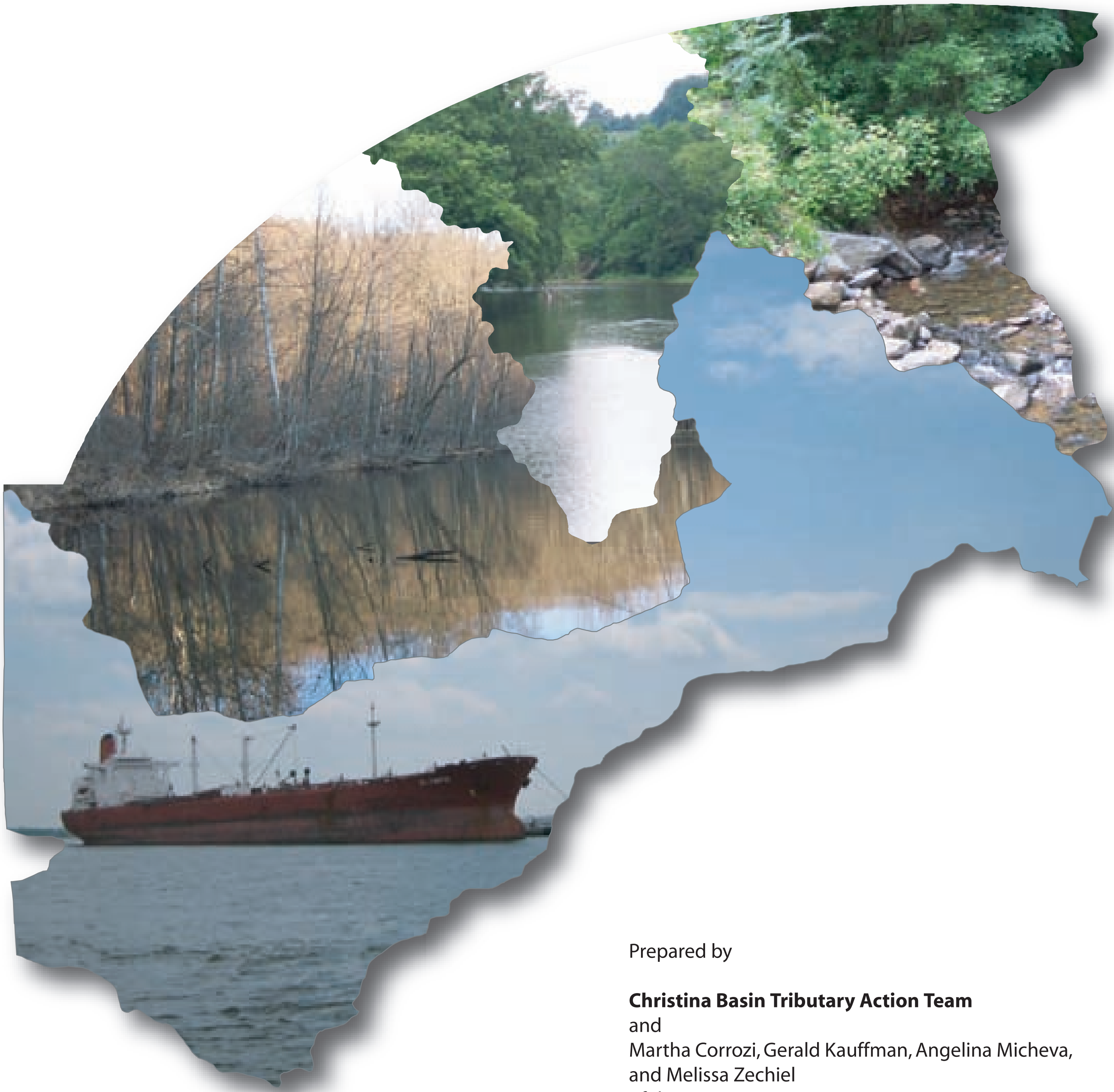
Christina Basin Pollution Control Strategy (PCS)

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



Prepared for

Watershed Assessment Branch
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FINAL REPORT
Christina Basin Pollution Control Strategy
November 2007

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November 5, 2007

Dear Secretary Hughes:

The Christina Basin is a unique watershed with headwaters in Pennsylvania and Maryland. It is the only source of public surface water supply in Delaware and the habitat of the only six trout streams in Delaware. In April 2005 the United States Environmental Protection Agency (USEPA) established the Christina Basin Total Maximum Daily Loads (TMDLs) for nutrients and bacteria to improve the water quality of the rivers and tributaries that comprise the Delaware portion of the Christina Basin. The intent of the Christina Basin Pollution Control Strategy (PCS) is to recommend practices to achieve the load reductions set forth in the USEPA's TMDLs for the Delaware portion of the basin. On behalf of the Christina Basin Tributary Action Team, I propose for your consideration 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*. This document was prepared by the University of Delaware's Institute for Public Administration-Water Resources Agency (IPA-WRA) in coordination with and on behalf of the Christina Basin Tributary Action Team.

DNREC appointed the University of Delaware's IPA-WRA to form and facilitate the Christina Basin Tributary Action Team to develop the Christina Basin PCS. The team is comprised of nonprofit; local, county, and state government; private industry; water utility; citizen; and academic representatives. The team met 13 times over a year and a half in diverse locations throughout the Christina Basin watershed to develop this strategy. Numerous individuals and organizations assisted in the development of this document. Key contributors include: Artesian Water Company, Brandywine Valley Association, Christina Conservancy, Citrosuco, City of Newark, City of Wilmington, Delaware Center for Horticulture, DNREC, Delaware Nature Society, Greeley and Hansen, New Castle County, Partnership for the Delaware Estuary, Taproot Native Design on behalf of New Castle Conservation District, Red Clay Valley Association, United Water Delaware, URS Corp., VanDemark & Lynch, Inc., USDA, White Clay Creek Watershed Management Committee, and multiple volunteer citizens and organizations.

The PCS includes narrative on the unique characteristics of the basin, the resources that make the basin valuable, the TMDLs set for the basin, and the Christina Basin Tributary Action Team process. The most significant component of this document are the 40 recommendations grouped by the following categories: stormwater, open space, wastewater, agriculture, and education. These recommendations were developed through a collaborative effort by the Christina Basin Tributary Action Team. The PCS also includes a chapter on the monitoring stations located throughout the Delaware portion of the basin and the water quality parameters tested at these stations. This chapter discusses the importance of water quality monitoring upon implementation of the PCS. The final chapter in the PCS quantifies the economic benefits of the Christina Basin and provides an estimate of the cost of implementing the recommendations set forth in the PCS. This chapter provides quantifiable evidence that improving the water quality in the Christina Basin makes economic sense.

The Christina Basin Tributary Action Team would like to thank DNREC for the opportunity to develop this consensus-driven document. This document is evidence of a successful watershed management endeavor with cooperation and contributions from many people and organizations. We hope that through our leadership in this process we have developed an executable plan to achieve the nutrient and bacteria reductions necessary to return the Christina Basin to fishable and swimming criteria. We thank all of the organizations and individuals who committed multiple hours of work and volunteer time to this process. Based on the recommendations from these groups, the Christina Basin Tributary Action Team proposes that DNREC promulgate the PCS for the Delaware portion of the Christina Basin including the Brandywine, Red Clay, and White Clay Creeks, and Christina River watersheds in Delaware.

Sincerely,

Martha Corrozi
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List of Terms

ACT – Alliance for Community Trees
BCI – Biotic Condition Index
BMP – Best Management Practice
BOD – Biochemical Oxygen Demand
BVA – Brandywine Valley Association
CAFOs – Confined Animal Feed Operations
CCCD – Chester County Conservation District
CFR – Code of Federal Regulations
CIB – Center for the Inland Bays
CRP – Conservation Reserve Program
CSOs – Combined Sewer Outflows
CSS – Combined Sewer Systems
CUFR – Center for Urban Forest Research
DCH – Delaware Center for Horticulture
DDT – Dichloro-Diphenyl-Trichloroethane
DelDOT – Delaware Department of Transportation
DEN – Delaware Environmental Navigator
DNMC – Delaware Department of Agriculture's Nutrient Management Commission
DNREC – Delaware Department of Natural Resources and Environmental Control
DNS – Delaware Nature Society
DO – Dissolved Oxygen
EQIP – Environmental Quality Incentives Program
ERES – Exceptional Recreational and Ecological Significance
ERU – Equivalent Residential Unit
ESU – Equivalent Stormwater Unit
FEMA – Federal Emergency Management Agency
FHD – Flood Hazard District
FLEP – Forest Land Enhancement Program
FS – Factor of Safety
FY – Fiscal Year
GAMN – General Assessment Monitoring Network
GIS – Geographic Information Systems
HOAs – Homeowner Associations
IPA-WRA – Institute for Public Administration-Water Resources Agency
LA – Load Allocation
LID – Low Impact Development
LIP – Landowner Incentive Program
LOQ – Limit of Quantification
LTCP – Long-Term Control Plan
LU – Land Use
MDL – Method Detection Limit
mg – Million gallons
mg/L – Milligrams per Liter
mgd – Million Gallons per Day
MS4 – Municipal Separate Storm Sewer System
N – Nitrogen
NCC – New Castle County

NCCD – New Castle Conservation District
NJDEP – New Jersey Department of Environmental Protection
NMP – Nutrient Management Plan
NPDES – National Pollutant Discharge Elimination System
NPS – Non-Point Source
NRCS – Natural Resources Conservation Service
OS – Open Space
OWTS – Onsite Wastewater Treatment Systems
PADEP – Pennsylvania Department of Environmental Protection
PAH – Polycyclic Aromatic Hydrocarbons
PCBs – Polychlorinated Biphenyls
PCS – Pollution Control Strategy
PS – Point Source
RC – Red Clay
RCRA – Resource Conservation and Recovery Act
RCVA – Red Clay Valley Association
RPATAC – Resource Protection Area Technical Advisory Committee
SARA – Superfund Amendments and Reauthorization Act
SF – Superfund
SIRB – Site Investigation and Restoration Branch
SLAMM – Source Loading and Management Model
SSA – Sewer Service Area
SW – Stormwater
SWM – Storm Water Management
SWRC – Stroud Water Research Center
TAT – Tributary Action Team
TMDL – Total Maximum Daily Loads
TN – Total Nitrogen
TP – Total Phosphorus
TRI – Toxic Release Inventory
TSS – Total Suspended Sediment
UD – University of Delaware
UDC – Unified Development Code
UFORE – Urban Forest Effects
USDA – United States Department of Agriculture
USEPA – United States Environmental Protection Agency
USGS – United States Geological Survey
UST – Underground Storage Tank
UWD – United Water Delaware
WC – White Clay
WHIP – Wildlife Habitat Incentives Program
WLA – Waste Load Allocation
WMP – Watershed Management Plan
WQ – Water Quality
WRAS – Watershed Restoration Action Strategy
WRP – Wetlands Reserve Program
WRPA – Water Resource Protection Area
WW – Wastewater
WWTP –Wastewater Treatment Plant

Executive Summary

The Christina Basin is a 565 sq. mi. watershed contained in the larger watershed, the Delaware River Basin. The Christina Basin spans three states, Delaware, Pennsylvania, and Maryland, and includes four subwatersheds: Brandywine, Red Clay, and White Clay Creeks, and the Christina River. On April 8, 2005, the U.S. Environmental Protection Agency (USEPA) assigned Total Maximum Daily Loads (TMDLs) to the Christina Basin. The TMDLs will require specific reductions in nonpoint sources of pollution, such as nitrogen, phosphorus, and bacteria, to restore the rivers and streams of the Christina Basin to a healthy condition for our use and recreation.

The Delaware Department of Natural Resources and Environmental Control (DNREC) and the Water Resources Agency, a unit of the University of Delaware's Institute for Public Administration (IPA-WRA), have been working together to form and facilitate a Tributary Action Team for the Delaware portion of the Christina Basin. This team has developed and is recommending a Pollution Control Strategy (PCS) to DNREC. The process of drafting the PCS strives to involve multiple stakeholders representing the community to develop feasible recommendations to reduce the nonpoint source nitrogen, phosphorus, and bacteria loads in the waters of the Delaware portion of the Christina Basin to achieve the USEPA's targeted TMDL levels. The Tributary Action Team began this process in February 2006 and has held 13 meetings and a public forum over the past 17 months.

The process of developing and recommending a PCS for the Delaware portion of the basin began with IPA-WRA identifying potential team members. IPA-WRA aimed to gather a diverse group of stakeholders in the Christina Basin so that all stakeholders in the basin were represented. Team members include representatives from nonprofit organizations, industry, water utilities, state and local government entities, private consultants, and residents of the basin.

The next course of action was to provide the steering committee with background on the Christina Basin: the value of the basin, ecologically, recreationally, and historically; the TMDLs and the assigned nitrogen, phosphorus, and bacteria limits; and the sources of pollution in the basin. After building a base of knowledge about the process and the needs for the Christina Basin, the team developed an agenda and strategy to hold a public forum. The public forum is a critical component of any PCS process. Through this public forum the team gained additional members and created an email list to keep all interested community members and organizations up-to-date on the process and activities in the basin. The forum also served to gather input on what was most important to the stakeholders in the Christina Basin to guide the development of the PCS. This input was used as the guiding principles in developing and shaping the PCS for the Delaware portion of the Christina Basin. It is the team's intent that the recommendations set forth in the Christina Basin PCS meet the guiding principles set forth at the public meeting in June 2006.

In December 2006, after ten Tributary Action Team meetings and the public forum, the group finalized 40 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 40 recommendations include:

Stormwater

- Require urban tree canopy.
- Require stormwater BMPs be designed to reduce nutrients according to the TMDLs.
- Limit addition of new impervious cover to less than 20 percent of the watershed above public water supply intakes.
- Promote LID in new construction and redevelopment.
- Amend stormwater ordinances to create consistency throughout the watershed.
- Expand the role of RPTAC to create a Christina Basin group responsible for reviewing new development applications.
- Implement a stormwater utility.
  - Maintain BMPs.
  - Reduce and manage existing impervious cover.
- Identify areas where stormwater retrofits would effectively reduce sediment and nutrients.

Open Space

- Map, inventory, and prioritize existing wooded open space areas.
- Protect existing wooded/vegetated open space areas.
- Require management plans for community and HOA open space areas.
- 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.
- Implement stream restoration projects.
- Acquire/conserve additional open space and retain conservation easements.
- Reforest watersheds and headwaters.

Wastewater

- Require OWTS performance standards, and conduct inspections and pump-outs.
- Eliminate cesspools and seepage pits.
- Remove OWTS through connection to centralized WWTP.
- Prohibit new OWTS drainfields within 100 feet of wetlands, tidal waters, perennial streams, perennial ditches, and ponds in-line with perennial watercourses.
- Abate combined sewer overflows.
- Continue sewer repair projects and conduct regular inspections.
- Remediate contaminated substance sites.

Agriculture

- Implement agriculture BMPs including, but not limited to:
  - Nutrient management plans.
  - Cover crops.
  - Pasture stream fencing.

– Grassed filter strips.
– Grassed waterways.
– Forested riparian buffers.
– Pasture and hay planting.

Education

- Educate Christina Basin stakeholders on nonpoint source pollution and their role in reducing it, specifically targeting behavior change.
- Encourage nutrient management plans for turf fields at education facilities.
- Encourage golf course managers to decrease nutrient application, stormwater runoff, and erosion.
- Educate pet owners on cleaning up pet waste.
- Educate homeowners on residential stormwater BMPs and BMP maintenance.
- Integrate education into state and local permitting processes.
- Encourage corporate environmental stewardship programs.
- Coordinate nonprofit organizations throughout the basin.
- Support and encourage water conservation and water quality measures to reduce nutrients leaving a site.
- Work with organizations to provide education programs on lawn and garden BMPs.
- Advise DNREC to research nutrient reductions related to bacteria counts and BMPs.

The PCS emphasizes the importance of water quality monitoring pre- and post-BMP implementation. The Christina Basin is a highly monitored watershed with water quality records dating as far back as 30 years. Currently the waters of the Christina Basin contain 24 DNREC General Assessment Monitoring Network (GAMN) stations where sampling is conducted for numerous water quality parameters including nitrogen, phosphorus, and bacteria, once per month. Eight of these 24 monitoring stations are also USGS gage stations where real-time flow monitoring occurs. In addition to the importance of DNREC and USGS monitoring stations, the citizen monitoring program, a volunteer program whereby citizens monitor specific stream segments, is encouraged throughout the Christina Basin and is an important supplement to the DNREC and USGS monitoring that occurs in the Christina Basin upon the implementation of the Christina Basin PCS.

Currently the streams in the Christina Basin are potable and fishable, which means they have significant economic value to the residents of the state and the basin. The streams do not meet the USEPA's swimming criteria. The objective of the Christina Basin PCS is to improve the water quality to meet the federal Clean Water Act goals of fishable and swimming by implementing the 40 recommendations outlined in the strategy. Implementing the recommendations laid out in the Christina Basin PCS is a costly endeavor and is estimated at $31.28 million dollars per year but the Christina Basin provides numerous benefits through its water supply, ecology, and recreation. The PCS quantifies the economic value of the Christina Basin through a present value analysis. This analysis calculates that per year the total present value of the Christina Basin is $51.4 million per year.

The final stage prior to implementation of the PCS is for the Christina Basin Tributary Action Team to propose the Christina Basin PCS to DNREC. This document will then be reviewed by DNREC and once accepted by DNREC the regulatory recommendations will be promulgated into law. Throughout the process the Tributary Action Team has been updating Pennsylvania on its activities and recommendations. Once the document has been accepted by DNREC, the PCS for the Delaware portion of the basin will be implemented through the work of numerous organizations and individuals in the Delaware portion of the basin and will be joined with the ongoing pollution reduction efforts in the Pennsylvania portion of the Christina Basin.

Chapter 1: Pollution Control Strategy

1.1 What Is a Pollution Control Strategy?

A pollution control strategy (PCS) is a set of discrete and specific measures identified and implemented to achieve reductions in pollution levels. The purpose of the measures is to meet set standards and goals in a specific watershed. The measures may vary by source type as well as by the pollutant that is being targeted. These measures may include practices such as pasture fencing in the agriculture sector, retrofitting stormwater Best Management Practices (BMPs) in the urban sector, and providing public education forums on watershed topics to name just a few examples.

Developing the PCS is a multifaceted and comprehensive process that according to the USEPA is made up of four main steps: determine priority pollutants, identify control measures, incorporate the control measures into a plan, and involve the public in development and implementation of the plan. The Christina PCS was realized by working through these four steps. As a result, it is a document developed through a public process and is the best combination of management practices and control technologies intended to meet the Christina Basin TMDLs.

The following sections in Chapter 1 discuss the role and process of developing a Tributary Action Team and the elements that have gone into developing the Christina Basin PCS. The following chapters discuss the key components discussed by the Tributary Action Team throughout the development of the PCS. The information in these chapters, specifically Chapters 2 and 3, is critical in understanding the Christina Basin and the nutrient and bacteria reduction goals that need to be met. The information presented in these chapters is also a critical component in developing the recommendations set forth in Chapter 4 of this document. The Christina Basin PCS is unique in that it also dedicates a portion of the PCS to monitoring and a cost/benefit analysis. Chapter 5 summarizes the current and ongoing water quality monitoring in the Delaware portion of the basin and the importance of monitoring in the implementation of the PCS. Chapter 6 of the Christina Basin PCS provides a detailed look at the economic benefits that the Christina Basin provides and the costs of the implementation of the recommendations outlined in Chapter 4.

1.2 Tributary Action Teams

The Delaware PCS process places great importance on public participation. In the state of Delaware the concept of Tributary Action Teams (TAT) was first developed by the Center for the Inland Bays (CIB). The team process enables citizens to get involved in sorting out the difficult issues, wrestling with the trade-offs, and developing ways to reduce pollution and improve the health of the environment. In this way, the strategies have greater support in the communities they impact (*www.dnrec.state.de.us/water2000/Sections/Watershed/WS/pcs.htm*).

A TAT holds the responsibility of preparing the PCS. A TAT is comprised of a group of local stakeholders with varying interests in the watershed. The team is convened by a “neutral” organization such as Cooperative Extension, a school district, or a local watershed group. The team, led by a facilitator, defines the issues specific to the watershed in multiple ways so that all people within the community understand the water quality problems and the connection to what occurs on land and the resulting water quality problems. After defining the problems, the team frames the potential solutions in various ways to make the solutions understandable and the goals achievable for multiple stakeholders. Once the process is completed and the document is finalized, the team submits the strategy to DNREC for review and, ultimately, promulgation. The team decides which approaches will be most effective in its watershed, based on extensive study, comments at citizen forums, advice from experts, and discussions at public team meetings. In this way, the community defines a strategy that it is willing to implement.

1.3 The Christina Basin Tributary Action Team Process

The Christina Basin TMDLs were established by the USEPA in April 2005. After finalizing the high flow TMDLs, the Christina Basin Clean Water Partnership Policy Committee recommended a schedule for the TAT approach to achieve the high flow TMDLs in the Delaware portion of the Christina Basin. In January 2006 the USEPA modified the Christina Basin high and low flow TMDLs. DNREC requested IPA-WRA serve as a neutral convening organization for the team and provide the following functions: correspond with the team about monthly meetings, bring the team's recommendations to DNREC, and manage the funds made available to the team for purposes of completing the PCS. In December 2005 and January 2006 IPA-WRA began the process of forming a TAT for the Christina Basin PCS.

IPA-WRA identified interested stakeholders and citizens, who represent various interest groups, for appointment/membership on the Christina Basin TAT. The individuals contacted included water utilities, nonprofit organizations in the basin (for example, Brandywine Conservancy, Delaware Nature Society, Red Clay Valley Association, Christina Conservancy, and White Clay Creek Wild and Scenic Committee), state, county, and local government organizations, homebuilders, industry, and citizens living and working in the Delaware portion of the Christina Basin. Even though members were identified and invited to join the team at the initial stage, new members joined the team throughout the entire process. The Christina Basin TAT process has benefited from a committed group of stakeholders over the 18-month process. These individuals attended the Christina Basin TAT monthly meetings on a consistent basis and contributed significantly to the development of the Christina Basin PCS. Table 1.1 lists the Christina Basin TAT Members.

The TAT process began with contacting potential Team members and continued with an initial meeting to discuss the TMDLs set for the Delaware portion of the Christina Basin, the roles and responsibilities of the TAT, and the goals of the PCS. The team continued to meet on a monthly basis to discuss the issues and concerns unique to the Christina Basin and to develop an issues framework. In June 2006 the Christina Basin TAT hosted a public forum to identify the guiding principles for the PCS. The public forum is discussed in more detail in Section 3.4. Once the guiding principles for the PCS were determined, the TAT identified the sector-specific recommendations through a series of meetings and forums. The meetings were held throughout the Christina Basin with the intent of exposing the group to the diversity of land use and water quality concerns contained within the Christina Basin. Table 1.2 outlines the Christina Basin TAT meeting schedule, meeting locations, and meeting tasks.

Table 1.1 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 (Pa.)
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
Elaine Grehl	University of Delaware, Institute for Public Administration-Water Resources Agency
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
Angelina Micheva	University of Delaware, Institute for Public Administration-Water Resources Agency
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
Melissa Zechiel	University of Delaware, Institute for Public Administration-Water Resources Agency

Table 1.2 Christina Basin Tributary Action Team Time Table and Meeting Schedule

Meeting	Date	Location	Task
	April 8, 2005		USEPA issues Christina Basin high flow TMDLs
	December 9, 2005		Christina Basin Clean Water Partnership Policy Committee recommends schedule for Delaware Tributary Action Team approach to develop implementation strategy by December 2006
	January 2006		USEPA modifies Christina Basin high and low flow TMDLs
	December 2005/January 2006		Christina Basin Tributary Action Team Assembled
1	February 15, 2006	University of Delaware Newark, Del.	Kickoff Meeting
Conference	March 11, 2006	Delaware National Estuarine Research Reserve Dover, Del.	DNREC Tributary Action Team Conference
2	March 15, 2006	University of Delaware, Wilmington Campus Wilmington, Del.	Poster Presentation and Generation of Concerns
3	April 12, 2006	Delaware Nature Society Hockessin, Del.	Issues Framework/Public Engagement
4	May 17, 2006	Kalmar Nyckel Tall Ship Wilmington Riverfront (Christina River) Wilmington, Del.	Committee Forum
5	June 20, 2006	Delaware Center for Horticulture Wilmington, Del.	Public Forum
6	July 12, 2006	Winterthur Winterthur, Del.	Forum and Poster Session Debriefing
7	August 16, 2006	University of Delaware Newark, Del.	Review Sector Specific BMP Matrices
Bus Tour	September 8, 2007	Christina Basin Del. and Pa.	Christina Basin Watershed Annual Bus Tour
8	September 13, 2006	Longwood Gardens Kennett Square, Pa.	Recommendations Drafted
9	October 18, 2006	Deerfield Country Club Newark, Del.	Recommendations Drafted
10	November 14, 2006	Porky Oliver Golf Course Wilmington, Del.	Recommendations Drafted
11	December 14, 2006	Marriott Hotel, University of Delaware Newark, Del.	Christina Basin Clean Water Partnership Policy Committee Meeting Final Recommendations/Future Role
Briefing	March 6, 2007	Newark Municipal Building Newark, Del.	Briefing for City of Newark Representatives
12	March 28, 2007	Delaware Nature Society Hockessin, Del.	PCS Review
Briefing	April 5, 2007	City/County Building Wilmington, Del.	Briefing for City of Wilmington Representatives
Conference	May 12, 2007	Rusty Rudder Rehoboth, Del.	PCS Review
13	June 6, 2007	Blue Ball Dairy Barn Wilmington, Del.	PCS Review
Briefing	July 31, 2007	New Castle County Department of Special Services	Briefing for New Castle County Representatives
14	November 5, 2007	Chase Center on the Riverfront Wilmington, Del.	Final Meeting PCS Proposal to DNREC

1.4 Christina Basin Tributary Action Team Public Forum

The TAT approach practiced in Delaware emphasizes the importance of holding public forums. Through public forums and educational resources the TAT helps the local communities become familiar with the major issues and the potential solutions for achieving the TMDLs. The forum serves as a venue for the public to provide input on the priorities in the watershed and a strategy that will be implemented. During the public forums the community comes together to discuss the various approaches to the issues and the potential solutions and ultimately identifies "common ground" on which the team can base its strategy. The public forum plays a central role in getting community feedback from members of the community who cannot participate regularly on the team but would like to stay up-to-date on the process and provide input.

The Christina Basin TAT determined that hosting a public forum in a central location in the basin, in the beginning of the process, would be beneficial. A public forum was held at the Delaware Center for Horticulture in Wilmington, Delaware, on Tuesday, June 20, 2006. The forum attracted over 50 participants. The forum participants included stakeholders from a variety of organizations as well as residents with a personal interest in the health of the rivers and tributaries in the basin.

The Christina Basin TAT developed three approaches to bring to the public forum to serve as points of discussion and to obtain feedback on the community's concerns related to developing a strategy to achieve the Christina Basin TMDLs. The following approaches were developed for the public forum and used as a basis for the discussion:

- *Approach 1*–We Can All Pitch in to Help the Christina Basin: Everyone has a role in cleaning up the basin and voluntary actions will reduce the pollution.
- *Approach 2*–Science and Regulation are the Solution to Pollution: Science and regulation are the best and only way to reduce the pollution.
- *Approach 3*–Equity for All: Everyone should contribute to the clean up according to their pollutant load contribution, pay-as-you-go.

These approaches were outlined in detail in an issues document that was distributed at the forum. The issues document was used to educate the group, facilitate discussion, and help identify what is most important to the participants and other stakeholders not represented at the forum. The participants were asked which approach most closely represented their interests or was the most feasible approach to achieve the TMDLs promulgated by the USEPA for the Delaware portion of the Christina Basin.

This forum served as a useful educational tool for the stakeholders and the team. Several members of the public mentioned that this was the first time they were hearing about many of the pollution problems in the basin. Some were taught about sources of pollution they did not know were an issue, for example septic systems and CSOs. People living in the basin learned about some of the negative behaviors impacting the waters of the Christina Basin as well as some of the concerns of other citizens, community activists, government entities, and nonprofit organizations in the basin. People were connected with others in the community who have an interest in protecting the Christina Basin.

After extensive discussion for all three approaches the outcome of the forum is that there are pros and cons to each approach and all three approaches must be considered when developing the recommendations for achieving the high flow TMDLs in the Delaware portion of the basin.

Major themes that resulted from the forum for the team to consider when developing the Christina Basin PCS included:

- Equity for all stakeholders in the basin is a critical.
- Money is a major roadblock. All of these solutions take money. No matter how educated stakeholders become, money is an essential consideration.
- There is no quick fix, improving the water quality is a long and difficult process.
- Other cities have fixed these problems, Delaware can too.
- Move beyond "preaching to the choir."
- Education is key to any approach.
- A Christina Basin community is necessary to connect everyone who wants to help clean up the basin.
- Enlightened leadership is essential.
- This is a tri-state effort, Delaware, Pennsylvania, and Maryland must be involved.
- Delaware is a small state, and we need to use this opportunity to our advantage.

The public forum served to identify that the best approach to reducing the nutrient and bacteria loads is a combination of the three approaches presented at the forum. A multi-faceted approach—considering recreational, economic, water supply, and biological components—is the way to get everyone in the basin involved and to care about what happens. Achieving the TMDLs set for the basin will need to include all stakeholders—government, citizens, corporations, and legislators—in the form of regulatory, scientific, and voluntary efforts that are equitable to everyone in the basin.

The forum informed people about the TAT process, which most did not know was occurring in the areas where they live, work, or play. The public forum served to identify the stakeholders' concerns and priorities. An additional benefit of the forum was that several people became members of the TAT. In addition to new team members, individuals who did not want to participate on the team on a regular basis, but were interested in following the development of the strategy were able to become involved in the process and stay up-to-date on the activities of the group through email communication. The information collected at the forum was used to guide the development of the recommendations contained in this document, specifically the recommendations outlined in Chapter 4.

Chapter 2: The Christina Basin

2.1 A Unique Watershed

Figure 2.1 Base Map of the Christina Basin

The Christina Basin is a distinctive natural resource in Delaware (Figure 1.1). The watershed is unique in the First State because it is the:

- Only source of public surface water supply in Delaware. The streams and wells in the basin provide drinking water for over 400,000 people, which is over 70 percent of the population in New Castle County or 60 percent of the state population.
- Home of almost half of the state's citizens in the most northern and populous county in Delaware.
- Address of the first- and third-largest cities in Delaware: Wilmington and Newark.
- Habitat of the only six trout streams in Delaware.
- Environment of neo-tropical bird species in hilly, contiguous Piedmont forests that are found in only three percent of Delaware.
- Only watershed in Delaware to encompass three states: Delaware, Pennsylvania, and Maryland.

2.2 Geography and Land Use

The Christina Basin is a diverse, suburbanizing watershed with waters often under conflicting uses. Due to its desirable pastoral quality and proximity to job centers in Wilmington, West Chester, and Philadelphia, the Christina Basin has lost 15 percent of its open land to development since 1970. The Christina Basin is indeed a microcosm of many suburbanizing watersheds in the Delaware Valley.

The Christina River Basin:

- Occupies 565 square miles (sq. mi.)–an area a little larger than the size of New Castle County (Greig, Bowers, and Kauffman, 1998).
- Has its headwaters and 2/3 of its land area in Pennsylvania, and its lower third located within Delaware and a small slice of Maryland.
- Includes four major watersheds, shown in Table 2.1:
    - Brandywine Creek 325 sq. mi.
    - Red Clay Creek 54 sq. mi.

- White Clay Creek 107 sq. mi.
- Christina River 78 sq. mi.

- Has inter-governmental coordination challenges including:
  - Three states: Delaware, Pennsylvania, and Maryland.
  - Five counties: Chester, Lancaster, and Delaware counties in Pennsylvania, New Castle County in Delaware, and Cecil County in Maryland.
  - Over 60 townships, boroughs, and cities such as Elsmere, Newark, Newport, and Wilmington in Delaware and Avondale, Coatesville, Downingtown, Kennett Square, West Chester, and West Grove in Pennsylvania.
- Is home to over 0.5 million people in three states (according to population data from 2000).
- Is generally divided among three land uses of similar, but changing proportions – urban/suburban (⅓), agriculture (⅓), and open space/forests (⅓).

Table 2.1 Land Area of Watersheds in Delaware, Pennsylvania, and Maryland

Watershed	Pa.	Del.	Md.	Total
Brandywine Creek	300.14	24.58	0	324.72
Red Clay Creek	31.7	22.4	0	54.1
White Clay Creek	62.16	45.09	0	107.25
Christina River	2	67.6	8.4	78
Total	**396 sq. mi.**	**159.67 sq. mi.**	**8.4 sq. mi.**	**564.07 sq. mi.**
Watershed	**Pa.**	**Del.**	**Md.**	**Total**
Brandywine Creek	92%	8%	0%	100%
Red Clay Creek	59%	41%	0%	100%
White Clay Creek	58%	42%	0%	100%
Christina River	3%	87%	11%	100%
Total	**70%**	**28%**	**1%**	

Source: Greig, Bowers, and Kauffman, 1998

2.3 Land Use

The Christina Basin falls principally within two states, Pennsylvania to the north and Delaware to the south. The Pennsylvania portion is characterized by more open space, including agricultural land and forests, while the more urban, southerly portion in Delaware tends to have more built-up land. Figures 2.4 and 2.5 represent the land use distribution of five broad land use categories—high-intensity development, lower-intensity development, agricultural uses, forest land, and other uses—in the Christina Basin for the years 1992 and 2001.

Figure 2.2 Land Cover in the Christina Basin, 1992

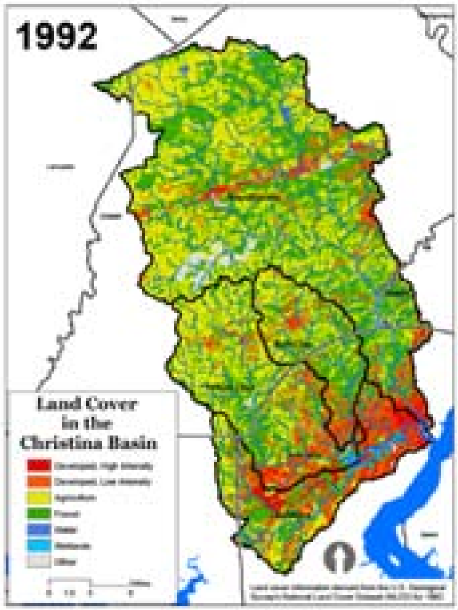
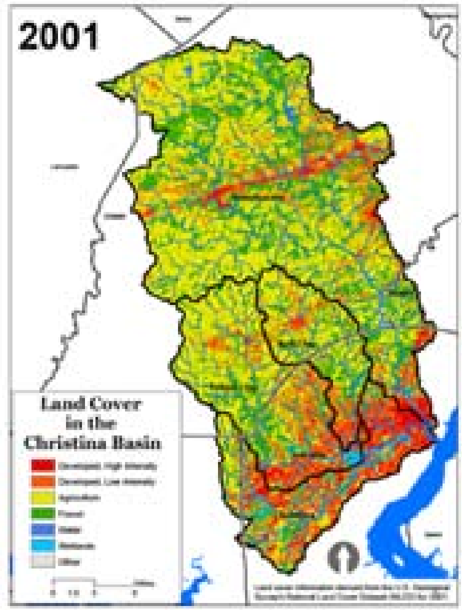


Figure 2.3 Land Cover in the Christina Basin, 2001



Across the basin as a whole, there has been a significant loss of open space, particularly forests. Data derived from the USGS National Land Cover Datasets for the years 1992 and 2001 reveal that forest cover within the basin has gone from more than 40 percent of the land area to just over 25 percent, much of this having been converted to agricultural uses. At the same time, the amount of developed land went from 15.8 percent to 21.0 percent, and agricultural land increased from nearly 40 percent to over 47 percent of the whole basin. Low-intensity development accounted for one of the highest percentage increase in the basin, while forest land made up the largest loss, in absolute and by percentage. Figures 2.6 and 2.7 show the proportion of the five land use categories in the basin as a whole, in 1992 and 2001. Table 2.3 summarizes the land use categories across the entire basin and shows the net gains and losses, in square miles and by percentages.

Figure 2.4 Proportion of Land Use Types in the Christina Basin in 1992

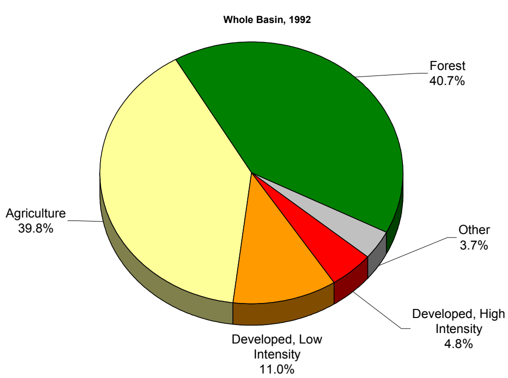


Figure 2.5 Proportion of Land Use Types in the Christina Basin in 2001

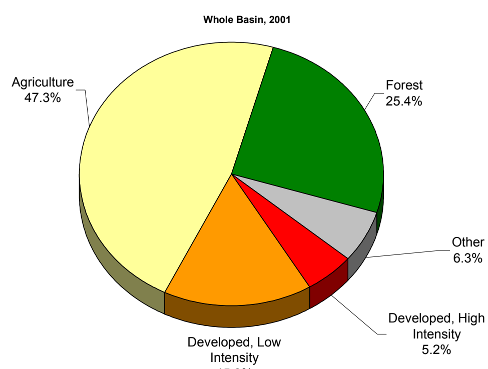


Table 2.2 Summary of Land Use Areas and Changes for 1992 and 2001 in the Christina Basin (area figures are in square miles)

	Developed, High Intensity	**Developed, Low Intensity**	**Agriculture**	**Forest**	**Other**	**Total**
Entire Basin, 1992	27.12	62.32	224.56	229.78	20.79	**564.56**
Entire Basin, 2001	29.19	89.44	266.84	143.52	35.57	
Net Change	2.07	27.12	42.28	-86.26	14.79	
% Change	7.6%	43.5%	18.8%	-37.5%	71.1%	

The Christina Basin in Delaware

The portion of the basin that falls within Delaware is characterized by a relatively high percentage of built land uses. Figures 2.8 and 2.9 show the relative proportions of land uses within the Delaware portion of the basin, for the years 1992 and 2001. In 1992 nearly 38 percent of the land area was developed, and by 2001 this figure rose to almost 45 percent. During the same period, forest cover declined dramatically, from nearly 38 percent to approximately 20 percent. Both agricultural land and low-intensity development saw large percentage gains in Delaware, while, as in the basin as a whole, forested lands saw the largest drop in area and percentage. Table 2.4 summarizes the areas and changes of land use categories for the Delaware portion of the basin.

Figure 2.6 Proportion of Land Use Types in the Delaware Portion of the Christina Basin in 1992

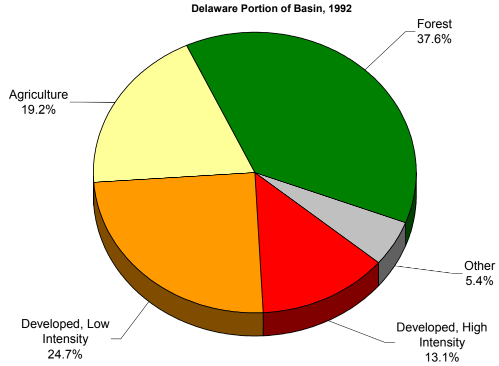


Figure 2.7 Proportion of Land Use Types in the Delaware Portion of the Christina Basin in 2001

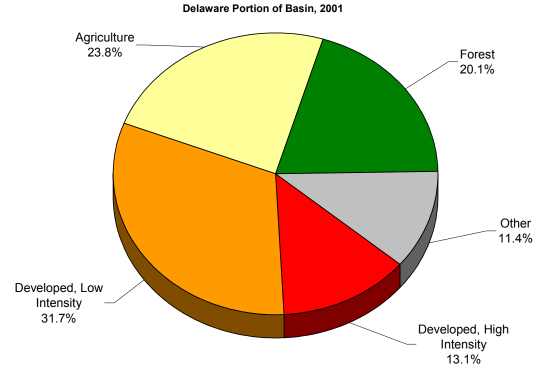


Table 2.3 Summary of Land Use Areas and Changes for 1992 and 2001 in the Delaware Portion of the Christina Basin
(area figures are in square miles)

	Developed, High Intensity	**Developed, Low Intensity**	**Agriculture**	**Forest**	**Other**	**Total**
Delaware Portion of Basin, 1992	20.53	38.86	30.21	59.00	8.47	**157.07**
Delaware Portion of Basin, 2001	20.50	49.74	37.34	31.64	17.84	
Net Change	-0.03	10.88	7.13	-27.36	9.37	
% Change	-0.1%	28.0%	23.6%	-46.4%	110.6%	

The Four Watersheds of the Christina Basin
The land use in the four watersheds—Brandywine, Red Clay, and White Clay Creeks, and Christina River—in the Delaware portion of the basin have exhibited distinct patterns of land use change in the period from 1992 to 2001. Since these areas have been highly developed for many years, the amount of high-intensity development has stayed fairly stable. Low-intensity development has been particularly pronounced in the White Clay and Christina River sub-watersheds, which saw increases in this land use type of 36.6 percent and 30.5 percent, respectively. A significant proportion of land in the Brandywine and Red Clay sub-watersheds were converted to agricultural uses: 60.7 percent and 67.6 percent respectively. As in the basin as a whole, the loss of forest during the period was uniformly large. Figure 2.10 illustrates the net percentage gains and losses of each of the four sub-watersheds within the Delaware portion of the Christina Basin.

While all sub-watersheds in the Delaware portion of the Christina Basin are fairly urbanized, the Christina has the greatest percentage of developed land (54.0%), followed by the White Clay (42.6 percent). While all watersheds lost forest land, Red Clay and Brandywine have retained the most, with 31.7 percent and 26.2 percent, respectively. Figure 2.11 illustrates the proportion of land use in each of the sub-watershed in 2001. Table 2.5 summarizes the land use changes in these watersheds.

Figure 2.8 Land Use Changes in the Delaware Portion of the Christina Basin for the Four Watersheds

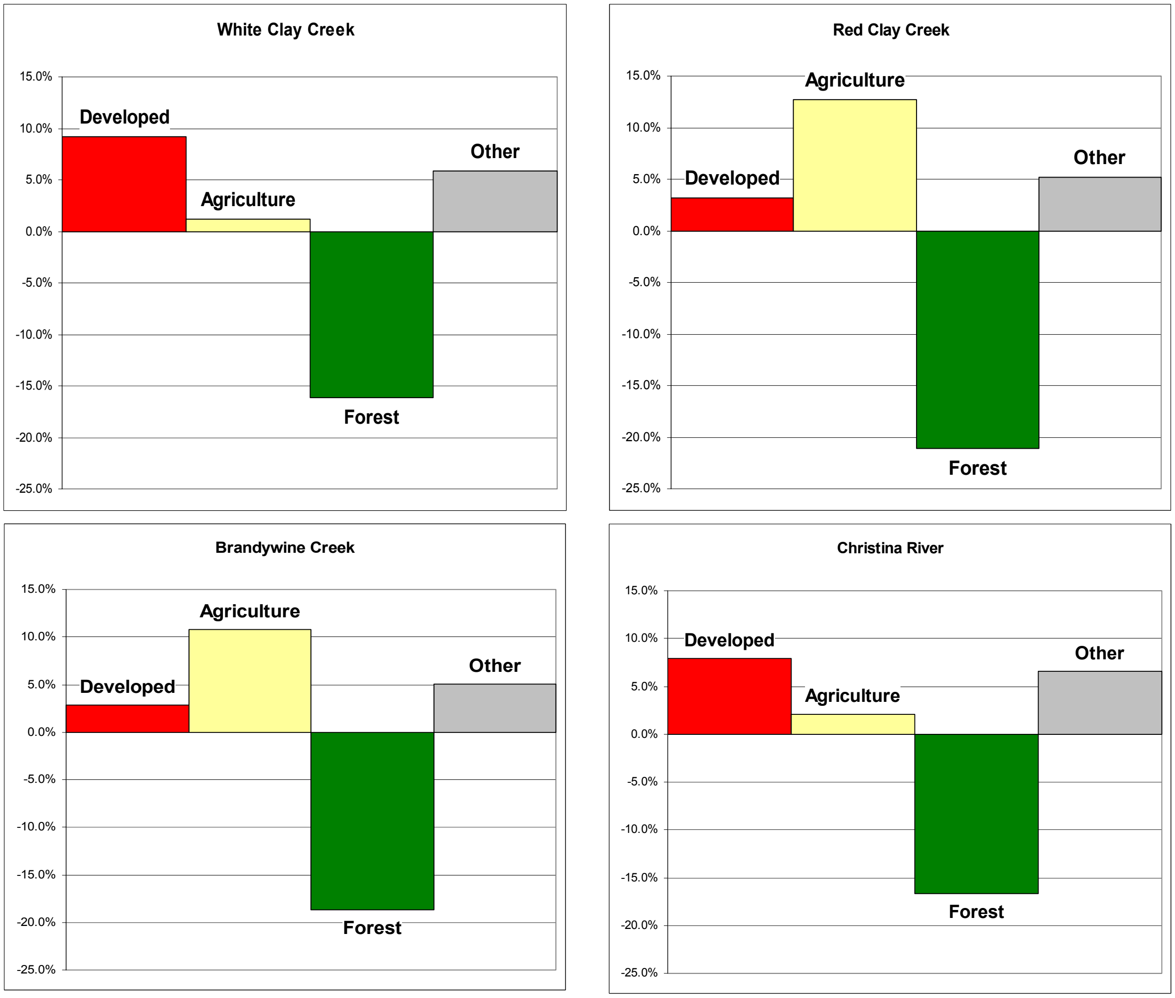


Figure 2.9 Proportions of Land Use Types in the Delaware Portion of the Christina Basin for the Four Watersheds

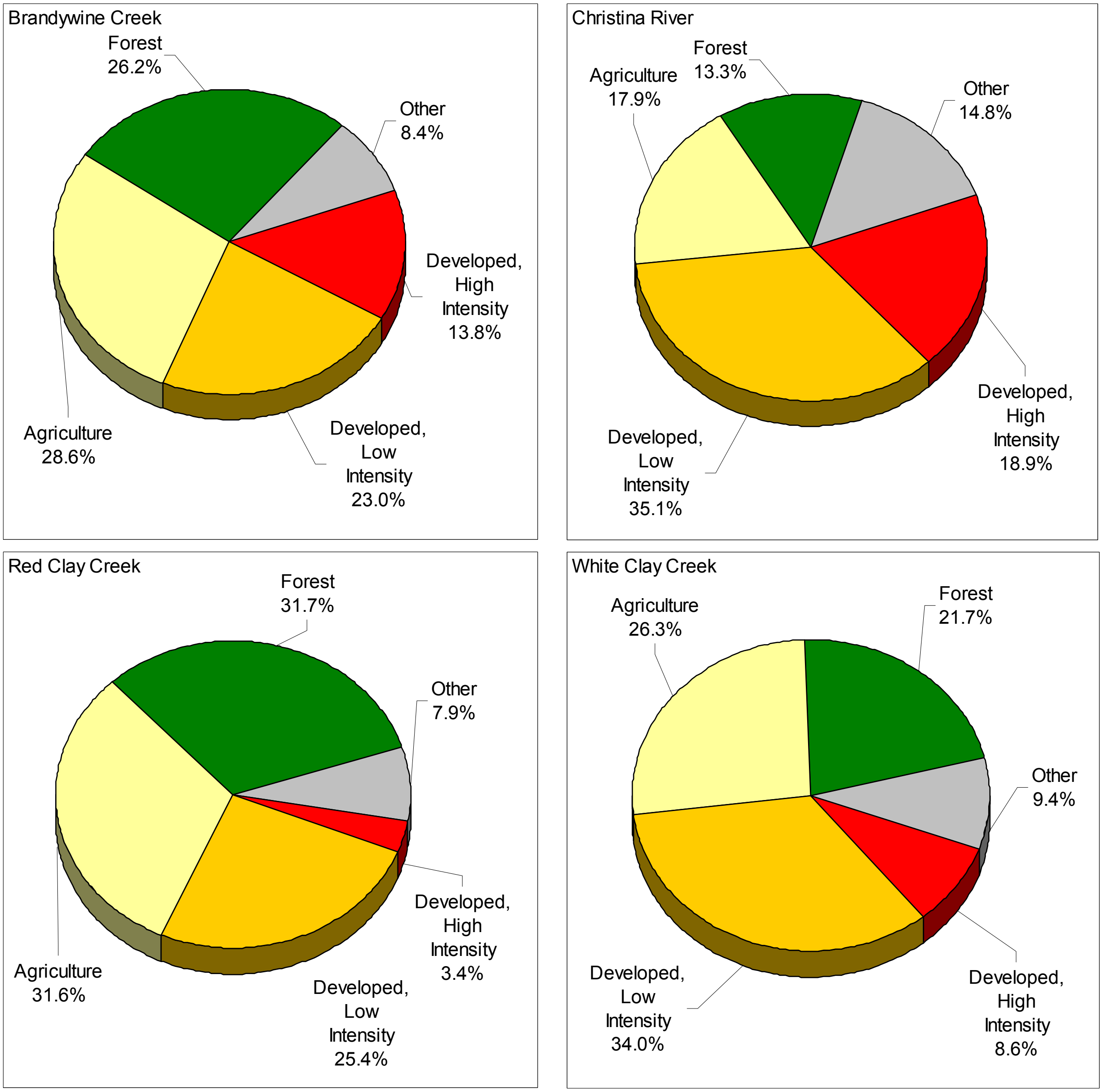


Table 2.4 Summary of Land Use Areas and Changes for 1992 and 2001 in the Delaware Portion of the Christina Basin, for the Four Watersheds
(area figures are in square miles)

	Developed, High Intensity	Developed, Low Intensity	Agriculture	Forest	Other	Total
Brandywine Creek (Del. Portion), 1992	3.06	4.74	4.09	10.33	0.78	**23.01**
Brandywine Creek (Del. Portion), 2001	3.17	5.29	6.58	6.03	1.94	
Net Change	0.11	0.55	2.49	-4.30	1.16	
% Change	3.5%	11.6%	60.7%	-41.7%	148.8%	
White Clay Creek (Del. Portion), 1992	3.98	11.52	11.65	17.53	1.66	**46.34**
White Clay Creek (Del. Portion), 2001	4.00	15.74	12.18	10.04	4.37	
Net Change	0.02	4.22	0.53	-7.49	2.71	
% Change	0.6%	36.6%	4.6%	-42.7%	163.8%	
Red Clay Creek (Del. Portion), 1992	0.72	4.71	3.99	11.18	0.57	**21.17**
Red Clay Creek (Del. Portion), 2001	0.72	5.37	6.69	6.72	1.67	
Net Change	0.00	0.66	2.70	-4.46	1.10	
% Change	0.5%	14.1%	67.6%	-39.9%	193.1%	
Christina River (DE Portion), 1992	12.77	17.89	10.47	19.95	5.47	**66.55**
Christina River (DE Portion), 2001	12.61	23.34	11.89	8.85	9.86	
Net Change	-0.16	5.45	1.41	-11.10	4.40	
% Change	-1.3%	30.5%	13.5%	-55.6%	80.5%	

2.4 Impervious Cover

Many studies in Delaware and other states indicate that watersheds become stressed when the percent of impervious cover, the ratio of roof and pavement area, reaches 10–15 percent of the watershed area. Impervious cover in the Christina Basin (including both the Delaware and Pennsylvania portions) increased from 16 percent in 1990 to 19 percent in 2000 or 0.3 percent per year (Cloud, 2007). If the impervious cover follows this same growth pattern, the impervious cover is projected to reach 22 percent by 2010. Table 2.6 shows the impervious cover estimates in five-year increments for each watershed in the Christina Basin from 1990–2000. According to a GIS analysis, the percentage of impervious cover in 2000 in the

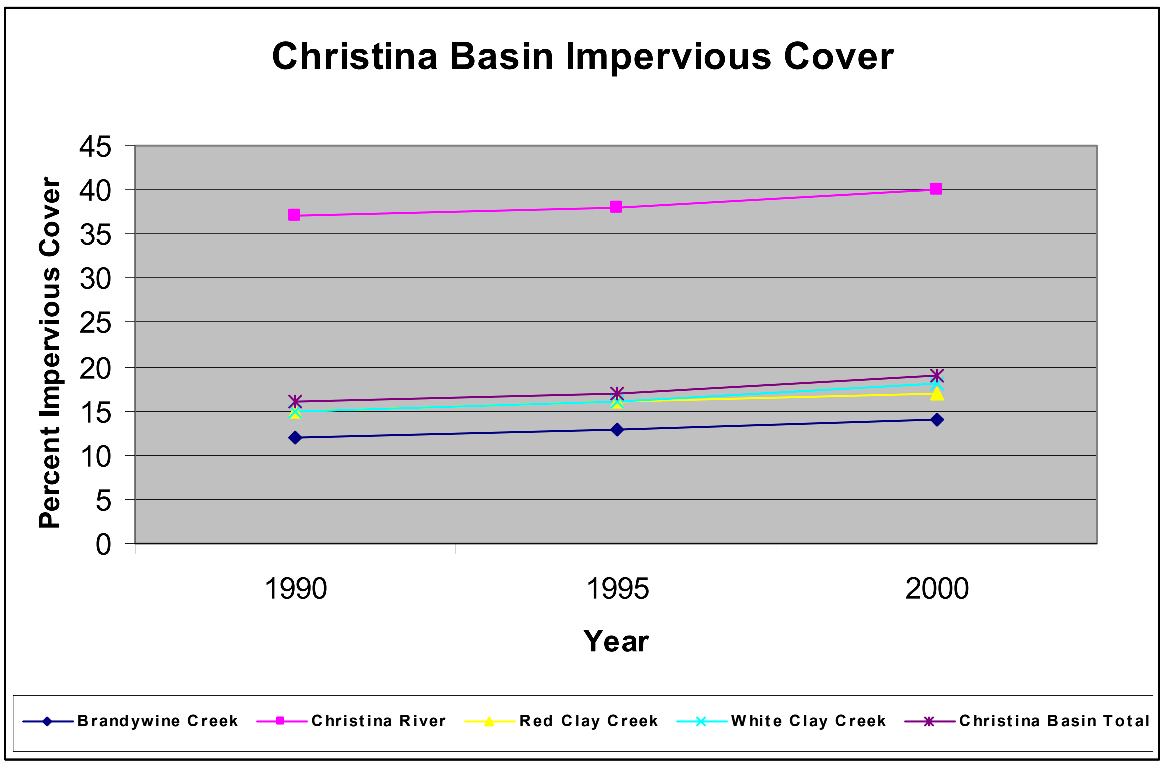
Brandywine, Red Clay, and White Clay Creeks watersheds are less stressed at 14, 17, and 18 percent impervious cover, respectively. Figure 2.12 shows the changes in the percentage of impervious cover from 1990–2000 according to Cloud's master's thesis research.

Table 2.5 Christina Basin Percent of Impervious Cover by Watershed, 1990–2000

Watershed	1990	1995	2000
Brandywine Creek	12%	13%	14%
Christina River	37%	38%	40%
Red Clay Creek	15%	16%	17%
White Clay Creek	15%	16%	18%
Christina Basin Total	**16%**	**17%**	**19%**

Source: Cloud, 2007

Figure 2.10 Christina Basin Percent of Impervious Cover by Watershed, 1990–2000



Source: Cloud, 2007

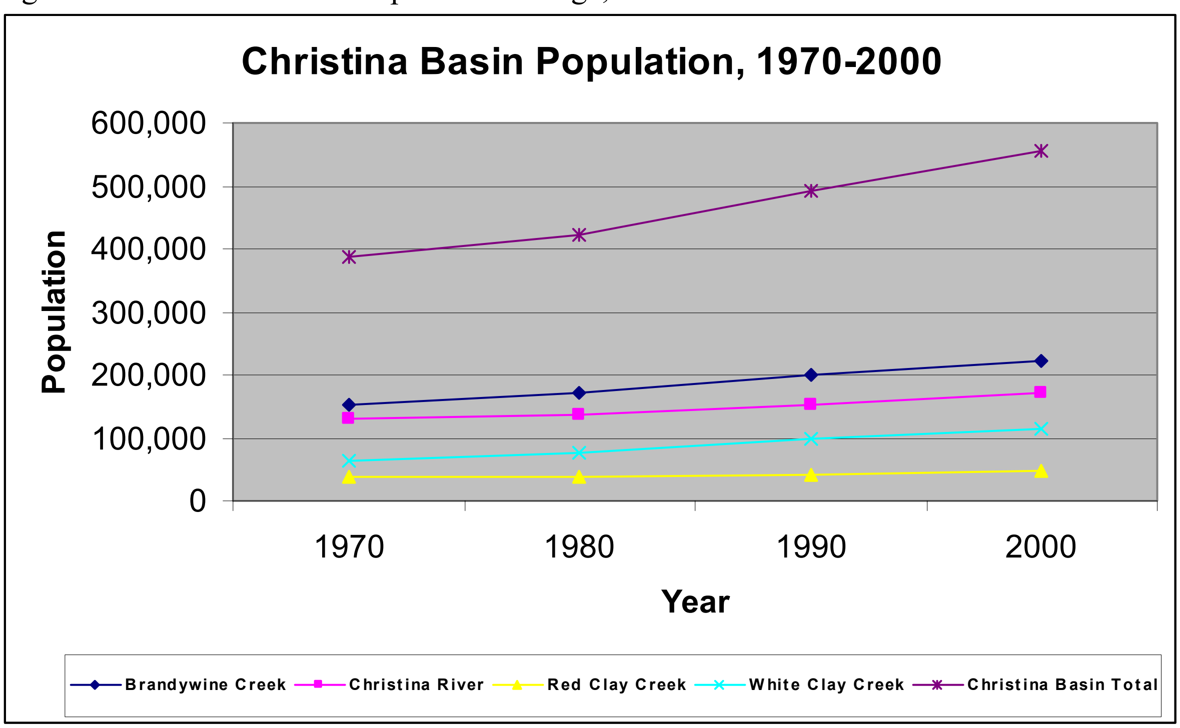
2.5 Population

With its pastoral beauty in the Wyeth country of the Brandywine Valley and its increasing popularity as a bedroom suburb for the job centers in Wilmington and Philadelphia, the population in the Christina Basin (including the Pennsylvania and Delaware portion of the watershed) is increasing. According to the report, "Changes and Trends in Streamflow during Floods and Droughts in the Urbanizing Christina River Basin," population in the Christina Basin increased 44 percent from 387,000 people in 1970 to 556,800 people in 2000 equaling a population density of 985 people per square mile in 2000, as shown in Table 2.7. (Cloud, 2007) According to research conducted by the University of Delaware's Institute for Public Administration-Water Resources Agency, the Christina Basin is the fourth most densely populated among the 21 watersheds in the entire Delaware River Basin and had the seventh most rapidly growing population in the Delaware River Basin between 1990–2000. Figure 2.13 shows the estimated population growth in the Christina Basin from 1970–2000. Cloud also provides population estimates in the Christina Basin according to the average population density (people per square mile) by watershed, as shown in Table 2.8. This analysis shows that in 2000 the Christina River watershed had the highest population density, with 2,186 people per square mile, in the entire Christina Basin (Cloud, 2007).

Table 2.6 Christina Basin Population from 1970–2000

Watershed	**1970**	**1980**	**1990**	**2000**
Brandywine Creek	153,292	170,290	199,604	222,909
Christina River	130,838	136,423	151,694	171,351
Red Clay Creek	38,760	39,375	41,709	47,484
White Clay Creek	64,152	76,431	98,192	115,056
Christina Basin Total	**387,045**	**422,521**	**491,201**	**556,800**

Figure 2.11 Christina Basin Population Change, 1970–2000



Source: Cloud, 2007

Table 2.7 Average Population Density by Watershed

	People Per Square Mile					
Watershed	**1970**	**1980**	**1990**	**2000**	**1970-2000**	**Percent Change**
Brandywine Creek	718.25	750.16	847.03	919.96	201.71	28.08
Christina River	1,542.48	1,626.92	1,857.35	2,186.04	643.55	41.72
Red Clay Creek	867.52	842.67	857.31	935.36	67.84	7.82
White Clay Creek	743.03	883.86	1,121.70	1,303.72	560.69	75.46
Basin Average	**874.55**	**935.95**	**1,080.19**	**1,222.88**	**348.33**	**39.83**

Source: Cloud, 2007

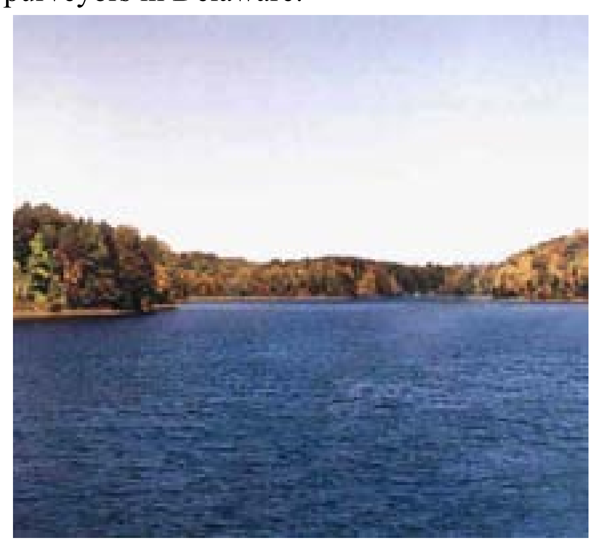
2.6 Geology

The Christina Basin in Delaware is perched along the fall zone, which runs along the Atlantic seaboard from Maine to Alabama (U.S. Army Corps of Engineers, 2002). The fall zone runs through a line stretched between Newark and Wilmington and separates the hilly, rocky Piedmont physiographic province from the flat, sandy Coastal Plain. North of the fall line lies the hilly Piedmont where rolling streams provide all of the surface water supply for Delaware and the Wissahickon, Wilmington, and Cockeysville formations provide some amount of groundwater. South of the fall line is the Coastal Plain where the sand and gravel deposits provide reasonable groundwater yields. The Christina Basin occupies 90 percent of the Piedmont in Delaware and is the only watershed in Delaware that provides surface and groundwater supplies from the Piedmont and Coastal Plain provinces.

2.7 Water Supply

The streams and wells of the watershed provide 70 percent of the water supply for New Castle County and up to 40 percent of the water supply for Chester County. The streams and wells provide up to 100 million gallons per day (mgd) of public drinking water. The Christina Basin is the source of water supply for the following water purveyors in Delaware:

- Artesian Water Company
- City of Wilmington
- United Water Delaware
- City of Newark



Protected areas of the Christina Basin provide water storage for the following reservoirs:

- Hoopes Reservoir (2,000 mg, Del.)
- Smalley's Pond (40 mg, Del.)
- Marsh Creek Reservoir (7,500 mg, Pa.)
- Chambers Lake (350 mg, Pa.)
- Rock Run Reservoir (200 mg, Pa.)
- Struble Lake (100 mg, Pa.)

2.8 Recreational Resources

The streams provide a variety of primary and secondary recreational opportunities such as:

- *Canoeing*: The Brandywine Creek hosts many canoe and kayak enthusiasts at public boat landings and commercial liveries.
- *Hiking and Biking:* The White Clay Creek State Park, Brandywine Creek State Park, and numerous municipal and county parks provide hiking and biking trails for the community.
- *Boating*: Delaware mariners own 8,400 registered boats that ply the tidal waters of the Christina River and Brandywine Creek.
- *Trout Fishing*: Over 2,700 trout stamps are sold to anglers, and 30,000 trout are stocked annually along the only six trout streams in Delaware:
    - White Clay Creek above Newark
    - Upper Christina River near Newark
    - Pike Creek
    - Mill Creek
    - Beaver Run
    - Wilson Run
- *Warm Water Fishing*: The tidal waters of the Christina River support a striped bass fishery and spawning grounds, while the nontidal waters of the Brandywine Creek provide exceptional smallmouth bass fishing habitat.

2.9 Historic and Cultural Resources

The Christina Basin enjoys a deep historic and cultural character including:

- *Battlefields*: It is the site of two Revolutionary War battlefields: Brandywine near Chadds Ford, Pennsylvania, and Cooches Bridge near Newark, Delaware.

- *Farming*: The rolling hills and productive soils are conducive to horse farming near the University of Pennsylvania Veterinary College, cattle farming at the King Ranch (the largest ranch east of the Mississippi River), and increasing settlement by Amish and Mennonite farmers.
- *Museums*: The old water-powered mills along the Brandywine (such as the Hagley Museum in Wilmington and the Brandywine Museum in Chadds Ford) are popular tourist destinations.
- *Art*: The Brandywine Valley is the inspiration for the “Brandywine School” and Wyeth style of art.
- *Gardens*: The temperate and humid mid-Atlantic climate is conducive to some of the most productive public gardens in the world at Winterthur and Longwood.

- *Education*: Many universities provide higher-level education in and around the Christina Basin including the University of Delaware, Wilmington College, Widener University School of Law, and West Chester University.

2.10 Economic Resources

The Christina Basin is home to the following economic sectors:

- *Corporations*: Wilmington and Newark are the international home of many companies including DuPont, Bank of America, and W.L. Gore.
- *Wilmington Riverfront Revitalization*: An urban renaissance along the tidal Brandywine and Christina is underway resulting in the Riverfront Arts Center, Tubman-Garrett Riverfront Park, Christina Riverwalk, factory store outlets, restaurants, the Wilmington Blue Rocks minor league baseball stadium, urban wetland restoration, and a wildlife refuge.
- *Port of Wilmington*: The port is one of the largest importers of orange juice, Chilean grapes, bananas, and automobiles nationally.
- *Mushroom Farms*: The Red Clay and White Clay Creeks watersheds are the home of the largest concentration of mushroom growers in the United States.

2.11 Ecological and Natural Functions

The Christina Basin provides many ecological and natural functions:

- *Parks*: Brandywine Creek State Park near Wilmington, White Clay Creek State Park near Newark, and White Clay Creek Preserve and Marsh Creek State Park in Pennsylvania are located in the Christina Basin. New Castle County parks are situated at Middle Run near Newark and Delcastle Park near Wilmington.
- *Conservation Areas*: Large, privately owned conservation areas in the basin include Woodlawn Trustees land along the Brandywine Creek, Delaware Nature Society land along the Red Clay Creek in Delaware, and Brandywine Conservancy, Red Clay Valley Association, and Brandywine Valley Association holdings in Pennsylvania.
- *Habitat*: Contiguous forests and wetlands provide habitat for several federal or state-listed endangered or threatened species:
  - Bog Turtle (*Glyptemys muhlenbergii*)
  - Cerulean Warbler (*Dendroica cerulea*)
  - Long-tailed Salamander (*Eurycea longicauda*)
  - Bald Eagle (*Haliaeetus leucocephalus*)

- *Exceptional Value Waters*: The Brandywine Creek above Wilmington and the White Clay Creek above Newark have more protective water quality standards through their designation by the Delaware DNREC as waters of Exceptional Recreational and Ecological Significance (ERES waters).
- *Wild and Scenic Status*: President Clinton and the U.S. Congress approved a National Park Service recommendation to designate the White Clay Creek and its tributaries for

Wild and Scenic status. The White Clay Creek is the only wild and scenic river in Delaware, and it is the first river nationally to be protected on a watershed basis as opposed to a river-segment basis.

