference between pre- and post-restoration activities was a substantial increase in relative abundance (Figure 2). For all but one species detected in both pre- and post-monitoring, CPUE increased (Table 1). The largest increase in relative abundance was observed for *Rhinichthys atratulus* which is a tolerant species (Figure 2). It is expected that tolerant species would be the first to show a positive response after large-scale habitat disturbance and change.

The large increase in the overall number of individuals likely had some impact on detectability and the probability of capture of less common species. *Anguilla rostrata* was the only species that decreased in relative abundance. This species is typically difficult to capture. This factor along with the fact that the survey crew was more focused on other species, *Anguilla rostrata* may be more abundant than observed. This may have also factored into not detecting *Lampetra appendix* due to similarity in habitat and body shape. Therefore, the loss of *Lampetra appendix* after restoration does not necessarily mean it was extirpated from the site or that its preferred habitat was lost. It is a Species of Greatest Conservation Need and was not abundant in this section of stream prior to restoration. It does still occur in Pike Creek downstream from TLB so it should return over time. However, future surveys should be conducted to determine what impacts stream restoration activities might have on this species.

The large increase in overall total relative abundance combined with no short-term loss in species richness is a promising indication that the instream restoration work was successful at improving habitat conditions for fish. Restoration work also made improvements to the riparian area of Pike Creek including planting shrubs and trees along the streamside. An increase in woody vegetation should further improve instream habitat conditions though nutrient uptake, shading, and an increase in coarse organic matter deposition. However, the results of the streamside work will not be fully realized for some years when the trees and shrubs mature. Long-term improvements to the instream habitat from streamside restoration should be realized by detecting increases in species richness, the number of intolerant species, the number of Species of Greatest Conservation Need and more species from different trophic designations. Monitoring at this site should be continued so long-term comparisons can be made to pre-restoration surveys.

Independence School/Meadowdale

Pre-monitoring at the Ind Sch site indicates that the community is quite similar to TLB but with slightly lower species richness, native species, and intolerant species (Table 1). The relative abundance is similar to pre-restoration survey at TLB (Table 1). These results are expected as it is a slightly narrower stream located just upstream from TLB.

Literature Cited

Angermeier, P.L. and I.J. Schlosser. 1989. Species-area relationships for stream fishes. Ecology 70:1450-1462.

Angermeier, P.L. and R.A. Smogor. 1995. Estimating number of species and relative abundances in stream-fish communities: effects of sampling effort and discontinuous spatial distributions. Can. J. Fish. Aquat. Sci. 52:936-949.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates, and fish, second edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Paller, M.H. 1995. Relationships among number of fish species sampled, reach length surveyed, and sampling effort in South Carolina Coastal Plain streams. N. Am. J. Fish. Manage. 15:110-120.

Figure 1. Three Little Bakers (TLB) and Independence School/Meadowdale (Ind Sch) fish monitoring sites.

