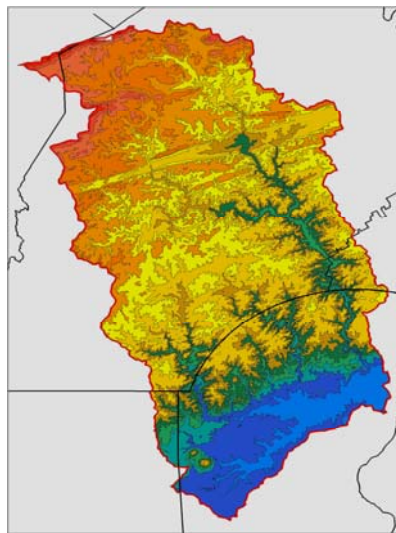


EXECUTIVE SUMMARY

A Watershed 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 Christina River in Delaware"

June 2003



Prepared for:

Christina Basin Clean Water Partnership

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Table of Contents

Chapter	Page
1. The Watershed Environment	1
2. Problems, Goals, and Objectives	4
3. Christina Basin Report Card	9
4. Priority Watersheds of the Christina Basin	16
5. Recommended Watershed Restoration Action Strategy	19
6. WRAS Progress in Delaware	24
References	28

Figures	Page
1. Base Map of Christina Basin	1
2. Land Use in Christina Basin	2
3. Christina Basin Stream Reaches on the DE 1998 303 (d) List	5
4. Reduction in TMDL of Nutrients and D.O. under Low Flow Conditions	5
5. Members and Organization of the Christina Basin Clean Water Partnership	7
6. Accomplishments of the Christina Basin Partnership Since 1995	8
7. Criteria to Assign Watershed Grades	11
8. Preliminary Watershed Grading Measurements	12
9. Watershed Grades per Criteria	13
10. Report Card Summarizing Stream Water Quality	14
11. Report Card Summarizing Indicator Quality	15
12. Recommended Watershed Protection or Restoration Strategies	16
13. Impaired Stream Segments	17
14. Watershed Pollution Potential	17
15. Watershed Restoration Action Strategy (WRAS) Map	18
16. Protection/Preservation Watershed BMPs	21
17. Restoration Watershed BMPs	22
18. Relationship of WRAS BMPs to Watershed Goals	23

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Funding

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Purpose of the Report

This report provides a recommended Watershed Restoration Action Strategy (WRAS) for the Delaware portion of the Christina River Basin. The WRAS draw on information obtained from two previous reports (Christina Basin Water Quality Management Strategy Phase I and II report, May 1998 and the Phase III report, August 1999) and is intended to provide a guideline for future watershed protection and restoration actions. The WRAS is also designed to interconnect with the low flow, point source Total Maximum Daily Loads (TMDLs) for the Christina Basin that were established by U.S. Environmental Protection Agency in 2002 and the high flow, nonpoint source TMDLs which are due to be set in 2004.

Chapter 1: The Watershed Environment

A Unique Watershed

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

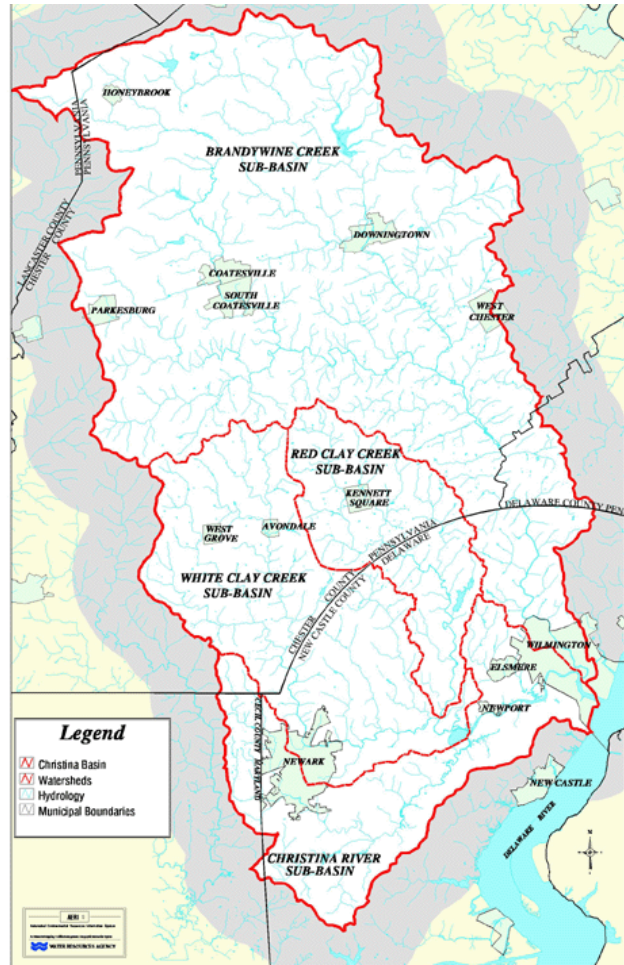
- Only source of public surface water supply in Delaware. The streams and wells in the basin provide 100 mgd of drinking water for over 400,000 people, which is over 70% of the population in New Castle County or 60% of the state population.
- Home to almost half of the State’s citizens in the most northern and populous county in Delaware.
- Address of the first and third largest cities in Delaware: Wilmington and Newark.
- Habitat to the only six trout streams in Delaware.
- Environment of neo-tropical bird species in hilly, contiguous Piedmont forests that are found in only 3% of Delaware.
- Only watershed in Delaware to encompass three states: Delaware, Pennsylvania, and Maryland.