2.12 Watershed Organizations

Numerous nonprofit watershed organizations are located in the Christina Basin. These nonprofit groups, some dating back as far as 1945, serve to protect and preserve the rivers and tributaries in the basin. This watershed stewardship is performed through groups including the:

- Brandywine Conservancy (*www.brandywineconservancy.org*)
- Brandywine Valley Association (*www.bva-rcva.org*)
- Red Clay Valley Association (*www.bva-rcva.org*)
- Delaware Nature Society (*www.delawarenaturesociety.org*)
- White Clay Watershed Association (*www.ccil.org/-wcwa/index.html*)
- Stroud White Clay Creek Laboratory (*www.stroudcenter.org*)
- Christina Conservancy
- Wilmington River-City Steering Committee

Additionally the White Clay Creek watershed was designated a Partner Wild and Scenic River by an act of Congress signed into law by President Clinton in 2000. As a result of this national designation, the White Clay Creek Watershed Management Committee, a local watershed management committee, works with the U.S. Department of the Interior, National Park Service, and numerous organizations and stakeholders in the White Clay Creek watershed to implement the White Clay Creek Watershed Management Plan.

Chapter 3: Water Quality and Total Maximum Daily Loads

3.1 Water Quality Concerns

The streams of the Christina Basin in Delaware suffer from impaired water quality due to the following problems:

1) *Nutrients*: One hundred and thirty stream miles have higher than desired nitrogen and phosphorus loads, which deplete dissolved oxygen (DO) levels.
2) *Toxics* (metals): Thirteen stream miles are impaired due to elevated zinc levels.
3) *Bacteria* (pathogens): Concentrations along 134.2 miles of stream frequently exceed the primary recreation standards for swimming of 100 colonies per 100 milliliters.
4) *Sediment*: The streams are degraded by high sediment loads that range between 311 and 975 pounds per acre annually depending on the subwatershed.
5) *Stream Habitat*: While biological diversity of the streams has been improving, 39 percent of the nontidal streams in the Piedmont have poor habitat due to the increased frequency and rate of runoff from urban/suburban development and rural activities (Shaver et al., 1995).
6) *Contaminated Waste Sites:* Contaminated waste sites are situated throughout the watershed, with numerous sources located in close proximity to the drinking water supply intakes.
7) *Fish Consumption Advisories*: Health warnings advising against the consumption of fish have been posted along 82.2 stream miles due to PCB contaminated sediment and high PCB levels in fish tissue.

Sections 2.2 through 2.8 discuss each one of these water quality problems in detail.

3.2 Nutrient Trends

The Delaware DNREC has set water quality criteria for nitrogen and phosphorus as summarized in Table 3.1. The University of Delaware's IPA-WRA has summarized the water quality trends in the Christina Basin to determine how well the rivers and streams are meeting DNREC's water quality criteria. The total nitrogen (TN), total phosphorus (TP), data used in this analysis is collected from the stream monitoring stations operated by the Delaware DNREC, Division of Water Resources, Watershed Assessment Section. Table 3.2 lists the monitoring station by watershed and Figure 3.1 shows the spatial distribution of the monitoring sites throughout the basin. The map labels for each monitoring station depicted in Figure 2.2 are noted in Table 2.2.

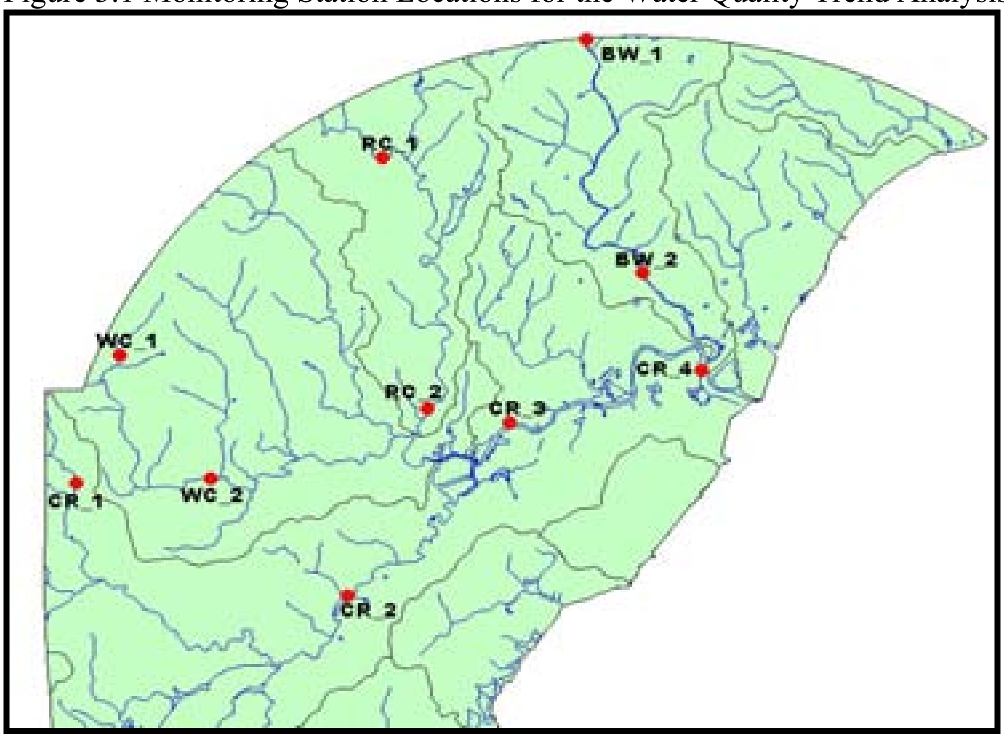
Table 3.1 Delaware Nutrient Criteria

Nutrient Range	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
Low	< 1.0	< 0.05
Moderate	1.0 – 3.0	0.05 – 0.10
High	> 3.0	> 0.10

Table 3.2 Select Monitoring Sites in the Christina Basin Used in Chapter 2 Trend Analysis

Watershed	Station Location	Figure 2.1 Label	USGS Number
Christina River	Route 273, above Newark	CR_1	
	Smalley's Dam Spillway	CR_2	
	Route 141, Newport	CR_3	USGS Tide Gage 01480065
	Contrail Bridge	CR_4	USGS Tide Gage 01481602
Brandywine Creek	Smith Bridge	BW_1	
	Foot Bridge	BW_2	
Red Clay Creek	Ashland, Road 258a	RC_1	
	Stanton, Route 4	RC_2	USGS Gage 01480015
White Clay Creek	Chambers Rock Road	WC_1	
	Stanton, Old Route 7 Bridge	WC_2	

Figure 3.1 Monitoring Station Locations for the Water Quality Trend Analysis in Chapter 2



Total Nitrogen

According to the state of Delaware 305(b) report, average Total Nitrogen (TN) concentrations have been divided into three categories: low < 1.0 mg/L, moderate 1.0–3.0 mg/L, and high > 3.0 mg/L. TN levels in the Brandywine, Red Clay, and White Clay Creeks, and Christina River are discussed in more detail below.

Brandywine Creek

The elevated TN levels in the Brandywine Creek at Smith Bridge and at Foot Bridge display no apparent trend, or are slightly increasing. The values were recorded to be 2.9 and 2.8 mg/L in 1985, and then rose for the next decade to levels of 3.2 and 2.95 mg/L. Both values then dropped again to 3.1 and 2.8 mg/L in 2000 before rising to 3.2 mg/L in 2005. During 2000 through 2005, most TN levels were below the 3.0 mg/L guidance standard set by Delaware DNREC with about 10 percent of the samples during this 5-year period exceeding the standard. TN levels are projected to decrease in the future as the 2005 Total Maximum Daily Loads (TMDLs) enacted by Delaware, Pennsylvania, and the USEPA require TN loads to decrease by 42 percent at the Del./Pa. state line. The Chester County Conservation District continues to cost share with farmers through USDA programs to reduce TN loads from manure and fertilizer sources. Figure 3.2 shows the median TN levels in the Brandywine Creek from 1971–2005.

Red Clay Creek

The TN levels in the Red Clay Creek at Ashland have experienced a slightly downward trend for the past 20 years from approximately 4.5 to 4.05 mg/L in 2005. The TN levels in the Red Clay Creek at Stanton have no apparent trend. The levels initially decrease from 3.5 mg/L in 1985 to a low point of 3.1 mg/L in 1995. For the past ten years these values have risen to a highly elevated level of 3.3 mg/L. Figure 3.3 shows the median TN levels in the Red Clay Creek from 1971–2005.

White Clay Creek

The TN levels in the White Clay Creek at Chambers Rock Road and at Stanton exhibit an increasing trend and are rather elevated. Values correspondingly increase from 3.5 and 3.1 mg/L in 1975 to 3.8 and 3.2 mg/L in 1985. Both values then converge to 3.5 mg/L in 1990. In 2005, Chambers Rock eventually peaks at 4.7 mg/L and Stanton at 3.9 mg/L. Figure 3.4 shows the median TN levels in the White Clay Creek from 1971–2005.

Christina River

Throughout the past 30 years the trend for TN levels in the Christina River all remain at a moderate level. The water quality monitoring data from the Route 273 site shows slight increases from 2.4 mg/L in 1980 to 2.6 mg/L in 1985. It then remains constant until present day. The TN levels at Smalley's Dam Spillway decrease from a high point of 2.4 mg/L in 1975 to 1.75 mg/L in 1985, where it remains until 2005. The Route 141 monitoring data shows a decrease from a highpoint of 3.45 mg/L in 1975 to a low point of 1.2 mg/L in 2000. The levels then rebound up to 3.0 mg/L in 2005. The TN levels at the Conrail Bridge site remain relatively consistent from 1995–2005 at approximately 2.6 mg/L. Figure 3.5 shows the median TN levels in the Christina River from 1971–2005.

Figure 3.2 Median TN in the Brandywine Creek

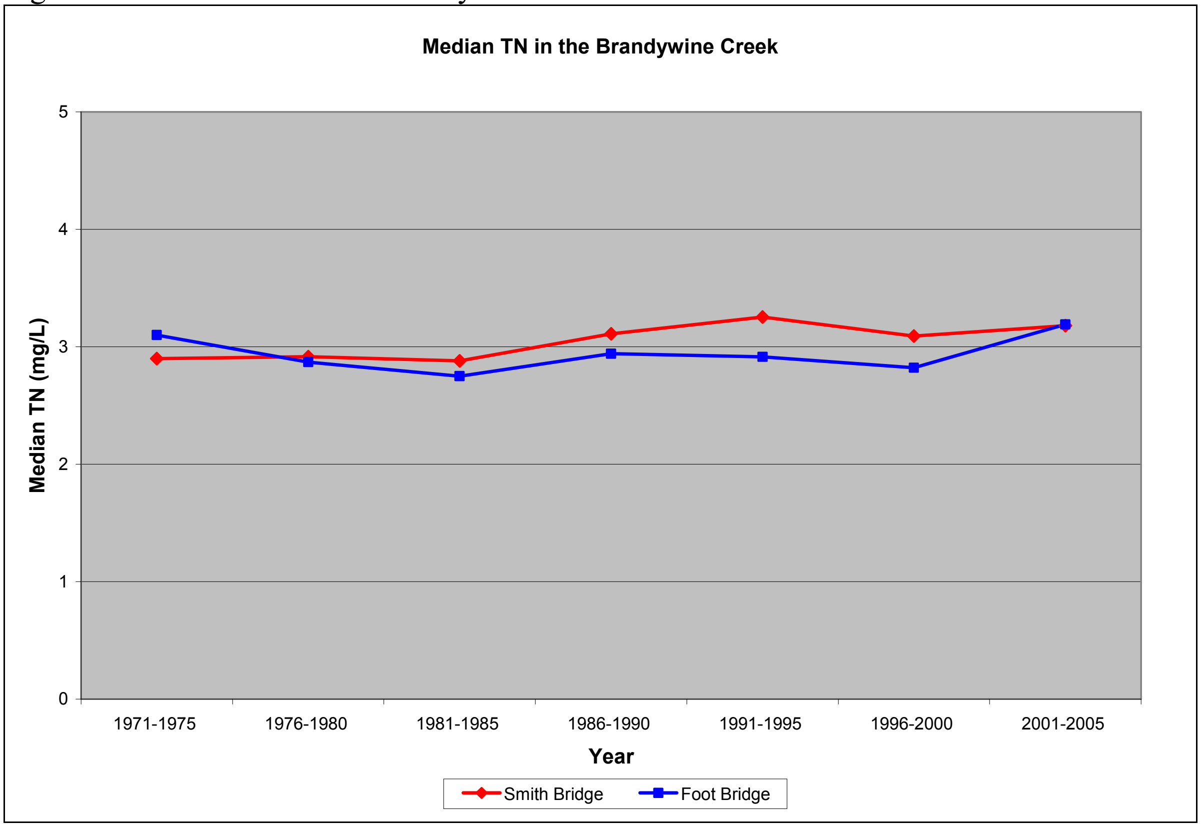


Figure 3.3 Median TN in the Red Clay Creek

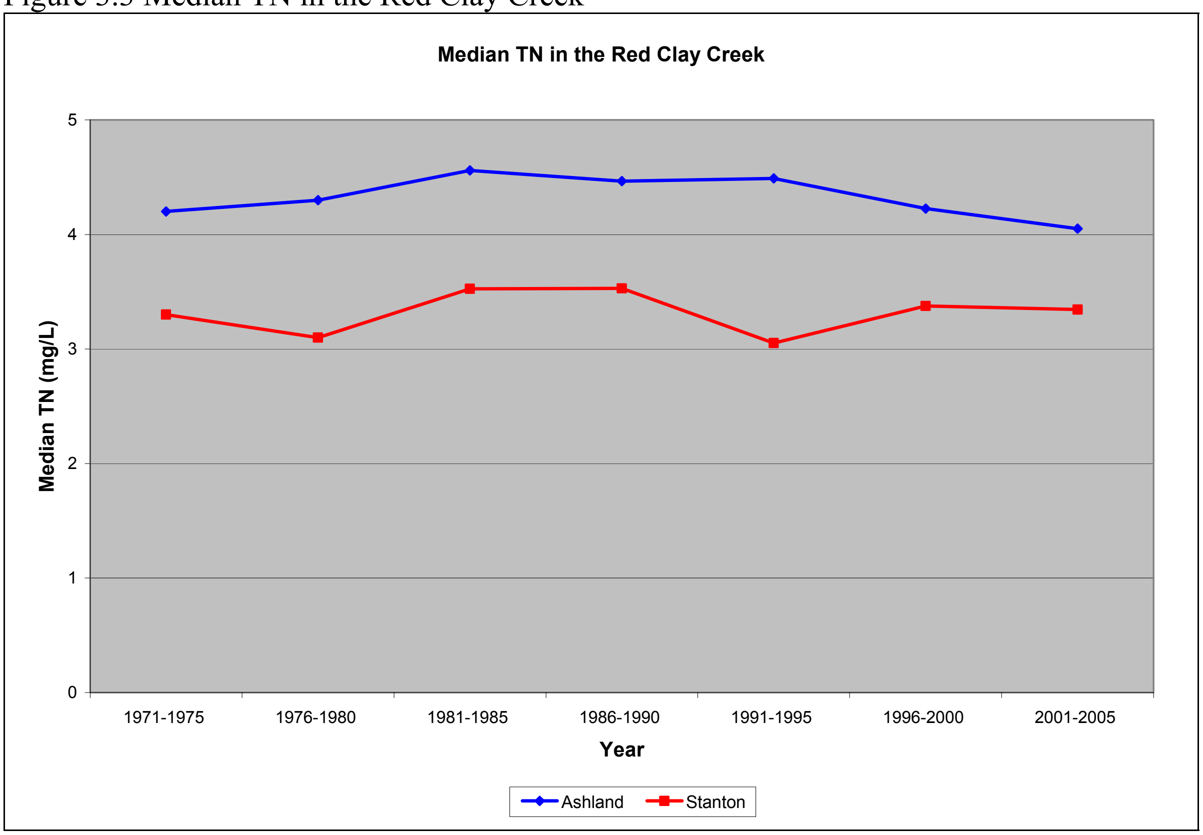


Figure 3.4 Median TN in the White Clay Creek

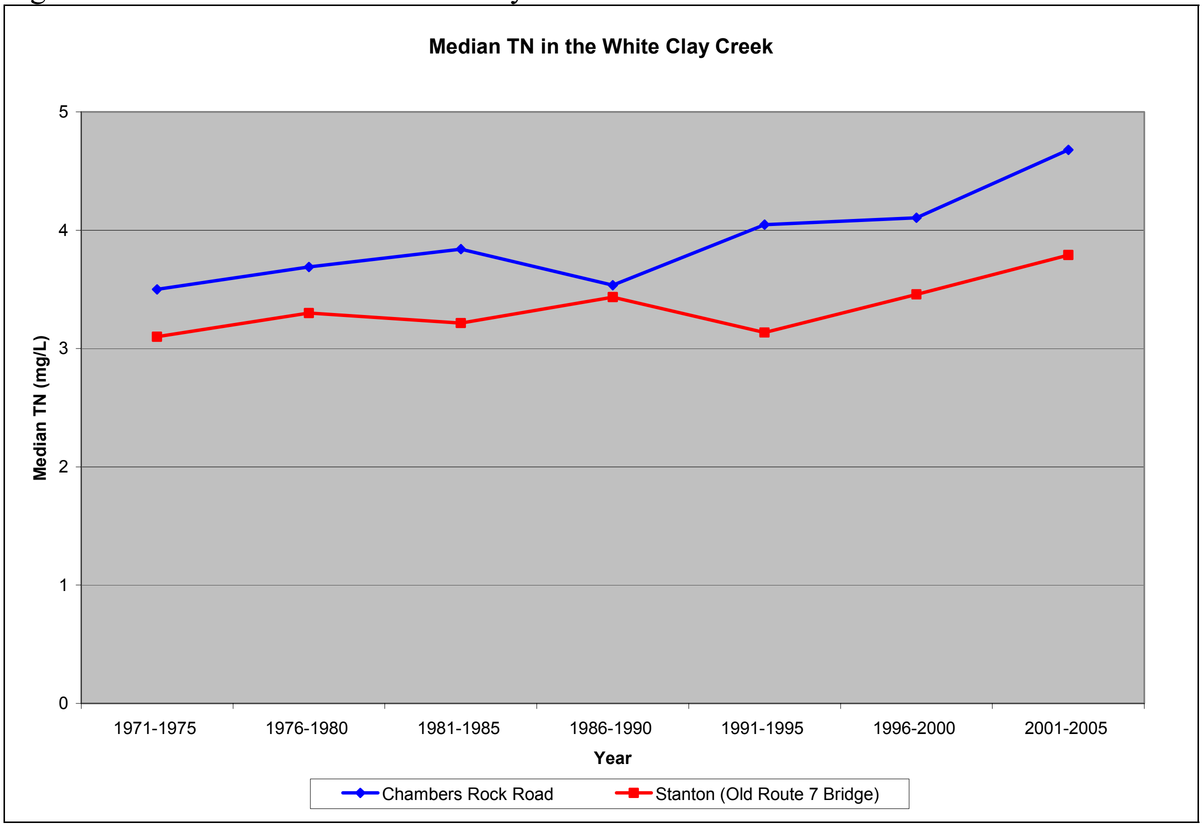
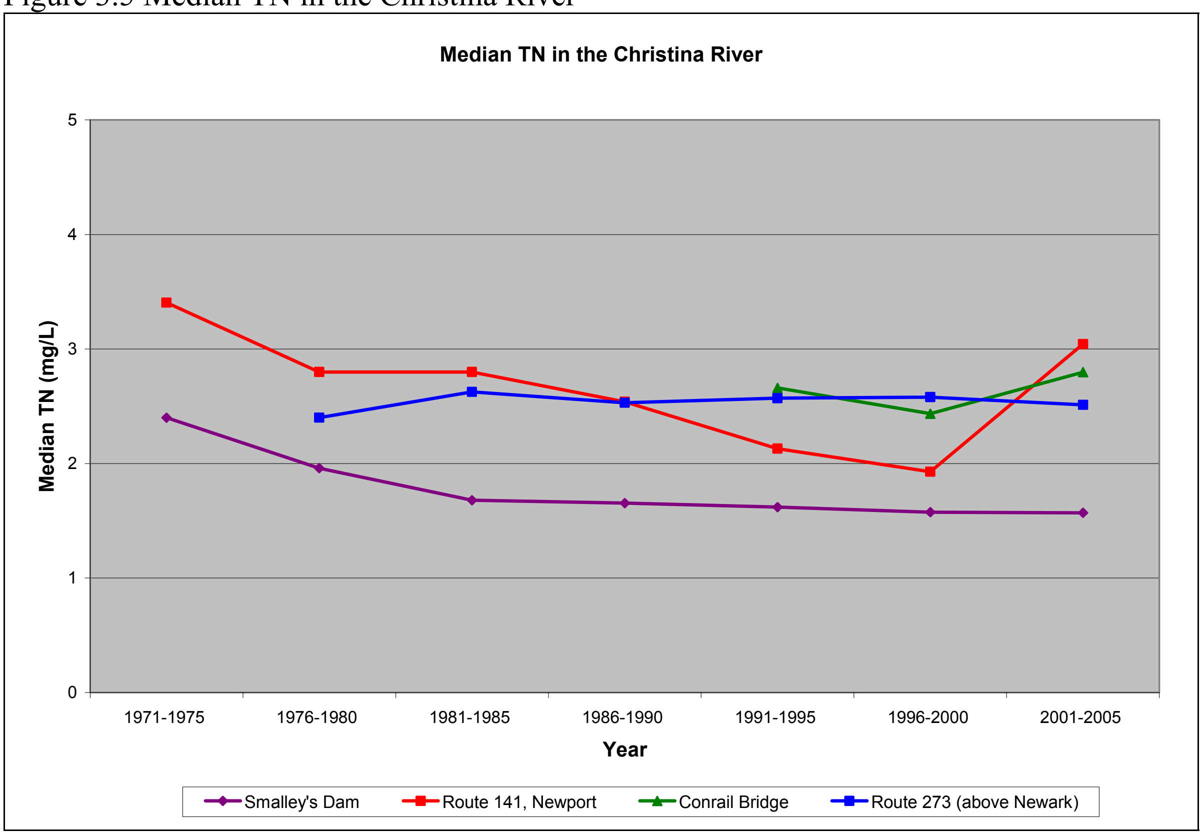


Figure 3.5 Median TN in the Christina River



Total Phosphorus

According to the state of Delaware 305(b) report, the average Total Phosphorus (TP) concentrations have been divided into three categories: low < 0.05 mg/L, moderate 0.05–0.10 mg/L, and high >0.10 mg/L. Phosphorus levels in the Brandywine, Red Clay, and White Clay Creeks, and Christina River are discussed in more detail below.

Brandywine Creek

The TP levels in the Brandywine Creek at Smith Bridge and at Foot Bridge are high, but have exhibited a downward trend throughout the last 25 years. After the levels peaked in 1980 at levels of 0.36 and 0.25 mg/L correspondingly, these values then decreased to a low point of 0.11 and 0.12 mg/L in 1995. For the past ten years the levels remained relatively constant. The decline in TP levels due to several regulatory requirements for phosphorus in the 1990s including: removal at wastewater treatment plants regulated by the PADEP since 1990 NPDES permit renewals, the Pennsylvania ban on phosphate laundry detergents in 1990 and the end of phosphate detergent manufacture nationwide in 1994, and agriculture conservation plans implemented by the Chester County Conservation District at close to 100 farms in the watershed to date. Figure 3.6 shows the median TP levels in the Brandywine Creek from 1971–2005.

Red Clay Creek

There is a downward trend for the high TP levels in the Red Clay Creek at the Ashland and Stanton monitoring stations. Initially these levels correspondingly decreased from approximately 0.54 and 0.35 mg/L in 1980 to values of 0.34 and 0.19 mg/L in 2000. These values then increased to 0.4 and 0.21 mg/L before declining to low values of 0.21 and 0.17 mg/L in 2005. Figure 3.7 shows the median TP levels in the Red Clay Creek from 1971–2005.

White Clay Creek

The TP levels in the White Clay Creek at Chambers Rock Road and at Stanton have remained at a slightly elevated level for the past 25 years. Values initial decrease from 0.156 and 0.11 mg/L in 1980 to a low point of 0.056 mg/L in 1990. These values then increased from the next 10 years to approximately 0.13 mg/L. In 2005 the TP levels in the White Clay Creek at Chambers Rock Road and at Stanton were recorded as 0.13 and 0.09 mg/L correspondingly. There is no apparent trend in these values. Figure 3.8 shows the median TP levels in the White Clay Creek from 1971–2005.

Christina River

The TP levels in the Christina River are also divided into four sections: Route 273 above Newark, Smalley's Dam Spillway, Route 141, and Conrail Bridge. The trend for all stations initially decreases, and then remains relatively constant from 1985 forward. The TP levels are only moderately elevated. Route 273 TP levels declines from a high point of 0.148 mg/L in 1980 to 0.048 mg/L in 1985, and remains fairly constant for the next 20 years. In 2005 the TP level was recorded at 0.049 mg/L. The TP levels at Smalley's Dam Spillway initially decrease from a high point of 0.22 mg/L in 1980 to 0.057 in 1985. This value remains relatively consistent until 2005. Route 141 decreases from a highpoint of 0.19 mg/L in 1980 to a low point of 0.1 mg/L in 1985, and then remains constant until 2005. Route 141 decreases from a highpoint of 0.19 mg/L in 1980 to a low point of 0.1 mg/L in 1985. The levels then slightly increase for the next 20 years to a value of 0.13 mg/L in 2005. The Conrail Bridge levels slightly decrease from 0.155 mg/L in 1995 to 0.13 mg/L in 2005. Figure 3.9 shows the median TP levels in the Christina River from 1971–2005.

Figure 3.6 Median TP in the Brandywine Creek

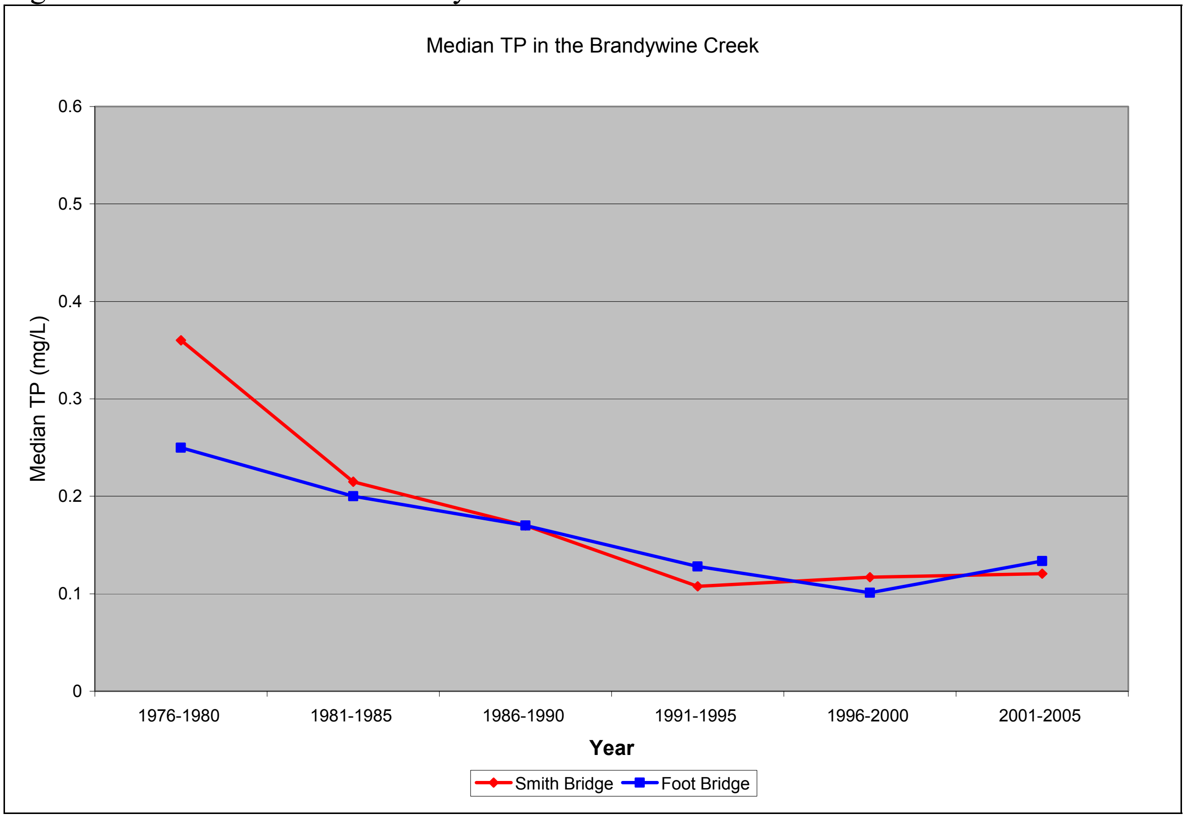


Figure 3.7 Median TP in the Red Clay Creek

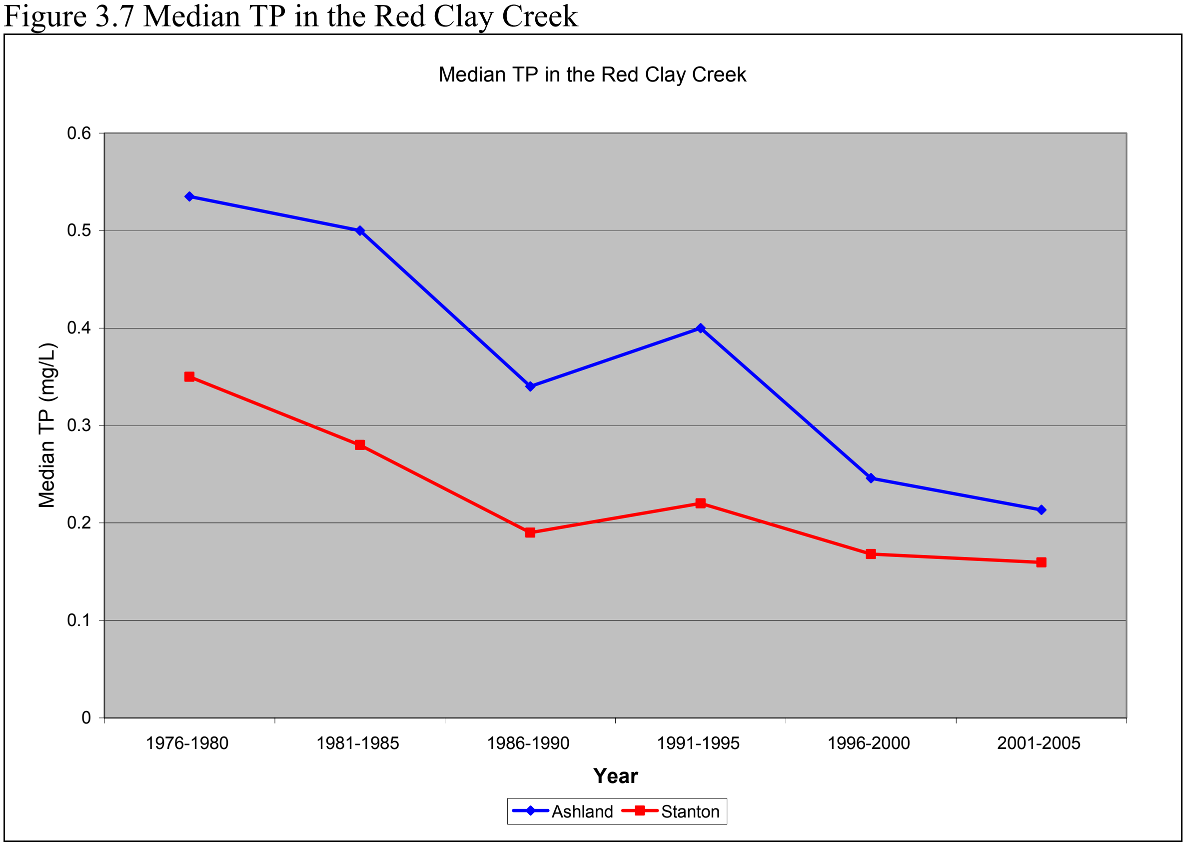


Figure 3.8 Median TP in the White Clay Creek

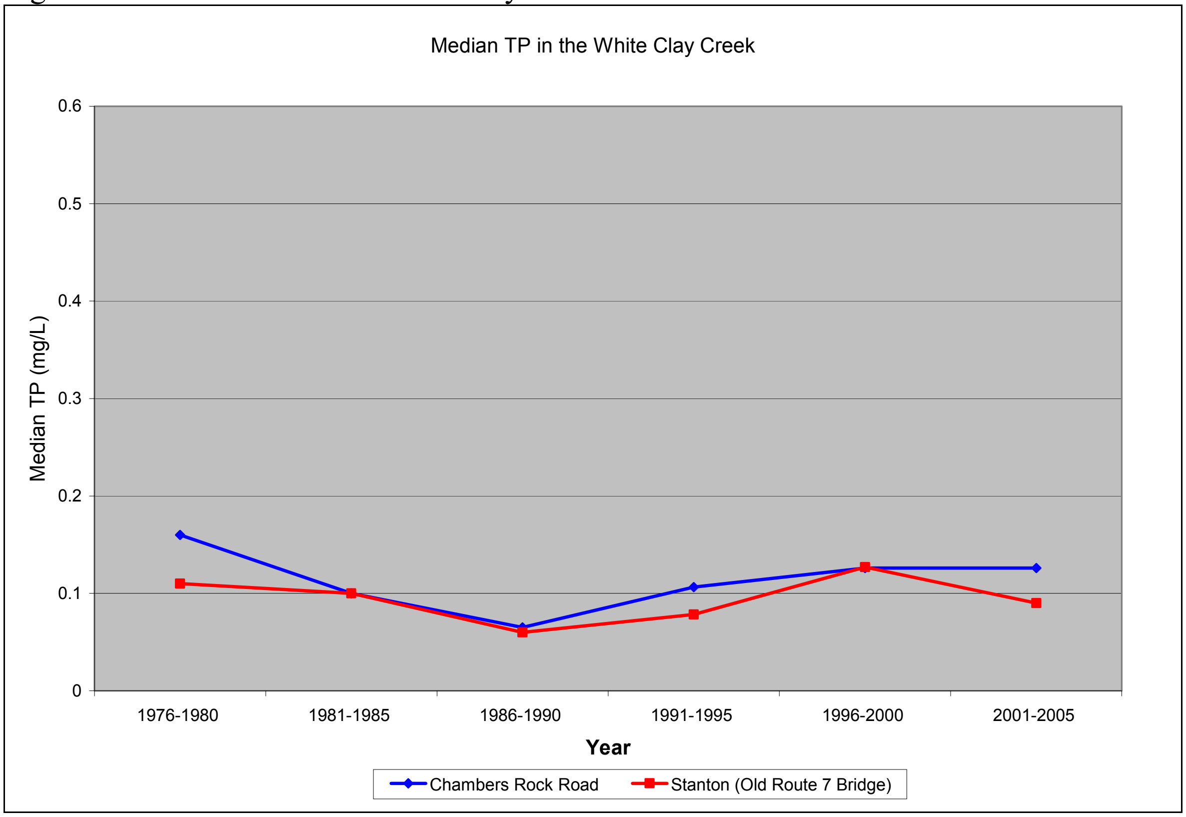
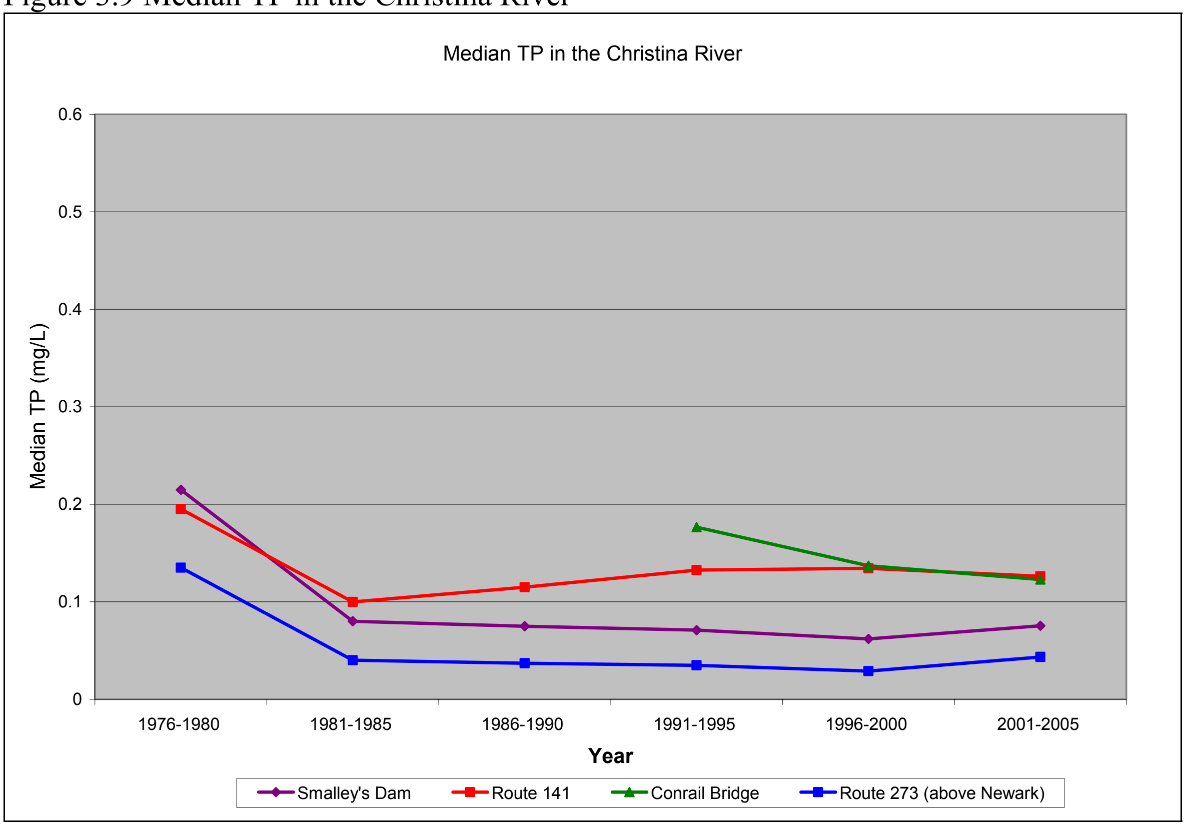


Figure 3.9 Median TP in the Christina River



3.3 Dissolved Oxygen Trends

The Delaware portion of the Christina Basin has TMDLs (discussed in detail in Section 2.9) set for TN, TP, and bacteria but does not have a dissolved oxygen (DO) TMDL. Although a DO TMDL has not been set, DO trends are important to discuss because low DO levels are directly connected to elevated levels of nitrogen and phosphorus loads. Low DO levels cause negative impacts in the stream including harmful algae blooms, reduced stream habitat, fish kills, and oxygen starved hypoxic or "dead" zones.

According to the state of Delaware 305(b) report, standards for average DO concentrations are considered to be met if less than 10 percent of the data indicate average DO concentrations below the criteria of 5 mg/L for marine waters and 5.5 mg/L for fresh waters. Except for the Lewes-Rehoboth Canal, the statewide minimum DO concentration for surface waters is 4.0 mg/L at any time. It is important to note that the values used for trend analysis in this report are the median of average yearly values. DO levels in the Brandywine, Red Clay, and White Clay Creeks, and Christina River are discussed in more detail below.

Brandywine Creek

The DO levels in the Brandywine Creek at the Smith Bridge and Foot Bridge monitoring stations have increased since 1990. These values declined from approximately 10.5 mg/L in 1980 to a low point in 1990 of 8.5 and 9.1 mg/L correspondingly. At Foot Bridge, DO has hovered around 9.5 mg/L for the past 17 years and in 2005 was recorded as 10 mg/L. The DO at Smith Bridge remained constant from 1988–1993 at 8.5 mg/L. It then increased for the next ten years to a value of 10.2 mg/L in 2005. The Pennsylvania Department of Environmental Protection's (PA DEP) National Pollutant Discharge Elimination System (NPDES) permit program requirements to upgrade the Pennsylvania municipal wastewater treatment plant and both the USDA Natural Resources Conservation Service's (NRCS) and the Chester County Conservation District's (CCCD) efforts to implement agricultural conservation plans to reduce manure and nutrient inputs at close to 100 farms, upstream in the Brandywine Creek, may be the cause for the increased DO levels in the Delaware portion of the creek. The 5-year median levels and all individual samples were satisfactorily above the minimum Delaware DO stream water quality standard of 4 mg/L. Figure 3.10 shows the median DO levels in the Brandywine Creek from 1971–2005.

Red Clay Creek

The DO levels in the Red Clay Creek at the Ashland and Stanton monitoring stations initially decrease from 10.2 and 11 mg/L in 1980 to a low point in 1995 at approximately 8.5 mg/L. Throughout the past ten years the DO levels in the Red Clay Creek at the Ashland and Stanton monitoring stations has been increasing, and in 2005 the values were recorded as 9.9 and 10.1 mg/L correspondingly. Figure 3.11 shows the median DO levels in the Red Clay Creek from 1971–2005.

White Clay Creek

The DO levels in the White Clay Creek at the Chambers Rock Road and Stanton monitoring stations slightly decrease from 11.1 and 10.8 mg/L in 1985 to a low point of 9.0 and 9.4 mg/L in 1995. The DO at both White Clay Creek at Chambers Rock Road and at Stanton monitoring stations then increased for the next ten years to values of 10.2 and 9.9 mg/L. Figure 2.12 shows the median DO levels in the White Clay Creek from 1971–2005.

Christina River

The DO levels in the Christina River are divided into four sections: Route 273 above Newark, Smalley's Dam Spillway, Route 141, and Conrail Bridge. The apparent trend for all stations seems relatively constant from 1985–2005. The DO levels at the Route 273 monitoring station decrease from 10.9 mg/L in 1980 to a low point of 9.4 mg/L in 1990. The level then peaks again at 10.5 mg/L in 2000 before decreasing to 10.1 mg/L in 2005. The DO at Smalley's Dam decreases to a low point of 7.9 mg/L in 1990 followed by an increase to 8.9 mg/L in 2005. The monitoring station at Conrail Bridge experienced a sharp increase in DO from its 5.5 mg/L low point in 1995 to 7.4 mg/L in 2000. Over the next five years the DO trend remains increasing and has reached a level of 7.8 mg/L in 2005. Figure 3.13 shows the median DO levels in the Christina River from 1971–2005.

Figure 3.10 Median DO in the Brandywine Creek

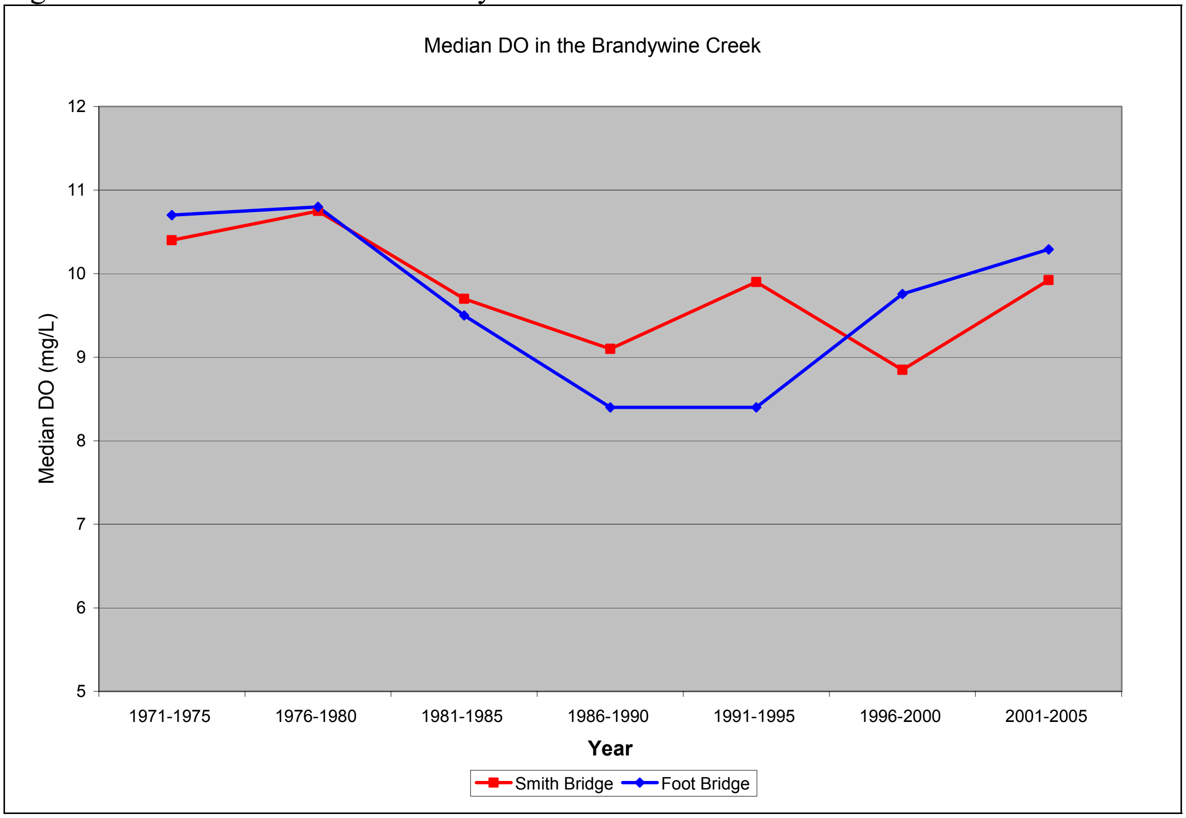


Figure 3.11 Median DO in the Red Clay Creek

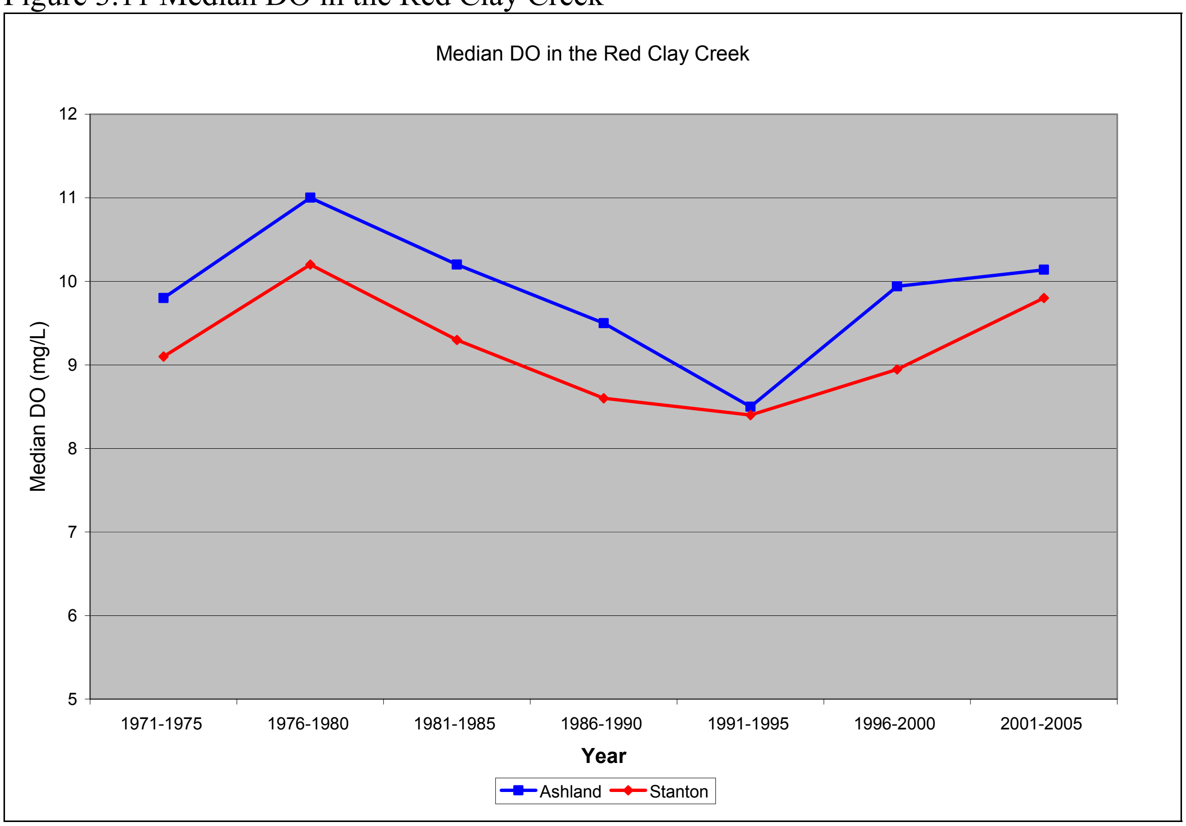


Figure 3.12 Median DO in the White Clay Creek

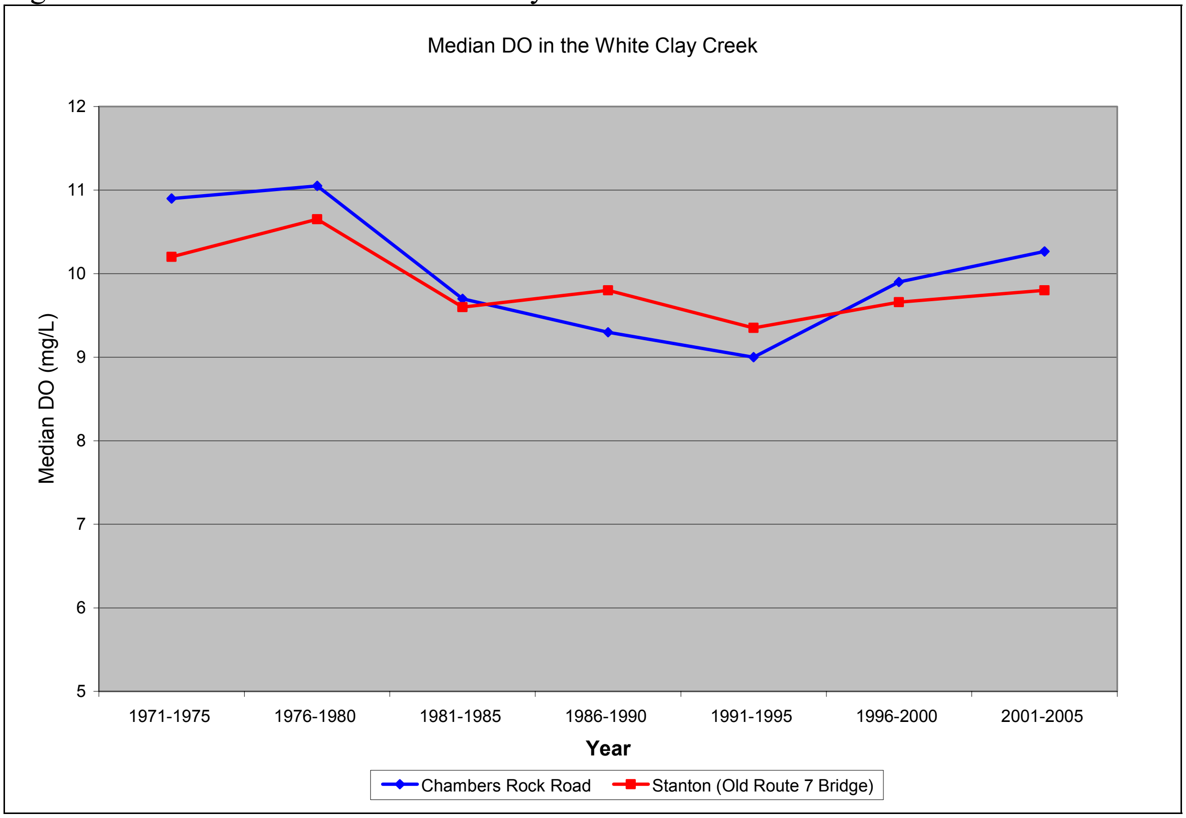
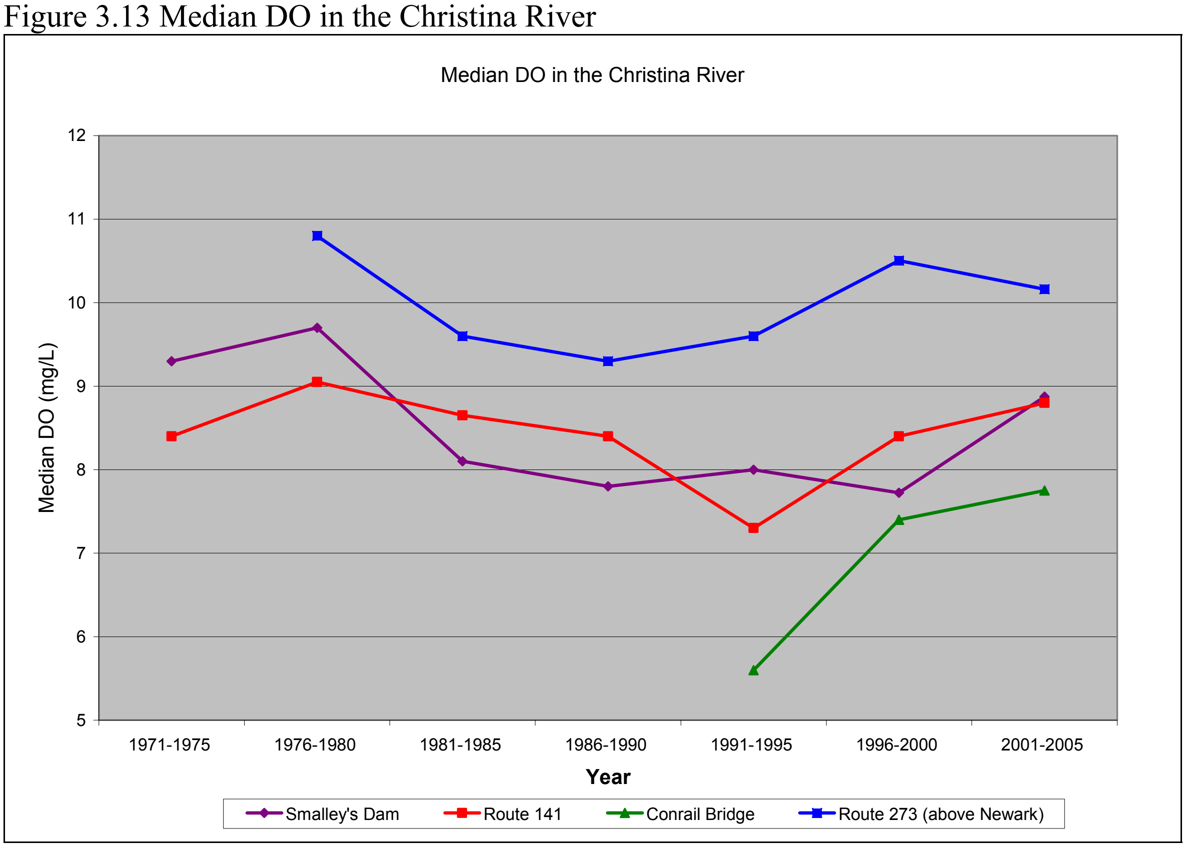


Figure 3.13 Median DO in the Christina River



3.4 Bacteria Trends

The State of Delaware Surface Water Quality Standards, as amended July 11, 2004, provides specific numeric criteria for bacteria for the waters of the Christina Basin. The water quality standard for enterococcus bacteria in the Christina Basin is as follows for primary contact recreation for fresh waters:

- Single-sample value is 185 enterococcus colonies per 100 ml.
- The geometric mean of representative samples should not exceed 100 colonies per 100 ml.

The median enterococcus bacteria levels in the Brandywine, Red Clay, and White Clay Creeks, and Christina River are discussed in more detail below.

Brandywine Creek

The enterococcus bacteria levels in the Brandywine Creek show no apparent trend. At the Foot Bridge sampling station there was an initial increase in the levels from 82 cfu/ml to166 cfu/ml, followed by a leveling off at the higher end of the range. At Smith Bridge, the levels continue to fluctuate, most recently at a high point of 127 cfu/ml. Figure 3.14 shows the median enterococcus bacteria levels in the Christina River from 1991–2005.

Red Clay Creek

The levels of enterococcus bacteria in the Red Clay Creek differ between the two sampling stations. Both the Ashland and Stanton sites began with similar readings of slightly above 200 cfu/ml. The bacteria level at the Stanton site then increased to 310 cfu/ml before decreasing in the last five years to its original level slightly above 200 cfu/ml. At the Ashland sampling station, the enterococcus levels fluctuated between the initial level slightly above 200 cfu/ml level and the lower level 160 cfu/ml range. Figure 3.15 shows the median enterococcus bacteria levels in the Christina River from 1991–2005.

White Clay Creek

The enterococcus bacteria levels at both sampling sites in the White Clay Creek were initially around 120 cfu/ml. The levels at the Stanton sampling site spiked to reach 325 cfu/ml, then dipped, and spiked sharply again. At the Chambers Rock Road sampling site the levels stayed relatively flat. Figure 3.16 shows the median enterococcus bacteria levels in the White Clay Creek from 1991–2005.

Christina River

The levels of enterococcus bacteria recorded at the sampling sites in the Christina River vary significantly depending on the time and the site. At the Route 273 site there was a nearly 300 cfu/ml spike after the initial 150 cfu/ml reading, followed by a decrease in levels, and then another a spike in bacteria. The Smalley's Dam site also showed a spike, yet to a lesser degree, in the same time period, but has then steadily declined. The Conrail Bridge site was also relatively high when the other sites peaked and, like Smalley's Dam, has steadily declined since.

The Route 141 site shows a higher initial level than the other sites, but then declines and follows a similar pattern to the Smalley's Dam and Conrail Bridge sites. Figure 3.17 shows the median enterococcus bacteria levels in the Christina River from 1991–2005.

Figure 3.14 Median Enterococcus Bacteria in the Brandywine Creek

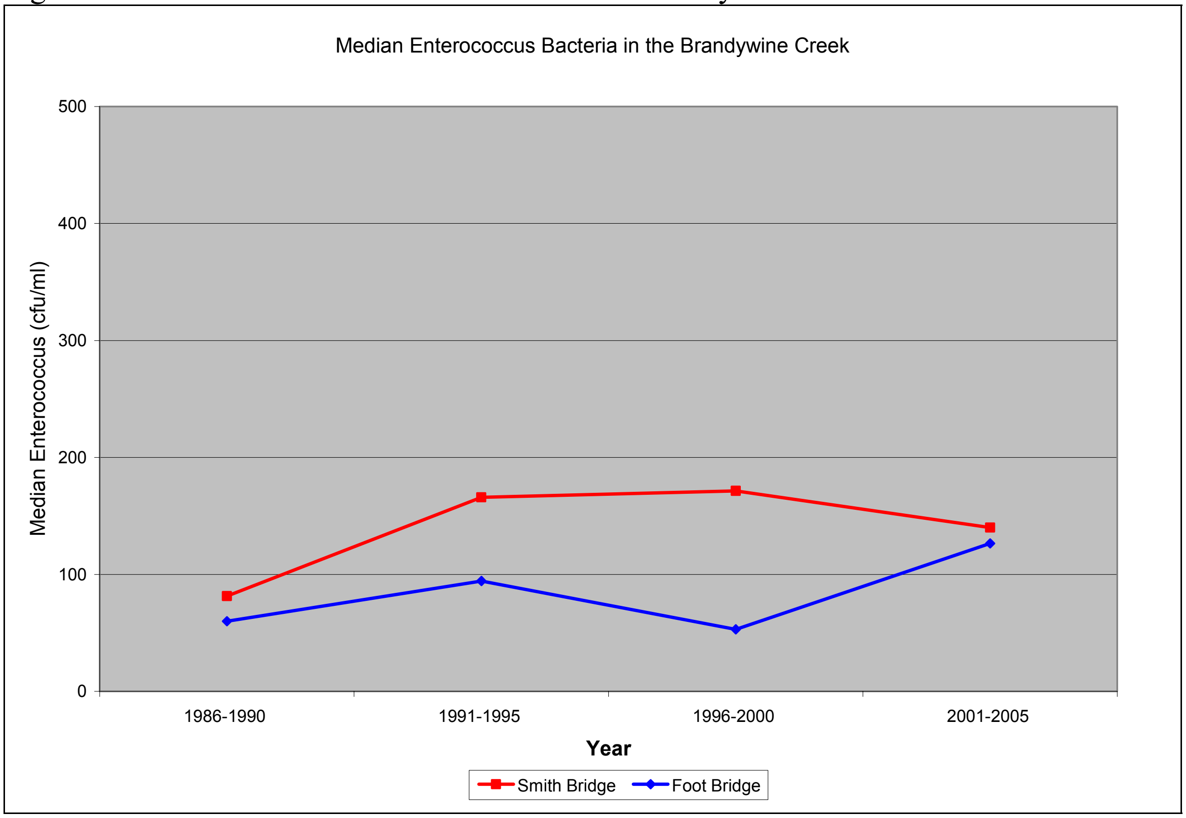


Figure 3.15 Median Enterococcus Bacteria in the Red Clay Creek

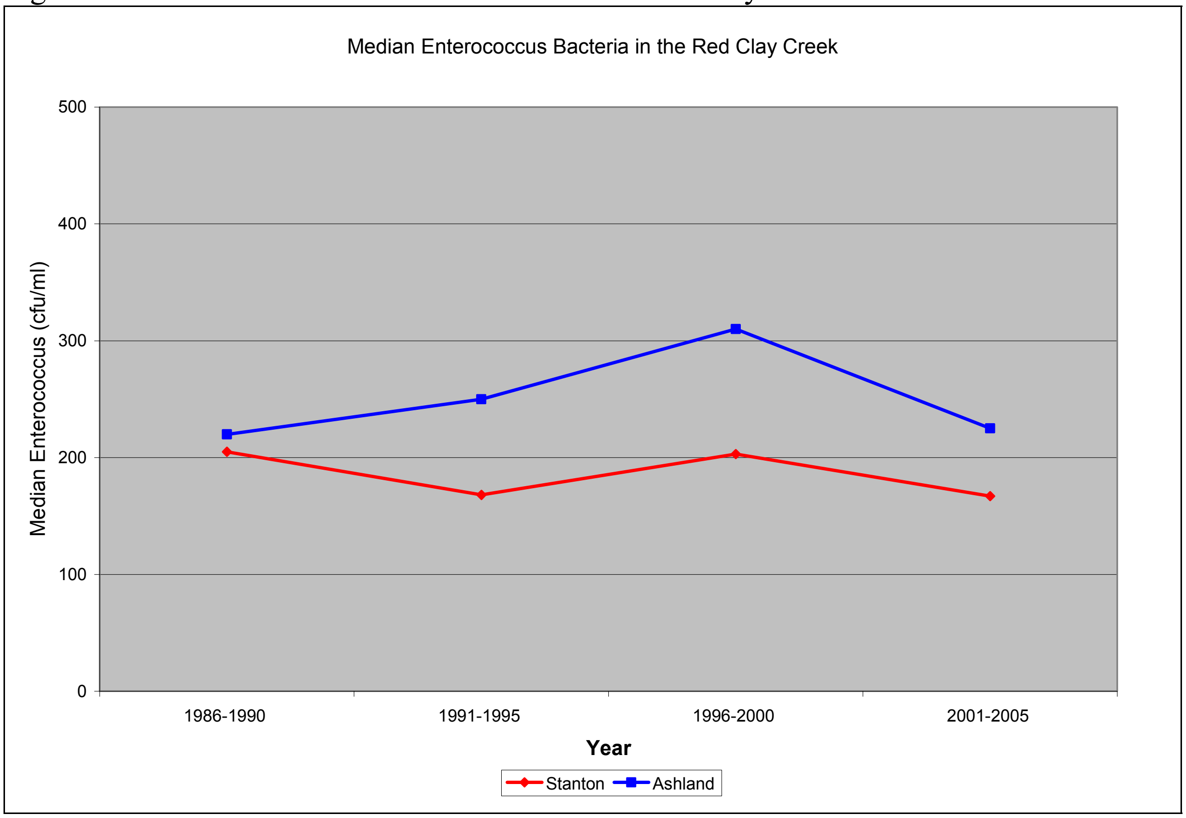


Figure 3.16 Median Enterococcus Bacteria in the White Clay Creek

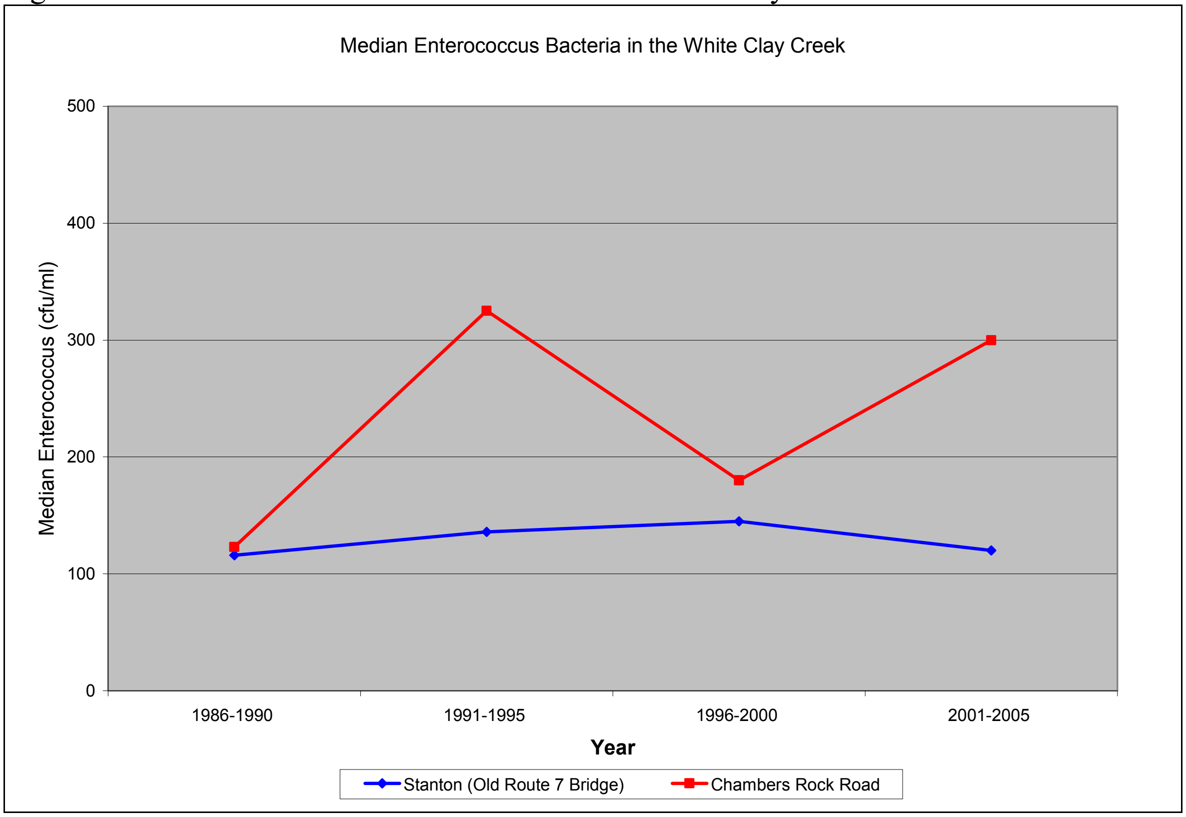
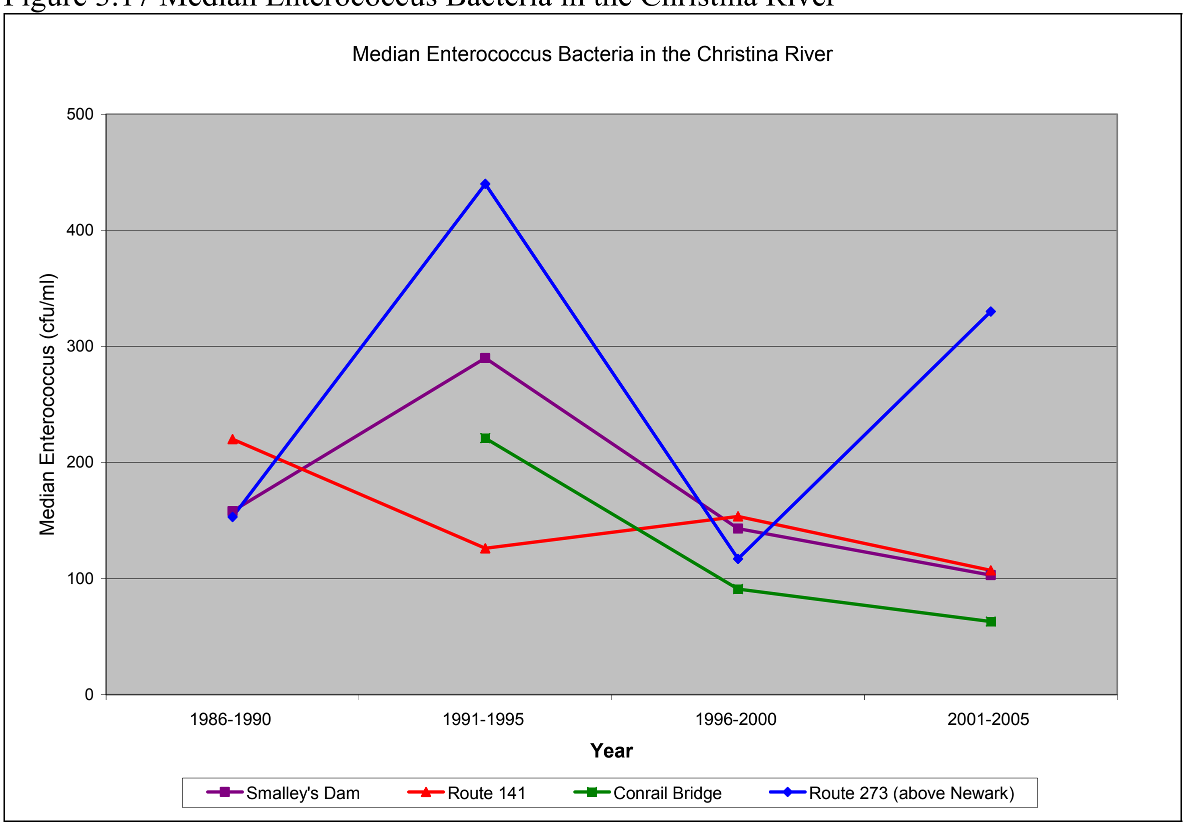


Figure 3.17 Median Enterococcus Bacteria in the Christina River



3.5 Total Suspended Sediment

Total suspended sediment (or total suspended solids) (TSS) is suspended or dissolved matter in the water column. Excess suspended or dissolved matter in the water column can harm the aquatic life and stream habitat. Minimizing the sediment entering a stream is an important component of water quality protection. Currently Delaware does not have stream water quality standards for TSS. New Jersey sets a maximum level of 40 mg/L for warm water streams and 20 mg/L for cold water streams. These standards are used in the following TSS analysis.

