Christina Basin Pollution Control Strategy

November 2011

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List of Terms

BMP – Best Management Practice
CRP – Conservation Reserve Program
CSO – Combined Sewer Overflow
CSS – Combined Sewer System
DelDOT – Delaware Department of Transportation
DNREC – Delaware Department of Natural Resources and Environmental Control
DO – Dissolved Oxygen
EQIP – Environmental Quality Incentives Program
ERU – Equivalent Residential Unit
ESU – Equivalent Stormwater Unit
GAMN – General Assessment Monitoring Network
GIS – Geographic Information Systems
HOA – Homeowner Association
LID – Low Impact Development
LIP – Landowner Incentive Program
LTCP – Long-Term Control Plan
LUST – Leaking Underground Storage Tank
MGD – Million Gallons Per Day
MS4 – Municipal Separate Storm Sewer System
NCC – New Castle County
NCCD – New Castle Conservation District
NMP – Nutrient Management Plan
NPDES – National Pollutant Discharge Elimination System
NRCS – Natural Resources Conservation Service
OWTS – Onsite Wastewater Treatment System
PAH – Polycyclic Aromatic Hydrocarbons
PCBs – Polychlorinated Biphenyls
PCS – Pollution Control Strategy
RCRA – Resource Conservation and Recovery Act
SIRB – Site Investigation and Restoration Branch
TAT – Tributary Action Team
TMDL – Total Maximum Daily Loads
TN – Total Nitrogen
TP – Total Phosphorus
TSS – Total Suspended Sediment
UDC – Unified Development Code
USDA – United States Department of Agriculture
USEPA – United States Environmental Protection Agency
USGS – United States Geological Survey
UST – Underground Storage Tank
WHIP – Wildlife Habitat Incentives Program
WRA – Water Resources Agency
WRP – Wetlands Reserve Program
WRPA – Water Resource Protection Area
WWTP –Wastewater Treatment Plant

Executive Summary

The Christina Basin is a 565 square mile basin contained in the larger Delaware River Basin. The Christina Basin spans three states, Delaware, Pennsylvania, and Maryland, and includes four watersheds: Brandywine Creek, Red Clay Creek, White Clay Creek, 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. Total Maximum Daily Loads (TMDLs) are the maximum amount of a pollutant that a waterbody can assimilate and still achieve water quality standards. These TMDLs called for a reduction in nitrogen, phosphorus and bacteria loading. An implementation plan was developed by a Tributary Action Team, a diverse group of citizens and government agency personnel and presented to DNREC for promulgation to reach the prescribed TMDLs. This document, the Pollution Control Strategy (PCS), reflects those recommendations made by the Tributary Action Team for the Delaware portion of the Christina Basin based on a consensus-seeking process.

Each group of recommendations is intended to reduce the levels of nitrogen, phosphorus, and bacteria from nonpoint sources of these pollutants in the Delaware portion of the Christina Basin. For each of the 41 recommendations, the PCS details the specific recommendation, nutrient and bacteria reductions that should result from implementing the recommendation, costs associated with implementing the recommendation, potential sources of funding and partnership, and an implementation schedule. These 41 recommendations include:

Stormwater

- Increase urban tree canopy.
- Design stormwater BMPs and sediment and stormwater management plans to reduce nutrients and bacteria according to the TMDLs, where feasible and effective.
- Limit addition of new effective impervious cover watershed-wide, especially above public drinking water supply intakes.
- Promote LID in new construction and redevelopment.
- Amend stormwater ordinances to create consistency throughout the watershed.
- Implement a stormwater utility.
- Identify areas where stormwater retrofits would effectively reduce sediment and nutrients.

Open Space

- Map, inventory, and prioritize existing open space areas.
- Protect existing wooded/vegetated open space areas.
- Require management plans for community open space areas that are designed for water quality protection, including reduced nutrient loading.
- Require forested riparian buffers of adequate and proper widths sufficient to reduce or eliminate nonpoint source pollution for all new development.
- Implement stream restoration projects.
- Acquire/conserve additional open space and retain conservation easements.
- Reforest watersheds and headwaters.

Wastewater

- Install new and replacement systems that are designed to meet performance standards for onsite wastewater treatment systems (OWTS).
- Conduct inspections and pump-outs of OWTS, especially when properties are sold or otherwise transferred to other ownership prior to completion of sale.
- Eliminate cesspools and seepage pits in a systematic way.
- Eliminate OWTSs through connection to centralized wastewater treatment plants (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 sites.

Agriculture

- Implement agricultural best management practices (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 residents and business owners 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 the need to clean 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 Christina 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.
- Research nutrient reductions related to bacteria counts and BMPs.

The objective of the Christina Basin PCS is to improve water quality to meet the federal Clean Water Act goals by implementing the 41 recommendations outlined in the Strategy.

Implementing the recommendations laid out in the Christina Basin PCS is a costly endeavor and is estimated at $31.3 million dollars per year. However, residents, visitors, and businesses reap numerous water supply, ecological, recreational and other benefits from the Christina Basin. The PCS quantifies the economic value of the Christina Basin through a present value analysis. This analysis calculates the total present value of the Christina Basin as $51.4 million per year.

This Strategy is designed to reduce pollutant loadings from current and future land use practices. This combination of actions will lead to the achievement of the TMDL. The PCS for the Delaware portion of the Christina Basin will be implemented through the work of numerous organizations and individuals and will be coordinated with the ongoing pollution reduction efforts in the Pennsylvania portion of the Christina Basin.

Chapter 1: Introduction

1.1 What Is a Pollution Control Strategy?

A Pollution Control Strategy (PCS) is a set of 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. 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 PCS and the elements that have gone into developing it. The following chapters outline the key components discussed 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 Christina 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. Finally, Chapter 7 discusses how the implementation of this PCS will reach the required nutrient reductions set forth in the TMDLs.

1.2 Tributary Action Teams

The Delaware PCS process places great importance on public participation. 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.

A Tributary Action Team (TAT) holds the responsibility of making recommendations towards the creation of a 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 recommendations are finalized, the team submits the strategy to DNREC for review, incorporation into a final PCS

and, ultimately, promulgation if regulations are necessary. 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 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 recommendations. In December 2005, WRA began the process of forming a TAT for the Christina Basin PCS.

WRA identified interested stakeholders and citizens, who represent various interest groups, for participation on the Christina Basin TAT. The individuals contacted included water utilities, nonprofit organizations in the Christina 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 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. 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.

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 including stakeholders from a variety of organizations as well as residents with a personal interest in the health of the rivers and tributaries in the Christina 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 Christina 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 and 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.

After extensive discussion of all three approaches the outcome of the forum was 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 Christina Basin is critical.
- The weak economy 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 communities 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 Christina Basin involved and to care about what happens. Achieving the TMDLs set for the Christina 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

The Christina Basin is a distinctive natural resource in Delaware (Figure 2.1). The Christina Basin 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 Christina 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 Delaware population,
- Home to almost half of Delaware'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, and the
- Only basin in Delaware to encompass three states: Delaware, Pennsylvania, and Maryland.

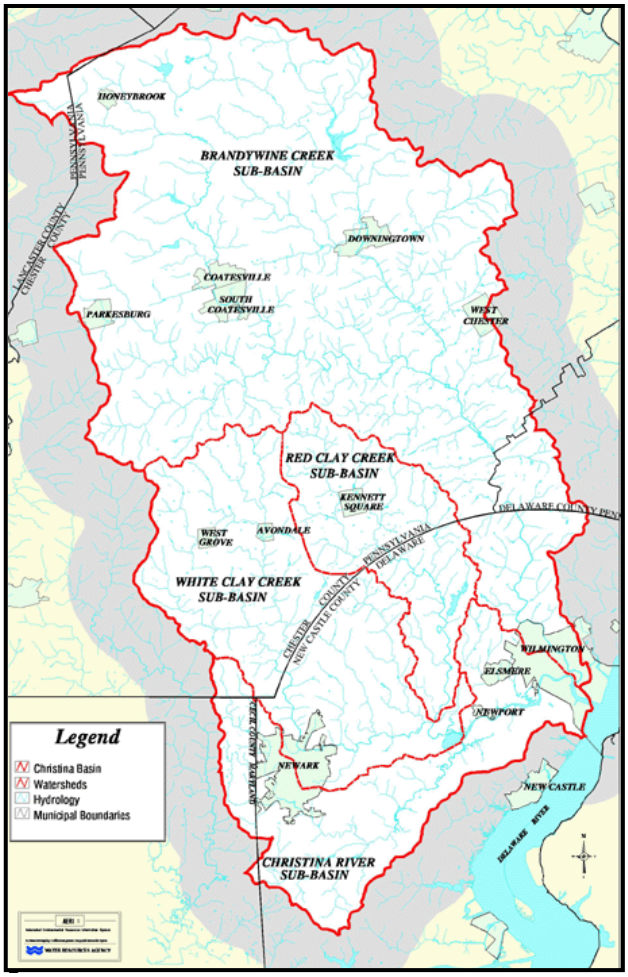


Figure 2.1 Base Map of the Christina Basin

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 Basin:

- Occupies 565 square miles – an area a little larger than the size of New Castle County.
- 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 2010 U.S. Census population data).
- Is generally divided among three land uses of similar, but changing proportions – urban/suburban, agriculture, and open space/forests.

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

Watershed	Pa. (sq. miles)	Del. (sq. miles)	Md. (sq. miles)	Total (sq. miles)
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**	**159.67**	**8.4**	**564.07**
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

2.2 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. Figure 2.2 represents the land use distribution of six broad land use categories—developed, open land, agricultural uses, forest land, water, and wetlands—in the Delaware portion of the Christina Basin for the years 1992 and 2007.

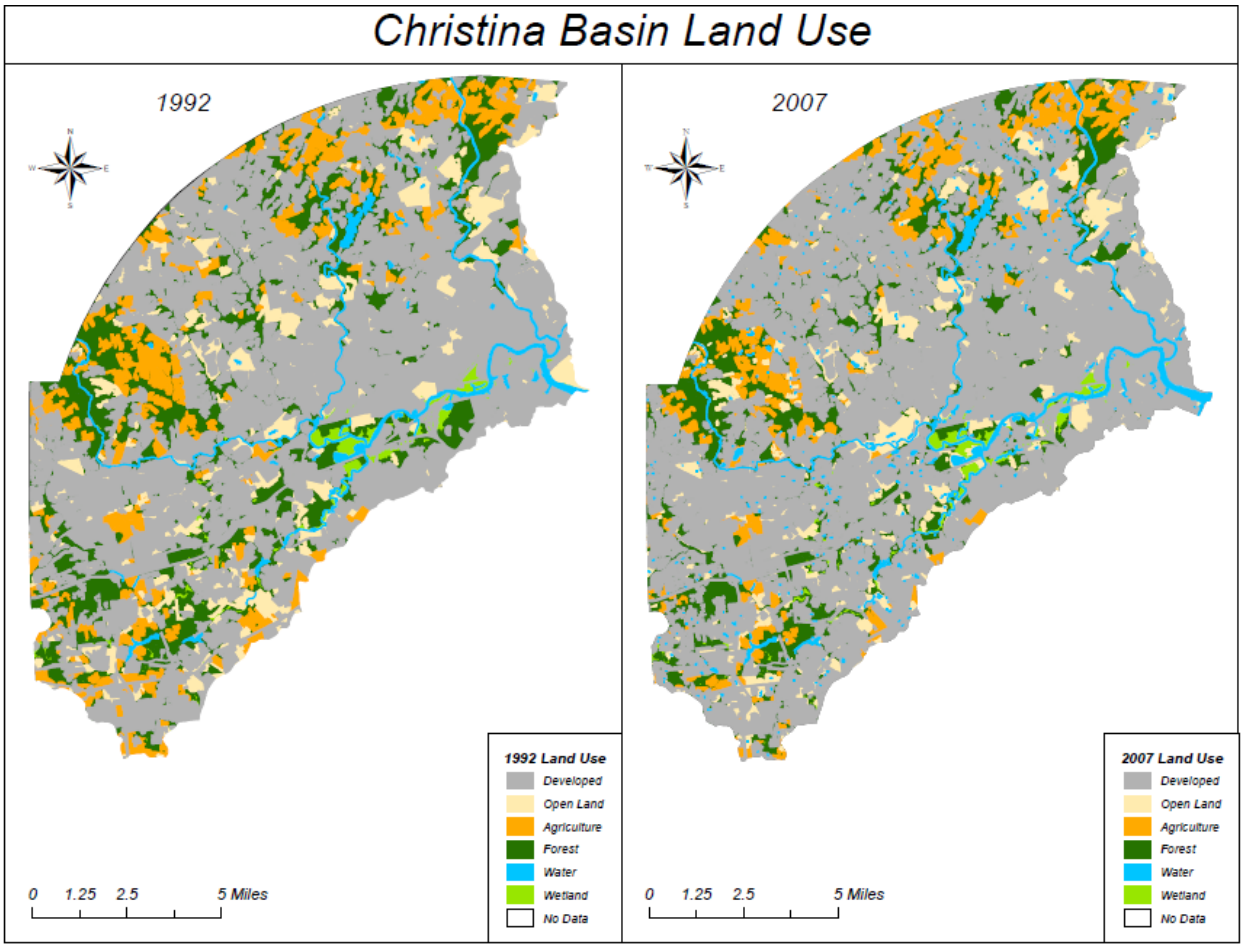


Figure 2.2 Land Use Changes in the Delaware Portion of the Christina Basin (1992 and 2007)

The portion of the Christina Basin that falls within Delaware is characterized by a relatively high percentage of built land uses. Figure 2.2 shows the relative proportions of land uses within the Delaware portion of the Christina Basin, for the years 1992 and 2007. In 1992, nearly 53 percent of the land area was developed, and by 2007 this figure rose to almost 59 percent. During the same period, forest cover declined , from nearly 24 percent to approximately 21 percent and agriculture declined from 10% to 8% of the Delaware portion of the Christina Basin.

The Four Watersheds of the Christina Basin

The land use in the four watersheds (Brandywine Creek, Red Clay Creek, White Clay Creek, and Christina River) in the Delaware portion of the Christina Basin have exhibited distinct patterns of land use change in the period from 1992 to 2007. Since these areas have been highly developed for many years, the amount of development has stayed fairly stable, although the Christina and White Clay Creek watersheds have had increases of developed areas of 16.5% and 15% respectively. Agricultural areas in the Christina and White Clay Creek watersheds have also had extreme reductions of almost 50% and 24% from 1992 to 2007. The Brandywine Creek watershed has had almost 10% loss of agricultural land and 12% loss of forest and open spaces with an almost 7% increase in developed land. The Red Clay Creek watershed has also had

smaller changes with a negligible change in agricultural lands, a 9% loss in forest land and an 11% increase in open space.

Table 2.2 Summary of Land Use Areas and Changes for 1992 and 2007 in the subwatersheds of the Delaware Portion of the Christina Basin (area figures are in acres)

	Developed	**Open Land**	**Agriculture**	**Forest**	**Wetland**	**Water**
Brandywine Creek (Del. Portion), 1992	6,947	1,906	1,958	3,549	44	266
Brandywine Creek (Del. Portion), 2007	7,422	1,795	1,771	3,323	48	326
Net Change	475	-111	-187	-226	4	60
% Change	6.8%	-5.8%	-9.6%	-6.4%	9.0%	22.6%
White Clay Creek (Del. Portion), 1992	14,474	2,397	3,496	8,040	439	196
White Clay Creek (Del. Portion), 2007	16,697	2,111	2,644	6,912	483	335
Net Change	2,223	-286	-852	-1,128	44	139
% Change	15.4%	-11.9%	-24.4%	-14.0%	10.0%	70.9%
Red Clay Creek (Del. Portion), 1992	7,322	715	1,617	3,551	53	264
Red Clay Creek (Del. Portion), 2007	7,568	795	1,610	3,227	58	313
Net Change	246	80	-7	-324	5	49
% Change	3.4%	11.2%	-0.4%	-9.1%	9.4%	18.6%
Christina River (DE Portion), 1992	23,673	3,444	3,239	9,000	2,296	817
Christina River (DE Portion), 2007	27,575	2,914	1,632	7,221	2,303	1,045
Net Change	3,902	-530	-1,607	-1,779	7	228
% Change	16.5%	-15.4%	-49.6%	-19.8%	0.3%	27.9%

2.3 Population

Between 2000 and 2010, the population within the Christina Basin grew from 549,000 to 591,000 (Table 2.6), an increase of 42,000, or greater than the combined populations of Newark, Del., and West Chester, Pa. Every year, 4,200 people (12 people per day) move to this pastoral Christina Basin to live near job centers in Philadelphia, Baltimore, Wilmington, Newark, and the Exton corridor near the Pennsylvania Turnpike. Over the past 10 years, nearly 11,000 people have moved to the Delaware, 31,000 to the Pennsylvania, and 430 to the Maryland portions of the Christina Basin, respectively.

The Brandywine Creek is the most populous watershed, with 247,000 people or 42 percent of the Christina Basin population, followed by the Christina River (174,000), White Clay Creek (124,000), and Red Clay Creek (47,000) with 29 percent, 21 percent, and 8 percent of the population, respectively. More than 335,000 people (57%) live in the Delaware portion of the Christina Basin, 254,000 (43%) in the Pennsylvania portion, and 2,500 in the Maryland portion. The Christina Basin is home to over 40 percent of Delaware's population, and its streams and wells supply drinking water to more than 70 percent of the people in Delaware.

In Delaware, high population densities are concentrated in the I-95 transportation corridor between Wilmington and Newark at the downstream points of the four watersheds. These highly populated areas in Delaware account for higher water demands, wastewater loads, urban/suburban pollution loads, and incidences of floodplain damage. In Pennsylvania, high population densities occur along U.S. Route 1, U.S. Route 202, and U.S. Route 30 corridors, which connect the towns and boroughs of West Grove, Avondale, Kennett Square, West Chester, Downingtown, Exton, and Coatesville. In the rural areas outside of these town centers, population densities are low.

By 2010, the population density of the Christina Basin edged over 1,000 people per square mile, a threshold that the U.S. Census Bureau defines as an "urban area." The urbanized Christina River watershed lies in the Wilmington–Newark I-95 corridor and by far has the highest 2010 population density (2,230 people/sq. mi.) followed by the White Clay Creek (1,150 people/sq. mi.), Red Clay Creek (870 people/sq. mi.), and Brandywine Creek (760 people/sq. mi.). At a per capita rate of 100 gallons per day, the increased population has resulted in an added water demand and wastewater flow of 4.2 million gallons per day since 1995.

Table 2.3 Christina Basin population change, 2000-2010

Watershed	Area (sq. mi.)	2000 pop.	2010 pop.	Change	2000 (p/sq. mi.)	2010 (p/sq. mi.)
Brandywine Creek	326	221,413	246,702	25,289	679	757
Christina River	78	166,435	174,196	7,761	2,134	2,233
Red Clay Creek	54	42,630	46,893	4,263	789	868
White Clay Creek	107	118,579	123,506	4,927	1,109	1,155
Christina Basin	564	549,057	591,297	42,240	972	1,047

Source: U. S. Census

2.4 Geology

The Christina Basin in Delaware is perched along the fall line, which runs along the Atlantic seaboard from Maine to Alabama (U.S. Army Corps of Engineers, 2002). The fall line stretches 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.

2.5 Water Supply

The streams and wells of the Christina Basin 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 provide water storage for some of the reservoirs in the area including:

- Hoopes Reservoir (2,000 mg, Del.)
- Smalley's Pond (40 mg, Del.)
- Newark Reservoir (318 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.)

2.6 Recreational Resources

The streams of the Christina Basin 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.

2.7 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 Creek (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.

2.8 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.

2.9 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 Christina 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.
- *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.

2.10 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 Christina Basin. This watershed stewardship is performed through groups including the:

- Brandywine Conservancy (*www.brandywineconservancy.org*)
- Brandywine Valley Association (*www.bva-rcva.org*)
- Christina Conservancy
- Delaware Nature Society (*www.delawarenaturesociety.org*)
- Red Clay Valley Association (*www.bva-rcva.org*)
- Stroud White Clay Creek Laboratory (*www.stroudcenter.org*)
- White Clay Watershed Association (*www.ccil.org/-wcwa/index.html*)
- 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 could cause low dissolved oxygen (DO) levels.
2) *Bacteria* (pathogens): Concentrations along 134.2 miles of stream frequently exceed the primary recreation standards for swimming of 100 colonies per 100 milliliters.
3) *Sediment*: The streams are degraded by high sediment loads that range between 311 and 975 pounds per acre annually, depending on the subwatershed.
4) *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).
5) *Contaminated Waste Sites:* Contaminated waste sites are situated throughout the watershed.
6) *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 3.2 through 3.8 discuss some of these water quality problems in detail.

3.2 Nutrient Trends

The University of Delaware's WRA has summarized the water quality trends in the Christina Basin in the following sections to determine how well the rivers and streams are meeting their applicable water quality criteria.

Nitrogen

Nitrogen levels in the Brandywine Creek, Red Clay Creek, White Clay Creek, and Christina River are discussed in more detail below. The type of nitrogen that is shown in these trends is inorganic nitrogen, which is made up of ammonia, nitrate and nitrite. There is no official water quality standard for inorganic nitrogen but it is a good indicator of the water quality in the area.

Brandywine Creek

The inorganic nitrogen levels in the Brandywine Creek display are slightly increasing. Figure 3.1 shows the median inorganic nitrogen levels in the Brandywine Creek from 1995–2009.