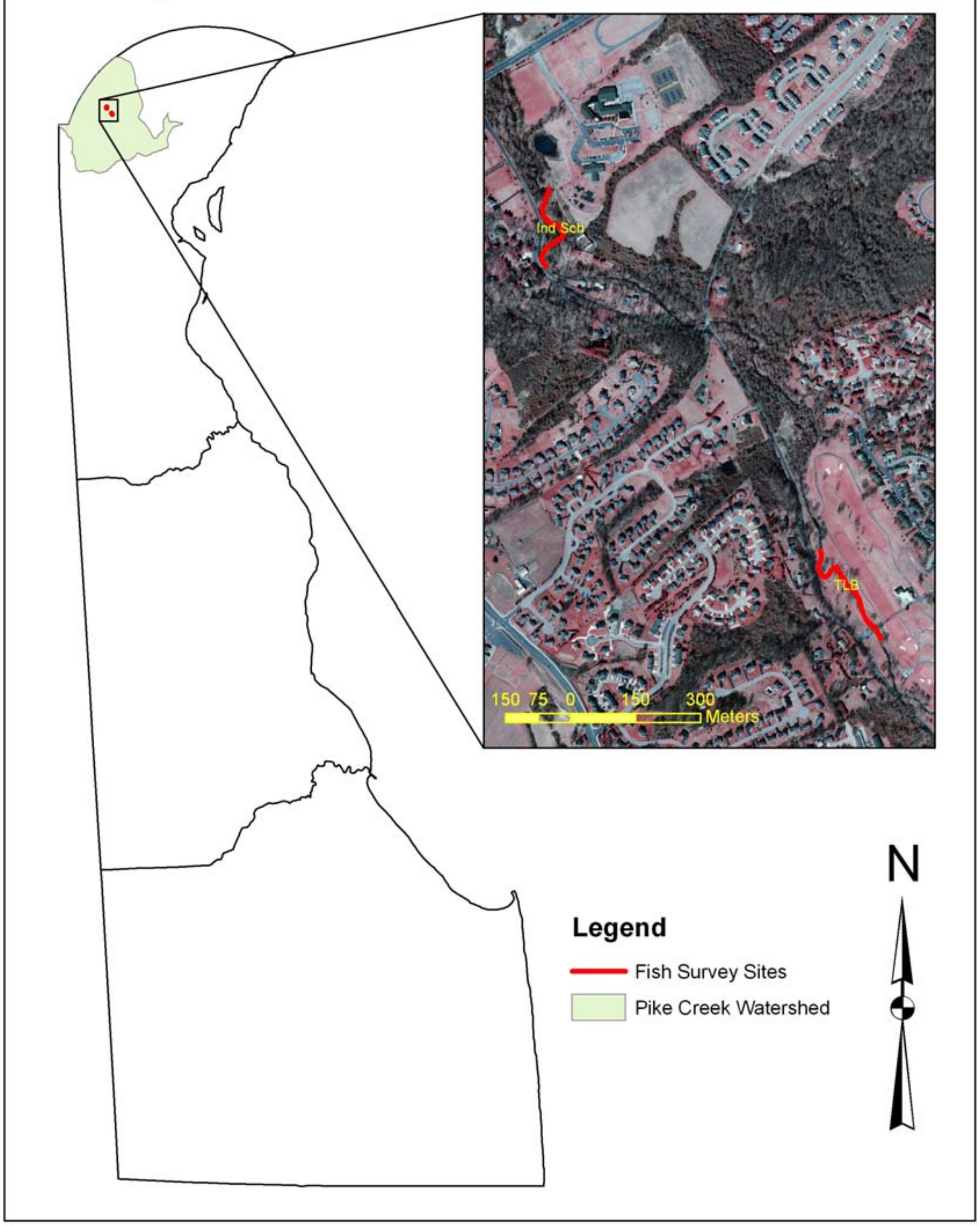
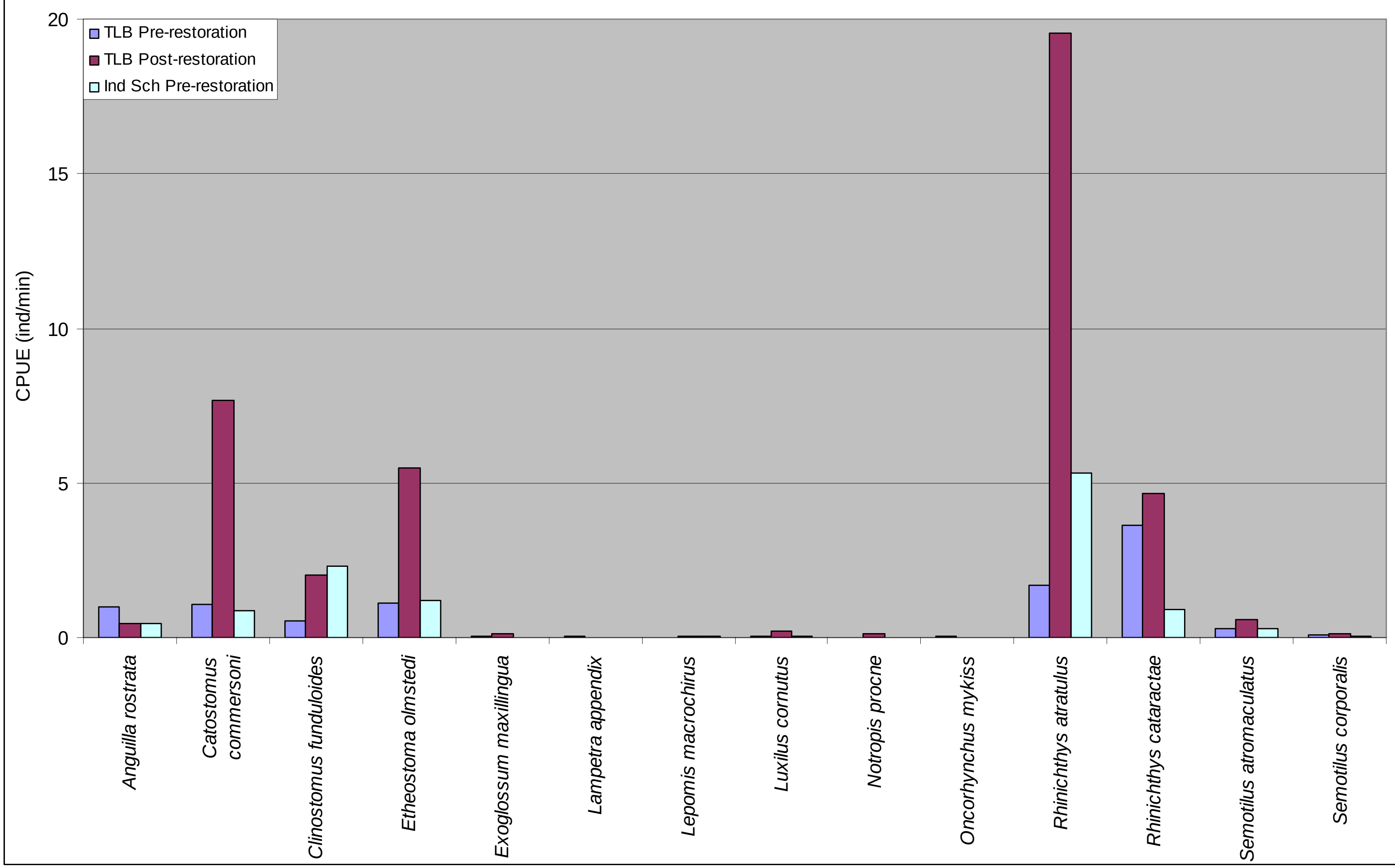


Table 1. Species observed at pre- and post-restoration surveys at TLB and pre-restoration survey at Ind Sch. Each species relative abundance value (CPUE), trophic and tolerance designations, and heritage rank is provided.