Median levels and all but a few individual samples are comfortably below a sediment stream water quality standard of 40 mg/L (adopted from New Jersey Department of Environmental Protection (DEP) as a default standard). The decline in sediment levels since the 1970s is attributed to soil erosion and sediment control ordinances enacted since then and implemented at new development and on farms by the Chester County and New Castle Conservation Districts in Pennsylvania and Delaware. TSS levels in the Brandywine, Red Clay, and White Clay Creeks, and the Christina River are discussed in more detail below.

Brandywine Creek

The trend for TSS in the Brandywine Creek at Smith Bridge and at Foot Bridge has a downward trend. The median TSS levels were 16 and 18 mg/L in 1975, and correspondingly decrease for the next 20 years to 4.9 and 5.0 mg/L in 1995. The TSS levels at Foot Bridge remain at this level, while at Smith Bridge the levels increase to 6.0 mg/L in 2000 before declining to a low point of 4.0 mg/L in 2005. Figure 3.18 shows the median TSS levels in the Brandywine Creek from 1971–2005.

Red Clay Creek

The trend for TSS in the Red Clay Creek at Ashland and Stanton is generally decreasing. TSS decreased for 20 years from levels of 14.0 and 12.5 mg/L in 1975 to low values of 6.0 and 3.5 mg/L in 1995. By 2005 this value has increased to approximately 6.0 mg/L. Figure 3.19 shows the median TSS levels in the Red Clay Creek from 1971–2005.

White Clay Creek

The trend for TSS in the White Clay Creek at Stanton sharply decreased from 25 mg/L in 1975 to 10 mg/L just five years later. This value slightly drops for the next two decades and in 2005 reaches a value of 6 mg/L. The TSS in the White Clay Creek at Chambers Rock Road decreases from 14 mg/L in 1975 to 5 mg/L in 1985 where it remains constant until 2000. This value then slightly increases to 7 mg/L in 2005. Figure 3.20 shows the median TSS levels in the White Clay Creek from 1971–2005.

Christina River

All stations on the Christina River experience a ten-year-period decrease in TSS from 1975–1985. TSS values then level off and remain relatively constant until 2005. Route 273 slightly decreases from 10.0 mg/L in 1980 to a low point of 2.0 mg/L in 2000. This value increases to approximately 4.0 mg/L in 2005. The TSS levels at Smalley's Dam Spillway decrease from a high point of 29 mg/L in 1975 to 16 mg/L in 1980. The TSS levels then increase to 20 mg/L in 1990 before reaching a low of 11 mg/L in 2005. Route 141 decreases from a high point of 57 mg/L in 1975 to 28 mg/L in 1985. It then remains relatively constant and ends at 25 mg/L in 2005. Conrail bridge decreases from 24 mg/L in 1995 to 19.5 mg/L in 2005. Figure 3.21 shows the median TSS levels in the Christina River from 1971–2005.

Figure 3.18 Median TSS in the Brandywine Creek

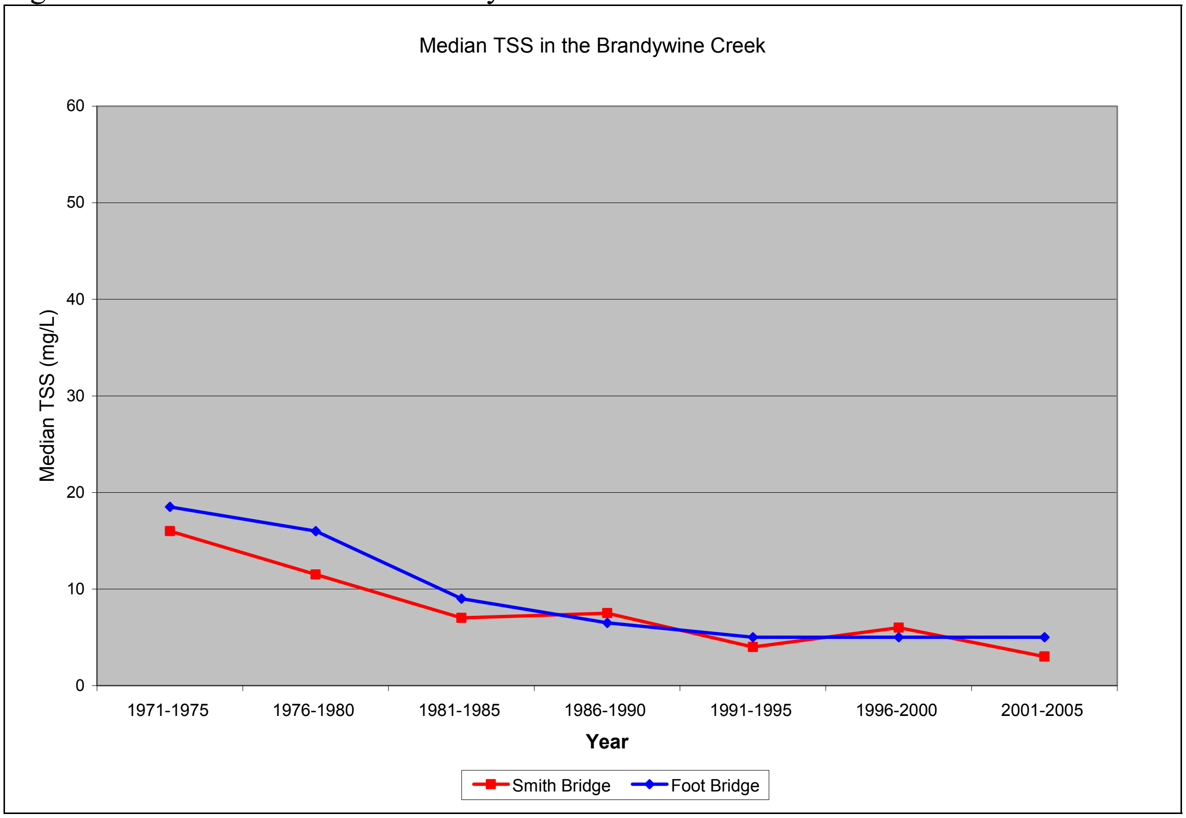


Figure 3.19 Median TSS in the Red Clay Creek

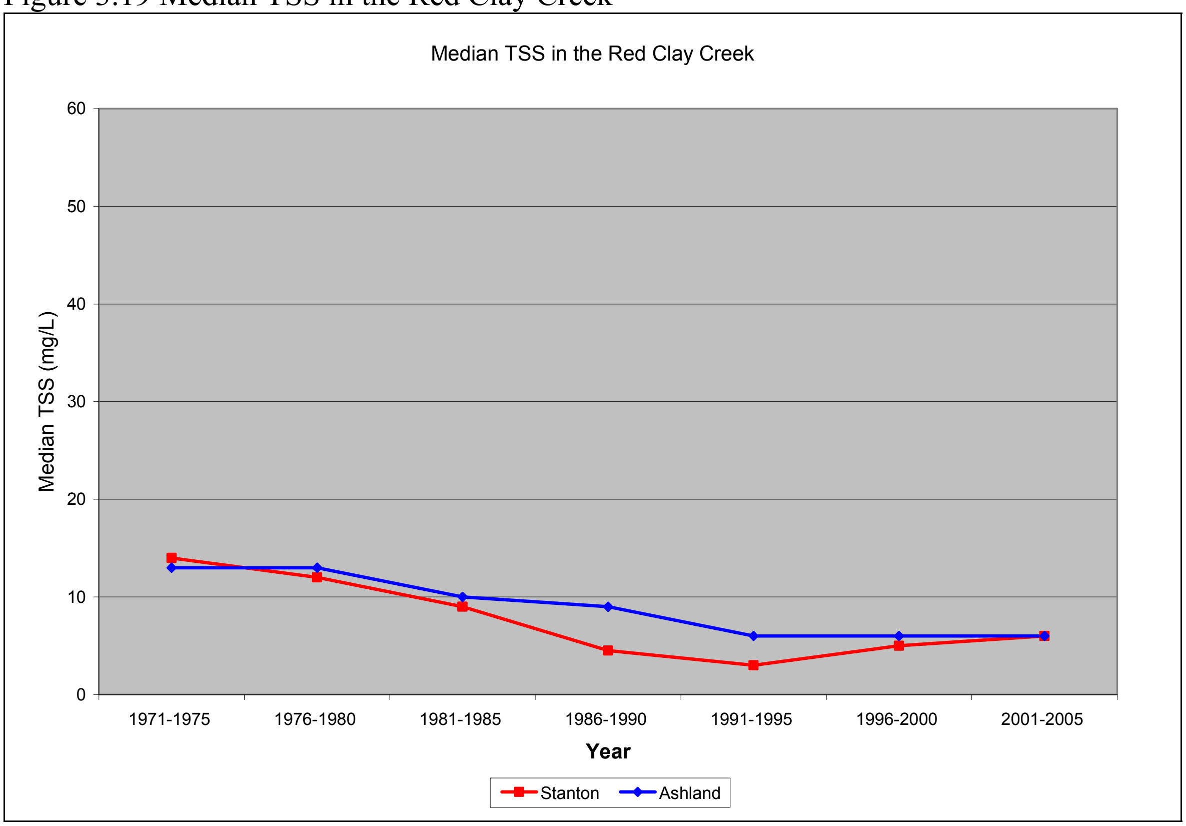


Figure 3.20 Median TSS in the White Clay Creek

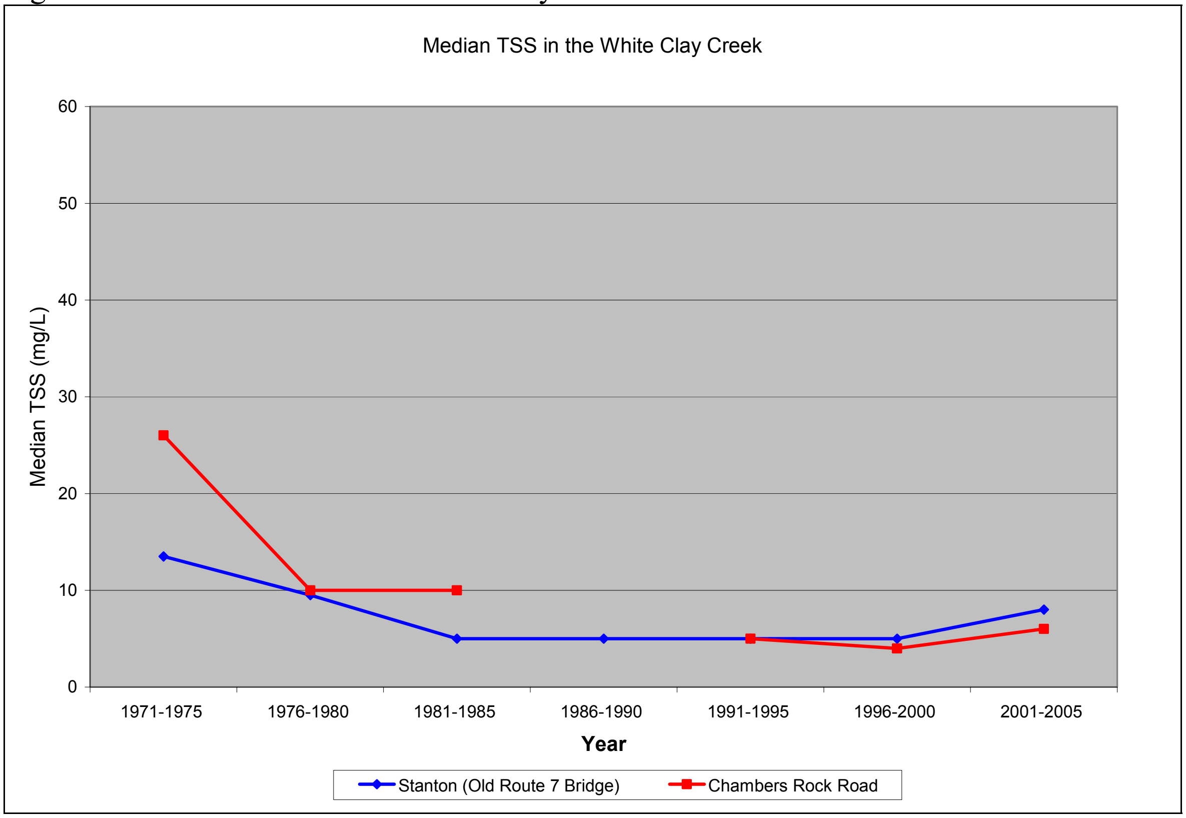
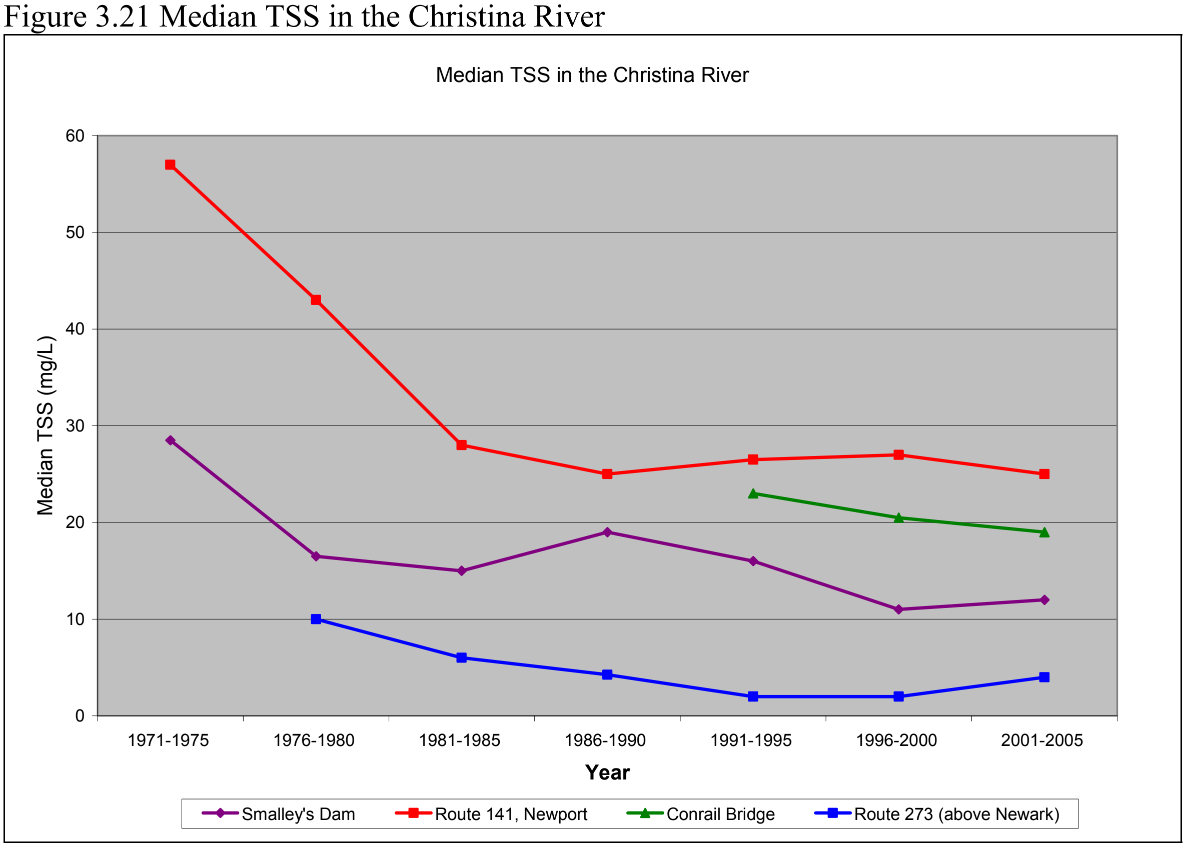


Figure 3.21 Median TSS in the Christina River



3.6 Stream Habitat and Biological Health of the Streams

Trout Streams

There are no reproducing wild trout streams in the Delaware portion of the Christina Basin because the water becomes too warm during the summer. Waters are cool enough in the spring and fall to support a put-and-take stocked trout fishery along the following Delaware Piedmont streams. These are the only six trout streams in Delaware as the Piedmont streams with habitat support trout occupy only 3 percent of Delaware's land area. The put-and-take trout streams in the Delaware portion of Christina Basin are:

- Christina Creek (5.2 mi.)
- White Clay Creek (5.3 mi.)
- Pike Creek (3.3 mi.)
- Mill Creek (3.8 mi.)
- Beaver Creek, tributary to Brandywine (0.6 mi.)
- Wilson Run, tributary to Brandywine (1.0 mi.)

Dams (Hydrologic Impediment)

According to the U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers, 36 dams exist in the Christina Basin. Of these dams, 15 are situated along the downstream reaches of the Brandywine, Red Clay, and White Clay Creeks, and Christina River thus serving as hydrologic impediments to the migration of anadromous fish species such as shad and herring. If these low head (less than 10 feet), former mill dams are removed or fitted with fish ladders, then the Brandywine Creek and Christina River watersheds can be open to the potential for American shad restoration. The Brandywine Conservancy in Chadds Ford, Pennsylvania, recently received a grant from the National Fish and Wildlife Foundation and the Partnership for the Delaware Estuary to collaborate with the DNREC Division of Fish and Wildlife to improve fish passage at the low head dams along the Brandywine Creek through and above Wilmington, Delaware. Table 3.3 lists the dams serving as impediments to fish passage along streams in the Christina Basin.

Table 3.3 On-stream Dams in the Christina Basin

Stream	River Mile, or Feet above Mouth	Name of Dam	Height of Dam (ft.)
Brandywine Creek	2.37 mi.	Baynard Boulevard (No. 1)	4
	3.04	City Dam (No. 2)	5
	3.50	No. 3	5
	3.75	No. 4	2
	4.35	No. 5	6
	4.62	No. 6	7
Red Clay Creek	9,500 ft.	Kiamensi Road (No. 1)	12
	13,500	Kirkwood Highway (No. 2)	8
	17,000	No. 3	5
	26,000	Lancaster Pike (No. 4)	2
	35,000	No. 5	7
	43,900	No. 6	6
	56,300	Sharpless Road (No. 7)	7
	58,800	(No. 8)	8
	62,200	Yorklyn Road (No. 9)	4
	67,300	State Line (No. 10)	8
White Clay Creek	22,300	Delaware Park Race Track (No. 1)	8
	40,200	Kirkwood Highway (No. 2)	3
	50,000	No. 3	4
	53,300	Route 72 Paper Mill Road (No. 4)	6
	58,400	No. 5	10
	61,300	No. 6	3
	67,000	No. 7	6
Christina River	60,500	Smalley's Pond (No. 1)	10
	101,000	I-95, Cooch Farm (No. 2)	11

Source: FEMA Flood Insurance Study for New Castle County, Delaware and National Inventory of Dams

Macroinvertebrates

The principal causes of biological impairment to macroinvertebrates are nonpoint source stormwater runoff from agricultural and urban/suburban land uses. Bans on agricultural pesticides such as DDT by the USEPA in 1972 are thought to have improved the macroinvertebrate health of the streams. Table 3.4 summarizes the biological health of the streams in the Christina Basin according to a 1998 macroinvertebrate survey conducted by the Delaware DNREC's Division of Water Resources, Watershed Assessment Section.

Table 3.4 Macroinvertebrate Survey Results in the Christina Basin

Assessment	**Rating (Percent of BCI)**	**Number of Stream Miles**	**Percent of Stream Miles**
Good	67 – 100 %	26.9	21.5 %
Fair	34 – 66 %	59.7	47.8 %
Poor	0 – 33 %	19.6	15.8 %
Unassessed		18.6	14.9 %
Total		**124.9**	**100.0 %**

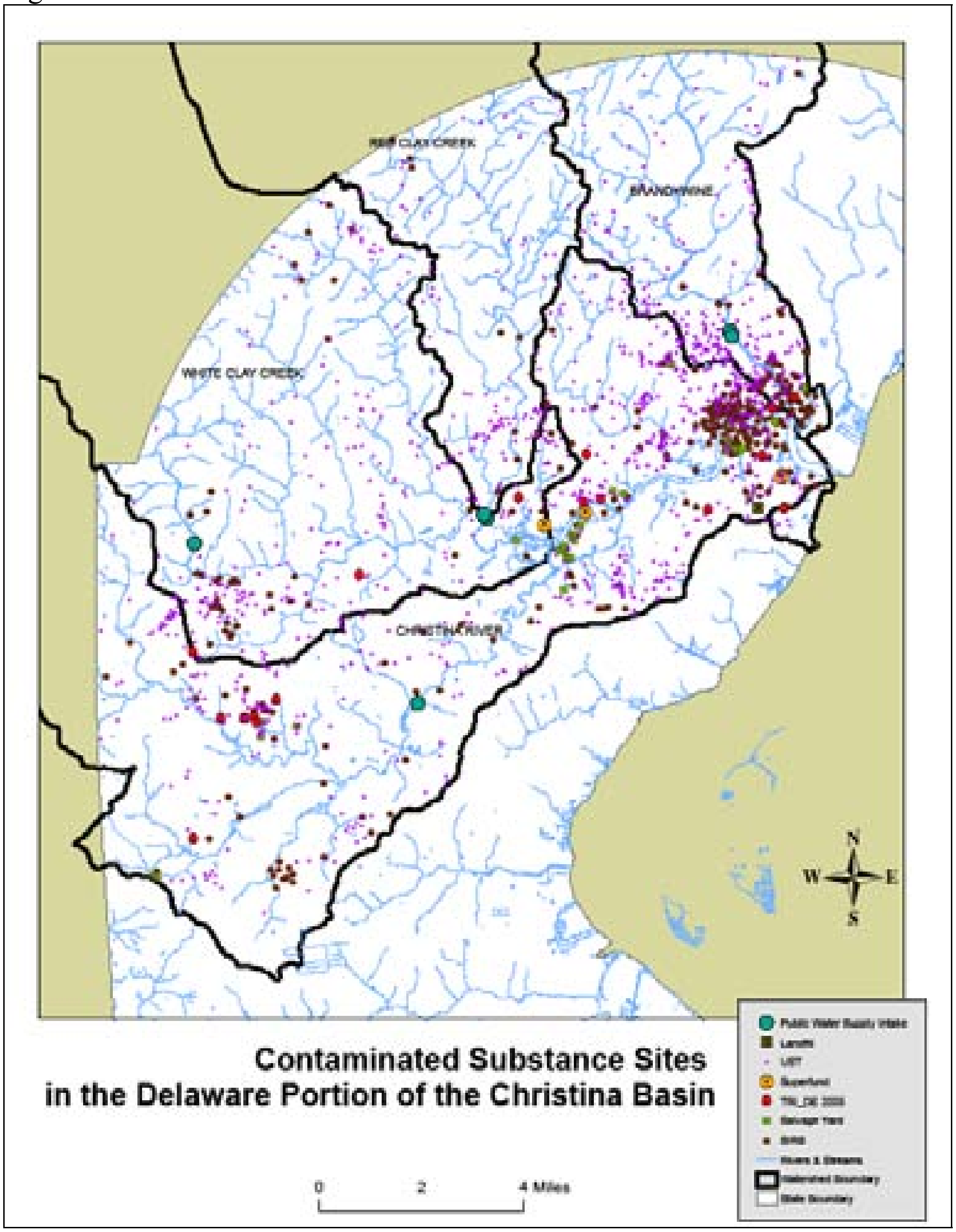
3.7 Contaminated Substance Sites

The Delaware portion of the Christina Basin contains contaminated substance sites that are potential threats to the water quality. These sites range from highly toxic pollutant contributors such as the three federal superfund sites to sites of lesser pollutant potential, such as the 1,256 underground storage tanks (UST). This contaminated substance site data for the Delaware portion of the Christina Basin is downloaded from DNREC's Delaware Environmental Navigator (DEN). The contaminated substance sites in the Delaware portion of the Christina Basin that are discussed in this section include: federal superfund sites, site investigation and remediation branch sites (SIRB), salvage yards, toxic release inventory (TRI) sites, landfills, and USTs. Table 3.5 lists the contaminated substance sites in the Delaware portion of the Christina Basin and divides them according to the respective watershed and type of site. According to Table 3.5 there are 1,650 contaminated substance sites in Delaware with the potential to negatively impact public drinking water supplies and the water quality in the Brandywine, Red Clay, and White Clay Creeks, and Christina River in Delaware. Figure 3.22 shows the spatial distribution of the contaminated substance sites in the Christina Basin. The map clearly illustrates that the Christina River watershed contains a disproportionately higher number of sites.

Table 3.5 Contaminated Substance Sites in the Christina Basin

Type of Contaminated Substance Site	Number of Contaminated Sites per Watershed				Total Sites in the Christina Basin
	Christina River	White Clay	Red Clay	Brandywine	
Superfund	2	1	0	0	**3**
SIRB	228	46	9	56	**339**
Salvage Yards	31	1	0	1	**33**
TRI	15	2	0	1	**18**
Landfills	1	0	0	0	**1**
UST	672	229	100	255	**1256**
TOTAL Contaminated Substance Sites per Watershed	**949**	**279**	**109**	**313**	**1,650**

Figure 3.22 Contaminated Substance Sites in the Christina Basin



3.8 Fish Consumption Advisories

Seven streams in the Christina Basin in Delaware have full or limited fish consumption advisories due to high levels of PCBs, dieldrin, and dioxin in the fish fatty tissue. A summary of the fish consumption advisories in the rivers and streams of the Delaware portion of the Christina Basin are shown in Table 3.6.

Table 3.6 Christina Basin Fish Consumption Advisories

Waterbody	Species	Geographical Extent	Contaminants of Concern* **	Advice
Tidal Brandywine River	All Finfish	River Mouth to Baynard Blvd.	PCBs	No Consumption
Non-tidal Brandywine River	All Finfish	Baynard Blvd. to Pennsylvania Line	PCBs, Dioxin	No more than two 8-ounce meals per year
Tidal Christina River	All Finfish	River Mouth to Smalley's Dam	PCBs, Dieldrin	No Consumption
Non-tidal Christina River	All Finfish	Smalley's Dam to Del./Md. Line	PCBs, Dieldrin, Chlordane	No more than six 8-ounce meals per year
Tidal White Clay Creek	All Finfish	River Mouth to Route 4	PCBs	No Consumption
Non-tidal White Clay Creek	All Finfish	Route 4 to Del./Pa. Line	PCBs	No more than one 8-ounce meal per month
Red Clay Creek	All Finfish	State Line to Stanton	PCBs, Dioxin, Chlorinated Pesticides	No more than two 8-ounce meals per year
Little Mill Creek	All Finfish	Creek Mouth to Kirkwood Highway	PCBs	No Consumption
Becks Pond	All Finfish	Entire Pond	PCBs, Mercury	No more than one 8-ounce meal per year
Christina Creek	Stocked Trout	Rittenhouse Park to Del./Md. Line	PCBs, Dieldrin	No more than six 8-ounce meals per year
Designated Trout Streams and Ponds other than Christina Creek	Stocked Trout	Designated Trout Stocking Areas are listed in the Delaware 2006 Fishing Guide and at *http://www.dnrec.state.de.us/fw/Trout/TroutMaps.htm*	PCBs	No more than one 8-ounce meal per month

3.9 Total Maximum Daily Loads in the Delaware Portion of the Christina Basin

In 1997, a federal court case required Delaware to set pollution limits for our waterways because existing pollution control activities in the Christina Basin were not sufficient to meet Delaware state water quality standards. The low flow (point source) Total Maximum Daily Loads (TMDLs) were issued by the U.S. Environmental Protection Agency (EPA) in October 2002. EPA completed the high flow (stormwater) TMDLs in April 2005 and issued a revised version in September 2006. Appendix A summarizes the section 303(d) list of waters needing TMDLs in the Christina Basin.

TMDLs set limits on the amount of pollutants that can be discharged into a waterbody and still protect its water quality. They are established along impaired waterways in accordance with Section 303(d) of the federal Clean Water Act. The maximum amount of a particular pollutant discharged to a waterway without violating stream water quality standards, or the TMDL, is determined using hydrologic and hydraulic computer models according to the following equation:

$$TMDL = WLA + LA + FS$$

Where WLA is the waste load allocation from point sources such as wastewater treatment plants during low flow conditions, LA is the load allocation from nonpoint sources such as stormwater and agricultural runoff during high flow conditions, and FS is the factor of safety to account for imprecision in modeling and monitoring. Delaware identified over a dozen stream segments on its 2006 Section 303(d) list that do not meet water quality standards for nutrients (nitrogen and phosphorus) and low DO within the Christina Basin. Table 3.7 lists the impaired stream reaches on this list.

Table 3.7 Christina Basin Stream Reaches on the Delaware 2006 303(d) List

Watershed ID	Watershed Name	Subwatershed	Miles	Pollutants
B16	Brandywine Creek	Brandywine Creek above Wilmington	9.3	nutrients
B17	Brandywine Creek	Brandywine Creek below Wilmington	3.8	nutrients
R3	Red Clay Creek	Burroughs Run	2.6	nutrients
R4 and R5	Red Clay Creek	Red Clay Creek above and below Wooddale	12.8	nutrients
W5	White Clay Creek	Mill Creek	8.3	nutrients
W6	White Clay Creek	Pike Creek	5.4	nutrients
W7	White Clay Creek	Middle Run	4.5	nutrients
W8, W9, W10	White Clay Creek	White Clay Creek above/below Newark	15.6	nutrients
C1	Christina River	Upper Christina River above Cooches Bridge	13.6	nutrients
C4	Christina River	Little Mill Creek	5.1	nutrients, DO
C5	Christina River	Christina River below Newark	7.5	nutrients
C6	Christina River	Tidal Christina below Smalley's Pond	7.5	nutrients, DO

The Christina Basin high flow TMDLs require specific reductions in nonpoint sources of pollutants, including nitrogen, phosphorus, and bacteria, to restore the rivers and streams of the Delaware portion of the Christina Basin to a healthy condition for use and recreation. Nitrogen, phosphorus, and bacteria enter our waterways from a variety of sources including point and nonpoint sources. Point sources include end-of-pipe discharges from municipal and industrial wastewater treatment plants, industrial uses, and the combined sewer system (CSS). In addition to these point source discharges that directly enter the surface water, the atmospheric deposition of nitrogen from regional sources such as motor vehicle exhaust and fossil fuel burning power plants also increase nitrogen levels in the waterways of the Christina Basin. Previous pollution control efforts have focused on the point source and atmospheric sources of nitrogen, phosphorus, and bacteria, and it is the intent of this document to focus solely on reducing the nonpoint sources of these contaminants. The Christina Basin TMDLs addressed in this PCS specifically target nonpoint source pollution including runoff from agricultural and urban areas and seepage from septic systems and cesspools.

The designated uses of the streams in the Delaware portion of the Christina Basin vary, and therefore the allocated nutrient and bacteria reduction levels vary. Table 3.8 lists the designated uses of the streams in the Delaware portion of the Christina Basin as excerpted from the State of Delaware Surface Water Quality Standards (DNREC, 2004). The level of pollution reductions necessary to achieve the designated uses in the streams of the Delaware portion of the basin vary significantly. For example, bacteria levels need to be reduced as much as 95 percent in some areas, nitrogen levels need to be reduced as much as 50 percent in some areas, and phosphorus levels need to be reduced as much as 89 percent in some areas. In contrast, other areas of the basin are relatively free of excess nitrogen, phosphorus, and bacteria and simply need to be protected in their current state. Figures 3.23–3.26 graphically represent the pollution reductions as mandated by the USEPA for the Brandywine, Red Clay, and White Clay Creeks, and the Christina River.

Table 3.8 Designated Uses in the Streams of the Christina Basin

Waterbody	Public Water Supply	Industrial Water Supply	Primary Contact Recreation	Secondary Contact Recreation	Fish, Aquatic Life, and Wildlife	Cold Water Fish (Put and Take Trout)	Agriculture Water Supply	ERES* Waters
Brandywine Creek	Freshwater only	X	X	X	X	Beaver Run, Wilson Run	Freshwater only	Pa./Del. line to Wilmington city line
Red Clay Creek	X	X	X	X	X	Pa./Del. line to Yorklyn	X	--
White Clay Creek	Freshwater only	X	X	X	X	Pa./Del. line to Curtis Mill**	Freshwater only	Pa./Del. line to Curtis Mill
Christina River	Freshwater only	X	X	X	X	Md./Del. line to Rittenhouse Park.	Freshwater only	--
* ERES = Streams of ecological and recreational significance.								
** Also Mill Creek from Brackenville Road to Route 7 and Pike Creek from Route 72 to Henderson Road.								

Figure 3.23 TMDLs in the Delaware Portion of the Red Clay Creek Watershed

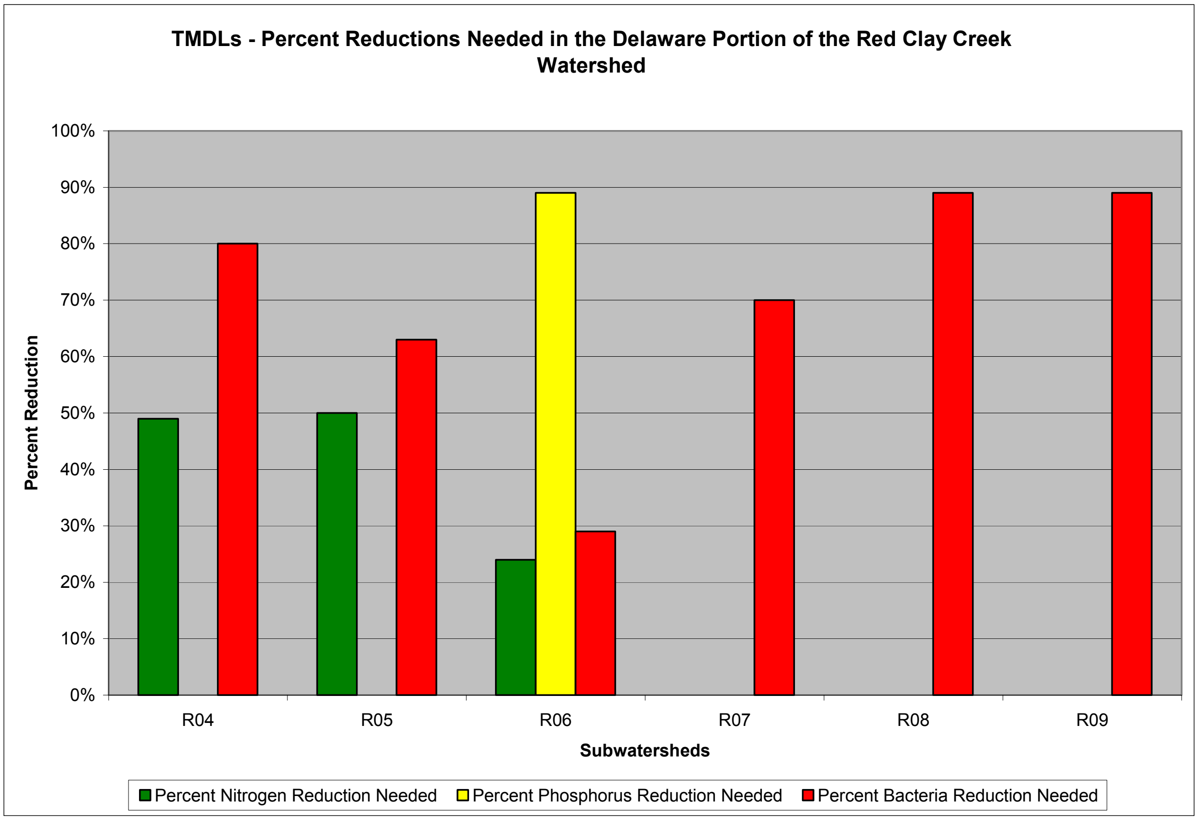


Figure 3.24 TMDLs in the Delaware Portion of the White Clay Creek Watershed

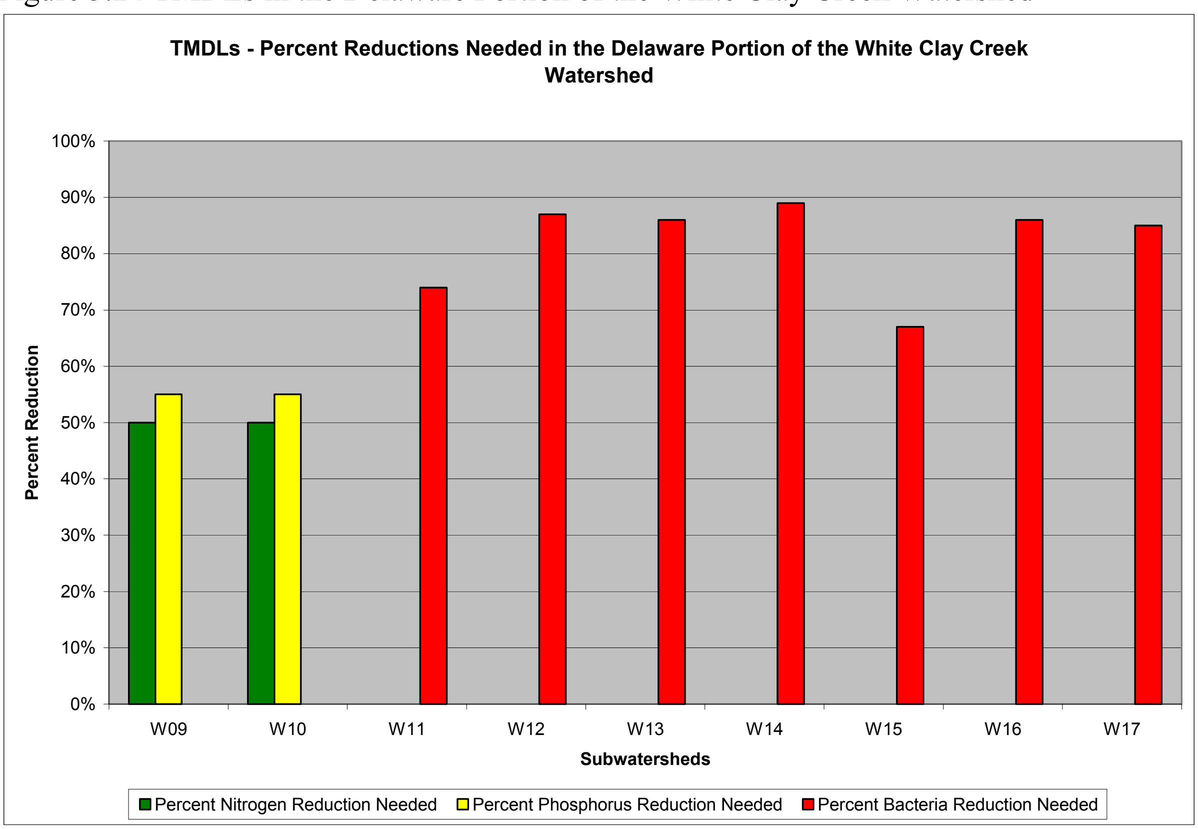


Figure 3.25 TMDLs in the Delaware Portion of the Brandywine Creek Watershed

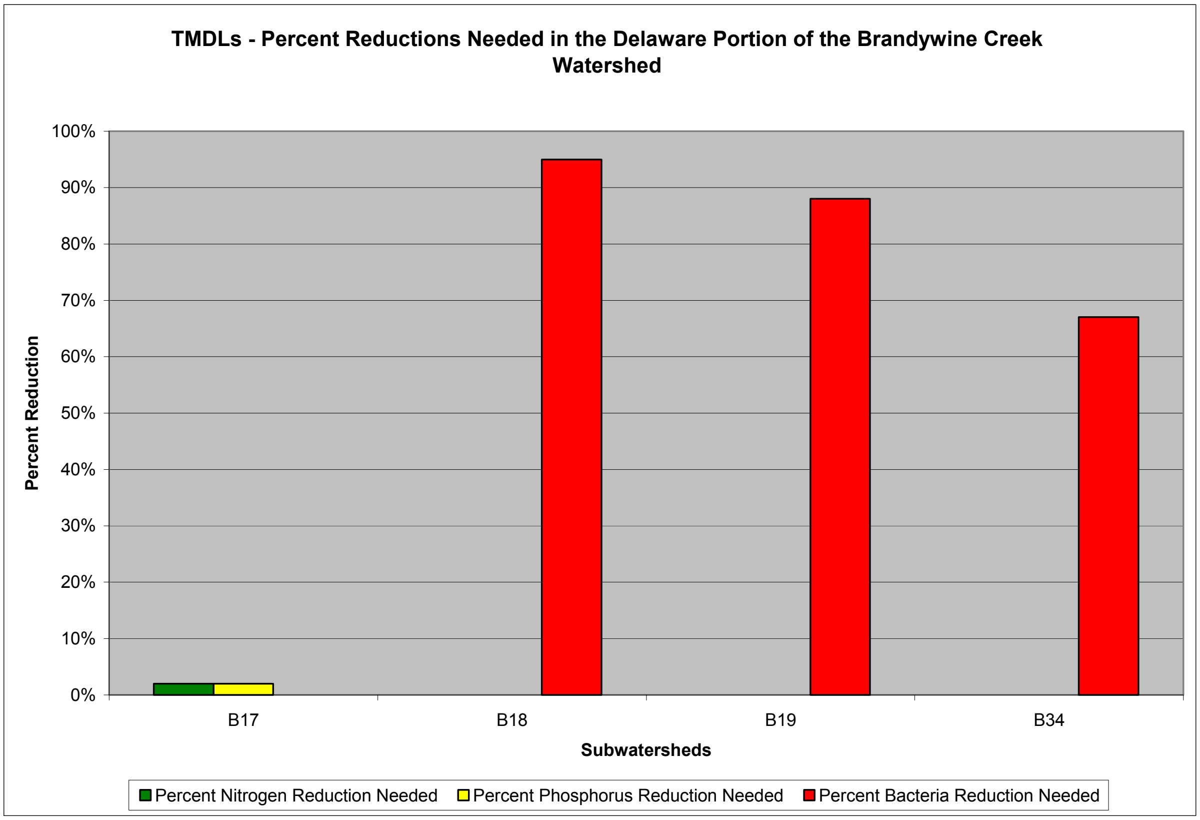
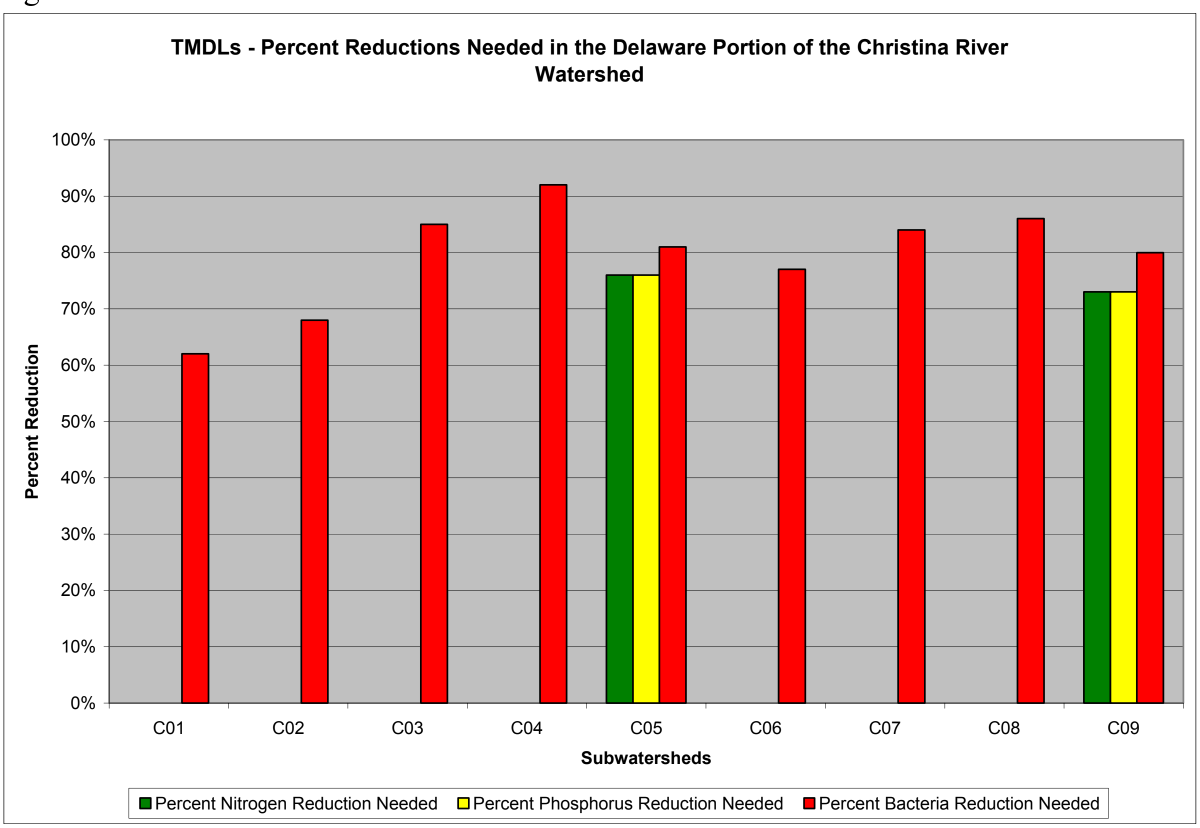


Figure 3.26 TMDLs in the Delaware Portion of the Christina River Watershed



Chapter 4: Recommendations to Achieve the TMDLs

4.1 Recommendations

This chapter of the Christina Basin Pollution Control Strategy (PCS) includes discrete and specific measures that the Christina Basin Tributary Action Team (TAT) has identified as having the potential to achieve the TMDLs set for the Delaware portion of the Christina Basin. This PCS, specifically chapters 4, 5, and 6, is a living document and as additional information and data is collected the document will be refined. The Christina Basin TAT has developed and accepted 40 recommendations that are discussed in detail in this chapter. These 40 recommendations will serve as the tools, and the supporting information provided for each recommendation will serve as a resource, to begin the efforts of achieving the Christina Basin TMDLs.

The Team's 40 specific recommendations are divided among five major categories: stormwater, open space, wastewater, agriculture, and education. The stormwater category contains 8 recommendations, the open space category contains 7 recommendations, the wastewater category contains 7 recommendations, the agriculture category contains 7 recommendations, and the education category contains 11 recommendations. Each one of these 40 recommendations contains detailed information on the recommendation, the nutrient and bacteria reductions associated with the recommendation, the cost of implementing the recommendation, the source of funding associated with the implementation, the priority location for implementing the recommendation, the organizations or stakeholders involved with implementing the recommendation, and the type of action (regulatory, ordinance, or voluntary). The stormwater, open space, wastewater, agriculture, and education recommendations are discussed in detail in Sections 4.2, 4.3, 4.4, 4.5, and 4.6 respectively. Appendix B contains an outline of the 40 recommendations discussed in detail in the following sections.

4.2 Stormwater Recommendations

The stormwater recommendations for the Delaware portion of the Christina Basin are an essential component of the PCS as a large percentage of the land use in this portion of the watershed is urban/suburban. Approximately 87 sq. mi. or 52.4 percent of the Delaware and Maryland portions of the Christina Basin are categorized as urban/suburban. This land use estimate includes both the Delaware and Maryland portions of the entire Christina Basin yet the Maryland portion is minimal, less than one percent of the entire Christina Basin. The Christina Basin Tributary Action Team has developed eight recommendations to reduce the nitrogen, phosphorus, and bacteria contributions from stormwater runoff in the Christina Basin. These recommendations are listed in Table 4.1 and are described in more detail in this section. The intent of these stormwater recommendations is to make progress toward achieving the Christina Basin TMDLs.

Table 4.1 Stormwater Recommendations

Stormwater
SW1. Increase urban tree canopy.
SW2. Design stormwater best management practices to reduce nutrients according to the total maximum daily loads, where feasible and effective.
SW3. Limit addition of new impervious cover to less than 20 percent of the watershed above public drinking water supply intakes.
SW4. Promote low impact development in new construction and redevelopment.
SW5. Amend stormwater ordinances to create consistency throughout the watershed.
SW6. Expand the role of the Resource Protection Area Technical Advisory Committee to create a Christina Basin group responsible for reviewing new development.
SW7. Implement a stormwater utility: a. Maintain best management practices b. Reduce and manage existing impervious cover.
SW8. Identify areas where stormwater retrofits would effectively reduce sediment and nutrients.

Although bacteria estimates are not quantified in several of the nutrient reduction sections in this analysis, bacteria reductions tied to the stormwater recommendations are implied. Further research quantifying the bacteria reductions associated with the stormwater recommendations is an important tool in identifying which practices will be the most effective in decreasing the bacteria loads reaching the streams and rivers of the Christina Basin. In addition to the eight specific tools outlined in Table 4.1, the team recommends an overarching research request related to bacteria research and the stormwater recommendations. The team requests that DNREC conduct a literature review to quantify the bacteria reduction values associated with the stormwater BMPs outlined in this document. If completed, this research will provide reduction estimates that will support implementation and funding for stormwater BMPs, which will lead to improvements in water quality and achieving the bacteria TMDLs.

SW1. Increase Urban Tree Canopy

The Christina Basin TAT recommends increasing the tree canopy in the urban areas and urban corridors of the Delaware portion of the Christina Basin. Trees have proven to be valuable resources for urban communities. Urban trees provide environmental, social, and economic benefits to a community. The values of an urban tree canopy include improved water and air quality, reduced energy costs, increased real estate values, and better business. Trees provide a natural filter to our water supply and reduce stormwater runoff, flooding, and erosion.

According to the Alliance for Community Trees (ACT), it is estimated that one tree reduces approximately 4,000 gallons of stormwater runoff annually, and 400 trees will capture approximately 140,000 gallons of rainwater annually (http://actrees.org /site/resources /index.php). In addition it has been estimated that trees are an economic benefit in terms of reducing stormwater management costs. Research has shown that planting one million trees is equivalent to spending $3.5 million in annual stormwater runoff costs (<http://www.fs.fed.us /psw/programs/cufr/products/cufr604_newsletter _summer2005.pdf>). This, and additional data on the benefits of urban trees, shows that urban trees reduce the volume of stormwater runoff in a cost-effective and aesthetically pleasing way. Reducing the volume of stormwater runoff reaching the streams will directly reduce the nutrient and bacteria loads to the streams while reducing annual stormwater management costs.

To achieve the goals of this recommendation, the tree ordinances for urban areas in the communities in the Delaware portion of the Christina Basin must be reviewed and updated to assist the communities with increasing the urban tree canopy. It is also important that the ordinances include urban tree maintenance requirements. In addition to reviewing existing tree ordinances and developing specific regional tree canopy goals for urban areas, this recommendation must also include an urban tree education component. The goals for this recommendation include:

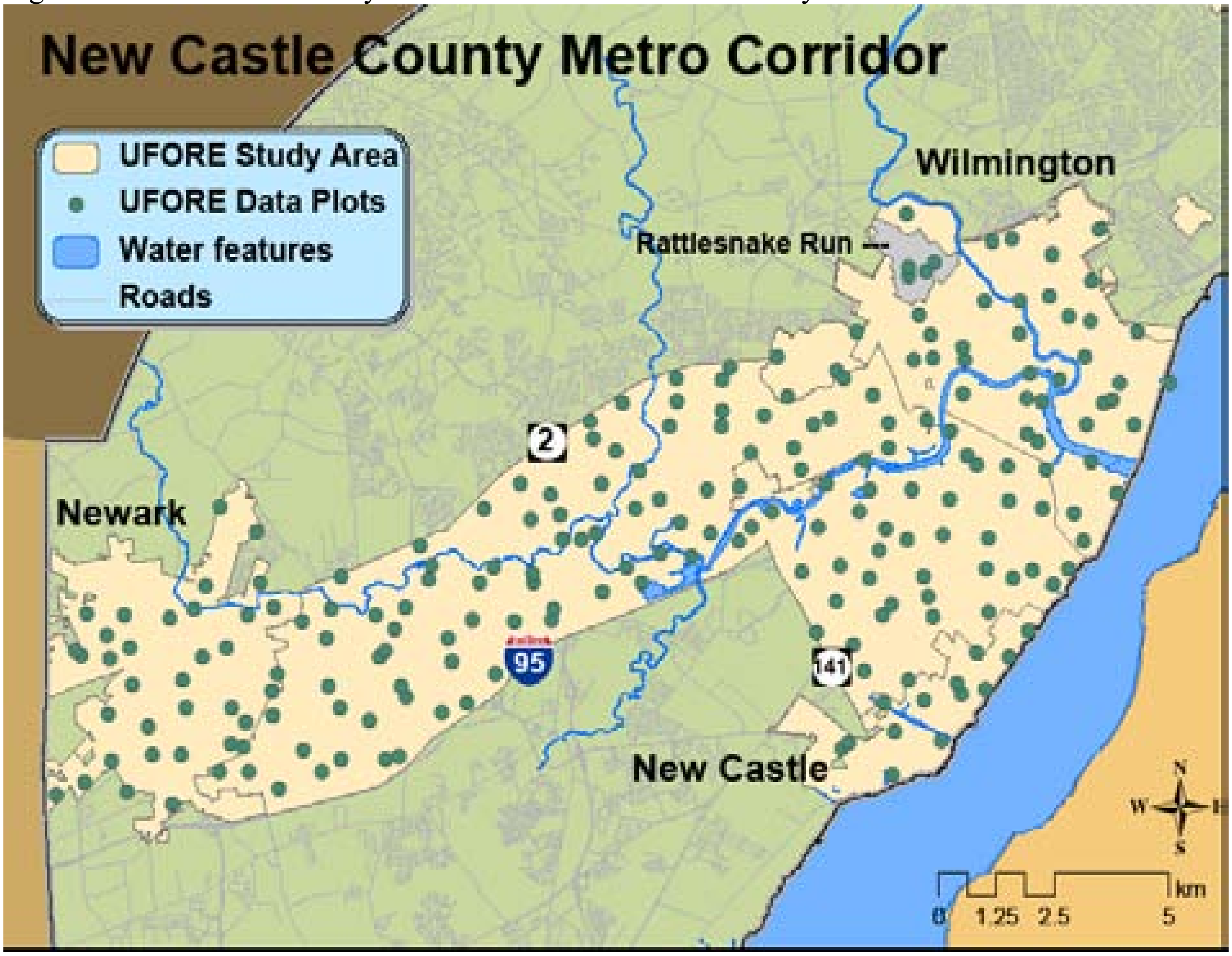
- Convene an urban tree canopy task force or host a forum to present the benefits and nutrient and bacteria reductions associated with increasing the urban tree canopy .
- Review ordinances impacting tree plantings.
- Establish a tree inventory and prioritizing areas for urban tree plantings.
- Set specific urban tree canopy goals.
- Create an arboreal plan for public tree maintenance.
- Develop and adopt rules to protect urban trees.
- Establish an education component to provide public information on the importance and benefits of urban trees as well as the types of trees to plant.

Current Research and Resources for SW1

The USDA Forest Service, SUNY College of Environmental Science and Forestry, and the Delaware Center for Horticulture (DCH), using the Urban Forest Effects (UFORE) model (*www.ufore.org*), have conducted research on the urban forest of the New Castle County metropolitan corridor. This research includes the metropolitan corridor in New Castle County (stretching from the City of Wilmington southwest to the City of Newark), the City of Wilmington, and Rattlesnake Run sewershed within the City of Wilmington (Figure 4.1). This analysis has established estimates for various urban forest structure characteristics including: species composition, tree density, tree health, leaf area, leaf and tree biomass, and species diversity. The researchers studied other components of urban trees including the environmental benefits of the urban tree canopy (ecosystem services), compensatory value of the forest, and potential impacts of infestations.

The knowledge and information gained from this study about the urban forest in the New Castle County metropolitan corridor will be useful tools in the implementation of the Christina Basin PCS urban tree canopy recommendation. This information, in addition to forums and additional research on urban trees, will help to provide a baseline of the current state of the urban tree canopy, the characteristics of the forest, and the benefits of urban trees specifically to water quality and nutrient management. This information is critical in achieving the goals of this recommendation.

Figure 4.1 New Castle County Metro Corridor and UFORE Study Area



Source: Vikram Krisnamurthy, Delaware Center for Horticulture and University of Delaware Center for Energy and Environmental Policy

DCH in Wilmington, Delaware, a local nonprofit dedicated to improving the quality of life in Delaware by promoting knowledge and appreciation of gardening, horticulture, and conservation has developed several tools to encourage establishing a native urban tree canopy. Appendix C and Table 4.2 contain information about native trees. Appendix C contains information compiled by DCH and the National Tree Trust on urban trees recommended for planting in Wilmington and the surrounding areas. The trees listed in Table 4.2 are native to Delaware and the Eastern United States and are highly recommended over planting nonnative trees. Information about invasive species can be found at the DCH, the Delaware Nature Society, and the New Castle Conservation District. Additional information on native plant communities can be found in *A Guide to the Natural Communities of the Delaware Estuary,* produced by Nature Serve and the Partnership for the Delaware Estuary, June 2006. The following are invasive species and are *not* recommended by the Christina Basin TAT:

- *Acer ginnala* – Amur Maple
- *Kolreuteria paniculata* – Goldenrain Tree
- *Prunus subhirtella* – “Autumnalis” Cherry

Appendix D is a document also developed by DCH to provide residents with assistance on urban tree plantings and maintenance.

Table 4.2 Native Trees in Delaware and the Eastern United States

Botanical Name	**Common Name**
Carpinus caroliniana	American Hornbeam
Crataegus viridis	"Winter King" Hawthorne
Ostrya virginiana	American Hophornbeam
Acer rubrum	Red Maple
Acer saccharum	Sugar Maple
Betula nigra	River Birch
Celtis occidentalis	Common Hackberry
Fraxinus americana	White Ash
Fraxinus pennsylvanica	Green Ash
Gleditsia triacanthos "inermis"	Thornless Honey Locust
Gymnocladus dioica	Kentucky Coffeetree
Liquidambar styraciflua	American Sweetgum
Nyssa sylvatica	Black Gum
Quercus bicolor	Swamp White Oak
Quercus imbricaria	Shingle Oak
Quercus palustris	Pin Oak
Quercus phellos	Willow Oak
Quercus rubra	Northern Red Oak
Taxodium ascendens	Pond Cypress
Taxodium distichum	Common Baldcypress

Nutrient and Bacteria Reductions

Urban trees improve water quality primarily by reducing the volume of stormwater runoff. Individual trees intercept from 10–68 percent volume of a rainfall event depending on the tree species. Table 4.3 outlines the benefit of trees versus other land use types based on the total nutrient loads in the stormwater.

Table 4.3 Annual Nutrient Loads in Stormwater

Land Use Type	**Total Phosphorus (lbs/acre/yr)**	**Total Nitrogen (lbs/acre/yr)**
Forest	0.1	0.6
Turf	1.6	7.9
Impervious Surface	2.8	14.7

Source: Cappiella, Schueler, and Wright, 2005

The stormwater benefits of an urban tree canopy have also been demonstrated in Washington, D.C., a highly urbanized area. The USEPA published the report *The Green Build-out Model: Quantifying Stormwater Benefits of Trees and Green Roofs in Washington, D.C.,* by Casey Trees and Limno-Tech, Inc., which details the benefits of green roofs and urban tree canopy. The study was conducted in Washington, D.C., and is a planning tool to quantify the cumulative stormwater benefits of urban tree canopy and green roofs at different coverage scenarios in Washington, D.C. Although Washington, D.C., is a much larger metropolitan area, there are similarities between New Castle County, Delaware, and the study area, such as climate, tree species, and seasonality. Due to these similarities the stormwater volume reductions and nutrient load reductions demonstrated in this research can be loosely applied to the Christina Basin.

In discussing the results of this study it is important to note two points. The researchers used conservative assumptions in the model for the trees' uptake of rainwater. Only interception storage, the amount of rainwater that trees intercept and hold in their leaves, is considered. Stem flow, or the amount of rainwater stored on branches and the trunk, is not considered. [Deutsch, and Heather Whitlow (Casey Trees) and Michael Sullivan, Anouk Savineau, and Brian Basiek (Limno Tech), 2007]

This study assesses the impact of both green roofs and trees. The impact of increasing only the urban tree canopy without the green roof component is provided in this report. The urban tree canopy analysis provides the volume runoff estimates for different urban tree canopy scenarios. There are many benefits of green roofs and the Christina Basin TAT encourages green roofs but this recommendation focuses solely on the portion of the report related to increasing urban tree canopy. The benefits of green roofs are addressed in further detail in SW4.

This study concludes that increasing urban tree cover, especially over impervious areas, reduces the volume flow of stormwater runoff. As the volume of runoff decreases, the pollutant loads reaching the rivers and streams will also decrease. According to this report, green roofs and increased tree cover could keep thousands of pounds of nutrients, metals, and other pollutants out of area waterways (Deutsch, et al. 2007). In the model used in this study, the base tree cover is 35 percent and under the scenario where the tree cover is increased to 40 percent (low-end scenario) and 57 percent (green build-out scenario) tree cover will reduce stormwater and CSO discharges by 73 and 193 million gallons respectively city-wide each year under average conditions (Deutsch, et. al. 2007). The stormwater benefits of tree cover are primarily from trees that have a canopy that is over impervious surfaces. For example, for every incremental percentage point increase in tree cover over impervious surfaces in D.C., this study has found that there is a corresponding reduction in stormwater runoff city-wide in an average year of approximately 11 million gallons. Since the pollutant load will decrease as the volume of runoff decreases, increasing the urban tree canopy is a method that will help achieve the nitrogen and phosphorus TMDL levels in the Christina Basin. This study also demonstrates the importance of urban tree canopy in older cities, such as Wilmington, with a combined sewer system.

Although there is some data from studies, such as the Washington, D.C., study, on nutrient and bacteria reductions from urban tree canopy, further research and data are necessary. As part of the urban tree canopy recommendation, the Christina Basin Tributary Action Team recommends convening an urban tree canopy task force or holding a forum to quantify the nutrient and bacteria reductions resulting from increased urban tree canopy in the Christina Basin. It is important to convene a group to gather this data to further support the implementation of this recommendation.

Cost

The costs for establishing an urban tree canopy are variable and dependent on the types of trees are planted, how the trees are planted, the extent of the canopy, and the maintenance requirements. For example, some cities might plan on planting 100,000 street trees (e.g., Indianapolis) that are usually 2-inch diameter trees at installation and cost about $200 per tree. Strategies that involve open space restoration in urban areas require more reforestation efforts and smaller bare-root seedlings, which are much cheaper and are often less than $1 per tree. The cost also depends on the types of trees planted, the mortality rate, the depth of follow-up, tree maintenance, education efforts, and staff time dedicated to developing urban tree canopy ordinances.

The following costs were obtained from individual urban tree cases studies:

- Conservative cost estimates (e.g., San Antonio, Tex., and Puget Sound, Wash.) use $2 per cubic foot construction cost for stormwater management, not including maintenance costs. It is assumed that the work the trees do naturally will take the place of stormwater management control and municipalities can avoid these stormwater costs by implementing an urban tree canopy (<http://www.americanforests.org/news/display.php?id=91>).
- Modesto, Cal., spent $2.6 million for urban forestry in fiscal year 1997–1998 ($14.36/resident, $28.77/tree), this program included 91,179 trees. Modesto spent 74 percent of their urban tree budget on mature tree care. The net benefits for fiscal year 1997–1998 were $2,329,900 ($12.76/resident, $25.55/tree). The net benefits include annual air pollution uptake, aesthetics and other benefits, energy benefits (building shade), stormwater runoff, and atmospheric carbon dioxide (McPherson, Simpson, Peper and Xiao, 1999).
- Estimates designate approximately $250–$500 per tree purchase and installation. Tree life span is expected to be approximately 20 or more years with normal pruning and maintenance as needed. The expected lifespan of a landscape tree is longer than the expected lifespan of a street tree (<http://ohioline.osu.edu/for-fact/0061.html>).