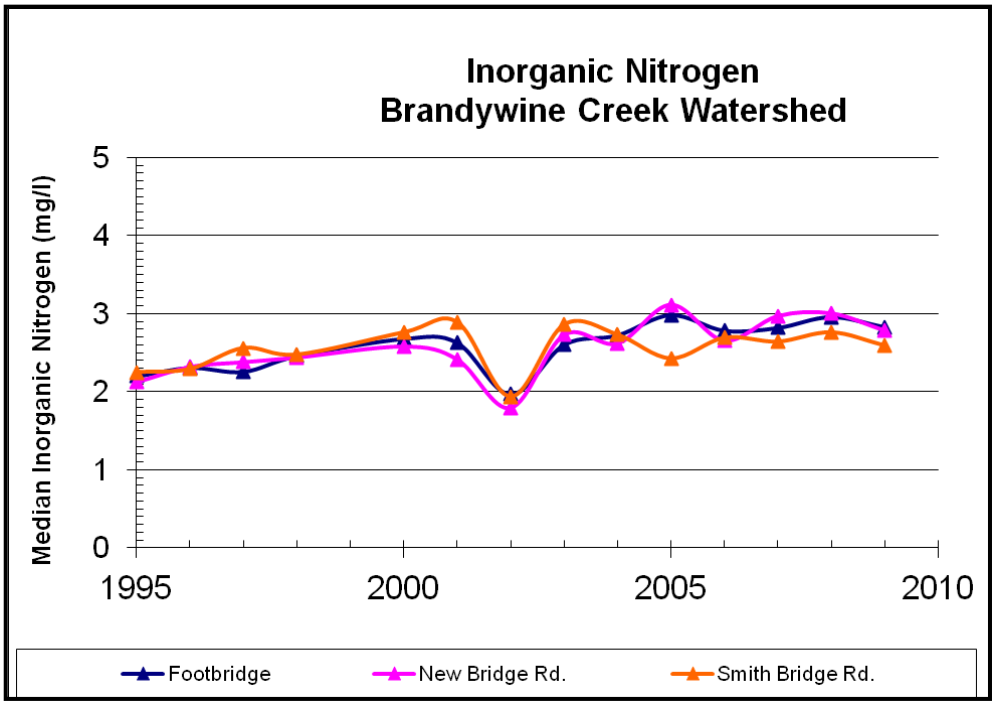


Figure 3.1 Median Inorganic Nitrogen in the Brandywine Creek Watershed

Red Clay Creek

The inorganic nitrogen levels in the Red Clay Creek have been increasing with streams near Ashland being the most degraded, with levels consistently above 3 mg/l. Figure 3.2 shows the median inorganic nitrogen levels in the Red Clay Creek from 1995–2009.

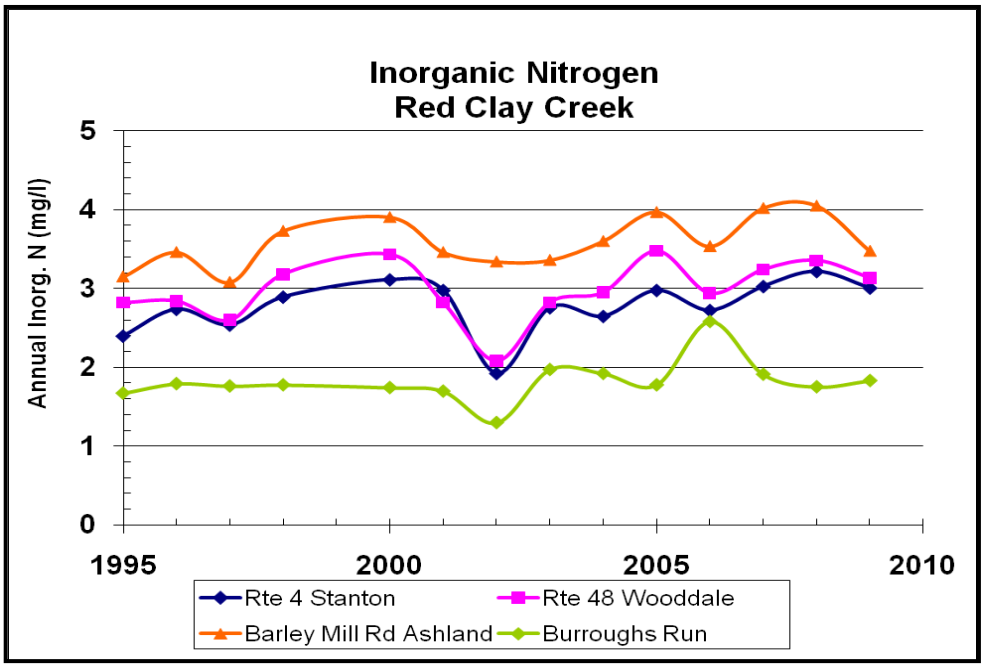


Figure 3.2 Median Inorganic Nitrogen in the Red Clay Watershed

White Clay Creek

The inorganic nitrogen levels in the White Clay Creek exhibit an increasing trend. The tributary along Chambers Rock Road has the highest levels, well above the 3 mg/l level. Figure 3.3 shows the median inorganic nitrogen levels in the White Clay Creek from 1995–2009.

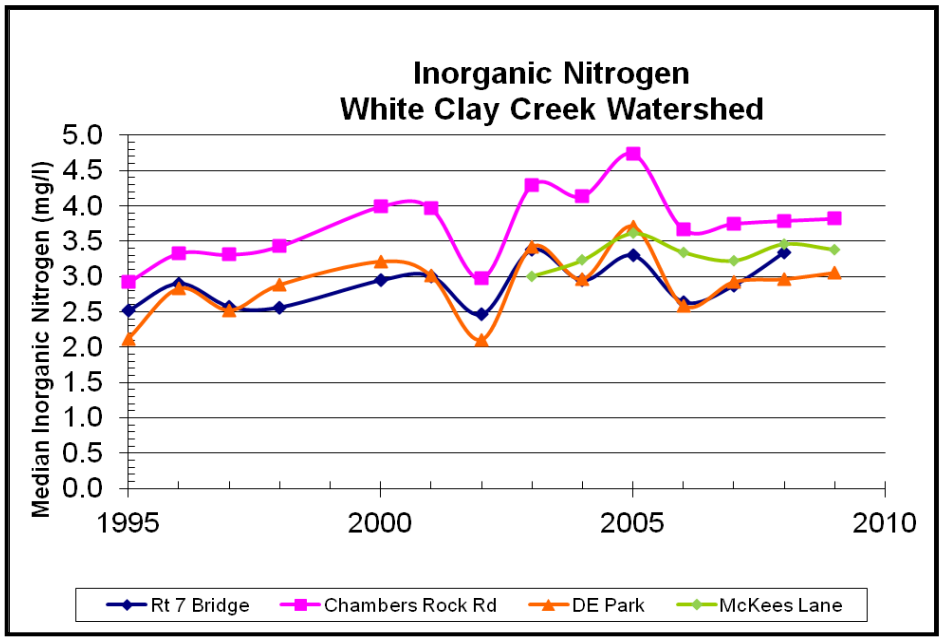


Figure 3.3 Median Inorganic Nitrogen in the White Clay Creek Watershed

Christina River

Current levels of nitrogen in the Christina are very close to where they were in 1995 with the greatest changes in tributaries on Rt. 141 in Newport and along Nottingham Road, which show increasing trends. Figure 3.4 shows the median inorganic nitrogen levels in the Christina River from 1995–2009.

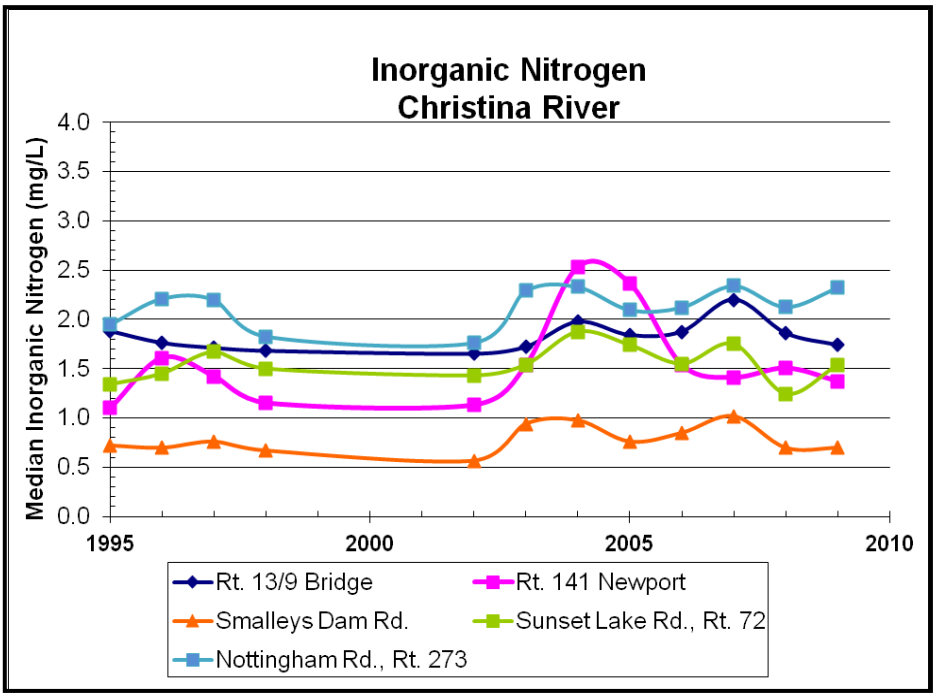


Figure 3.4 Median Inorganic Nitrogen in the Christina River Watershed

Phosphorus

Phosphorus levels in the Brandywine Creek, Red Clay Creek, White Clay Creek, and Christina River are discussed in more detail below. The type of phosphorus that is shown in these trends is orthophosphate, which is the inorganic part of phosphorus. There is no official water quality standard for orthophosphate but it is a good indicator of water quality in the area.

Brandywine Creek

The orthophosphate levels in the Brandywine Creek are relatively high, but have exhibited a downward trend throughout the last 15 years. After the levels peaked in 2002, these values then decreased, especially at the Smith Bridge Road tributary. Figure 3.5 shows the median orthophosphate levels in the Brandywine Creek from 1995–2009.

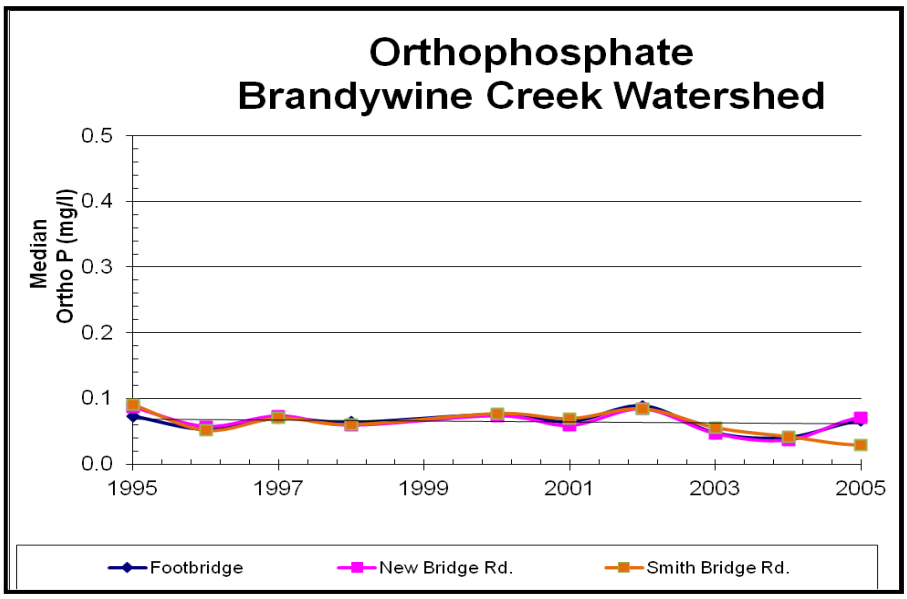


Figure 3.5 Median Orthophosphate in the Brandywine Creek Watershed

Red Clay Creek

There is a downward trend for the orthophosphate levels in the Red Clay Creek. Following high levels in 1997 and 2000, orthophosphate levels have steadily gone down since. Figure 3.6 shows the median orthophosphate levels in the Red Clay Creek from 1995–2009.

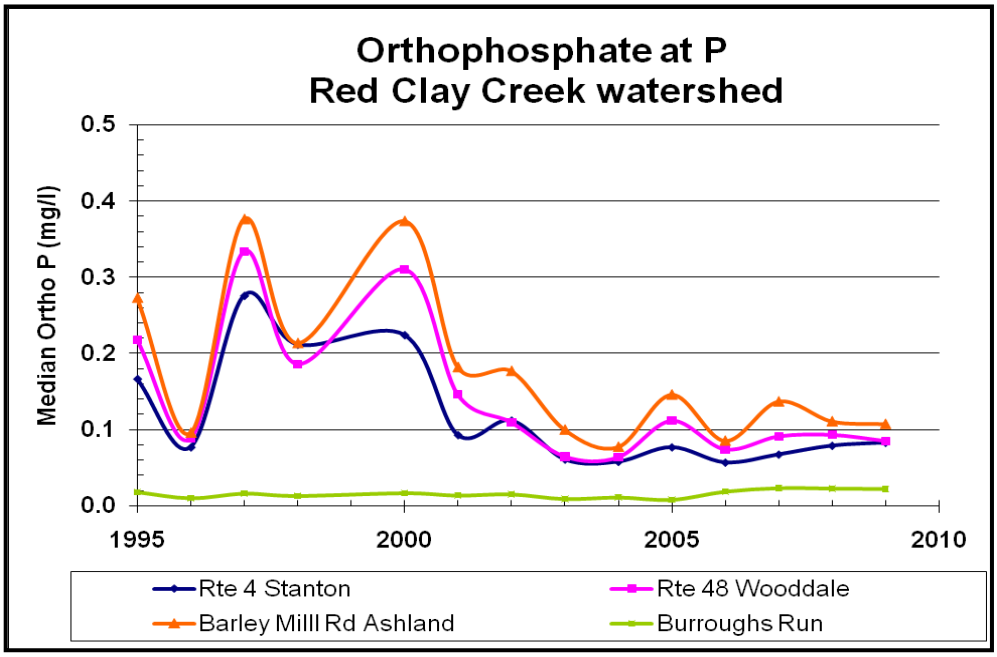


Figure 3.6 Median Orthophosphate in the Red Clay Creek

White Clay Creek

The orthophosphate levels in the White Clay Creek have slightly decreased in the past 15 years. Figure 3.7 shows the median orthophosphate levels in the White Clay Creek from 1995–2009.

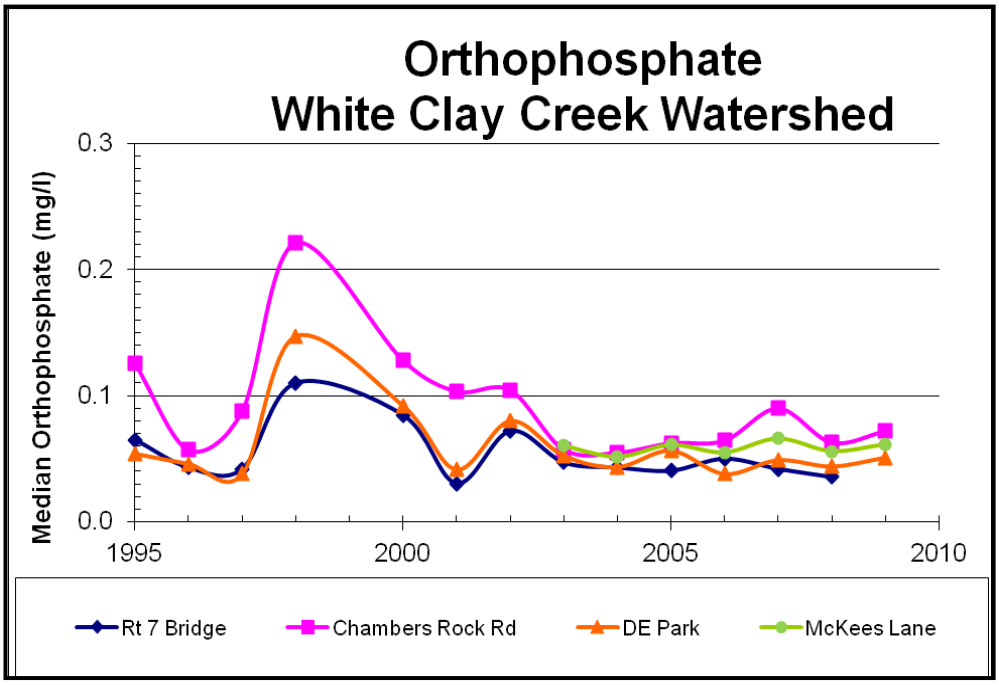


Figure 3.7 Median Orthophosphate in White Clay Creek Watershed

Christina River

The orthophosphate levels in the Christina River have remained low throughout the past 15 years. Figure 3.8 shows the median orthophosphate levels in the Christina River from 1995–2009.

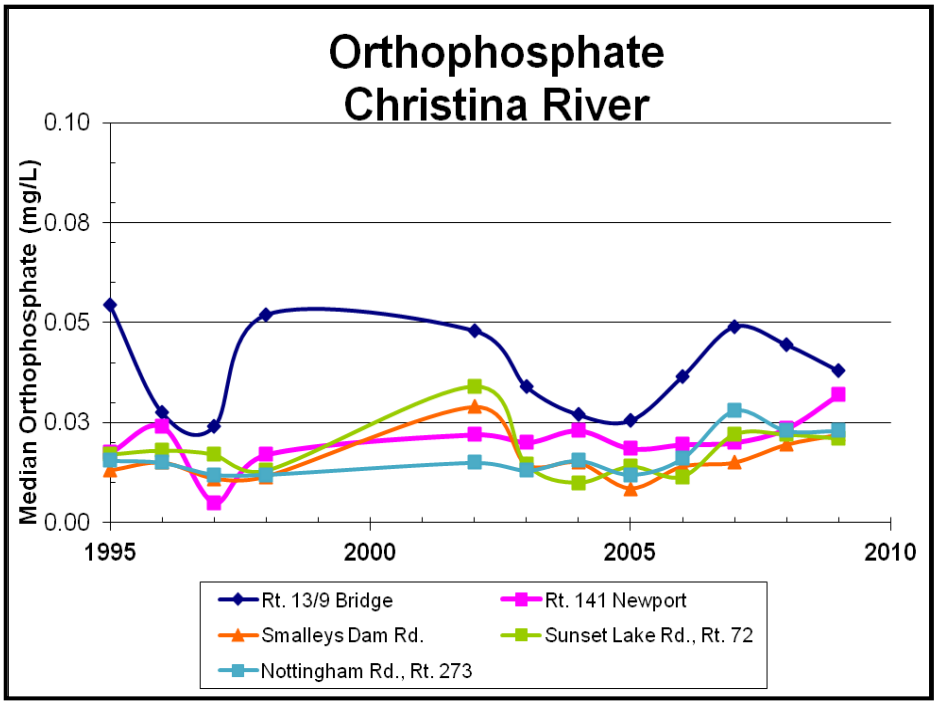


Figure 3.8 Median Orthophosphate in the Christina River

3.3 Dissolved Oxygen Trends

The Delaware portion of the Christina Basin has TMDLs (discussed in detail in Section 3.9) 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 fish kills and oxygen starved hypoxic or "dead" zones.

Delaware's water quality standards for DO is 5 mg/L for marine waters and 5.5 mg/L for fresh waters (as daily average) and 4.0 mg/L minimum 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 Creek, Red Clay Creek, White Clay Creek, and Christina River are discussed in more detail below.

Brandywine Creek

The DO levels in the Brandywine Creek increased since 1995. The 5-year median levels and all individual samples were above the Delaware DO stream water quality standard of 5.5 mg/L. Figure 3.9 shows the median DO levels in the Brandywine Creek from 1995–2009.

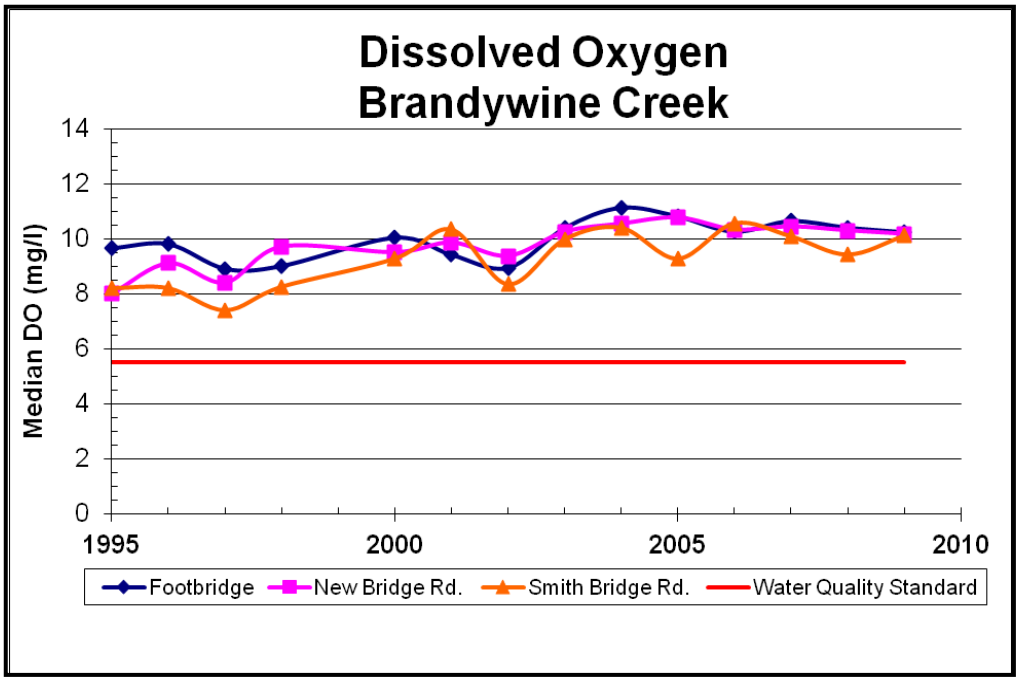


Figure 3.9 Dissolved Oxygen in Brandywine Creek Watershed

Red Clay Creek

Throughout the past fifteen years the DO levels in the Red Clay Creek have been increasing. Figure 3.10 shows the median DO levels in the Red Clay Creek from 1995–2009.