The Christina River Basin:

- Occupies 565 square miles - a little larger than the size of New Castle County.
- Includes the upper 2/3 in the headwaters of Pennsylvania and the lower third within Delaware and a small slice of Maryland (Figure 1).
- Includes 4 major watersheds:
 - 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:
 - 3 states: Delaware, Pennsylvania, and Maryland.
 - 5 counties: Chester, Lancaster, Delaware counties (PA), New Castle County (DE), and Cecil County (MD).
 - Over 60 townships, boroughs, and cities such Newark and Wilmington in Delaware and Coatesville, Downingtown and West Chester in Pennsylvania.
- Is the home to close to 0.5 million people in three states:

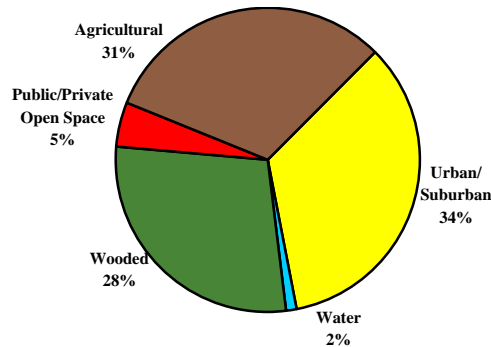
<i>State</i>	<i>Population (1995)</i>	<i>% Pop.</i>
DE	310,638	62 %
MD	8,039	2 %
PA	181,079	36 %
Total	499,751	100%

Figure 1. Base Map of Christina Basin



- Divides into three land uses of similar, but changing proportions – urban/suburban (1/3), agriculture (1/3), and open space/forests (1/3).

Figure 2. Land Use in the Christina Basin



- Is perched along the geologically unique Fall Line. The Fall Line runs through a line stretched between Newark and Wilmington and separates the hilly, rocky Piedmont province from the flat, sandy Coastal Plain.

Recreational Resources

The streams of the Christina Basin provide a variety of recreational opportunities such as:

- *Canoeing*: The Brandywine Creek hosts many canoe and kayak enthusiasts.
- *Boating*: 8,400 registered boats ply the tidal waters of the Christina River.
- *Trout Fishing*: Over 2,700 trout stamps are sold to anglers and 30,000 trout stocked annually along the only six trout streams in Delaware.
- *Warm Water Fishing*: The tidal waters support a striped bass fishery and the nontidal waters of the Brandywine Creek provide exceptional smallmouth bass fishing habitat.

Historic and Cultural Resources

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

- *Revolutionary War Battlefields*: Brandywine near Chadds Ford, Pennsylvania, and Cooches Bridge near Newark, Delaware.
- *Farming*: University of Pennsylvania Veterinary College, cattle farming at the King Ranch (largest ranch east of the Mississippi River), and settlement by Amish farmers.
- *Museums*: Hagley Museum in Wilmington and the Brandywine Museum at Chadds Ford.
- *Art*: Inspiration for the "Brandywine School" and Wyeth style of art.
- *Gardens*: Winterthur and Longwood Gardens.
- *Higher Education*: University of Delaware in Newark, Wilmington College, Widener University School of Law, University of Pennsylvania Veterinary School, and West Chester University.

Economic Resources

The Christina Basin is home to the following economic sectors:

- *Corporations*: International home of companies including DuPont, MBNA, and W.L. Gore.
- *Wilmington Riverfront Revitalization*: An urban renaissance along the tidal Brandywine and Christina River.
- *Port of Wilmington*: One of the largest importers of grapes, bananas, and automobiles nationally.
- *Mushroom Farms*: The White Clay and Red Clay Creek watersheds are the home of the largest concentration of mushroom growers in the U.S.

Ecological and Natural Functions

The Christina Basin provides many ecological and natural functions:

- *Parks*: Brandywine Creek State Park, White Clay Creek State Park, Middle Run Preserve near Newark and Delcastle Park near Wilmington.
- *Conservation Areas*: Large privately owned conservation areas include Woodlawn Trustees land along the Brandywine Creek and Delaware Nature Society open space land along the Red Clay Creek in Delaware.
- *Habitat*: Habitat for several Federal or State-listed endangered or threatened species:
 - Bog Turtle (*Clemmys muhlenbergi*)
 - 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 are designated by DNREC as waters of Exceptional Recreational and Ecological Significance (ERES waters)
- *Wild and Scenic Status*: The White Clay Creek is the only wild and scenic river in Delaware and is the first river nationally to be protected on a watershed basis.

Watershed Organizations

The people of the Christina Basin provide watershed stewardship through various nonprofit organizations such as:

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

Additional information regarding the Christina Basin can be obtained from the following web sites:

- University of Delaware, Institute for Public Administration, Water Resources Agency (www.wr.udel.edu)
- Delaware DNREC Whole Basin program (www.delaware.gov)
- Chester County Water Resources Authority (www.chesco.org)
- Pennsylvania Department of Environmental Protection (www.state.pa.us)
- Delaware River Basin Commission (www.drbc.net)
- US Environmental Protection Agency (www.epa.gov/owow)
- U.S. Geological Survey (www.usgs.gov)
- Delaware Geological Survey (www.dgs.udel.edu)
- University of Delaware Spatial Analysis Lab (www.bluehen.ags.udel.edu/spatlab/)

Chapter 2: Problems, Goals, and Objectives

Water Quality Problems

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

- 1) *Nutrients*: 130.5 stream miles have higher than desired nitrogen and phosphorus loads, which deplete dissolved oxygen levels
- 2) *Toxics (metals)*: 13 stream miles are impaired due to elevated zinc levels
- 3) *Bacteria (pathogens)*: Concentrations along 134.2 miles of stream frequently exceed the primary recreation standards for swimming of 100 colonies per 100 milliliters
- 4) *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
- 5) *Sediment*: The streams are degraded by high sediment loads which range between 311 to 975 pounds per acre annually depending on the subwatershed.
- 6) *Stream Habitat*: While biological diversity of the streams has been improving, 39% 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).