The costs provided below are Delaware urban tree canopy cost estimates for trees and installation in both afforestation (planting in open space or barren areas) and urban areas. These costs are for the entire state; costs may be on the higher end of the range in New Castle County (Hall, 2007).

- Tree Costs:
  - Seedlings: $0.02–$0.40 per tree.
  - Ball and Burlap: $165–$225 for trees 2–2 ½ inches and 6–9 feet in height. Natives are becoming less available, so highly sought native trees may be slightly higher, approximately $265 per tree. This price for the ball and burlap trees includes installation costs.
  - Landscape Trees: $300–$800 per tree.
- Installation:
  - General Rule: 40 percent of the cost of a tree is installation costs.
  - Manual Installation: $0.15–$0.40 (varies depending on location and necessary tools) per tree.
  - Mechanical Planting: $0.21 per tree.
  - Additional $650 per tree for trucking for the landscape trees.
- Requirements for Plantings:
  - Converted open space sites will include seedlings and whips, a mix of larger trees, and seedlings.
  - The City of Newark and City of Wilmington require 2 ½-inch or greater caliper and 7- to 10-foot height for trees in urban areas. The height and caliper requirements are required to protect the trees from vandalism.

Tables 4.4 and 4.5 itemize the costs for planting a loblolly pine using two different planting methods: mechanical planting and manual installation.

Table 4.4 Cost Example #1 (Mechanical Planting)

Expense	Cost
Loblolly Pine	$0.05
Mechanical Planting	$0.21
Total Cost for Buying and Planting One Tree	**$0.026**

Table 4.5 Cost Example #2 (Manual Installation)

Expense	Cost
Loblolly Pine	$0.05
Manual Installation	$0.15–$0.40
Total Cost for Buying and Planting One Tree	**$0.020–$0.45**

Costs Specific to the New Castle County Metropolitan Corridor Research Area

Research, being conducted in conjunction with the UFORE study, proposes to increase the urban tree canopy in the New Castle County metropolitan area to 30 percent by 2030. Calculations, factoring in the tree mortality rate for existing trees and new trees, estimate that 4.53 million new trees will need to be planted in the next 23 years, which results in 197,000 new trees planted per year.

As suggested previously, providing cost estimates for increasing urban tree canopy is highly variable. Depending on the type of land use and maintenance needs, a wide variety of tree sizes and species will be planted, which is a desirable strategy. The type of trees planted, and therefore the cost, will vary considerably depending on whether the trees are planted in open space, residential areas, or highly urbanized areas. The open space and residential areas will require less costly trees, while plantings in highly urban areas will require hardier trees often costing as much as $225 per tree. Contracted tree plantings versus voluntary efforts will also contribute to variations in cost. Assuming a mix of seedlings and larger trees are used in urban reforestation efforts, the cost of trees can vary anywhere from $0.02–$225. Using this information and an average value of $50 per tree, planting 197,000 trees per year in the New Castle County metropolitan area will cost approximately $9.8 million per year.

Consideration should be given to the fact that the full $9.8 million will not be assumed by the local government entities. There are numerous tree plantings that are occurring throughout the New Castle County metropolitan corridor as a result of existing development codes and stormwater regulations as well as reforestation efforts of nonprofit organizations in the area. These trees that are planted will contribute toward the annual goal. Therefore, a percentage of the cost of planting 197,000 trees will be assumed by private or nonprofit entities as a result of existing tree planting requirements and public-private partnerships. Essential to this accounting will be the creation of a regional tree registry or database to track current and future planting efforts.

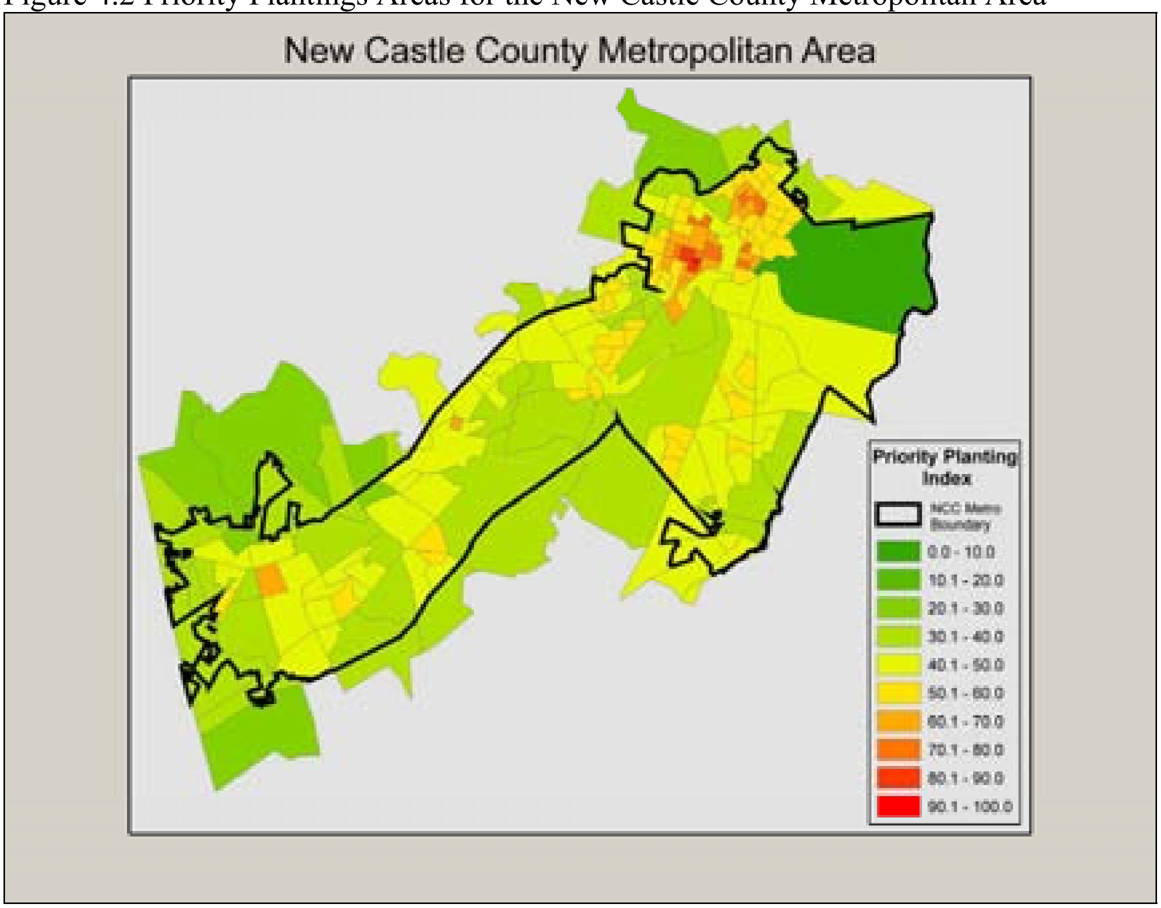
Source of Funding

- Delaware Department of Agriculture, Urban Forestry Group
- Residents
- City of Wilmington
- City of Newark
- Developers

Location

Using the Forest Opportunity Spectrum tool for Urban and Community Forestry (<www.unri.org/fos/>), the UFORE study has produced an index of priority areas for plantings in the New Castle County metropolitan area based on tree canopy and impervious cover maps from the National Land Cover Data and the 2000 U.S. Census data. The priority areas have been determined using the following criteria: population density, tree stocking levels, and tree cover per capita. Figure 4.2 shows the Priority Planting Index values for the New Castle County metropolitan area. The higher the index value, the higher the priority area for tree planting. The index values calculated in this research will be essential in prioritizing the urban tree plantings implemented through the Christina Basin PCS. Because the necessary data are readily available by download, this tool could also be applied to create a Priority Planting Index for the entire Christina Basin.

Figure 4.2 Priority Plantings Areas for the New Castle County Metropolitan Area



Source: Nowak, Hoehn, Wang, and Krishnamurthy

Implementing Organization(s)

- DNREC, Division of Water Resources, Watershed Assessment Section
- New Castle County
- Municipalities
- Delaware Center for Horticulture
- Developers
- Citizens

Type of Action

Ordinances

SW2. Design Stormwater Best Management Practices to Reduce Nutrients According to the Total Maximum Daily Loads Where Feasible and Effective

The team recommends that stormwater best management practices (BMPs) in the Delaware portion of the Christina Basin are designed to reduce nutrients and bacteria according to the Christina Basin TMDLs. The team recommends implementing infiltration BMPs rather than structural retention and detention BMPs. Infiltration BMPs slow down, spread out, and soak up precipitation and runoff. Water percolating into the soil becomes a stable supply of groundwater, and the runoff is naturally filtered of impurities before it reaches creeks, streams, rivers, and bays. These recommended BMPs allow stormwater to infiltrate, rather than retaining it, which has the potential to meet the required nutrient load reductions according to the Christina Basin TMDLs. In addition to the nutrient and bacteria reductions associated with infiltration BMPs, these types of BMPs are also advantageous and cost effective because they require less maintenance than structural retention and detention BMPs. Infiltration BMPs may also save homeowner associations (HOAs) money and maintenance requirements.

It is important to note that this recommendation is important in the Delaware portion of the Christina Basin, but is even more important in the Pennsylvania portion of the basin because there is a much higher volume of new development in the portion located in Pennsylvania.

Nutrient and Bacteria Reductions

Stormwater runoff volumes can be reduced over 90 percent when infiltration practices are incorporated into new sites. Studies also indicate that infiltration practices can provide up to an 83 percent reduction in TN and 65 percent in TP if the BMP is constructed and managed properly. Appendix E contains the nutrient and bacteria reduction values associated with a select number of infiltration stormwater BMPs.

Cost

The cost per year for city or county staff to establish and maintain a regulation that requires the design of BMPs to reduce nutrients according to the TMDLs and encourages infiltration BMPs is estimated at 25 percent of a full-time salaried staff or $20,000 per year. The costs associated with implementing these BMPs are the cost of doing business (Jones, 2007).

Source of Funding

Development Community

Location

New development areas

Implementing Organization(s)

- DNREC, Division of Water Resources
- DNREC, Division of Soil and Water Conservation

Type of Action

Regulatory

SW3. Limit Addition of New Impervious Cover to Less than 20 Percent of the Watershed above Drinking Water Intakes

The Christina Basin TAT recommends limiting the addition of impervious cover on new development to less than 20 percent of the watershed above the drinking water intakes. Impervious cover is any surface in the landscape that cannot effectively absorb or infiltrate rainfall. This includes: driveways, roads, parking lots, rooftops, and sidewalks. When natural landscapes are intact, rainfall is absorbed into the soil and vegetation. These natural mediums, or pervious cover, naturally slow down, spread out, and soak up precipitation and runoff. Water percolating into the soil becomes a stable supply of groundwater, and the runoff is naturally filtered of impurities before it reaches creeks, streams, rivers, and bays. A growing body of scientific literature has shown that groundwater recharge, stream base flow, and water quality measurably change and decrease as impervious cover increases. Studies have shown a direct relationship between the intensity of development, as indicated by the amount of impervious surface, and the degree of damage in a watershed. Based on research in Delaware and elsewhere, streams can show signs of degradation and can be considered stressed in watersheds where the impervious coverage exceeds 10–15 percent. Impervious cover can be an important and measurable indicator of stream water quality and watershed health.

In the Christina Basin, local ordinances limiting impervious cover for new development to less than 20 percent of the watershed above drinking water intakes shall be established. If a new development proposal located within one of the watersheds above the four drinking water supply intakes in the Christina Basin exceeds the 20 percent threshold, a mitigation project within the watershed will be required. Adding the flexibility of permitting mitigation within the watershed and establishing a mitigation bank will provide incentives for the business community. An awareness of the implications of high percentages of impervious cover in a concentrated area and taking the necessary steps to reduce and mitigate it accordingly are key tools in reducing the negative impacts of impervious cover throughout the watershed and achieving the TMDLs in the Christina Basin.

The typical impervious surface coverage for land uses common in Delaware and other states is shown in Table 4.6. Most developed land uses exceed the threshold of 10–15 percent impervious cover, which defines a healthy watershed or stream system. It may initially appear from Table 4.6 that dispersed development is desirable; that building homes on lots of one or two acres with scattered commercial areas ("sprawl scenario") would result in the lowest percentage of impervious surface coverage. However, on a regional or watershed level, greater overall water quality and supply protection is achieved through more concentrated development. Under the "sprawl scenario," development is spread over a much broader area, and additional impervious area, in the form of roads, is needed to link the dispersed houses and community. Therefore, dispersed development can result in a significant increase in the total impervious cover in the watershed. Concentrated development results in greater protection for the overall watershed, as a much larger percentage of the watershed is left in its natural condition, preserving water supply and quality. In addition, such centralized development can be directed away from sensitive areas, such as stream banks, to minimize the negative impact on water quality.

Table 4.6 Typical Percent Impervious Coverage of Land Uses in Delaware

Land Use	Percent Impervious Cover
Commercial and business district	85%
Industrial	72%
Residential district ⅛ acre or less lot size (townhouses)	65%
¼ Acre lot size	38%
⅓ Acre lot size	30%
½ Acre lot size	25%
1 Acre lot size	20%
2 Acre lot size	12%

Source: University of Delaware, Water Resources Agency, 1998 and USDA, Soil Conservation Service, TR-55, 1983

In 1991, New Castle County adopted the Water Resource Protection Area (WRPA) ordinance. The WRPA ordinance is contained in the New Castle County Unified Development Code (UDC) and protects environmentally sensitive areas that are very important to the state's water supply and water quality. This ordinance limits impervious cover to 20 percent in new development in WRPAs in the county. The New Castle County Resource Protection Area Technical Advisory Committee (RPATAC), consisting of planners and scientists, meets monthly to review new development applications within WRPAs and assists New Castle County in administering the WRPA ordinance. In 2001, IPA-WRA conducted research using Geographic Information Systems (GIS) to evaluate whether the WRPA ordinance was effective in limiting new development to less than 20 percent of the WRPAs. This research found that the WRPAs composite impervious cover in New Castle County was 15 percent, less than the 20-percent code requirement. The history of developing and obtaining approval for the WRPA ordinance demonstrates that the 20-percent impervious cover threshold was acceptable to developers, environmental groups, and the local governments. Additionally IPA-WRA's research has proven that a numerical limit of 20-percent impervious cover is an effective requirement to minimize impervious cover in designated areas and supports a composite impervious cover at or below 15 percent, the healthy watershed threshold. The history of the WRPA ordinance, most specifically its acceptance and effectiveness in limiting impervious cover to 15 percent, provides both a framework for implementing a 20-percent impervious cover limit in new development above the drinking water intakes in the Christina Basin and encouragement that the implementation of this recommendation will result in reduced impervious cover and therefore improved water quality in the Christina Basin.

The WRPA maps serve as decision-making tools for the RPATAC to implement the WRPA Ordinance in New Castle County. The maps depict several data layers that represent four main categories of WRPAs in New Castle County, Delaware. These categories include the Surface Water WRPAs. The Surface Water WRPAs on the New Castle County WRPA maps will serve as the watershed boundaries for the 20-percent impervious cover limits for new development contained in the watersheds above the drinking water intakes. The maps and said watershed boundaries can be found at *www.wr.udel.edu/publicservice/index.html.*

As land use decision-makers are evaluating development projects, it is important to understand the connection between land use and impervious cover percentages and their impacts on water quality. Limiting the addition of new impervious cover to less than 20 percent of the watershed above drinking water intakes provides decision-makers with the appropriate tool to protect water quality and water supplies in the Christina Basin. Watershed zoning based on impervious cover thresholds is a measurable and scientifically defensible technique to protect stream water quality in watersheds. Watersheds provide the natural boundaries to guide land use planning decisions that affect stream water quality. These tools utilize the watershed boundaries as planning units and encourage decision-makers to address impervious cover on a watershed basis, not parcel by parcel. By employing watershed zoning based on impervious cover thresholds into the county and municipal zoning codes, growth can be concentrated into those areas with existing development and infrastructure and away from the undeveloped or less developed watersheds in the Christina Basin. Setting a numerical limit provides regulatory agencies a defensible tool to limit impervious cover and will assist governments in meeting additional federal water quality regulations like the Source Water Program requirements that are designed to protect drinking water resources.

Nutrient and Bacteria Reductions

As areas become more developed, the amount of impervious cover increases and the natural filter systems are no longer in place to intercept the runoff. This has serious implications for water quality and flood control. Typical pollutants in runoff from impervious areas include pesticides, oil, litter, fertilizers, sediment, salt, and bacteria. Impacts on water quality include chemical, physical, and biological degradation. Chemically, an increased presence of bacteria, nutrients, pathogens, and sediment in receiving waters can limit the viability of drinking water and recreational activities. Physically, decreases in stream bank stability, the amount of large woody debris, and channel roughness consequently lower the quality of habitat available for biologic species. Biologically, species diversity declines, biological interactions are altered, and pollution-tolerant organisms become more prevalent.

The specific nutrient and bacteria reductions associated with stormwater BMPs that can potentially be installed to mitigate the impacts of impervious cover are included in Appendix E.

Cost

The true cost for this recommendation is the staff time of city or county staff to develop and maintain the regulation for the impervious cover thresholds. The cost per year for city or county staff to establish and maintain the regulation is estimated at 25 percent of a full-time salaried staff or $20,000 per year. The costs of implementing BMPs and planning methods to meet the impervious cover thresholds is a developer's cost of doing business.

Ignoring the negative impacts of increased impervious cover can lead to economic disaster and social difficulties. There are several examples of this in the past few years in northern Delaware where near-record flooding incidents have resulted in devastation for homeowners and infrastructure. Heavy rains and flash floods have submerged low lying areas, washed out roads, and swept away bridges. In September 2004, for example, 149 of 159 homes in the Glenville community of northern Delaware in the Red Clay Creek watershed were made uninhabitable. Homes in the nearby Yorklyn and Hockessin areas were also damaged and uninhabitable. This was a result of increased runoff rates and peak discharge rates (as well as development in the floodplains). The increased impervious surfaces in this area created a situation where the runoff can no longer be absorbed which, combined with increased peak discharges, results in severe and numerous flooding events. In instances such as this, the area may be in need of federal disaster assistance as well as state and local aid. This will cost the local, county, state, and federal governments, as well as insurance companies, large amounts of money while displacing residents and damaging the community character. Circumstances such as these demonstrate the need to act proactively to reduce the amount of impervious cover.

Reducing impervious cover through BMP implementation and specific planning techniques can present high upfront costs, but not necessarily. In some cases, reducing impervious cover and utilizing impervious cover thresholds for the sake of improving water quality actually can save money. Roads, sidewalks, and other infrastructure can account for over half the cost of a subdivision. For example, if a 32-foot wide roadway were narrowed to 30 feet, the savings would be up to $100 per linear foot or up to $528,000 per mile. Reducing the imperviousness of new development not only benefits the environmental health of streams, the economy, and the local community, but it also results in economic savings for the development (Schueler, 1997 and Schueler, 1994). The negative impacts of impervious cover in the future will be far worse than the cost of developing regulation or implementing BMPs today. Cost estimates for BMPs that can be implemented to help mitigate the negative impacts of impervious cover are contained in Appendix F. To protect our communities and water bodies, it is most beneficial and cost-effective to work to reduce impervious cover thresholds through zoning ordinances and prior to developing sites when possible, rather than working to reduce impervious cover impacts on existing development.

Source of Funding

- Developers
- Municipalities
- New Castle County

Location

The Christina Basin Tributary Action Team recommends amending the New Castle County Unified Development Code to establish a 15–20 percent impervious cover limit in watershed zoning districts for any new development in the Brandywine, Red Clay, and White Clay Creeks, and Christina River watersheds that are upstream from the only four drinking water intakes in New Castle County and hold the only six trout streams in Delaware. Proposals are underway to modify the New Castle County Zoning Code to incorporate these watershed-based impervious cover thresholds in the Delaware portion of the Christina Basin.

The team recognizes that DNREC's Brownfield Program requires flexibility to allow site-specific decisions to be made regarding stormwater management and the extent of impervious surfaces allowed during redevelopment on brownfields sites. Many times at brownfields sites impervious cover is a required element of the corrective actions that limit human exposure to contaminants found in surface soils. Some brownfields properties may lend themselves to less impervious cover than others. It is important to note that due to the unique nature of brownfields, new development is not brownfield development. A decision should be made on a site-specific basis that is both protective of human health and the environment and that promotes redevelopment.

Implementing Organization(s)

- Developers
- City of Wilmington
- City of Newark
- New Castle County

Type of Action

Ordinances

SW4. Promote Low Impact Development in New Construction and Redevelopment

The Christina Basin Tributary Action Team recommends promoting Low Impact Development (LID) in new construction and redevelopment projects in the Christina Basin. Promoting LID in new construction and redevelopment is important for the Delaware portion of the Christina Basin, but it is an especially significant recommendation in the Pennsylvania portion of the basin where there is more undeveloped land. LID is the integration of site ecological and environmental goals and requirements into all phases of urban planning and design from brownfields sites and the individual residential lot level to the entire watershed. LID varies from traditional stormwater practices. LID reduces runoff volumes by attempting to recreate drainage patterns to the pre-construction state. LID practices include but are not limited to: green roofs, permeable pavers, bioretention areas, grass swales, rain gardens, and minimizing impervious areas. These practices increase runoff infiltration, storage, filtering, evaporation, and detention onsite.

LID allows greater development and redevelopment potential with less environmental impacts through smarter designs and advanced technologies that achieve a better balance between conservation, growth, ecosystem protection, and public health/quality of life. LID has several benefits and advantages over conventional stormwater management approaches:

- Encourages environmentally sound technology.
- Increases economic sustainability by addressing the negative impacts of urbanization.
- Requires managing runoff close to its source through intelligent design, which can enhance the local environment, protect public health, and improve community livability.
- Saves developers and local governments money.
- Enables flexibility on a site by site basis for brownfields.

The Christina Basin TAT encourages implementing innovative LID practices such as green roofs. Green roofs have proven to be effective tools for controlling stormwater, especially in urban areas. Benefits of green roofs include: vegetation slows down the rate of runoff and reduces the volume of runoff; water temperature is moderated before draining to the streams; foliage collects dust, transpires moisture, and provides shade; and heavy metals and nutrients present in stormwater are bound in the soil substrate. In addition to these water quality benefits, green roofs also serve numerous ecological amenities and are aesthetically pleasing.

Presently there are state and local regulations encouraging the incorporation of LID. DNREC regulation encourages green technology. DNREC also regulates brownfields and encourages LID design into these redevelopment efforts. Currently the City of Wilmington and New Castle County encourage the implementation of LID in new development. The Delaware Department of Transportation (DOT) is reviewing the feasibility of implementing LID into its development practices. Below is a summary of New Castle County's Storm Drainage Regulation related to LID. For more detailed information on this ordinance see Section 40.22.210 Storm Drainage of the New Castle County Unified Development Code (UDC):

> Stormwater management should utilize the most effective low impact stormwater drainage practices to the maximum extent feasible as part of the overall conservation design approach to address stormwater conveyance and management objectives as required in Chapter 12 of the county code. These practices include techniques such as: disconnecting long reaches of stormwater flowing over impervious areas, maximizing infiltration potential through the natural capacity of soils, maintaining post-development stormwater flow velocities to an intensity that does not adversely impact natural resources, and utilizing other practices or techniques approved by the Department (<http://www.co.new-castle.de.us/CZO /txtframe_ns.asp?Section=021&Level=1>).

Nutrient and Bacteria Reductions

Research shows significant reductions in runoff volume associated with LID practices, but the volume of reduction varies considerably based on the LID practice that is implemented and the site characteristics. Nitrogen, phosphorus, and bacteria reductions for specific LID practices, such as porous pavement and bioswales, can be found in Appendix E and like the volume runoff values, the nutrient and bacteria reduction values are highly variable based on the specific type of LID practice implemented and the site characteristics.

Cost

The true cost for this recommendation is the cost of city or county staff to establish and maintain the regulation promoting LID in new construction and redevelopment. The cost per year for city or county staff to establish and maintain the regulation is estimated at 25 percent of a full-time salaried staff or $20,000 per year (Jones, 2007). The costs for implementing LID practices are the cost of doing business, and examples of these costs are included below.

It is typically thought that implementing LID practices into site design or new construction will be more expensive than conventional stormwater practices, yet LID is becoming more widespread and the inconveniences of longer project time approvals and higher design and construction costs may be misconceptions. According to the Low Impact Development Center, Inc., LID still saves money over conventional practices due to the reduced infrastructure and site preparation work. LID pilot programs have demonstrated at least a 25–30 percent reduction in costs associated with site development, stormwater fees, and maintenance for residential developments that use LID techniques. According to the Low Impact Development Center, Inc., savings are achieved by reductions in clearing, grading, pipes, ponds, inlets, curbs, and paving, and these cost savings enable builders to add value-enhancing features, to be more flexible and competitive in pricing products, and to recover more developable space (<http://www.lid-stormwater.net/permeable_pavers/permpaver_costs.htm>). Although a 25–30 percent reduction has been seen, cost savings are extremely site specific and will vary depending on soil conditions, topography, existing vegetation, land availability, and additional site specific variables. Additional cost benefits to consider for LID practices include:

- Multifunctional (i.e., landscaped areas serving as stormwater controls).
- Lower lifetime costs.
- Additional environmental and social benefits.
- Reduced off-site costs.
- Functional use of open space and land.

Tables 4.7 and 4.8 provide examples of the costs of two specific LID practices: permeable pavers and commercial/industrial bioretention. It is important to note that this cost information varies considerably depending on the site design and characteristics.

Table 4.7 Permeable Paver Cost Comparison

Data or studies that compare construction, maintenance, and life cycle costs for stormwater management systems are limited. The wide range of site conditions and design requirements also makes it difficult to determine the life cycle cost benefits. It is recommended that each potential application be evaluated on a site-by-site basis. However, a range of cost estimates for the basic installation of permeable paver materials is given in the table below for comparison purposes.[7] The wide range of costs for the paver systems should be noted.

Paver System	Cost Per Square Foot (Installed)
Asphalt	$0.50 to $1.00
Porous Concrete	$2.00 to $6.50
Grass / gravel pavers	$1.50 to $5.75
Interlocking Concrete Paving Blocks	$5.00 to $10.00*

**Dependent on depth of base and site accessibility, per conversation with Maryland Unilock® representative (2002)*

Users should also keep in mind that a more accurate price comparison would involve the costs of the full stormwater management paving system. For example, a grass/gravel paver and porous concrete representative stated that when impervious paving costs for drains, reinforced concrete pipes, catch basins, outfalls, and stormwater connects are included, an asphalt or conventional concrete stormwater management paving system costs between $9.50 and $11.50 per square foot, compared to a permeable paving stormwater management system at $4.50 to $6.50 per square foot. The savings are considered to be even greater when pervious paving systems are calculated for their stormwater storage; if designed properly, they can eliminate retention pond requirements.[8]

[7] Numbers compiled from:
Peterson, C., 2001: Pervious Paving Alternatives. *http://www.petrusutr.com/paving_paper.htm*.

EPA, 2000: Low Impact Development (LID) – A Literature Review. EPA-841-B-00-005, Office of Water, Washington, D.C.

Booth, D.B., J. Leavitt and K. Peterson, 1997: The University of Washington Permeable Pavement Demonstration Project–Background and First-Year Field Results. Accessible at *http://depts.washington.edu/cuwrm/* under Research.

[8] Chere Peterson of PETRUS UTR, Inc., 2002, *personal communication*

Source: <*http://www.lid-stormwater.net/permeable_pavers/permpaver_costs.htm*>

Bioretention cells can be installed along parking lot perimeters and between parking stalls. These can be constructed as retrofits in existing parking lots and as new designs. Commercial, industrial, and institutional site costs can range between $10–$40 per square foot, based on the need for control structures, curbing, storm drains, and underdrains. The cost of plants varies substantially and can account for a significant portion of the facility's expenditures. When looking at the cost estimates, it is important to consider that landscaping costs will need to be incurred anyway and that bioretention will significantly decrease the infrastructure costs. According to the Low Impact Development Center, Inc., for example, a medical office in Maryland was able to reduce the amount of storm drain pipe that was needed from 800–230 feet—a cost savings of $24,000 (EPA Office of Water, 1999).

Table 4.8 Bioretention Cell Cost Data

Commercial/Industrial Bioretention Cell Cost Estimates		
	Commercial New	**Commercial Retrofit**
	The storm drainage discharge system is not included as part of the bioretention costs since it is treated as a general site expense.	Total retrofit costs are higher than those for new construction due to economies of scale. Design costs are lower because the drainage conveyance system is already in place.
Planning Phase	$845	$350
Design Phase	$3,600	$2,410
Construction Phase	$5,237	$7,943
Closeout Phase	$675	$1,652
TOTAL	**$10,357**	**$12,355**

Source: <http://www.lid-stormwater.net/bioretention/bio_costs.htm#4>

The Christina Basin TAT encourages development on brownfields when possible rather than developing open space and undeveloped lands in the watershed. The team encourages providing incentives (financial-based and others) to developers who are willing to build on brownfields in a way that promotes smart growth and LID.

Source of Funding

- 319 Monies
- Developers

Location

Watershed-wide

Implementing Organization(s)

Developers

Type of Action

Ordinances (DNREC and New Castle County have existing regulations that encourage green technology and low-impact development)

SW5. Amend Stormwater Ordinances to Create Consistency throughout the Watershed

The Christina Basin Tributary Action Team recommends that townships, boroughs, cities, and counties throughout the Christina Basin research and amend stormwater ordinances to create consistent standards throughout the basin. Local ordinances aimed toward water resource protection are critical to watershed protection and restoration. Local land use regulations are an essential tool and offer great potential for resource protection. The 565-sq. mi. Christina Basin includes over sixty townships, boroughs, and cities and five counties across three states—Chester, Lancaster, Delaware Counties in Pennsylvania, New Castle County in Delaware, and

Cecil County in Maryland. With the upper two-thirds of the basin contained in Pennsylvania, it is important that there is consistency among the upstream townships and the downstream municipalities and counties in the lower portion of the basin. For the streams and rivers in the Christina Basin to be restored to USEPA's designated nutrient and bacteria levels, townships, municipalities, and counties throughout the watershed need to strive for consistency between their stormwater ordinances and codes. These governing units in Delaware and Pennsylvania shall strive to have ordinances and codes that are consistent and in alignment with the water quality goals throughout the watershed.

This recommendation aims to unify the stormwater ordinances, such as buffer requirements, percent impervious cover, and erosion and sediment controls, throughout the watershed. There are efforts underway in select areas to review these stormwater ordinances and to provide recommendations for consistency. For example, the *Phase I and II Report for the Christina River Basin Water Quality Management Strategy* details an inventory of the existing stormwater ordinances and identifies modifications that will further protect water quality (Greig, Bowers, and Kauffman, 1998). Research is also being conducted in the Brandywine, Red Clay, and White Clay Creeks watersheds on the specific content of the existing stormwater ordinances. The Red Clay Valley Association (RCVA) and the Brandywine Valley Association (BVA) are conducting MS4 reviews throughout the watershed. Finally, the White Clay Creek Watershed Management Committee is working with the Brandywine Conservancy to review stormwater ordinances in the Pennsylvania portion of the White Clay Creek watershed. The analysis conducted by the Brandywine Conservancy is intended to gauge municipal consistency with the White Clay Creek Watershed Management Plan (WMP) and has analyzed 12 municipalities in the Pennsylvania portion of the White Clay Creek watershed, checking to see which are implementing the WMP's guidelines pertaining to stormwater management. Local ordinances are also being reviewed against the Chester County Water Resource Authority's *10 Principles for Effective Stormwater Management.* Appendix G provides an overview of the stormwater regulations in the Delaware portion of the Christina Basin.

Identifying the appropriate criteria to review the stormwater ordinances for consistency is essential to streamline this process. For example, when reviewing the stormwater ordinances the Brandywine Conservancy used the criteria in the White Clay Creek WMP which recommends municipal adoption of eight stormwater management provisions. These provisions range from general such as erosion control to very specific such as directing roof drains directly onto impervious surfaces. The Brandywine Conservancy assessment used both the eight stormwater management provisions from the White Clay Creek Watershed Management Plan and the Chester County Resource Authority's *10 Principles for Effective Stormwater Management* to produce 11 specific stormwater management review criteria that will be used to review the ordinances. The 11 stormwater ordinance review criteria used in the Brandywine Conservancy's research study include:

1. MS4 Status
2. Erosion and Sediment Control Planning
3. Pre-Development Conditions
4. Operations and Maintenance Plans
5. Land Disturbance Minimization
6. Adjacent Lands Protection
7. Runoff Disconnection
8. Runoff Reduction Hierarchy
9. Volume Control/Infiltration
10. Peak Flow Attenuation

11. Water Quality Treatment

Establishing a specific set of criteria, similar to the above list, in which to review the ordinances is essential. The stormwater ordinance inventory in the *Phase I and II Report Christina River Basin Water Quality Management Strategy* and the current research that is occurring throughout the Christina Basin is a valuable starting point for establishing consistency in the stormwater ordinances throughout the basin. This recommendation supports the existing ordinance review research and encourages the continuation of this research on stormwater ordinances on a watershed-wide basis.

Nutrient and Bacteria Reductions

Using existing progressive local land use regulations and natural resource protection tools as the standard and improving less stringent stormwater regulations to create consistency through the basin will benefit the water quality and indirectly decrease the nutrient and bacteria loads in the basin.

Cost

The White Clay Creek Wild and Scenic Management Committee paid approximately $6,000 to fund the Brandywine Conservancy's ordinance review project, which researched the stormwater ordinances of the 12 Pennsylvania townships in the White Clay Creek Watershed. This project will include a report and follow-up meetings with the townships. The Christina Basin has over 60 townships, boroughs, and cities in Pennsylvania, Maryland, and Delaware. Using the costs associated with the White Clay Creek Water Management Committee's ordinance review project, it can be estimated that an ordinance review project will cost approximately $500 per township, borough, or city. This translates to approximately $30,000 for an ordinance review for the entire watershed (Stapleford, 2006).

Source of Funding

- Utilities
- Municipalities
- Watershed Groups

Location

Watershed-wide

Implementing Organization(s)

- Local engineers
- White Clay Creek Wild and Scenic Management Committee
- Christina Basin Clean Water Partnership
- Red Clay Valley Association
- Brandywine Valley Association
- City of Wilmington
- City of Newark
- New Castle County

Type of Action

Regulatory

SW6. Expand the Role of the Resource Protection Area Technical Advisory Committee to Review and Make Recommendations on New Development in the Christina Basin

The Christina Basin Tributary Action Team recommends that New Castle County expand the role of the existing Resource Protection Area Technical Advisory Committee (RPATAC). The team ascertains that if the role of this existing group is expanded the group can play an additional role of a technical advisory group that has the authority to review and make recommendations on all new development in the Delaware portion of the Christina Basin. This group will review and make recommendations with the understanding that a balance must be achieved between achieving the TMDL reductions and development in the basin.

In 1991 New Castle County approved the Water Resource Protection Area (WRPA) ordinance, which has since been amended in 1999 and 2003, creating the New Castle County RPATAC. The intent of this ordinance is to protect the quantity and quality of ground and surface water drinking supplies by limiting new development in WRPAs–such as areas of ground water recharge, wellhead protection, drainage above reservoirs, and limestone aquifers–through setting a maximum 20-percent impervious cover threshold. According to the New Castle County Unified Development Code (UDC) Section 40.10.387, this committee has the following purposes and duties:

1. Provide technical support and recommendations to the Department concerning the technical definition and criteria of any Resource Protection Area or level as depicted in Table 40.10.010 of the UDC.
2. Advise the Department when it is determined that environmental standards contained in Article 10 of this chapter should be amended.
3. Provide technical support and recommendations to the Department, Board of Adjustment and Planning Board concerning any application.
4. Provide technical support, review, and recommendations on all variance applications concerning the reduction of the required OSR for major residential land developments depicted in Table 40.04.1110.
5. Provide recommendations through RPATAC regarding application of the standards to rezoning, subdivision, and land development submissions relative to any issue involving a protected resource upon the request of the Department.

6. Assist the Department as requested.

The intent of this recommendation is to expand the role of the RPATAC to review all new development applications in New Castle County that are contained within the Christina Basin. Creating such a committee can occur in one of two ways:

1. Add a seventh purpose and duty to Section 40.10.387, stating that RPATAC will provide technical support and recommendations to the Department concerning all applications in the Christina Basin and will advise the Department accordingly. This will take an act of the New Castle County Council.
2. Issue a policy memo by New Castle County Department of Planning to the current RPATAC committee stating they must review all applications in the Christina Basin.

Overall, the New Castle County Resource Protection Area Ordinance has proven effective protecting the ground and surface water supplies by limiting impervious cover to a 20-percent threshold. Research has proven that the WRPA ordinance in New Castle County has kept the impervious cover of most water resource protection areas at 15 percent, which is less than the impervious threshold on new development set by the New Castle County UDC. The expansion of RPATAC to provide a review for all new development in the Christina Basin would provide a similar benefit to the water quality in the basin. This recommended committee, serving as a review board to protect the natural resources in the basin, will help to encourage infiltration practices, impervious cover reduction, and open space preservation throughout the watershed to reduce nutrient and bacteria loads into the rivers and streams in the Delaware portion of the basin.

Nutrient and Bacteria Reductions

A quantifiable reduction in nutrient and bacteria loads cannot be estimated for this recommendation, yet research has shown that the RPATAC's review and recommendations for the development plans in the WRPAs has proven effective in keeping the amount of impervious cover in these areas below the 20-percent threshold. It is the intent of this recommendation that expanding the role of RPATAC will have similar positive results for the water resources in the Delaware portion of the Christina Basin. The intent of SW6 is that the recommendations made by this expanded RPATAC will help to achieve a balance between reductions in nitrogen, phosphorus, and bacteria and development in the basin.

Cost

The cost of this recommendation would translate to the staff time of the chair of the committee, staff of New Castle County Department of Land Use, which costs approximately $500 per day (Kauffman, 2006). The group will meet approximately 12 times per year and at the cost of $500 per day the cost will total approximately six thousand dollars per year. All other committee members will be asked to serve on a volunteer basis.

Source of Funding

New Castle County, Department of Land Use

Location

Watershed-wide

Implementing Organization(s)

New Castle County

Type of Action

Ordinances

SW7. Implement a Stormwater Utility

The Christina Basin PCS recommends that all New Castle County municipalities in the Christina Basin which do not have a stormwater utility, and the county, implement a stormwater utility or participate in the process to adopt a stormwater utility. A stormwater utility is a special assessment district set up to generate a stable source of funding for stormwater management within a region, usually through user fees. A stormwater utility should be considered for residential, commercial, and agricultural parcels throughout the Christina Basin. The stormwater utility generates an annual dedicated revenue stream for the stormwater management needs of the municipality or county controlling the stormwater utility.

There are many benefits of a stormwater utility. According to DNREC, Division of Water Resources, Watershed Assessment Section, a stormwater utility can generate up to $10 per capita per $1/month/equivalent residential unit (ERU). It is estimated that approximately one-eighth to one-sixth of the annual revenue from a $1/month/ERU stormwater utility rate results in approximately $30,000–$40,000 for cities and approximately $180,000–$250,000 for counties (DNREC, 2006). In general, the smaller the municipality, the higher the relative cost to implement a stormwater utility. The revenue generated from the utility can be used to fund a variety of stormwater management and water quality programs. This tool can be used in the Christina Basin to contribute to the reduction of nutrients and bacteria reaching the rivers and streams by implementing best management practices with the funds generated from the stormwater utility. Specific recommendations for the funds generated from the stormwater utility include the following recommendations from the Tributary Action Team. These recommendations are not intended to limit the use of the revenue generated from the stormwater utility, but are intended to serve as a guide to direct funding.

The Christina Basin Tributary Action Team specifically recommends dedicating stormwater utility revenue to BMP maintenance. There are over 700 stormwater BMPs throughout New Castle County, and it is difficult and costly to maintain all of them. Regulatory agencies have experience maintaining stormwater BMPs, but are currently unable to maintain all of them due to high capital and labor costs associated with BMP maintenance. If regulatory agencies were provided with a dedicated source of funding to maintain BMPs, the homeowner associations (HOAs) would be relieved from the responsibility of maintaining them or hiring someone to maintain them. A consistent maintenance program is the best way to ensure that BMPs will continue to perform their water quality and quantity control functions. If BMPs are properly maintained, their nutrient reductions will be in alignment with the estimates provided on the stormwater BMP document attached in Appendix E.

The team also recommends dedicating stormwater utility revenue to reducing and managing existing impervious cover. A stormwater utility can encourage this reduction by charging a fee proportional to the amount of impervious cover. Reducing existing impervious cover in abandoned sites and managing the impervious cover that cannot be reduced are important components of reducing pollutant loads in stormwater runoff. Research has shown that parking lots and streets are responsible for a significant contribution of the nitrogen and phosphorus loads in a watershed. Reducing the impervious cover in abandoned sites, and wherever possible, has the potential to reduce the stormwater runoff loads and improve the aesthetics of the area. Reducing the existing impervious cover is the primary objective, but unfortunately there are many developed areas in the Christina Basin where it is not possible to reduce the existing impervious cover. In these instances, managing the impervious cover so it contributes the least possible amount of nitrogen, phosphorus, and bacteria is an important tool—and the only available tool. In these areas, it is important to manage the existing impervious cover in a way that encourages the flow of the runoff through a stormwater management system and reduces the pollutant loads in that runoff. There are a variety of stormwater BMPs that can be used to promote flow through the system while providing stormwater treatment for trash, litter, coarse sediment, oil, and other debris before the runoff proceeds through the system. For example, street sweeping seeks to remove the buildup of pollutants that have been deposited along the street or curb, using a vacuum-assisted sweeper truck. Additional tools include catch basin inserts, oil/grit separators, hydrodynamic structures, and a variety of proprietary tools. In addition to these BMP tools, maintaining existing BMPs that mitigate impervious cover impacts, such as wet ponds, dry ponds, and manufactured BMP devices, according to the appropriate maintenance standards is essential to their proper functioning and role in reducing impervious over impacts. If these stormwater BMP tools are employed and proper maintenance occurs, the impacts of the existing impervious cover runoff can be reduced. A stormwater utility can encourage the utilization and upkeep of BMPs by offering a credit for their use. Removing the existing impervious cover in abandoned parking lots and areas throughout the watershed is also an important tool to reduce stormwater loads from impervious surfaces.

To date, there are varying degrees to which the local governing units have addressed implementing a stormwater utility in the Christina Basin. The City of Wilmington has established a stormwater utility for residential and commercial customers in the municipality. This utility was implemented January 1, 2007. New Castle County has set up a working group to determine whether a stormwater utility is feasible in the county and how it can be implemented. The county has reviewed the feasibility of a stormwater utility and has invited municipalities such as the City of Newark to participate in the process. To implement a stormwater utility, a rate structure must be calculated. This rate structure must be defensible and must consider socioeconomic factors in the community. The rate structure for the City of Wilmington's stormwater utility is provided as an example for a stormwater utility that has been implemented in the Christina Basin. A four-tiered stormwater charge is established to accommodate the variety of impervious cover areas that exist for single family residential parcels in the city. The stormwater charge is assessed quarterly and the tiers are assigned by the City of Wilmington's Public Works Department, based on information in New Castle County's Department of Land Use records. The four tiers for single family parcels in the city are outlined below in Table 4.9. A stormwater utility structure for "All Other Stormwater Classes" is assessed based on the runoff coefficients of each stormwater class. The impervious area will be estimated by applying the runoff coefficients to a parcel's gross parcel area, based on the information in New Castle's

County's Department of Land Use records. The ESU factor will then be multiplied by the ESU Rate. Table 4.10 outlines the runoff coefficients for "All Other Stormwater Classes" (City Code, Wilmington, Del., Chapter 45, Section 45-53). According to the Wilmington City Code, Chapter 45, Section 45-53, all city-owned parcels are exempt from any stormwater charges. A system of credits that can reduce a parcel's quarterly stormwater charge can be issued at the discretion of the Commissioner of the Department of Public Works. Both structural and nonstructural practices that reduce the quantity and improve the quality of stormwater runoff on-site may be considered. More detailed information regarding the City of Wilmington's stormwater utility can be found in Ordinance No. 06-019, an ordinance to amend Chapter 45 of the City Code.

Table 4.9 Single Family Residential Parcels

Tier	Impervious Area Square Feet	Equivalent Storm Water Unit Ratio (ESU)	Quarterly Stormwater Charge*
Tier 1	0 – 799	1.00	$8.14
Tier 2	800 – 1,299	1.45	$11.80
Tier 3	1,300 – 2,399	2.48	$20.19
Tier 4	2,400 and over	4.40	$35.82

*The Stormwater Charge is based on the ESU and ESU Rate. In this Table 1.00 ESU = $8.14
Source: City Code, Wilmington, Del. Chapter 45, Section 45-53

Table 4.10 All Other Stormwater Classes

Stormwater Classes	Description	Runoff Coefficients
COM	Commercial	0.95
GOV	Government	0.95
IND	Industrial	0.90
INS	Institutional	0.90
MFA	Multi-family Apartments	0.75
NSD	Non-sewered	0.10
PAR	Parks and Cemeteries	0.25
PAV	Paved	0.95
PKG	Parking Structures	0.95
REC	Recreational Arenas/Playgrounds	0.35
UTI	Utility	0.90
VAC	Vacant	0.30

The Equivalent Stormwater Unit is 789 square feet and the equivalent storm water quarterly rate is $8.14.
Source: City Code, Wilmington, Del. Chapter 45, Section 45-53

Nutrient and Bacteria Reductions

Reduction is a function of how the funds generated from the utility are used.

Cost

The City of Wilmington spent approximately $400,000 to establish a stormwater utility. This cost estimate includes: performing the technical work, establishing a defensible rate system, and conducting public outreach. (Srinivasan, 2006)

Source of Funding

- Municipalities
- New Castle County
- DNREC

Location

Watershed-wide

Implementing Organization(s)

- Municipalities
- New Castle County
- DNREC

Type of Action

Ordinances and Regulatory

SW8. Identify and Prioritize Areas Where Stormwater Retrofits Would Effectively Reduce Sediment and Nutrients

The Christina Basin TAT recommends updating the stormwater best management practices inventory and identifying priority retrofits based on the stormwater BMP data contained in the inventory. Best management practices (BMPs) such as wet ponds, dry detention ponds, and retention basins have been installed throughout the Delaware portion of the Christina Basin to control stormwater volume and to improve the water quality of the stormwater runoff. These stormwater BMPs have been installed in the Delaware portion of the Christina Basin over the past several decades in a piece-meal fashion. The stormwater BMPs are scattered throughout the Delaware portion of the Christina Basin, and it is important to have an inventory of all of the stormwater BMPs in the basin as well as a database to prioritize the retrofitting efforts.

It has been determined through the Christina Basin PCS process that there is not a complete up-to-date database with the stormwater BMP information for the entire Delaware portion of the Christina Basin. There have been efforts to identify where stormwater BMPs are located and which stormwater BMPs are the highest priority for retrofitting. The report *Phase I & II Christina River Basin Water Quality Management Strategy, May 1998* identifies and maps existing stormwater BMPs installed in the Delaware and Pennsylvania portions of the Christina Basin. Figure 4.3 shows the location of the Delaware stormwater BMPs inventoried in this report. These data, while important, need to be updated to reflect current conditions. DNREC, Division of Water Resources, Watershed Assessment Section has compiled a more recent inventory, but it is incomplete and lacks critical information, such as installation date and the location of the BMPs within the municipal boundaries (Newark, Wilmington, Newport, and Elsmere). The City of Newark has its own BMP inventory, illustrated in Figure 4.4.

The team recommends that all stormwater BMP data for the stormwater BMPs in the Delaware portion of the Christina Basin be compiled in a central database that may be used to generate a GIS layer. Once this inventory is compiled, a prioritization exercise shall be conducted to determine which BMPs shall be retrofitted based on the criteria contained in the database. Through this process, stormwater BMPs will be retrofitted based on those that are ranked as highest priority for retrofitting. Stormwater BMP retrofits are costly, and it is essential to prioritize the efforts based on the year the BMP was installed and the acreage the BMP drains to maximize the retrofit efforts in the basin.

Nutrient and Bacteria Reductions

Stormwater retrofits have the potential to restore the BMPs to their properly functioning nutrient and sediment reduction loads. BMP reduction estimates are included in Appendix E.

Cost

According to cost estimates provided by New Castle County Department of Special Services, the cost of retrofitting (design plus construction) an existing stormwater management facility ranges from a low of $100,000 (Barley Mill) to a high of $365,000 (Salem Woods). The cost varies depending on the size and complexity of the facility (Srivastava, 2006).

If the cost ranges from $100,000 to $365,000 per stormwater management facility retrofit, and approximately five basins per year are retrofitted, the estimated annual cost for implementing this recommendation is $500,000–$1,825,000 per year.

Source of Funding

- Stormwater Utility
- Development Impact Fees
- Development Permit Fees

Location

Figure 4.3 identifies the location of existing stormwater BMPs which have been installed in the Delaware portion of the Christina Basin based on 1998 New Castle County Department of Public Works estimates. The stormwater BMPs in New Castle County are the detention ponds installed since 1991 in accordance with the Delaware Sediment and Stormwater regulations. This map should be updated to include new detention ponds and priority areas for the stormwater BMP retrofits. A prioritized plan should be developed to retrofit stormwater BMPs and the retrofits should be carried out accordingly.

Figure 4.4 identifies the location of existing stormwater BMPs installed within the City of Newark's municipal boundaries. The data is current through 2007 and it is continually updated as stormwater BMP projects are completed. It is important to note that the BMPs in Figure 4.2 are both the City of Newark's BMPs (municipal responsibility) and privately owned. The City of Newark is required to inspect all of the stormwater BMPs annually. Stormwater retrofits in

City of Newark should be carried out according to the needs determined through the annual inspection process. Retrofits should be prioritized based on the BMPs that are the most significant nutrient and bacteria contributors to the rivers and streams of the Christina Basin due to their disrepair.

Implementing Organization(s)

- New Castle County
- New Castle Conservation District

Type of Action

Voluntary

Figure 4.3 New Castle County's Inventory of Stormwater BMPs in the Delaware Portion of the Christina Basin (1998)

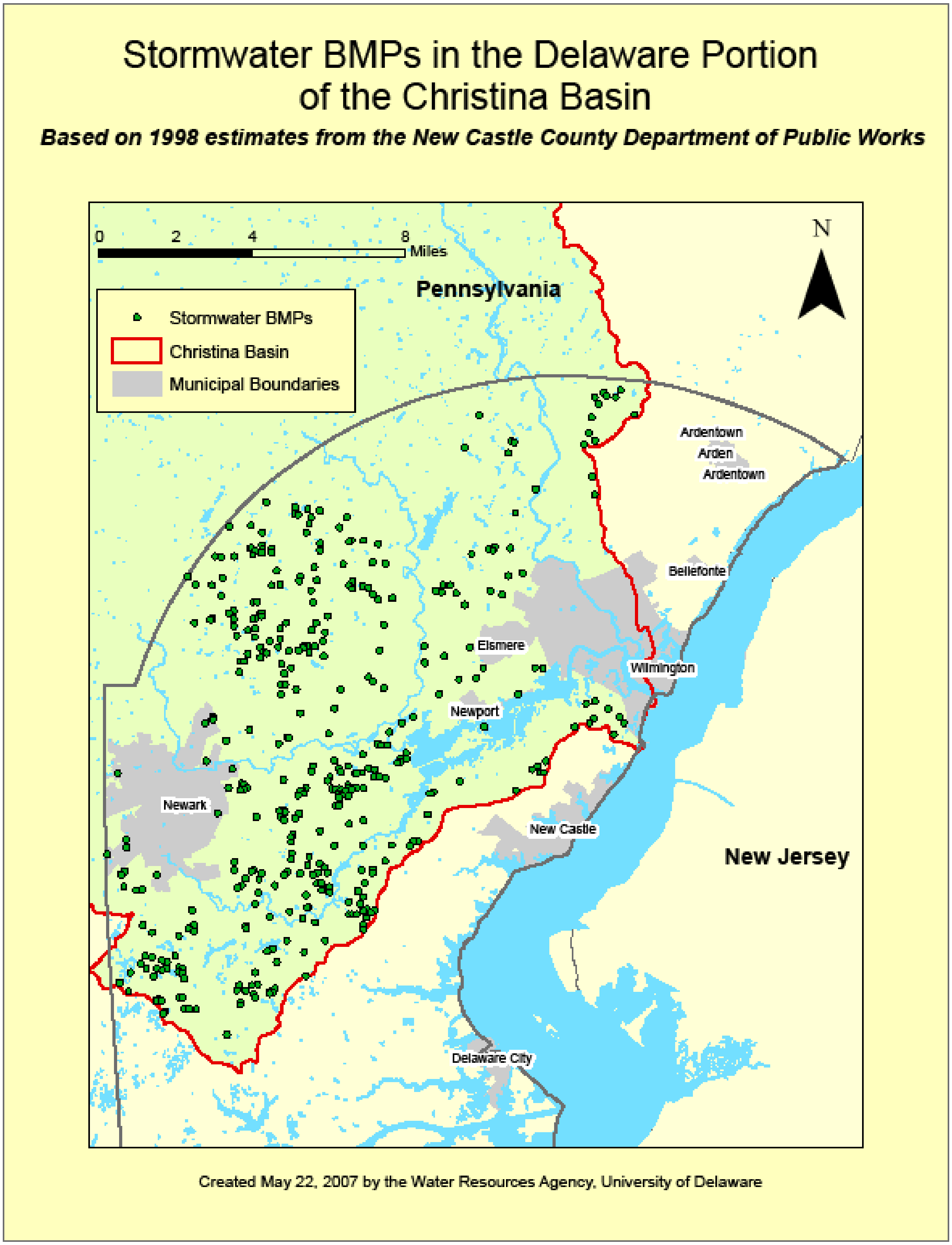
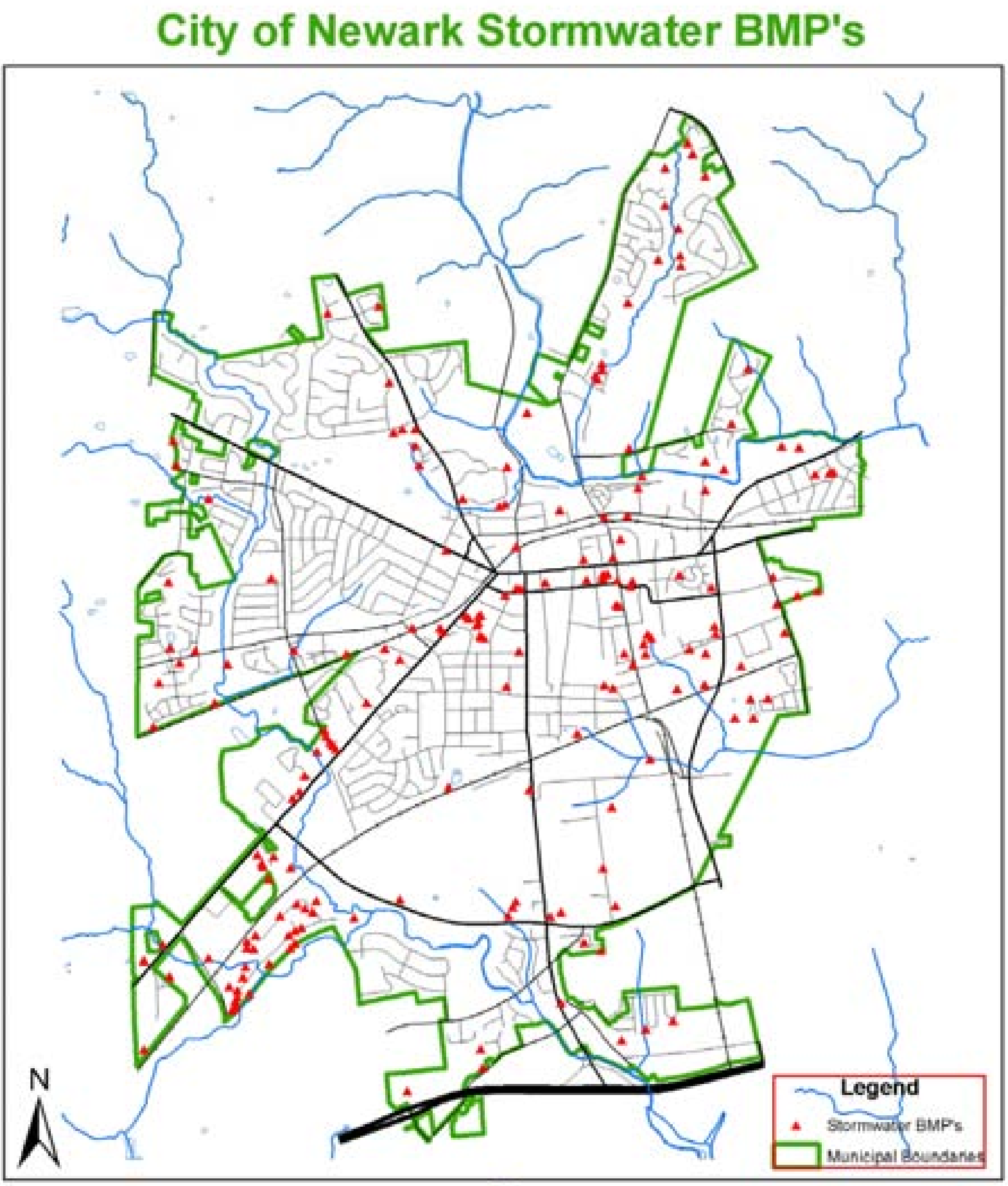


Figure 4.4 Stormwater BMPs within the City of Newark's Municipal Boundaries (2007)



4.3 Open Space Recommendations

Open space has proven to be a valuable amenity for communities while providing water quality benefits and, in some instances, wildlife habitat. The term *open space* in this section of the PCS refers to all lands not developed within tax parcels. Open space shall be categorized as either natural resources area open space or community area open space. Open space is intended to preserve environmentally sensitive areas and protected resources, provide active and passive recreation facilities, establish greenways, provide wildlife habitats, facilitate stormwater management functions, and serve as landscaped bufferyards. Both natural resource area open space and community area open space can be public or private. This section specifically states recommendations to protect, increase, and maintain natural resource area and community area open spaces. The Christina Basin Tributary Action Team has developed seven recommendations to reduce the nitrogen, phosphorus, and bacteria contributions from open space areas in the Christina Basin. These recommendations are listed in Table 4.11 and are described in more detail in this section. The intent of these open space recommendations is to make progress toward achieving the Christina Basin TMDLs.

Table 4.11 Open Space Recommendations

Open Space
OS1. Map, inventory, and prioritize existing wooded open space areas.
OS2. Protect existing wooded/vegetated open space areas.
OS3. Require management plans for community and homeowner association open space areas.
OS4. 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.
OS5. Implement stream restoration projects.
OS6. Acquire/conserve additional open space and retain conservation easements.
OS7. Reforest watersheds and headwaters.

Although bacteria reduction estimates are not specifically addressed or quantified in several of the nutrient reduction sections in this analysis, bacteria reductions tied to the open space recommendations are implied. As recommended in the stormwater, agriculture, wastewater, and education sections of the Christina Basin PCS, further research quantifying the bacteria reductions associated with the open space recommendations outlined in this document is an important tool to improve the water quality in the streams and rivers of the Christina Basin. The team recommends that DNREC conduct research to quantify the bacteria reduction values associated with the open space BMPs outlined in this document. This research will provide reduction estimates that will support the implementation and funding of the open space BMPs that will lead to improvements in water quality and achieving the bacteria TMDLs.

OS1. Map, Inventory, and Prioritize Land Areas for Water Quality Protection

The Christina Basin TAT recommends using existing land use data to create a basin-wide open space protection tool. The team recommends existing data be collected in a central clearinghouse where the land use data for the entire Delaware portion of the basin can be compiled and, if necessary, any gaps in the data can be filled. GIS layers will be generated to create this inventory, and a prioritization scheme will be developed based on the land use characteristics in the inventory. This land use mapping and inventory exercise will be used to prioritize the open space protection and preservation efforts in the basin. A basin-wide land use inventory and map is an essential tool for prioritizing open space protection efforts throughout the basin.

This inventory will include key natural features including but not limited to: woodlands, wetlands, floodplains, recharge areas, water resource protections areas, and critical natural areas. These natural key features will provide a framework on which to base the prioritization process. A prioritization scheme based on protecting the most important natural key features, which serve as natural nutrient and bacteria filters, will help to protect the most significant open space and natural resource areas in the Delaware portion of the basin. Special attention will be given to differentiating wooded open space, according to the density of the wooded areas on these parcels. For example, the wooded areas may be classified according to the density and/or type of vegetation to prioritize protection among the vegetated areas, with the densest native woodlands classified as the highest priority for protection. In addition to the type of land use, the inventory will identify whether the land areas are public or private, which will help identify the best approach to protect the priority open space areas.

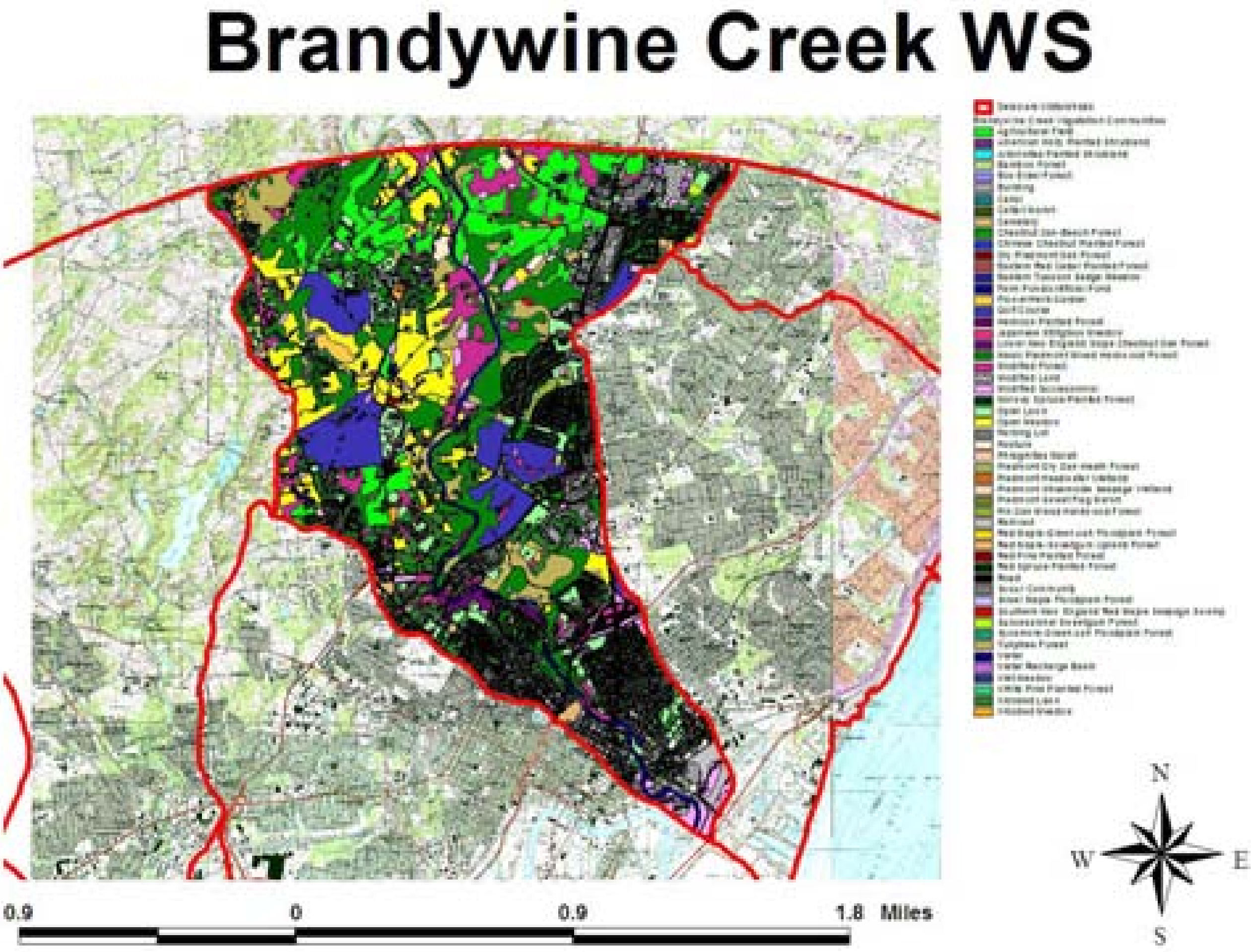
Extensive land use mapping and analysis has been conducted throughout the Brandywine, Red Clay, and White Clay Creeks, and Christina River watersheds. Several nonprofit and government organizations and academic institutions throughout the Christina Basin have compiled land use inventories. These inventories have been or are being used to create maps that illustrate the land use in the watersheds or in specific areas within the basin. For example, DNREC's Division of Fish and Wildlife, Natural Heritage and Endangered Species Program, New Castle County, Brandywine Conservancy, Delaware Nature Society, Red Clay Valley Association, and the University of Delaware's IPA-WRA have data that can be incorporated into the development of this inventory. For example, Figure 4.5 illustrates a land use inventory conducted by the Delaware Division of Fish and Wildlife for the Brandywine River watershed in the Christina Basin. This map characterizes the land use in the Delaware portion of the Brandywine Creek watershed by vegetation type and in some cases land use. Work on compiling this type of inventory for the Red Clay Creek watershed is underway. Priority land use maps developed by the state such as the State Resource Areas and Natural Areas maps may also serve as important tools in the inventory and prioritization exercise. This recommendation will require combining some of these existing inventories into a basin-wide map, filling any gaps, and modifying the existing data to create a usable prioritization tool.

Land use prioritization tools have been developed for watersheds in the region as well as within the Christina Basin. One example of a land use prioritization tool that has been developed for this region is the Green Alliance of Southeastern Pennsylvania's *Regional Open Space Priorities Report* for Southeastern Pennsylvania. This analysis identifies three open space uses—agriculture, natural resources, and recreation—and developed data layers to determine how valuable land across the region is for each use. Each layer contains measurable criterion such as soil quality, riparian buffers, or population. Layers were weighted by the project's advisory group to determine the relative value of the different criteria for each layer. After a series of GIS analyses were performed, the task force then identified areas within the region that were of particular value for agriculture, natural resources, or recreation. A prioritization exercise of this type has also been performed by the Brandywine Conservancy through the White Clay Creek Watershed Management Committee for the White Clay Creek watershed. This exercise has also been performed for the entire Christina Basin in *A Watershed Restoration Action Strategy for the*

Delaware Portion of the Christina Basin, published in June 2003. Each one of these tools will serve as useful models and data sources for the implementation of this recommendation.

Compiling this basin-wide inventory will provide a planning tool to identify the valuable existing open space areas and woodland corridors—irrespective of whether these are private or public lands—in the Christina Basin. It is critical to preserve those lands that are already in a natural state and can perform ecological functions that are beneficial to the surrounding developed lands. Using this type of preservation and protection tool is critical to reduce the nitrogen, phosphorus, and bacteria loads in the basin.