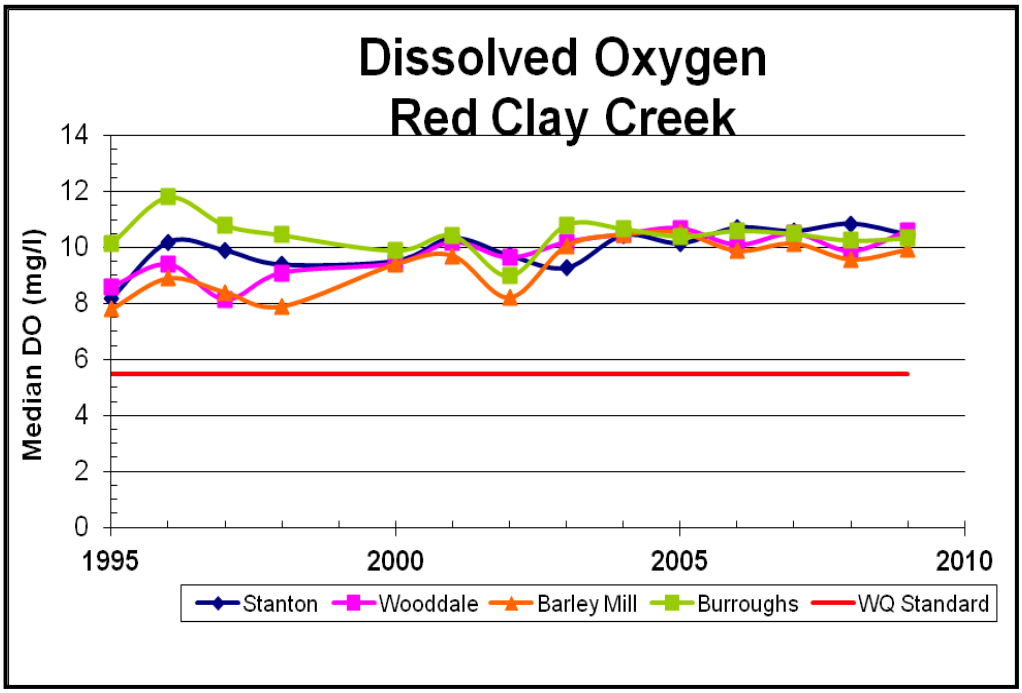


Figure 3.10 Dissolved Oxygen in Red Clay Creek

White Clay Creek

Throughout the past fifteen years the DO levels in the White Clay Creek have been increasing with the exception of the McKees Lane tributary which has slightly decreased. Figure 3.11 shows the median DO levels in the White Clay Creek from 1995–2009.

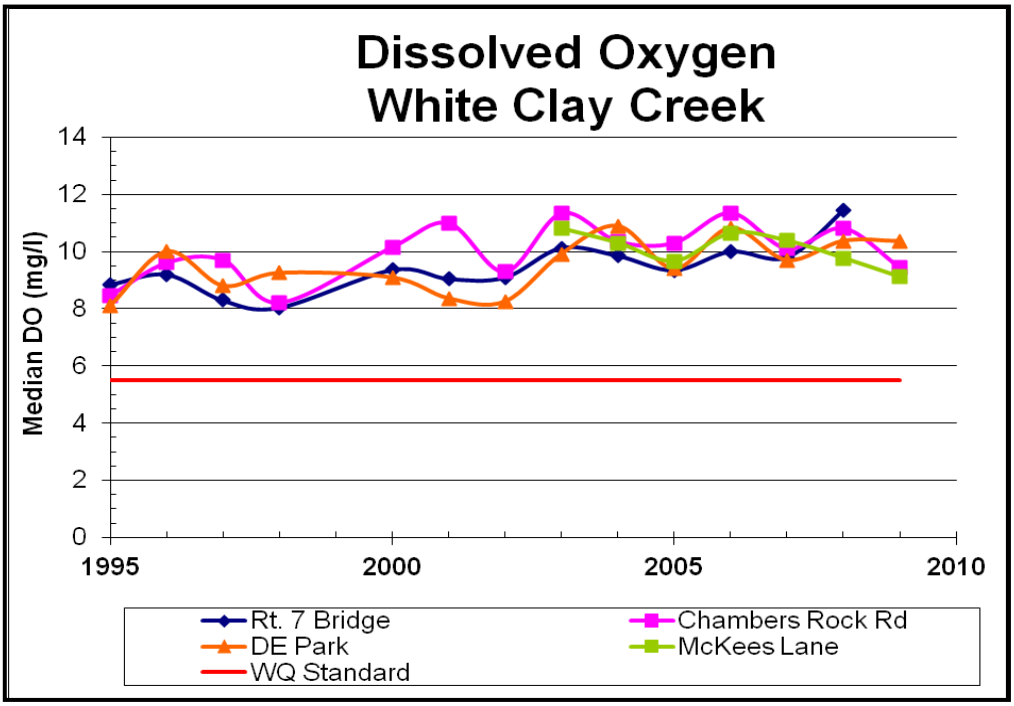


Figure 3.11 Median Dissolved Oxygen in White Clay Creek Watershed

Christina River

Throughout the past fifteen years the DO levels in the Christina River have been increasing with the exception of the Smalleys Dam Road tributary which has slightly decreased. Figure 3.12 shows the median DO levels in the White Clay Creek from 1995–2009.

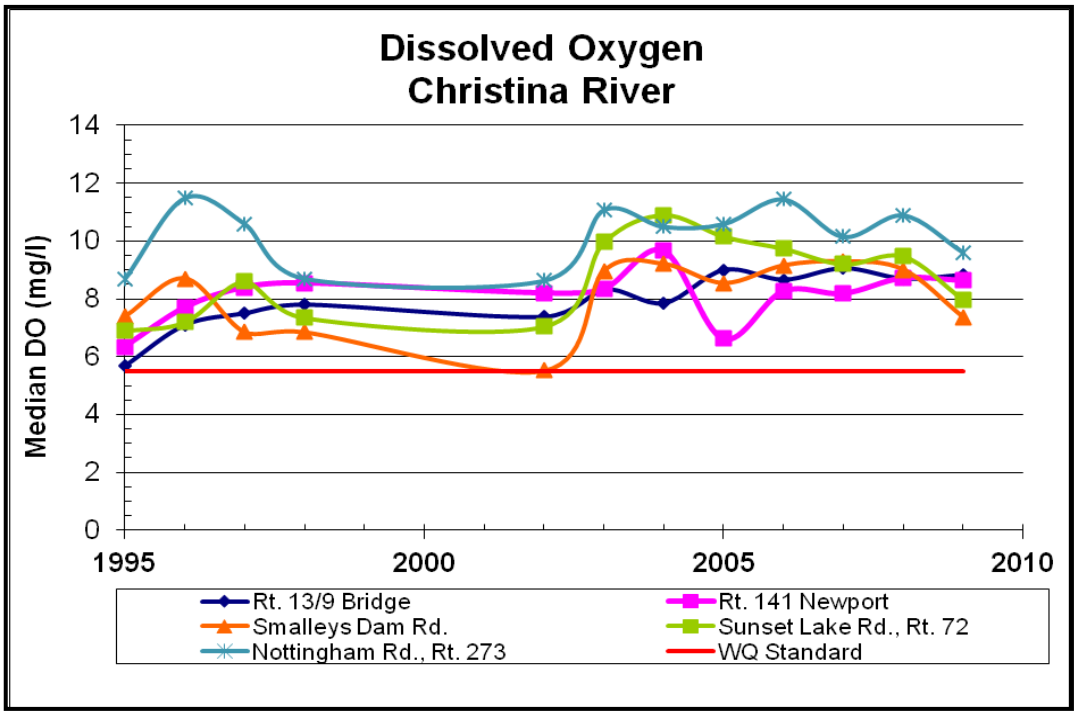


Figure 3.12 Median DO in the Christina River

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 geometric mean enterococcus bacteria levels in the Brandywine Creek, Red Clay Creek, White Clay Creek, and Christina River are discussed in more detail below.

Brandywine Creek

The enterococcus bacteria levels in the Brandywine Creek show no apparent trend. The levels continue to fluctuate. Figure 3.13 shows the geometric mean enterococcus bacteria levels in the Brandywine Creek from 1999–2010.

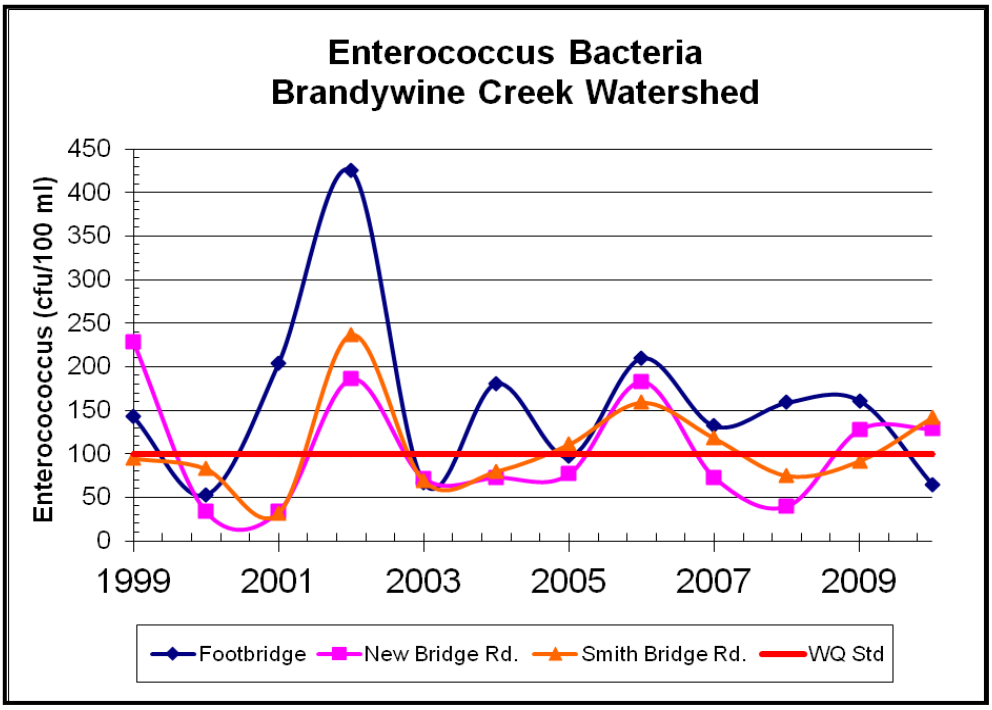


Figure 3.13 Geometric Mean Bacteria in the Brandywine Creek

Red Clay Creek

The levels of enterococcus bacteria in the Red Clay Creek have fluctuating levels with a mostly decreasing trend across stations. Figure 3.14 shows the geometric mean enterococcus bacteria levels in the Red Clay Creek from 1999–2010.

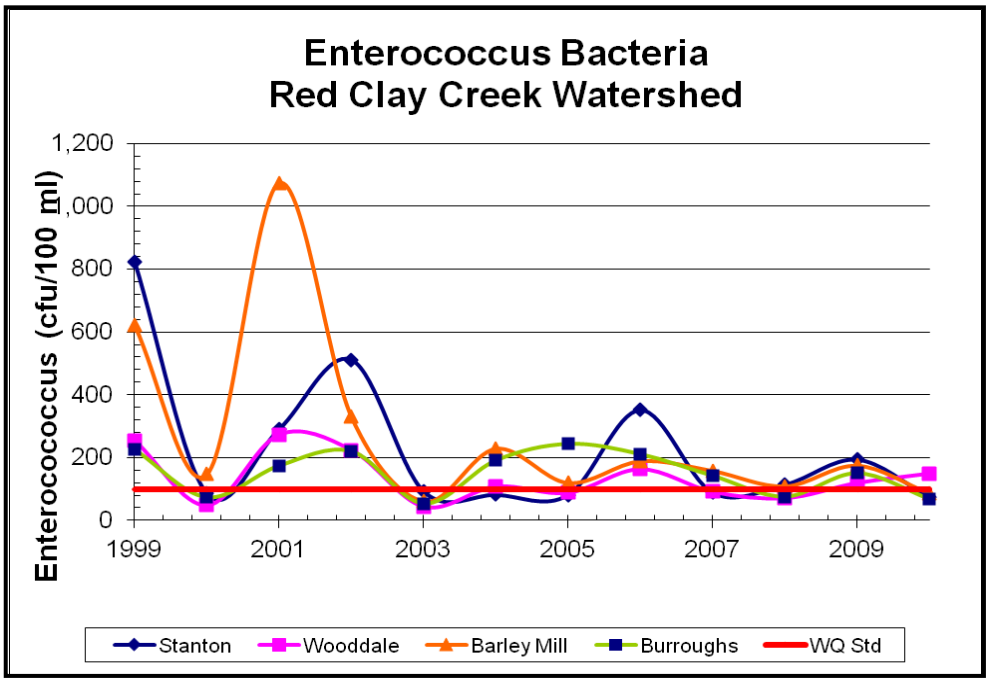


Figure 3.14 Geometric Mean Bacteria in the Red Clay Creek Watershed

White Clay Creek

The levels of enterococcus bacteria in the White Clay Creek have fluctuating levels with a mostly decreasing trend across stations. Figure 3.15 shows the geometric mean enterococcus bacteria levels in the White Clay Creek from 1999–2010.

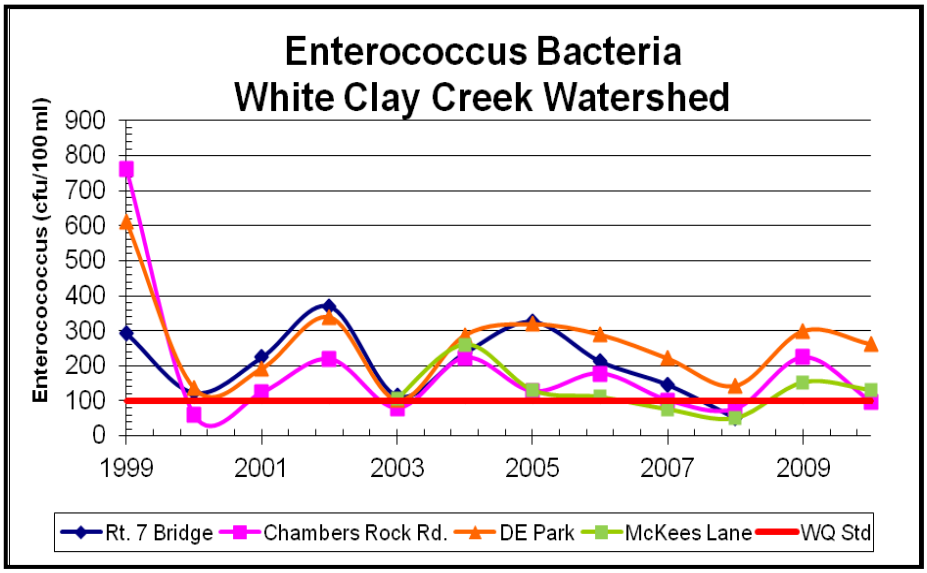


Figure 3.15 Geometric Mean Bacteria in the White Clay Creek

Christina River

The levels of enterococcus bacteria in the Christina River have fluctuating levels with a mostly decreasing trend across stations. Figure 3.16 shows the geometric mean enterococcus bacteria levels in the Christina River from 1999–2010.

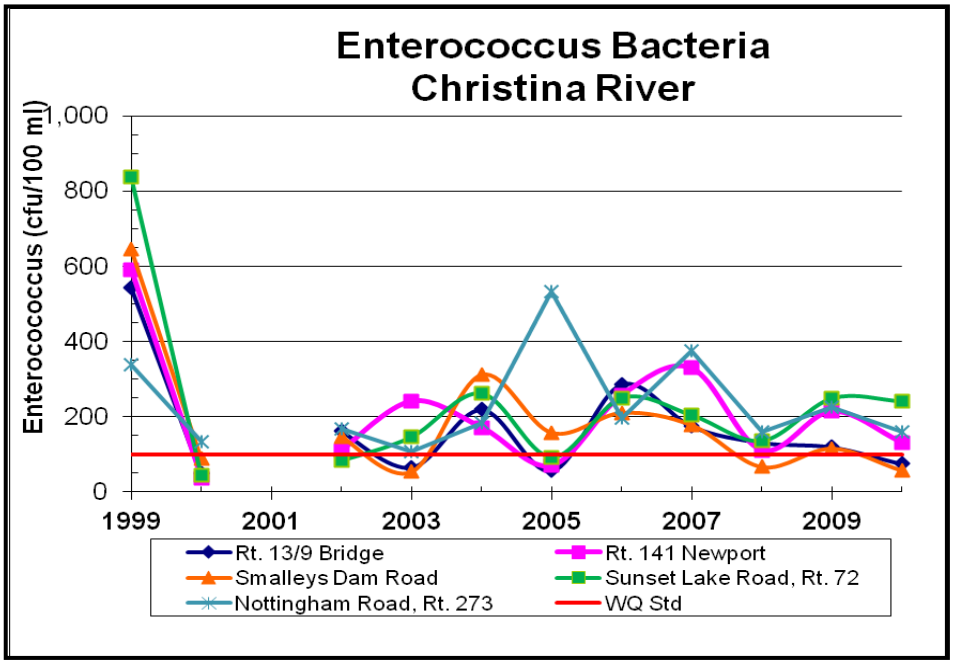


Figure 3.16 Geometric Mean Enterococcus Bacteria in the Christina River Watershed

3.5 Total Suspended Sediment

Total suspended sediment (or total suspended solids) (TSS) is suspended matter in the water column. Excess suspended 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.

In Delaware, median levels and all but a few individual samples are below a sediment stream water quality value of 40 mg/L. 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 Conservation Districts in Pennsylvania and Delaware. TSS levels in the Brandywine Creek, Red Clay Creek, White Clay Creek, and the Christina River are discussed in more detail below.

Brandywine Creek

The trend for TSS in the Brandywine Creek is fairly constant with peaks in 2002 and 2004. Figure 3.17 shows the median TSS levels in the Brandywine Creek from 1995–2009.

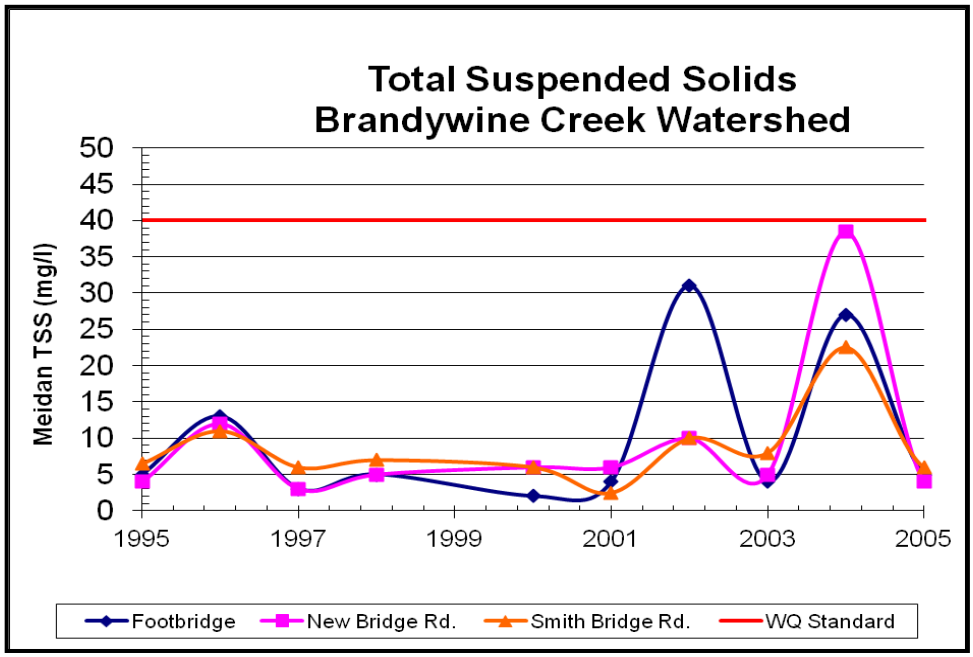


Figure 3.17 Median TSS in the Brandywine Creek

Red Clay Creek

The trend for TSS in the Red Clay Creek is slightly decreasing over the past 15 years. Figure 3.18 shows the median TSS levels in the Red Clay Creek from 1995–2009.

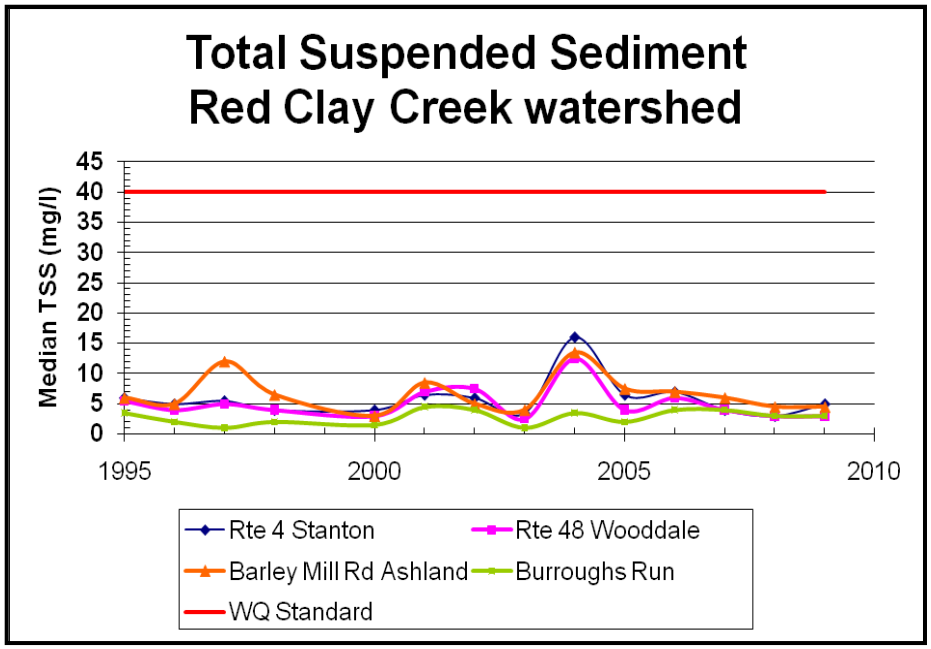


Figure 3.18 Median TSS in Red Clay Creek

White Clay Creek

Levels of suspended solids in the White Clay Creek have fluctuated over the last 15 years. Tributaries at Rt. 7 and Delaware Park have increased overall while the tributary at Chambers Rock Road has decreased. Figure 3.19 shows the median TSS levels in the White Clay Creek from 1995–2009.