Watershed Pollution Potential

Based on the May 1998 Phase I and II watershed inventory conducted for the Christina Basin Water Quality Management Strategy, the potential sources of pollutant loads in the watershed include (in alphabetical order):

	Delaware	Pennsylvania
• Agriculture		40% of watershed in PA
• Combined Sewer Overflows	37 CSOs	
• NPDES Wastewater Discharges	14 Outfalls	82 Outfalls
• Roadways	2 % of watershed in DE	2 % of watershed in PA
• Solid Waste/Hazardous Waste/Superfund Sites	78 Sites identified	
• Underground Storage Tanks	763 sites identified	
• Urban/Suburban Runoff	53% of watershed in DE	27 % of watershed in PA

Total Maximum Daily Loads

In 1997, Delaware and Pennsylvania consented with the U. S. Environmental Protection Agency to establish low flow and high flow Total Maximum Daily Loads (TMDLs) in the Christina Basin. The low flow (point source) TMDLs were issued by the USEPA in October 2002. USEPA expects to complete the high flow (stormwater) TMDLs by December 2004. TMDLs are established along impaired waterways in accordance with Section 303(d) of the Federal Clean Water Act. TMDLs are determined using hydrologic and hydraulic computer models according to the following equation:

$$TMDL = WLA + LA + FS$$

TMDL = Maximum amount of a particular pollutant discharged to a waterway without violating stream water quality standards

WLA = The waste load allocation from point sources such as wastewater treatment plants during low flow conditions

LA = Load allocation from nonpoint sources such as stormwater and agricultural runoff during high flow conditions

FS = Factor of safety to account for imprecision in modeling and monitoring

Delaware identified 15 stream segments on its 1998 Section 303(d) list as not meeting water quality standards for nutrients and low dissolved oxygen within the Christina Basin. Figure 3 lists the impaired stream reaches on this list.

Figure 3. Christina Basin Stream Reaches on the DE 1998 303(d) List

Watershed ID	Watershed Name	Subwatershed	Miles	Pollutants
B16	Brandywine Creek	Brandywine Creek above Wilmington	9.3	nutrients
B17	Brandywine Creek	Brandywine Creek below Wilmington	3.8	nutrients
R3	Red Clay Creek	Burroughs Run	4.5	nutrients
R4 and R5	Red Clay Creek	Red Clay Creek above and below Woodale	12.8	nutrients
W5	White Clay Creek	Mill Creek	16.6	nutrients
W6	White Clay Creek	Pike Creek	9.4	nutrients
W7	White Clay Creek	Middle Run	5.8	nutrients
W8, W9, W10	White Clay Creek	White Clay Creek above/below Newark	18.2	nutrients
C1	Christina River	Upper Christina River above Cooches Bridge	28.3	nutrients
C4	Christina River	Little Mill Creek	12.8	nutrients, DO
C5	Christina River	Christina River below Newark	7.5	nutrients
C6	Christina River	Tidal Christina below Smalley's Pond	1.5	nutrients, DO

Low Flow TMDL

In October 2002 USEPA issued the low flow TMDL for the Christina Basin. The TMDL calls for eight wastewater dischargers to reduce chemical/biological oxygen demand (CBOD5), Nitrogen (NH3-N), and Total Phosphorus (TP) loads in accordance with the amounts listed in Figure 4. Necessary reductions in pollutant loads will be accomplished as part of renewal of NPDES discharge permits.

Figure 4. Reduction in TMDL of Nutrients and Dissolved Oxygen under Low Flow Conditions in the Christina Basin

NPDES Facility	Permit Number	Flow (mgd)	Level 1 and 2 Reduction		
			CBOD5	NH3-N	TP
East Branch Brandywine Creek					
Broad Run Sew. Co	PA0043982	.4	8%	0%	6%
Sonoco Products	PA0012815	1.028	28%	28%	28%
Downingtown Area Reg. Auth.	PA0026531	7.134	36%	36%	36%
West Branch Brandywine Creek					
PA American Water Co.	PA0026859	3.85	28%	0%	28%
NW Chester Co. Mun. Auth.	PA0044776	.6	10%	10%	10%
West Branch Red Clay Creek					
Kennett Square	PA0024058	1.1	34%	34%	34%
Sunny Dell Foods, Inc.	PA0057720-001	.05	5%	5%	5%
West Branch Christina River					
Meadowview Utilities, Inc.	MD0022641	.7	0%	69%	0%

High Flow TMDL

The U.S. Geological Survey was retained to prepare a high flow, nonpoint source TMDL watershed model for the Christina Basin using the Hydrologic Simulation Program - Fortran (HSPF). The model is designed to simulate effects of nonpoint source loads for nutrients (N and P) and suspended sediment for the high flow TMDL. The USGS prepared four subwatershed HSPF models according to the following schedule (Senior and Koerkle, 2001, 2002, and 2003):

Brandywine Creek Subwatershed	Draft Report October 19, 2001
Red Clay Creek Subwatershed	Draft Report November 1, 2002
White Clay Creek Subwatershed	Draft Report June 13, 2002
Christina River Subwatershed	Draft Report February 1, 2002
Christina Basin High Flow TMDL due	December 2004

Watershed Governance

Since 1994, local agencies in Delaware and Pennsylvania have coordinated the activities of the overall watershed strategy on behalf of the Christina Basin Clean Water Partnership. The Chester County Water Resources Authority and Chester County Conservation District serve as local watershed coordinators for the Pennsylvania portion of the basin. The University of Delaware, Institute for Public Administration, Water Resources Agency serves as a local coordinator for the Delaware portion of the Basin. An alliance of federal, state, and local entities have served the following roles:

<i>Watershed Coordination:</i>	Chester County Water Resources Authority Chester County Conservation District University of Delaware, Water Resources Agency
<i>GIS Watershed Inventory:</i>	University of Delaware, Institute for Public Administration, Water Resources Agency
<i>Stream Monitoring:</i>	Pennsylvania Dept. of Environmental Protection Delaware Dept. of Natural Resources and Environmental Control
<i>Stormwater Monitoring:</i>	U.S. Geological Survey University of Delaware, College of Agriculture and Natural Resources
<i>Total Maximum Daily Load</i>	Delaware River Basin Commission
<i>(TMDL) Modeling:</i>	U.S. Environmental Protection Agency
<i>Public Education/Outreach:</i>	Brandywine Valley Association Red Clay Valley Association Christina Basin Task Force Delaware Nature Society
<i>BMP Implementation Projects:</i>	Chester County Conservation District New Castle Conservation District
<i>Integrated Watershed Programs:</i>	Chester County Water Resources Authority (Water Resources Mgmt. Plan) Delaware DNREC (Piedmont Whole Basin Program)
<i>Section 319 Funding:</i>	Pennsylvania DEP, Bureau of Watershed Conservation Delaware DNREC, Div. of Soil and Water Conservation U.S. Environmental Protection Agency, Region III
<i>Watershed Funding Banker:</i>	Delaware River Basin Commission

Figure 5. Members and Organizations of the Christina Basin Clean Water Partnership

Category	Entities Represented
<i>Policy Committee</i>	Delaware Department of Natural Resources and Environmental Control Delaware River Basin Commission Pennsylvania Department of Environmental Protection U.S. Environmental Protection Agency, Region III
<i>Local Co- Coordinators</i>	Chester County Water Resources Authority, Pennsylvania Chester County Conservation District, Pennsylvania University of Delaware, Institute for Public Administration, Water Resources Agency
<i>Members</i>	Brandywine Valley Association and Red Clay Valley Association Chester County Board of Commissioners, Pennsylvania Christina Conservancy Delaware Nature Society New Castle Conservation District, Delaware New Castle County Executive and Department of Planning, Delaware U.S. Department of Agriculture, Natural Resources Conservation Service U.S. Department of Interior, National Park Service U.S. Department of Interior, U.S. Geological Survey White Clay Watershed Association



Mission Statement

The mission of the Christina Basin Clean Water Partnership is to conduct a cooperative, interstate effort to restore the water quality of the streams and tributaries in the Brandywine, Red Clay and White Clay Creeks, and Christina River watersheds of Delaware, Maryland, and Pennsylvania to fishable, swimmable, and potable status by 2015.

Goals and Objectives

To protect and improve stream water quality, the Christina Basin WRAS hopes to achieve the following goals:

Goal No. 1 – Nutrients: Substantially reduce nutrient (nitrogen and phosphorus) pollutant loads to meet the fishable water quality standards in accordance with the future Christina Basin Total Maximum Daily Loads

Goal No. 2 – Toxics: Remediate the existing sources of zinc to reduce toxics loads in accordance with Delaware water quality standards and the Christina Basin TMDLs

Goal 3 – Bacteria: Reduce bacteria loads in the streams to meet the Delaware swimmable primary recreation water quality standard of less than 100#/100 ml

Goal No. 4 – Fish Consumption Advisories: Cleanup the hazardous waste sources of PCBs to reduce loads and ultimately lift existing fish consumption advisories

Goal 5 – Sediment: Reduce total sediment loads from land and stream erosion sources to less than 250 pounds per acre per year

Goal No. 6 – Stream Habitat: Improve stream habitat to a "good" rating (above 81% for Habitat Community Index and 61% for Biological Community Index) in the Delaware portion of the Christina Basin

Figure 6. lists some of the accomplishments of the Christina Basin Clean Water Partnership since 1995.

Figure 6. Accomplishments of the Christina Basin Partnership since 1995

1	Developed, promulgated, and implemented a series of low-flow TMDLs
2	Conducted monitoring and modeling for development of high-flow nonpoint source (NPS) TMDLs
3	Installed over 50 agricultural Best Management Practices (BMPs)
4	Restored over 10,000 linear feet of stream banks
5	Established a Storm Water BMP Tour for municipal officials and designers
6	Engaged over 300 residential property owners in SMARTYARD lawn management and rain barrel stewardship programs
7	Established the Christina Basin Task Force as a mechanism for stakeholder participation
8	Updated municipal comprehensive plans and zoning ordinances in dozens of municipalities to incorporate sustainable land use management strategies
9	Preserved hundreds of acres of riparian and other lands
10	Overcame issues of inconsistent policies and institutional barriers that spanned multiple jurisdictions

Chapter 3: Christina Basin Report Card

Existing Watershed Data

This chapter issues a report card summarizing the health of the streams and subwatersheds in the Christina Basin. Drawing from existing water quality, stream habitat, and watershed data, the report card grades the streams and subwatersheds of the Christina Basin in an "A" through "F" format. The following data sources are used to assess the health of the watersheds:

- 1) Source Water Assessment Reports, Delaware Source Water Assessment and Protection Program including:
 - City of Wilmington Public Water Supply Intake Located on the Brandywine Creek
 - City of Newark Public Water Supply Intake Located on the White Clay Creek
 - United Water Delaware at Stanton Water Supply Intake Located on the White Clay and Red Clay Creeks
 - United Water Delaware Public Water Supply Intake Located on the Christina River at Smalley's Pond
- 2) Delaware Clean Water Act Section 303(d) List of Water Quality Limited Segments (Delaware Department of Natural Resources and Environmental Control, 1998)
- 3) Non-point Source Water Quality Monitoring in the Christina River Basin, Pennsylvania and Delaware (Senior and Koerkle, U. S. Geological Survey, 1997 – 1998)
- 4) Christina Basin Subwatershed Impervious Cover, Population Density, and Forest Cover Estimates (Greig, Bowers, and Kauffman, May 1998 and August 1999)
- 5) Christina Basin Watershed Indicator Report Card (Greig, Bowers, and Kauffman, August 1999)

Christina Basin Report Card

The following watershed report card method employs the water quality ladder approach, which helps the public understand how different pollutants affect water quality (Smith and Desvousages, 1986). The top of the ladder corresponds to the best water quality (Grade = A). The bottom of the ladder indicates the worst water quality (grade = F). The following ladder will be used to grade the water quality of each of the subwatersheds in the Delaware portion of the Christina Basin:

<u>Grade</u>	<u>Water Quality</u>	<u>Basis of Rating</u>
A	Excellent	So pure one could drink water from stream.
B	Good	Meets fishable/swimmable standards, supports cold water trout fishery
C	Average	Clean enough to support warm water fishery, not swimmable.
D	Unsatisfactory	Polluted, okay for boating not swimming or fishing
F	Poor	Polluted, has raw sewage and floating trash

Christina Basin watershed report card grades are assigned according to 19 water quality, habitat, and watershed health indicators. Grading criteria were derived from the following sources:

Stream Water Quality

- *Total Nitrogen*: Public Drinking Water Standards (DE Div. of Public Health, 2002)
- *Total Phosphorus*: Section 303 (d) Report (DE DNREC, 1998)
- *Chlorophyll*: Chesapeake Chlorophyll-a Criteria (Chesapeake Bay Program, 2002)
- *Copper*: Public Drinking Water Standards (DE Div. of Public Health, 2002)
- *Lead*: Public Drinking Water Standards (DE Div. of Public Health, 2002)
- *Zinc*: Public Drinking Water Standards (DE Div. of Public Health, 2002)
- *Dissolved Oxygen*: DE Surface Water Quality Standards (DE DNREC, 2002)
- *Enterococcus Bacteria*: Public Drinking Water Standards (DE Div. of Public Health, 2002)
- *Total Suspended Solids*: Public Drinking Water Standards (DE Div. of Public Health, 2002)

Stream Habitat

- *Aquatic Life Support*: Section 303 (d) Report (DE DNREC, 1998)
- *Waters of Exceptional Recreational and Ecological Significance (ERES)*: Section 303 (d) Report (DE DNREC, 1998)
- *Cold Water Fishery*: Section 303 (d) Report (DE DNREC, 1998)
- *Fish Consumption Advisories*: Section 303 (d) Report (DE DNREC, 1998)
- *Biological Community Index*: Section 303 (d) Report (DE DNREC, 1998)
- *Habitat Community Index*: Section 303 (d) Report (DE DNREC, 1998)

Watershed Health

- *Delaware Hazardous Substance Sites*: Source Water Protection Reports (Wollaston and Kauffman, 2002)
- *Watershed Imperviousness*: Rapid Watershed Planning Handbook (Center for Watershed Protection, 1998)
- *Population Density*: Phase III Christina Basin Report (CCCD, CCWRA, UDWRA, 1999)
- *Forest/Open Space Cover*: Forest Cover, Impervious Surface Area and the Mitigation of Urbanization Impacts in King County, WA, 2000

Figures 7, 8, and 9 provide the criteria used to assign watershed grades. For instance, if the peak nitrogen level in a particular watershed is undetected, the grade would be an "A" (excellent). If the peak nitrogen level exceeded the drinking water standard 10 mg/L, the grade for this parameter would be a "D" (unsatisfactory). The overall grade for a particular subwatershed is the mean of the grades assigned for the 19 indicators.

Final watershed letter grades are based on the following scale:

A	= 4.0 – 3.68	C	= 2.0 – 1.68
A-	= 3.67 – 3.34	C-	= 1.67 – 1.34
B+	= 3.33 – 3.01	D+	= 1.33 – 1.01
B	= 3.00 – 2.68	D	= 1.00 - .68
B-	= 2.67 – 2.34	D-	= .67 - .34
C+	= 2.33 – 2.01	F	= < .34

Figure 10 provides a listing of the individual grades for each subwatershed. The composite grade for the Delaware portion of the Christina Basin is "C" (average) signifying that there is an opportunity to improve watershed health through a Watershed Restoration Action Strategy outlined in the next chapters. Figure 11 provides a listing of the overall grades for water quality, habitat, and watershed health indicators for the subwatersheds.