Figure 4.5 Land Use Inventory for the Delaware Portion of the Brandywine Creek Watershed



Source: Robert Coxe, DNREC Division of Fish and Wildlife

Nutrient and Bacteria Reductions

The nutrient and bacteria reductions are a function of the preservation and protection of the natural land cover systems. Creating a central inventory for the Delaware portion of the Christina Basin and determining a prioritization scheme for protecting and preserving the natural land cover have the potential to significantly reduce the nitrogen, phosphorus, and bacteria loads reaching the streams.

Cost

IPA-WRA has committed to working on achieving this recommendation. The cost of this recommendation is estimated at $14,000, the cost of an IPA-WRA graduate student completing this project in one year.

Source of Funding

In-kind

Location

Watershed-wide

Implementing Organization(s)

- IPA-WRA
- Nonprofit Organizations in the Basin with Existing Data Sources
- Government Organizations in the Basin with Existing Data Sources

Type of Action

Voluntary

OS2. Protect Existing Wooded/Vegetated Open Space Areas

The Christina Basin Tributary Action Team recommends protecting existing wooded/vegetated open space areas to utilize these land areas as natural filters for nitrogen, phosphorus, and bacteria loads in the basin. Open space areas, particularly those that are wooded and vegetated, have been scientifically proven to reduce nitrogen, phosphorus, and bacteria loads to the rivers and streams. The team recommends using the information gathered in the mapping, inventory, and prioritization exercise recommended in OS1 to protect existing open space areas in the Christina Basin.

There are relatively undeveloped "green" watersheds in the Christina Basin which have healthy water quality due to low amounts of impervious surfaces, few contaminant sources, and high overall amounts of wooded and vegetated open spaces. The strategy for these areas is to retain "green" watersheds as they are and maintain existing good water quality through preserving and protecting these wooded and vegetated open spaces. In addition to preserving the "green" watersheds, it is important to consider urban and suburban open space areas and ensure that these open space areas are not continually fragmented, but are protected as linear corridors that provide links between wildlife habitat areas, population centers, smaller open space areas, or larger landscaped open space areas.

Nutrient and Bacteria Reductions

The reductions associated with implementing this recommendation are not available because the nutrient and bacteria reductions will vary greatly and are dependent upon the amount of land preserved, the land use surrounding the open space, the soil conditions, and numerous other factors. Table 4.12 provides annual nutrient load reduction estimates for three land use types. These estimates provide support that preserving existing open space as wooded or vegetated land is beneficial. These nutrient load estimates support that protecting the existing open space in the basin has the potential to act as a natural filter and significantly reduce nutrient loads entering the rivers and streams in the Delaware portion of the Christina Basin.

Table 4.12 Annual Nutrient Loads in Stormwater

Land Use Type	**Total Phosphorus (lbs/acre/yr)**	**Total Nitrogen (lbs/acre/yr)**
Forest	0.1	0.6
Turf	1.6	7.9
Impervious Surface	2.8	14.7

Source: Cappiella, Schueler, and Wright, 2005

Cost

There is no cost associated with this recommendation.

Source of Funding

There is no cost associated with this recommendation, so there is no source of funding necessary to implement this recommendation.

Location

The report *A Watershed Restoration Action Strategy for the Delaware Portion of the Christina Basin,* published in June 2003, contains a subwatershed prioritization plan. The prioritization plan was completed by combining four steps: (1) watershed characterization, (2) existing water quality, (3) watershed pollution potential, and (4) assigning a protection or restoration strategy (Kauffman, Wozniak, and Vonck, 2003). Based on these characteristics, the report recommends the following subwatersheds as priority areas in the Delaware portion of the Christina Basin for open space protection:

- Brandywine Creek above Wilmington
- Burrows Run
- Red Clay Creek above Wooddale
- Middle Run
- White Clay Creek above Newark
- Upper Christina River PA/MD

- Muddy Run
- Belltown Run

These locations, in addition to the data obtained through the prioritization exercise recommended in OS1, will provide a guide for the open space protection efforts suggested in this recommendation. It should also be noted that in an effort to protect existing wooded and vegetated open space areas, brownfield sites should be considered as priority redevelopment areas over development in open space areas where feasible.

Implementing Organization(s)

- New Castle County
- DNREC, Division of Parks and Recreation
- Municipalities
- Private and Nonprofit Conservancies

Type of Action

Ordinances

OS3. Require Management Plans for Community and Homeowner Association Open Space Areas

This recommendation requires that open space management plans for community and homeowner associations (HOA) are in place prior to the developer's turnover to the maintenance corporation or HOA. In the management plans, specific narrative related to reducing the nutrient loads applied and running off the land, management of the land, and the source of funding for these activities will be required. Currently, open space in subdivisions and neighborhoods in New Castle County must pass an inspection by New Castle County officials and, once the open space passes the inspection, the open space is turned over to the neighborhood association or the HOA. New Castle County code requires the HOA to be responsible for owning, maintaining, and/or managing the open space and common facilities. Maintenance corporations or HOAs are often inadequately organized and funded to take full responsibility for maintaining open space. It is essential for the watershed health to manage the open space lands appropriately. There are many open space areas throughout the watershed, and neglecting or improperly managing (for example, mowing to the creek's edge) these open space areas can have a significant cumulative impact on nutrient loads in the rivers and streams.

In Pennsylvania some townships have adopted an Open Space Management Plan Ordinance. These Open Space Management Plans may include verbiage that goes beyond simply "maintaining the open space" and expands the ordinance to encourage meadow establishment in the open space and stormwater facilities and requires management of the wetlands, woodlands, and meadows. For example, London Grove Township's Zoning, Subdivision, and Land Development Ordinance states that an open space management plan is required and must include the following narrative discussion:

- The manner in which the open space and any facilities included therein will be owned and by whom it will be managed and maintained.
- The conservation, land management, and agricultural techniques and practices which will be used to conserve and perpetually protect the restricted open space, including conservation plans approved by the Chester County Conservation District where applicable.
- The professional and personnel resource that will be necessary to maintain and manage the property.
- The nature of public or private access planned for the open space.
- The source of funding that will be available for such management preservation maintenance on a perpetual basis (Benjamin, 2006).

If the county and the municipalities in the Delaware portion of the Christina Basin require open space management plans for community or HOA open space areas, significant improvements can be made in the maintenance and overall care of these areas. If language similar to what is used in some of Pennsylvania townships, open space areas in Delaware will serve as natural filters and can have a significant impact in reducing the nitrogen, phosphorus, and bacteria loads. A detailed open space management plan for community or HOA open space areas in the Christina Basin has the potential to identify and secure funding sources, necessary maintenance practices, parties responsible for the maintenance, and effective planting and maintenance practices for the benefit of the rivers and streams.

Nutrient and Bacteria Reductions

Although we know that there will be reduction from this action, we are currently unable to assign a specific nutrient load reduction to this activity.

Cost

The cost per year for city or county staff to establish and maintain a regulation is estimated at 25 percent of a full-time salaried staff or $20,000 per year (Jones, 2007). The costs associated with implementing this recommendation are the responsibility of the maintenance corporations or HOAs.

Source of Funding

- New Castle County
- Municipalities
- HOAs and Maintenance Corporations

Location

Open Space Lands Watershed-wide

Implementing Organization(s)

- DNREC, Division of Water Resources, Watershed Assessment Section, Urban Nutrient Management
- New Castle County
- Municipalities

Type of Action

Ordinances

OS4. Require Forested Riparian Buffers of Adequate and Proper Widths in New Development

The Christina Basin Tributary Action Team recommends requiring forested riparian buffers of adequate and proper widths for new development abutting all waters of the state including private, state, and county lands. In addition to requiring forested riparian buffers on new development, the team recommends restoring forested riparian stream buffers on existing development. In the circumstances where it is not feasible or appropriate for a forested riparian buffer on a site, the team recommends native vegetated stream buffers.

Riparian buffers are an essential management practice in any watershed, providing benefits that cannot be mimicked by other management practices (Chester County Water Resources Authority, 2002). Researchers conclude that reforesting riparian buffers will lead to a dramatic improvement in water quality. A forested riparian buffer serves numerous benefits including:

- Protects stream waters from direct sunlight which significantly varies the stream temperature.
- Provides detritus in the stream that serves as food and shelter for aquatic species.
- Stabilizes stream banks, stream channels, and floodplains from erosion and scour.
- Absorbs and "take up" nutrient and other pollutants from groundwater as it migrates through the root system.
- Filters sediments and pollutants from overland runoff and stormwater.
- Contributes to bacteria removal in the runoff from urban and agriculture lands.
- Creates a naturally wider stream channel, consequently increasing the total habitat and number of stream organisms, and therefore the total ecosystem processing of pollutants is increased.

Research in 16 temperate streams in the rural Piedmont watersheds in eastern North America found that forested streams are more efficient at removing pollutants in the water than non-forested streams (Sweeney, Bott, Jackson, Kaplan, Newbold, Standley, Hession, and Horwitz, 2004). According to Sweeney, et al., specifically in the case of nitrogen, forested stream segments remove 200 to 800 percent more than non-forested segments (Sweeney, et al., 2004). In addition to the high nitrogen removal rates that forested riparian buffers provide, they are essential for a healthy and thriving stream ecosystem.

The team has determined that for this recommendation to be effective, the forested riparian buffer requirements should be consistent throughout the Delaware portion of the Christina Basin and should be in accordance with the New Castle County Unified Development Code (UDC) criteria at a minimum. According to the New Castle County UDC, a Riparian Buffer Area consists of land that forms a transition zone between aquatic and terrestrial environments. At a minimum, the Christina Basin Tributary Action Team recommends:

- One hundred feet on either side of the perennial and intermittent streams, lakes, and tidal wetlands as well as land adjacent to identifiable stream channels that drain greater than 10 acres.
- All of the floodplain, plus an additional 50 feet of adjacent land.
- All of a nontidal wetland greater than 20,000 square feet in area, plus an additional 50 feet of adjacent land.
- All of any size nontidal wetland classified as a Piedmont Stream Valley Wetland, as defined in the 1997 New Castle County Comprehensive Plan Update and designated by DNREC's Division of Fish and Wildlife, Natural Heritage and Endangered Species Program, plus an additional 50 feet of adjacent land.

Specific criteria pertaining to identification and calculation can be found in the New Castle County UDC.

Education and maintenance are important tools for retaining forested riparian buffers. Installing signage that indicates that the area is a designated buffer area and is important to the health of the stream will increase public awareness about forested riparian buffers and will prevent inadvertent mowing in the area. Preventing and removing invasive species from the forested riparian buffers so that the trees can thrive and perform their ecological functions are also critical components of installing and retaining forested riparian buffers.

Although the Christina Basin Tributary Action Team recommends requiring forest riparian buffers at a minimum of the New Castle County Unified Development criteria, it is important to mention that some states have implemented much more stringent forested riparian buffer regulations based on the critical role they play in watershed management. For example, in 2004 New Jersey established a 300-foot buffer on Category 1 Waters and their tributaries. Information on this progressive buffer ordinance is in Appendix I.

Nutrient and Bacteria Reductions

In addition to the multitude of habitat and aesthetic benefits that forested riparian buffers provide, they also effectively reduce the nutrient and bacteria loads in the streams. Numerous literature sources support that a buffer of 100 feet (or larger) in width, primarily of forested vegetation, is the optimal buffer width. Researchers have found that as the buffer width increases, sediment removal increases. Phosphorus is often found bound to sediment and is mobilized in surface runoff. So as sediment is trapped, phosphorus loads are also decreased. The width of the buffer is also important for the nitrogen removal as denitrification is highly spatially variable. According to the DNREC fact sheet, buffers have the following range of reduction efficiencies:

- TN: 20–60 percent
- TP: 20–60 percent
- TSS: 20–80 percent

Research has shown that forested riparian buffers are more efficient than grass buffers at removing nitrogen from ground waters.

A buffer's effectiveness in reducing bacteria pollution is dependent on the type of vegetation, the width of the buffer, the bacteria load of the capture runoff, and whether the buffer is in an urban or agriculture setting. A study conducted in Virginia in 2003 indicates that buffers can reduce bacteria by 43–57 percent, especially in agricultural watersheds. The Center for Water Protection stresses that the bacteria removal rates of stream buffers is sparse, but it is assumed that an urban stream buffer's bacteria removal rate will not exceed a 70 percent removal rate, which can be achieved for agricultural stream buffers (Schueler and Holland, 2000).

Cost

The cost estimate for preserving forested riparian buffers on new development is based on the cost for DNREC staff to establish and maintain this regulation. The cost per year for city or county staff to establish and maintain a regulation that requires forested riparian buffers of adequate and proper widths in new development is estimated at 25 percent of a full-time salaried staff person's total time or approximately $20,000 per year (Jones, 2007). The cost for trees, installation, and management costs that are required for installing the forested riparian buffers in new development is considered the cost of doing business for developers and homeowners.

The cost estimates for restoring riparian forested buffers on existing development vary from the costs for installing riparian forested buffers in new development and are highly variable. A cost estimate for the plantings to revegetate forested riparian buffers is included below:

- $2,500/acre for 300 trees/acre using containerized seedlings and 4-foot tree shelters (without labor costs).
- $4,860/acre at a density of 400 trees/acre using containerized seedlings and 4-foot tree shelters installed (without labor costs).
- Approximately $14 to $15 (varies according to contractor) to install containerized seedlings and 4-foot tree shelters and approximately $12.00 to install a 2-foot, 1-gallon shrub (Benjamin, February 2007).

Source of Funding

- USDA Conservation Reserve Program
- Federal Wild and Scenic Rivers Program
- Stroud Water Research Center Riparian Buffer Program
- Delaware Forest Service
- Delaware Coastal Program
- DNREC Division of Fish and Wildlife
- DNREC Division of Water Resources

Location

This recommendation requires forested riparian buffers on all new development projects in the Delaware portion of the Christina Basin based on the New Castle County UDC criteria at a minimum. In addition to requiring forested riparian buffers on new development in the basin, forested and vegetated riparian buffers are recommended on existing development in the developed subwatersheds in the basin.

The subwatersheds within the Christina Basin with a high density of existing development generally have poor water quality due to high amounts of impervious surfaces, high densities of contaminant sources, and low overall amounts of forested and open spaces. According to the report *A Watershed Restoration Action Strategy for the Delaware Portion of the Christina Basin,* published in June 2003, the strategy for these highly developed subwatersheds is to restore them and improve the existing impaired water quality through the implementation of several restoration and retrofitting BMPs, including restoring forested riparian buffers (Kauffman, et al., 2003). According to Kauffman et al., the following areas in the four major watersheds in the Christina Basin have high watershed pollution potential:

- Brandywine Creek–Main Stem through Wilmington
- Red Clay Creek–Main Stem below Wooddale
- White Clay Creek–Mill Creek
- White Clay Creek–Pike Creek
- White Clay Creek–Main Stem above Delaware Park
- White Clay Creek–Main Stem at Churchmans Marsh
- Christina River–East/West Branch above Coochs Bridge
- Christina River–Main Stem above Smalley's Pond
- Christina River–Main Stem Lower Tidal

These areas are high priority areas for forested riparian buffer implementation efforts for existing development.

Specific stream segments or parcels where it is a priority to implement this recommendation have been identified through research conducted by Jessie Laurel Benjamin, representing Stroud Water Research Center (SWRC) and in collaboration with the USDA NRCS and the Brandywine Conservancy. Benjamin has worked with the USDA NRCS and Brandywine Conservancy to create two Riparian Buffer Opportunity Maps for the Red Clay and White Clay Creeks watersheds in the Christina Basin. SWRC partnered with the Red Clay Valley Association for the Red Clay portion of the watershed. These maps identify areas of open stream, based on the criteria of no trees within approximately 75 feet of the stream. The open stream areas, represented in red in Figures 4.6 and 4.7, are considered priority areas to establish forested riparian buffers in the Red and Clay and White Clay Creeks watersheds within the Delaware portion of the Christina Basin. Partial canopy areas are shown in yellow, and fully canopied areas are shown in green. Parcel numbers and contact information were assigned to these opportunity areas. According to Benjamin, it is important to note that when identifying priority areas for forested riparian buffers it is not only important to identify the streams that are lacking trees within 75 feet of the stream, but it is also critical to assess the following key factors:

1) Is there a willing landowner?
2) Are these headwater stream areas?
3) Will these areas create contiguous canopy cover?

These maps do not show the areas that have been restored since the project began nor do they show the Pennsylvania portion of these watersheds. Updating these maps and creating maps for the other two watersheds contained in the Christina Basin are priorities for the near future. The maps will serve as useful tools to prioritize the areas to implement the forested riparian buffer recommendation.

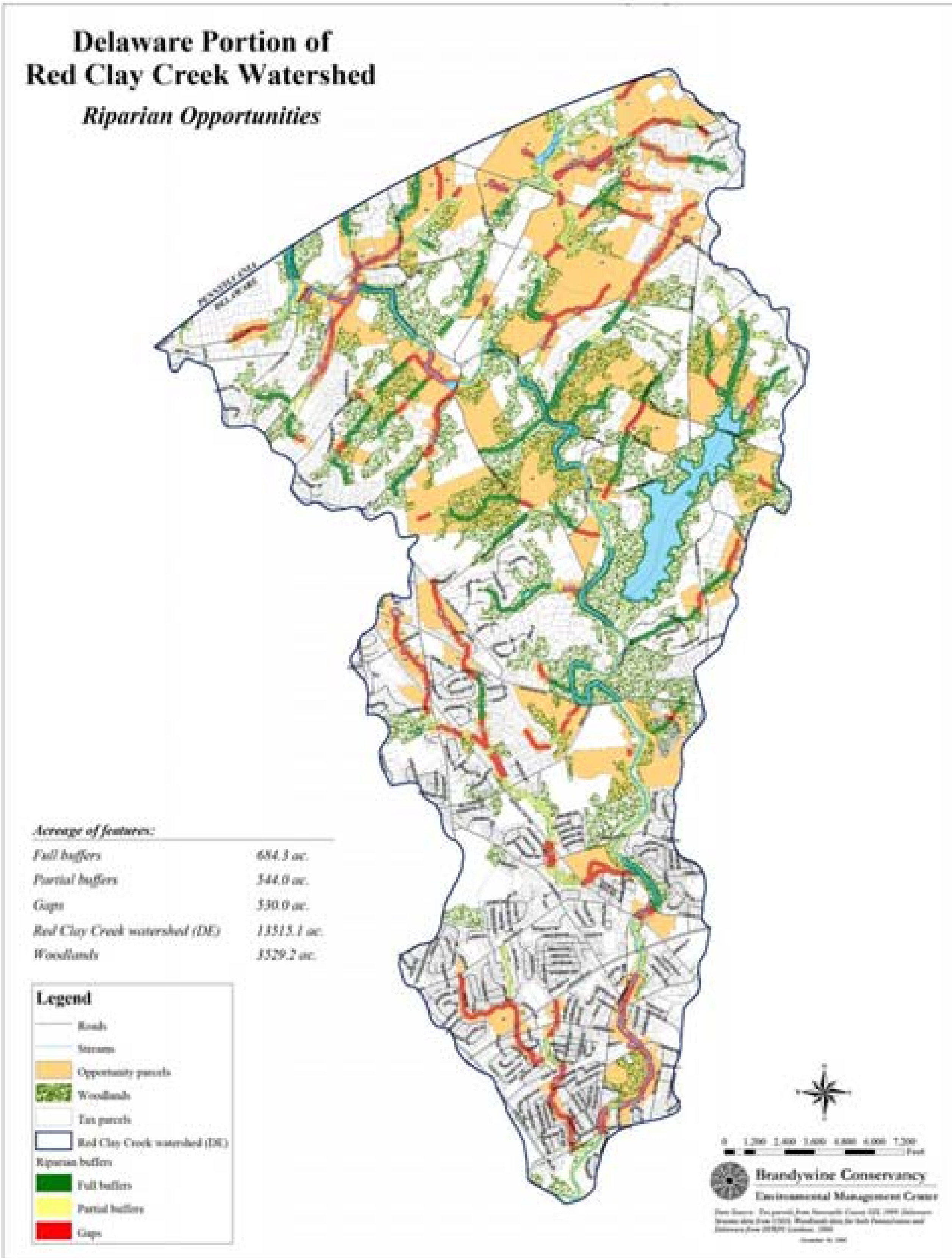
Implementing Organization(s)

- New Castle County
- Municipalities

Type of Action

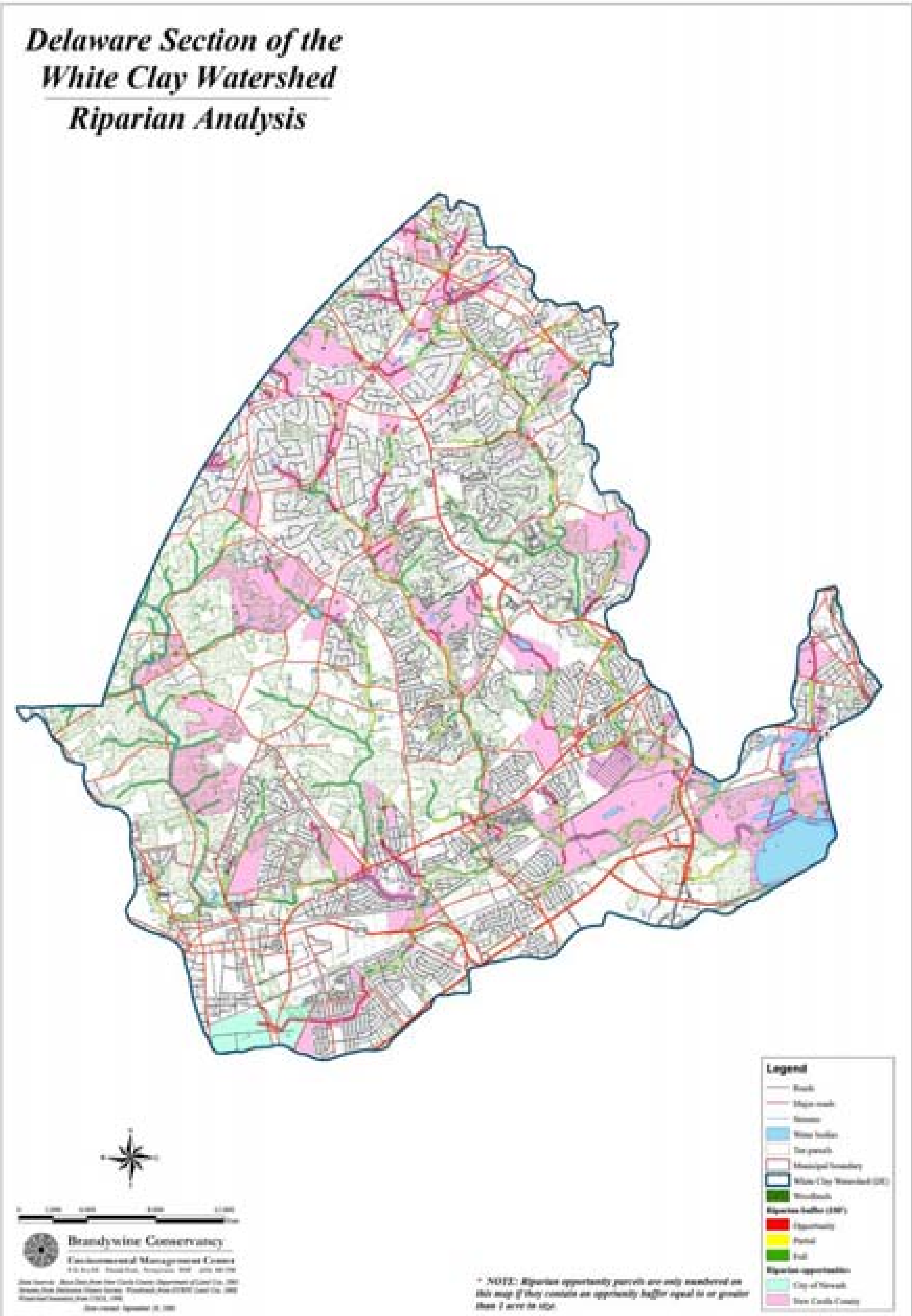
Regulatory

Figure 4.6 Delaware Portion of the Red Clay Creek Watershed: Riparian Opportunities



Source: Brandywine Conservancy, Environmental Management Center, 2007

Figure 4.7 Delaware Section of the White Clay Creek Watershed Riparian Analysis



Source: Brandywine Conservancy, Environmental Management Center, 2007

OS5. Stream Restoration

Stream restoration is a tool that the Christina Basin PCS recommends to restore the natural function of benefits of a stream. It is essential to recognize the importance of healthy aquatic ecosystems and their role in improving water quality to receiving waters. Land cover changes in the contributing watersheds disrupt the existing natural balance between the water flow regime and sediment flux, destabilize stream channels, and increase the loadings of pollutants to downstream areas. The objectives, opportunities, and measures for stream restoration may differ in urban and rural areas. This recommendation focuses on stream restoration in non-agriculture, or urban, areas. The objectives for stream restoration in urban areas include, but are not limited to, reducing stream channel erosion, promoting physical channel stability, reducing the transport of pollutants downstream, and working toward a stable habitat with a self-sustaining, diverse aquatic community. Stream restoration activities should result in a stable stream channel that experiences no net aggradation or degradation over time.

In addition to instream restoration activities, addressing upland sources of stream impacts (for example, reducing watershed runoff and associated pollutant loads, or encouraging groundwater recharge) is critical to ensuring the success of stream restoration projects in urban areas. Projects should be planned in the context of a comprehensive watershed assessment or inventory, where upland sources of the problem are considered in the project design. To ensure the success of a stream restoration project in an urban area, the project must have adequate watershed controls of upstream sources of urban runoff or be designed to accommodate the current and future urban runoff volume and velocity from upstream sources. The primary goal of the Christina Basin PCS is to improve the water quality and remove excess pollutants. Stream restoration is a valuable best management practice for removing nitrogen and phosphorus loads to the streams and receiving waters in urban areas.

Nutrient and Bacteria Reductions

The nutrient reduction values associated with stream restoration vary considerably depending on several factors including: soils, water table, elevation, vegetation, buffer width, and whether the project is in a rural or urban setting. Research typically estimates that TN and TP efficiencies range from greater than 30 percent but less than 90 percent. According to a Baltimore County, Maryland, Spring Branch Stream Study 2002, used by the USEPA's Chesapeake Bay Program, reductions in pollutant loads from stream restoration in urban areas are estimated to be:

- TN = .02 lb/linear foot/year
- TP = 0.0035 lb/linear foot/year
- TSS = 2.55 lb/linear foot/year

It is important to note that there is sparse data related to bacteria reductions for urban stream restoration. The TN, TP, and TSS load reductions are based on a limited number of studies (<http://www.chesapeakebay.net/pubs/subcommittee/nsc/uswg/BMP_Stream_Restoration_and_Pollutant_Load_Reductions.PDF>).

Cost

In March 2005, DNREC began implementing a stream restoration project along Pike Creek. Approximately 5,000 feet (or one mile) of the stream channel and adjacent banks were restored using state-of-the-art restoration techniques. This method of stream restoration measures the watershed inputs and valley type (for example, size of drainage area, topographic relief, and 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 function. The restoration project also included planting streamside vegetation that will further protect the banks, improving and maintaining water quality, and providing wildlife habitat. This project cost approximately $1 million to restore one mile of the Pike Creek and is representative of an urban stream restoration project in the Delaware portion of the Christina Basin (Williams, February 2007).

Source of Funding

- DelDOT
- DNREC
- New Castle Conservation District
- USDA NRCS
- USEPA

Location

Stream restoration in northern Delaware, contained within the Piedmont physiographic province, is considered a high priority by DNREC's Ecological Restoration and Protection Team. Stream restoration locations are determined by evaluating severely impaired reaches that can offer multiple environmental benefits when restored. When considering potential restoration sites, the following are some of the parameters that are considered for stream restoration projects:

- Does the stream serve as a source of public drinking water?
- Is the reach proximal to an area that is stocked with trout?
- Will enhancements provide for an improved habitat corridor, or better connectivity to existing corridors?
- Does the reach serve as potential migratory corridor for the federally endangered bog turtle?
- Is the site located within the White Clay Creek National Wild & Scenic River System?

Once a stream restoration location has been selected, the following are the implementation goals for each project:

- Stabilization of the stream banks to reduce erosion.
- Creation of habitat—putting in sequences of riffles and pools in the stream channel and planting the banks with a large number of trees and shrubs.
- Improvements to water quality.
- Reduction in the number of out-of-bank flooding events.
- Maintenance of the natural look of the stream as nature would dictate.

Other critical components of the prioritization process include level of impairment in the watershed or subwatershed, feasibility to implement, location, nutrient and bacteria reductions, and costs (Williams, February 2007).

Currently DNREC identifies impaired areas and focuses their restoration projects on the most impaired areas. It is the goal of the department to implement a comprehensive restoration approach in a particular subwatershed rather than restoring stream segments in a piece-meal fashion throughout a large geographic region. Currently Pike Creek (part of the White Clay Creek watershed) is considered a priority watershed, and DNREC has and will continue to focus restoration efforts in this subwatershed. Mill Creek is another subwatershed of concern in the White Clay Creek system. The Red Clay Creek watershed is also a watershed of high interest and concern in the Christina Basin. A study to evaluate potential stream and riparian corridor habitat restoration projects is currently underway through a cooperative effort between the U.S. Army Corps of Engineers, New Castle County, and DNREC along with other governmental and nonprofit environmental organizations. Opportunities in the other watersheds of the Christina Basin will not be passed up, but recently the majority of the stream restoration projects and the highest level of interest have been in the Red Clay and White Clay Creeks watersheds of the Christina Basin (Williams, February 2007).

Implementing Organization(s)

DNREC, Division of Soil and Water Conservation

Type of Action

Voluntary

OS6. Acquire/Conserve Additional Open Space and Retain Conservation Easements

The Christina Basin PCS recommends protecting *existing* open space in OS2 and recommends acquiring *additional* open space and conservation easements in this recommendation (OS6). Acquiring and conserving open space and retaining conservation easements provide numerous benefits to receiving streams. Open space and conservation easements:

- Increase stormwater runoff infiltration.
- Reduce pollutant export.
- Reduce the amount of impervious cover.
- Increase the amount of natural land conserved.
- Improve the performance of stormwater treatment practices.

Open space areas, particularly forested tracts and headwater streams, are priority areas for acquiring additional open space in the basin. When acquiring additional open space and conservation easements, it is important to recognize the benefits of tracts or corridors of open space rather than preserving land in a piece-meal fashion throughout the basin.

In addition to acquiring open space on forested tracts and adjacent to headwater streams, conserving open space in residential development through design practices is important. Practices such as open space designs, conservation design, or cluster development concentrate density on one portion of a site to conserve open space by relaxing lots sizes, frontages, road sections, and other design techniques. Several studies and modeling calculations have shown that when comparing similar developments of conventional design and open space design, open space design decreases the amount of impervious cover, decreases residential lawn, decreases stormwater runoff, increases stormwater infiltration, decreases phosphorus export, decreases nitrogen export, and decreases the development cost. Currently the New Castle County UDC requires 50 percent open space in residential developments. This recommendation encourages the local governments in the Christina Basin to adopt similar open space requirements in their comprehensive plans.

In addition to requiring open space for residential developments, this recommendation encourages mitigation in commercial developments through tax incentive programs that encourage an increase in open space (green areas) in the commercial developments. Tax incentive programs for commercial developments will encourage open space in areas that are typically highly impervious, thus reducing the percentage of impervious surface, reducing the nutrient contributions, and providing incentives for developers to develop in environmental sensitive ways.

It is important to recognize that this recommendation is calling for additional public open space areas, and adding public open space areas will require additional funding to maintain these areas. Maintenance of these areas is an important component when considering open space acquisition.

Nutrient and Bacteria Reductions

See OS2 nutrient and bacteria reductions

Cost

This recommendation calls for both acquiring and conserving open space and retaining conservation easements. The costs associated with buying open space land and retaining conservation easements are very different and are distinguished below.

Costs for acquiring open space vary considerably depending on the type of land and where the land is located in the watershed. The range for acquiring open space in the Delaware portion of the basin is $45,000–$80,000 per acre. This estimate is based on the purchase price for the following properties in the Delaware portion of the Christina Basin: City of Newark Reservoir, Thompson Station Reservoir in White Clay Creek Preserve, and Glasgow Regional Park. Assume a goal of 100 additional acres per year of open space. Using the maximum cost of $80,000 per acre, the estimated cost of this recommendation is approximately $8,000,000 per year to acquire 100 additional acres of open space in the Christina Basin.

The costs associated with acquiring conservation easements are much lower than the costs for acquiring public open space, but the details and maintenance aspects of conservation easements can also be quite complex. The estimated cost per year for a staff member of a nonprofit organization to work with property owners and acquire and manage additional conservation easements is estimated at 25 percent of a full-time salaried staff person’s time or $20,000 per year.

Source of Funding

Open Space:
- Developers
- State of Delaware
- New Castle County
- Municipalities

Conservation Easements:
- In-kind

Location

Prioritize preserving open space and conservation easements lands according to the following criteria:
- Land that has high value public domain with public access—acquire through fee simple acquisition
- Land that has public value in preservation but public access is not needed—acquire permanent conservation easements without public access, this has the added benefit of no land management at the public's expense.
- Areas that are very sensitive in terms of natural resource values or otherwise are most appropriately protected by private conservation organizations—work cooperatively (city, county, state, nonprofits) to make it happen.

Additional consideration for open space acquisition should be given to acquiring public open space that are forested tracts and/or located adjacent to headwater streams, like areas in or adjacent to the Brandywine Creek State Park, White Clay Creek State Park, Middle Run Preserve, Sunset Lake, and Becks Pond. In addition to public open space, encourage open space design in new residential and commercial developments.

Additional considerations for conservation easements are to continue to seek opportunities to acquire conservation easements for the preservation of open space, especially in areas with low pollution potential. Acquiring conservation easements in these areas will preserve the water quality through protection of the land in these areas. Tracts of land near Woodlawn Trustees parcels in the Brandywine Valley and near White Clay Creek State Park and the Delaware Nature Society (specifically Ashland, Burrows Run, and Flint Woods) in the Red Clay Valley are priority areas.

Implementing Organization(s)

Open Space:
- DNREC, Division of Parks and Recreation
- State of Delaware, Open Space Council
- New Castle County, Department of Special Services
- City of Newark, Department of Parks

Conservation Easements:

- Brandywine Conservancy
- Delaware Nature Society
- The Nature Conservancy

Type of Action

Voluntary

OS7. Reforest Watersheds and Headwaters

The Christina Basin TAT recommends reforesting areas in both Delaware and Pennsylvania. Reforestation efforts will offset the loss in forested land and have the potential to reduce the nutrient and sediment loads to the waterways. Forests provide a healthier environment for people and wildlife while playing a major role in improving and maintaining water quality. According to The Nature Conservancy, Delaware has lost 80 percent of its original forest due to timber operations and development <http://www.nature.org/wherewework/northamerica /states/delaware/science/art16920.html>. This recommendation aims to reduce the loss of forested land in the Christina Basin. Reforestation efforts should occur in both the Delaware and Pennsylvania portions of the Christina Basin watershed due to the positive impacts of forests on headwater streams. Overall, the Christina Basin TAT recommends a goal of reforesting 100 acres per year of watershed land and the headwaters in the watersheds in the Christina Basin.

Reforestation using species of native trees and shrubs, in proportions similar to local native woodlands, is ideal. Planting suggestions for most of Delaware, according to The Nature Conservancy, include deciduous hardwoods such as oaks and hickories with a very small percentage of conifers, such as Virginia Pines. Virginia Pines primarily grow in the Coastal Plain and therefore would only be found infrequently at the southern portion of the Christina Basin. More specific reforestation guidance can be obtained from the Delaware Department of Agriculture Forestry Section, Delaware Center for Horticulture, and Delaware Nature Society.

Although this PCS focuses on the Delaware portion of the Christina Basin, it is essential to implement reforestation efforts in the headwater streams of the watershed in Pennsylvania. Watersheds are interconnected and the streams and rivers carry water and sediment from high elevations to downstream rivers, estuaries, and oceans. Land uses in the headwater streams in the Pennsylvania portion of the watershed directly impact the water quality of the streams and rivers in the Delaware portion of the basin. Reforestation initiatives of the watershed may be a cost-effective alternative to installing more costly BMPs downstream in the Delaware portion of the watershed. The team encourages directing funding to reforestation efforts in Pennsylvania if the reforestation is expected to benefit the Delaware portion and helps achieve the TMDLs in a cost-effective manner. In addition to encouraging reforestation in the Delaware portion and the Pennsylvania headwaters, it is important to emphasize reducing development in the headwater areas due to the high sensitivity of these areas and their impact on downstream water quality and users.

Maintenance of reforested areas is also an important consideration. Maintenance may include practices such as selective thinning or harvesting existing forest/woodland areas and controlling invasive species to maintain a healthy forest ecosystem. A maintenance plan with detailed information on thinning operations and invasive species controls is recommended as part of any reforestation effort.

Nutrient and Bacteria Reductions

Reforestation efforts have proven to benefit the water quality, but the actual nutrient and bacteria reduction estimates are difficult to quantify. Table 4.13 summarizes the hydrologic and water quality benefits of a single tree (Capiella, Schueler, and Wright, July 2005).

Table 4.13 Hydrologic and Water Quality Benefits for a Single Tree

Hydrologic and Water Quality Benefits of a Single Tree		
Benefit	**Per Tree Annual Quantification of Benefit**	**Source and Description**
Rainfall Interception	760 gallons of water per tree per year	Annual rainfall interception by a large deciduous front yard tree* (CUFR, 2001)
Evapotranspiration	100 gallons of water per tree per year	Transpiration rate of poplar trees for one growing season (EPA, 1998)
Nutrient Uptake	0.05 pounds nitrogen per tree per year	Based on daily rate of nitrogen uptake by poplar trees (Licht, 1990)
*A 40-year-old London plane tree growing in a semi-arid climate		

Source: Capiella, Schueler, and Wright, July 2005

Cost

Costs for reforestation efforts are highly variable. The cost variables for reforestation include:

- Existing land use.
- Land acquisition and variability in property prices.
- Ability for regeneration from natural seed dispersal.
- Need for active planting.
- Invasive species management.

According to a Nature Conservancy document, if native woodlands are next to a site, the field may be able to go fallow and regenerate on its own from natural seed dispersal. Therefore no cost is associated with the reforestation. Currently, this method is not a preferred option due to the intensity of invasive species in the watershed. If a site is surrounded by agriculture or developed areas, it will require active planting of small tree and shrub seedlings.

Most reforestation sites must be planted and maintained. The costs for the tree plantings and shelters for this reforestation recommendation are the costs outlined in the forested riparian buffers recommendation (OS4). These costs are included below:

- The cost is equal to $2,500/acre for 300 trees/acre using containerized seedlings and 4-foot tree shelters (without labor costs).
- The cost is equal to $4,860/acre at a density of 400 trees/acre using containerized seedlings and 4-foot tree shelters installed (without labor costs).
- The cost is approximately $14–$15 (varies according to contractor) to install containerized seedlings and 4-foot tree shelters and approximately $12 to install a 2-foot, 1-gallon shrub (Benjamin, August 4, 2006).

Within a reforestation area, creating "islands" with clusters of larger trees will help speed the process along by creating localized favorable microclimates by shielding young seedlings from wind, sun, and drought. Tree islands also speed the regeneration of forests by roots sprouting, spreading their seeds, and giving birds a place to perch (while dispersing seeds). If you are planting trees along a stream corridor, the greatest habitat value will be achieved if you reforest at least 300 feet wide next to the wetland. The cost estimates listed above do not include land acquisition costs; land acquisition estimates are included in the costs section of the open space recommendation (OS6). The invasive species management costs are not included in this cost estimate either and will add additional costs to the reforestation efforts. If tree planting is funded under a federal or state cost-share program, a minimum of 300 well-spaced seedlings per acre must be present after the first growing season.

The Christina Basin Tributary Action Team recommends a goal of reforesting 100 acres in the Christina Basin. The cost of trees and labor for reforesting 100 acres in the Christina Basin, exclusive of land acquisition costs and invasive species management costs, will cost approximately $560,000. Figure 4.5 illustrates the calculation used to estimate the cost to reforest 100 acres in the Christina Basin.

Figure 4.8 Estimated Cost to Reforest 100 Acres in the Christina Basin

$560,000 to reforest 100 acres	=	100 acres	X	($14 labor/tree	X	400 trees)

More detailed cost information for a reforestation project in the Delaware portion of the Christina Basin is included in Appendix J. This appendix includes a project description for the Delaware Nature Society's Middle Run Natural Area reforestation project, including both reforestation and management costs.

Source of Funding

- U.S. Department of Agriculture (CRP, WHIP, EQIP, WRP)
- Delaware Department of Agriculture Forest Service (FLEP)
- U.S. Fish and Wildlife Service (Partners for Fish & Wildlife Program, Coastal Program, Private Stewardship Grant)
- New Castle Conservation District (Conservation Cost-Share Program)
- DNREC, Division of Fish and Wildlife (LIP)

Location

The priority reforestation efforts in the Christina Basin are in the following areas:

- Along stream corridors and surrounding wetlands.
- Around the edges of existing forest patches to expand them.

- In openings surrounded by forest to fill in "gaps."
- Between forest patches to connect them.
- On marginal agriculture lands that are too wet to yield well.
- On soils where rainwater infiltrates and recharges groundwater aquifers.
- Above public drinking water sources.

The Christina Basin TAT recommends a reforestation goal of 100 acres per year in the Christina Basin.

Specifically, priority reforestation efforts should be in the Delaware portion of the Christina Basin in areas where a watershed has been identified as having high pollution potential. According to the report *A Watershed Restoration Action Strategy for the Delaware Portion of the Christina Basin,* published in June 2003, ten subwatersheds within the Delaware portion of the Christina Basin have high watershed pollution potential (Kauffman, et al., 2003). This classification is based on an analysis of the sediment load, impervious cover, agriculture land data, wooded land data, designated use, and fish consumption advisories. The following watersheds are identified as having high watershed pollution potential and are priority locations for the reforestation efforts in the Delaware portion of the basin:

- Brandywine Creek: Main Stem through Wilmington.
- Red Clay Creek: Main Stem below Wooddale.
- White Clay Creek: Mill Creek, Pike Creek, Main Stem above Delaware Park, Main Stem at Churchmans Marsh.
- Christina River: East/West Branch above Coochs Bridge, Little Mill Creek, Main Stem above Smalley's Pond, Main Stem Lower Tidal.

In addition to the reforestation efforts in the Delaware portion of the basin it is important to prioritize reforestation efforts in Pennsylvania. The recommendations put forth in the Brandywine, Red Clay, and White Clay Creeks Watershed Action Plans published in December 2002 and prepared by Chester County Water Resources Authority, Chester County Planning Commission, Camp Dresser and McKee, and Gaadt Perspectives, LLC will serve as potential tools to prioritize reforestation efforts in the Pennsylvania portion of the basin. Funding directed from Delaware to Pennsylvania for reforestation efforts in the headwaters should be considered when appropriate.

Implementing Organization(s)

- Delaware Department of Agriculture, Forestry Section
- Delaware Nature Society
- New Castle Conservation District

Type of Action

Voluntary

4.4 Wastewater Recommendations

The Christina Basin Tributary Action Team has developed seven recommendations that have the potential to reduce the wastewater sector's nitrogen, phosphorus, and bacteria contributions for the rivers and streams in the Christina Basin. These seven recommendations are listed in Table 4.14 and are described in more detail in this section. The intent of these wastewater recommendations is to make progress toward achieving the Christina Basin TMDLs.

Table 4.14 Wastewater Recommendations

Wastewater
WW1. Install performance standards and conduct inspections and pump-outs of onsite wastewater treatment systems.
WW2. Eliminate cesspools and seepage pits in a systematic way.
WW3. Remove onsite wastewater treatment systems through connection to a centralized wastewater treatment plant.
WW4. Prohibit new onsite wastewater treatment system drainfields placed within 100 feet of wetlands, tidal waters, perennial streams, perennial ditches, and ponds in-line with perennial watercourses.
WW5. Abate combined sewer overflows.
WW6. Continue sewer repair projects and conduct regular inspections.
WW7. Remediate contaminated sites.

Although bacteria estimates are not quantified in this water quality impact analysis, bacteria reductions tied to the wastewater recommendations are implied. As recommended in the open space, stormwater, agriculture, and education sections of this document, further research quantifying the bacteria reductions associated with the wastewater recommendations outlined in this document is an important tool to improve the water quality in the streams and rivers of the Christina Basin. The team recommends that DNREC Division of Water Resources conduct research to quantify the bacteria reduction values associated with the wastewater BMPs outlined in this document. This research will provide reduction estimates that will support the implementation and funding of wastewater BMPs that will lead to improvements in water quality and achieving the bacteria TMDLs.

The major bacteria and nutrient contribution from the wastewater sector of the Delaware portion of the Christina Basin are onsite wastewater treatment systems (OWTS), combined sewer overflows (CSOs), separate sewer discharges, unpermitted discharges, and stormwater discharges. OWTS are widely used in the Delaware portion of the Christina Basin and include septic systems, cesspools, and seepage pits. The Christina Basin, like many watersheds that contain older cities in their watershed boundaries, contains a combined sewer system that discharges directly to the Brandywine Creek and Christina River during storm events or when the system is overwhelmed. The basin also contains a separate sewer system that requires maintenance and elimination of illicit discharges. All of these wastewater sources contribute nutrient and bacteria to the ground and surface water, and the recommendations to reduce these loads are outlined in this chapter.

Research has indicated that human sewage contributes significantly to the bacteria loads in the waters of the Christina Basin, but the human contribution is only a portion of the bacteria source in the Christina Basin. When addressing bacteria sources, it is important to consider that bacteria sources from non-anthropogenic sources contribute significantly to the bacteria loads, and the wastewater recommendations alone will not eliminate the bacteria loads in the basin. Table 4.13

shows the bacteria sources, as a percentage, in two small creeks flowing through one subdivision served by septic systems and one subdivision served by a sewer district. This Table demonstrates the multitude of sources that contribute bacteria to the rivers and streams and also shows the differences between the sewered and unsewered areas. Due to the multitude of bacteria sources, the open space, stormwater, agriculture, and education recommendations also play a critical role in reducing the bacteria loads in the basin. Implementing the wastewater recommendations alone will not achieve the bacteria reductions necessary to meet the TMDLs.

Table 4.15 Bacteria Sources

Bacterial Source	Brookridge-Septic Systems	Skyline-Sewered
Horse	0	20
Waterfowl	0	7
Deer	5	2
Raccoon	6	9
Rodent	8	15
Birds	26	24
Dog	8	12
Cat	2	0
Human	22	1
Sewage	5	1
Unknown	18	9

Onsite Wastewater Treatment Systems

South of the Chesapeake and Delaware Canal, surface and groundwater are directly connected; consequently, impacts on one will affect the other. In the summer, surface water flow is primarily groundwater seepage into the stream. Nutrients from septic systems will reach the surface water through the groundwater. Nitrate contributions from septic systems take years to be removed from the groundwater. In the Christina Basin, however, which is entirely north of the canal, the connection between surface and groundwater is not as direct or obvious. The Christina Basin is in the Piedmont Province of Delaware that consists of hard (igneous and metamorphic) rock. As the rock gets close to the surface, it becomes highly weathered. These rocks occur on gently rolling hills that have steep slopes and incised streams. When homes are placed on these landscapes in un-sewered areas, their septic systems tend to drain down slope as a result of the geology and terrain. The down-slope drainage often results in seeps or wet areas that can flow directly into surface water. As a result, New Castle County has restricted septic system placement on steep slopes. Although New Castle County has restrictions on OWTS (including septic systems and cesspools) on steep slopes, the Delaware portion of the Christina Basin contains thousands of OWTS and Table 4.16 below provides the most recent inventory of OWTS in the Christina Basin.

Table 4.16 Inventory of OWTS in the Christina Basin

Watershed	Number of OWTS	Septics	Cesspools	Percent Failure Rate for Septic Systems
Brandywine Creek	587	0	587	10.9
Christina River	1,682	420	1,262	2.9
Red Clay Creek	1,358	1,358		11.2
White Clay Creek	1,799	1,799		7.1
Total	**5,426**	**3,577**	**1,849**	**7.2 (Piedmont Basin exclusive of Shellpot and Naamans Creeks)**

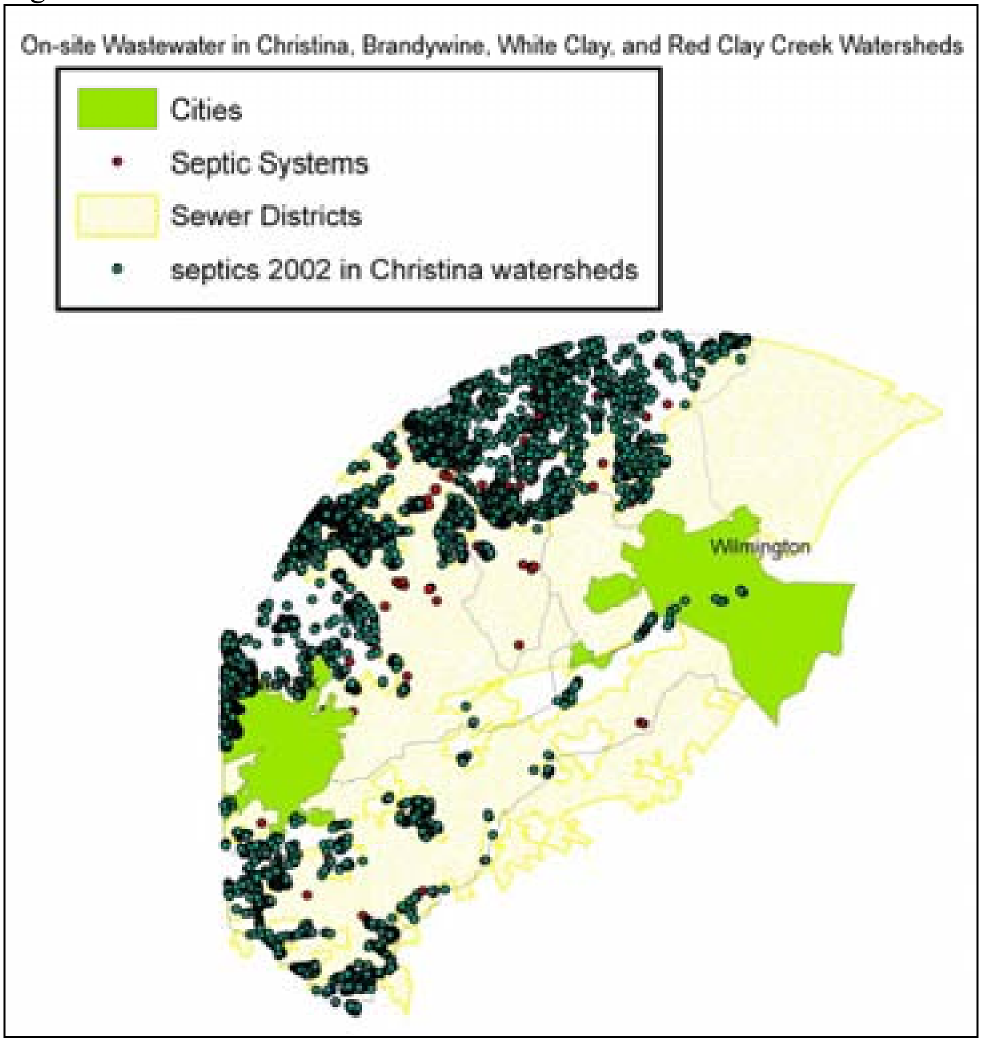
Source: DNREC, Division of Water Resources, Watershed Assessment Section

Septic Systems

A septic system consists of a tank and soil absorption field. The septic tank receives both solids and water from the homes and businesses they treat. The tank allows organic solids to settle, and some digestion of the solids by microorganisms will occur. Most of the solids will remain in the tank while the liquid (effluent) will drain into the soil adsorption field. The soil absorption field consists of a trench or bed cut into the soil that is filled with gravel and a piping system to distribute the effluent throughout the absorption field. The effluent contains pathogens (bacteria) and nutrients (nitrogen and phosphorus) that are harmful to ground and surface waters when in excessive amounts. The typical septic system is only secondary level of treatment, whereas a wastewater treatment plant in New Castle County typically provides tertiary treatment, which means the wastewater goes through three different steps before it is discharged into the river. With septic systems, most of the treatment occurs in the soil adsorption field, which has a limited capacity to treat effluent.

It is assumed that the septic systems in the Christina Basin are individual residential septics and are not large community systems. According to an analysis conducted by the Inland Bays PCS, the septic systems in Delaware have a 1,000 gallon capacity on average. The Christina Basin PCS will use 1,000 gallons for the average capacity of OWTS in the basin. Figure 4.9 maps the septic systems according to a 2002 inventory conducted by DNREC Division of Water Resources Watershed Assessment Section. The septic layers (red and green dots) represent data from two different time periods. Although the data points are different colors, the red and green both represent the septic systems in the Christina Basin.

Figure 4.9 OWTS in the Christina Basin



Source: DNREC, Division of Water Resources, Watershed Assessment Section

Cesspools and Seepage Pits

In addition to the septic systems in un-sewered areas, there are a significant number of homes in the Delaware portion of the Christina Basin that are served by seepage pits or cesspools. Seepage pits and cesspools are essentially reverse wells. Effluent drains into a hole in the ground that may be lined or unlined. These systems can easily clog, allowing waste to accumulate on the land surface and run off into streams and ditches. In some cases, effluent may seep through cracks and crevices in the weathered rock deep in the ground, potentially contaminating groundwater aquifers. Cesspools can be as deep as 6–25 feet deep. Cesspools and seepage pits can intercept groundwater because they are so deep, and the rocky Piedmont formation does not provide adequate filtration. If the cesspool areas are connected to septic systems, the solid waste can settle in the tank, filter through the soil medium, and encourage bacteria, nitrogen, phosphorus reductions. The rock-like medium that the cesspools utilize in the deeper ground has little retention time and does less filtering than a septic system. Ultimately, a cesspool has a lesser degree of filtration than septics and should be eliminated to reduce the nutrient and bacteria loads in the basin, as detailed in WW2.

According to communication with the DNREC Division of Water Resources, Watershed

Assessment Section, there are approximately 1,849 cesspools in the Delaware portion of the basin. If the distribution is broken down by watershed, it is estimated that 100 percent of the OWTS located in the Brandywine Watershed and 75 percent of the OWTS located in the Christina Watershed are cesspools. The approximate number of cesspools contained in the Red Clay and White Clay Creeks watersheds is currently unknown. Based on this data, the current estimate of cesspools and seepage pits in the Christina Basin, used for the purpose of this report and shown in Table 4.16, is 1,849.

Water Quality Impacts of OWTS (Septic Systems, Cesspools, and Seepage Pits)

A typical household generates 10–15 pounds of nitrogen per year and 1–2 pounds of phosphorus per year. Thus, if there are 5,426 OWTS in the Christina Basin, it can be assumed that the OWTS will generate 54,260–81,390 pounds of nitrogen, some of which will enter ground and surface waters. Due to the nature of the soils in the Piedmont Province, very little phosphorus would likely reach surface streams or groundwater. It is difficult to estimate the bacteria loads that will result from OWTS in the Delaware portion of the basin.

Recommendations WW1 – WW4 Relate Directly to Onsite Wastewater Treatment Systems

WW1. Performance Standards, Inspections, and Pump-Outs of Onsite Wastewater Treatment Systems

Encouraging the use of performance standards and enforcing pump-outs and inspections will reduce excessive nutrients from the OWTS in the Delaware portion of the Christina Basin. Incorporating pump-outs and inspections will help to detect failing systems, protect systems from major failures, and may increase the life of the septic system. These OWTS measures are costly, but they have the potential to deter new residential developments with individual systems and will encourage development only in sewered areas of the basin, which will help to reduce the pollutant loads from OWTS. Community and large OWTS are not encouraged in the basin. Information is provided below detailing the performance standards, inspections, and pump-outs.

Performance Standards

Wastewater pretreatment technologies are installed to remove nitrogen, phosphorus, or both from wastewater prior to soil dispersal or the effluent. Individual residential new and existing OWTS sited in a watershed with an established TMDL shall be designed and installed in accordance with the nutrient load reductions prescribed by the TMDL, or they shall use the best available technologies when possible to achieve the required nutrient reduction targets for the particular watershed. The Christina Basin TAT recommends that all existing, new, and replacement OWTS be designed or redesigned (for existing) to achieve advanced nutrient removal standards when possible through the use of performance standards.

It is important to consider that the nutrient loading rates are highly influenced by the geology of the watershed. In the Christina Basin the formations of the Piedmont in Delaware and Maryland include the Wissahickon Schist, Gneiss, and Cockeysville Marble. The Cockeysville and other limestone marble formations are the most productive water supplies for ground and surface water, but are highly vulnerable to contamination. The lower portion of the basin below the fall line in Delaware includes the Columbia and Potomac sediments of the Coastal Plain. Due to this high vulnerability to contamination, 50-percent performance standards are recommended. These standards vary based on system size, but the team generally recommends a 50-percent reduction of effluent total nitrogen concentration when compared to the total nitrogen influent concentration. Small systems are the most common systems in the Christina Basin. Based on analysis by the DNREC Division of Water Resources, Watershed Assessment Section, a 50-percent performance standard is the most effective additional pretreatment technology for small OWTS (less than 2,500 gallons per day).

Nutrient and Bacteria Reductions

According to DNREC's Division of Water Resources, Watershed Assessment Section, the estimated TN and TP load per septic system without a 50-percent performance standard is:

- 0.000493 lbs/gallon TN
- 0.000127 lbs/gallon TP (Jones, March 12, 2007)

The equation in Figure 4.10, used in the Inland Bays PCS, is used to estimate the additional TN and TP reductions based on upgrading the septic systems in the basin to a 50-percent performance standard. According to this calculation, if a 50-percent performance standard is installed on 3,577 systems, assuming 221 gallons per day and a 48-percent soil conversion rate, the reduction rates will be 93 lbs/day of TN and 24 lbs/day of TP. Table 4.17 shows the TN and TP loading rates for OWTS with and without a 50-percent performance standard. The calculations for the TN and TP values are shown in Appendix K.

Figure 4.10 TN and TP Reduction Equation for a 50-Percent Performance Standard

Nutrient Load Reduction (lbs/day)	=	OWTS Loading Rate (lbs/gallon)	X	# of Existing OWTS (septics only)	X	Reduction Efficiency

Table 4.17 TN and TP Loading Rates With and Without Performance Standards

TN and TP Loading Rates With and Without Performance Standards (Per Septic System)		
	Without 50% PS (lbs/day)	With 50% PS (lbs/day)
TN	187	93
TP	48	24

Cost

The estimated cost per year for DNREC staff to establish and maintain the performance standard regulation is estimated at 25 percent of a full-time salaried staff or $20,000 per year (Jones, 2007). The homeowner is responsible for covering the remaining costs for adding advanced treatment systems and the annual maintenance costs. Adding advanced treatment systems to standard systems costs $5,000–$7,000 per system. The annual maintenance fee is $300–$500 per system.

Source of Funding

- DNREC
- Homeowners

Location

All septic systems in the basin, specifically new and replacement septic systems.

Implementing Organization(s)

DNREC, Division of Water Resources, Groundwater Discharges Section

Type of Action

Regulatory

Inspections and Pump-Outs

The TAT recommends regular inspections and pump-outs of OWTS to promote compliance and reduce the OWTS failure rate in the basin. The Christina Basin TAT recommends that DNREC, Division of Water Resources, Ground Water Discharges Section implement a compliance and inspection program for individual OWTS to enforce the existing requirements. As it currently stands, the associated tanks are required to be pumped every three years by a licensed liquid waste hauler, and alternative systems are to be maintained in accordance with the manufacturer's specifications. This recommendation emphasizes the importance of compliance with these requirements.

Nelson et al. (1999), in the USEPA's *National Management Measures Guidance to Control Nonpoint Source Pollution from Urban Areas,* reported that estimates of partial and total system failure rates in some states range as high as 50 percent and more in some cases. Definitions of failure were highly variable and included all systems that were not designed according to the state revised codes (USEPA, EPA-841-B-05-004, 2004). In the Christina Basin, the percent failure rate of OWTS in the basin is estimated at 10.9 percent in the Brandywine Creek, 2.9 percent in the Christina River, 11.2 percent in the Red Clay Creek, and 7.1 percent in the White Clay Creek, as shown in Table 4.18. Failing OWTS are major contributors to the bacteria, nitrogen, and phosphorus loads in the surface waters in the Christina Basin. These high OWTS failure rates in the Christina Basin watersheds support this recommendation for implementing an inspection program and routine pump-out program for OWTS in the Christina Basin. An inspection and pump-out program can help to reduce the failure rate thus helping to achieve the TMDLs set for the basin.

Table 4.18 OWTS in the Christina Basin

Failure Rate in the Christina Basin	
Brandywine Creek	10.9
Christina River	2.9
Red Clay Creek	11.2
White Clay Creek	7.1
Piedmont Basin (exclusive of Shellpot and Naamans Creeks)	7.2

According to the New Castle County UDC, all septic systems must be inspected and maintained in accordance with the state of Delaware DNREC onsite wastewater treatment and disposal regulations. According to Section 8.0000 of the "Regulations Governing the Design, Installation and Operation of On-site Wastewater Disposal and Treatment Systems," owners are responsible for maintaining and operating OWTS. On July 11, 2003, the Governor signed House Bill 150 into law, which amended Title 7, Chapter 60 of the Delaware Code relating to the DNREC. This legislation authorizes the department to establish a license for persons who inspect septic systems and other OWTS, and sets an annual license fee for septic system designers, installers, site evaluators, liquid waste haulers, inspectors, and percolation testers, similar to other license fees charged by the department. A Class H license was developed and implemented January 1, 2006, for a system inspector. A draft inspection form for use by these inspectors is contained in Appendix L. The DNREC Groundwater Discharges Section will supply the sufficient form to be used. This tracking system will be used in the inspection and pump-out program recommended in this section.

When calculating the reduction efficiency that will result from increasing the frequency of pump-outs and ensuring pump-out compliance in the basin, it is important to provide the current compliance rate estimate for the OWTS in the basin. The Inland Bays PCS estimates a 77-percent pump-out compliance rate in the Inland Bays watershed, according to the Sussex County Engineering Department, South Coastal Wastewater Treatment Plant (personal communication, 2000 and 2002). Unfortunately, it is not possible to estimate the pump-out compliance rate in the Christina Basin because there are no detailed records of the OWTS waste received at the facilities in New Castle County. The New Castle County Special Services Department accepts OWTS waste from haulers at the Airport Road facility and keeps records of the type of waste (whether residential, restaurant, or industrial), but the department does not keep records of where the waste is coming from (in some instances, the waste is coming from OWTS outside of Delaware). To refine the OWTS nutrient and bacteria contributions based on the compliance rate of OWTS pump-outs in the Christina Basin, it is essential for the county to track the amount of waste received from the OWTS waste haulers at the Airport Road facility. The Christina Basin TAT recommends that New Castle County implement a tracking system for the waste received at the Airport Road facility. If the county requires the waste haulers to provide them with an estimate of the amount, origin, and the type of waste (residential, restaurant, or industrial), the estimates of the existing nutrient and bacteria load and the associated reductions from OWTS pump-outs can be more accurately estimated. A 77-percent pump-out compliance rate used for the Inland Bays watershed is too high for the OWTS in the Christina Basin. The soils in the Christina Basin are not as wet as those in the Inland Bays watershed, and, with cesspools and seepage pits, pump-out should not be that frequent. For the purpose of this report, the percent pump-out compliance rate for the Christina Basin is estimated at zero percent. This figure can be refined as records from waste haulers are tracked in the future.

Nutrient and Bacteria Reductions

According to the DNREC Division of Water Resources, Watershed Assessment Section, there are 5,426 OWTS and of these 5,426 OWTS, 3,577 are septic systems. It can be assumed that an inspection and pump-out program is not applicable to the 1,849 cesspools and seepage pits, and the inspection and pump-out recommendation applies only to the 3,577 septic systems in the basin. Table 4.19 outlines the TN and TP reduction estimates for the OWTS pump-out, according to the calculations used in the Inland Bays PCS. These concentrations are used in the calculations in Figure 4.9 to estimate the TN and TP reductions associated with the pump-outs every three years for the 3,577 septic systems in the basin, assuming a zero-percent compliance rate as discussed in the section above. The load reduction in the water column achieved through the pump-out recommendation can be estimated by applying the calculation in Figure 4.11. Appendix M shows the calculations for TN and TP nutrient load reductions based on a pump-out program, or pumping-out the septic systems in the basin every three years. Table 4.20 shows the results of the calculations and compares the nutrient loads from OWTS with and without a pump-out program.

Table 4.19 Nutrient Reductions from an OWTS Pump-out

Nutrient Reductions from an OWTS Pump-Out		
	Total N (lbs/system/pump-out)	**Total P (lbs/system/pump-out)**
OWTS Effluent	0.37	0.10
OWTS Septage	1.25	0.52
Total	1.62	0.62
Effluent: Nutrients Removed (lbs/system/pump-out) = Conc. (mg/l) x (lb/453,592 mg) x 750 gal/system) x (3.7854 l/gal) Septage: Nutrients Removed (lbs/system/pump-out) = Conc. (mg/l) x (lb/453,592 mg) x (250 gal/system) x (3.7854)		

Figure 4.11 Load Reduction Equation for Implementing OWTS Pump-outs

$$\text{Nutrient Load Reduction (lbs/yr)} = \text{Reduction Rate (lbs/system/pump-out)} \times \left(\left(\text{No. of Existing OWTS} \times \frac{1\ \text{pump-out}}{3\ \text{years}} \right) - \text{No. of compliant OWTS} \right)$$

Table 4.20 Nutrient Load Reduction from Pump-out Program

	TN (lbs/yr)	**TP (lbs/yr)**
Without Pump-out	5,795	2,218
With Pump-out	1,932	739
Reduction per Year from Pump-outs	**3,863**	**1,479**

Cost

The cost per year for DNREC staff to establish and maintain the inspection and pump-out regulation is estimated at 25 percent of a full-time salaried staff person's total time or $20,000 per year (Jones, 2007). The homeowner is responsible for covering the remaining costs. Pump-outs cost approximately $300–$700 per system. If a system is pumped-out once every three years, the cost is $100–$230 per year per system.

Source of Funding

- DNREC
- Homeowners

Location

All septic systems in the basin

Implementing Organization(s)

DNREC, Division of Water Resources, Groundwater Discharges Section

Type of Action

Regulatory

WW2. Eliminate Cesspools and Seepage Pits in a Systematic Way

Eliminating cesspools and seepage pits in the Christina Basin has the potential to reduce significant sources of nitrogen, phosphorus, and bacteria. Cesspools and seepage pits provide less filtration than septic systems and contribute significantly more nutrient and bacteria into the ground and surface waters than septic systems or sewer systems since they discharge nutrients and bacteria directly into the groundwater. The Christina Basin TAT recommends removing these outdated wastewater disposal systems, which typically provide little or no treatment, and replacing them with either septic systems or connecting directly to the centralized sewer system.