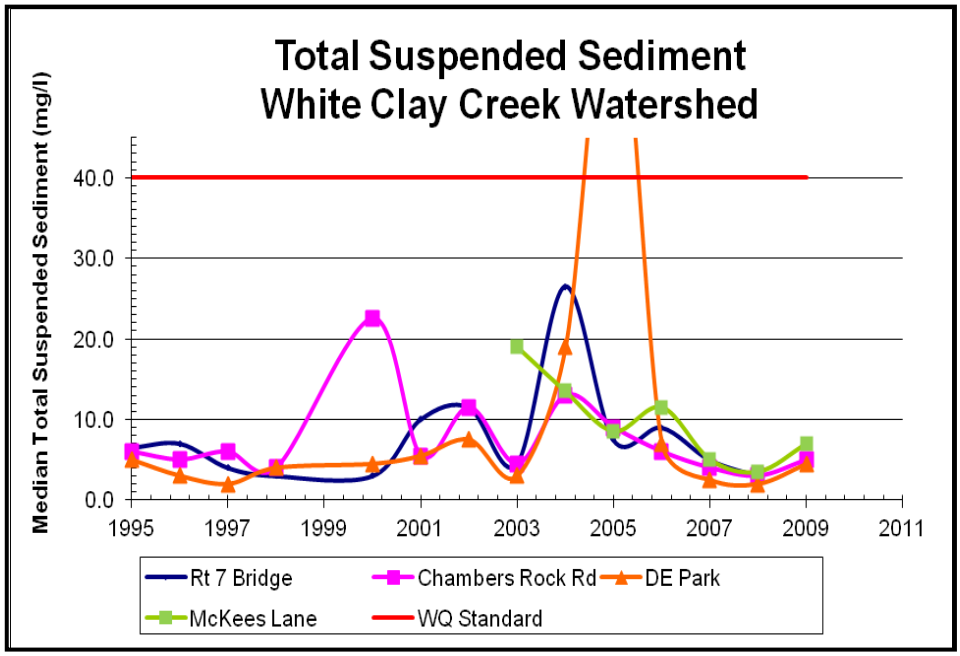


Figure 3.19 Median TSS in the White Clay Creek

Christina River

All stations on the Christina River have experienced an overall decrease in TSS over the last 15 years. Figure 3.20 shows the median TSS levels in the Christina River from 1995–2009.

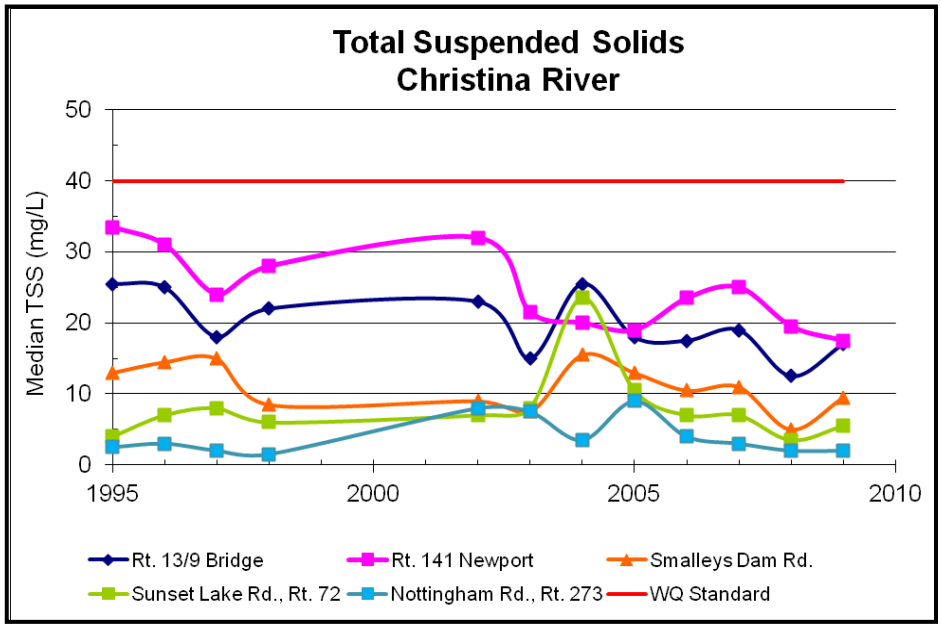


Figure 3.20 Median TSS in the Christina River

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 because the Piedmont streams with habitat that can 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 Creek (0.6 mi.)
- Wilson Run, tributary to Brandywine Creek (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 Creek, Red Clay Creek, White Clay Creek, 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 alternative fish passageways then anadromous fish can freely migrate up the rivers of the Christina Basin.

In 2003, the Brandywine Conservancy in Chadds Ford, Pennsylvania, received a grant from the National Fish and Wildlife Foundation, led by support from the National Oceanic and Atmospheric Administration, to improve fish passage at the low head dams along the Brandywine Creek through and above Wilmington, Delaware. Today, the Brandywine Conservancy continues to work with DNREC and the dam owners to develop site-specific concept and design plans to provide fish passage in the Brandywine Creek. In 2009, WRA received funding from the National Fish and Wildlife Foundation to conduct a feasibility study of the dams in the Delaware portion of the White Clay Creek. This study, completed in June 2010, found six obstacles to fish passage with Dam No. 1 (Delaware Park dam) being the first impediment to fish passage. In 2010, WRA received additional funding from the FishAmerica Foundation to design the removal of Dam No.1 in the White Clay Creek watershed. WRA continues to work with project partners to restore American shad and anadromous fish passage to the National Wild and Scenic White Clay Creek. Table 3.1 lists the dams serving as impediments to fish passage along streams in the Christina Basin.

Table 3.1 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 (No. 1)	3
	40,200	Red Mill (No. 2)	3
	50,000	Karpinski Park (No. 3)	4
	53,300	Paper Mill (No. 4)	6
	58,400	Newark Intake (No. 5)	10
	61,300	Creek Road (No. 6)	0
	67,000	Deerfield (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

Macroinvertebrates are organisms without backbones that are large enough to be seen with the naked eye and associated with freshwater systems. 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 (Dichloro-Diphenyl-Trichloroethane) by the USEPA in 1972 are thought to have improved the macroinvertebrate health of the streams. Table 3.2 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 3.2 Macroinvertebrate Survey Results in the Christina Basin

Assessment	Rating (Percent of Biotic Condition Index)	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 (as of August 2011) that are potential threats to water quality. This contaminated substance site data for the Delaware portion of the Christina Basin was downloaded from DNREC's Delaware Environmental Navigator. The contaminated substance sites in the Delaware portion of the Christina Basin that are discussed in this section include: hazardous waste generators, site investigation and remediation section sites (SIRS), salvage yards, above ground storage tanks, landfills, leaking underground storage tanks (LUST) and underground storage tanks (UST). 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 3.3 there are 2,294 contaminated substance sites in Delaware with the potential to negatively impact public drinking water supplies and the water quality in the Brandywine Creek, Red Clay Creek, White Clay Creek, and Christina River in Delaware.

Table 3.3 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	
Hazardous Waste Generator	181	51	0	79	**311**
SIRS	266	46	11	76	**399**
Salvage Yards	13	0	0	1	**14**
Above Ground Storage Tanks	39	6	0	21	**66**
Landfills	0	0	0	1	**1**
UST and LUST	578	120	0	367	**1,065**
TOTAL Contaminated Substance Sites per Watershed	**972**	**197**	**0**	**540**	**2,294**

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 as of 2011 are shown in Table 3.4.

Table 3.4 Christina Basin Fish Consumption Advisories

Waterbody	Species	Geographical Extent	Contaminants of Concern	Advice (One Meal = 8 oz. adult and a 3 oz. child)
Tidal Brandywine River	All Finfish	River Mouth to Baynard Blvd.	PCBs	None
Non-tidal Brandywine River	All Finfish	Baynard Blvd. to Pennsylvania Line	PCBs, Dioxin	No more than 6 meals per year
Tidal Christina River	All Finfish	River Mouth to Smalley's Dam	PCBs, Dieldrin	None
Non-tidal Christina River	All Finfish	Smalley's Dam to Del./Md. Line	PCBs, Dieldrin, Chlordane	No more than six meals per year
Tidal White Clay Creek	All Finfish	River Mouth to Route 4	PCBs	None
Non-tidal White Clay Creek	All Finfish	Route 4 to Del./Pa. Line	PCBs	No more than one meal per month
Red Clay Creek	All Finfish	State Line to Stanton	PCBs, Dioxin, Chlorinated Pesticides	No more than six meals per year
Little Mill Creek	All Finfish	Creek Mouth to Kirkwood Highway	PCBs	None
Christina Creek	Stocked Trout	Rittenhouse Park to Del./Md. Line	PCBs, Dieldrin	No more than six meals per year
Designated Trout Streams and Ponds other than Christina Creek	Stocked Trout	Designated Trout Stocking Areas are listed in the Delaware 2009 Fishing Guide and at *http://www.fw.delaware.gov/Fisheries/Documents/2009fishingguidewebfinal.pdf*	PCBs	No more than one 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's water quality standards. The low flow (point source) Total Maximum Daily Loads (TMDLs) were issued by the U.S. Environmental Protection Agency (USEPA) in October 2002. EPA completed the high flow (stormwater) TMDLs in April 2005 and issued a revised version in September 2006 alongside bacteria and sediment TMDLs. Appendix A contains the TMDLs for 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:

$$TMDL = WLA + LA + MS$$

WLA is the waste load allocation from point sources such as wastewater treatment plants, LA is the load allocation from nonpoint sources such as stormwater and agricultural runoff, and MS is the margin of safety to account for imprecision in modeling and monitoring. Delaware identified over twenty stream segments on its 2010 Section 303(d) list that do not meet water quality standards for nutrients (nitrogen and phosphorus), bacteria, and DO within the Christina Basin.

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 3.5 lists the designated uses of the streams in the Delaware portion of the Christina Basin as taken 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 Christina 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 Christina Basin are relatively free of excess nitrogen, phosphorus, and bacteria and simply need to be protected in their current state. Figure 3.21 shows the subwatersheds that were used to determine the TMDLs for the Christina Basin. Figures 3.22–3.25 graphically represent the pollution reductions as mandated by the USEPA for the Brandywine Creek, Red Clay, and White Clay Creeks, and the Christina River.

Table 3.5 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.

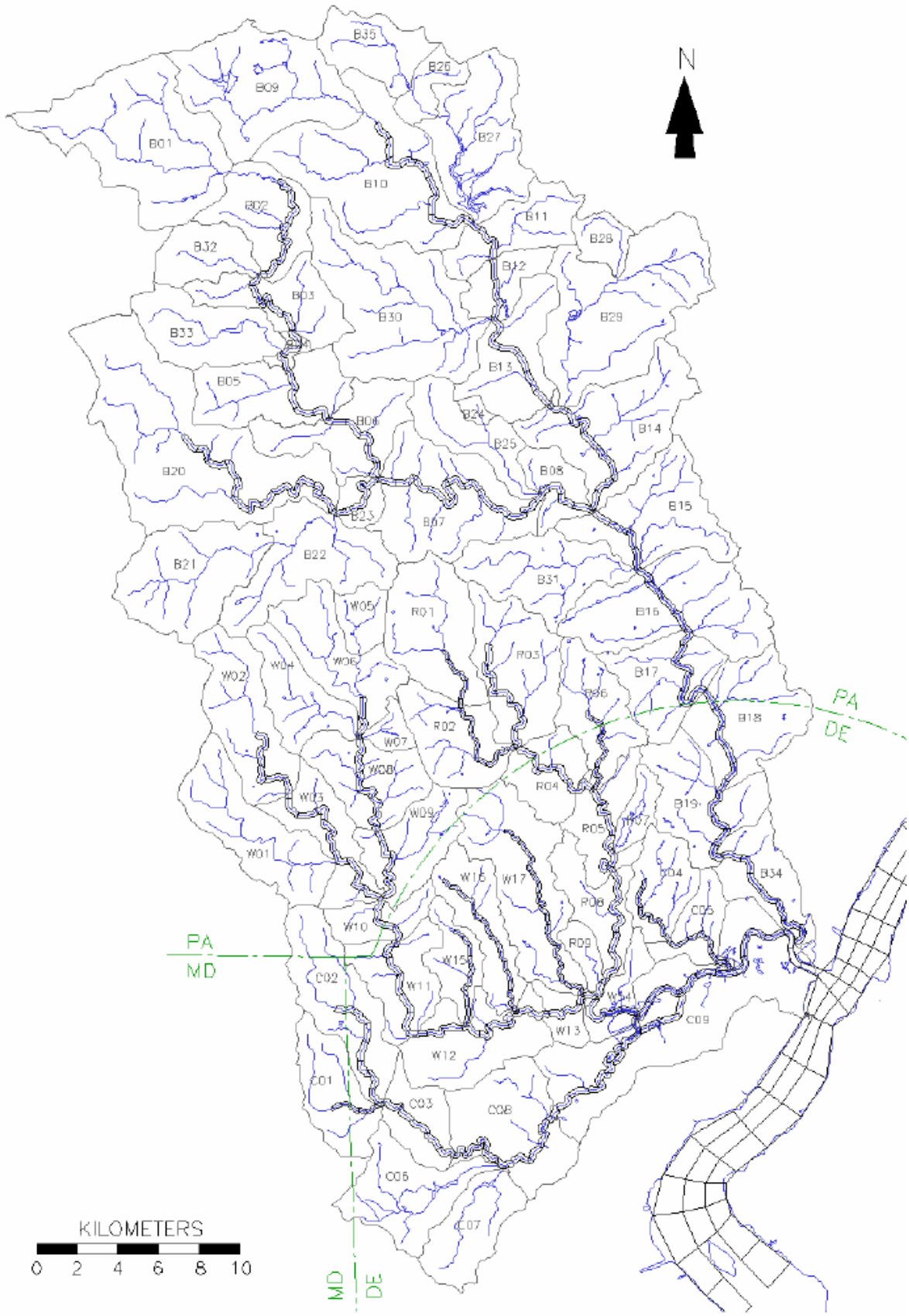


Figure 3.21 Subwatersheds of the Christina Basin

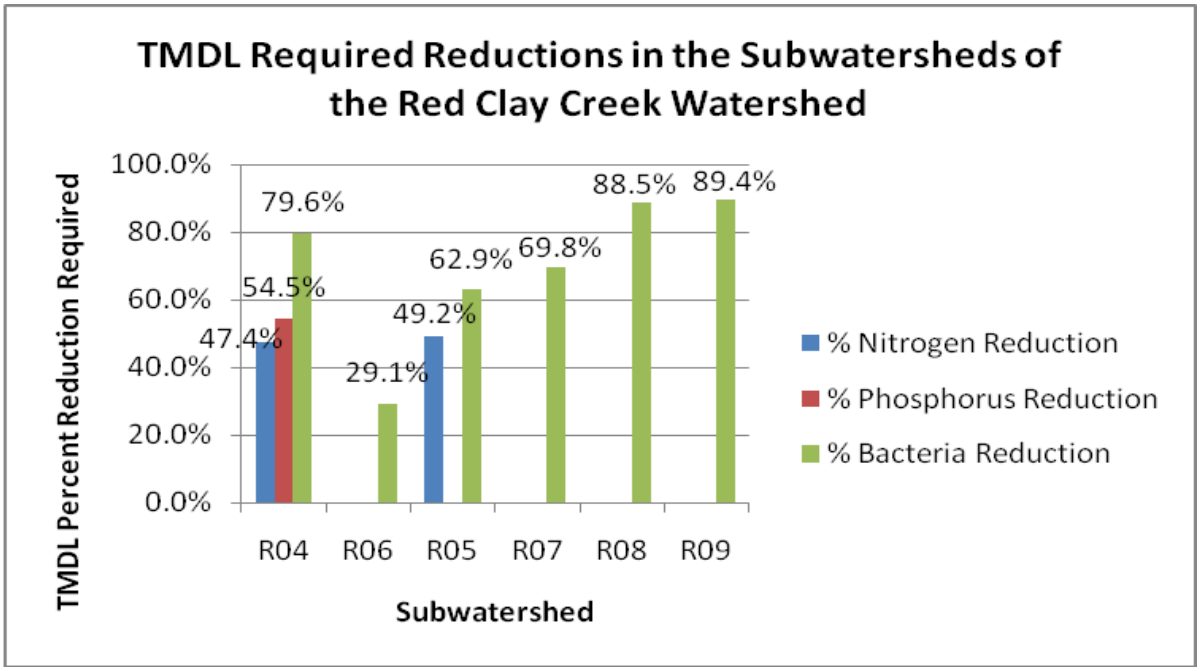


Figure 3.22 TMDL Reductions in the Delaware Portion of the Red Clay Creek Watershed

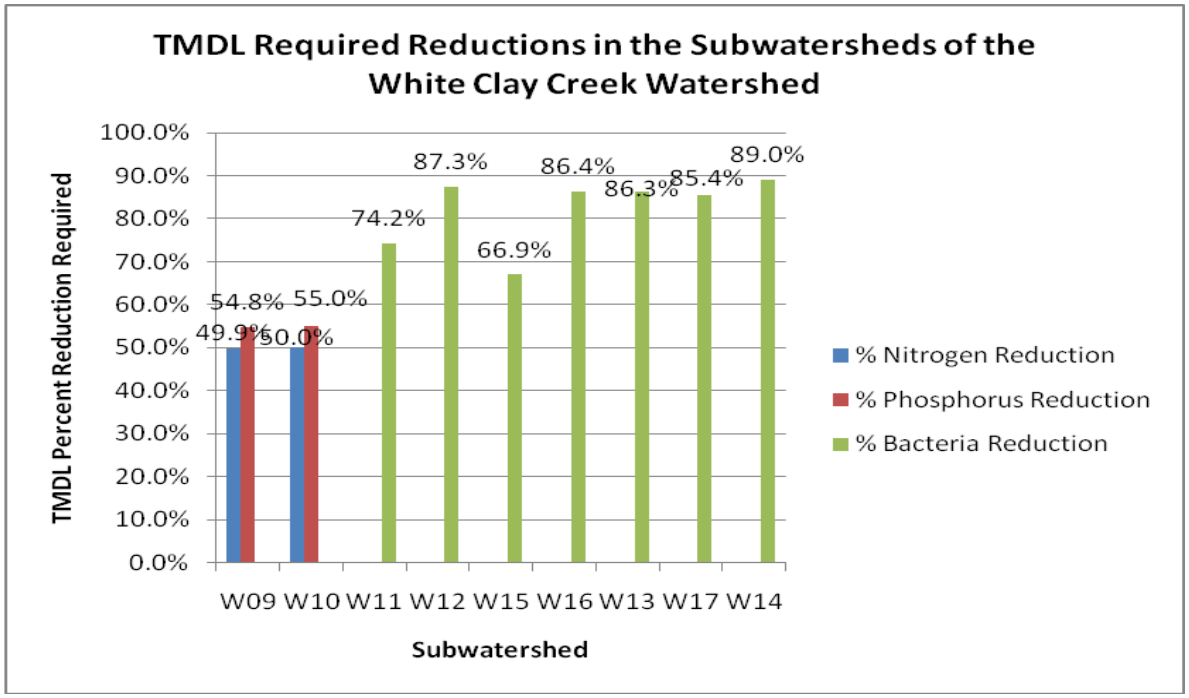


Figure 3.23 TMDL Reductions in the Delaware Portion of the White Clay Creek Watershed

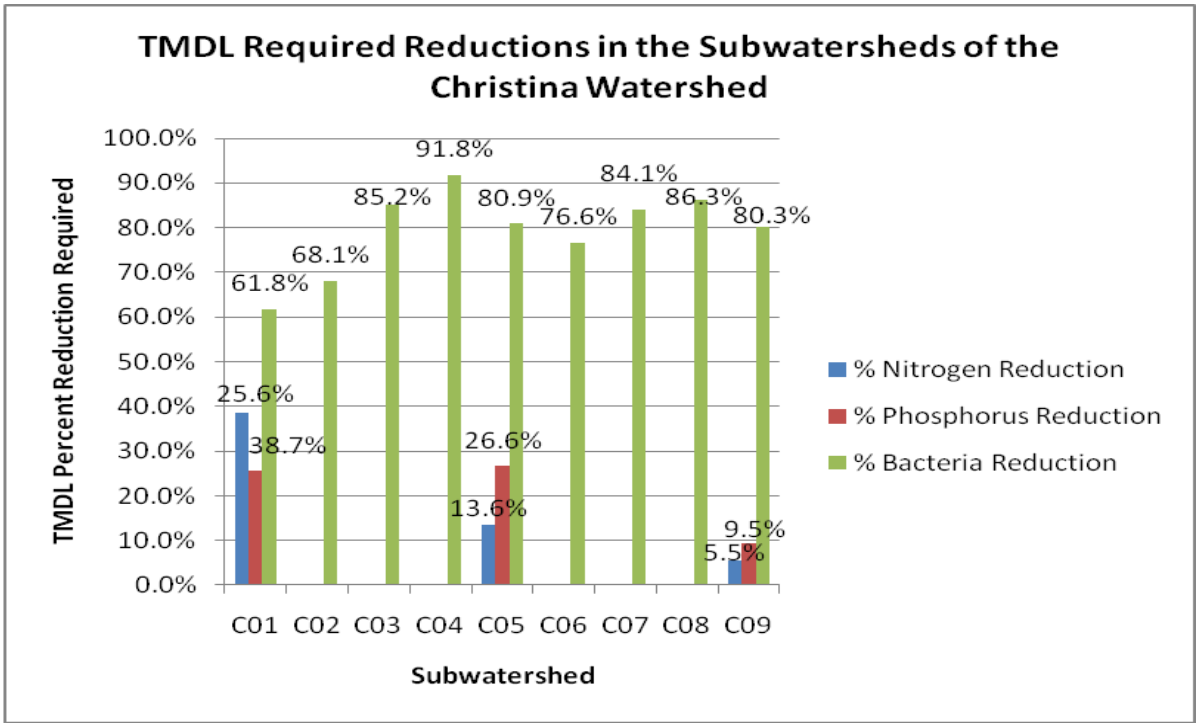


Figure 3.24 TMDL Reductions in the Delaware Portion of the Christina River Watershed

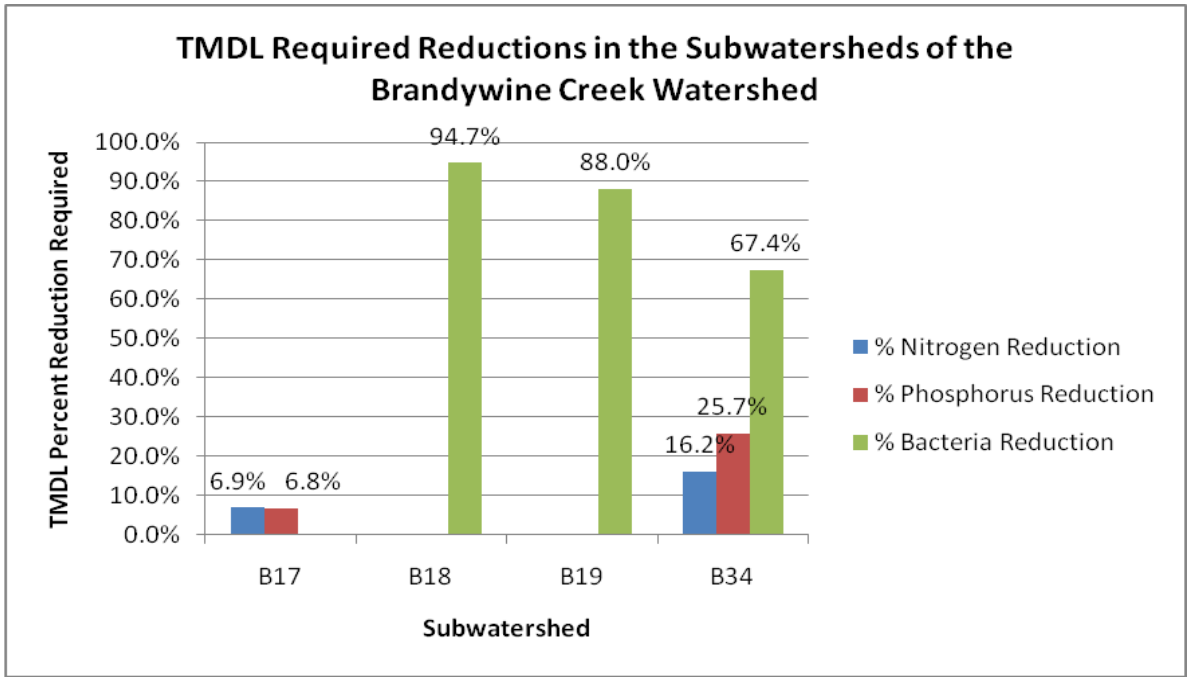


Figure 3.25 TMDL Reductions in the Delaware Portion of the Brandywine Creek Watershed

Chapter 4: Recommendations to Achieve the TMDLs

4.1 Background

This chapter of the Christina Basin Pollution Control Strategy (PCS) includes specific measures identified as having the potential to achieve the TMDLs set for the Delaware portion of the Christina Basin. This PCS, specifically chapters 4, 5, 6 and 7, is a living document and as additional information and data is collected the document will be refined. These 41 recommendations will serve as the tools, and the supporting information for each recommendation will serve as a resource to achieve the Christina Basin TMDLs.