Figure 7. Criteria to Assign Watershed Grades

	Water Quality	<i>Total Nitrogen</i>	<i>Total Phosphorus</i>	<i>Chlorophyll</i>	<i>Copper</i>	<i>Lead</i>	<i>Zinc</i>	<i>Dissolved Oxygen</i>	<i>Enterococcus Bacteria</i>	<i>Total Suspended Solids</i>	Stream Habitat	<i>Aquatic Life Support</i>	<i>ERES</i>	<i>Cold Water Fishery</i>	<i>Fish Consumption Advisory</i>	<i>Biological Community Index</i>	<i>Habitat Community Index</i>	Watershed Health	<i>Del. Hazardous Substance Sites</i>	<i>Watershed Imperviousness</i>	<i>Population Density</i>	<i>Forest / Open Space Cover</i>
A	Excellent	<0.50 mg/L	<0.10 mg/L	<3 ug/L	<0.065 mg/L	<0.001 mg/L	<.25 mg/L	>6.750 mg/L	<10 mg/L	<25 mg/L	Excellent	full support	yes	yes	none	> 80	91 to 100	Excellent	0	<8%	<250 sq mi	>75%
B	Good	0.50 to 5.00 mg/L	0.10 to 1.00 mg/L	3.1 to 7.0 ug/L	0.065 to 0.650 mg/L	0.001 to 0.008 mg/L	0.25 to 2.50 mg/L	4.501 to 6.750 mg/L	10 to 100 mg/L	25 to 250 mg/L	Good	.	.	.	.	61 to 80	81 to 90	Good	1 to 5	8.1% to 15%	251 to 500 sq mi	45.1% to 75%
C	Average	5.01 to 10.00 mg/L	1.01 to 2.00 mg/L	7.1 to 25.0 ug/L	0.651 to 1.300 mg/L	0.009 to 0.016 mg/L	2.51 to 5.00 mg/L	2.251 to 4.500 mg/L	101 to 200 mg/L	251 to 500 mg/L	Average	partial support	no	no	partial	41 to 60	61 to 80	Average	6 to 10	15.1% to 25%	501 to 1000 sq mi	25.1% to 45%
D	Unsatisfactory	10.01 to 15.00 mg/L	2.01 to 3.00 mg/L	25.1 to 50.0 ug/L	1.301 to 1.950 mg/L	0.016 to 0.023 mg/L	5.01 to 7.50 mg/L	.225 to 2.250 mg/L	201 to 300 mg/L	501 to 750 mg/L	Unsatisfactory	.	.	.	.	21 to 40	31 to 60	Unsatisfactory	11 to 30	25.1% to 40%	1000 to 1500 sq mi	10% to 25%
F	Poor	>15.00 mg/L	>3.00 mg/L	> 50.0 ug/L	>1.950 mg/L	>0.023 mg/L	>7.50 mg/L	< .225 mg/L	>300 mg/L	>750 mg/L	Poor	non-support	.	.	full	< 20	0 to 30	Poor	> 30	>40%	>1500 sq mi	<10%

Figure 8. Preliminary Watershed Grading Measurements

	B16. Brandywine Creek above Wilmington	B17. Brandywine Creek below Wilmington	R3. Burroughs Run	R4. Red Clay Creek above Woodale	R5. Red Clay Creek below Wooddale	W5. Mill Creek	W6. Pike Creek	W7. Middle Run	W8. White Clay Creek above Newark	W9. White Clay Creek below Newark	W10. White Clay Creek Tidal	C1. Upper Christina River above Cooches Bridge	C2. Muddy Run	C3. Belltown Run	C4. Little Mill Creek	C5. Christina River below Newark	C6. Tidal Christina below Smalley's Pond
Total Nitrogen (mg/L)	4.9	5.6	3.9	6.7	6.7	4.5	5.5	4.6	6.5	6.5	6.5	3.9	-	-	264.2	2.7	3.7
Total Phosphorus (mg/L)	.743	.566	.268	.8	.8	.752	.348	.19	1.17	1.17	1.17	.282	-	-	.268	.215	.777
Chlorophyll (ug/L)	16	13	13	45	45	11	5	24	16	16	16	13	-	-	8	11	45
Maximum Copper (mg/L)	.0385	-	-	-	-	-	-	-	.0447	-	.0643	-	-	-	-	.0336	-
Maximum Lead (mg/L)	.0446	-	-	-	-	-	-	-	.00988	-	.146	-	-	-	-	.0141	-
Maximum Zinc (mg/L)	.61	-	-	-	-	-	-	-	.0639	-	2.010	-	-	-	-	.155	-
Dissolved Oxygen (mg/L)	6.2	6.7	8.1	4.9	4.9	6.6	8	8.1	5.9	5.9	5.9	8.2	-	-	4.8	3.9	3.1
Enterococcus Bacteria (mg/L)	106	147	109	148	148	252	109	102	199	199	199	121	-	-	376	225	242
Total Suspended Solids (mg/L)	345	975	481	316	506	530	483	428	311	759	792	651	421	479	654	633	928
Aquatic Life Support	P	P	P	N	N	N	P	P	N	N	N	N	N	F	N	N	F/N *
Exceptional Recreational and Ecological Significant Waters	ERES	NO	NO	NO	NO	NO	NO	NO	ERES	NO	NO	NO	NO	NO	NO	NO	NO
Cold Water Fishery	CWF	NO	NO	NO	NO	CWF	CWF	NO	CWF	NO	NO	CWF	NO	NO	NO	NO	NO
Fish Consumption Advisories	PC	NC	C	NC	NC	C	C	C	C	PC	NC	C	C	C	NC	PC	NC
Biological Community Index	75	75	38	38	38	25	38	50	50	50	50	38	38	38	13	25	25
Habitat Community Index	70	70	73	87	87	67	70	81	85	85	85	58	-	82	38	66	71
Delaware Hazardous Sites (Superfund and SIRB)	-	4	-	-	-	-	-	-	3	-	37	-	-	-	-	34	-
Watershed Imperviousness	13	49	9	16	32	28	26	10	9	38	48	22	16	24	37	30	44
Population Density	613	5743	321	553	2426	1913	2077	1451	947	3015	1644	1149	1145	887	3595	2710	2437
Forest/Open Space Cover	56	29	27	45	25	22	22	45	60	21	39	27	50	43	27	35	37

* Note: Portions of this segment of stream are designated as both fully-supporting and non-supporting.