In 1999, USEPA promulgated regulations prohibiting the use of cesspools for the disposal of sewage from multi-family dwellings, and any other buildings where cesspool capacity was for 20 or more persons per day, such as schools, hospitals, and manufacturing facilities. These regulations also contain a prohibition against the use of any seepage pit, drywell, septic system, or other subsurface disposal system for the disposal of hazardous or toxic substances (Title 40 CFR part 144). It is also important to note that the EPA discourages the use of seepage pits for onsite sewage (or septic) system effluent, particularly on steep slopes, fractured rock areas, areas with shallow ground water, and/or areas where groundwater provides the sole source of drinking water. (USEPA 909-F-01-001, April 2001)

Nutrient and Bacteria Reductions

The nutrient reductions will vary significantly depending on whether the cesspool or seepage pit is converted to a septic system or a centralized sewer system. According to the Conservation Council of New Brunswick Inc., cesspools, or simple holding receptacles from which effluent can flow directly in the subsoil, have no leaching field, and, therefore, retention of nitrogen does not occur. Thus, for each cesspool or seepage pit eliminated and connected to a septic or sewer system there will be a significant reduction in nitrogen, phosphorus, and bacteria loads reaching the streams and rivers of the Christina Basin (Conservation Council of New Brunswick, Inc., 2004).

It is important to note that if a cesspool or seepage pit is eliminated and replaced with a septic system, the reduction in nutrients will be less than if connected to the centralized sewer, yet the reduction will still make a significant contribution to achieving the TMDLs in the basin. If a cesspool or seepage pit is connected to a centralized sewer, the nutrient reduction rate will be a 100 percent reduction in the nutrients and bacteria. The reduction rate is 100 percent because a point source TMDL has been set for the Christina Basin, and this TMDL already accounts for the wastewater treatment plant discharge in the City of Wilmington's NPDES permit. If connected to a septic system, the reduction will be much less than the 100 percent reduction rate.

Cost

The current cost of providing sewer in New Castle County ranges between $30,000 and $35,000 per household. The county assumes 30 percent of this cost and the homeowner must pay the remaining 70 percent of the costs. According to these costs, the estimated cost to the county for this recommendation will be approximately $9,000–$10,500 per household to provide sewer; the remaining cost will be the responsibility of the homeowner or developer. Costs are a function of the type of elimination and the location.

Source of Funding

- New Castle County
- Homeowners

Location

DNREC has conducted inspections of the existing septic systems in the Christina Basin to identify the failure rate of the systems as well as the number of cesspools in the basin. There are 5,426 OWTS in the basin, and according to a recent inspection of 101 of these systems:

- Five cesspools are confirmed.
- Nine systems are not confirmed as to whether the system is a cesspool or septic system.
- Eighty seven systems are confirmed septics with drainfields.

The priority areas for this recommendation are the five confirmed cesspools in the basin.

In addition to the five confirmed cesspools, this recommendation focuses on areas where DNREC, Division of Water Resources, Watershed Assessment Section estimates that there are a high percentage of cesspools and seepage pits, specifically the Brandywine Creek and Christina River watersheds. According to communication with the DNREC Division of Water Resources, Watershed Assessment Section, 100 percent of the OWTS in the Brandywine Creek watershed and 75 percent of the OWTS in the Christina River watershed are cesspools. This equals approximately 1,849 cesspools in the basin, contained in the Brandywine Creek and Christina River watersheds. The approximate number of cesspools contained in the Red Clay and White Clay Creeks watersheds is currently unknown.

Implementing Organization(s)

- DNREC, Division of Water Resources, Groundwater Discharge Section
- New Castle County, Department of Special Services

Type of Action

Regulatory

WW3. Remove Onsite Wastewater Treatment Systems through Connection to the Centralized Wastewater Treatment Plant

The Christina Basin TAT recommends that DNREC and New Castle County optimize and prioritize areas in the Christina Basin where OWTS can be eliminated by connecting to the centralized sewer system. According to communication with Veolia Water Northeast, LLC, operators of Wilmington's Wastewater Treatment Plant (WWTP), the current service population of the WWTP is approximately 500,000 people. The design capacity of the WWTP is 134 million gallons per day (mgd) at the average daily flow, and the WWTP currently averages about 75 mgd at the average daily flow (Fagerstrom, November 3, 2006). Therefore, physical capacity appears available at Wilmington's WWTP for additional connections from OWTS to the centralized WWTP. However, regional upgrades to the sewer systems would be necessary to safely transport the additional sewage to the treatment plant.

Nutrient and Bacteria Reductions

The estimated load per septic system without performance standards is:

- 0.000493 lbs/gal/day for TN
- 0.000127 lbs/gal/day for TP

The City of Wilmington's WWTP, the WWTP where all of the sewer waste in the Delaware portion of the Christina Basin is sent, utilizes stream discharge into the Delaware River. The reduction efficiency if an OWTS is eliminated and connected to the WWTP will be 100 percent because the TMDL already accounts for the wastewater treatment plant discharge in the TMDL.

Cost

According to the New Castle County Department of Special Services records of sewer agreements, in New Castle County there was an average of 32 systems per year eliminated and connected to the public sewer. These estimates are determined from the records of sewer agreements for 2004, 2005, and 2006. These estimates can be divided into two groups, individual septic eliminations and septic elimination projects partially funded by New Castle County. The septic elimination projects in Table 4.21 below were performed under the previous septic elimination program, in which property owners paid a flat fee of $6,500, and the county paid the balance of the project. In the latest program, New Castle County pays 30 percent of the cost and the homeowners pay 70 percent of the cost (Zern, September 4, 2007).

Table 4.21 New Castle County Septic Elimination

Year	Individual Elimination	Septic Elimination Project
2004	25	11
2005	22	7
2006	29	4
Total	**76**	**22**
Average	**25**	**7**

The current cost of providing sewer in New Castle County ranges from $30,000–$35,000 per household if a subdivision or definable service area decides to eliminate OWTS collectively. The county assumes 30 percent of this cost and the homeowner must pay the remaining 70 percent of the cost. Using these figures, the estimated cost to the county will be $9,000–10,500 per system. Using the information in Table 4.18 provided by New Castle County's Department of Special Services, the Christina Basin Tributary Action Team recommends a goal of eliminating 32 septic systems per year, including both individual eliminations and septic elimination projects. If 25 of these systems are no cost to the county, the remaining 7 will cost the county between $9,000–$10,500 per system, or $63,000–$73,500.

Source of Funding

- New Castle County
- Homeowners

Location

This recommendation focuses on areas where DNREC, Division of Water Resources, Watershed Assessment Section estimates that there are large clusters of OWTS. The map in Figure 4.9 shows that the Christina River and the Red Clay and White Clay Creeks watersheds have the highest number of OWTS. These three watersheds contain 89 percent of the OWTS in the basin. According to DNREC, Division of Water Resources, Watershed Assessment Section estimates, the Red Clay Creek contains 25 percent of the OWTS in the basin, and the systems located there have the highest failure rate for systems in the basin (Jones, March 6, 2007). The Red Clay Creek watershed is a high priority area for elimination of OWTS, due to both the number of OWTS and the high failure rate of these OWTS in the Red Clay Creek watershed. The percentage of OWTS in each watershed is shown in Table 4.22. It should be noted that some areas with OWTS are not included in the county's Sewer Service Area (SSA), which supports the Comprehensive Development Plan. Eliminating OWTS in areas outside the SSA would require additional upgrades to the regional sewer system.

Table 4.22 OWTS in the Christina Basin by Watershed and Failure Rate

Watershed	Number of OWTS	Percentage of OWTS in the Basin	Failure Rate of OWTS
Brandywine Creek	587	11	10.9
Christina River	1,682	31	2.9
Red Clay Creek	1,358	25	11.2
White Clay Creek	1,799	33	7.1
Total	**5,426**	**100**	**7.2** (Piedmont Basin exclusive of Shellpot and Naamans Creeks)

Implementing Organization(s)

New Castle County, Department of Special Services

Type of Action

Regulatory

WW4. Prohibit New Onsite Wastewater Treatment System Drainfields Placed Within 100 Feet of Wetlands, Tidal Water, Perennial Streams, Perennial Ditches, and Ponds in Line With Perennial Watercourses

In addition to eliminating existing cesspools and seepage pits, the Christina Basin TAT recommends that no new OWTS drainfields are placed within 100 feet of wetlands, tidal waters, perennial streams, perennial ditches, and ponds in line with perennial watercourses. Drainfields within 100 feet of these areas will have more significant bacteria, nitrogen, and phosphorus contributions to the surface waters than drainfields set further back. If drainfields are not permitted in these areas, this recommendation has the potential to reduce additional nutrient and bacteria loads coming from new developments with OWTS in the Christina Basin.

Nutrient and Bacteria Reductions

This action has the potential to decrease additional loadings of nutrients and bacteria from new OWTS into the rivers and streams in the Delaware portion of the Christina Basin.

Cost

The estimated cost per year for DNREC staff to establish and maintaining the regulation is 25 percent of a full-time salaried staff person's time or $20,000 per year (Jones, 2007). The remaining costs are considered the cost of doing business.

Source of Funding

- Developers
- Homebuilders

Location

Areas within 100 feet of wetlands, tidal waters, perennial streams, perennial ditches, and ponds in line with perennial watercourses

Implementing Organization(s)

DNREC, Division of Water Resources, Ground Water Discharges Section

Type of Action

Regulatory

WW5. Abate Combined Sewer Overflows

Combined sewer overflows (CSOs) are contributors to the pollutant loads in the Christina River and Brandywine Creek watersheds. Combined sewer systems (CSSs) carry both sanitary waste and stormwater drainage, and the CSOs are outlets that, in high flow conditions, dump excess stormwater runoff and sewage from overflow points in the combined sewer system to the rivers and streams. The overflow points are intended to prevent the system from backing up into homes, businesses, and streets during high-volume storm events. The City of Wilmington, like many of the nation's older northeastern cities, has a CSS and 42 CSOs. Thirty-seven of the 42 CSOs are in the urban, lower Christina Basin. The CSO locations in the lower Christina Basin include:

- Nineteen CSOs to Brandywine Creek
- Fifteen CSOs to Christina River
- Two CSOs to Silverbrook Run
- One CSO to Little Mill Creek

CSO overflow includes nutrients (nitrogen and phosphorus), bacteria, and organics. Research has shown that the water quality standards for bacteria were exceeded in the waters in the Christina River, in dry and wet weather alike, with little difference in bacteria levels in CSO waters and non-CSO waters. This is a clear indication that all sources of pollution in the watershed need to be addressed to achieve the necessary nutrient and bacteria reductions in the basin. Although the City of Wilmington's Enhanced Long Term Control Plan (LTCP) is the regulatory tool to address the City of Wilmington CSOs, the Christina Basin PCS would not be complete if it did not address the importance of the systematic management and nutrient and bacteria reductions associated with the CSOs.

The City of Wilmington has been planning, expanding, and implementing a CSO management program since the late 1980s. In 2003, the City of Wilmington, in conjunction with Greeley-

Hansen, LLC, developed an Enhanced LTCP that addresses the progress made thus far and the desired levels of CSO control (consistent with the National CSO policy and the CSO Task Force) and integrates water quality initiatives in the watershed.

The National CSO Policy requires that the City of Wilmington's LTCP provide defined levels of CSO control and ultimate compliance with appropriate water quality standards. Capturing 85 percent of wet weather flow, on an annual average basis, is one of the control objectives in the policy. Other key objectives include complying with the Christina Basin TMDLs, pursuing pollution sources upstream of the City's CSO areas, and meeting LTCP objectives by 2010. According to the CSO Program's Enhanced LTCP, there are key CSO controls that are cost-effective control measures that make sense regardless of the water quality goals that provide at least 87 percent capture of combined wet weather flows on a systemwide, annual average basis.

A key goal of the CSO Enhanced LTCP is to integrate the city's CSO program with other water quality initiatives in the Christina Basin, and the plan will be revised accordingly to meet the TMDL goals. Greeley-Hansen, LLC and the City of Wilmington are currently working on the following projects to reduce the impact of the CSOs on the water quality in the Christina River and Brandywine Creek. The projects include:

- Installing a retention basin for storage at Canby Park (CSO 28/29).
- Transferring flows from Mill Creek (CSO 27) to Canby Park (CSO28/29).
- Separating the storm and sanitary sewer into two pipes at the Rockford Road location, a sensitive location upstream of the city's public water supply intake.
- Installing Global Real Time Control devices for "smart" flow management that will optimize management and maximize use of available interceptor capacity.
- Disconnecting roof drains to reduce the rain water flowing into the sewers to increase capacity for sanitary water usage of the sewer pipes.
- Using meteorological forecasting as a prediction tool that can be utilized to determine where and when sewer needs are likely to be greatest for stormwater.

A detailed description of the projects can be viewed in the city's Enhanced Long Term Control Plan.

Nutrient and Bacteria Reductions

Water quality modeling of the CSOs was performed as part of the Christina Basin TMDL development. The level of CSO control that will be provided with implementation of the City's Enhanced LTCP will provide the basis for assessing CSO loads and wasteload allocations in relation to all other load sources in the Christina Basin during TMDL development (Greeley and Hansen, December 2003). The City of Wilmington will also be revising the LTCP to comply with the USEPA's TMDL for bacteria.

Cost

Key CSO controls will have capital costs of approximately $26.9 million and a target completion date of 2010. The $26.9 million price tag does not include the $30 million already spent on the WWTP plant upgrade. Table 4.21 details the projects and capital costs associated with the $26.9 million price tag. Including the $30 million already spent, the city is committing approximately

$57 million to reduce CSOs and further optimize the use of CSS and wastewater treatment infrastructure. It is estimated that complete elimination of the system would cost $338–$344 million.

Table 4.23 Capital Costs for Key CSO Projects

Capital Costs for Key CSO Projects		
Key CSO Project	**Construction Cost**	**Total Capital Cost (1)**
Canby Park Storage, CSOs 28/29 (2)	$5,650,000	$5,650,000
CSO 4a/4b Regulator Modifications	$ 220,000	$ 290,000
CSO 27 Diversion Sewer	$3,500,000	$ 4,030,000
Rockford Road Sewer Separation	$1,500,000	$ 1,730,000
Real Time Control System	$6,000,000	$ 7,200,000
Brandywine Siphon Modifications	$1,500,000	$1,730,000
11th Street Pump Station Upgrade	$4,000,000	$4,600,000
Price Run Diversion Interceptor	$1,500,000	$1,730,000
Total	$23,870,000	$26,960,000
(1) Total capital costs include construction plus engineering and administration costs.		
(2) Engineering costs expended prior to the LTCP planning timeframe are not included here.		

Source: City of Wilmington, Department of Public Works, CSO Program, Enhanced Long Term Control Plan, Greeley and Hansen, LLC, December 2003

Source of Funding

- City of Wilmington
- State of Delaware
- Federal Grant Sources

Location

Priority projects are the CSOs above the drinking water intakes and the priority projects outlined in the Enhanced LTCP.

Implementing Organization(s)

- City of Wilmington
- State of Delaware

Type of Action

Federal mandate under the National CSO Policy

WW6. Continue Separate Sewer Repair Projects, Inspection, and Elimination of Unpermitted Storm Drain Discharges

The Christina Basin TAT recommends instituting an inspection process of sanitary lines and manholes—either watershed-, county-, or municipal-wide—to correct any leaking sewer lines and eliminate any illicit discharges in the separate sewer system. These inspections must be performed on the sanitary lines and manholes on a regular basis with up-to-date technology. According to the report *A Watershed Restoration Action Strategy for the Delaware Portion of the Christina Basin,* published in June 2003, point sources in the Delaware portion of the Christina Basin have declined by 70 percent from 34 discharges in 1977 to 10 in 1999 due to regional wastewater plans implemented by DNREC, City of Wilmington, and New Castle County governments (Kauffman, et al., 2003). Most of the discharges were removed by consolidating flows into the northern New Castle County regional sewer system. Although the point source TMDL addresses the NPDES discharges in the basin, it is important to recognize that in addition to the permitted NPDES discharges there are failures in the separate sewer systems and illicit storm drain discharges that can be found and eliminated if a regular inspection program is implemented. In addition, several sewer lines and manholes are close to creeks and discharge in or near the creeks. Regularly inspecting sewer lines in these areas and finding leaks or problems related to the sewer system can help to eliminate the problems and can prevent raw sewage from flowing into the stream. Inspection of the system will improve water quality and reduce volume overflow.

Nutrient and Bacteria Reductions

Damaged separate sewers and unpermitted storm drain discharges are a significant source of nitrogen, phosphorus, and bacteria. It is difficult to quantify the reductions resulting from investment in separate sewer repair projects, inspection programs, and eliminating unpermitted storm drain discharges, but it will have a significant role in decreasing the nutrient and bacteria loads in the streams and tributaries of the Delaware portion of the Christina Basin.

Cost

Costs associated with repairing, rehabilitating, and replacing separate sewer infrastructure in New Castle County, City of Newark, and City of Wilmington systems are highly variable. Sample costs for sewer repair projects in New Castle County and City of Newark are provided in Tables 4.21 and 4.22. Costs for sewer repair in the City of Wilmington are not included because the majority of the sewer system is a combined system, and the costs for Wilmington are highly skewed due to the nature of this system. The costs related to abating the combined sewer system are detailed in recommendation WW5.

The New Castle County cost information in Table 4.21 is from the *Fiscal Year 2007 Comprehensive Annual Budget Summary, New Castle County Delaware.* The New Castle County report notes that the ongoing rehabilitation of existing sewer lines continues to involve both large and small projects. The report breaks down the project costs into separate fiscal year budget requests, but, for the purposes of the PCS, the total project costs are the most important in assessing the economic feasibility of this recommendation and are included in the Table. The projects included in Table 4.24 are those that are contained either entirely or partially within the Delaware portion of the Christina Basin, with the exception of projects 0219 and 0511. Project numbers 0219 and 0511 are manhole rehabilitation and general sewer repairs and rehabilitation for the entire county that contains areas both within the Christina Basin watershed boundary and outside of it. The costs will be slightly higher then for the projects contained within the Christina Basin. These projects will significantly alleviate SSOs in the Christina Basin. The costs in Table 4.25 are from the *City of Newark, Delaware Capital Improvement Program Project Detail 2007 – 2011* report. The costs reflect total sewer rehabilitation budget funding, requests, and five-year improvement program recommended funding (2008-2011). The City of Wilmington funding estimates are not included because the majority of the sewer system is a combined system. The City of Wilmington does have two main areas of separate sewers in Brandywine Hills and portions of south Wilmington; these areas are included as priority areas for this recommendation.

Table 4.24 New Castle County Separate Sewer Repair Project Cost Estimates as of August 2007

Project	**Project Description**	**Total Budget (through FY 2013)**
Boxwood Road Sanitary Sewer Improvements (Project 0610)	Hydraulic analysis, metering, field investigation, and design of sewer improvements to sanitary sewer located in the vicinity of the Little Mill Creek Interceptor near Boxwood Road.	$600,000
Turkey Run Interceptor Rehabilitation (Project 0224)	Rehabilitate the Turkey Run Interceptor between Washington Street through Fairfax Development.	$2,500,000
County-wide Manhole Rehabilitation (Project 0219)	This project will rehabilitate and repair over 3,500 manholes identified as deficient. The work includes replacing the frame, cover, and internal repairs and renovations as needed.	$11,000,000
Brandywine Hundred South Rehabilitation (Project 0218)	Rehabilitation of sewer system in south Brandywine Hundred Area (Shellpot Interceptor) to correct capacity shortages due to infiltration and inflow.	$93,263,000
Pike Creek Improvements (Project 0422)	Infiltration and inflow analysis of the interceptor and design improvements to the interceptor to accommodate additional flows and to connect the system to the new White Clay Interceptor.	$11,000,000
Sewer Repairs and Rehabilitation (Project 0511)	Sewer repairs and rehabilitation as determined by the Department of Special Services from analysis.	$15,520,000
Hyde Run Relief (Project 9604)	Relief sewer construction to alleviate identified system constriction points.	$7,628,000
White Clay Creek Pump Station Rehabilitation (Project 0002)	Installation of fifth pump, waterproofing, and rehabilitation of electrical/mechanical systems.	$3,350,000
Mill Creek Interceptor Relief (Project 0323)	Place 4,900 linear feet of 24" relief sewer along Mill Creek between Limestone Road and Stoney Batter Road.	$2,300,00

Source: Zern, August 2007

Table 4.25 City of Newark Sewer Rehabilitation

Year	Budget Funding (2006), Request (2007), and Five-Year Improvements Program Recommended Funding (2008-2011)
2006	$0
2007	$0
2008	$20,000
2009	$20,000
2010	$20,000
2011	$20,000
Total	**$80,000**

Source of Funding

- New Castle County
- City of Newark
- City of Wilmington

Location

New Castle County, City of Newark, and City of Wilmington already have priority sewer repair and rehabilitation projects. The repairs and rehabilitation that occur throughout the Delaware portion of the Christina Basin should be prioritized with consideration to the county's and cities' priority schemes. In addition, implementing a thorough inspection program will identify the biggest threats to water quality in the existing systems, and repairs should be prioritized based on the biggest pollutant contributors to the water quality in the Christina Basin.

Implementing Organization(s)

- New Castle County, Department of Special Services
- City of Newark, Water and Wastewater Department
- City of Wilmington, Public Works Department

Type of Action

Regulatory

WW7. Remediate Contaminated Sites

Contaminated sites such as state and federal superfund sites, Resource Conservation and Recovery Act (RCRA) sites, hazardous substance sites, landfills (active and inactive), leaking underground storage tanks, and gravel pits and borrow pits can be potential contaminant sources of pollutants in stormwater runoff. These sites can cause the water quality in the streams and rivers to become increasingly degraded and can create a threat to our drinking water supplies. Contaminants from these sites can also be negatively impact groundwater quality, which can impact surface water quality. It is important to include the remediation of these contaminated sites in the Christina Basin PCS due to their potential negative impact on surface water quality.

The USEPA and DNREC Division of Air and Waste Management have cleaned up many superfund sites, leaking underground storage tanks, and hazardous substance sites in the Christina Basin including, but not limited to, the following sites:

- **DE-1084 Amtrak Centralized National Operations Center**
  The site was used formally as an operational shipyard and other heavy industry. The area was remediated, and the Certificate of Completion of the Remedy was issued. The site now serves as the location of the Amtrak National Operation Center.
- **DE-1085 Madison Street Connection**
  This was the site of ship building and other heavy industrial activities. The site was remediated by removal and selective reuse of excavated soil and currently serves as a paved roadway.
- **DE-1116 Riverwalk Park**
  This site is approximately two acres in size and is located on the north shore of the Christina River. During work on the property, several USTs and PAH contaminated soil were discovered. The site was remediated by placement of a cap and institutional controls.
- **DE-1044 CSX**
  The site is comprised of approximately 2.4 acres. The investigation showed elevated concentrations of arsenic and PAHs. The site was remediated by capping with clean soil and/or building construction. The site currently is being used as a commercial space.
- **DE-0199 NVF-Newark Company Site (Timothy's Restaurant/Mill at White Clay)**
  This Voluntary Cleanup Program site is comprised of 14 acres. The site historically contained fiber and paper mills along the White Clay Creek downstream from Paper Mill Road. Leaking USTs were removed as part of the remediation. Additionally, surface soils contaminated with zinc, lead, and PAHs were removed or capped with clean soil, parking lots, or buildings. The creek-side site has been renovated with the construction of a restaurant—Timothy's—and offices.
- **DE-0163 Del Chapel**
  Del Chapel is an 8.5 acre site with a small tributary of the White Clay Creek flowing through. The site previously was a fiber factory near downtown Newark dating back to 1907. The soils were contaminated with zinc, arsenic, and organic chemicals and were remediated by removing the contamination and constructing private student housing for University students. The zinc-contaminated groundwater, which discharges into surface water, is planned to be treated in the third quarter of 2007.
- **DE-1321 Christina Landing**
  The approximately 9.5 acre site is on the southern banks of the Christina River in Wilmington, between the Market Street and Walnut Street bridges. During construction activities for the development of the site into townhomes and condominium towers, free-phase petroleum products were discovered on a portion of the site, which had previously been used as an above-ground storage tank farm. The free-phase petroleum laden soils were properly excavated and disposed of as were oily waters associated with the excavation.
- **PCBs in Piedmont Streams**
  DNREC's Division of Water Resources, Watershed Assessment Section is leading a focused effort in the lower Christina River to develop a PCS for PCBs. PCBs in the Piedmont streams have the potential to reduce human health and increase ecological risks.

- **Site Index Database**
  There is a statewide identification of potential contaminant sources including: underground storage tanks, superfund sites, animal feed operations, NPDES, landfills, and other potential contaminant sources.

DNREC's Brownfields Program will continue to work with the City of Wilmington and its consultants on remediating sites that are attributed to the city's industrial past. The most current data available was collected using DNREC's Environmental Navigator, and this data was used to compile the contaminated source data in Table 4.26. Table 4.26 summarizes the contaminated substance sources by category for the Brandywine, Red Clay, and White Clay Creeks, and Christina River watersheds.

Table 4.26 Contaminated Substance Sites in the Christina Basin

Type of Contaminated Substance Site	**Number of Contaminated Sites per Watershed**				**Total Sites in the Christina Basin**
	Christina River	**White Clay**	**Red Clay**	**Brandywine**	
Superfund	2	1	0	0	**3**
SIRB	228	46	9	56	**339**
Salvage Yards	31	1	0	1	**33**
TRI	15	2	0	1	**18**
Landfills	1	0	0	0	**1**
UST	672	229	100	255	**1256**
TOTAL Contaminated Substance Sites per Watershed	**949**	**279**	**109**	**313**	**1650**

Nutrient and Bacteria Reductions

It is difficult to estimate the nutrient and bacteria reductions associated with this recommendation. Past site remediation has shown improvements in water quality in nearby streams and tributaries.

Cost

The range of costs associated with the remediation of an average hazardous substance site is \$100,000–\$3,000,000. However, there are a few sites that will end up costing in the range of \$20 million. These reference amounts provide a range for costs associated with the remediation of a Brownfield site. These costs are approximated, and the presented values are not absolute. Costs per site can vary due to various factors including, but not limited to, the size of the site, chosen remedy, types of contaminants, concentration of contaminates, extent of contamination, type of site, end use of the site, length of monitoring after the remediation required, and other miscellaneous costs associated with the identification, investigation, remediation, and oversight.

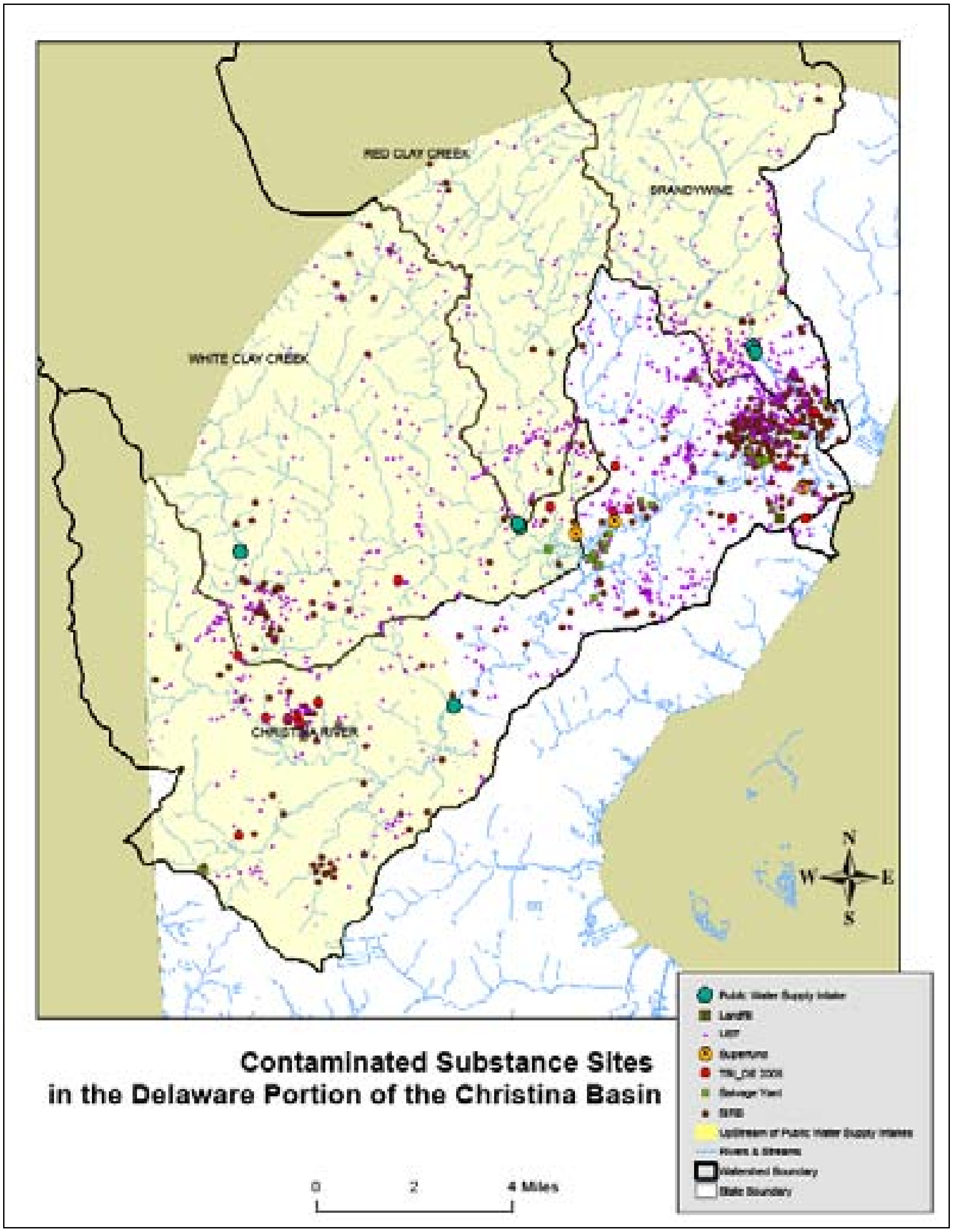
Source of Funding

- DNREC, Division of Air and Waste Management
- Site Owners

Location

Location for the remediation of a contaminated substance site is determined on a site-by-site basis. Table 4.23 provides an accounting of the contaminated substance sites, including federal superfund sites, SIRB sites, salvage yards, TRI sites, landfills, and USTs located in the Christina Basin. Some of these sites are directly upstream from the public water supply intakes in the Brandywine, Red Clay, and White Clay Creeks, and Christina River watersheds. The light yellow shaded area in Figure 4.12 illustrates the watershed areas that are upstream of the public water supply intakes. The Christina Basin PCS recommends that the contaminated substance sites in the shaded areas in Figure 4.12, which are upstream of the public water supply intakes, should be given the highest priority for remediation.

Figure 4.12 Priority Remediation Sites for Contaminated Substance Sites in the Delaware Portion of the Christina Basin



Implementing Organization(s)

DNREC, Division of Air and Waste Management

Type of Action

Regulatory

4.5 Agriculture Recommendations

The Christina Basin TAT has selected several agriculture BMPs to serve as examples of potential practices for the agriculture sector to implement to reduce the nitrogen, phosphorus, and bacteria contributions to the tributaries of the Christina Basin. There are numerous BMPs that can be implemented in the agriculture sector, but the Christina Basin Tributary Action Team has chosen to highlight the nutrient and bacteria reductions and costs associated with a small selection of them due to the high number of BMPs available and the low percentage of agriculture land in the Delaware portion of the Christina Basin. The largest portion of the agriculture lands in the Christina Basin is contained within the Pennsylvania portion. Although the majority of the agriculture land in the Christina Basin is contained in Pennsylvania, it is important for Delaware's PCS to provide recommendations to reduce the agriculture nutrient and bacteria loads in the Delaware portion of the Christina Basin. Select BMPs from the numerous agriculture BMPs available are listed in Table 4.27 and are described in more detail in this section. The intent of the agriculture recommendations is to make progress toward achieving the Christina Basin TMDLs.

Table 4.27 Select Agriculture Recommendations

Agriculture
Select BMPs from Agriculture Recommendations
AG1. Nutrient Management Plans
AG2. Cover Crops
AG3. Pasture Stream Fencing
AG4. Grassed Filter Strips
AG5. Grassed Waterways
AG6. Forested Riparian Buffers
AG7. Pasture and Hay Planting
It is important to note that the manure and waste transfer and the feed-related amendment best management practices are not applicable in the Delaware portion of the Christina Basin.

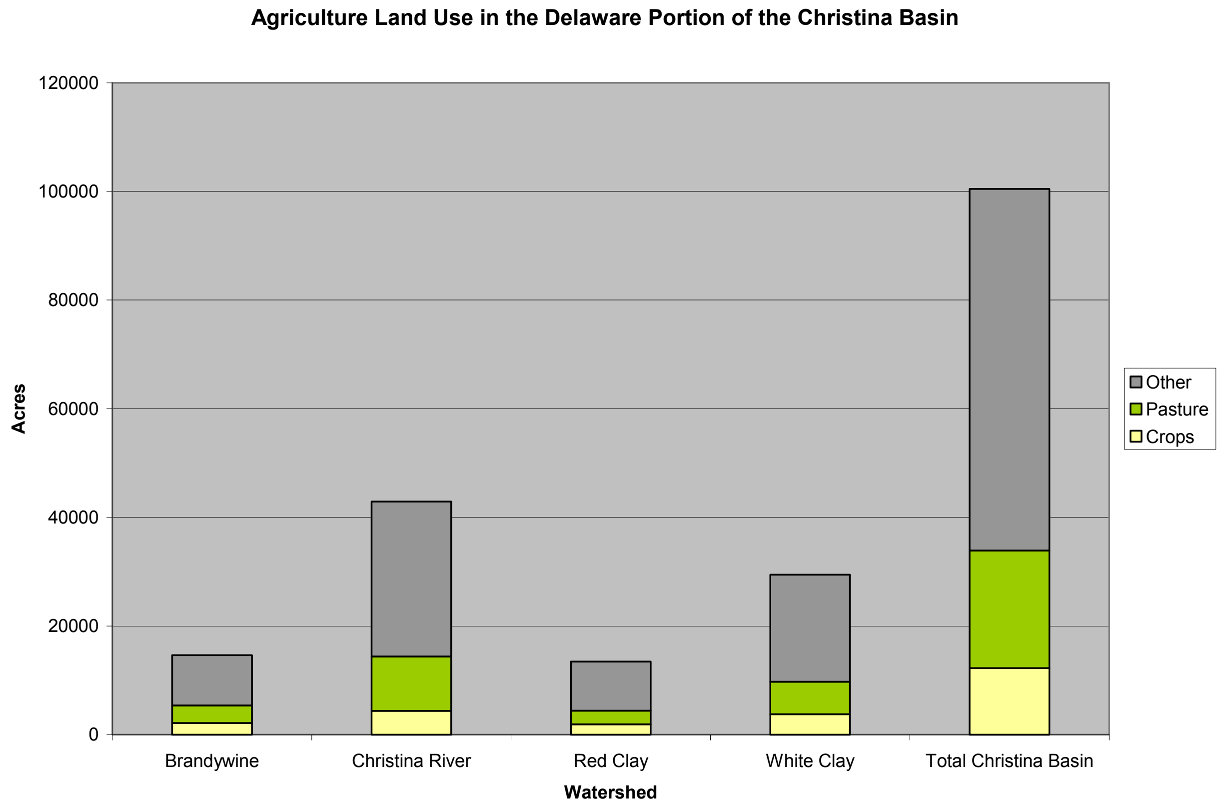
According to the USDA's Agriculture Statistics Services, 2002 cropland data, the largest amount of crop and pasture land in the Delaware portion of the Christina Basin is contained in the Christina River watershed, with approximately 14,388 acres. The Red Clay Creek has the smallest amount of agriculture acreage with approximately 4,403 acres. Figure 4.13 illustrates the breakdown of the agriculture land use that is shown in Table 4.28 for the Delaware portion of the Christina Basin. For the purpose of this exercise, the data collected from the USDA's Agriculture Statistics Services data was grouped according to three categories: pasture, crop, and other. The other category includes all land uses that were not classified as crop or pasture, which include: urban, wetlands, woods, woodland, clouds, water, and grassland.

Table 4.28 Agriculture Acreage in the Delaware Portion of the Christina Basin

Watershed	**Crops (acres)**	**Pasture (acres)**	**Other (acres)**
Brandywine Creek	2,169	3,231	9,246
Christina River	4,364	10,024	28,537
Red Clay Creek	1,910	2,493	9,042
White Clay Creek	3,785	5,936	19,733
Christina Basin	**12,229**	**21,684**	**66,559**

Source: 2002 Cropland Data produced by the USDA National Agriculture Statistics Services

Figure 4.13 Agriculture Land Use in the Delaware Portion of the Christina Basin



Source: 2002 Cropland Data produced by the USDA National Agriculture Statistics Services

The farms in the Delaware portion of the Christina Basin are predominantly hay farms with a very small sampling of the following types of farms: dairy farm, milk processor, cattle and pig farms, and less than six mushroom farms. In identifying the most effective ways to decrease nitrogen, phosphorus, and bacteria loads coming from these agriculture lands, it is essential to identify what farms are active in this portion of the basin and which of these farms have not implemented nutrient management plans (NMPs).

In addition to the crops and pastures that are contained in the Delaware portion of the basin, it is important to consider the equine industry and its impact on water quality. Delaware's equine industry is significant to the economy and helps to keep land in open space, but it also contributes to the nutrient input to the tributaries of the Christina Basin. Equine operations are diverse in terms of the size of the farm, the type of equine at the farm, and the types of activities the equine are engaged in at the farm. New Castle County, Delaware, contains the smallest percentage of horses in the state, yet it is important to recognize that this is a contributor to the nutrient loads in the tributaries in the Christina Basin. According to the USDA Delaware State Office, there are approximately 17 horse farms located in the Delaware portion of the Christina Basin. When considering nutrient and bacteria reductions for agriculture areas, equine as well as cropland and pasture are important to recognize and consider.

Table 4.29 Agriculture BMPs for Water Quality Improvements

WATER QUALITY BMPS FOR AGRICULTURE					
	TARGET POLLUTANT				
SOURCE	Excessive Nutrients and Organics in Surface Water	Excessive Suspended Sediment and Turbidity in Surface Water	Harmful Levels of Pathogens in Surface Water	Harmful Levels of Pesticides in Surface Water	Harmful Temperatures of Surface Waters
Animal Waste	Waste Storage Structure	Use Exclusion	Waste Storage Structure		
	Animal Mortality Facility	Roof Runoff Structure	Animal Mortality Facility		
	Composting Facility	Access Road	Manure & Waste Transfer		
	Use Exclusion	Heavy Use Protection			
	Heavy Use Protection				
	Manure & Waste Transfer				
Crop Management	Residue Management	Residue Management	Residue Management	Cover Crop	
	Cover Crop	Cover Crop	Cover Crop	Pest Management	
	Irrigation Water Management	Critical Area Planting	Irrigation Water Management		
	Nutrient Management	Irrigation Water Management	Nutrient Management		
		Nutrient Management			
Fish & Wildlife	Riparian Forested Buffer	Field Border	Riparian Forested Buffer	Riparian Forested Buffer	Riparian Forested Buffer
	Filter Strip	Riparian Forested Buffer	Filter Strip		
		Filter Strip			
Structures		Diversion	Roof Runoff Structure		
		Grade Stabilizing Structure			
		Grassed Waterway			
		Roof Runoff Structure			
Grazing	Fence	Forage Harvest Mgmt	Forage Harvest Management		
	Forage Harvest Management	Pasture & Hay Planting	Pasture & Hay Planting		
	Pasture & Hay Planting	Prescribed Grazing	Prescribed Grazing		
	Prescribed Grazing	Watering Facility			

Source: EQIP Ranking Tool – FY 2007

Nutrient and Bacteria Reductions

Table 4.30 lists several agriculture BMPs and their associated nutrient and bacteria reductions. The Christina Basin TAT Agriculture Subcommittee will consider these BMPs and those listed in the section above for implementation on the agriculture lands in the Delaware portion of the Christina Basin.

Although bacteria estimates are not quantified for some of the agriculture BMPs in this Table, bacteria reductions tied to the agriculture recommendations are implied. As recommended in the stormwater, open space, wastewater, and education sections of the Christina Basin PCS, further research quantifying the bacteria reductions associated with the agriculture recommendations outlined in this document is an important tool to improve the water quality in the streams and rivers of the Christina Basin. The team recommends that DNREC conduct research to quantify the bacteria reduction values associated with the agriculture BMPs outlined in this document. This research will provide reduction estimates that will support the implementation and funding of agriculture BMPs that will lead to improvements in water quality and achieving the bacteria TMDLs.

Table 4.30 Approximate Reduction Efficiencies for Select Agriculture BMPs

Recommendation	Approximate Percent Reduction		
	TN	TP	Bacteria
Cover Crops	~59, but varies depending on species used	5	
Pasture Stream Fencing	NA	NA	100
Grassed Waterways	Reductions result from land use conversion from agriculture to grasslands		
Riparian Forest Buffers	62	62	43-57
Grassed Filter Strips and Grassed Buffers	46	54	44
Wetland Restoration	62	62	30

Costs and Source of Funding

The Christina Basin TAT Agriculture Subcommittee will prioritize existing USDA, Conservation Reserve Program (CRP), Wildlife Habitat Incentives Program (WHIP), Wetlands Reserve Program (WRP), and Environmental Quality Incentives Program (EQIP) funds for implementing the following agriculture BMPs. The BMPs in Table 4.26 are the recommended BMPs from the *EQIP Ranking Tool – FY 2007* for water quality improvements specifically related to: excessive nutrients and organics in surface water, excessive suspended sediment and turbidity in surface water, harmful levels of pathogens in surface water, harmful levels of pesticides in surface water, and harmful temperatures of surface waters.

Agriculture BMP funding is based on the cost-share options with the existing federal cost-share programs such as: CRP, WHIP, EQIP, WRP, etc. Unit cost estimates for agriculture BMPs are provided in Table 4.31. These cost estimate lists are used by NRCS and NCCD pending the program funding source. The cost-share list is updated each year, these are 2007 unit cost estimates. The unit costs in these lists reflect only the capital costs of implementing agriculture BMPs. In order to qualify for farmland assessment, farms with ten acres or greater must have at least $1,000 income per year from gross sales from agriculture, horticulture, or forest products within a two-year period, and farms less than ten acres must have at least $10,000 income to qualify for farmland assessment.

Table 4.31 Delaware Eligible Practices by Code – 2007 Unit Cost Estimates

Water Quality BMPs					
BMP Name	**BMP Code**	**Unit Type**	**Unit Cost**	**Cost Type**	**Share Rate**
Waste Storage Structure	313	Sq. Ft.	8	Actual Cost	75
Animal Mortality Facility	316	Per	10302	Actual Cost	50
Composting Facility	317	Per	3000	Actual Cost	75
Residue Management	329	Acre	10	Flat Rate	100
Cover Crop	340	Acre	35	Flat Rate	100
Critical Area Planting	342	Acre	217	Actual Cost	75
Diversion	362	Ft.	3	Actual Cost	50
Fence	382	Ft.	1.5	Actual Cost	50
Field Border	386	Acre	75	Actual Cost	50
Riparian Forested Buffer	391	Per	5	Actual Cost	75
Filter Strip	393	Acre	160	Actual Cost	75
Grade Stabilizing Structure	410	No.	4500	Actual Cost	75
Grassed Waterway	412	Acre	3000	Actual Cost	75
Irrigation Water Management	449	Acre	8	Flat Rate	100
Use Exclusion	472	Ft.	3	Actual Cost	75
Forage Harvest Management	511	Acre	10	Flat Rate	100
Pasture & Hay Planting	512	Acre	200	Actual Cost	50
Prescribed Grazing	528	Acre	40	Flat Rate	100
Roof Runoff Structure	558	Sq. Ft.	13	Actual Cost	75
Access Road	560	Ft.	16	Actual Cost	50
Heavy Use Protection	561	Sq. Ft.	4	Actual Cost	75
Nutrient Management	590	Acre	3	Flat Rate	100
Pest Management	595	Acre	6	Flat Rate	100
Watering Facility	614	No.	1100	Actual Cost	50
Manure and Waste Transfer	634	No.	2500	Actual Cost	75

Location

The Delaware Nutrient Management Commission requires development of an NMP for any business operation that applies nutrients to greater than ten acres of land or manages 8,000 pounds of animals. The Christina Basin TAT Agriculture Subcommittee will target their efforts on identifying specific farms in the Delaware portion of the basin that do not have NMPs nor implement agriculture BMPs.

According to data provided by the USDA, NRCS, and the New Castle Conservation District in the Delaware portion of the basin, there are:

- Twenty one active contracts or farms that have plans and BMPs have been implemented.
- Two hundred and seventy inactive folders which include properties that have not had active conservation plans within recent years or older contacts where the new property owners have not contacted NRCS for further assistance, many which are over twenty years old and are most likely now developed.

- Sixty nine have plans on file, but no contracts. Some of these farms have BMPs implemented and some do not.

Of the contacts with EQIP contracts and Conservation Plans, all are situated on agriculture-zoned property. This information is provided by watershed in Table 4.32.

Table 4.32 EQIP Contracts and Conservation Plans in the Christina Basin

Watersheds	EQIP	Inactive	Conservation Plans
Brandywine Creek	11	41	11
White Clay North	0	45	10
White Clay South	3	41	15
Red Clay North	1	29	10
Red Clay South	2	32	3
Christina River East	2	35	11
Christina River West	2	47	11
Subtotal	21	270	69
Total Folders	**360**		

Source: USDA, NRCS and NCCD

Using GIS mapping and analysis as well as local expertise and existing data, the subcommittee will identify which agriculture areas in the Delaware portion of the basin have implemented NMPs and various BMPs. The areas that are identified as deficient of NMPs and BMPs will be the focus of the subcommittee's efforts. The agricultural area in the Delaware portion of the Christina Basin (approximately 11 percent) is small enough that this type of approach will be the most effective.

The Brandywine Creek subwatershed contains the largest portion of agricultural lands in the Delaware portion of the Christina Basin. In addition to using GIS mapping and analysis to identify the priority agriculture lands, the PCS will focus on working with the Woodlawn Trustees. The Woodlawn Estates is approximately 2,000 acres of agriculture land in the Brandywine Creek watershed, and the Woodlawn Trustees have a history of willingly implementing BMPs on their lands, which are in easement.

It is also important to note that the Pennsylvania portion of the watershed is largely agricultural, and implementing NMPs and BMPs on the agricultural lands in Pennsylvania is essential in reducing the nutrient and bacteria loads in the rivers and streams in the Delaware portion of the Christina Basin.

Implementing Organization(s)

There are several organizations devoted solely to the management of agriculture lands in New Castle County and the state. Due to the institutional knowledge that representatives of these groups possess, the Christina Basin TAT recommends convening a subcommittee of these federal, state, and local agriculture representatives to discuss the status of the existing agriculture lands in this portion of the basin. A Christina Basin TAT Agriculture Subcommittee has been identified, and IPA-WRA will serve to coordinate and facilitate this group. The subcommittee shall consist of the following representatives of federal, state, and local agriculture organizations:

- Delaware's USDA, NRCS: Jack Lakatosh

- New Castle Conservation District: Robert Baker, Jessie Benjamin, Andy Burger, Carl Otte, Dariel Rakestraw, and Dave Woodward
- Delaware Department of Agriculture
- Pennsylvania's USDA, NRCS: Sam High
- Facilitators: University of Delaware IPA-WRA – Martha Corrozi and Jerry Kauffman

In addition to working with these subcommittee members, IPA-WRA will work with representatives of the Delaware Department of Agriculture to obtain additional data on plans implemented on agriculture areas in the Delaware portion of the Christina Basin.

Type of Action

Regulatory (Nutrient Management Plans) and Voluntary

4.6 Education Recommendations

Develop a Comprehensive Education Plan for the Urban/Suburban Sector on Issues of Water Quality and Urban Nutrients

Nonpoint source pollution stems from a variety of activities on land from the public, industry, homeowners, abandoned lots, agriculture, wastewater, and numerous other activities. Most of the BMPs that have been recommended in the stormwater, open space, wastewater, and agriculture sections focus on treatment and disposal of pollution after it has been produced rather than preventing it at the source. Source reduction is an alternative approach to pollution control, and is a more desirable and efficient approach to controlling nutrient and bacteria loads to the rivers and tributaries of the Christina Basin. The recommendations in this section are intended to prevent or reduce nonpoint source pollutant loadings from the urban/suburban sector through targeted education programs. Unlike most stormwater BMPs, the pollution prevention practices outlined in this section are nonstructural in nature and can be used to reduce pollution at its source. Public education is one of the most cost-effective BMPs that can be implemented to improve water quality.

The Christina Basin TAT recommends the 11 pollution prevention activities listed in Table 4.33 to reduce the adverse impacts of nonpoint source pollution at its source in urban and suburban areas. The team recommends that these activities will be most effective if a comprehensive education plan is developed. The pollution prevention activities are described in more detail in this section.

Table 4.33 Education Recommendations

Education
ED1. Educate Christina Basin stakeholders on nonpoint source pollution and their role in reducing it, specifically targeting behavior change.
ED2. Encourage nutrient management plans for turf fields at education facilities.
ED3. Encourage golf course managers to decrease nutrient application, stormwater runoff, and erosion.
ED4. Educate pet owners on cleaning up pet waste.
ED5. Educate homeowners on residential stormwater best management practices and maintenance of best management practices.
ED6. Integrate education into state and local permitting processes.
ED7. Encourage corporate environmental stewardship programs.
ED8. Coordinate nonprofit organizations throughout the basin.
ED9. Support and encourage water conservation and water quality measures to reduce nutrients leaving a site.
ED10. Work with organizations to provide education programs on lawn and garden best management practices.
ED11. Advise DNREC to research nutrient reductions related to bacteria counts and best management practices.

There are numerous resources available to aid in the development of pollution prevention programs. Briefly, each program must focus on an overall framework/plan for each measure with goals and objectives, a target audience, marketing strategy, distribution, and outreach material development. The group also recommends, if possible, focusing on one urban/suburban sector pollution source or issue at a time so that the message is consistent and thoroughly explored and taught. The team recommends that these activities will be most effective if a comprehensive education plan is developed.

How the Education Recommendations Will Be Achieved

The Christina Basin TAT recommends that the educational component of this plan be implemented through the creation and support of an education task force drawing from the existing environmental education community in the Delaware portion of the basin. Included in this community are nonprofit organizations like the Delaware Nature Society and the Partnership for the Delaware Estuary with strong records for developing and delivering educational programs related to watershed resources. This community also includes government agencies like DNREC, New Castle County, and the City of Newark that provide environmental education relevant to their programs and jurisdictions. The University of Delaware's Institute for Public Administration-Water Resources Agency (IPA-WRA) which has been involved in research, education, and watershed management in the Christina Basin for over ten years, and water suppliers like Artesian Water Company and United Water Delaware, which educate their consumers and residents about issues relevant to their water supplies, are also important participants. A list of other potential environmental education partners is listed in the implementing organizations section below. Several of these organizations and agencies were represented on the Christina Basin Tributary Action Team and are already engaged in programs related to increasing the understanding of water resources, promoting water conservation, and encouraging changes in social behavior to reduce the nutrient, bacteria, and chemical contributions to the Delaware portion of the Christina Basin.

In addition to the work of the organizations listed above, the Christina Basin Clean Water Partnership, formerly known as the Christina Basin Water Quality Management Committee, was established in 1993 as an interstate, public/private, collaborative, and coordinated effort to preserve and protect the basin. This group serves to coordinate the surface water quality management policies of Pennsylvania, Delaware, and the federal government within the Christina Basin. The committee is comprised of a number of government and nonprofit representatives. The Chester County Water Resources Authority and Chester County Conservation District serve as the local watershed coordinators for the Pennsylvania portion of the basin. IPA-WRA serves as the local watershed coordinator for the Delaware portion of the watershed and also has some capacity for coordinating and/or delivering water resource education programs in the watershed.

By creating and empowering the Christina Basin Education Task Force, instead of creating a new organization or education position, redundancy and inefficiency can be avoided, and this task force can pool and leverage existing resources and strengthen educational partnership and collaboration in the watershed. This task force will be a network of the existing agencies and organizations that are currently working on education programs in the Delaware portion of the basin. It will focus on implementing the education recommendations in the PCS through joint forces and existing programs in an attempt to reduce the nonpoint source pollution, including nitrogen, phosphorus, and bacteria, in the Christina Basin. This group will play a critical role in tracking and coordinating existing efforts and directing resources to the PCS education recommendations. This subcommittee will primarily serve the Delaware portion of the basin, but since the watershed crosses state boundaries, the efforts of collaboration and implementing education programs to improve the health of the Christina Basin will not stop at the state line.

Many, but not all, of the organizations that will be involved in the implementation of the Christina Basin Education Task Force serve on the Christina Basin Clean Water Partnership. The Education Task Force, the recommended vehicle for implementing the Christina Basin PCS education recommendations, can be created as an arm of the Christina Basin Clean Water Partnership. This structure will serve to keep the lines of communication of the education efforts open between the Christina Basin Clean Water Partnership and the Education Task Force, but will enable the task force to work independently as a subcommittee concentrating solely on achieving the TAT's education recommendations for the basin.

The Education Task Force will be a voluntary partnership dedicated to achieving the PCS education recommendations. The group will consist of representatives from nonprofit, public, and private organizations and stakeholders and will be open to the public. The Education Task Force may be funded through the IPA-WRA or another partner organization that has the capacity to accept, manage, and regrant funds. The coordinator will serve for two years and his or her responsibilities will be limited to organizing the meetings, leading the discussion, and working with the group on the priority programs. A modest stipend will be offered to the coordinator each year to compensate for his or her time, providing greater opportunity for nonprofit leadership.

The group will meet approximately four times per year. The goals of the task force will include:

- Develop and prioritize the outreach strategy for the Christina Basin according to the PCS education recommendations.
- Utilize existing resources/programs.
- Promote water resources education in the Christina Basin.
- Enhance coordination of the existing education efforts in the basin.

- Increase public involvement and engage the broad community in achieving the TMDLs.
- Connect the residents and stakeholders to the watershed through these education recommendations.
- Track the education efforts in the Christina Basin.
- Obtain funding to implement the education recommendations.
- Implement the Christina Basin PCS education recommendations.

The estimated costs associated with the task force will be related to leading the group/task force, group organization, and costs associated with implementing the education efforts. Whenever possible, implementation costs will take the form of grants to qualified task force members for delivery of the educational program called for under this plan. This will reduce costs by eliminating the need to create programs and recruit educators from scratch and utilizing the strengths of existing programs. The task force's role will be primarily limited to engaging qualified education providers and targeting and coordinating these programs to ensure that the recommendations for the Christina Basin are being achieved. The group will also play a role in cultivating funding sources for education initiatives that help achieve the Christina Basin TMDLs. However, the provision of implementation funding is critical to establishing the task force, engaging relevant members, and getting educational programming underway. The benefits of this approach, over creating a new group, will be to use the diversity of organizations that already exist in the basin, and leverage their individual strengths and skills to bring resources to the watershed and work in a targeted and strategic fashion to achieve the education recommendations in the Christina Basin PCS. More detailed cost estimates are provided in the cost section below.

Education Recommendations

ED1. Educate homeowners, corporations, golf courses, education facilities, and all other Christina Basin stakeholders on the concept of nonpoint source pollution. Emphasize that individuals have a significant role in reducing nutrient and bacteria loads. Specifically identify values that are affecting residential land management and potential polluting activities and target those that will effect behavior change.

ED2. Encourage education facilities to develop nutrient management plans for any turf athletic facilities where nutrients are applied.

ED3. Encourage golf course managers in the basin to go above and beyond the Delaware Nutrient Management Commission's nutrient application regulations. Encourage the supervisors to decrease nutrient application, nutrient laden stormwater runoff, and stream bank erosion.

ED4. Educate pet owners about the importance of cleaning up pet waste and install highly visible dog-waste bag dispensers in targeted areas.

ED5. Educate homeowners and homeowner associations on stormwater BMPs and BMP maintenance to reduce the impact on water quality. The education should specifically address the costs and benefits of implementing BMPs and the concept of a stormwater utility.

ED6. Integrate education into various (state and local) permitting and regulatory processes. Programs that may benefit from education campaigns include regulatory programs and efforts such as:

- Septic system maintenance
- CSOs
- HOA stormwater management
- MS4 stormwater management
- BMP implementation

Education may include lectures, workshops, and information campaigns, so that the public is aware of the environmental permits and the regulatory process in their community. Education efforts focused on informing the public about how their actions and behavior may affect the rivers and streams in their community are also important. Public information campaigns should be based upon a goal of behavior change.

ED7. Encourage corporate environmental stewardship through a program like the Partnership for the Delaware Estuary's Corporate Environmental Stewardship Program (CESP).

ED8. Coordinate the nonprofit organizations throughout the watershed to channel the resources to cover basin-wide education.

ED9. Support and encourage water conservation and water quality measures that individuals can use to help reduce the amount of nutrients leaving a site. Measures may include encouraging individuals to:

- Use gray water from around the home on plants, gardens, and for other watering purposes. Ensure that the gray water source is detergent free or from sources that use phosphate-free detergents.
- Install rain collection systems such as rain barrels and rain gardens.
- Direct stormwater runoff from roofs and impervious surfaces onto grassy areas.
- Use a drip pan to catch leaking motor oil.
- Conduct a soil test and develop nutrient management for residential lawns.
- Use water saving devices in and around the home.
- Reduce water usage in households and on lawns.
- Wash cars on the grass or away from impervious surfaces. Using a car wash instead of washing a car in the driveway or on impervious surfaces is encouraged because these facilities recycle the water. The team also discourages community groups from hosting fundraisers where cars are washed in parking lots. An alternative is to work with local car washes and sell coupons for the car washes.

ED10. Work with the Delaware Nutrient Management Commission, DNREC Urban Nutrient Management Program, master gardeners, retailers, and local nonprofit organizations to provide education and programs for homeowners on lawn and garden BMPs such as:

- Encouraging proper lawn care maintenance, including preserving a buffer along the stream edge, leaving lawn clippings on the lawn, using proper mowing practices, and using lawn and garden chemicals (including natural fertilizers and compost) properly.
- Reducing lawn size.
- Implementing water conservation measures and stormwater BMPs for the lawn and garden.

- Encouraging the use of native species and noninvasive species, for example encourage purchasing native landscaping species through coordination of nonprofit and government outreach messages with retail centers.
- Discouraging ideas that lawns need chemicals to be green.
- Using compost rather than chemicals as a means of reducing synthetic chemical fertilizers.
- Administering Smartyard programs for homeowners.
- Developing an advertising strategy that promotes the use of soil tests to the urban/suburban homeowner.
- Working with the University of Delaware to revise its soil test results sheet for homeowners to make it easier to understand and provide specific fertilizer application recommendations based upon existing fertilizer blends found within the state.
- Educating fertilizer retailers so they are educated about the impacts of lawn fertilizers and can pass this information along to consumers. Encourage fertilizer retailers to pass out educational materials with the purchase of fertilizer and provide soil testing material to the consumers.
- Supporting a demonstration project/workshop for homeowners on the application of fertilizers and composting methods.

ED11. Advise DNREC to research bacteria reductions associated with specific BMPs. Most of the bacteria reductions tied to the recommendations in the Christina Basin PCS are implied. DNREC has gathered some information regarding reducing bacteria with BMPs, this information is provided in Appendix N, but further research is necessary. Future research quantifying the bacteria reductions associated with the stormwater, open space, agriculture, and wastewater recommendations outlined in this document is an important tool to improve the water quality in the streams and rivers of the Christina Basin. The team recommends DNREC conduct research to quantify the bacteria reduction values associated with the BMPs recommended in this document. This research will provide reduction estimates that will support the implementation and funding of the BMPs in this PCS, which will lead to improvements in water quality and achieving the bacteria TMDLs.

Nutrient and Bacteria Reductions

It is not possible to estimate the nutrient and bacteria reductions resulting from the 11 education recommendations, but an environmental education component is critical for achieving the Christina Basin TMDLs.

Cost

The source control costs are typically associated with programmatic expenses such as signage, workshops, outreach materials, and development and enforcement of ordinances. Achieving these recommendations will also require dedicated staff to implement the programs and initiatives. Table 4.34 shows the estimated costs associated with establishing the Christina Basin Education Task Force and implementing the education recommendations in the Christina Basin PCS:

Table 4.34 Education Recommendation Costs

Task	Cost
Task Force Coordination/Facilitation	$4,000 (annually)
Regrants for Project Implementation	$75,000 (minimum per year to make meaningful progress on the recommended education initiatives over a 3-5 year period, not including any substantial advertising costs).*
Research	$35,000 (addition or use of one part-time DNREC staff person, approximate cost estimate)
Total	**$114,000**

*Actual costs are practically impossible to determine without assessing project-specific information on the watershed. Collecting, analyzing, and assessing that information to shape and prioritize these programs must be part of the task force's focus, especially early on and may require some resource (i.e., a paid project manager or consultant time) in itself.

Source of Funding

- 319 Monies
- EPA Pollution Prevention Grant Program
- Local Nonprofit Groups
- Water Utilities
- Government Agencies (municipal, county, and state levels)
- Private Companies

Location

Watershed-wide

Implementing Organization(s)

Potential environmental education partners include, but are not limited to:

- Artesian Water Company
- Brandywine Conservancy
- Brandywine Valley Association
- Christina Conservancy
- City of Newark
- City of Wilmington
- Coalition for Natural Stream Valleys
- DNREC
- Delaware Nature Society
- Green Delaware
- Mount Cuba Center
- New Castle Conservation District
- New Castle County
- Partnership for the Delaware Estuary
- Red Clay Valley Association
- Sierra Club

- State of Delaware
- Stroud Water Research Center
- USDA-NRCS
- USEPA
- United Water Delaware
- University of Delaware, IPA-WRA
- University of Delaware, College of Agriculture and Natural Resources
- White Clay Creek Wild and Scenic Management Committee
- White Clay Creek Watershed Association

Type of Action

Voluntary

Chapter 5: Monitoring

5.1 Christina Basin Water Quality Monitoring

The Christina Basin TAT stresses the importance of water quality monitoring to assess the water quality pre- and post-BMP implementation. Once the recommendations (or BMPs) in the Christina Basin PCS are implemented, it is important to assess the changes in the water quality to better understand the impact of the practices recommended in this strategy. Delaware is fortunate to have the Surface Water Quality Monitoring Program that addresses pre- and post-TMDL progress monitoring and supports the TMDL Program.

DNREC's Water Resources Division, Watershed Assessment Section is actively involved in technical monitoring throughout the state. Delaware maintains a General Assessment Monitoring Network (GAMN) of 181 stations throughout the state and has one Special Projects monitoring station in a select watershed. The GAMN stations are long-term monitoring stations and are used to conduct long-term status and trend assessments of water quality conditions. The Special Project monitoring stations are for short-term projects that require data to meet the Department's needs (Department of Natural Resources and Environmental Control, Division of Water Resources, Watershed Assessment Section, 2007).

Delaware is fortunate to have an aggressive and frequent monitoring program in place. In the past, GAMN stations were sampled 4–6 times per year and are currently being sampled 6–12 times per year. The Christina Basin is a highly monitored watershed in the state. The Watershed Assessment Section has water quality monitoring records dating back 30 years for select monitoring sites in the Christina Basin. According to the *Surface Water Quality Monitoring Program FY07* report, within the basin there are 24 DNREC GAMN stations, and each site will be sampled once a month. Table 5.1 provides a summary of the sampling schedule for the sites in the Christina Basin (Department of Natural Resources and Environmental Control, Division of Water Resources, Watershed Assessment Section, 2007).

Table 5.1 Sampling Schedule for the Christina Basin GAMN Stations

FY 2007 Sampling Schedule	GAMN Stations
July 2006	24
August 2006	24
September 2006	24
October 2006	24
November 2006	24
December 2006	24
January 2007	24
February 2007	24
March 2007	24
April 2007	24
May 2007	24
June 2007	24

The Brandywine Creek watershed contains four GAMN stations, the Christina River watershed contains seven GAMN stations, the Red Clay Creek watershed contains four GAMN stations, and the White Clay Creek watershed contains nine GAMN stations. Table 5.2 provides more detailed information on these stations in the Christina Basin. Figure 5.1 shows the location of each site in the Christina Basin.

Table 5.2 Stream Monitoring Locations and Information

Station Information	Map Identifier	Storet Number	Station Type	Monitor for Metals Criteria	Other Parameters and Testing
			GAMN	Copper, Lead, Zinc	Datasonde
Brandywine Creek					
Foot Bridge	BW_2	104011	12	12	
Rd. 279 Bridge (USGS gage 01481500)		104021	12	12	
Smith Bridge		104051	12	12	
Brandywine Creek, 0.6 miles upstream of the confluence with Christina River		104081	12		
Christina River					
Rt. 13/Rt. 9 Bridge		106011	12	12	
Route 141, Newport (USGS Tide Gage 01480065)	CR_3	106021	12	12	
Smalley's Dam Spillway	CR_2	106031	12	12	
Old Baltimore Pike, below Newark (USGS Gage 01478000)		106141	12	12	X
Route 273, above Newark	CR_1	106191	12	12	
Little Mill Creek, Atlantic Avenue (USGS Gage 01480095)		106281	12	12	
Conrail Bridge (USGS Tide Gage 01481602)	CR_4	106291	12	12	X
Red Clay Creek					
Stanton, Route 4 (USGS Gage 01480015)		103011	12	12	X
Wooddale, Rt. 8 (USGS gage 01480000)		103031	12	12	
Ashland, Rd. 258a		103041	12	12	
Burrough's Run Confluence		103061	12	12	X
White Clay Creek					
Stanton, Old Route 7 Bridge		105011	12	12	
Chambers Rock Road		105031	12	12	X
Mill Creek Confluence above Rt. 4 at Delaware Park		105071	12	12	
Pike Creek Confluence, Upper Pike Creek Rd.		105101	12	12	X
Middle Run Confluence, Possum Park Rd.		105131	12	12	
DE Park Race Track (USGS gage 01479000)		105151	12	12	X
White Clay Creek, at the end of McKees Lane		105171	12	12	
Pike Creek at Paper Mill Road Bridge		105181	12		
0.8 miles upstream of confluence with Christina River		105161	12		

Eight of the 24 monitoring stations in the Christina Basin are also USGS gage stations where real-time flow monitoring occurs. Real-time data are typically recorded at 15–60 minute intervals, stored onsite, and then transmitted to USGS offices every one to four hours. The USGS and DNREC's Watershed Assessment Section work together to share this data, which results in more detailed data at these eight DNREC monitoring sites. Seven sites in the Christina Basin have datasonde testing. The YSI (or similar) datasondes are continuous water quality monitoring stations that collect data for DO and other parameters several times each day. The continuous monitoring datasonde testing will begin in the Piedmont watersheds, which includes the Christina Basin, and will be rotated in the following years. As of May 2007, the monitoring has not begun due to the need for additional sampling procedure analysis (Department of Natural

Resources and Environmental Control, Division of Water Resources, Watershed Assessment Section, 2007).

According to the *State of Delaware Surface Water Quality Monitoring Program FY 2007* prepared by the Department of Natural Resources, Division of Water Resources, Watershed Assessment Section, the water quality parameters in Table 5.3 are analyzed using the following methods at all stations in the Monitoring Network, FY 2007. Table 5.4 provides information on the metal parameters and the testing method associated with these parameters.