These 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 8 recommendations, the agriculture category contains 7 recommendations, and the education category contains 11 recommendations. Each one of these 41 recommendations contains detailed information on the nutrient and bacteria reductions, cost of implementing the recommendation, potential sources of funding and partnership, and an implementation schedule.

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. There are eight recommendations included 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 and sediment and stormwater management plans to reduce nutrients and bacteria according to the total maximum daily loads, where feasible and effective.
SW3. Limit the addition of new effective impervious cover watershed-wide, especially 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. Implement a stormwater utility.
SW7. 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.

SW1. Increase Urban Tree Canopy

It is recommended to increase 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, 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.

<u>IMPLEMENTATION GOAL:</u>
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 January 2011, The City of Wilmington adopted a new tree ordinance to protect and enhance Wilmington's tree resources. The new law provides for the planning, policy, management, and enforcement needed to ensure a healthy urban forest. The City's new tree ordinance can serve as a sample ordinance for other urban communities in the Christina Basin.

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 prioritize 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.

Although there is some data from studies, on nutrient and bacteria reductions from urban tree canopy, further research and data are necessary. As part of the urban tree canopy recommendation, it is recommended to convene an urban tree canopy task force 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.

IMPLEMENTATION SCHEDULE

Research, being conducted in conjunction with the Urban Forest Effects 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 from 2007 on, which results in 197,000 new trees planted per year. Within a year of finalizing the PCS, Tributary Action Team members will convene to develop a plan for prioritization of future plantings and education.

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 4.2 outlines the benefit of trees versus other land use types based on the total nutrient loads in the stormwater.

Table 4.2 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. 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. 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). Also, 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.

COST

The costs for establishing an urban tree canopy are variable and dependent on the types of trees that 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 which 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 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 of Delaware; 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.

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 could 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.

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

Delaware Center for Horticulture 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 B contains information about native trees. Appendix B contains information compiled by the Delaware Center for Horticulture and the National Tree Trust on urban trees recommended for planting in Wilmington and the surrounding areas.

Other potential partners include:

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

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

IMPLEMENTATION GOAL

It is recommended that stormwater best management practices (BMPs) and sediment and stormwater plans in the Delaware portion of the Christina Basin are designed to reduce nutrients and bacteria according to the Christina Basin TMDLs. Implementing infiltration BMPs rather than structural retention and detention BMPs is the goal where appropriate. 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.

The Delaware Sediment and Stormwater Regulations are currently under revision and will be modified to better address volume management by increasing emphasis on recharge and infiltration of stormwater, where it is technically and environmentally feasible. In addition, regulations will include design criteria to reduce nutrient contributions through practices such as using treatment trains of stormwater controls or reducing impervious cover.

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 Christina Basin

because there is a much higher volume of new development in the portion located in Pennsylvania.

IMPLEMENTATION SCHEDULE

With the promulgation of the new proposed Sediment and Stormwater Regulations by the end of 2012, the Department believes that this recommendation will be met. If the new regulations are not promulgated as anticipated, the Department will promulgate stormwater regulations for the Christina Basin that meet this recommendation and the required TMDL reduction.

NUTRIENT AND BACTERIA REDUCTIONS

Stormwater runoff volumes are reduced and water quality is improved when implementing the types of stormwater BMPs promoted by the new proposed Sediment and Stormwater Regulations.

COST

The cost per year for staff to 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).

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

- Development Community
- DNREC
- Municipalities
- New Castle County

SW3. Limit Addition of Effective Impervious Cover Especially above Drinking Water Intakes

IMPLEMENTATION GOAL

It is recommended to limit the addition of effective impervious cover on new development. Impervious cover is any surface in the landscape that cannot effectively absorb or infiltrate rainfall. This includes: driveways, roads, parking lots, rooftops, and sidewalks. Effective impervious cover is the portion of the total amount of impervious cover that is directly connected to the storm drain system. Impervious cover that drains to vegetated areas where stormwater can infiltrate, or be filtered and stored, is not considered part of the effective impervious cover.

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 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 Delaware's water supply and water quality. This ordinance limits impervious cover to 20 percent in new development in WRPAs in the county. In 2001, 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 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.

Local ordinances limiting effective impervious cover for new development and redevelopment especially above drinking water intakes need to be established to further this goal. The new State of Delaware Sediment and Stormwater Regulations are expected to limit some of the negative effects of effective impervious cover by virtue of the requirement that stormwater must be infiltrated rather than discharged through a conveyance system. If infiltration is not possible on the site, the stormwater treatment on site must have several best management practices designed to reduce the stormwater nutrient and bacteria load. As for existing property that will be redeveloped, unless new construction will be undertaken on the property, no reduction of impervious cover will result.

IMPLEMENTATION SCHEDULE

With the promulgation of the new proposed Sediment and Stormwater Regulations by the end of 2012, the Department believes that this recommendation to establish limits for effective impervious cover will be met. The Department will work with New Castle County or any municipality to develop effective impervious cover reduction controls through ordinances on new and redeveloped properties.

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 biological 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 C.

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.

Reducing impervious cover through BMP implementation and specific planning techniques may present high upfront costs. However, 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 (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.

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

- Developers
- Municipalities
- New Castle County
- DNREC

SW4. Promote Low Impact Development in New Construction and Redevelopment

IMPLEMENTATION GOAL

It is recommended to promote 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 Christina 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 development.
- 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.

Presently there are state and local regulations encouraging the incorporation of LID. DNREC Sediment and Stormwater Regulations encourage green technology. DNREC also regulates brownfields and encourages LID design into these redevelopment efforts. Currently the City of Wilmington, DelDOT, and New Castle County encourage the implementation of LID in new development.

IMPLEMENTATION SCHEDULE

With the promulgation of the new proposed Sediment and Stormwater Regulations by the end of 2012, the Department believes that this recommendation to promote LID in construction and redevelopment will be met.

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 and phosphorus reductions for specific LID practices can be found in Appendix C and like the volume runoff values, the nutrient 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.

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

- DNREC
- Developers
- Municipalities
- New Castle County

SW5. Amend Stormwater Ordinances to Create Consistency throughout the Watershed

IMPLEMENTATION GOAL

It is recommended that local governments throughout the Christina Basin research and amend their stormwater ordinances to create consistent standards throughout. 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 Christina 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 Christina 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. Research is being conducted in the Brandywine Creek, Red Clay, and White Clay Creeks watersheds on the specific content of the existing stormwater ordinances. The Red Clay Valley Association and the Brandywine Valley Association 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. Also, the White Clay Creek Watershed Management Committee worked with Gaadt Perspectives, LLC to evaluate the City of Newark in Delaware and to implement a series of ordinances covering wetlands protection and buffering, riparian buffer protection, steep slopes, tree protection, and landscaping. The analysis conducted by the Brandywine Conservancy is intended to gauge municipal consistency with the White Clay Creek Watershed Management Plan and has analyzed 12 municipalities in the Pennsylvania portion of the White Clay Creek watershed, checking to see which are implementing the plan'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.*

Establishing a specific set of criteria, similar to those being used in other current projects, 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 Christina Basin. This recommendation supports the existing ordinance review research and encourages the continuation of this research on stormwater ordinances on a watershed-wide basis.

IMPLEMENTATION SCHEDULE

Within the first 3 years after the completion of the PCS, a group will convene to determine the steps necessary to reach this goal, criteria will be created and ordinances will be reviewed for consistency.

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 Christina Basin will benefit the water quality and indirectly decrease the nutrient and bacteria loads in the Christina Basin. Specific reductions cannot be given for this recommendation.

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).

POTENTIAL SOURCES OF FUNDING AND PARTNERSHIP

- Utilities
- Municipalities
- DNREC
- White Clay Creek Wild and Scenic Management Committee
- Christina Basin Clean Water Partnership
- Red Clay Valley Association
- Brandywine Valley Association
- New Castle County

SW6. Implement a Stormwater Utility

IMPLEMENTATION GOAL

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 research, 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.

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.

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 4.3. The impervious area will be estimated by applying the runoff coefficients to a parcel's gross parcel area. The Equivalent Stormwater Unit (ESU) factor will then be multiplied by the ESU

Rate. Table 4.4 outlines the runoff coefficients for some stormwater classes in Wilmington (City Code, Wilmington, Del., Chapter 45, Section 45-53). Both structural and nonstructural practices that reduce the quantity and improve the quality of stormwater runoff onsite may be considered to reduce costs. 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 4.3 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 4.4 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

IMPLEMENTATION SCHEDULE

Within two years of finishing the PCS, Tributary Action Team members will meet with staff from New Castle County, State of Delaware and the City of Newark to discuss the option of creating a stormwater utility.

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)

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

- Municipalities
- New Castle County
- DNREC

SW7. Identify and Prioritize Areas Where Stormwater Retrofits Would Effectively Reduce Sediment and Nutrients

IMPLEMENTATION GOAL

It is recommended to update the stormwater best management practices inventory and identify 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 Christina 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. These data, while important, need to be updated to reflect current conditions. DNREC, Division of Watershed Stewardship has also compiled a BMP 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).

It is recommended 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 Christina Basin.

IMPLEMENTATION SCHEDULE

Within a year of finishing the PCS, Tributary Action Team members (including representatives from all governments) will meet to discuss the creation of one cohesive BMP inventory and set a plan towards finding funding for implementation.

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 C.

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.

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

- Stormwater Utility
- Development Impact Fees
- Development Permit Fees
- New Castle County
- New Castle Conservation District
- Municipalities

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 buffers. 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. There are seven recommendations to reduce the nitrogen, phosphorus, and bacteria contributions from open space areas in the Christina Basin. These recommendations are listed in

Table 4.5 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 4.5 Open Space Recommendations

Open Space
OS1. Map, inventory, and prioritize existing open space areas.
OS2. Protect existing wooded/vegetated open space areas.
OS3. Require management plans for community open space areas that are designed for water quality protection, including reduced nutrient loading.
OS4. Require forested riparian buffers of adequate and proper widths sufficient to reduce or eliminate nonpoint source pollution for all new development.
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.

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

Compiling a basin-wide inventory of land areas 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 Christina Basin.

IMPLEMENTATION GOAL

It is recommended to use existing land use data to create a basin-wide open space protection tool. Existing data should be collected in a central clearinghouse where the land use data for the entire Delaware portion of the Christina 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 Christina 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 Christina 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 Creek, 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 Christina 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 WRA have data that can be incorporated into the development of this inventory. Priority land use maps developed by Delaware 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 criteria 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.

IMPLEMENTATION SCHEDULE

Within a year of finishing the PCS, Tributary Action Team members will meet to discuss the creation of an open space inventory and set a plan towards finding funding for implementation.

NUTRIENT AND BACTERIA REDUCTION

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

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

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

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

OS2. Protect Existing Wooded/Vegetated Open Space Areas

IMPLEMENTATION GOAL

It is recommended to protect existing wooded/vegetated open space areas to utilize these land areas as natural filters for nitrogen, phosphorus, and bacteria loads in the Christina 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. It is recommended to use 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.

IMPLEMENTATION SCHEDULE

Within a year of finishing the open space inventory, Tributary Action Team members will meet to discuss a plan towards finding funding to preserve and protect land in the existing "green" watersheds.

NUTRIENT AND BACTERIA REDUCTION

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 4.6 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 Christina 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 4.6 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.

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

- 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 that are Designed for Water Quality Protection, Including Reduced Nutrient Loading

IMPLEMENTATION GOAL

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 (including the creation of an open space plan) 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.

While New Castle County requires this plan already, there is need for all maintenance corporations and municipalities to make this requirement. 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 New Castle County and some of the 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.

IMPLEMENTATION SCHEDULE

Within two years of developing an open space inventory, Tributary Action Team members will convene to review the open space requirements of all local governments in the Christina Basin and take action to improve these requirements as necessary.

NUTRIENT AND BACTERIA REDUCTION

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.

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

- New Castle County
- Municipalities
- HOAs and Maintenance Corporations

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

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 “takes 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.

IMPLEMENTATION GOAL

It is recommended that forested riparian buffers of adequate and proper widths for new development abutting all waters of the state including private, state, and county lands are encouraged. In addition, it is recommended to restore 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, it is recommended to plant native vegetated stream buffers.

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.

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 it is recommended that forest riparian buffers meet at a minimum 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.

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 and in collaboration with the USDA NRCS and the Brandywine Conservancy as seen in Figures 4.1 and 4.2. 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. Stroud Water Research Center 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 Department, along with partners such as the University of Delaware, will work alongside Newport and Elsmere, the only local governments in the Christina Basin to not currently have riparian buffer protection, to create ordinances or programs that will adequately promote riparian buffer protection.

IMPLEMENTATION SCHEDULE

Within two years of finishing the PCS, Tributary Action Team members will meet with Elsmere and Newport and discuss with them the possibility of creating riparian buffer ordinances.

NUTRIENT AND BACTERIA REDUCTION

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.

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).

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.

COST

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.

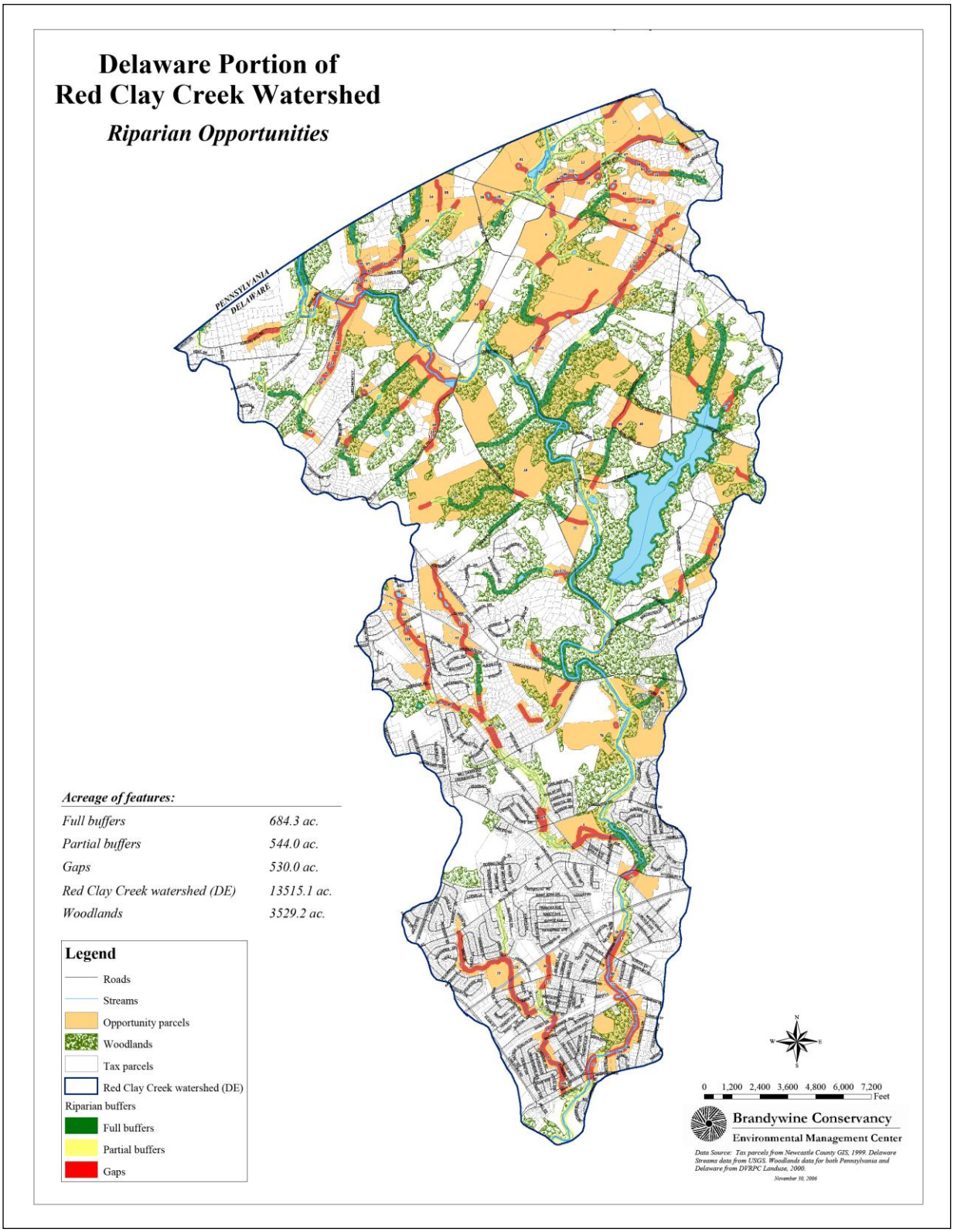
The cost estimates for restoring riparian forested buffers on existing development vary from the costs for installing riparian forested buffers in new development and are highly variable. A cost estimate for the plantings to revegetate forested riparian buffers is included below:

- $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).