Figure 9. Watershed Grades per Criteria

	B16. Brandywine Creek above Wilmington	B17. Brandywine Creek below Wilmington	R3. Burroughs Run	R4. Red Clay Creek above Woodale	R5. Red Clay Creek below Wooddale	W5. Mill Creek	W6. Pike Creek	W7. Middle Run	W8. White Clay Creek above Newark	W9. White Clay Creek below Newark	W10. White Clay Creek Tidal	C1. Upper Christina River above Cooches Bridge	C2. Muddy Run	C3. Belltown Run	C4. Little Mill Creek	C5. Christina River below Newark	C6. Tidal Christina below Smalley's Pond
Total Nitrogen	B	C	B	C	C	B	C	B	C	C	C	B	-	-	F	B	B
Total Phosphorus	B	B	B	B	B	B	B	B	C	C	C	B	-	-	B	B	B
Chlorophyll	C	C	C	D	D	C	B	C	C	C	C	C	-	-	C	C	D
Maximum Copper	A	-	-	-	-	-	-	-	A	-	A	-	-	-	-	A	-
Maximum Lead	F	-	-	-	-	-	-	-	C	-	F	-	-	-	-	C	-
Maximum Zinc	B	-	-	-	-	-	-	-	A	-	B	-	-	-	-	A	-
Dissolved Oxygen	B	B	A	B	B	B	A	A	B	B	B	A	-	-	B	C	C
Enterococcus Bacteria	C	C	C	C	C	D	C	C	C	C	C	C	-	-	F	D	D
Total Suspended Solids	C	F	C	C	D	D	C	C	C	F	F	D	C	C	D	D	F
Aquatic Life Support	C	C	C	F	F	F	C	C	F	F	F	F	F	A	F	F	A/F
Waters of Exceptional Recreational and Ecological Significance	A	C	C	C	C	C	C	C	A	C	C	C	C	C	C	C	C
Cold Water Fishery	A	C	C	C	C	A	A	C	A	C	C	A	C	C	C	C	C
Fish Consumption Advisories	C	F	A	F	F	A	A	A	A	C	F	A	A	A	F	C	F
Biological Community Index	B	B	D	D	D	D	D	C	C	C	C	D	D	D	F	D	D
Habitat Community Index	C	C	C	B	B	C	C	B	B	B	B	D	-	B	D	C	C
Delaware Hazardous Sites (Superfund and SIRB)	-	B	-	-	-	-	-	-	B	-	F	-	-	-	-	F	-
Watershed Imperviousness	B	F	B	C	D	D	D	B	B	D	F	C	C	C	D	D	F
Population Density	C	F	B	C	F	F	F	D	C	F	F	D	D	C	F	F	F
Forest/Open Space Cover	B	C	C	C	C	D	D	B	B	D	C	C	B	C	C	C	C
TOTAL GRADE	B⁻	C	B⁻	C	C⁻	C	C⁺	B⁻	B	C⁻	C⁻	C⁺	B⁻	B⁻	D⁺	C	C⁻ / D⁺

Figure 10. Report Card Summarizing Stream Water Quality

Subwatershed	Grade	Watershed Health	Watershed Impervious	Notes
B16. Brandywine Creek above Wilmington	B⁻	Good	13 %	Exceptional Recreational Ecological Significance (ERES) water. Two tributaries are cold water trout streams. Biological Community Index of 75%. Higher amounts of forests/open space. Source of potable water for Wilmington.
B17. Brandywine Creek below Wilmington	C	Average	49 %	Combined sewer overflow discharges. Full fish consumption advisory. High watershed impervious and pop.density. Biological Community Index of 75%.
R3. Burroughs Run	B⁻	Good	9%	Protected by Burroughs Run Preserve. No fish consumption advisory. Low watershed impervious and pop. density. Biological Community Index of 38%.
R4. Red Clay Creek above Wooddale	C	Average	16 %	Full fish consumption advisory. Non-supported for aquatic life. Habitat Community Index of 87%.
R5.Red Clay Creek below Wooddale	C⁻	Average	32 %	Full fish consumption advisory Non-supported for aquatic life High watershed impervious and pop.density.
W5. Mill Creek	C	Average	28 %	Supports put and take cold water trout fish. No fish consumption advisory. Non-supported for aquatic life. High watershed impervious and pop.density.
W6. Pike Creek	C⁺	Average	26 %	Supports put and take cold water trout fish. No fish consumption advisory. High watershed impervious and pop.density.
W7. Middle Run	B⁻	Good	10 %	Protected by Middle Run Preserve. No fish consumption advisory. Low watershed impervious. Higher amounts of forests/open space.
W8. White Clay Creek above Newark	B	Good	9 %	Exceptional Recreational Ecological Significance (ERES) water. Supports put and take cold water trout fish.. Low watershed impervious. Higher amounts of forest/open space. Source of potable water for City of Newark
W9. White Clay Creek below Newark	C⁻	Average	38 %	Non-supported for aquatic life. High watershed impervious and pop.density.
W10. White Clay Creek Tidal	C⁻	Average	48%	Full fish consumption advisory. Non-supported for aquatic life. High watershed impervious and pop.density. Several Superfund and SIRB sites.
C1. Upper Christina River above Cooches Bridge	C⁺	Average	22 %	Supports put and take cold water trout fish. No fish consumption advisory. Non-supported for aquatic life.
C2. Muddy Run	B⁻	Good	16 %	No fish consumption advisory. Non-supported for aquatic life. Higher amounts of forest/open space.
C3. Belltown Run	B⁻	Good	24%	Fully supported for aquatic life. No fish consumption advisory. Biological Community Index of 38%.
C4. Little Mill Creek	D⁺	Unsatisfactory	37%	Only 13% of biological habitat intact. Full Fish consumption advisory. High watershed impervious and pop.density.
C5. Christina River below Newark	C	Average	30%	Several Superfund and SIRB sites. High watershed impervious and pop.density. Non-supported for aquatic life.
C6. Tidal Christina River below Smalley's Pond	C⁻/ D⁺	Average/ Unsatisfactory	44 %	Combined sewer overflow discharges. Full fish consumption advisory. High watershed impervious and pop.density.
Average Grade = C				