Table 5.3 Water Quality Parameters and Methods

Parameter	***Method Reference (EPA)***	***Reporting Level***[1]
Water Column Nutrients		
Total Phosphorus	EPA365.1 M	0.005 mg/l P
Soluble Ortho-phosphorus	EPA365.1	0.005 mg/l P
Ammonia Nitrogen	EPA350.1	0.005 mg/l N
Nitrite+Nitrate N	EPA353.2	0.005 mg/l N
Total N	SM 4500 NC	0.08 mg/l N
Carbon and Organics		
Total Organic Carbon	EPA415.1	1 mg/l
Dissolved Organic Carbon	EPA415.1	1 mg/l
Chlorophyll-a (Corr)	EPA 445.0	1 µg/l
Biochemical Oxygen Demand		
BOD_5, N-Inhib (CBOD)	SM20thed-5210B	2.4 mg/l
BOD_{20}, N-Inhib (CBOD)	SM20thed-5210B	2.4 mg/l
General		
Dissolved oxygen – Winkler[2]	EPA360.2	0.25 mg/l
Dissolved oxygen – Field	EPA360.1	0.1 mg/l
Total Suspended Solids	EPA160.2	2 mg/l
Alkalinity	EPA310.1	1 mg/l
Hardness	EPA130.2	5 mg/l
Field pH	EPA150.1	0.2 pH units
Conductivity – Field	EPA120.1	1 µS/cm
Salinity	SM20thed-2520B	1 ppt
Temperature	EPA170.1	°C
Secchi Depth[3]	EPA/620/R-01/003	meters
Light Attenuation[4]	EPA/620/R-01/003	%
Turbidity	EPA180.1	1 NTU
Chloride	EPA325.2	1 mg/l
Bacteria		
Enterococcus cfu/100 ml	SM20thed-9230C	1 cfu/100 ml

[1]As documented in the ELS Quality Assurance Management Plan, the ELS defines the Limit of Quantitation (LOQ) as the lowest standard in the calibration curve or, in instances where a standard curve is not specified by the procedure, LOQ represents the limitations of the method. For those tests where reference spiking material exists, the ELS measures Method Detection Limit (MDL), as defined in the Federal Register 40 CFR Part 136 Appendix B. MDL values are generated or verified once per year.
Results less than the MDL are considered to be not detected and "< MDL" is reported.
Results greater than the MDL but less than the LOQ are qualified with a J to indicate a result that is extrapolated or estimated. For tests where MDL is not applicable, results less than the LOQ are reported as "< LOQ". ELS MDLs meet or exceed (i.e., are lower than) the reporting level requirements listed in Table 5.3.
[2]Secchi Depth to be measured at designated stations.
[3] Light attenuation to be conducted as practical to obtain correlation with Secchi disk readings.

Table 5.4 Metals Parameters

Metals (dissolved and total)	***Method Reference (EPA)***	***Reporting Level***
Copper	EPA 200.7 M	5.0 ug/l
Lead	EPA 200.7 M	3.0 ug/l
Zinc	EPA 200.7 M	10 ug/l
Arsenic (III)	EPA 200.7 M	10 ug/l
Chromium (hex) – Dissolved	SM13thed-117A	10 ug/l
Iron	EPA 200.7 M	100 ug/l

DNREC, Water Resources Division, Watershed Assessment Section is committed to providing the resources necessary to ensure that the streams and rivers in the Christina Basin are appropriately monitored. The Watershed Assessment Section is willing to consider supplemental monitoring or relocating monitoring stations where feasible if the current monitoring stations are not deemed adequate (Department of Natural Resources and Environmental Control, Division of Water Resources, Watershed Assessment Section, 2007).

5.2 Citizen Technical Monitoring Program

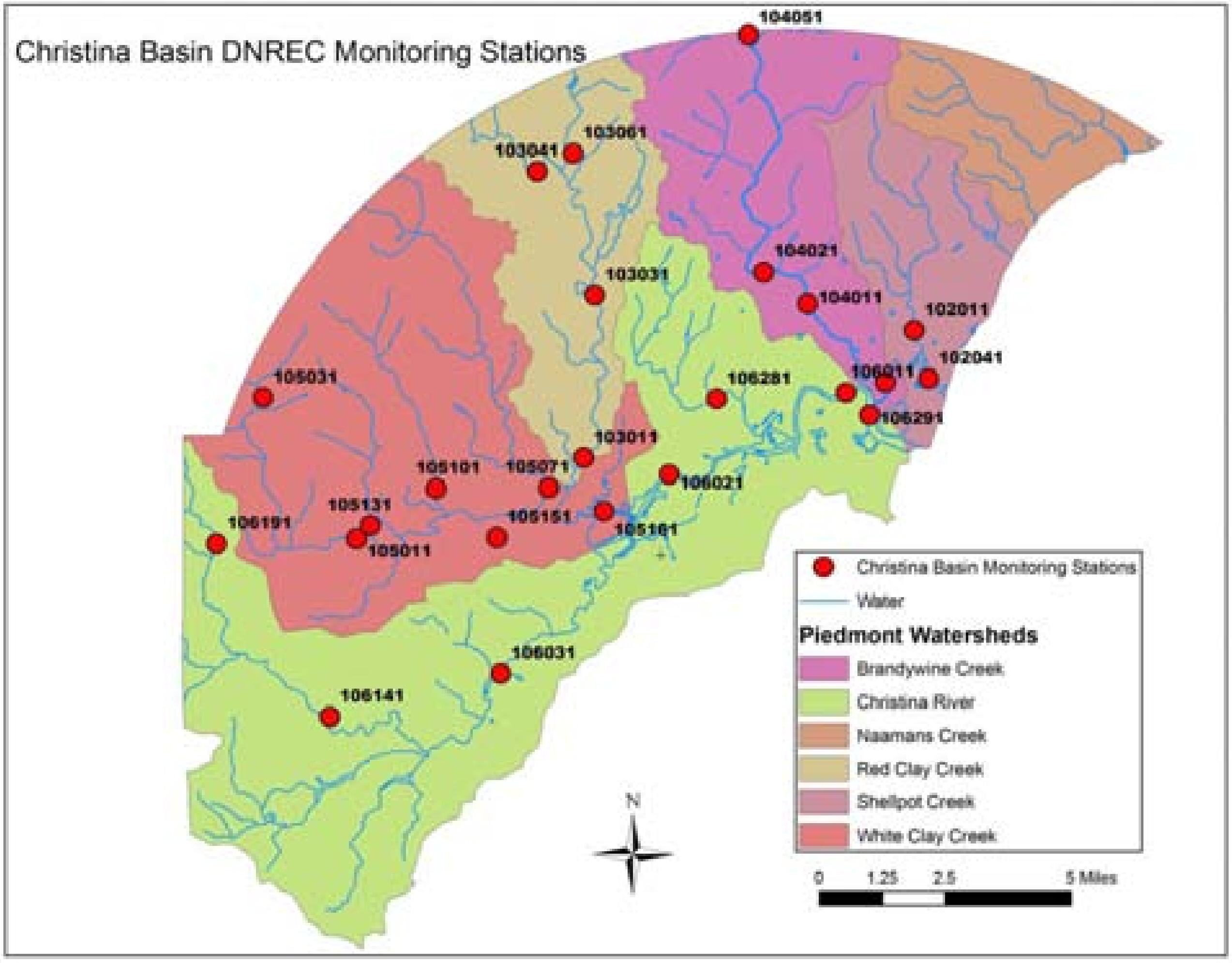
Several citizen monitoring programs have been established throughout the state to support DNREC's monitoring efforts. A citizen monitoring program is a volunteer program set up to encourage citizens to monitor specific stream sites for a variety of parameters. The monitoring typically occurs on a monthly basis. Volunteers in the program range from students to professionals. Testing is typically conducted for the following parameters:

- DO
- pH
- Alkalinity
- Nitrates
- Phosphates
- Conductivity
- Salinity in Tidal Reaches
- Temperature
- Flow

The Delaware Nature Society (DNS) has established a citizen technical monitoring program in the Christina Basin. Volunteers in New Castle County collect data on tributaries of the Brandywine, Red Clay, and White Clay Creeks, and the Christina River. According to the Delaware Nature Society, technical monitoring data has been collected at 30 locations within the Delaware portion of the Christina River Basin since 1995. The data is used to augment the DNREC monitoring stations and is published in the Delaware Nature Society's State of the Christina Basin Watershed reports and every two years as part of DNREC's Watershed Assessment Report (305(b)) (<http://www.delawarenaturesociety.org>).

The Delaware Nature Society's Citizen Technical Monitoring Program and citizen technical monitoring programs throughout the state are encouraged. The information these groups collect provides DNREC with valuable data and encourages watershed stewardship. Volunteers become the eyes and ears for the streams and provide valuable water quality monitoring data as well as information related to any degradation or unusual circumstances that may become apparent during their monthly monitoring visits.

Figure 5.1 Christina Basin Stream Water Quality Monitoring Stations



Chapter 6: Economic Analysis

6.1 The Cost of Implementing the Christina Basin Pollution Control Strategy

The ultimate goal of this Christina Basin Pollution Control Strategy is to improve the water quality and meet the federal Clean Water Act (CWA) goals of fishable and swimmable in the Delaware portion of the Christina Basin. Currently the streams in the Delaware portion of the basin are potable and fishable, but they are not swimmable. Through the implementation of the 40 recommendations outlined in Chapter 4, the Christina Basin Tributary Action Team hopes to achieve both the fishable and swimmable criteria.

The reduction values set by the USEPA for the high flow TMDLs in the Delaware portion of the Christina Basin mandate significant reductions in the nitrogen, phosphorus, and bacteria loads in the Brandywine, Red Clay, and White Clay Creeks, and Christina River watersheds. This PCS recommends 40 specific methods that have the potential to reduce these loads. All of these recommendations are important tools to reduce the loads. In addition to the detailed information provided for each recommendation in Chapter 4 of this report, an additional cost analysis is an important component of the Christina Basin PCS. It is valuable to identify the costs associated with each recommendation because it helps prioritize which recommendations are the most and least expensive and which recommendations, or suite of recommendations, will achieve the highest reductions at the lowest cost. Cost shall not be the only tool to prioritize implementation, but it is one of the ways to identify which recommendations will be the most cost-effective tools to achieve the fishable and swimmable goals of the Clean Water Act. Additionally, estimating the costs and quantifying the benefits of the Christina Basin (discussed in Section 6.2), provides a starting point for further analysis on whether the benefits of the Delaware portion of the Christina Basin outweigh the costs of implementing the PCS to achieve the goals of the federal Clean Water Act.

There are significant costs associated with each one of the 40 recommendations set forth in the PCS. Tables 6.1–6.5 provide a summary of the cost estimates for each recommendation set forth. It is important to note the cost estimates provided in these Tables are approximations and will vary significantly depending on variables, including but not limited to: size of the site, chosen BMP on the site, characteristics of the site, characteristics of the BMP, types of nutrients and contaminants being treated on the site, concentration of nutrients and contaminants on the site, extent of contamination, and other miscellaneous costs associated with the implementation of a particular BMP. The costs presented in Tables 6.4–6.5 have been collected throughout the PCS development process from February 2006–September 2007 and are estimates based on existing literature research and communication with practitioners in Delaware. These cost estimates are provided as a general range for discussing the costs associated with implementing the Christina Basin PCS and may vary considerably upon implementation of the recommendation.

This cost analysis only considers costs to the state, county, and local governments and nonprofit organizations. The cost analysis provided for each recommendation does not reflect the costs for developers and homeowners to implement these recommendations. The costs for several recommendations in Tables 6.1–6.5 are estimated at $20,000 per year. This estimate was determined through discussion with DNREC staff in the Division of Water Resources, Watershed Assessment Section. The cost per year for city or county staff to establish and maintain a regulation is estimated at 25 percent of a full-time salaried staff or $20,000 per year (Jones, 2007). According to our analysis, this estimate is the true cost for those recommendations that require only state or local regulations and city, county, or state staff time to establish and maintain the regulation. For those recommendations with the cost estimated of $20,000, any additional costs associated with the recommendation beyond the scope of developing and maintaining a regulation are considered private costs to the business or homeowner and are not considered part of the cost estimate. The private costs associated with implementing the recommendation are considered the cost of doing business for the developer or homeowner.

Stormwater Costs

Table 6.1 outlines the costs associated with each stormwater recommendation. The total cost for implementing the nine stormwater recommendations is estimated at a range of $10.8–$12.1 million per year. In reviewing the stormwater recommendations it becomes obvious that the most costly recommendation is SW1 (require urban tree canopy). Assuming the highest end of the range of costs (or $12.1 million per year), recommendation SW1 accounts for 81 percent of the total cost of implementing the entire suite of stormwater recommendations on an annual basis. The second most expensive stormwater recommendation is implementing SW8 (stormwater retrofits), which costs $1.8 million at the high end of the range provided for the stormwater recommendations. Stormwater is a major source of nonpoint source pollution, specifically nitrogen, phosphorus, and bacteria loads to the streams. These stormwater recommendations cost estimates prove that implementing the Christina Basin PCS is costly but implementing the stormwater recommendations is critical to achieving the high flow TMDLs in the Delaware portion of the basin. To maximize the efforts in achieving the TMDLs at the lowest cost it is important to consider ways to decrease the annual cost of some of the more expensive recommendations, like SW1 and SW8, to ensure that important BMPs like these are implemented. For example reducing the cost of SW1, require urban tree canopy, can be accomplished by decreasing the number of trees planted, increasing the level of volunteer plantings, establishing a corporate donors program, and utilizing various methods. If the costs of these two most expensive BMPs are removed, the cost of implementing the remaining stormwater recommendations is relatively low at approximately $0.5 million per year. This demonstrates that by identifying ways to reduce the cost of SW1 and SW8 the feasibility of implementing the stormwater recommendations of the Christina Basin PCS is largely increased. Considering the highly urbanized nature of the land use and the high population density in the Delaware portion of the Christina Basin, it is not surprising that the costs of the stormwater recommendations are so high. Once the costs for the stormwater recommendations are further refined, the costs may be significantly reduced and, meanwhile, this suite of recommendations has the potential to greatly improve the water quality in the most heavily populated and urbanized watershed in the state.

Table 6.1 Estimated Annual Costs of the Stormwater Recommendations

Recommendation	Basis	Unit Cost	Quantity	Total (per year)
SW1. Require urban tree canopy.	According to cost estimates provided by the Delaware Department of Agriculture Forest Service, Urban and Community Forestry Program.	$50 per tree (assuming varied types of trees planted and maintenance costs not included)	197,000 trees/year	$9,850,000
SW2. Design stormwater BMPs to reduce nutrients according to the TMDLs.	Estimated cost per year for DNREC staff to establish and maintain the regulation (costs of the BMPs are the cost of doing business).	$20,000 (25% of a full-time position)	per year	$20,000
SW3. Limit addition of new impervious cover to less than 20% of the watershed above public water supply intakes.	Estimated cost per year for city or county staff to establish and maintain the regulation (methods to reduce impervious cover are the cost of doing business).	$20,000 (25% of a full-time position)	per year	$20,000
SW4. Promote LID in new construction and redevelopment.	Estimated cost per year for City of County staff to establish and maintain the regulation (implementing LID is the cost of doing business).	$20,000 (25% of a full-time position)	per year	$20,000
SW5. Amend stormwater ordinances to create consistency throughout the watershed.	Based on cost estimates provided by the White Clay Creek Wild and Scenic Committee on an existing ordinance review project.	$500 per township, borough or city	60 (townships, boroughs, cities)	$30,000
SW6. Expand the role of RPTAC to create a Christina Basin group responsible for reviewing new development.	Based on cost figures associated with the RPTAC committee.	Staff time (chair, staff of NCC Dept. of LU) (approximately $500.00 per day) meets 12 times per year = $500.00 x 12 = $6,000. All other committee members serve on a volunteer basis.	per year	$6,000
SW7. Implement a stormwater utility.	Based on costs for establishing and implementing the City of Wilmington stormwater utility.	City of Wilmington = $400,000, this cost estimate includes: technical work, establishing a defensible rate system, and public outreach.	per city/county to establish a stormwater utility	$400,000
SW8. Identify areas where stormwater retrofits would effectively reduce sediment and nutrients.	Based on cost estimates provided by New Castle County Department of Special Services.	$100,000 - $365,000 per existing SWM facilities.	assume 5/year	$500,000 - $1,825,000
SW TOTAL				**$10,846,000-$12,171,000**

Open Space Costs

Table 6.2 outlines the costs associated with each open space recommendation. The total cost for implementing the seven open space recommendations is estimated at approximately $9.7 million per year. Many of the recommendations in the open space sector are relatively inexpensive due to the fact that they require analysis using existing data sources, development of plans, and the creation of and management of new ordinances that have the potential to further protect water quality. The most expensive recommendation in this suite of recommendations is recommendation OS6 (acquiring and conserving additional open space). The estimated cost of this recommendation is approximately $8 million per year to acquire and conserve 100 acres per year of open space in the Delaware portion of the Christina Basin. It is important to note that land acquisition costs are highly variable based on location and other price factors. This recommendation (OS6) accounts for over 80 percent of the total annual estimated costs to implement the open space recommendations. This cost may be reduced significantly by decreasing the number of acres acquired, identifying land donors, and identifying other key tools used in land acquisition efforts. Although OS6 is a major portion of the total costs of these recommendations, it is an important tool that will provide natural filter systems throughout the watershed and it is a key tool in meeting the Clean Water Act goals of fishable and swimmable.

Table 6.2 Estimated Annual Costs of the Open Space Recommendations

Recommendation	Basis	Unit Cost	Quantity	Total (per year)
OS1. Map, inventory, and prioritize existing wooded open space areas.	Based on cost estimates for an IPA-WRA graduate student full-time.	$14,000	per year	$14,000
OS2. Protect existing wooded/vegetated open space areas.	There is no cost associated with this recommendation.	$0	per year	$0
OS3. Require management plans for community and HOA open space areas.	Estimated cost per year for city or county staff to establish and maintain the regulation (maintenance costs are the responsibility of the HOA).	$20,000 (25% of a full-time position)	per year	$20,000
OS4. Require riparian forest 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 riparian forested buffers on existing development.	Estimated cost per year for DNREC staff to establish and maintain the regulation (tree, installation, and management costs for new development are the cost of doing business).	$20,000 (25% of a full-time position)	per year	$20,000
	Based on current cost estimates for establishing riparian forest buffers on existing development in the Christina Basin.	$2,500/acre for 300 sheltered trees, $4,860/acre for 400 sheltered trees, $14-$15 per tree for labor costs (Existing Development)	$4,860 per acre and 5 acres/year	$24,300
OS5. Implement stream restoration projects.	Based on cost estimates for the Pike Creek stream restoration project.	$1 million per 1 mile	1 mile/year	$1,000,000
OS6. Acquire/conserve additional open space and retain conservation easements.	Using maximum cost of open space acquisition in New Castle County, this estimate is based on the purchase price for the following properties in the Delaware portion of the Christina Basin: City of Newark Reservoir, Thompson Station Reservoir in White Clay Creek Preserve, and Glasgow Regional Park.	$45,000 - $80,000 per acre (Open Space Acquisition)	100 acres/year	$8,000,000
	Estimated cost per year for nonprofit organizations to work with property owners and manage conservation easements.	$20,000 (25% of a full-time position) (Conservation Easements)	per year	$20,000
OS7. Reforest watersheds and headwaters.	400 trees per acre x $14 per tree for installation = $5,600 per acre for tree costs and installation (costs for land acquisition and invasive species management are not included) x 100 acres = $560,000.	$5,600 per acre	100 acres/year	$560,000
OS Total				**$9,658,300**

Wastewater Costs

Table 6.3 outlines the costs associated with each wastewater recommendation. The total cost for implementing the seven wastewater recommendations is estimated at approximately $9.3 million per year. Table 6.3 includes CSO elimination cost estimates, but the total cost estimated for the wastewater recommendations that are discussed in this chapter does not include the costs associated with eliminating the CSOs in the City of Wilmington because this recommendation is not under the purview of the Christina Basin PCS. The combined sewer system is regulated according to the federal CSO policy, and controls associated with this program are not within the realm of the Christina Basin PCS. Since Chapter 4 of this document discusses the importance of eliminating the CSOs and notes their significant role in reducing the pollutant loads to the waters of the Christina Basin, it is included in the cost comparison provided in Table 6.3 but shall not be considered in the final cost analysis for implementing the Christina Basin PCS. The CSO recommendation (WW5), which carries an estimated cost of $26.9 million dollars to eliminate the entire system, is the most expensive wastewater recommendation, and the second most expensive wastewater recommendation is WW6 (continue sewer repair projects and conduct regular inspections) with an estimated cost of $8.19 million per year. The estimated cost for this recommendation is expensive due to the high costs associated with aging infrastructure improvements and repair. This recommendation accounts for approximately 89 percent of the annual total cost of implementing the wastewater recommendations in the Delaware portion of the Christina Basin. The cost of WW6 may appear high, but it is important to consider that the majority of the Delaware portion of the Christina Basin is served by a centralized sewer and much of this infrastructure is aged and entails costly repairs. Committing to repairing the infrastructure, however, has the potential to greatly improve the water quality.

Table 6.3 Estimated Annual Costs of the Wastewater Recommendations

Recommendation	Basis	Unit Cost	Quantity	Total (per year)
WW1. Performance standards, inspections, and pump-outs of OWTS.	Estimated cost per year for DNREC staff to establish and maintain the performance standard regulation (remaining costs are the cost to the homeowner: $5,000–$7,000/system; annual maintenance fee: $300–$500/system).	$20,000 (25% of a full-time position)	Per year	$20,000
	Estimated cost per year for DNREC staff to establish and maintain the inspection and pump-out regulation (remaining costs are the costs to the homeowner $100-$230/system/year).	$20,000 (25% of a full-time position)	Per year	$20,000
WW2. Systematically eliminate cesspools and seepage pits.	Based on cost estimates from New Castle County Department of Special Services. Cost range is $30,000–$35,000/household to connect to sewer. If the removal is part of the county's cost-share program the county covers 30%, and the homeowner covers 70%, therefore $9,000–$10,500 is the cost to the County.	Cost-share program	7 systems/year (part of NCC cost-share program)	$63,000-$73,500
WW3. Remove OWTS through connection to centralized WWTP.		Individual to Sewer	25 systems/year (cost to homeowner)	$0

Recommendation	Basis	Unit Cost	Quantity	Total (per year)
WW4. No new OWTS drainfields placed within 100-feet of wetlands, tidal waters, perennial streams, perennial ditches, and ponds in-line with perennial watercourses.	Estimated cost per year for DNREC staff to establish and maintain the regulation (remaining costs are the cost of doing business).	$20,000 (25% of a full-time position)	Per year	$20,000
WW5. Abate combined sewer overflows.	$30 million already spent, $26,900,000 + $30,000,000 = $57, 000,000 for entire system to meet Enhanced Long Term Control Plan goals.	$26,900,000	Entire system	$26,900,000
WW6. Continue sewer repair projects and conduct regular inspections.	The New Castle County cost information is from the Fiscal Year 2007 Comprehensive Annual Budget Summary, New Castle County Delaware. The New Castle County report notes that the ongoing rehabilitation of existing sewer lines continues to involve both large and small projects.	Average cost of NCC sewer projects slated for FY07 budget = $8,190,000	Per year	$8,190,000
WW7. Remediate contaminated sites	According to DNREC Site Investigation and Restoration Branch, this cost estimate provides a range for costs associated with the remediation of a Brownfield site. These costs are approximated and the presented values are not absolute. Costs per site can vary due to various factors including, but not limited to, size of the site, chosen remedy of the site, types of contaminants on the site, concentration of contaminates on the site, extent of contamination, type of site, end use of the site, length of monitoring after the remediation required, and other miscellaneous costs associated with the identification, investigation, remediation, and oversight.	Remediation of an average Hazardous Substance site is $100,000 to $3,000,000. A few sites cost in the range of $20 million.	It is difficult to estimate the number of sites per year, so assume $1,000,000 per year dedicated to site remediation.	$1,000,000
Wastewater Total (including CSOs)				**$36,213,000-36,223500**
Wastewater Total (excluding CSOs)				**$9,313,000-9,323,500**

Agriculture Costs

Table 6.4 outlines the costs associated with a select group of agriculture recommendations listed in the Christina Basin PCS. The total cost for implementing the seven agriculture recommendations is estimated at approximately $21,620 per year. In this cost analysis the cost estimates are used by the USDA's NRCS and NCCD pending the program funding source. The cost share list is updated each year, and these costs are the 2007 unit cost estimates. These unit costs reflect only the capital costs of implementing agriculture BMPs. In addition, there are only a select number of BMPs listed, yet there are numerous agriculture BMPs that can be implemented. In comparison to the costs outlined for the recommendations in the stormwater, open space, and wastewater sectors, the agriculture costs are relatively inexpensive. The lower costs are due to the cost-share programs, the limited agriculture areas available for agriculture BMP implementation in the Delaware portion of the basin, and the lower costs associated with these types of BMPs.

Table 6.4 Estimated Annual Costs of the Agriculture Recommendations

Recommendation	**Basis**	**Unit Cost**	**Quantity**	**Total (per year)**
Select BMPs from Ag Recommendations				
AG1. Nutrient Management Plans	These cost estimate lists are used by the NRCS and NCCD pending the program funding source. The cost share list is updated each year. These are 2007 unit cost estimates. These unit costs reflect only the capital costs of implementing agriculture BMPs.	$3/acre (100% cost share)	750 acres/year	$ 2,250
AG2. Cover Crops		$35.00/acre (100% cost share)	125 acres/year	$4,375
AG3. Pasture Stream Fencing		$1.50/foot (50% cost share)	700 feet/year	$525
AG4. Grassed Filter Strips		$160/acre (75% cost share)	6 acres/year	$720
AG5. Grassed Waterways		$3,000/acre (75% cost share)	1 acre/year	$2,250
AG6. Riparian Forested Buffers		$5/large seedling (75% cost share)	5 acres/year and 400 trees/acre	$7,500
AG7. Pasture and Hay Planting		$200/acre (50% cost share)	40 acres/year	$4,000
Agriculture Total				**$21,620**

Education Costs

Based on estimates provided by the group and representatives of nonprofit organizations that have worked on projects such as this in the basin, the total annual cost estimated for implementing a portion of the education recommendations each year is $114,000 per year. The education recommendations are the least costly of the five groups of recommendations. Although the education recommendations are the least expensive, they are one of the most important sets of recommendations due to the significant impact that behavior change and social awareness can have on reducing the impact of individuals' daily activities on the waters that make up the Christina Basin. Research has shown that behavior changes and the goals and programs outlined in the education set of recommendations are very difficult to achieve and require a very focused and concerted effort, but, if successful, result in beneficial behavior changes and positive impacts on water quality. Table 6.5 outlines each recommendation and the associated cost estimate per year to implement the education recommendations.

Table 6.5 Estimated Annual Costs of the Education Recommendations

<table>
<tr><th>Recommendation</th><th>Basis</th><th>Unit Cost</th><th>Quantity</th><th>Total (per year)</th></tr>
<tr><td>ED1. Educate Christina Basin stakeholders on nonpoint source pollution and their role in reducing it, specifically targeting behavior change.</td><td rowspan="11">This estimate is based on a rough calculation of the following: $35,000 for DNREC part-time staff person for research, $4,000 stipend for task force coordination, $75,000 for regrant project implementation, totaling $114,000 per year.</td><td rowspan="11">$114,000</td><td rowspan="11">Per year</td><td rowspan="11">$114,000</td></tr>
<tr><td>ED2. Encourage nutrient management plans for turf fields at education facilities.</td></tr>
<tr><td>ED3. Encourage golf course managers to decrease nutrient application, stormwater runoff, and erosion.</td></tr>
<tr><td>ED4. Educate pet owners on cleaning up pet waste.</td></tr>
<tr><td>ED5. Educate homeowners on residential stormwater BMPs and BMP maintenance.</td></tr>
<tr><td>ED6. Integrate education into state and local permitting processes.</td></tr>
<tr><td>ED7. Encourage corporate environmental stewardship programs.</td></tr>
<tr><td>ED8. Coordinate nonprofit organizations throughout the basin.</td></tr>
<tr><td>ED9. Support and encourage water conservation and water quality measures to reduce nutrients leaving a site.</td></tr>
<tr><td>ED10. Work with organizations to provide education programs on lawn and garden BMPs.</td></tr>
<tr><td>ED11. Advise DNREC to research nutrient reductions related to bacteria counts and BMPs.</td></tr>
<tr><td colspan="4">Education Total</td><td>$114,000</td></tr>
</table>

Total Costs of the PCS Recommendations for the Delaware Portion of the Christina Basin

Overall, the total cost of implementing the recommendations set forth in Christina Basin PCS is estimated at $31.28 million per year. The basis for the $31.28 cost estimate is literature research, communication with practitioners, and peer review. These costs are a reflection of 39 of the 40 recommendations that the Christina Basin Tributary Action Team formulated for the stormwater, open space, wastewater, agriculture, and education categories. The CSO elimination recommendation (WW7) is not included in this final cost estimate. As discussed previously, CSO elimination is not part of the charge of this group and is handled separately through the national CSO Policy. Therefore the cost is not included in the final estimated annual cost in Table 6.6. Table 6.6 summarizes the costs for each category discussed in the sections above. In Tables 6.1 and 6.3 a range of costs is estimated for the stormwater and wastewater categories but for the purposes of these tables the highest end of the range of the cost estimate is used to estimate the total annual costs to implement the Christina Basin PCS.

Table 6.6 shows that the suite of stormwater recommendations is the most expensive set of recommendations with a total estimated cost of $12.17 million per year. This is not surprising due to the fact that the Christina Basin is a highly urbanized watershed with over half of the state's population contained in it. Overall, the stormwater, open space, and wastewater recommendations are relatively close in cost and make up 99 percent of the costs for implementing the Christina Basin PCS.

While the cost of implementing the Christina Basin PCS is significant at $31.28 million per year, there are three recommendations that make up over 80 percent of the total annual cost totaling approximately $26 million per year. These BMPs include SW1 (requiring urban tree canopy), OS6 (acquiring open space), and WW6 (repairing and inspecting the centralized sewer). Although these three recommendations are costly, it does not mean that they should not be implemented. There are ways that the costs associated with these recommendations can be reduced, for example reducing the number of urban trees planted, making efforts to get trees and planting labor donated, acquiring fewer than 100 acres of open space per year, finding ways for landowners to donate tracks of open space, and utilizing multiple other options that can serve as alternatives. All of the recommendations outlined in this document—no matter what the cost—have the potential to significantly reduce the nitrogen, phosphorus, and bacteria loads and all are important to consider for implementation.

It is important to note that although there are several recommendations contained in each of the five categories that are costly, there are numerous recommendations that can be considered low cost options. Specifically, the agriculture and education categories are the least costly recommendations contained in the Christina Basin PCS. The education recommendations may be the most difficult to implement and achieve success, but, if the programs are successful, the potential to have a significant impact on pollution reduction is high and it is at a minimal cost. The agriculture recommendations are relatively inexpensive as well for a variety of reasons. These reasons are that a lot of agriculture BMPs have already been implemented in the Delaware portion of the Christina Basin, the agriculture land in the Delaware portion of the Christina Basin in which implementation is feasible is limited, and the cost-share programs significantly reduce the costs associated with implementing the agriculture BMPs. Although the education and agriculture recommendations have a relatively low cost, the land use in the Delaware portion of the Christina Basin is largely urbanized and the pollutant loads that are coming from the urban and suburban areas are significant and essential to address. The stormwater, open space, and wastewater recommendations are intended to address these areas and, therefore, although they are costly, these recommendations are extremely significant in achieving the fishable and swimmable goals of the Clean Water Act for the waters of the Christina Basin. There are several recommendations within these three categories that are as low as $20,000 or less per year and require minimal expense. These include the following recommendations:

- SW2. Design stormwater BMPs that reduce nutrients according to the TMDLs.
- SW3. Limit addition of new impervious cover to less than 20 percent of the watershed above public drinking water supply intakes.
- SW4. Promote LID in new construction and redevelopment.
- SW6. Expand the role of RPTAC to create a Christina Basin group responsible for reviewing new development.
- OS1. Map, inventory, and prioritize existing wooded open space areas.
- OS2. Protect existing wooded/vegetated open space areas.
- OS3. Require management plans for community and HOA open space areas.
- OS4. Require vegetated 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, and county land.
- OS6. Acquire/conserve additional open space and retain conservation easements (applies only to the conservation easements portion of the recommendation).
- WW1. Install performance standards and conduct inspections and pump-outs of OWTS.

- WW3. Remove OWTS through connection to centralized WWTP (applies only to the cases where the homeowners and developers do not use the county cost-share program).
- WW4. Prohibit new OWTS drainfields placed within 100 feet of wetlands, tidal waters, perennial streams, perennial ditches, and ponds in-line with perennial watercourses.

Although the total annual cost estimates for implementing the Christina Basin PCS is in the millions of dollars, the waters of the Christina Basin in Delaware, Maryland, and Pennsylvania provide numerous benefits to the region. The waters provide water supply, ecological, and recreational benefits, and these benefits provide substantial economic value to society. The estimated economic value of these benefits provided by the waters of the Christina Basin can be quantified and will be discussed in detail in the following section.

Table 6.6 Estimated Annual Cost

Recommendations	**Total Costs ($M/per year)**
Stormwater	12.17
Open Space	9.66
Wastewater	9.32
Agriculture	0.02
Education	0.11
Total	**$31.28**

6.2 The Benefits of the Christina Basin and Meeting the TMDLs

In September 2006, the USEPA issued a high flow TMDL that recommends load reductions of at least 60 percent for bacteria, 20–80 percent for nitrogen, and 50–90 percent for phosphorus to meet Delaware stream water quality standards. This Christina Basin Pollution Control Strategy, prepared by DNREC, the University of Delaware's IPA-WRA, and the Christina Basin Tributary Action Team, recommends multimillion dollar costs to implement solutions to meet the TMDLs as required by the federal Clean Water Act.

The waters of the Christina Basin in Delaware provide substantial water supply, ecological, and recreational benefits to society. The University of Delaware's IPA-WRA conducted an analysis of the economic benefits of the waters of the Delaware portion of the Christina Basin and, based on this analysis, the benefits amount to approximately $51.4 million per year. The total benefits are divided among the three areas and further divided within these categories. For example, the drinking water supply is worth at least $25.9 million annually. Using plug-in values, the warm water fishery is estimated to be worth $4.4 million per year. Additionally, primary recreation (boatable water quality) in the Delaware portion of the Christina Basin is estimated to be worth $4.7 million annually. The canoe and kayak ecotourism businesses are estimated to earn approximately $0.8 million annually. The trout fishing industry is worth approximately $1.2 million per year. Motor boating in the tidal waters of the Christina Basin is worth approximately $7.2 million annually. Further economic analysis estimates the present value of wetland habitat using the mid-range plug-in value is equal to $7.2 million per year. Overall, the net present value of these water-related benefits in the basin over a 30-year period, assuming a 3 percent annual discount rate, is over $1 billion. The lofty economic value of the Delaware portion of the

Christina Basin indicates it is worth substantial public and private investments to improve the quality of its waters. Detailed information on the calculations for the economic benefits of the drinking water supply, warm water fishery, primary recreation, ecotourism, trout fishing, motor boating, and wetlands are provided below.

Drinking Water Supply

Public water purveyors in the Delaware portion of the Christina Basin deliver 71 million gallons per day (mgd) of drinking water (peak) to residential, industrial, commercial, and institutional customers. Table 6.7 provides information obtained from the four water purveyors that supply drinking water to residents and industry in the Delaware portion of the Christina Basin, the sources of the drinking water supply, and the peak withdrawal amount obtained from the associated water source.

Table 6.7 Public Drinking Water Supply in the Delaware Portion of the Christina Basin

Purveyor	***Source***	***Peak Withdrawal (mgd)***
City of Wilmington	Brandywine Creek	35
City of Newark	White Clay Creek	3
United Water Delaware	White Clay/Red Clay Creeks	30
Artesian Water Company	Cockeysville Formation/Mill Creek	3
Total		**71**

Northern Delaware water purveyors estimate that the approximate cost to withdraw and pump the water from the streams, or the value of the raw water supply, is $1.00 per 1,000 gallons or $1,000 per one million gallons. A recent analysis of the value of the raw water supply in New Jersey, conducted by the Department of Environmental Protection, places the in situ market value of untreated water supply at $0.394 per 1,000 gallons (Mates, 2007). For the purposes of this analysis, the economic benefit of the raw water in the Christina Basin will be estimated using the value of the raw water supply at $1,000 per one million gallons as provided by the northern Delaware water purveyors. Therefore, assuming a peak withdrawal value of 71 million gallons per day, the present value of the raw water supply in the Delaware portion of the Christina Basin is estimated at $25.9 million per year and is calculated using the following equation:

$$PV_{ws} = 71 \text{ mgd } (\$1{,}000\text{ /mg})\ (365\text{ days/yr})$$
$$= \$25{,}915{,}000\text{/yr}$$
$$= \$25.9\text{ M/yr}$$

Where:

PV_{ws} = present value of the raw water supply
mgd = million gallons per day
mg = million gallons
yr = year
M = million dollars

Warm Water Fishery

The streams in the Christina Basin support a warm water fishery. The economic benefit of the fishery can be estimated using plug-in environmental shadow price values (Boardman, Greenberg, Vining, Weimer, 2006). The plug-in value of rough fishing (warm water fishery) ranges from $12.70–$51.00 per year per household with a mid-range value of $32.00 per year per household. It is estimated that approximately 400,000 people live in the Delaware portion of the Christina Basin. Using this population estimate and the U. S. Census's estimate that there are approximately 2.9 people per household, the present value of the warm water fishery using the mid-range plug-in value can be estimated at $4.4 million per year using the following equation:

$$PV_{fh} = \$32/\text{yr/household } (400{,}000 \text{ p}) / (2.9 \text{ p/household})$$
$$= \$4{,}414{,}000/\text{yr}$$
$$= \$4.4 \text{ M/yr}$$

Where:
PV_{fh} = present value of the warm water fishery
p = people
p/household = people per household

Primary Recreation (Boating)

The streams in the Christina Basin have sufficient water quality to support primary recreation such as boating and canoeing. Currently, the water quality is not sufficient to support secondary recreation such as swimming due to high bacteria levels. The plug-in value used in this analysis to determine the economic value of boatable water quality ranges from $8.50–$59.00 per year per household with a mid-range value of $34.00 per year per household (Boardman et al., 2006). The present value of boatable water quality in the Christina Basin using the mid-range plug-in value is $4.7 million per year using the following equation:

$$PV_{bt} = \$34/\text{yr/household } (400{,}000 \text{ p}) / (2.9 \text{ p/household})$$
$$= \$4{,}700{,}000 \text{ /yr}$$
$$= \$4.7 \text{ M/yr}$$

Where:
PV_{bt} = present value of primary recreation

Ecotourism

The Brandywine Creek in the Christina Basin supports a sizable ecotourism business through canoe and kayak liveries. Two outfitters—Wilderness Canoe Travels and Northbrook Canoe—provide services to approximately 20,000 customers per summer. The average cost of a canoe or kayak trip is $40 per person. Therefore, using the estimate of 20,000 customers per year at a fee of $40 per person, the present value of the ecotourism business can be estimated at $0.8 million per year using the following equation:

PV_{et}	=	\$40(20,000 p/yr)
	=	\$800,000/yr
	=	\$ 0.8 M/yr

Where:

PV_{et} = present value of ecotourism

Trout Fishing

The Christina Basin in Delaware has sufficient watershed health to support six put and take trout streams that are cold enough to support a stocked cold water fishery during the winter, spring, and fall seasons of the year. Presently, the streams are too warm during the summer to support a reproducing wild trout fishery. Over 2,700 Delaware trout stamps are sold to licensed anglers, and 30,000 trout are stocked annually to fish in the following trout streams:

- White Clay Creek above Newark
- Beaver Run
- Wilson Run
- Mill Creek
- Upper Christina River above Newark
- Pike Creek

According to Boardman et al., the value of recreational fishing is estimated at \$43.63 per activity day (Boardman et al., 2006). If each licensed trout fisherman wets a line ten days per year, the present value of trout fishing can be estimated at \$1.2 million per year using the following equation:

PV_{tf}	=	\$43.63 per day (2,700 fishermen) (10 days/yr)
	=	\$1,178,000/yr
	=	\$1.2 M/yr

Where:

PV_{tf} = present value of the warm water fishery

Motor Boating

Delaware recreational mariners own 8,400 registered boats that ply the tidal waters of the Christina River and Brandywine Creek. According to Boardman et al., the value of recreational motor boating is estimated at \$42.80 per activity day (Boardman et al., 2006). If a registered boater cruises the waters for an average of 20 days per year, the present value of motor boating is estimated at \$7.2 million per year using the following equation:

PV_{mb}	=	\$42.80 per day (8,400 boaters) (20 days/yr)
	=	\$7,190,000/yr
	=	\$7.2 M/yr

Where:

PV_{mb} = present value of motor boating

Wetlands

According to 2002 land use data, there were three square miles (1,920 acres) of wetlands in the Delaware portion of the Christina Basin. According to Boardman et al., the existence value of wetland habitat ranges from \$8–\$97 per household per year with a mid-range value of \$52 per household per year (Boardman et al., 2006). About 400,000 people live in the Delaware portion of the Christina Basin, and there are approximately 2.9 people per household. Therefore, the present value of the wetland habitat using the mid-range plug-in value is estimated at \$7.2 million per year using the following equation:

$$
\begin{aligned}
PV_{we} &= \$52/\text{yr/household } (400{,}000 \text{ p}) / (2.9 \text{ p/household}) \\
&= \$7{,}172{,}000/\text{yr} \\
&= \$7.2 \text{ M/yr}
\end{aligned}
$$

Where:
PV_{we} = present value of the wetlands

Total Present Value

Based on the values calculated above, it can be estimated that the total present value of the Delaware portion of the Christina Basin, including the economic benefits of the water supply, warm water fishery, primary recreation, ecotourism, trout fishing, and wetlands in the Delaware portion of the Christina Basin, is estimated at a value of \$51.4 million per year. Table 6.8 below sums all of these benefits and provides a total estimate of the present value of the benefits provided by the Delaware portion of the Christina Basin in million dollars per year.

Table 6.8 Present Value of the Benefits Provided by the Delaware Portion of the Christina Basin

Benefit	Present Value ($M/yr)
Drinking Water Supply	25.9
Warm Water Fishery	4.4
Recreation (Boating)	4.7
Ecotourism (Kayaking)	0.8
Trout Fishing	1.2
Motor Boating	7.2
Wetlands	7.2
Total	**$51.4 M/yr**

6.3 Discussion of the Costs and Benefits of the Christina Basin

Meeting the Delaware stream water quality standards is a necessary improvement for the rivers and streams that make up the Delaware portion of the Christina Basin. Not only does it benefit the water supply, recreation, and habitat uses in the basin, but it also makes good economic sense. According to the cost and benefit analysis conducted for the Delaware portion of the Christina Basin, achieving the fishable and swimmable criteria has significant economic value to the citizens, businesses, and community in the Christina Basin region. At this time, the streams in the Delaware portion of the Christina Basin do not meet the water quality criteria, and reductions must be made in the nitrogen, phosphorus, and bacteria loads. The reductions that must be made range anywhere from 20–90 percent and the highest overall reductions are necessary for the bacteria loads reaching the rivers and streams. Making the reductions mandated by the high flow TMDL will return the waters of the Christina Basin to fishable and swimmable status. If the water quality criteria are met, the streams will not only serve their current benefit of providing water supply, habitat, boating, and fishing value, but the waters will be accessible for swimming and will offer an even greater economic value to the residents of the state and the basin.

As reflected in the cost analysis in Section 6.1, implementing the Christina Basin PCS is a costly endeavor at an estimated $31.28 million per year. The PCS outlines 40 recommendations in the stormwater, open space, wastewater, agriculture, and education categories that, if implemented, have the potential to return the streams and tributaries in the Delaware portion of the Christina Basin to fishable and swimmable status. It is difficult to precisely determine the costs of implementing the recommendations outlined in the Christina Basin PCS, yet it is critical to the implementation of these recommendations that an analysis and calculation of the major costs are performed. The costs outlined in this report are highly variable and are likely to change, but they serve as a useful tool in estimating the cost of achieving the Christina Basin high-flow TMDL. This analysis is a way to begin prioritizing the recommended pollution reduction activities, determining the best approach, and identifying where further research is needed to begin the implementation phase of the Christina Basin Pollution Control Strategy. New sources of money are not being requested, but existing sources of funding shall be prioritized to focus on the most cost-effective recommendations and ways to achieve the goals of the federal Clean Water Act goals set for the Delaware portion of the Christina Basin. These recommendations are costly but if the costs are viewed in light of the benefits gained from the resources in the Christina Basin, the benefits far exceed the costs to implement the PCS.

The benefit analysis estimates that if the waters of the Delaware portion of the Christina Basin meet the Delaware water quality criteria, the estimated annual benefit is approximately $51.4 million per year. Clearly this analysis demonstrates that the Christina Basin is worth restoring, and it is economically beneficial to begin implementing the Christina Basin recommendations and working toward achieving the fishable and swimmable status. Freshwater is a necessity, and it is becoming increasingly scarce. It is difficult to estimate the economic value of the benefits of a freshwater system like water supply, recreation, and habitat, but, based on existing studies, the benefits calculated for the Delaware portion of the Christina Basin reflect a highly valuable resource that is worth restoration, preservation, and investment.

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Appendices

Appendix A: Section 303(d) List of Waters Needing TMDLs in the Christina Basin

FINAL DETERMINATION FOR THE STATE OF DELAWARE 2006 CLEAN WATER ACT SECTION 303(d) LIST OF WATERS NEEDING TMDLs													
WATERBODY ID	WATERSHED NAME	SEGMENT	Overall CALM Code	DESCRIPTION	SIZE	POLLUTANT OR STRESSOR	PROBABLE SOURCE(S)	YEAR LISTED	TARGET DATE FOR TMDL	TMDL DATE	Pollutant CALM Code	Year Changed from Category 5 Per 305(b) Assessment and Methodology	Notes
Piedmont Basin													
DE230-001-01	Naamans Creek	Lower Naamans Creek	4a	From the mouth at the Delaware River, upstream to the first railroad bridge	0.30 miles	Bacteria	NPS	1996	2004	2005	4a	2006	
						Nutrients	NPS	2002	2004	2005	4a	2006	
DE230-001-02	Naamans Creek	North Branch and South Branch	5	Upper Naamans Creek, including all tributaries on the North Branch and	7.8 miles	Nutrients	NPS	1996	2004	2005	4a	2006	
						Bacteria	NPS	1996	2004	2005	4a	2006	
				First tributary after the headwaters of South Naamans Creek to the mainstem	1.15 miles	Biology and Habitat	NPS	1998	2009		5		
				From the confluence of Naamans Creek and West Branch Naamans Creek to the confluence of Naamans Creek and North Branch Naamans Creek	0.56 miles	Biology and Habitat	NPS	1998	2009		5		
DE300-001-01	Shellpot Creek	Lower Shellpot Creek	5	From the head of tide below the east set of railroad tracks to the mouth of the Delaware River	1.0 miles	Nutrients	NPS Del River	1996	2004	2005	4a	2006	
						DO		1996	2004	2005	4a	2006	
						Bacteria		2002	2004	2005	4a	2006	
						PCBs		2002	2006		5		
						Chlordane		2002	2006		5		
DE300-001-02	Shellpot Creek	Upper Shellpot Creek	5	From the headwaters to the head of tide below the east set of railroad tracks	7.7 miles	Bacteria	NPS	1996	2004	2005	4a	2006	
						Nutrients	NPS	1996	2004	2005	4a	2006	
				Western tributary of the headwaters to the confluence of the next larger stream order	1.4 miles	Biology and Habitat	NPS	1998	2009		5		
				From the headwaters of Matson Run to the confluence with mainstem Shellpot Creek	1.3 miles	Biology and Habitat	NPS	1998	2009		5		
DE300-001-03	Shellpot Creek	All other tributaries located in the watershed but NOT on the mainstem	5	Western tributary of the headwaters of Stoney Creek to the confluence with mainstem Stoney Creek	0.63 miles	Habitat	NPS	1998	2009		5		
				From the confluence of the headwaters of Stoney Creek to the mouth of the Delaware River	1.2 miles	Biology and Habitat	NPS	1998	2009		5		
DE040-001	Brandywine Creek	Lower Brandywine	5	Mainstem Lower Brandywine	3.8 miles	Nutrients	PS, NPS, SF	1996		2000	4a	2004	
						PCBs		1996	2009		5		
						Bacteria		2002	2004	2005	4a	2006	
						Habitat	NPS	1998	2009		5		

WATERBODY ID	WATERSHED NAME	SEGMENT	Overall CALM Code	DESCRIPTION	SIZE	POLLUTANT OR STRESSOR	PROBABLE SOURCE(S)	YEAR LISTED	TARGET DATE FOR TMDL	TMDL DATE	Pollutant CALM Code	Year Changed from Category 5 Per 305(b) Assessment and Methodology	Notes
DE040-002	Brandywine Creek	Upper Brandywine	5	From State Line to Wilmington	9.3 miles	Bacteria	PS, NPS, SF	1996	2004		1	2006	Bacteria, listed in 1996, delisted 2006
						Nutrients		1996		2000	4a		
						PCBs		1996	2009		5		
						Dioxin		2002	2009		5		
				From State line to the confluence with the Christina River	8.9 miles	Habitat	NPS	1998	2009		5		
DE040-003	Brandywine Creek	All tributaries on Brandywine Creek from the headwaters at PA-DE line to the confluence with the Christina River	5	Eastern tributary of Beaver Creek, from headwaters to the confluence with mainstem Beaver Creek	0.96 miles	Biology and Habitat	NPS	1998	2009		5		
				Tributary originating in Pennsylvania on the western side of Brandywine Creek	0.26 miles	Biology and Habitat	NPS	1998	2009		5		
				Tributary of Brandywine Creek, off Route 100 (near PA-DE border)	0.92 miles	Habitat	NPS	1998	2009		5		
				Tributary of Brandywine Creek just below Beaver Creek	0.85 miles	Habitat	NPS	1998	2009		5		
				Eastern tributary of the headwaters of Rocky Run (upper half)	1.16 miles	Habitat	NPS	1998	2009		5		
				Eastern tributary of the headwaters of Rocky Run (lower half)	1.16 miles	Biology and Habitat	NPS	1998	2009		5		
				From the confluence of the headwaters of Wilson Run to the next larger stream order (lower half)	0.64 miles	Habitat	NPS	1998	2009		5		
				From the confluence of the headwaters of Wilson Run to the next larger stream order (upper half)	0.64 miles	Biology and Habitat	NPS	1998	2009		5		
				Wilson Run, from start of the third order stream to the confluence with Brandywine Creek	0.88 miles	Biology	NPS	1998	2009		5		
				Tributary of Wilson Run on Montchanin Road from the headwaters to the first confluence	0.45 miles	Habitat	NPS	1998	2009		5		

WATERBODY ID	WATERSHED NAME	SEGMENT	Overall CALM Code	DESCRIPTION	SIZE	POLLUTANT OR STRESSOR	PROBABLE SOURCE(S)	YEAR LISTED	TARGET DATE FOR TMDL	TMDL DATE	Pollutant CALM Code	Year Changed from Category 5 (For 303(d) Assessment and Methodology)	Notes
DE260-001	Red Clay Creek	Mainstem	5	From PA-DE line to the confluence with White Clay Creek	13.8 miles	Bacteria	PS, NPS, SF	1996	2004	2005	4a	2006	
						Nutrients		1996		2000	4a	2004	
						Zn		1996		1999	4a	2004	
						PCBs		1996	2009		5		
						Dioxin		2002	2009		5		
						Chlorinated Pesticides		2002	2009		5		
				From the confluence of West Branch Red Clay Creek to the confluence with White Clay Creek (lower half)	6.4 miles	Habitat	NPS	1998	2009		5		
				From the confluence of West Branch Red Clay Creek to the confluence with White Clay Creek (upper half)	6.4 miles	Biology and Habitat	NPS	1998	2009		5		
DE260-002	Red Clay Creek	Burroughs Run	5	From PA-DE line to the confluence with Red Clay Creek	2.6 miles	Bacteria	NPS	1996	2004	2005	4a	2006	
					2.6 miles	Nutrients	NPS	1996		2000	4a	2004	
				From the confluence of the headwaters of Burroughs Run to the confluence with Red clay Creek	4.21 miles	Biology	NPS	1998	2009		5		
DE260-003	Red Clay Creek	All other tributaries located in the watershed but NOT on the mainstem	5	Second tributary below Burroughs Run to the confluence with Red Clay Creek	1.4 miles	Habitat	NPS	1998	2009		5		
				Western tributary of the headwaters of Hyde Run to the confluence with the next larger stream order	1.2	Biology and Habitat	NPS	1998	2009		5		
DE260L-01	Red Clay Creek	Reservoir	5	Hoopes Reservoir	200.6 acres	Bacteria	PS, NPS	1996			5	2004	This segment was listed in 1996, apparently based on earlier reports but no data were used for the listing. No data has been collected in the interim. The Department will study the segment to determine if a listing is appropriate.

WATERBODY ID	WATERSHED NAME	SEGMENT	Overall CALM Code	DESCRIPTION	SIZE	POLLUTANT OR STRESSOR	PROBABLE SOURCE(S)	YEAR LISTED	TARGET DATE FOR TMDL	TMDL DATE	Pollutant CALM Code	Year Changed from Category 5 (For 303(d) Assessment and Methodology)	Notes
DE320-001	White Clay Creek	Mainstem	5	From the PA-DE line to the confluence with the Christina River	13.6 miles	Bacteria	PS, NPS	1996	2004	2005	4a	2006	
						Nutrients	PS, NPS	1996		2000	4a	2004	
						Zn (below Paper Mill Road)	PS, NPS	1996		1999	1	2004	Zinc, listed in 1996 delisted 2004 based on improved water quality
						PCBs	PS, NPS	1996, 2006	2009		5		Advisory updated in 2006 to relate White Clay Creek from PA line to River Mouth
				From the confluence of East Branch White Clay Creek and West Branch White Clay Creek to the confluence with the Christina River	16.2 miles	Biology and Habitat	NPS	1998	2009		5		
DE320-002	White Clay Creek	Mill Creek	5	From the headwaters to the confluence with White Clay Creek	8.3 miles	Bacteria	NPS	1996	2004	2005	4a	2006	
						Nutrients	NPS	1996		2000	4a	2004	
				From the confluence of the headwaters of Mill Creek to the confluence with the next larger stream order	0.27 miles	Biology and Habitat	NPS	1998	2009		5		
				Second western tributary-- From the headwaters of mainstem Mill Creek	0.04 miles	Habitat	NPS	1998	2009		5		
				From the confluence of the headwaters of Mill Creek to the confluence with White Clay Creek (upper half)	1.64 miles	Habitat	NPS	1998	2009		5		
				From the confluence of the headwaters of Mill Creek to the confluence with White Clay Creek (lower half)	1.64 miles	Biology and Habitat	NPS	1998	2009		5		

WATERBODY ID	WATERSHED NAME	SEGMENT	Overall CALM Code	DESCRIPTION	SIZE	POLLUTANT OR STRESSOR	PROBABLE SOURCES	YEAR LISTED	TARGET DATE FOR TMDL	TMDL DATE	Pollutant CALM Code	Year Changed from Category 5 For 303(d)s Assessment and Methodology	Notes
DE120-001	Christina River	Lower Christina River	5	Mainstem Lower Christina River	1.5 miles	Nutrients	NPS, SP	1996		2001	4a	2004	
						DO	NPS, SP	1996			1	2002	DO, listed in 1996, delisted 2002
						PCBs	NPS, SP	1996	2009		5		
						Bacteria	PS, NPS	2002	2004	2005	4a	2006	
						Dieldrin	PS, NPS	2002	2009		5		
DE120-002	Christina River	Mid-Christina River	5	Between White Clay Creek and Brandywine River	7.5 miles	Nutrients	NPS	1996		2001	4a	2004	
						PCBs	SP	1996	2009		5		
						Bacteria	PS, NPS	2002	2004	2005	4a	2006	
						Dieldrin	NPS	2002	2009		5		
DE120-003	Christina River	Upper Christina River	5	Mainstem Upper Christina River	6.5 miles	Nutrients	NPS, PS	1996		2001	4a	2004	
						PCBs	NPS, PS	1996	2009		5		
						Bacteria	NPS, PS	1996	2004	2005	4a	2006	
						DO	NPS, PS	2004		2001	1	2006	DO, listed in 2004, delisted 2006
						Chlordane	NPS, PS	2006	2013		5		
				Segments from Smalley's Pond overflow to the confluence with White Clay Creek	5.75 miles	Biology and Habitat	NPS	1998	2009		5		
				Tributary downstream of Smalleys Pond on the Christina River	0.65 miles	Biology	NPS	1998	2009		5		
DE120-003-02	Christina River	Lower Christina Creek	5	Tributary from Smalleys Pond overflow to White Clay Creek	1.6 miles	Biology and Habitat	NPS	1998	2009		5		
						Nutrients	NPS	2002		2001	4a	2004	
						DO	NPS	2002		2001	4a	2004	
						Bacteria	NPS	2002	2004	2005	4a	2006	

WATERBODY ID	WATERSHED NAME	SEGMENT	Overall CALM Code	DESCRIPTION	SIZE	POLLUTANT OR STRESSOR	PROBABLE SOURCES	YEAR LISTED	TARGET DATE FOR TMDL	TMDL DATE	Pollutant CALM Code	Year Changed from Category 5 For 303(d)s Assessment and Methodology	Notes
DE120-004-01	Christina River	Lower Christina Creek	5	Mainstem Lower Christina Creek	8.4 miles	Bacteria	NPS	1996	2004	2005	4a	2006	
						Nutrients	NPS	1996		2001	4a	2004	
						PCBs	NPS, SP	1996	2009		5		
						DO	NPS	2002		2001	1	2006	DO, listed in 2002, delisted 2006
						Dieldrin	NPS	2006	2013		5		
				From the confluence of West Branch Christina River to the confluence with the mainstem	6.0 miles	Biology and Habitat	NPS	1998	2009		5		
DE120-004-02	Christina River	Belltown Run	5	From the headwaters above Becks Pond to the confluence with the Christina River	3.4 miles	Bacteria	NPS	1996	2004	2005	4a	2006	
						Nutrients	NPS	2002	2004		4a	2006	
						DO	NPS	2002	2004		4a	2006	
				Eastern tributary of the headwaters of Belltown Run to the confluence with the Christina River	4.2 miles	Biology and Habitat	NPS	1998	2009		5		
				Western tributary of the headwaters of Belltown Run to its confluence	0.88 miles	Habitat	NPS	1998	2009		5		
DE120-004-03	Christina River	Muddy Run	5	From the headwaters above Sunset Pond to the confluence with Belltown Run below Becks Pond	8.0 miles	Bacteria	NPS	1996	2004	2005	4a	2006	
				From the headwaters of Iron Hill Run to the next larger stream order	2.5 miles	Habitat	NPS	1998	2009		5		
				Eastern tributary of the headwaters of Iron Hill Run to the next larger stream order	0.71 miles	Habitat	NPS	1998	2009		5		
				Eastern tributary above Sunset Pond to the confluence of the next larger stream order	3.3 miles	Biology	NPS	1998	2009		5		
				Eastern tributary of the headwaters of Muddy Run to its confluence	0.63 miles	Habitat	NPS	1998	2009		5		
DE120-005-01	Christina River	West Branch	5	West Branch including Persimmon Run and Dme Haskell Branch	3.3 miles	Bacteria	NPS	1996	2004	2005	4a	2006	
						Nutrients	NPS	1996		2001	4a	2004	

WATERBODY ID	WATERSHED NAME	SEGMENT	Overall CALM Code	DESCRIPTION	SIZE	POLLUTANT OR STRESSOR	PROBABLE SOURCES	YEAR LISTED	TARGET DATE FOR TMDL	TMDL DATE	Pollutant CALM Code	Year Changed from Category 5 (For 303(b) Assessment and Methodology)	Notes
DE120-006	Christina River	Upper Christina Creek	5	Mainstem Upper Christina Creek	1.5 miles	Bacteria	NPS	1996	2004	2005	4a	2006	
						Nutrients		1996		2004	4a	2004	
				From the confluence of the headwaters of Upper Christina River to the confluence of West Branch	2.6 miles	Biology and Habitat		1998	2009		5		
				First western tributary after the headwaters of the Upper Christina River to mainstem Upper Christina River (upper half)	0.67 miles	Habitat		1998	2009		5		
				First western tributary after the headwaters of the Upper Christina River to mainstem Upper Christina River (lower half)	0.67 miles	Biology and Habitat		1998	2009		5		
DE120-007-01	Christina River	Little Mill Creek and Willow Run	5	From the confluence of Willow Run and Chestnut Run to the confluence with the Christina River	5.1 miles	Bacteria	NPS	1996	2004	2005	4a	2006	
						Nutrients	NPS	1996		2004	4a	2004	
						DO		1996			1	2002	DO, listed in 1996, delisted 2002
						PCBs	NPS	1996	2009		5		
				First western tributary after the headwaters of Little Mill Creek to the confluence with mainstem Little Mill Creek	1.4 miles	Habitat	NPS	1998	2009		5		
				From the headwaters of Willow Run to the confluence with the Christina River	0.54 miles	Habitat	NPS	1998	2009		5		
				From the confluence of the headwaters of Little Mill Creek to the confluence of Chestnut Run	4.4 miles	Biology and Habitat	NPS	1998	2009		5		
				Little Mill Creek--from the confluence of Chestnut Run to the confluence with the Christina River	3.4 miles	Biology and Habitat	NPS	1998	2009		5		
DE120-007-02	Christina River	Chestnut Run	5	From the headwaters of Chestnut Run to the confluence with the Christina River	2.8 miles	Bacteria	NPS	1996	2004	2005	4a	2006	
				Eastern tributary of the headwaters of Chestnut Run to the confluence of the next largest stream order	1.1 miles	Habitat	NPS	1998	2009		5		
				Left tributary of the headwaters of Chestnut Run to the confluence of the next largest stream order	0.40 miles	Biology and Habitat	NPS	1998	2009		5		

WATERBODY ID	WATERSHED NAME	SEGMENT	Overall CALM Code	DESCRIPTION	SIZE	POLLUTANT OR STRESSOR	PROBABLE SOURCES	YEAR LISTED	TARGET DATE FOR TMDL	TMDL DATE	Pollutant CALM Code	Year Changed from Category 5 (For 303(b) Assessment and Methodology)	Notes
DE120-L01	Christina River	Smalleys Pond	5	Smalleys Pond east of Newark	30.0 acres	Bacteria	NPS	1996	2004	2005	4a	2006	
						Nutrients	NPS	1996	2004		4a	2006	
						PCBs	NPS	1996	2009		5		
						DO	NPS	2004	2004		4a	2006	
DE120-L02	Christina River	Becks Pond	5	Becks Pond southeast of Newark	25.0 acres	Bacteria	NPS	1996	2004	2005	4a	2006	
						Nutrients	NPS	1996			1	2002	Nutrients, listed in 1996, delisted 2002
						PCBs	NPS	2002	2009		5		
						Mercury	NPS	2002	2009		5		
DE120-L03	Christina River	Sunset Pond	5	Sunset Pond south of Newark	40.0 acres	Bacteria	NPS	1996	2004	2005	4a	2006	
						Nutrients	NPS	2002	2004		4a		
						DO	NPS	1996	2004		4a	2006	

Appendix B: Christina Basin Pollution Control Strategy Recommendations

Stormwater	Type	Implementing Organization(s)
SW1. Increase urban tree canopy.	Ordinances	DNREC–Watershed Assessment Section, New Castle County, Municipalities, Delaware Center for Horticulture, Developers, Citizens
SW2. Design stormwater best management practices to reduce nutrients according to the total maximum daily loads, where feasible and effective.	Regulatory	DNREC–Division of Water Resources and Division of Soil and Water Conservation
SW3. Limit addition of new impervious cover to less than 20 percent of the watershed above public drinking water supply intakes.	Ordinances	Developers, City of Wilmington, City of Newark, New Castle County
SW4. Promote low impact development in new construction and redevelopment.	Ordinances	Developers
SW5. Amend stormwater ordinances to create consistency throughout the watershed.	Regulatory	Local engineers, White Clay Creek Wild and Scenic Management Committee, Christina Basin Clean Water Partnership, Red Clay Valley Association, Brandywine Valley Association, City of Wilmington, City of Newark, New Castle County
SW6. Expand the role of the Resource Protection Area Technical Advisory Committee to create a Christina Basin group responsible for reviewing new development.	Ordinances	New Castle County.
SW7. Implement a stormwater utility: a. Maintain best management practices b. Reduce and manage existing impervious cover.	Ordinances and Regulatory	Municipalities, New Castle County, DNREC
SW8. Identify areas where stormwater retrofits would effectively reduce sediment and nutrients.	Voluntary	New Castle County, New Castle Conservation District

Open Space	Type	Implementing Organization(s)
OS1. Map, inventory, and prioritize existing wooded open space areas.	Voluntary	IPA-WRA, nonprofit and government organizations in the basin with existing data sources
OS2. Protect existing wooded/vegetated open space areas.	Ordinances	New Castle County, DNREC–Division of Parks and Recreation, Municipalities, Private and Nonprofit Conservancies
OS3. Require management plans for community and homeowner association open space areas.	Ordinances	DNREC–Watershed Assessment Section, Urban Nutrient Management
OS4. 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.	Regulatory	New Castle County, Municipalities
OS5. Implement stream restoration projects.	Voluntary	DNREC–Division of Soil and Water Conservation
OS6. Acquire/conserve additional open space and retain conservation easements.	Voluntary	DNREC–Division of Parks and Recreation, State of Delaware Open Space Council, New Castle County–Department of Special Services, City of Newark–Department of Parks
OS7. Reforest watersheds and headwaters.	Voluntary	Delaware Department of Agriculture, Delaware Nature Society, New Castle Conservation District

Wastewater	Type	Implementing Organization(s)
WW1. Install performance standards and conduct inspections and pump-outs of onsite wastewater treatment systems.	Regulatory	DNREC–Division of Water Resources, Groundwater Discharges Section
WW2. Eliminate cesspools and seepage pits in a systematic way.	Regulatory	DNREC–Division of Water Resources, Groundwater Discharges Section, New Castle County–Department of Special Services
WW3. Remove onsite wastewater treatment systems through connection to a centralized wastewater treatment plant.	Regulatory	New Castle County–Department of Special Services
WW4. Prohibit new onsite wastewater treatment system drainfields placed within 100 feet of wetlands, tidal waters, perennial streams, perennial ditches, and ponds in-line with perennial watercourses.	Regulatory	DNREC–Division of Water Resources, Groundwater Discharges Section
WW5. Abate combined sewer overflows.	Federal Mandate	State of Delaware, City of Wilmington
WW6. Continue sewer repair projects and conduct regular inspections.	Regulatory	New Castle County–Department of Special Services, City of Newark–Water and Wastewater Department, City of Wilmington–Public Works Department
WW7. Remediate contaminated sites.	Regulatory	DNREC–Division of Air and Waste Management

Agriculture	Type	Implementing Organization(s)
Select BMPs from Agriculture Recommendations		
AG1. Nutrient Management Plans	Regulatory	Delaware USDA–NRCS, New Castle Conservation District, Delaware Department of Agriculture, Pennsylvania USDA–NRCS, University of Delaware IPA-WRA
AG2. Cover Crops	Voluntary	
AG3. Pasture Stream Fencing	Voluntary	
AG4. Grassed Filter Strips	Voluntary	
AG5. Grassed Waterways	Voluntary	
AG6. Forested Riparian Buffers	Voluntary	
AG7. Pasture and Hay Planting	Voluntary	
It is important to note that the manure and waste transfer and the feed-related amendment best management practices are not applicable in the Delaware portion of the Christina Basin.		