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

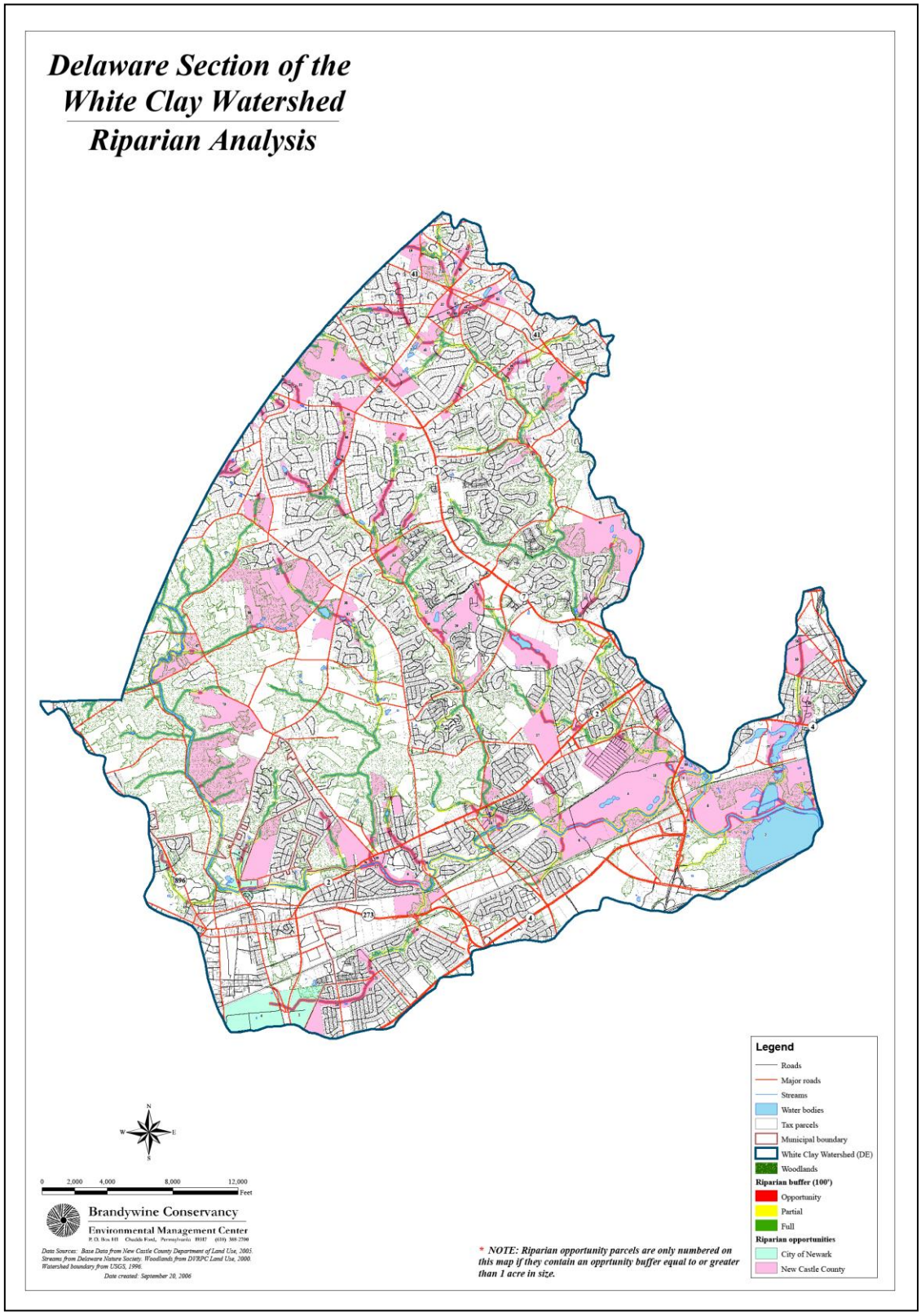
- USDA Conservation Reserve Program
- Federal Wild and Scenic Rivers Program
- Stroud Water Research Center Riparian Buffer Program
- Delaware Forest Service
- Delaware Coastal Program
- DNREC Division of Fish and Wildlife
- DNREC Division of Water
- New Castle County
- Municipalities

Figure 4.1 Delaware Portion of the Red Clay Creek Watershed: Riparian Opportunities



Source: Brandywine Conservancy, Environmental Management Center, 2007

Figure 4.2 Delaware Section of the White Clay Creek Watershed Riparian Analysis



Source: Brandywine Conservancy, Environmental Management Center, 2007

OS5. Stream Restoration

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.

IMPLEMENTATION GOAL

Stream restoration is a tool that is recommended to restore the natural function 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.

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.

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 a 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. 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).

IMPLEMENTATION SCHEDULE

Within two years of finishing the PCS, Tributary Action Team members will meet with DNREC staff to develop a prioritization plan for stream restoration in the Christina Basin and to find funding for implementation.

NUTRIENT AND BACTERIA REDUCTION

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

Other studies provide higher reduction values than those listed above in the Spring Branch Stream Study. Therefore, actual reductions from stream restoration projects may be higher and vary based on site conditions and restoration practices implemented.

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).

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

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

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

Open space and conservation easements have many important benefits including the following:

- Increases stormwater runoff infiltration
- Reduces pollutant export
- Reduces the amount of impervious cover
- Increases the amount of natural land conserved
- Improves the performance of stormwater treatment practices

IMPLEMENTATION GOAL

It is recommended to acquire *additional* open space and conservation easements. Acquiring and conserving open space and retaining conservation easements provide numerous benefits to receiving streams.

Open space areas, particularly forested tracts and headwater streams, are priority areas for acquiring additional open space in the Christina 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 Christina Basin.

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.

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.

IMPLEMENTATION SCHEDULE

Within three years of developing an open space inventory, Tributary Action Team members will meet to discuss a strategy for acquiring critical open spaces in the Christina Basin.

NUTRIENT AND BACTERIA REDUCTION

See OS2 for 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 Christina 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. Assuming a goal of 100 additional acres per year of open space and 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.

POTENTIAL FUNDING AND PARTNERSHIP SOURCE

Open Space:

- Developers
- State of Delaware
- New Castle County
- Municipalities
- DNREC Division of Parks and Recreation

Conservation Easements:

- In-kind
- Brandywine Conservancy
- Delaware Nature Society
- The Nature Conservancy
- Natural Lands Trust

OS7. Reforest Watersheds and Headwaters

IMPLEMENTATION GOAL

It is recommended to reforest 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, it is recommended to have 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 Christina 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.

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.

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.

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 Christina 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.

IMPLEMENTATION SCHEDULE

Within three years of finishing the PCS, Tributary Action Team members will meet with partners including the Brandywine Conservancy and White Clay Wild and Scenic Management Committee to prioritize reforestation efforts in the Christina Basin.

NUTRIENT AND BACTERIA REDUCTION

Reforestation efforts have proven to benefit the water quality, but the actual nutrient and bacteria reduction estimates are difficult to quantify. Table 4.7 summarizes the hydrologic and water quality benefits of a single tree (Capiella, Schueler, and Wright, July 2005).

Table 4.7 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).

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 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.

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

- U.S. Department of Agriculture (CRP, WHIP, EQIP, WRP)
- Delaware Department of Agriculture Forest Service
- 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)
- Nonprofit Organizations

4.4 Wastewater Recommendations

There are eight 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 recommendations are listed in Table 4.8 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 4.8 Wastewater Recommendations

Wastewater
WW1. Install new and replacement systems that are designed to meet performance standards for onsite wastewater treatment systems.
WW2. Conduct inspections and pumpouts of onsite wastewater treatment systems, especially when properties are sold or ortherwise transferred to other ownership prior to completion of sale.
WW3. Eliminate cesspools and seepage pits in a systematic way.
WW4. Remove onsite wastewater treatment systems through connection to a centralized wastewater treatment plant.
WW5. 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.
WW6. Abate combined sewer overflows.
WW7. Continue sewer repair projects and conduct regular inspections.
WW8. 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 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 Christina Basin also contains a separate sewer system that requires maintenance and elimination of illicit discharges. All of these wastewater sources contribute nutrients and bacteria to the ground and surface water.

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 Christina Basin. Table 4.9 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 Christina Basin.

Table 4.9 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 unsewered 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 rest of the Delaware portion of the Christina Basin contains thousands of OWTS and Table 4.10 below provides the most recent inventory of OWTS in the Christina Basin.

Table 4.10 Inventory of OWTS in the Christina Basin

Watershed	Septics[2]	Cesspools[1]
Brandywine Creek	690	587
Christina River	1,769	1,262
Red Clay Creek	1,630	
White Clay Creek	1,921	
Total	**6,010**	**1,849**

Source: DNREC, Division of Watershed Stewardship
[1]2007 data
[2]2009 data

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.

Figure 4.3 maps the septic systems according to a 2009 inventory conducted by DNREC Division of Watershed Stewardship Watershed Assessment Section.

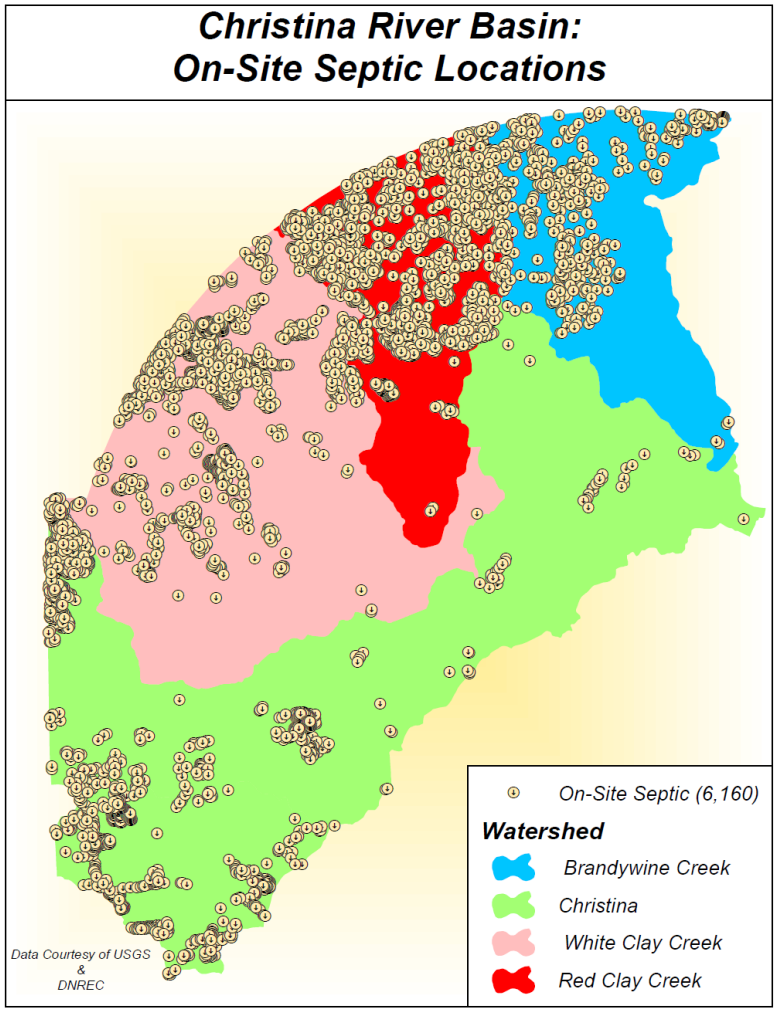


Figure 4.3 Septic Systems in the Christina Basin

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 Christina Basin, as detailed in WW2.

There are approximately 1,849 cesspools in the Delaware portion of the Christina Basin as shown in Table 4.10.

WW1. Performance Standards for Onsite Wastewater Treatment Systems

Encouraging the use of performance standards will reduce excessive nutrients from the OWTS in the Delaware portion of the Christina Basin. 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 Christina Basin, which will help to reduce the pollutant loads from OWTS. Community and large OWTS are not encouraged in the Christina Basin.

IMPLEMENTATION GOAL

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 Christina 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. Small systems are the most common systems in the Christina Basin. Based on analysis by the DNREC Division of Watershed Stewardship, 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).

The overall goal to implement performance standards will be implemented with the promulgation of the revision of the Regulations Governing the Design, Installation and Operation of Onsite Wastewater Treatment and Disposal Systems in 2011. If the new regulations are not promulgated as anticipated, the Department will promulgate wastewater regulations for the Christina Basin that meet this recommendation and the required TMDL reduction.

IMPLEMENTATION SCHEDULE

One year after finalizing the PCS, Tributary Action Team members will meet to develop a plan towards maintaining implementation of performance standards.

NUTRIENT AND BACTERIA REDUCTION

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 4.4 is used to estimate the additional TN and TP reductions based on upgrading the septic systems in the Christina 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 4.11 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 C.

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

Figure 4.4 TN and TP Reduction Equation for a 50-Percent Performance Standard

Table 4.11 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.

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

- DNREC
- Homeowners

WW2. Inspections and Pump-Outs of Onsite Wastewater Treatment Systems

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.

IMPLEMENTATION GOAL

Regular inspections and pump-outs of OWTS are recommended, especially prior to the completion of a sale, to promote compliance and reduce the OWTS failure rate in the Christina Basin. The Christina Basin TAT recommends that DNREC, Division of Water, 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 Christina 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 4.12. 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 Christina Basin.

Table 4.12 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 Onsite 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. 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.

IMPLEMENTATION SCHEDULE

The overall goal to implement pump outs and inspections will be implemented with the promulgation of the revision of the Regulations Governing the Design, Installation and Operation of Onsite Wastewater Treatment and Disposal Systems in 2011. If the new regulations are not promulgated as anticipated, the Department will promulgate wastewater regulations for the Christina Basin that meet this recommendation and the required TMDL reduction.

NUTRIENT AND BACTERIA REDUCTION

According to the DNREC Division of Watershed Stewardship, Watershed Assessment Section, there are 7,859 OWTS and of these 6,010 are septic systems. It can be assumed that an inspection and pump-out program is not applicable to the 1,849 cesspools, and the inspection and pump-out recommendation applies only to the 6,010 septic systems in the Christina Basin. A loading rate of 1.56 lb N/system/pump-out and 0.62 lb/P/system/pump-out are assigned to this recommendation.

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.

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

- DNREC
- Homeowners

WW3. 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.

IMPLEMENTATION GOAL

It is recommended to remove these outdated wastewater disposal systems, which typically provide little or no treatment, and replace 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 Code of Federal Regulations 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)

The overall goal to have all seepage pits and cesspools eliminated will be implemented with the promulgation of the revision of the Regulations Governing the Design, Installation and Operation of Onsite Wastewater Treatment and Disposal Systems in 2011.

IMPLEMENTATION SCHEDULE

The overall goal to eliminate cesspools and seepage pits will be implemented with the promulgation of the revision of the Regulations Governing the Design, Installation and Operation of Onsite Wastewater Treatment and Disposal Systems in 2011. If the new regulations are not promulgated as anticipated, the Department will promulgate wastewater regulations for the Christina Basin that meet this recommendation and the required TMDL reduction.

NUTRIENT AND BACTERIA REDUCTION

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 Christina 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.

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

- New Castle County
- Homeowners
- DNREC

WW4. Eliminate Onsite Wastewater Treatment Systems through Connection to the Centralized Wastewater Treatment Plant

IMPLEMENTATION GOAL

It is recommended to 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.

IMPLEMENTATION SCHEDULE

Using the information in Table 4.13 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.

NUTRIENT AND BACTERIA REDUCTION

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 4.13 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 4.13 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 4.14 provided by New Castle County's Department of Special Services, it is recommended to eliminate 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.

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

- New Castle County
- Homeowners

WW5. 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

IMPLEMENTATION GOAL

In addition to eliminating existing cesspools and seepage pits, it is recommended 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.

IMPLEMENTATION SCHEDULE

The overall goal to prevent drainfields within 100 feet of sensitive areas for water quality protection will be implemented with the promulgation of the revision of the Regulations Governing the Design, Installation and Operation of Onsite Wastewater Treatment and Disposal Systems in 2011. If the new regulations are not promulgated as anticipated, the Department will promulgate wastewater regulations for the Christina Basin that meet this recommendation and the required TMDL reduction.

NUTRIENT AND BACTERIA REDUCTION

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 but specific loadings cannot be calculated at this time.

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.

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

- Developers
- Homebuilders
- DNREC

WW6. 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. 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.

IMPLEMENTATION GOAL

It is recommended to implement controls as addressed in the City of Wilmington's Enhanced LTCP. 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. 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.

IMPLEMENTATION SCHEDULE

The City of Wilmington has a Long Term Control Plan that is required and approved by the USEPA, and they will be using this plan to work toward eliminating the problems associated with CSOs.

NUTRIENT AND BACTERIA REDUCTION

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. The $26.9 million price tag does not include the $30 million already spent on the WWTP plant upgrade. Table 4.14 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 4.14 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

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

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

WW7. Continue Separate Sewer Repair Projects, Inspection, and Elimination of Unpermitted Storm Drain Discharges

IMPLEMENTATION GOAL

It is recommended to institute 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.

Although the point source TMDL addresses the NPDES discharges in the Christina 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.

IMPLEMENTATION SCHEDULE

This recommendation is being implemented. The Tributary Action Team will stay in contact with officials to ensure actions toward this goal are continued.

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 4.15 and 4.16. 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 WW6.

The New Castle County cost information in Table 4.15 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 projects included in Table 4.15 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. The costs in Table 4.16 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 4.15 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 4.16 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**

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

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

WW8. 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.

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, was treated in August of 2007 with the injection of a slurry of non-hazardous magnesium hydroxide compound into the ground in areas near the stream to create an underground barrier to take zinc out of the dissolved aqueous phase for conversion to solid zinc materials.
- **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 Watershed Stewardship, 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.

IMPLEMENTATION GOAL

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.

IMPLEMENTATION SCHEDULE

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 4.17. Table 4.17 summarizes the contaminated substance sources by category for the Brandywine Creek, Red Clay, and White Clay Creeks, and Christina River watersheds.

Table 4.17 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 REDUCTION

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.

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

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

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 4.18 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 4.18 Select Agriculture Recommendations

Agriculture
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

According to the USDA Natural Resource Conservation Service staff and GIS mapping, the acres of agricultural land in the Christina Basin were calculated as found in Table 4.19. , The Red Clay Creek has the smallest amount of agriculture acreage with approximately 1,535.6 acres acres. Figure 4.6 illustrates the breakdown of the agriculture land use that is shown in Table 4.19 for the Delaware portion of the Christina Basin. For the purpose of this exercise, the data collected was grouped according to four categories based on the predominant use per parcel: pasture, grain, hay, and trees and wildlife.

Table 4.19 Agriculture Acreage in the Delaware Portion of the Christina Basin

Watershed	**Grain Production**	**Pasture**	**Hay**	**Trees and Wildlife**	**Watershed Total**
Brandywine Creek	923.5	216.7	893.6	204.6	**2,238.4**
Christina River	1,097.2	235.8	218.6	29.5	**1,581.2**
Red Clay Creek	179.9	151.8	1,203.9	0	**1,535.6**
White Clay Creek	537.4	324.5	1,255.3	88.2	**2,205.4**
Land Use Total	**2,738**	**928.8**	**3,571.4**	**322.4**	**7,560.6**

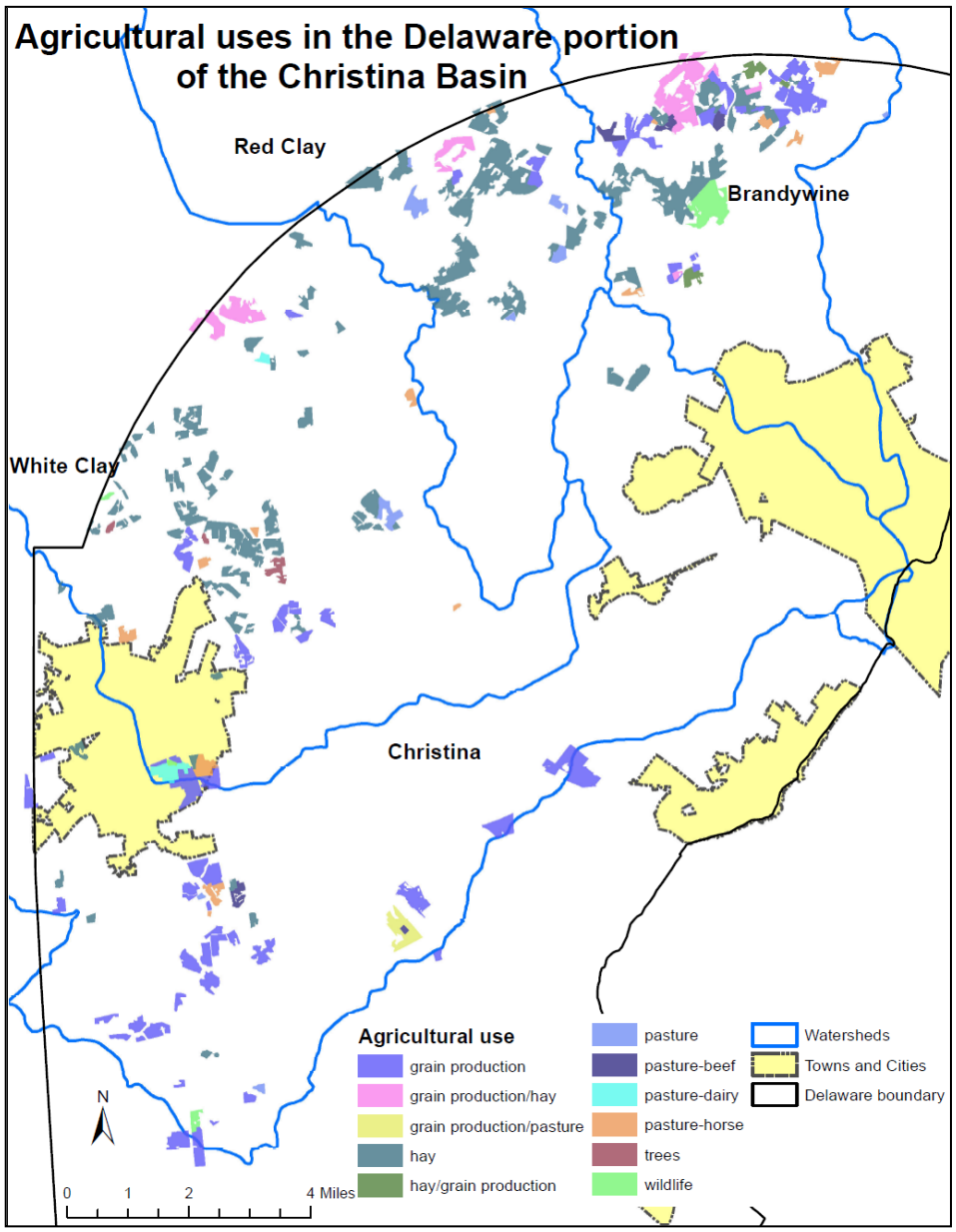


Figure 4.6 Agriculture Land Use in the Delaware Portion of the Christina Basin

IMPLEMENTATION GOAL

The farms in the Delaware portion of the Christina Basin are predominantly hay farms and grain production with a smaller sampling of the following types of farms: dairy farm, horse farm, and cattle and pig 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 have not implemented nutrient management plans (NMPs).

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.

In addition to the crops and pastures that are contained in the Delaware portion of the Christina 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 Delaware, yet it is important to recognize that this is a contributor to the nutrient loads in the tributaries in 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.

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.

IMPLEMENTATION SCHEDULE

Within a year of finishing the PCS, Tributary Action Team members will convene (including partners such as the USDA-NRCS) to determine which farms do not have a nutrient management plan and develop a plan for outreach.

NUTRIENT AND BACTERIA REDUCTION

Table 4.20 lists several agriculture BMPs and their associated nutrient and bacteria reductions. They will be considered 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.

Table 4.20 Approximate Reduction Efficiencies for Select Agriculture BMPs

Recommendation	Approximate Percent Reduction		
	TN	TP	Bacteria
Cover Crops	~55, but varies depending on species used	4.9	
Pasture Stream Fencing	NA	NA	100
Riparian Forest Buffers	62	62	43-57
Field Border	4	29	
Grassed Filter Strips and Grassed Buffers	46	54	44
Wetland Restoration	62	62	30

COST

The costs of implementing BMPs have been estimated using data gathered by United States Department of Agriculture (USDA), Natural Resource and Conservation Service (NRCS) at the county and state level. Recently, changes in the state cost share program have required a Pollution Control Strategy for watershed residents to receive funding. Thus, the state cost share information found in Table 4.21 is based on a PCS approved for the Christina Basin. These are estimates, as costs for specific project may vary.