Species	**TLB Pre-restoration CPUE (ind/min)**	**TLB Post-restoration CPUE (ind/min)**	**Ind Sch Pre-Restoration CPUE (ind/min)**	**Trophic Designation**	**Tolerance Designation**	**Heritage Rank**
Anguilla rostrata	0.97	0.46	0.45	Piscivore	Intermediate	S5
Catostomus commersoni	1.08	7.65	0.89	Omnivore	Tolerant	S5
Clinostomus funduloides	0.54	2.02	2.29	Invertivore	Intolerant	S4
Etheostoma olmstedi	1.12	5.49	1.19	Invertivore	Intermediate	S5
Exoglossum maxillingua	0.04	0.12		Invertivore	Intolerant	S4
Lampetra appendix	0.04			Filter	Intolerant	S2
Lepomis macrochirus		0.04	0.02	Invertivore	Intermediate	Exotic
Luxilus cornutus	0.02	0.21	0.02	Invertivore	Intermediate	S4
Notropis procne		0.10		Invertivore	Intolerant	S4
Oncorhynchus mykiss	0.02			Piscivore	Intermediate	Exotic
Rhinichthys atratulus	1.70	19.54	5.33	Generalist	Tolerant	S4
Rhinichthys cataractae	3.64	4.68	0.91	Invertivore	Intolerant	S4
Semotilus atromaculatus	0.28	0.58	0.28	Generalist	Tolerant	S4
Semotilus corporalis	0.06	0.10	0.02	Generalist	Intermediate	S4
Total CPUE	9.53	41.00	11.40			
Total Species	12	12	10			
Total Native	11	11	9			
Total Intolerant	4	4	2			
Total Species Greatest Conservation Need	1	0	0			

Figure 2. Fish relative abundance (CPUE) at Pike Creek restoration sites.



APPENDIX J

Summary of a Pre-restoration Fish Survey of Pike Creek in 2004

Summary of a Pre-restoration Fish Survey of Pike Creek in 2004

Kevin Kalasz
Delaware Natural Heritage and Endangered Species Program
Division of Fish and Wildlife

8 November 2005

The Delaware Natural Heritage Program completed a survey of Pike Creek on 16 September 2004. The survey location was along Upper Pike Creek Rd. approximately 1.6 km north of the intersection of Upper Pike Creek Rd and Linden Hill Rd. The intent was to obtain baseline information on the fish community at a proposed restoration site at the Three Little Bakers Country Club. Baseline information would be compared to future surveys conducted after the completion of restoration activities.

The habitat at this location of Pike Creek consisted of extensive sand, gravel, and cobble substrate with bedrock present. There was a mix of deep pools, shallow pools, runs, and riffles. The banks were undercut and there was little to no overhead cover.

A two-pass deletion method was used to survey 240 m of stream. A total of 12 species were encountered with *Rhinichthys cataractae* being the most abundant species (Table 1). A single *Lampetra appendix* was caught at the restoration site. It is rare within Delaware and considered a species of conservation concern by the Delaware Natural Heritage Program. Figure 1 compares the relative abundance based on catch per unit effort between the restoration site and a survey of Pike Creek conducted downstream in 2003. The latter was in a less disturbed area with a significant amount of forested riparian buffer. Five fewer species were detected at the restoration site as compared to the less disturbed site. Variations in habitat quality, particularly with regard to streamside habitat, as well as water quality are likely the main factors in the differences in species richness and relative abundances. In-stream restoration as well as vegetation restoration in the riparian zone would likely improve conditions for the fish community at this site.

Table 1. Species detected at Pike Creek restoration site in order of decreasing relative abundance. Relative abundance is calculated on catch per unit effort (CPUE) with individuals caught per minute of fishing.

Species	CPUE (ind/min)
Rhinichthys cataractae	3.67
Rhinichthys atratulus	1.72
Etheostoma olmstedi	1.13
Catostomus commersoni	1.09
Anguilla rostrata	0.98
Clinostomus funduloides	0.54
Semotilus atromaculatus	0.28
Semotilus corporalis	0.07
Lampetra appendix	0.04
Exoglossum maxillingua	0.04
Luxilus cornutus	0.02
Oncorhynchus mykiss	0.02

Figure 1. Fish relative abundance at the restoration site in 2004 (Pike2004) and at a survey location downstream conducted in 2003 (Pike2003).