Education	Type	Implementing Organization(s)
ED1. Educate Christina Basin stakeholders on nonpoint source pollution and their role in reducing it, specifically targeting behavior change.	Voluntary	Nonprofit, private, and government entities
ED2. Encourage nutrient management plans for turf fields at education facilities.	Voluntary	
ED3. Encourage golf course managers to decrease nutrient application, stormwater runoff, and erosion.	Voluntary	
ED4. Educate pet owners on cleaning up pet waste.	Voluntary	
ED5. Educate homeowners on residential stormwater best management practices and maintenance of best management practices.	Voluntary	
ED6. Integrate education into state and local permitting processes.	Voluntary	
ED7. Encourage corporate environmental stewardship programs.	Voluntary	
ED8. Coordinate nonprofit organizations throughout the basin.	Voluntary	
ED9. Support and encourage water conservation and water quality measures to reduce nutrients leaving a site.	Voluntary	
ED10. Work with organizations to provide education programs on lawn and garden best management practices.	Voluntary	
ED11. Advise DNREC to research nutrient reductions related to bacteria counts and best management practices.	Voluntary	

Appendix C: Recommended Urban Trees

DELAWARE CENTER FOR HORTICULTURE

NATIONAL TREE TRUST

RECOMMENDED URBAN TREES

WILMINGTON, DE AREA (USDA HARDINESS ZONE 7)

BEFORE PLANTING: THINGS TO REMEMBER!

- Street trees provide many benefits beyond beautification of our neighborhoods and city. They can reduce cooling costs in summer, improve property values, attract residents and businesses, and revitalize communities. Contact the **Delaware Center for Horticulture** to learn more about the many benefits of urban trees and to get involved with your own neighborhood street tree project, for further recommendations, or to request a new Wilmington street tree through the DCH Tree Program.

- **The approval of a Wilmington Street Tree Permit is required before planting any tree in the public right-of-way** (generally determined as between the sidewalk and the curb, in a tree lawn, grass strip or tree pit in sidewalk). According to the Wilmington City Code, Chapter 46 (Vegetation), street tree maintenance is the responsibility of the respective property owner. Contact the Delaware Center for Horticulture or the Wilmington Department of Parks & Recreation for a permit form or for more information.

- **The selection of an appropriate street tree is essential to its success.** Criteria such as soil space, underground or overhead utilities, sidewalk and curbing considerations, ultimate size, tolerance of urban conditions, and general species information must be considered before selecting a street tree for planting. **Proper care during establishment of a young tree is also crucial and can reduce the need for costly maintenance in the future.**

- Many popular trees do not appear on this list for a variety of reasons. The Delaware Center for Horticulture does **NOT** recommend nor approve the planting of **Callery pear cultivars (*Pyrus calleryana,* e.g. Bradford)** due to overuse, fruit litter, and structural problems. Other popular trees do not appear on this list due to the propensity for insect and disease problems (purple-leaf plum, ***Prunus cerasifera***), or due to intolerance of urban conditions (Japanese maple, ***Acer palmatum,*** and flowering dogwood, ***Cornus florida***). Some recommendations of this list are based on information specific to the City of Wilmington based on a street tree inventory completed in 2002.

- DCH receives many complaints about tree roots damaging sidewalks. By planting an appropriate tree for a given space, this can be greatly reduced. No tree is guaranteed to avoid conflicts with surrounding areas; in fact, the roots of most trees grow solely within the top 12-18" of surface soil. Watering deeply and maximizing soil space can discourage surface roots.

SMALL TREES – SUITABLE NEAR OVERHEAD UTILITY WIRES (>10')

Acer buergerianum **Trident Maple** **Spring or Fall Planting**
20-25 ft., rounded. Withstands drought and infertile soils and various temperatures. Exfoliating bark is quite striking, coloring gray, orange and brown. Yellow to red fall color.

✪ *Acer campestre* **Hedge Maple** **Spring or Fall Planting**
25-35 ft., rounded. Tolerates wide range of conditions including high soil pH and drought (once established). Relatively pest-free. Moderate road salt tolerance. Yellowish fall foliage drops late in season. Close spacing will create dense shade.

! *Acer ginnala* **Amur Maple** **Spring or Fall Planting**
15-20 ft., rounded. Excellent tolerance to dry and alkaline soils. One of the most cold-hardy and highly adaptable maples. Variable fall color. Has shown invasive tendencies in some areas.

? *Acer griseum* **Paperbark Maple** **Spring or Fall Planting**
20-30 ft., rounded. Extremely tolerant of well-drained acid or alkaline clay soils. No two specimens alike. Reddish-brown exfoliating bark. Brilliant red fall color. Sensitive to urban stress if planted in restricted area.

✪ *Acer triflorum* **Three-flower Maple** **Spring or Fall Planting**
20-30 ft., rounded. Prefers moist, acidic, well-drained soil in sun to part shade. Outstanding yellow to red fall color and exfoliating bark.

Acer truncatum **Shantung Maple** **Spring or Fall Planting**
20-25 ft., rounded. Tolerant of acid, alkaline and dry soils. Yellow flowers emerge before leaves. Variable fall color. Limited availability in nursery trade.

? ! *Aesculus X carnea* **Red Horsechestnut** **Spring or Fall Planting**
30-50 ft., rounded. Prefers moist, deep, well-drained soils, but is widely adaptable to soil types. Susceptible to a fungal disease that may cause browning of leaves. Spectacular rose-red flower.

? ✓*Carpinus caroliniana* **American Hornbeam** **Spring Planting**
25-35 ft., rounded to spreading. Prefers shaded, moist soils but will tolerate some intermittent drought as well as high pH soil once established. Good orange-red fall color and ornamental, muscle-like bark.

Chionanthus retusus **Chinese Fringe Tree** **Spring or Fall Planting**
15-25 ft., rounded. Extremely easy to grow. Withstands acid or alkaline, sandy loam or clay soils. Prospers in sun, but withstands part shade. Early summer white flower clusters.

? Unproven as street tree – proven in urban parks but suggest maximized soil space
✪ Example of species planted at DCH gardens/grounds
✓ Native to Delaware or Eastern U.S.
! Please note: invasive tendencies, disease/insect potential, or over-used in Wilmington area

SMALL TREES – SUITABLE NEAR OVERHEAD UTILITY WIRES (>10')

✪ *Cornus mas* **Corneliancherry Dogwood Spring or Fall Planting**
20-25 ft., oval-rounded. Tolerates acid and alkaline soils, as well as heavy clay, better than any other dogwood. Bright yellow flowers in March turn to cherry-red fruit in June and July.

Cornus officianalis **Japanese Cornel Dogwood Spring or Fall Planting**
20-25 ft., oval. Similar to *Cornus mas*, although it flowers earlier and the fruit ripen later. Exfoliating bark in gray, orange and brown.

Cotinus obovatus **American Smoketree Spring or Fall Planting**
20-30 ft., oval-rounded. Scaly gray-black bark, cloud-like flower panicles and outstanding fall color. Limited availability in tree-form but may be limbed up or pruned.

✪ ✓ *Crataegus viridis* **'Winter King' Hawthorne Spring Planting**
20-30 ft., oval. White flowers, red fruit persistent through winter. Tolerant of wide range of soil types. Exfoliating bard in gray, green, orange and brown.

Koelreuteria paniculata **Goldenrain Tree Spring Planting**
30-40 ft., rounded. Tolerates drought, heat, wind, alkaline soil, salt and air pollution. Fast-growing in moist, well-drained soil. Mid-summer yellow flower clusters mature to attractive brown, papery capsules. Choose good branch structure at the nursery. Water well to recover from transplanting.

✪ *Maackia amurensis* **Amur Maackia Spring or Fall Planting**
20-30 ft., rounded. Adaptable; performs best in loose, acid or alkaline, well-drained soils. Amber-colored bark peels with age. Clean green foliage and summer white, pea-like flowers.

✪ *Magnolia 'Galaxy'* **'Galaxy' Hybrid Magnolia Spring or Fall Planting**
25-35 ft., pyramidal. Pinkish-purple flowers open in April. Mildew can be a problem in moist, humid sites. Tendency to develop water sprouts. Deciduous magnolia.

✪ *Malus 'Donald Wyman'* **Flowering Crabapples Spring Planting**
25 ft., rounded. High disease resistance. Red buds that unfurl to while flowers. Glossy bright red fruit persist into winter. There are many disease-resistant crabapple cultivars to choose from with varying bud, flower, fruit colors, and growth habits.

✪ ✓ ? *Ostrya virginiana* **American Hophornbeam Spring Planting**
25-40 ft., pyramidal to rounded. Tolerates dry, acid and high pH soils. Prospers in full sun and is also an excellent understory tree. Grayish-brown exfoliating bark, hop-shaped seed nutlet is prized by many song birds. May be sensitive to air pollutants and road salts.

? Unproven as street tree – proven in urban parks but suggest maximized soil space
✪ Example of species planted at DCH gardens/grounds
✓ Native to Delaware or Eastern U.S.
! Please note: invasive tendencies, disease/insect potential, or over-used in Wilmington area

SMALL TREES – SUITABLE NEAR OVERHEAD UTILITY WIRES (>10')

Parrotia persica **Persian Parrotia** **Spring or Fall Planting**
20-35 ft., upright to rounded. Fantastic exfoliating gray, green white and brown bark. Reddish foliage when emerging changes to dark green in summer and brilliant yellow, orange and scarlet in autumn. Select a single-stem form for street tree use. Highly adaptable and tolerant of urban stresses once established.

Prunus X incam 'Okame' **'Okame' Cherry** **Spring Planting**
20-30 ft., vase-shaped to rounded at maturity. Excellent heat and cold tolerance. One of the first trees to flower in spring; rich pink flowers appear before the leaves. Excellent bronze-red fall color.

Prunus subhirtella **'Autumnalis' Cherry** **Spring Planting**
20-40 ft., upright to rounded. Tolerant of urban heat. Pinkish-white flowers appear in fall and spring. One of the longest-lived cherries. Excellent yellow-orange fall color.

Syringa reticulata **Japanese Tree Lilac** **Spring or Fall Planting**
20-30 ft., oval to rounded. Summer white flower clusters. Easily transplanted and adaptable. Pest-free, although powdery mildew, a common lilac problem, can occur during moist seasons.

MEDIUM to LARGE TREES – NOT SUITABLE NEAR OVERHEAD UTILITIES

! ✪ ✓*Acer rubrum* **Red maple** **Spring or Fall Planting**
40-70 ft. Acid, moist soils a necessity. Sensitive to road salt and drought. Superior cultivars for form (narrow) and fall color are available. Outstanding red fall color. Not recommended for small tree pits, as shallow roots tend to create a mass of roots and possible sidewalk heaving. Somewhat over-used as a street tree in Wilmington.

✪ ✓ ? *Acer saccharum* **Sugar maple** **Spring or Fall Planting**
60-80 ft., oval. Sensitive to road salt, urban heat, soil compaction and drought. One of our best native trees for fall color – brilliant yellows, orange and red. Limit use to wide tree lawns and parkways. Many cultivars available, 'Legacy' is reported as the toughest.

✪ ✓ *Betula nigra* **River birch** **Spring or Fall Planting**
40-70 ft., oval. Prefers acid, moist soils, but adaptable. Cultivars such as 'Heritage' and 'Little King' are resistant to bronze birch borer. Exfoliating pinkish-white bark. Single-stem forms should be sought for street tree use.

✪ *Carpinus betulus 'Fastigiata'* **European Hornbeam** **Spring or Fall Planting**
This upright form in youth becomes pyramidal with maturity, 30-40 ft. Tolerates drought, heavy soil and wide pH range. Water well in spring to overcome road salt intolerance. Clean green foliage turns yellow to brown in autumn.

? Unproven as street tree – proven in urban parks but suggest maximized soil space
✪ Example of species planted at DCH gardens/grounds
✓ Native to Delaware or Eastern U.S.
! Please note: invasive tendencies, disease/insect potential, or over-used in Wilmington area

MEDIUM to LARGE TREES – NOT SUITABLE NEAR OVERHEAD UTILITIES

Celtis laevigata **Sugar Hackberry** **Spring Planting**
40-50 ft., upright. Tolerates full sun or light shade, wet to dry sites, soil compaction, road salt and air pollution. Pest-free. Lemon yellow leaves in fall. Select straight-trunked trees, limited availability.

✓ *Celtis occidentalis* Common Hackberry **Spring Planting**
40-60 ft., upright. Tolerates light shade, wide range of soils, road salt and air pollution. Susceptible to gall on leaves, powdery mildew and leaf spots. Good choice where few trees of other species will prosper.

✪ *Cercidiphyllum japonicum* Katsura Tree **Spring or Fall Planting**
40-60 ft., pyramidal to rounded. Suffers from drought and compacted soils. Relatively pest-free. Prefers full sun and rich, moist soil. Excellent apricot-orange fall foliage. Water well to establish.

? *Cladastris kentuckea* **American Yellowwood** **Spring or Fall Planting**
30-50 ft., broad-rounded. Best growth occurs in higher pH soils, but adaptable. Pest-free. Attractive, fragrant, early summer cream-colored flowers mature to brown pods that can be a litter problem some years.

Corylus colurna **Turkish Filbert** **Spring or Fall Planting**
40-60 ft., pyramidal to oval. Grows in a variety of soils and displays excellent drought tolerance once established. Exfoliating bark, clean summer foliage. Widely used as a successful street tree in Europe but limited availability in the U.S.

! ✓ *Fraxinus americana* **White Ash** **Spring or Fall Planting**
50-80 ft., oval. Performs best in deep, moist, well-drained soils of varying pH. Sensitive to drought, requires large area, heavy seed producer. Splendid large shade tree with excellent yellow to purple fall color. Scale insects can be a problem and emerald ash borer (EAB) is a new potential threat.

! ✪ ✓ *Fraxinus pennsylvanica* **Green Ash** **Spring or Fall Planting**
40-60 ft., oval to rounded. Excellent tolerance of heat and cold, wet and dry soils, acidic to alkaline soils. Yellow fall color. Scale insects can be a problem and emerald ash borer (EAB) is a new potential threat.

✪ *Ginkgo biloba* **Ginkgo** **Spring or Fall Planting**
50-80 ft., variable and irregular. Limit use to male cultivars to avoid malodorous fruit. Many cultivars available for excellent golden yellow fall foliage ('Autumn Gold') or narrow growth habit ('Princeton Sentry'). Tolerates high soil pH, road salts and drought. Pest-free. Unique fan-shaped leaves. An extremely durable and long-lived urban tree. May be slow to establish.

? Unproven as street tree – proven in urban parks but suggest maximized soil space
✪ Example of species planted at DCH gardens/grounds
✓ Native to Delaware or Eastern U.S.
! Please note: invasive tendencies, disease/insect potential, or over-used in Wilmington area

MEDIUM to LARGE TREES – NOT SUITABLE NEAR OVERHEAD UTILITIES

! ✓ ***Gleditsia triacanthos* 'inermis'** **Thornless Honey Locust** **Spring or Fall Planting**
30-70 ft., broad oval. Very adaptable to soils, displays excellent road salt tolerance. Select a cultivar to avoid pods. Rich golden yellow fall color, compound leaf canopy produces pleasing dappled shade. Water deeply to avoid surface roots. Somewhat overused as a street tree.

✪ ✓ *Gymnocladus dioica* **Kentucky Coffeetree** **Spring or Fall Planting**
50-75 ft., irregular oval. Tolerates drought, alkaline soil and road salt. Pest-free. Grass grows well underneath canopy. Distinctive curled ridges on gray-brown bark. Yellow fall color. Male pod-less cultivars becoming more available. An excellent, under-used street tree.

✪ ✓ ? *Liquidambar styraciflua* **American Sweetgum** **Spring or Fall Planting**
50-75 ft., pyramidal to oval. Best on moist, sunny sites, does not tolerate higher pH soils. Brilliant fall colors include yellow, orange, reds, and purples to almost black. 'Rotundiloba' is reportedly seedless. Limit use to areas with plenty of soil space.

Metasequoia glyptostroboides **Dawn Redwood** **Spring or Fall Planting**
65-90 ft., pyramidal. Deciduous conifer. Prefers full sun and acid soil. Lower branches need to be removed for street tree use as tree matures. Requires large area. Orange-brown fall needle color.

✪ ✓ ? *Nyssa sylvatica* **Black Gum** **Spring Planting**
30-50 ft., pyramidal in youth to spreading with maturity. Lustrous green summer foliage changes to fantastic yellows and oranges to scarlet and purple in autumn. Bluish berry-like fruit is eaten by many bird species and as a result is not usually a litter problem. One of the best, most consistent native trees for fall foliage. Limit use to large areas, wide tree lawns or parkways. Not for heavy road salt use, polluted areas or high pH soils. Pest-free.

? *Pistacea chinensis* **Chinese Pistache** **Spring or Fall Planting**
30-50 ft., oval-rounded. Scaly gray bark flakes off to expose orange inner bark. Dark green leaves become brilliant orange-red in fall. Withstands poor, droughty soils and is highly adaptable. Pest-free. Under-used street tree that has great potential.

! *Platanus X acerifolia* **London Planetree** **Spring or Fall Planting**
70-90 ft., broad oval. Tolerates compacted soils, drought, road salts and varying pH. Resistant to anthracnose, but cankerstain is a very serious disease potential. Requires large area and is extremely tolerant of urban conditions and heavy pruning. Over-used as a street tree in Wilmington and many other areas. Cream to olive and brown bark can be a litter problem, as can early leaf drop some seasons.

Prunus sargentii **Sargeant Cherry** **Spring Planting**
25-40 ft., vase-shaped. 'Columnaris' is considered one of the best flowering cherries for street tree use. Pink flowers and bronze-red fall color. Prefers acid soil and full sun.

? Unproven as street tree – proven in urban parks but suggest maximized soil space
✪ Example of species planted at DCH gardens/grounds
✓ Native to Delaware or Eastern U.S.
! Please note: invasive tendencies, disease/insect potential, or over-used in Wilmington area

MEDIUM to LARGE TREES – NOT SUITABLE NEAR OVERHEAD UTILITIES

! *Quercus acutissima* **Sawtooth Oak** **Spring Planting**
40-50 ft., pyramidal to broad-rounded. Tolerates city conditions, including dry soils. Reasonably pest-free. Transplants more readily than most oaks. Acorn production can be heavy some years. Possibly invasive near open areas.

✿ ✓ *Quercus bicolor* **Swamp White Oak** **Spring Planting**
50-80 ft., pyramidal to rounded. Easier to transplant than other white oaks. Tolerates drought, road salts and soil compaction in urban areas. Clean green summer foliage changes to yellow and red-purple in autumn. Requires acid soil.

✓ *Quercus imbricaria* **Shingle Oak** **Spring Planting**
40-65 ft., pyramidal to rounded. Copper-tan fall color that persists into winter. Tolerant of urban conditions. A good, Delaware-native substitute for sawtooth oak, willow oak or pin oak.

! ✓ *Quercus palustris* **Pin Oak** **Spring Planting**
50-70 ft., pyramidal to oval. Tolerates a wide range of soils, but prefers acid soil and full sun. Moderate salt tolerance. Red-brown fall color. Lower branches hang down and can be a clearance problem. Bacterial leaf scorch (BLS) is a recent disease problem that has been found in Wilmington and affects other red oaks. Over-used as a street tree in many areas.

✓ *Quercus phellos* **Willow Oak** **Spring Planting**
55-75 ft., pyramidal to oval. Prefers acid soil and full sun. Withstands temporary flooding and dry soils. Yellow-brown to red fall color. Higher pH soils and road salts may cause chlorosis (yellowing of leaves).

Quercus robur 'Fastigiata' **Fastigiate English Oak** **Spring Planting**
Distinctly upright, a 50-60' tree may be only 10-20 ft. wide. Widely used as a street tree in Europe. Tolerant of a wide range of soil conditions. Clean, dark blue-green foliage in summer.

! ✓ *Quercus rubra* **Northern Red Oak** **Spring Planting**
60-80 ft., rounded. Tolerates urban conditions along streets with heavy traffic. Red to golden-brown fall color. Bacterial leaf scorch (BLS) is a recent disease problem that has been found in Wilmington and affects other red oaks. Many of Wilmington's largest street trees are red oaks.

✿ ✓ ? *Taxodium ascendens* **Pond Cypress** **Spring Planting**
70-80 ft., more columnar than *T. distichum*, otherwise very similar. Limited availability.

✓ *Taxodium distichum* **Common Baldcypress** **Spring or Fall Planting**
50-80 ft., columnar to pyramidal. Adaptable to a wide range of soil conditions, except high pH. Deciduous conifer with orange-brown fall color. Reddish-brown fibrous bark. Fast growth.

? Unproven as street tree – proven in urban parks but suggest maximized soil space
✿ Example of species planted at DCH gardens/grounds
✓ Native to Delaware or Eastern U.S.
! Please note: invasive tendencies, disease/insect potential, or over-used in Wilmington area

MEDIUM to **LARGE TREES** – NOT SUITABLE NEAR OVERHEAD UTILITIES

! *Tilia cordata* **Littleleaf Linden** **Spring or Fall Planting**
60-80 ft., dense pyramidal, many good cultivars. Best on moist, well-drained soils. Poor salt and drought tolerance, and urban heat may cause leaf scorching. Adaptable to wide soil pH range. Will withstand moderate soil compaction. Early summer yellow flowers. Yellow fall color. Over-used as a street tree, and aphid residue may cause litter on cars.

Tilia tomentosa **Silver linden** **Spring or Fall Planting**
60-70 ft., pyramidal. Tolerates drought and heat better than *T. cordata*. Attractive white underside of leaves. Tolerant of high soil pH and less susceptible to Japanese beetles than other lindens.

! *Ulmus americana* **hybrids** **American elm hybrids** **Spring or Fall Planting**
70-90 ft., upright spreading, vase-shaped. Select ONLY Dutch elm disease-resistant hybrids. High tolerance of urban conditions. Described as "majestic" and "gracefully beautiful." Yellow fall color. Do not plant in large groupings or entire blocks.

✪ *Ulmus parvifolia* **Lacebark Elm** **Spring or Fall Planting**
50-75 ft., rounded. Has proven highly resistant to Dutch elm disease. Attractive exfoliating bark. High degree of urban stress tolerance. Yellow to wine-red fall color.

! ✪ *Zelkova serrata* **Japanese Zelkova** **Spring or Fall Planting**
50-70 ft., vase-shaped. Adaptable to soil pH, compaction, pollution, partial shade and drought once established. Flaky bark with orange patches. Excellent bronze-red fall color. Widely planted and somewhat over-used as a street tree in Wilmington.

? Unproven as street tree – proven in urban parks but suggest maximized soil space
✪ Example of species planted at DCH gardens/grounds
✓ Native to Delaware or Eastern U.S.
! Please note: invasive tendencies, disease/insect potential, or over-used in Wilmington area

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Delaware Center for Horticulture
Tree Program
1810 N. Dupont St.
Wilmington, DE 19806
(302) 658-6262, ext. 33
(302) 658-6267 fax
www.dehort.org

The Delaware Center For Horticulture is a non-profit horticultural resource center dedicated to improving the quality of life in Delaware by promoting knowledge and appreciation of gardening, horticulture and conservation. Become a member today!

Appendix D: Wilmington Tree Program Work Permit and Request

Bilingual Format made possible by:

Application for
Tree Work Permit

Solicitud para el permiso de:
Trabajos de Árboles

Return to / *Enviar a:*
Delaware Center for Horticulture / *Centro para la Horticultura de Delaware*
1810 N. Dupont St.
Wilmington, DE 19806-3308
Phone (302)658-6262 Fax (302)658-6267 www.dehort.org

For work to be arranged and financed by applicant
Para trabajos a ser planificados y financiados por el solicitante

Date / *Fecha:* ____________
Address of Tree Work /
Dirección donde se hará el trabajo de árbol: ______________________________________
On Street (if different from address) /
*En Calle (en caso que sea diferente a la dirección)*__________________________________

APPLICATION TO: (Check sections that apply)

SOLICITUD PARA: *(Indique solo las secciones que aplican)*

O **Plant Tree(s)** / ***Sembrar Árbol(es)*** O
*Number & Species of Tree(s)__________________________*Número + Especie de Árbol(es)**

* Contact DCH for list of recommended and approved street tree species /
Contacte DCH para una lista de especies arbóreas recomendadas y aprobadas

O **Prune Tree(s)** / ***Podar Árbol(es)*** O
Number & Species of Tree(s)__________________________*Número + Especie de Árbol(es)*

Reason for Pruning____*Razón para la Poda*

Type of Pruning / ***Tipo de Poda***

- O **Crown Raising** (pruning lower limbs for clearance) /
  Poda de Crecimiento *(poda de ramas bajas para despejar)*
- O **Crown Cleaning** (removing deadwood for tree health and safety) /
  Poda de Limpieza (remoción de ramas muertas para la salud y seguridad del árbol)
- O **Crown Thinning** (no more than 25% live crown shall be removed) /
  Poda de Reducción de la corona *(no más del 25% de una corona viva puede ser removida)*
- O **Crown Reduction For Clearance** (buildings, utilities, traffic) /
  Poda de Reducción para Despeje *(edificios, oficinas públicas, tráfico)*
- O **Root Reduction** (sidewalk interference) / ***Reducción de Raíces*** *(interferencia de aceras)*

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O **Remove Tree & Stump** *Remover Árbol & Tocón* O

Number & Species of Tree(s)___________________________*Número + Especie de Árbol(es)*

Reason for Removal___________________________________*Razón por la que se Remueve*

Note: Bearing in mind the far ranging benefits provided by trees, we encourage you to replace the tree with an appropriate selection

Nota: *Tomando en cuenta la variedad de beneficios que proveen los árboles, les animamos a reemplazar el árbol por una selección apropiada.*

Application is hereby made to conduct the operations stated above. If a permit is granted, I (we) agree to perform all work in accordance with all specifications, rules and standards set forth in Chapter 46, Vegetation, Wilmington Code. Please allow two (2) weeks to receive notification by mail.

Afirmo en la presente solicitud que llevaré a cabo las operaciones aquí expuestas. Si se me otorga el permiso, declaro que estoy de acuerdo en llevar a cabo los trabajos de acuerdo con todas las especificaciones, reglas y estándares establecidos en el Capítulo 46, Vegetación del Código de Wilmington. Por favor permita dos (2) semanas para recibir la notificación por correo.

Applicant Name / *Nombre del Solicitante*: ____

Phone / *Telefono*: ________________

Property Owner / *Propietario de la Propiedad*: ____

Address / *Direccion*: ____

Home Phone / *Telefono Casa*: _____________**Bus. Phone / *Telefono Ofic*:** ________________

Resident or Tenant Name / *Nombre del Residente o Inquilino*: ___________________________

Signature / *Firma*: ____________________________________**Date / *Fecha:*** ______________

Landscape Contractor/Tree Surgeon / *Contratista Paisajista/Cirujano de Arbol*:

Phone / *Telefono*: _________________

Note: All tree work shall conform to Chapter 46, Vegetation, Wilmington Code and ANSI A300-1995 Pruning Standards- "Tree, Shrubs and Other Woody Plant Maintenance –Standard Practices" and the latest revision of the ANSI Z133-1 "Safety Requirements for Pruning, Trimming, Repairing, Maintenance, Removing Trees and for Cutting Brush". A copy of both documents (ANSI A300 and ANSI Z133-1) are available at DCH. Violation of these provisions shall, upon conviction, be subject to the Penalties set forth in Chapter 46 of Wilmington City Code.

Nota: *Todo trabajo de árboles debe estar conforme al Código de Wilmington, Capítulo 46, vegetación y a los Estándares de Poda de ANSI A300-1995 –"Prácticas y Estándares para el Mantenimiento de Árboles, Arbustos y Plantas de Bosque" y a la ultima revisión de ANSI Z133-1 "Requisitos de Seguridad para la Poda, Recorte, Reparación, Mantenimiento, Remoción de Árboles y para Corte de Maleza". Copias de ambos documentos (ANSI A300 y ANSI Z133) están disponibles en el DCH. La violación de estas disposiciones estará sujeta, luego de un juicio, a las Penas establecidas en el Capitulo 46 del Código de la Ciudad de Wilmington.*

DELAWARE CENTER FOR HORTICULTURE

Delaware Center For Horticulture
Centro de Horticultura de Delaware

Wilmington Tree Program Request
Solicitud Programa de Arboles de Wilmington

THIS PROGRAM IS CONTINGENT UPON FUNDING FROM GOVERNMENTAL ALLOCATIONS
ESTE PROGRAMA DEPENDE DE FONDOS PROVENIENTES DE CUOTAS DEL GOBIERNO

REQUEST TYPE ○Planting ○Pruning ○Removal and Planting ○Removal
TIPO DE SOLICITUD ○*Plantación* ○*Poda* ○*Remoción y Plantación* ○*Remoción*

Street Address:________________________________:*Dirección Calle*

Owner Name:________________________________:*Nombre del Propietario*

Phone:__________ Work Phone:__________ *Teléfono:*__________ *Teléfono del Trabajo:*__________

Owner Mailing Address:________________________________:*Dirección del Propietario*

Owner City, State, Zip:________________________________:*Ciudad del propietario, Estado, Zona Postal*

Resident Name:________________________________:*Nombre del Residente*
(if different from owner) *(Si es diferente del Propietario)*

Neighborhood Association:________________________________:*Asociación de vecinos*

Qty of Trees to Plant:_____ Species Preference:________________________(optional)
*Cantidad de árboles para plantar:*_____ *Especies preferidas:*________________________*(opcional)*

Sidewalk/pit alteration:________________________ Owner approval?:_____
*¿Cambios en la acera?:*________________________ *¿Aprobación del propietario?:*_____

Description of existing tree work (# and size of trees to prune, remove):
Descripción de los los árboles existentes para trabajar (Número y tamaño de árboles a podar, remover):

____
____
____

Signature & Date:________________________________:*Firma & Fecha*

Return to: Delaware Center for Horticulture
Regresar a: Centro de Horticultura de Delaware
1810 North Dupont St.
Wilmington DE 19806
(302) 658-6262/fax: 658-6267, www.dehort.org

Bilingual Format made possible by:
NATIONAL TREE TRUST

DCH/06/2004

Appendix E: BMP Nutrient Reduction Calculations–Stormwater

Stormwater BMP Pollutant Removal Information

The benefits of individual BMPs are site specific and depend on a number of factors including:

- Number, intensity, and duration of wet weather events.
- Pollutant removal efficiency of the BMP.
- Water quality and physical conditions of the receiving waters.
- Current and potential use of the receiving waters.
- Existence of nearby "substitute" sites of unimpaired waters.
- Existing land use in the watershed.

BMP TYPE	Number of Monitoring Studies	TYPICAL POLLUTANT REMOVAL (%)			
		Suspended Solids	Total Nitrogen	Total Phosphorus	Pathogens
Dry Detention Ponds[1]		30-65	15-45	15-45	<30
Dry Detention Ponds[4]		70	15	25	
Wet Ponds[4]			0.4	0.5	Bacteria 44-99
Retention Basins[1]		50-80	30-65	30-65	<30
Retention Basins[2]	35		30	46	Bacteria 74
Biofiltration[4]			25	34	Bacteria >99
Constructed Wetlands[1]		50-80	<30	15-45	<30
Constructed Wetlands[3]	17 reports	76	24	46	Bacteria 78
Constructed Wetlands[4]		-398	-103	-217	Bacteria 78-90
Infiltration Basin s[1]		50-80	50-80	15-45	65-100
Infiltration Trenches/Dry Well s[1]		50-80	50-80	15-45	65-100
Porous Pavements[1]		65-100	65-100	30-65	65-100
Infiltration Practices[2]	3 – infiltration trenches 2 – porous pavement	89	83	65	
Open Channel Vegetated Systems[2]	20	66	11	15	Bacteria -25
Filtration Systems[2]	13	81	32	45	Bacteria 37
Grassed Swales[1]		30-65	15-45	15-45	<30
Vegetated Filter Strips[1]		50-80	50-80	50-80	<30
Surface Sand Filters[1]		50-80	<30	50-80	<30
Surface Sand Filter[4]		57	47	41	Bacteria 36-83
Other Media Filter s[1]		65-100	15-45	<30	<30

- The blue rows provide ranges of the expected overall pollutant removal efficiency for properly sited, designed, sized, constructed, and maintained BMPs. Adapted from the USEPA, 1993c.
- The white rows provide numbers that are actual performance data contained in the literature on pollutant removal efficiencies for selected BMPs.
- By definition, pathogens include bacteria, viruses, protozoa, fungi, parasites, and protein.
- Efficiency means the ability of the management practice to remove pollutants from runoff.
- Effectiveness refers to the actual improvements in water quality, habitat, or other parameters as a result of implementing the management practice.
- "Evaluation of BMP data can give an indication of the range of pollutant removals expected, however arriving at a fixed numerical "percent removal" for each BMP type or category is a

difficult task. The main problem associated with comparing BMP performance data is the variety of techniques that are used to compute performance, as well as the variation in the ways that samples are collected and in the parameters that are measured in the samples. Performance calculations are further complicated by the errors that result from measuring flow rates and volumes of stormwater that pass through the BMP" (USEPA Preliminary Data Summary of Urban Storm Water Best Management Practices, August 1999).

[1] The expected pollutant removal (percent) data adapted from US EPA, 1993c.
[2] Brown and Schueler, 1997a.
[3] Strecker et al. (1992); Bacteria from Brown and Schueler, 1997a.
[4] Boyer, Allison, Watershed Assessment Section, DNREC Fact Sheet.

Appendix F: BMP Stormwater Cost Calculations

I. Wet and Dry Ponds: Typical costs for retention basins were retrieved from Chapter 6.0, "Costs and Benefits of Storm Water BMPs," of an USEPA online document (USEPA, 1999). In this document, it states that a retention basin treating a 50-acre residential site in 1999 costs about $100,000, such that the cost per unit area was $2,000/acre. All values reported in the document need to be divided by an adjustment factor to account for regional differences. Delaware falls in Region 2, which has a 0.90 adjustment factor (USEPA, 1999). Thus, retention basins in Delaware in 1999 cost approximately $2,222.22/acre. Using the average annual federal inflation rate (3 percent), the capital cost of Delaware retention basins in 2005 is $2,622.22/acre. Capitalized at a 3-percent interest rate over a 25 year finance period, this value becomes $150.59/acre/year. However, it should be noted that stormwater ponds can be expected to function for up to 50 years. To this value, the annual operation and maintenance costs must be added. Operation and maintenance costs for retention basins can range from 3–6 percent of the construction costs (USEPA, 1999). We have used an average value of 4.5 percent and applied this to the regionally adjusted construction cost, to get $118.00/acre/year operation and maintenance costs. Thus, the final cost of wet and dry ponds is $268.59/acre/year (Table 3). Wet and dry ponds have different nutrient reduction efficiencies. Using nutrient reduction estimates, the prior value equates to $112/lb TN reduced and $698/lb TP reduced for wet ponds, while the cost per pound nutrient reductions for dry ponds are $90/lb TN and $1,535/lb TP.

II. Infiltration Structures: The 1999 construction costs of infiltration trenches and infiltration basins treating 5-acre commercial sites were averaged to represent the range of infiltration structures utilized as stormwater BMPs throughout Delaware. These costs were $45,000 for trenches and $15,000 for basins (USEPA, 1999), which equates to $9,000/acre and $3,000/acre, respectively, and averages $6,000/acre. Once adjusted for the regional variability in cost (0.90 factor), and inflated to 2005, this value becomes $7,866.67/acre treated by infiltration structures. Infiltration structures are believed to have a 25-year life expectancy, thus the capitalized construction cost at a 3-percent rate is $451.77/acre/yr. Annual operation and maintenance costs for infiltration structures range anywhere from 1–20 percent of the construction cost (USEPA, 1999) and average 10.5 percent. This produces an annual operation and maintenance cost of $826.00/acre/yr. The total cost of infiltration structures annually is $1,277.77/acre/yr (Table 3). This corresponds to $100/lb TN reduced and $2,643/lb TP reduced.

III. Sandfilters: Cost data for sandfilters was obtained from a publication of the Environmental and Water Resources Institute of the American Society of Civil Engineers (ASCE, 2001). This guide reports costs of sandfilters installed in Delaware in the early 1990s. Since sandfilters treat runoff from pavement and impervious areas, the construction cost was reported as $10,117.36 per impervious acre. The 2005 cost, estimated using the average federal inflation rate, is $14,670.17/acre. Capitalized over 25 years at a 3-percent interest rate, this becomes $842.48/acre/yr. The operation and maintenance costs typically range from 11–13 percent of the construction costs (USEPA, 1999), which on average, is $1,760.42/acre/year. Taking the two values together yields a total cost of $2,602.90/acre/year (Table 3). The cost per pound nutrient reduction is thus $277/lb TN and $9,067/lb TP.

IV. Biofilters: The USEPA online document reported that the construction costs for biofiltration devices in 1999 were $60,000 for a 5-acre commercial site (USEPA, 1999), which equates to $12,000/acre. This value must also be divided by the 0.90 adjustment factor to account for regional cost differences, which yields $13,333.33/acre, and then adjusted to the 2005 value, $15,733.33/acre. This value becomes $903.53/acre/year when capitalized over the 25-year expected lifetime of the structure at a 3-percent interest rate. The annual O&M costs range from 5–7 percent of the construction cost (USEPA, 1999). When using 6 percent as the average, annual operation and maintenance costs $944/acre/year. Thus, total costs for biofilters are $1,847.53/acre/year Table 3). The price per pound nutrient reduction has not been determined since a recent inventory of stormwater BMPs in the watershed did not reveal any biofilters present.

Table F.1 Stormwater BMP Costs

Cost	**Wet and Dry Ponds**	**Infiltration Structures**	**Sandfilters**	**Biofilters**
Construction	$2,622.22/acre	$7,866.67/acre	$14,670.17/acre	$15,733.33/acre
Finance Period	25 years	25 years	25 years	25 years
Subtotal Capitalized over Lifespan	$150.59/acre/yr	$451.77/acre/yr	$842.48/acre/yr	$903.53/acre/yr
O&M (Percent of Construction)	4.5%	10.5%	12%	6%
Annual Operation and Maintenance	$118.00/acre/yr	$826.00/acre/yr	$1,760.42/acre/yr	$944.00/acre/yr
Total	**$268.59/acre/yr**	**$1,277.77/acre/yr**	**$2,602.90/acre/yr**	**$1,847.53/acre/yr**

References:

ASCE, Guide for Best Management Practice (BMP) Selection in Urban Developed Areas. American Society of Civil Engineers, Reston, Virginia, 2001.

USEPA, Preliminary Data Summary of Urban Storm Water Best Management Practices, Chapter 6: Costs and Benefits of Storm Water BMPs. U.S. Environmental Protection Agency, Office of Water, Washington, D.C., 1999.

Appendix G: Summary of Stormwater Ordinances in the Christina Basin

	DNREC	New Castle County	New Castle County	City of Newark	Newport	Elsmere	City of Wilmington
Name of Ordinance	Delaware Sediment and Stormwater Regulations Chapter 40, Title 7, Delaware Code	Chapter 12, New Castle County Drainage Code	Article XX, Chapter 23, Water Resource Protection Area District	City of Newark Municipal Code, Chapter 27, Subdivisions, also see DNREC Sediment and Stormwater Regulations	Zoning and Subdivision Ordinances	Zoning, Chapter 225 from the Code of the Town of Elsmere	See DNREC Sediment and Stormwater Regulations
Date of Ordinance/ Code	1/23/1991 Last amended on 10/11/2006	Last amended on 09/26/2006	01/11/94	Last amended on 5/23/2005	Last draft revisions on 05/11/2004	1996	
Funding Source	Fees	Permit Fees	No	Permit Fees	Fees	Fees	
Criteria for Designated Watershed	Yes	Yes	No	No	No	No	
Runoff Model (TR-20)	SCS TR-20, TR-55	TR-55, TR-20	No	TR-20, TR-55, DURMM, any approved by DNREC	No	No	
Design Frequency	10/100-year	100-year	100-year	FHD, 2/10/100-year, 2" (quality)	FHD, 100-year	FHD, 100-year	FHD, 100-year
Percent Impervious	No	No	10%-50%	50% (excluding buildings)	No	No	
Post-Development Discharge (cft/ac)	Yes	Yes	Yes	Yes (Persimmon and White Clay Creeks), No all others	No	No	
Water Quantity	Yes	Yes	Yes	Yes	Yes	No	
Water Quality	Yes	Yes	Yes	Yes	No	No	

Contractor Certification	Yes	Yes	No	Yes (if detailed SWPP required) No (all others)	No	No	
SE & SC	Yes	Yes	Yes	Yes	No	No	Yes
Available Watershed Plans	No	No	No	No	No	No	
Woodland Preservation	No	Harvest Permit	No	No	Yes	Yes	
Buffer Area (ft)	20	10	300 (wellhead area)	No	50	50	
Steep Slope (%)	No	15–25%	Erodible Soils	25%	No	No	
Cluster Development	No	Yes	No	Yes	Yes	No	
Filter Strips	No	Yes	No	Yes	No	No	
Bio-Swales	No	Yes	No	Yes	No	No	
Infiltration Basins	Yes	Yes	No	Yes	No	No	
Detention Basins	Yes	Yes	No	Yes	No	No	
Wetland Protection	Yes	No	No	Yes	No	No	

Appendix H: Maintenance Frequency and Costs for Stormwater BMPs

Stormwater BMP maintenance can be divided into two categories: Routine and Non-routine.

Routine maintenance includes regular inspections, vegetation management, embankment and outlet stabilization, debris and litter control, mechanical components, insect control, access maintenance, overall pond maintenance, sediment/pollutant removal, and components replacement.

As a general rule of thumb, annual maintenance will cost $100/acre for minimal maintenance, including mowing to $500/acre for more intensive maintenance including mowing, weed control, fertilization, debris removal, etc.

Non-routine maintenance needs will vary considerably depending on the type, size, depth of the facility, volume of the sediment trapped in the BMP, the accessibility of the BMP, and whether or not onsite disposal of the sediment is possible. Primary non-routine costs are sediment/pollutant removal and BMP renovation/reconstruction. Sediment removal costs for wet and dry ponds are included below:

Sample Wet and Dry Pond Sediment Removal Costs

Component	Surface Area							
	.25 acre		1 acre		2 acres		10 acres	
	Low	High	Low	High	Low	High	Low	High
Mobilization/Demobilization/Access Road	$1,000	$2,500	$3,000	$5,000	$5,000	$7,000	$5,000	$10,000
Dredging*	$1,613 ($8/cy)	$3,025 ($15/cy)	$12,090 ($15/cy)	$16,120 ($20/cy)	$24,195 ($15/cy)	$32,260 ($20/cy)	$120,990 ($15/cy)	$161,320 ($20/cy)
Disposal (Onsite/Offsite)	$1,008 ($5/cy)	$9,478 ($47/cy)	$4,030 ($5/cy)	$37,882 ($47/cy)	$8,065 ($5/cy)	$78,811 ($47/cy)	$40,330 ($5/cy)	$379,102 ($47/cy)
Total Cost	**$3,621**	**$15,003**	**$19,120**	**$59,002**	**$37,260**	**$118,071**	**$166,320**	**$550,422**
Typical Equipment	Backhoe		Truck Equipment (1) Loader/dozer (2) Crane Dragline or Clambucket					

*Dredging calculations assume a sediment accumulation of 6 inches. Cost will vary according to sediment depth. Estimated costs also assume that the facility is drained, and the silt is dewatered in place.

BMP	Sediment Removal Frequency	Facility Life Span
Wet Pond	5–15 years	20–50 years
Dry Pond	2–10 years	20–50 years
Infiltration Trench	As needed	10 years
Rain Garden	5+ years	Indefinite
Grassed Swale	As needed	Indefinite
Sand Filter	Every 6 months or as required	20–50 years

Non Routine maintenance costs for BMPs other than wet and dry ponds.

BMP	Type of BMP	Type of Maintenance	Cost
Infiltration Trench		Remove 6–12 inches of gravel, replace the filter cloth sediment barrier	$1,500–$2,000
Rain Garden		Non routine removal of sediments and replacement of some level of soil	$1,500–$2,000
Sand Filter		Remove top filter cloth and remove/replace filter gravel. Frequency of filter maintenance largely depends on the type of BMP	$1,500–$2,000 (dollars per impervious acre, i.e., parking lots, roadways, rooftops draining to the facility)
	DC Sand Filter	Requires carbon trap pumped and refilled every six months	$500–$700
		Filter cloth and gravel removed and replaced every three to five years	$1,500–$2,000 (dollars per impervious acre, i.e., parking lots, roadways, rooftops draining to the facility)
	Austin Sand Filter (typically residential use)	May only need to be cleaned when semi-annual inspection reveals it is necessary.	$1,500–$2,000 (dollars per impervious acre, i.e., parking lots, roadways, rooftops draining to the facility)

Source: *Maintaining Your BMPs: A Guidebook for Private Owners and Operators in Northern Virginia.* February 2000. Northern Virginia Planning District Commission.

Note: Cost estimates in this document are based on 1999 prices.

Appendix I: New Jersey 300-Foot Buffer

The New Jersey Stormwater Management rules, effective on February 2, 2004, significantly changed the stormwater management requirements for municipalities and the New Jersey Department of Environmental Protection. In these changes is an innovative requirement for the Special Water Resource Protection Area (SWRPA), which mandates a 300-foot buffer adjacent to all Category 1 Waters and their tributaries.*

In April 2006, the New Jersey Supreme Court rejected the New Jersey Builders Association's petition challenging the 300-foot buffer rule contained in New Jersey's stormwater regulations adopted in 2004. The correlation of riparian land use and water quality was noted in the Appellate ruling. The 300-foot buffer requirement adjacent to all Category One Waters and their tributaries stands as written in the New Jersey Stormwater Management rules (February 2004).

*Category One Waters are adopted into the New Jersey Surface Water Quality Standards (N.J.A.C. 7:9B) due to their clarity, color, scenic setting, aesthetic value, exceptional ecological significance, exceptional recreational significance, exceptional water supply significance, or exceptional fisheries resources. Category One Waters are afforded additional protection from measurable changes (including predicted or calculable changes) in water quality under the antidegradation provision of the Surface Water Quality Standards.

References:

State of NJ Nonpoint Source Report 2004-2006, April 1, 2006.

<www.delawareriverkeeper.org/newsresources/pressrelease.asp?ID=27>, accessed on October 20, 2006.

Appendix J: Forest Restoration at Middle Run Natural Area: A Coordinated Effort between New Castle County and Delaware Nature Society

New Castle County and the Delaware Nature Society (DNS) have joined together to restore the Middle Run Natural Area near Newark, Delaware, in the Christina Basin. Since 1992 the DNS has directed this forest restoration project on over 60 acres of abandoned farm fields in New Castle County's 815-acre Middle Run Natural Area Park. The project, funded by New Castle County, seeks to increase forest interior habitat of the Middle Run Natural Area while creating a forested buffer protecting the water quality of Middle Run.

The activities include seasonal plantings, vine control in the fall, and control of invasive nonnative plants. In addition, there are volunteer coordination and education programs as well as documentation that are critical components to the success of this project. The reforestation efforts in Middle Run have resulted in numerous environmental benefits including providing habitat for native wildlife and breeding ground for a variety of birds in the sapling forests.

A description of the restoration, volunteer, education, management, and project documentation efforts, as well as the estimated costs, is included below.

RESTORATION

- Determining the appropriate restoration areas within the Natural Area, reviewed annually.
- Coordinating two planting days per year, equaling ten plantings over the five-year period.
- Planting at least 500 native trees or shrubs, each planting day equals 5,000 trees or shrubs over a five-year period.
- Selecting native species and stock size for each planting.
- Selecting stock supplier for each planting.
- Planting trees that equal or exceed 5' tall and 4-gallon containers, shrubs in at least 4-gallon containers.
- Ensuring that all plantings are installed properly.
- Protecting all plantings with deer-proof cages.
- Obtaining and maintaining all management equipment.
- Communicating with grower(s) and New Castle County Department of Special Services.
- Coordinating off-loading, checking, and preparing tree stock.

VOLUNTEERS

- Recruiting and maintaining youth and adult volunteers (annually).
- Coordinating volunteers during planting and clip days (annually).
- Developing and distributing all mailings (annually).
- Managing all communications and databases (throughout project).
- Providing provisions for volunteers during planting days and clip days (annually).

EDUCATION

- Conducting volunteer instruction: planting techniques, restoration area management, and benefits of restoration projects (annually).

- Conducting two Delaware Nature Society outreach programs for New Castle County residents (annually).
- Conducting one Delaware Nature Society members program at Middle Run (annually).
- Offering restoration programs for schools (annually).

MANAGEMENT

- Creating a subcommittee within the Delaware Nature Society Land and Biodiversity Management Committee to oversee the project. Including designated New Castle County staff to participate.
- Coordinating pre-planting preparation for each planting day.
- Expanding invasive alien plant control project.
- Clearing all plantings of vines (annually) by coordinating six alien vegetation control, "clip-days," with volunteers per year.
- Establishing herbicide restoration areas with high concentrations of invasive alien plants (annually).
- Monitoring project success. Conducting eight follow-up inspections (per year) of all restoration areas.
- Seeking, obtaining, and installing additional donated plantings.
- Completing a comprehensive Land and Biodiversity Management Plan for the park during the first year and updating it annually.
- Holding at least one annual meeting with New Castle County Park maintenance staff to discuss management plans.

PROJECT DOCUMENTATION

- Recording project data (volunteer effort, plant material, general weather conditions, and survival rate).
- Creating photo and written documentation, including annual status and project history reports.
- Developing a PowerPoint presentation to showcase and promote the project.

PROJECT COSTS

New Castle County has a contract with DNS to administer and oversee the reforestation projects at the Middle Run Natural Area. The value of the contract is $50,000 per year. The contract is a five-year contract and will expire in 2010.

Table J.1 Costs for the Middle Run Restoration Project:

Item	Cost*
Labor (640 hours per year)	Confidential
Plantings (2 per year, approx. 1,000 plants total)	$14,000.00
Deer proofing	$2,000.00
Mailings	$150.00
Other supplies	$5,000.00 (approx.)
Total	**$16,650.00 (excluding labor)**

*The source of these cost estimates is email communication with DNS staff in April 2007.

Appendix K: Performance Standards Calculation

The calculations below show the TN and TP reduction due to upgrading small systems (less than 2,500 gpd) with a 50-percent performance standard, as recommended in WW1.

TN

93 lbs/day	=	0.000493 lbs/gallon TN	X	221 gallons/day	X	3,577 systems	X	48% Soil Conversion	X	50% PS

TP

24 lbs/day	=	0.000127 lbs/gallon TP	X	221 gallons/day	X	3,577 systems	X	48% Soil Conversion	X	50% PS

Appendix L: Onsite Wastewater Treatment System Field Inspection Report

DRAFT
Existing On-Site Wastewater System Field Inspection Report

Owner's Name: ______________________ Telephone #: ____________________

Mailing Address: ______________________ Septic Permit #: ____________________

______________________ Tax Map #: ____________________

Property Location: ______________________ Inspection Date: ____________________

Subdivision: ______________________ Inspection Time: ____________________

GENERAL INFORMATION

Site Condition: _____________ Weather: ___________________________ Permit: yes no

Age of Structure: ________ Age of System: ________ # Bedrooms: ______ # Bathrooms: ______

Occupied: yes no Length of vacancy: ______ weeks _____ months

# of Occupants presently: ______ # of Occupants of potential buyer, if known: _______

Is this a second opinion inspection? ( ) yes ( ) no
Is there evidence that sewage has backed up into the structure? ( ) yes ( ) no
Does gray water discharge somewhere other than the septic system? ( ) yes ( ) no ( ) Unk
Do trees or tree roots interfere with the system? ( ) yes ( ) no ( ) Unk
Is there evidence or documentation of wastewater surfacing? ( ) yes ( ) no
Is there a water treatment system discharging into the system? ( ) yes ( ) no

Date of last pumping: ____________ Pumping frequency: ____________

Have there been any repairs to the system? ______________________________________

System Maintainer: ____

( ) Single Family Dwelling ( ) Duplex ( ) Multi-Family ( ) Community/Large ( ) Commercial

Summary of System Component Inspections

	Satisfactory	Satisfactory w/concerns	Unsatisfactory
Treatment Tank(s)	( )	( )	( )
Distribution System(s)	( )	( )	( )
Absorption Facility(ies)	( )	( )	( )

Inspector's Name: ___________________________ Inspector's License #: _________

Signature: ___________________________ Date: _________ Phone #: ___________

SYSTEM COMPONENTS

- 1 -

Treatment Tank(s)

Tank Type:	Capacity (gal)*	# of Compartments	Material (Concrete, Metal, other)
( ) Septic Tank (tank 1)	________	_______	______________________
( ) Septic Tank (tank 2)	________	_______	______________________
( ) Aerobic	________	_______	______________________
( ) Cesspool	________	_______	______________________
( ) Other ______________	________	_______	______________________

* Round: D" X D"/ 292.5 X H"   Rectangular: L" X W"/ 231 X H"

Condition of:	**Satisfactory**	**Satisfactory w/concerns**	**Unsatisfactory**
Tank	( )	( )	( )
Top and Lids	( )	( )	( )
Inlet Baffle	( )	( )	( )
Outlet Baffle	( )	( )	( )
Liquid Level	( )	( )	( )
Effluent Filter ( ) N/A	( )	( )	( )
Distribution Box, if exposed	( )	( )	( )

If exposed, does the distribution box need to be leveled?	**( ) yes**	**( ) no**	**( ) N/A**
If exposed, is effluent above the lateral inverts in the distribution box?	( ) yes	( ) no	( ) N/A
Was/were the treatment tank(s) pumped during this inspection?	**( ) yes**	**( ) no**	
Does effluent from the absorption facility run back to the treatment tank?	( ) yes	( ) no	( ) N/A
Portions of the treatment tank(s) below a deck, driveway, walkway, etc.?	**( ) yes**	**( ) no**	
Is there evidence of effluent surfacing above the treatment tank(s)?	( ) yes	( ) no	
Are there any overflow lines?	**( ) yes**	**( ) no**	

Holding/Lift/Dosing Tank

Size: ____ X ____ X ____   Gallons: ________   Material: ______________________

Condition of:	**Satisfactory**	**Satisfactory w/concerns**	**Unsatisfactory**
Tank and Lid	( )	( )	( )
Pump/Siphon operational	( )	( )	( )
Alarm	( )	( )	( )
Timer	( )	( )	( )
Electrical Connections	( )	( )	( )
Check Valve & Purge Hole	( )	( )	( )
Pump elevated off tank floor	( )	( )	( )

Accumulated solids found in pump tank? ( ) yes ( ) no   **Infiltration of surface waters? ( ) yes ( ) no**

Is alarm on a separate circuit? ( ) yes ( ) no

Absorption Facility   Located: ( ) yes ( ) no

Is there more than one absorption facility? ( ) yes ( ) no   How many? _____   Total Sq. Ft: _________

Type:
- ( ) Bed _______ X ______ (approx. size)
- **( ) Trenches _______ X ______ (approx. size)**   **How many? ______**
- ( ) Sand Mound _______ X ______ (approx size)
- **( ) Seepage Pit _______ X ______ (approx. size)**
- ( ) Micro-Irrigation "Drip" _______ X _______ (approx. size)
- **( ) Other (describe)** ____

Are there any overflow lines?	( ) yes ( ) no
Portion of absorption facility below a deck, driveway, walkway, etc.?	**( ) yes ( ) no**
Are there signs of previous absorption facility failure?	( ) yes ( ) no
Does gray water discharge somewhere other than the septic system?	**( ) yes ( ) no**

Overall Comments & Concerns: ____

- 2 -

____
____
____
____
____
____
____
____

I attest the information I have provided is true and accurate to the best of my knowledge.

______________________________ ___________________

Owner's Signature Date

Sketch of On-Site Wastewater Treatment and Disposal System Location

	North

Identify **each** wastewater treatment and disposal system component. Mark distances to fixed reference points. Print clearly and draw to the best of your ability. Inspector may attach a copy of the permit indicating either no change or clearly marking changes on permit drawing.

Guidelines for Completing the Inspection Report

Page 1

Satisfactory

System components are in good shape, functioning properly, no damage

Satisfactory w/ Concerns

Possible areas include (but not limited to); broken lids, leaking risers/lids/inlet and outlet lines, unleveled distribution box, minor repairs needed to rectify problem. These minor repairs (as listed above) may be repaired at the time of inspection provided the Class H (System Inspector) has a Class F (Liquid Waste Hauler) or Class E (System Contractor) license. There is no permit necessary, note repairs on inspection form and rate as Satisfactory.

If the disposal bed or trenches are half full or more of effluent at the time of inspection and no signs of backup in the house or surfacing, rate as Satisfactory w/ Concerns. Please note however, the concern would be the system has some age to it and may need to be replaced in the near future or owner may need to watch their water use and to check for leaky faucets and toilets.

Advance treatment units not operating properly must be reported and checked by manufacture's representative or service provider.

Unsatisfactory

For the purposes of these Regulations obvious signs of system malfunction such as overland flow, direct discharge to surface waters, ditches, ground surface, cesspools, seepage pits, etc. These repairs (as listed above) would require system replacement the design permit to include pretreatment unit that meets PSN3 and a site evaluation must be performed prior to the system design if one is not on file.

Metal septic tanks used as septic tank are Unsatisfactory and are required to be replaced with a pretreatment unit that meets PSN3 standard. If disposal field is functioning and is not a seepage pit a site evaluation is not required to obtain a permit to replace the septic tank.

Broken distribution boxes, broken sewer and/or transmission lines. A permit is necessary to repair these items; however the Department can issue an emergency permit over the telephone if the Class H (System Inspector) has a Class E (System Contractor) license. If an emergency repair permit is issued the permit application must be submitted to the Department within three working days. Please note the Department would not require at the time of these types of repairs the addition of the ATU.

Separate gray water lines not connected to the system (gray water line to be connected to the system provided it is Satisfactory or Satisfactory with Concerns)

Page 2

Conditions of tanks, any electrical devices and associated parts require the tank(s) to be pumped first. **NOTE:** You should log the liquid depths, heights, scum layer thickness, sludge thickness, etc., prior to pumping the tank as well running the pump, if applicable.

If you encounter something not specifically covered on the inspection report or any situation or condition you feel needs to be addressed, note it in the comment section on page 3. Things like; garbage disposals, grease traps, home-made contraptions, components being bypassed, etc.

Overall Comments & Concerns

Provide any information that will help determine the operational status of the system and abnormalities or questions regarding any component(s). This area is for further explanation of concerns found or to better explain why/how a problem was noted. This is good place to record depth and thickness of scum and sludge layers to help determine previous maintenance practices. **NOTE:** If needed, site evaluation and permit required for replacement of the system. Repair permit required for any repair work to be performed

The sketch should be as accurate as possible with distances to fixed reference points recorded. If the area provided is not large enough to accomplish this please attach another 8 ½" X 11" sheet to report. If a permit is found that accurately depicts the overall system area it may be substituted instead of redrawing the system area.

If you require further guidance, contact the Department.

Appendix M: Onsite Wastewater Treatment System Pump-out Program Calculations

The calculations below show the TN and TP reduction due to implementing an OWTS pump-out program for all septic systems in the basin:

TN

$$\text{1931.58 TN lbs/year} = \text{1.62 TN lbs/system/pump-out} \times \left(\left(\text{3,577 systems} \times \frac{\text{1 pump-out}}{\text{3 years}} \right) - \text{0 compliant systems} \right)$$

TP

$$\text{739.25 TP lbs/year} = \text{0.62 TP lbs/system/pump-out} \times \left(\left(\text{3,577 systems} \times \frac{\text{1 pump-out}}{\text{3 years}} \right) - \text{0 compliant systems} \right)$$

Appendix N: Bacteria Load Reductions

REDUCING BACTERIA WITH BEST MANAGEMENT PRACTICES

Bacteria found in surface waters can be separated into two sources, point and non-point. Point sources can usually be directly identified, such as a discharge pipe from a sewage treatment plant. Non-point source pollution comes from many diffuse sources, making it difficult to determine the actual source(s) and even harder to control. Typically, non-point sources of bacteria result from rainfall or snowmelt moving over and through the ground. As runoff moves across surfaces, it picks up and carries bacteria, finally depositing them into lakes and rivers.

The bacteria that cause the most concern are those naturally found in the digestive tract of warm blooded animals, known as fecal bacteria. Fecal bacteria levels in water are determined by incubating a water sample for 24 hours and then counting the number of bacterial colonies that grew during that time. The unit for reporting fecal bacteria is "colony-producing units" per 100 milliliters of water (CPU/100 mL). CPUs/100 mL is used interchangeably with "organisms per 100 mL."

Listed below are examples of possible known sources that contribute to fecal bacteria contamination to our waterways:

- Livestock - cows, horses, donkeys, chickens, and sheep
- Pet wastes - dogs and cats
- Wildlife - deer, raccoons, and birds - such as geese and ducks
- Human - septic systems and wastewater treatment plants

Bacteria survival is dependent on soil moisture, temperature, pH, availability of nutrients and antagonistic organisms. Under ideal conditions the bacteria is retained near the soil surface long enough for infiltration into unsaturated soil to occur resulting in bacteria die off within the first two feet. Under less than ideal conditions, best management practices (BMPs) are the most effective and practical means of preventing or reducing bacteria from entering surface waters.

BMPs reduce bacteria levels in many different ways. Non-structural BMPs are practices that mainly control bacteria at the source. These practices include routine septic inspections and pump-outs. Septic tanks should be inspected every three years and pumped as needed, usually every three years or when the tank is about 1/3 filled. By maintaining your septic system regularly, it is less likely to fail and contaminate surface or ground water. It also extends the longevity of your septic system, saving money for costly repairs or replacements. Another very inexpensive non-structural BMP is simply being a good neighbor and managing pet waste properly. Another example is managing livestock manure.

Structural BMPs usually involve building a structure and may have a higher cost associated with it. Examples include buffers, constructed wetlands, sand filters, infiltration trenches, low impact development, and stream fencing. Dense vegetative buffers facilitate conventional bacteria removal through detention, filtration by vegetation, and infiltration into soil.

Other methods include the use of chemicals such as chlorine or even using ultraviolet lights. These methods can be costly and require considerable oversight

Constructed Wetlands

Constructed wetlands offer wildlife habitat, erosion control, surface water storage, flood control, ground water recharge, and pollutant removal. They can be useful in conjunction with other BMPs or they can function independently. It is very difficult to preserve the natural ecology of natural wetlands, which is why the use of constructed wetlands is much more prominent.

A study conducted in California (2001) indicated that a three cell constructed wetland could reduce bacteria by 90%.

Buffer Strips

Buffer strips are vegetated sections of land that are essentially flat or have low slopes designed to reduce the runoff volume. Densely vegetative cover removes pollutants through detention of runoff, filtration by the vegetation, and infiltration into soil. The effectiveness of buffers for reducing bacteria pollution, however, is dependent on the type of vegetation and the width of the buffer. Typically, the wider the buffer, the more pollution reduced. A study done in Virginia in 2003

indicated that buffers can reduce bacteria by 43 to 57%, especially in agricultural watersheds.

Sand Filters

Sand filters are a storm water treatment practice designed to remove sediment and pollutants from the first flush of runoff from pavement and impervious areas after a rain or storm event. Sand filters are very adaptable to their surroundings and tend to have a low failure rate. Sand filters require some maintenance, mainly removing trash and large debris that can clog the filter. Stormwater Best Management practices database (2001) indicated that sand filters are effective in removing from 36 to 83% of the bacteria in urban runoff.

Infiltration Trenches

An infiltration trench is an excavated trench that has been lined with filter fabric and backfilled with stone to form an underground basin. Storm water is directed into trenches through the use of grass areas or pretreatment devices. Trenches tend to be more suitable for ultra-urban situations, where the soil has low permeability. Experience suggests that if properly sited with adequate separation distance to ground water and maintained, infiltration BMPs will not result in bacteria contamination of groundwater.

Low Impact Development (LID)

LID is the integration of ecological and environmental goals and requirements into all phases of urban planning and site design from brownfields to individual residential lots to the entire watershed. LID varies from traditional stormwater practices by reducing runoff volumes as a result of attempting to recreate drainage patterns to the pre-construction state. LID practices include but are not limited to: green roofs, permeable pavers, bioretention areas, grass swales, rain gardens, and minimizing impervious areas. These practices increase runoff infiltration, storage, filtering, evaporation, and onsite detention. These examples are BMPs that can help reduce bacteria in surface water; however data is not available to determine the level of reduction that can be attributed to these practices.

Stream Fencing

Fencing livestock out of streams is a highly effective method of reducing the amount of bacteria in surface waters. A number of states have reduced bacteria contamination in impaired streams using this method. Soil and water conservation districts typically provide cost share for this practice, reducing the cost of installation.

Livestock Manure Management

Livestock manure can be a significant source of bacteria to our streams. Some studies have suggested that runoff from barnyards may have the highest potential of any agricultural operations to contaminate our streams. Runoff from manure treated fields could contain up to 25% of the bacteria applied to the field through the animal wastes. As stated above, livestock access to streams results in direct discharge of bacteria into stream. The proper collection, storage, transportation, and application of animal waste on the farm and significantly reduce bacteria loss from runoff. Some states restrict manure application during certain weather conditions. Other states, including Delaware, specify how manure must be stored, including the shape of the manure storage pile when stored outside. Long term storage (4 to 6 months) of livestock wastes can reduce bacteria numbers significantly and has been cited as the single most important BMP for livestock manures.

Pooper Scooping

Pet waste contains bacteria and parasites, as well as organic matter and nutrients, notably nitrogen and phosphorous. If not properly managed, pet wastes can contribute significant amounts of bacteria and pollutants to our waterways. Managing pet waste properly is something that everyone can do to make a difference in their respective watersheds. Individual actions result in significant water quality improvement when carried out by the majority. Unlike some forms of stormwater pollutants, pet waste can be easily and economically managed by the individual.

References

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TYPICAL BACTERIA, SUSPENDED SOLIDS, AND NUTRIENT REDUCTION FROM STORMWATER BEST MANAGEMENT PRACTICES.

BMP	Land Area Needed	Cost	Total Nitrogen % Reduction	Total Phosphorus % Reduction	Suspended Solids % Reduction	Bacteria Reduction %
Buffer Strips	Low	Medium	20 - 60	20 - 60	20 - 80	43-57
Constructed Wetlands	N/A	N/A	-103	-217	-398	78-90
Sand Filters	N/A	N/A	47	41	57	36-83
Dry Detention Pond	High	High	15	25	70	
Infiltration Trenches	Low	Medium	45 - 70	50 - 75	75 - 99	
Wet Ponds*	Medium	High	0.4	0.5	55-94	44-99
Biofiltration	N/A	N/A	25	34		>99
Bioswales	Low	Medium	25	34	70	
Storm water wetlands	N/A	N/A	30	49	N/A	78-90

*If Properly Managed

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