Table 4.21: Agricultural BMP Costs

	Installation Cost / Acre	*Lifespan (years)*	*Total Maintenance Costs over Lifespan*	*Total Cost/ Acre*
Cover Crops	$49.33	1	$5	$54.33
Ponds	$3,758.50	10	$5	$3,808.50
Grassed Waterways	$16,404.24	10	$5	$16,454.24
Filter Strips/Wildlife Habitat	$495.24	10	$5	$545.24
Forest Buffers	$495.24	15	$5	$570.24
Riparian Buffers	$502.00	15	$5	$577.00
Wetland Restoration	$4,374.50	15	$5	$4,449.50
Field Border	$495.24	10	$5	$545.24
Critical Area Planting	$7,229.24	10	$5	$7,279.24
Conservation Tillage	$17.33	4	$5	$37.33

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

There are several organizations devoted solely to the management of agriculture lands in New Castle County and the State of Delaware. Due to the institutional knowledge that representatives of these groups possess, DNREC 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 Christina Basin. The subcommittee shall consist of the following representatives of federal, state, and local agriculture organizations:

- Delaware's USDA, NRCS
- New Castle Conservation District
- Delaware Department of Agriculture
- Pennsylvania's USDA, NRCS
- University of Delaware WRA

4.6 Education Recommendations

Develop a Comprehensive Education Plan on Issues of Water Quality and 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 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.

It is recommended that the 11 pollution prevention activities listed in Table 4.22 are implemented throughout the Christina Basin to reduce the adverse impacts of nonpoint source pollution at its source in urban and suburban areas.

Table 4.22 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 Christina 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. 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 for each measure with goals and objectives, a target audience, marketing strategy, distribution, and outreach material development.

How the Education Recommendations Will Be Achieved

It is recommended 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 Christina 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 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 (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 potential partners 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 Christina 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 Christina Basin. 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 Christina 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, coordinating, and evaluating existing efforts and directing resources to the PCS education recommendations. This task force will primarily serve the Delaware portion of the Christina 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 education recommendations for the Christina Basin.

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

IMPLEMENTATION GOAL

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 Christina 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.

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, Delaware Livable Lawns, 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 Delaware.
- 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. Research bacteria reductions associated with specific BMPs. Most of the bacteria reductions tied to the recommendations in the Christina Basin PCS are implied. 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. 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.

IMPLEMENTATION SCHEDULE

Within 2 years of finishing the PCS, Tributary Team members will convene am Education Task Force that will develop a plan for the Christina Basin that incorporates these education and outreach recommendations.

NUTRIENT AND BACTERIA REDUCTION

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 4.23 shows the estimated costs associated with establishing the Christina Basin Education Task Force and implementing the education recommendations in the Christina Basin PCS.

Table 4.23 Education Recommendation Costs

Task	Cost
Task Force Coordination/Facilitation	$4,000 (annually)
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**

* 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.

POTENTIAL FUNDING AND PARTNERSHIP SOURCES

- DNREC Nonpoint Source 319 Monies
- EPA Pollution Prevention Grant Program
- Water Utilities
- Government Agencies (municipal, county, and state levels)
- Private Companies

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, WRA
- University of Delaware, College of Agriculture and Natural Resources
- White Clay Creek Wild and Scenic Management Committee
- White Clay Creek Watershed Association

Chapter 5: Monitoring

5.1 Christina Basin Water Quality Monitoring

Water quality monitoring is essential 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 Division of Watershed Stewardship is actively involved in technical monitoring throughout Delaware. Delaware maintains a General Assessment Monitoring Network (GAMN) of stations throughout Delaware. The GAMN stations are long-term monitoring stations and are used to conduct long-term status and trend assessments of water quality conditions. (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 Delaware. The Division of Watershed Stewardship has water quality monitoring records dating back 30 years for select monitoring sites in the Christina Basin. In 2011, 16 DNREC GAMN stations are in operation in the Christina Basin. Table 5.1 provides the sampling locations, parameters sampled, and the sampling frequency for the sites located in the Christina Basin (Department of Natural Resources and Environmental Control, Division of Watershed Stewardship, 2011).

Table 5.1 Christina Basin GAMN Stations

STATION INFORMATION	*STORET #*	*Type*	*Cu, Pb & Zn*	*Storm Sampling*	*No. of Samples in 2011*
Brandywine Creek					
Brandywine Creek @ Foot Bridge in Brandywine Park	104011	C2	✓		6
Brandywine Creek @ New Bridge Rd. (Rd. 279) (USGS gage 01481500)	104021	C1	✓	3 storms	12
Brandywine Creek @ Smith Bridge Rd. (Rd. 221)	104051	C2	✓		6
Christina River					
Christina River beneath Rt. 141 in Newport off Water St.	106021	C2	✓		6
Little Mill Creek @ DuPont Rd.	106281	C2	✓		6
Christina River @ Conrail Bridge (USGS gage 01481602)	106291	C1	✓		12
Christina River @ Nottingham Rd. (Rt. 273) above Newark	106191	C2	✓		6

Christina River @ Sunset Lake Rd. (Rt. 72) (USGS gage 01478000)	106141	C1	✓	3 storms	12
Smalleys Dam Spillway @ Smalleys Dam Rd.	106031	C2	✓		6
Red Clay Creek					
Red Clay Creek @ W. Newport Pike (Rt. 4) Stanton (USGS gage 01480015)	103011	C2	✓		6
Burrough's Run @ Creek Rd. (Rt. 82)	103061	C2	✓		6
Red Clay Creek @ Barley Mill Rd. (Rd. 258A) Ashland	103041	C2	✓		6
Red Clay Creek @ Lancaster Pike (Rt. 48) Wooddale (USGS gage 01480000)	103031	C1	✓	3 storms	12
White Clay Creek					
White Clay Creek @ Delaware Park Blvd. (Race Track) (USGS gage 014790000)	105151	C1	✓	3 storms	12
White Clay Creek @ McKees Lane	105171	C2	✓		6
White Clay Creek @ Chambers Rock Rd. (Road 329)	105031	C2	✓		6

Source: DNREC, Division of Watershed Stewardship, January 2011

The Brandywine Creek watershed contains three GAMN stations, the Christina River watershed contains six GAMN stations, the Red Clay Creek watershed contains four GAMN stations, and the White Clay Creek watershed contains three GAMN stations.

Some of the 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 Division of Watershed Stewardship work together to share this data, which results in more detailed data at these DNREC monitoring sites.

DNREC, Division of Watershed Stewardship is committed to providing the resources necessary to ensure that the streams and rivers in the Christina Basin are appropriately monitored. The Division 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 Stream Watch Technical Monitoring Program

Several citizen monitoring programs have been established throughout Delaware 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 has established a citizen technical monitoring program in the Christina Basin. Volunteers in New Castle County collect data on tributaries of the Brandywine Creek, 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 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 Delaware 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.

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 goals. Through the implementation of the 41 recommendations outlined in Chapter 4, the Christina Basin Tributary Action Team hopes to achieve these goals.

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 Creek, Red Clay Creek, White Clay Creek, and Christina River watersheds. This PCS recommends 41 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 is not 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 goals. 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 41 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 6.1–6.5 have been collected throughout the PCS development process 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 Watershed Stewardship, 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 eight 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 SW7 (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 Christina 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 SW7, 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 SW7 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 DE Dept. of Ag. 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 effective impervious cover in the watershed, especially 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. 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
SW7. 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 Stormwater Management facilities.	assume 5/year	$500,000 - $1,825,000
SW TOTAL				**$10,840,000-$12,165,000**

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.

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 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 max. cost of open space acquisition in New Castle County, estimate is based on the purchase price for the following properties in the DE 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 eight 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	Estimated cost/year for DNREC staff to establish and maintain the performance standard reg. (other costs are costs 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
WW2. Inspections and pump-outs of OWTS	Estimated cost/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

Recommendation	Basis	Unit Cost	Quantity	Total (per year)
WW3. Systematically eliminate cesspools and seepage pits.	Based on cost estimates from NCC Dept. 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
WW4. Eliminate OWTS through connection to centralized WWTP.		Individual to Sewer	25 systems/year (cost to homeowner)	$0
WW5. No new OWTS drainfields placed within 100-feet of wetlands, tidal waters etc.	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
WW6. 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
WW7. Continue sewer repair projects and conduct regular inspections.	The NCC cost info. is from the Fiscal Year 2007 Comprehensive Annual Budget Summary, New Castle County Delaware.	Average cost of NCC sewer projects slated for FY07 budget = $8,190,000	Per year	$8,190,000
WW8. 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. 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

The costs of implementing BMPs have been estimated using data gathered by United States Department of Agriculture (USDA), Natural Resource and Conservation Service (NRCS) at the

county and state level. Recently, changes in the state cost share program have required a Pollution Control Strategy for watershed residents to receive funding. Thus, the state cost share information found in Table 6.6 is based on a PCS approved for the Christina Basin. These are estimates, as costs for specific project may vary.

The total cost for implementing the seven agriculture recommendations is estimated at approximately $36,176 per year. 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 Christina Basin, and the lower costs associated with these types of BMPs.

Table 6.6 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. These are estimates and reflect capital and maintenance costs.	$3/acre	750 acres/year	$ 2,250
AG2. Cover Crops		$54.33/acre	125 acres/year	$6,791
AG3. Pasture Stream Fencing		$1.50/foot	700 feet/year	$525
AG4. Grassed Filter Strips		$545.24/acre	6 acres/year	$3,271
AG5. Grassed Waterways		$16,454.24/acre	1 acre/year	$16,454
AG6. Riparian Forested Buffers		$577/acre	5 acres/year	$2,885
AG7. Pasture and Hay Planting		$200/acre	40 acres/year	$4,000
Agriculture Total				**$36,176**

Education Costs

Based on estimates provided by the group and representatives of nonprofit organizations that have worked on projects such as this in the Christina Basin, the total annual cost estimated for implementing a portion of the education recommendations each year is $114,000 per year. Although the education recommendations are inexpensive, 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 6.7 outlines each recommendation and the associated cost estimate per year to implement the education recommendations.

Table 6.7 Estimated Annual Costs of the Education Recommendations

Recommendation	Basis	Unit Cost	Quantity	Total (per year)
ED1. Educate Christina Basin stakeholders on nonpoint source pollution and their role in reducing it, specifically targeting behavior change.	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.	$114,000	Per year	$114,000
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 BMPs and BMP maintenance.				
ED6. Integrate education into state and local permitting processes.				
ED7. Encourage corporate environmental stewardship programs.				
ED8. Coordinate nonprofit organizations throughout the Christina 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 BMPs.				
ED11. Advise DNREC to research nutrient reductions related to bacteria counts and BMPs.				
Education Total				**$114,000**

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 $31.3 million per year. The basis for the $31.3 cost estimate is literature research, communication with practitioners, and peer review. These costs are a reflection of 40 of the 41 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 6.8. Table 6.8 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 6.8 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 $31.3 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 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 effective impervious cover, especially above public drinking water supply intakes.
- SW4. Promote LID in new construction and redevelopment.
- 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).
- WW2. Conduct inspections and pump-outs of OWTS.
- WW5. 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 6.8 Estimated Annual Cost

Recommendations	**Total Costs ($M/per year)**
Stormwater	12.17
Open Space	9.66
Wastewater	9.32
Agriculture	0.036
Education	0.11
Total	**$31.30**

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 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 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 Christina 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 6.9 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. 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:

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

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:

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

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:

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

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:

PV_{we} = $52/yr/household (400,000 p) / (2.9 p/household)
= $7,172,000/yr
= $7.2 M/yr

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 6.10 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 6.10 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 Christina 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 Delaware and the Christina Basin.

As reflected in the cost analysis in Section 6.1, implementing the Christina Basin PCS is a costly endeavor at an estimated $31.3 million per year. The PCS outlines 41 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. 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.

Chapter 7: Analysis for TMDL Achievement

Six years have passed since the TMDL for the Christina Basin was promulgated. Since that time, population and pressures from development have increased throughout the watershed. However, stormwater and wastewater have improved and farmers have increased their use of best management practices (BMPs). Increased use of BMPs in all sectors reduces nutrient loading and contributes to progress towards achieving water quality standards.

Estimated water quality improvement from the installation of best management practices, after the TMDL baseline, was calculated. Various databases were used to gather the number of practices in place. Scientists researched the nutrient load reduction efficiencies associated with these practices in order to estimate pollution reductions. Appendix C documents those calculations.

It's important to note that the TMDL issued by EPA bases its required reductions on a subwatershed basis. The data that we collect in Delaware at this time is collected on a watershed basis. Thus, in order to provide an estimate of TMDL achievement, the subwatershed reductions were added together to provide an estimated watershed load reduction to reach. This is just an estimate but can be used as an indicator of where our watersheds stand.

Table 7.1 Estimated Watershed TMDL Required Reductions

Watershed	*TN lbs/day required reduction*	*TP lbs/day required reduction*
Brandywine	29.12	3.88
Christina	108.11	4.70
Red Clay	82.34	9.74
White Clay	123.97	24.76

Agriculture

Since the baseline period, the agricultural community has reduced the amount of nonpoint source nitrogen and phosphorus, leading the efforts to curtail nonpoint source loadings. Multiple BMPs have been implemented and the Delaware Nutrient Management Act was passed. As of January 2007, all farms that apply nutrients to 10 acres or more are required to have Nutrient Management Plans (NMPs). Subsequent Farm Bills have also led to increased funding levels of cost-share programs for BMPs that protect the environment, especially water quality.

Table 7.2: Implemented Nutrient Reducing Agricultural Best Management Practices (BMP) in the Brandywine Watershed

	Acres	*TN reduced (lb/day)*	*TP reduced (lb/day)*
Cover Crops	2.00	0.07	0.00
Ponds	1,182.20	37.00	3.31
Hay and Pasture Planting	1,895.20	70.88	7.39
Grassed Filter Strips	450.00	44.82	4.48
Critical Area Planting	517.00	0.00	0.01
Nutrient Management Plans	46.00	0.50	0.05

Total Progress to Date:

- Estimated Nutrient Reductions: 153.27 lbs/day TN; 15.24 lbs/day TP

Table 7.3: Implemented Nutrient Reducing Agricultural Best Management Practices (BMP) in the Christina Watershed

	Acres	*TN reduced (lb/day)*	*TP reduced (lb/day)*
Hay and Pasture Planting	378.00	0.64	0.04

Total Progress to Date:

- Estimated Nutrient Reductions: 0.64 lbs/day TN; 0.04 lbs/day TP

Table 7.4: Implemented Nutrient Reducing Agricultural Best Management Practices (BMP) in the Red Clay Watershed

	Acres	*TN reduced (lb/day)*	*TP reduced (lb/day)*
Cover Crops	3.10	0.03	0.00
Ponds	7.00	0.05	0.00
Hay and Pasture Planting	25.00	0.04	0.00
Grassed Filter Strips	728.00	13.81	1.17
Wildlife Habitat	36.90	0.06	0.00
Nutrient Management Plans	205.40	0.62	0.06

Total Progress to Date:

- Estimated Nutrient Reductions: 14.61 lbs/day TN; 1.24 lbs/day TP

Table 7.5: Implemented Nutrient Reducing Agricultural Best Management Practices (BMP) in the White Clay Watershed

	Acres	*TN reduced (lb/day)*	*TP reduced (lb/day)*
Cover Crops	7.30	0.08	0.00
Hay and Pasture Planting	704.30	1.20	0.07
Grassed Filter Strips	805.50	15.28	1.30
Wildlife Habitat	5,036.90	8.56	0.50
Forest Buffers	3.00	0.09	0.00

Total Progress to Date:

- Estimated Nutrient Reductions: 25.11 lbs/day TN; 1.87 lbs/day TP

Open Space

New Castle County and the local governments located in the Christina Basin have furthered nutrient reductions by making open space and riparian buffer preservation a priority in these developing communities. By setting aside area during the development process that must remain grassed open space and protecting areas that are within the riparian buffer area, these entities are helping to protect waterways from nutrient pollution. In total, there are 180 acres of grassed open space preserved in the development process in the Brandywine watershed, 2,500 acres of grassed open space preserved in the development process in the Christina watershed, 230 acres of grassed open space preserved in the development process in the Red Clay watershed and 1,112 acres of grassed open space preserved in the development process in the White Clay watershed.

Total Progress to Date:

- Estimated Total Nutrient Reductions Christina Basin: 6.64 lbs/day TN: 0.93 lbs/day TP
- Estimated Nutrient Reductions Brandywine: 5.84 lbs/ day TN; 0.61 lbs/day TP
- Estimated Nutrient Reductions Christina: 4.25 lbs/ day TN; 0.25 lbs/day TP
- Estimated Nutrient Reductions Red Clay: 0.00 lbs/ day TN; 0.08 lbs/day TP
- Estimated Nutrient Reductions White Clay: 0.80 lbs/ day TN; 0.24 lbs/day TP

Onsite Wastewater

Estimates of current septic system pump outs and conversion of onsite wastewater systems to central sewer systems, while not extensive, has helped to decrease the nutrient pollution entering the Christina Basin. Due to current regulations, it is estimated that 1/3 of all septic systems in the Christina Basin are required to be pumped out every year. Thus, 2,003 septic systems in the watershed are estimated to be currently being pumped out a year while New Castle County documents show that 32 properties per year in the watershed have been converted from septic systems to central sewer systems. The current wastewater reductions from these practices were assigned to each watershed based upon the percent of septic systems found in the watershed. For example, 29.4% of the septic systems in the Christina Basin are found in the Brandywine

watershed so 29.4% of the total wastewater reductions (10.07 lb N/day) was estimated for Brandywine watershed (2.961 lb N/day).

Table 7.6: Implemented Wastewater Best Management Practices (BMP)

Watershed	*TN reduced lb/day*	*TP reduced lb/day*	*Percent of Septics*
Brandywine	1.177	0.033	11.5%
Christina	3.010	0.085	29.4%
Red Clay	2.775	0.079	27.1%
White Clay	3.276	0.093	32%

Total Progress to Date:

- Estimated Total Nutrient Reductions Christina Basin: 10.24 lbs/day TN: 0.29 lbs/day TP
- Estimated Nutrient Reductions Brandywine: 1.158 lbs/ day TN; 0.032 lbs/day TP
- Estimated Nutrient Reductions Christina: 2.961 lbs/ day TN; 0.082 lbs/day TP
- Estimated Nutrient Reductions Red Clay: 2.729 lbs/ day TN; 0.075 lbs/day TP
- Estimated Nutrient Reductions White Clay: 3.223 lbs/ day TN; 0.089 lbs/day TP

Wastewater is one sector that is of great importance towards implementing future practices to reach TMDL goals. As such, there have been estimates created that incorporate some of the PCS recommendations for the future of wastewater including future septic pump outs, elimination of cesspools, installation of performance standards, and septic to sewer conversion.

Table 7.7: Future Wastewater Best Management Practices

Watershed	*TN reduced lb/day*	*TP reduced lb/day*	*Percent of Septics*
Brandywine	30.04	1.05	11.5%
Christina	76.81	2.69	29.4%
Red Clay	70.80	2.48	27.1%
White Clay	83.60	2.93	32%

Future Estimates:

- Estimated Total Nutrient Reductions Christina Basin:261.24 lbs/day TN: 9.16 lbs/day TP
- Estimated Nutrient Reductions Brandywine: 30.02 lbs/ day TN; 1.05 lbs/day TP
- Estimated Nutrient Reductions Christina: 76.76 lbs/ day TN; 2.69 lbs/day TP
- Estimated Nutrient Reductions Red Clay: 70.75 lbs/ day TN; 2.48 lbs/day TP
- Estimated Nutrient Reductions White Clay: 83.54 lbs/ day TN; 2.93 lbs/day TP

Stormwater

In June 1990, the Delaware Legislature passed the Sediment and Stormwater Law to help correct the state's water quality and quantity problems. The implementing program was initiated in July of 1991 and addresses sediment control during construction and post-construction, stormwater quantity and water quality control. Since this implementation, many BMPs for stormwater have been implemented and more are constructed each year. The Sediment and Stormwater Regulations are currently being revised to promote the use of stormwater management techniques that are more efficient at reducing nutrient loading and promote Green Technology

BMPs or stormwater management practices based on low impact development and conservation design. This does not serve as a comprehensive estimate of all the stormwater BMPs in the Christina Basin because there is a lack of complete data available. Thus, there are many more stormwater BMPs in the Christina Basin and these estimates are low.

Table 7.8: Total Stormwater BMPs Implemented to Date in Brandywine

BMP	*Acres*	*TN Reduced (lb/day)*	*TP Reduced (lb/day)*
Dry Pond	247.84	1.82	0.084
Wet Pond	244.00	1.79	0.207
Sand Filter	2.01	0.02	0.002
Biofiltration	3.63	0.04	0.004

Total Progress to Date:

- Estimated Nutrient Reductions: 3.679 lbs/day TN; 0.298 lbs/day TP

Table 7.9: Total Stormwater BMPs Implemented to Date in Christina

BMP	*Acres*	*TN Reduced (lb/day)*	*TP Reduced (lb/day)*
Dry Pond	3,890.78	10.62	0.778
Wet Pond	3,041.94	8.30	1.521
Sand Filter	69.01	0.25	0.041
Biofiltration	221.93	1.01	0.155

Total Progress to Date:

- Estimated Nutrient Reductions: 20.19 lbs/day TN; 2.50 lbs/day TP

Table 7.10: Total Stormwater BMPs Implemented to Date in Red Clay

BMP	*Acres*	*TN Reduced (lb/day)*	*TP Reduced (lb/day)*
Dry Pond	1,258.00	6.53	0.352
Wet Pond	566.77	2.95	0.397
Bioretention	12.19	0.11	0.012
Biofiltration	3.34	0.03	0.003

Total Progress to Date:

- Estimated Nutrient Reductions: 9.61 lbs/day TN; 0.76 lbs/day TP

Table 7.11: Total Stormwater BMPs Implemented to Date in White Clay

BMP	*Acres*	*TN Reduced (lb/day)*	*TP Reduced (lb/day)*
Dry Pond	3,703.01	23.11	0.815
Wet Pond	2,354.72	14.69	1.295
Infiltration	7.31	0.08	0.006
Biofiltration	21.18	0.22	0.016

Total Progress to Date:

- Estimated Nutrient Reductions: 38.10 lbs/day TN; 2.13 lbs/day TP

Stormwater is another sector that is of great importance towards implementing future practices to reach TMDL goals. As such, there have been estimates created that incorporate some of the PCS recommendations for the future of stormwater including estimates of nutrient reductions from future stormwater retrofits.

Table 7.7: Future Stormwater Best Management Practices

Watershed	*TN reduced lb/day*	*TP reduced lb/day*	*Acres of Future Retrofit*
Brandywine	1.10	0.09	149.24
Christina	6.06	0.75	2,167.10
Red Clay	2.88	0.23	552.39
White Clay	11.43	0.64	1,825.87

Future Estimates:

- Estimated Total Nutrient Reductions Christina Basin: 21.47 lbs/day TN: 1.71 lbs/day TP
- Estimated Nutrient Reductions Brandywine: 1.10 lbs/ day TN; .0.09 lbs/day TP
- Estimated Nutrient Reductions Christina: 6.06 lbs/ day TN; 0.75 lbs/day TP
- Estimated Nutrient Reductions Red Clay: 2.88 lbs/ day TN; 0.23 lbs/day TP
- Estimated Nutrient Reductions White Clay: 11.43 lbs/ day TN; 0.64 lbs/day TP

Overall Nutrient Load Reduction Progress

Promulgation of this Pollution Control Strategy and full implementation of its elements should lead to the achievement of the TMDLs for Total Nitrogen (TN) and Total Phosphorus (TP). Because of the lag time between seeing improvements in ground and surface water quality, estimated to be up to 30 years, improved water quality conditions will not be realized immediately. The Department will continue to monitor water quality as will many citizen volunteers. The Department is committed to revisit this Pollution Control Strategy in 10 years to ensure that water quality is improving with implementation of the regulations and voluntary practices called for within this document.

Analysis using a basic land use loading rate model shows that our watersheds have come a long way towards meeting TMDL requirements. The model shows that both the Brandywine and Christina watersheds are meeting TMDL requirements through implementation of the PCS. Due

to a lack of stormwater and open space BMP data and estimation methods for extrapolating stream segment data into watersheds, the model is unable to show that the Red Clay and White Clay watersheds will meet TMDL requirements with the help of this PCS. However, this does not mean that it will not reach TMDL requirements. When this lacking data is gathered, we believe that our model will show attainment. Figures 7.1 and 7.2 show all the load reductions able to be estimated and discussed in this chapter. Table 7.12 shows the reductions required and how far the current and future practices help to reach those reductions.

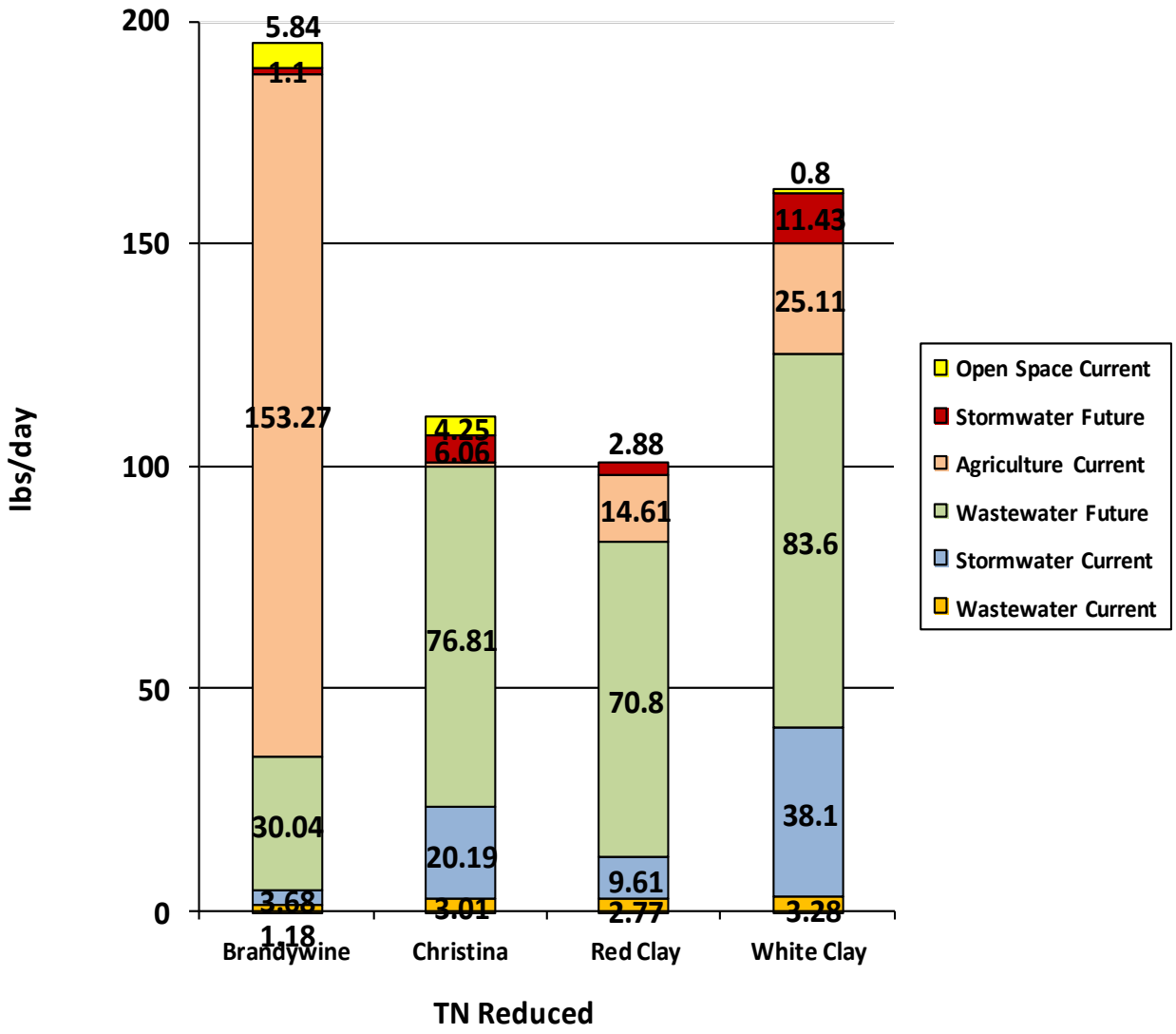


Figure 7.1 Total Nitrogen Reductions (lb/day)

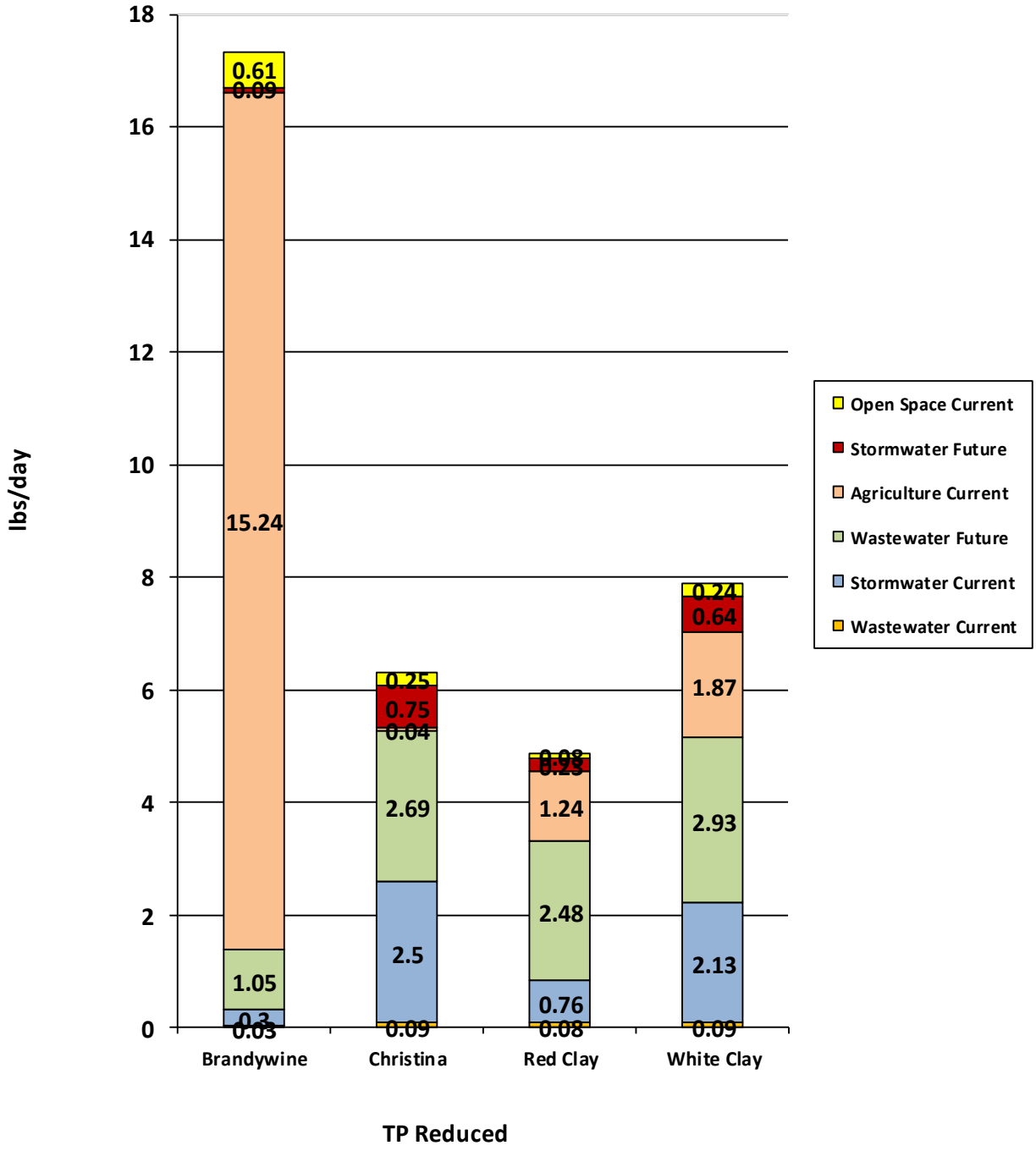


Figure 7.2 Total Phosphorus Reduced

Table 7.12: TMDL Achievement

Watershed	*TN lbs/day TMDL Requirement*	*TP lbs/day TMDL Requirement*	*Estimated TN lbs/day Reductions (Current and Future)*	*Estimated TP lbs/day Reductions (Current and Future)*
Brandywine	29.12	3.88	195.12	17.32
Christina	108.11	4.70	110.95	6.31
Red Clay	82.34	9.74	100.68	4.87
White Clay	123.97	24.76	162.31	7.91

Every effort has been made to make the Strategy fair and equitable. It impacts everyone in the watershed given that all activities contribute to nutrient loading. And, it attempts to take cost into consideration through promoting the least expensive actions and cost-share for those actions that are more expensive. The Department intends to review the Strategy in 10 years and update it if further actions are needed to improve water quality.

References

1. A. E. Boardman, D. H. Greenberg, A. R. Vining, and D. L. Weimer, *Cost - Benefit Analysis Concepts and Practice,* Second Edition, Prentice Hall Publisher, 2001.

2. A. E. Boardman, D. H. Greenberg, A. R. Vining, and D. L. Weimer, *Cost - Benefit Analysis Concepts and Practice,* Third Edition, Prentice Hall Publisher, 2006.

3. Arthur Fagerstrom, Veolia Water North America, "Nutrient load data for WWTP," e-mail message, November 3, 2006.

4. Barbara Deutsch and Heather Whitlow (Casey Trees) and Michael Sullivan, Anouk Savineau, and Brian Basiek (Limno Tech), "The Green Build-out Model: Quantifying the Stormwater Management Benefits of Greenroofs and Trees in Washington D.C.," under USEPA Cooperative Agreement CP-83282101-0, May 15, 2007.

5. Bernard W. Sweeney, Thomas L. Bott, John K. Jackson, Louis A. Kaplan, J. Denis Newbold, Laurel J. Standley, W. Cully Hession, and Richard J. Horwitz, "Riparian deforestation, stream narrowing, and loss of stream ecosystem services," *PNAS*, Volume 101, Number 39, September 28, 2004, p. 14132–14137.

6. Bryan Hall, Urban and Community Forestry Program, Delaware Forest Service, "Section 6 Forest Buffer Requirement" PowerPoint presentation, April 2007.

7. Chester County Water Resources Authority, *Watersheds: An Integrated Water Resources Plan for Chester County, Pennsylvania and Its Watersheds,* County of Chester, Pa., adopted September 17, 2002.

8. CH2M-Hill, "Costs of Providing Government Services to Alternative Residential Patterns," *Committee on Population Growth and Development,* USEPA Chesapeake Bay Program, Annapolis, Md., 1993, p. 168.

9. City Code, Chapter 45, Section 45–53, Wilmington, Delaware.

10. "City of Wilmington Enhanced Long Term Control Plan," Greeley and Hansen, LLC., December 2003.

11. Conservation Council of New Brunswick, Inc., *Estimating human-derived nitrogen-loading to New Brunswick estuaries: A simple export model,* 2004.

12. Dan Greig, Janet Bowers and Gerald Kauffman, *Final Phase I & II Report, Christina River Basin Water Quality Management Strategy: "A Christina Clean Water Strategy"* May 1998.

13. David J. Nowak, Robert E. Hoehn, Jun Wang, and Vikram Krishnamurthy, “Urban Forest Assessment in Northern Delaware,” USDA Forest Service, Northern Research Station, and SUNY College of Environmental Science and Forestry, In Press.

14. Delaware Environmental Navigator, 2000, 2001 Delaware Department of Natural Resources and Environmental Control, <http://www.nav.dnrec.delaware.gov/dnreceis/>, accessed on July 18, 2007.

15. Department of Natural Resources and Environmental Control, Division of Water Resources, Watershed Assessment Section, “State of Delaware Surface Water Quality Monitoring Program FY 2007,” 2007.

16. DNREC and Delaware Tributary Action Teams,” Third Workshop Draft, Inland Bays Pollution Control Strategy,” August 2006, p. 6–7 of Appendix E.

17. E. Gregory McPherson, James R. Simpson, Paula.J. Peper, and Qingfu Xiao, “Benefit-Cost Analysis of Modesto’s Municipal Urban Forest,” Journal of Arboriculture, Volume 25 Number 5, September 1999, p. 235–248.

18. Fiscal Year 2007 Comprehensive Annual Budget Summary, New Castle County Delaware, <http://www.co.new-castle.de.us/countyfinances/home /fileuploads/images/cabs2007smaller.pdf>, Accessed on May 25, 2007.

19. Gerald J. Kauffman, University of Delaware, WRA, conversation with Martha Corrozi, September 28, 2006.

20. Gerald Kauffman, Sara Wozniak, and Kevin Vonck. A Water Restoration Action Strategy (WRAS) for the Delaware Portion of the Christina Basin: A Clean Water Strategy to Protect and Restore the Watersheds of the Brandywine, Red Clay, and White Clay Creeks and the Christina River, June 2003.

21. <http://actrees.org/site/resources/index.php>, accessed on January 18, 2007.

22. <http://ohioline.osu.edu/for-fact/0061.html>, accessed on January 18, 2007.

23. <http://www.americanforests.org/news/display.php?id=91>, accessed on January 19, 2007.

24. <http://www.chesapeakebay.net/pubs/subcommittee/nsc/uswg/BMP_Stream_Restoration _and_Pollutant_Load_Reductions.PDF>, accessed on May 9, 2007.

25. <http://www.chesapeakebay.net/Info/wqcriteriatech/tributary_de.cfm>, accessed on March 12, 2007.

26. <http://www.co.new-castle.de.us/CZO/txtframe_ns.asp?Section=021&Level=1>, accessed on March 28, 2007.

27. <http://www.delawarenaturesociety.org>, accessed on April 24, 2007.

28. <http://www.lid-stormwater.net/bioretention/bio_costs.htm#4>, accessed on June 13, 2007.

29. <http://www.lid-stormwater.net/permeable_pavers/permpaver_costs.htm>, accessed on April 19, 2007.

30. <http://www.nature.org/wherewework/northamerica/states/delaware/science /art16920.html>, viewed on April 19, 2006.

31. <http://www.dnrec.state.de.us/water2000/Sections/Watershed/WS/pcs.htm>, viewed on February 10, 2007.

32. *Impacts of Impervious Cover on Aquatic Systems, Watershed Protection Research Monograph No.1,* Center for Watershed Protection, Ellicott City, Md., March 2003.

33. Jason Zern, New Castle County, Department of Special Services, "Christina Basin Study," e-mail message, August 18, 2007.

34. Jason Zern, Department of Special Services, "Christina Basin Study," e-mail message, September 4, 2007.

35. Jessie Benjamin, Landscape, Designer, Taproot Native Design, "Buffers," e-mail message, April 27, 2007.

36. Jessie Benjamin, Landscape, Designer, Taproot Native Design, "Buffer Costs," e-mail message, February 13, 2007.

37. Jessie Benjamin, Landscape, Designer, Taproot Native Design, "Open Space Maintenance Plans," e-mail message, November 29, 2006.

38. Jessie Benjamin, Landscape, Designer, Taproot Native Design, "Riparian Buffer Costs and Nutrient Reductions," e-mail message, August 8, 2006.

39. Karen Cappiella, Tom Schueler, and Tiffany Wright, Center for Watershed Protection, *Urban Watershed Forestry Manual Part 1: Methods for Increasing Forest Cover in a Watershed,* NA-TP-04-05, United States Department of Agriculture Forest Service Northeaster Area State and Private Forestry, Newtown, Pa., July 2005, p. A-2.

40. Karen Cappiella, Tom Schueler, and Tiffany Wright (Center for Watershed Protection), *Urban Watershed Forestry Manual Part 1: Methods for Increasing Forest Cover in a Watershed,* NA-TP-04-05, United States Department of Agriculture Forest Service Northeaster Area State and Private Forestry, Newtown, Pa., July 2005, p. 4.

41. Kash Srinivasan, Commissioner, City of Wilmington, Delaware, Public Works Department), conversation with Martha Corrozi, September 29, 2006.

42. Kimberly C. Cloud, "Changes and Trends in Streamflow during Floods and Droughts in the Urbanizing Christina River Basin," master's thesis, University of Delaware, Newark, Del., 2007.

43. Linda Stapleford, River Administrator, White Clay Creek Wild and Scenic Program, conversation with Martha Corrozi, September 28, 2006.

44. Lyle Jones, DNREC, Division of Water Resources, Watershed Assessment Section, conversation with Martha Corrozi, April 2007.

45. Lyle Jones, DNREC, Division of Water Resources, Watershed Assessment Section, conversation with Martha Corrozi, May 2007.

46. Lyle Jones, DNREC, Division of Water Resources, Watershed Assessment Section, "Loading Rates", e-mail message, March 12, 2007.

47. "Making Research Work for You: The Story of Greenprint," *Urban Forest Research,* Summer 2005, Center for Urban Forest Research, Pacific Southwest Research Station, USDA Forest Service, Davis, Cal., 2005, p. 1, <http://www.fs.fed .us/psw/programs/cufr/products/cufr604_newsletter_summer2005.pdf>.

48. R. Walsh, et al., *Benefit Transfer of Outdoor Recreation Demand Studies, 1968-1988.* Water Resources Research, 28. No. 3. 1992.

49. "Reducing Stormwater and Flooding: The Ten Principles of Effective Stormwater Management," Chester County Water Resources Authority and Chester County Planning Commission, December 2004.

50. Saurabh Srivastava, New Castle County Department of Special Services, e-mail message, December 14, 2006.

51. Stephen Williams, DNREC, Ecological Restoration Coordinator, "Stream Restoration," e-mail message, February 16, 2007.

52. *The Bioretention Manual*, Prince George's County Department of Environmental Resources Programs and Planning Division, Md., 2001.

53. Thomas Schueler, "Comparative Pollutant Removal Capability of Urban BMPs: A Reanalysis," *Watershed Protection Techniques*, Volume 2, Number 4, Center for Watershed Protection, Ellicott City, Md., 1997, p. 515–520.

54. Thomas Schueler, “Use of Cluster Development to Protect Watersheds,” *Watershed Protection Techniques*, Volume 1, Number 3, Center for Watershed Protection, Ellicott City, Md., 1994, p. 137–140.

55. Thomas, Schueler, “Comparative Pollutant Removal Capability of Urban BMPs: A Reanalysis,” *Watershed Protection Techniques*, Volume 2(4), Center for Watershed Protection, Ellicott City, Md., 1997, p. 515–520.

56. Thomas R. Schueler and Heather K. Holland, *The Practice of Watershed Protection: Techniques for Protecting Our Nation’s Stream, Lakes, Rivers and Estuaries,* Center for Watershed Protection, Ellicott City, Md., 2000.

57. USEPA Office of Water, “Storm Water Technology Fact Sheet: Bioretention,” EPA 832-F-99-012, 1999.

58. USEPA, *National Management Measures to Control Nonpoint Source Pollution from Urban Areas,* EPA-841-B-05-004, p. 6–40.

59. USEPA, Region 9, Ground Water Office, “Seepage Pits May Endanger Ground Water Quality,” EPA 909-F-01-001, April 2001.

60. Walsh, R., et al., *Benefit Transfer of Outdoor Recreation Demand Studies, 1968-1988,* Water Resources Research, 28, Number 3, 1992.

61. <www.unri.org/fos/>, accessed on June 15, 2007.

62. White Clay Creek Wild and Scenic Study Task Force with assistance from the National Park Service Northeast Region, Philadelphia Support Office, *White Clay Creek and Its Tributaries: Watershed Management Plan with Reference Sections*.

63. William Mates, *Valuing New Jersey’s Natural Capital: An Assessment of the Economic Value of the State’s Natural Resources, Part III: Natural Goods.* New Jersey Department of Environmental Protection, 2007.