Figure 11. Report Card Summarizing Indicator Quality

Indicator	Grade	Sources of Impairment
<u>Stream Water Quality</u>	B⁻	
• Total Nitrogen	C⁺	Fertilizer, wastewater treatment, failing septic systems
• Total Phosphorus	B	Fertilizer, wastewater treatment, failing septic systems
• Chlorophyll	C	Fertilizer, wastewater treatment, failing septic systems
• Copper	A	Natural deposits, sewage treatment
• Lead	D	Brake linings, wastewater treatment
• Zinc	A⁻	Industries
• Dissolved Oxygen	B⁺	High nutrient loads
• Enterococcus Bacteria	C⁻	Leaking septic systems, manure
• Total Suspended Solids	D⁺	Erosion from agriculture, land development and stream banks
<u>Stream Habitat</u>	C	
• Aquatic Life Support	D⁺ / D	Point and nonpoint sources of pollution
• Waters of Exceptional Recreational and Ecological Significance	C⁺	Brandywine Creek above Wilmington and White Clay Creek above Newark are ERES waters
• Cold Water Fishery	B⁻	Urbanization in watersheds
• Fish Consumption Advisories	C⁺	High PCB and Zinc levels in fish tissue
• Biological Community Index	C⁻	Urbanization in watersheds
• Habitat Community Index	C⁺	Urbanization in watersheds
<u>Watershed Health</u>	C⁻	
• Delaware Hazardous Substance Sites (Superfund and SIRB)	C⁻	Legacy from industrial development
• Watershed Imperviousness	C⁻	Urban and suburban development
• Population Density	D	Urban and suburban development
• Forest / Open Space	C⁺	Agricultural and Urban/Suburban development
Average Grade = C		

Chapter 4: Priority Watersheds of the Christina Basin

Methodology

The 565 square-mile Christina Basin includes four major watersheds and 38 subwatersheds occupying five counties in three states. There is a need to prioritize the watersheds to focus funding and implement best management practices depending on whether the goal is to protect or restore existing stream water quality in a particular watershed. The subwatersheds of the Christina Basin were prioritized according to the following four-step process:

- Step 1: Characterize the watershed based on land use
- Step 2: Identify existing water quality
- Step 3: Compute the watershed pollution potential
- Step 4: Prioritize the watershed for protection or restoration BMPs

The subwatersheds in the Christina Basin were prioritized for three types of protection or restoration strategies:

- *Preservation/Protection Subwatersheds:* These relatively undeveloped "green" subwatersheds have generally healthy water quality, particularly in the headwater tributaries, due to low amounts of impervious surfaces (less than 15%) and high amounts of forested and open space lands (over 30%). These healthy watersheds have few contaminant sources such as wastewater discharges and hazardous waste sites. The strategy here is to keep the green subwatersheds green and maintain existing good water quality through protection, prevention, and preservation BMPs.
- *Urban/Suburban Restoration Subwatersheds:* These watersheds are more urbanized with greater amounts of impervious surfaces (more than 20%) and lower amounts of forested and open space land (less than 10%). Water quality in these more developed watersheds is generally impaired. These restoration subwatersheds have many contaminant sources such as wastewater discharges and hazardous waste sites. The strategy here is to restore these brown watersheds and improve water quality through restoration, retrofitting, and reforestation BMPs.
- *Agricultural BMPs:* These watersheds are largely rural with high percentages of agricultural land (more than 40%) and are primarily in the PA portion of the basin. The strategy in these rural watersheds is to improve water quality implemented through a variety of Chester County Conservation District and USDA Natural Resources Conservation Service agricultural restoration programs.

Figure 12 recommends protection or restoration strategies for subwatersheds in the Delaware portion of the Christina Basin.

Figure 12. Recommended Watershed Protection or Restoration Strategies

Subwatershed	Area (sq. mi.)	% Impervious Cover (1995)	Forested / Open Space (1995)	BMP Strategy
B16. Brandywine Creek above Wilmington	27	13 %	34 %	P - Open Space Protection
B17. Brandywine Creek through Wilmington	6	49 %	14 %	R - Urban Restoration
R3. Burroughs Run	7	9%	25%	P - Open Space Protection
R4. Red Clay Creek above Wooddale	12	16 %	35 %	P - Open Space Protection
R5.Red Clay Creek below Wooddale	7	32 %	13 %	R - Suburban Restoration
W5. Mill Creek	13	28 %	12 %	R - Suburban Restoration
W6. Pike Creek	7	26 %	13%	R - Suburban Restoration
W7. Middle Run	4	10 %	12 %	P - Open Space Protection
W8. White Clay Creek above Newark	10	9 %	54 %	P - Open Space Protection
W9. White Clay Creek below Newark	15	38 %	13 %	R - Suburban Restoration
W10. White Clay Creek Tidal	6	48 %	13 %	R - Urban Restoration
C1A. Upper Christina River PA/MD	8	8 %	31%	P - Open Space Protection
C1. Upper Christina River ab. Cooches Br.	13	22 %	21 %	R - Suburban Restoration
C2. Muddy Run	9	16 %	38 %	P - Open Space Protection
C3. Belltown Run	6	24%	34%	P - Open Space Protection
C4. Little Mill Creek	9	37%	14 %	R - Urban Restoration
C5. Christina River below Newark	11	30%	27%	R - Suburban Restoration
C6. Tidal Christina R. below Smalley's Pond	22	44 %	13 %	R - Urban Restoration

Figure 13. Impaired Stream Segments

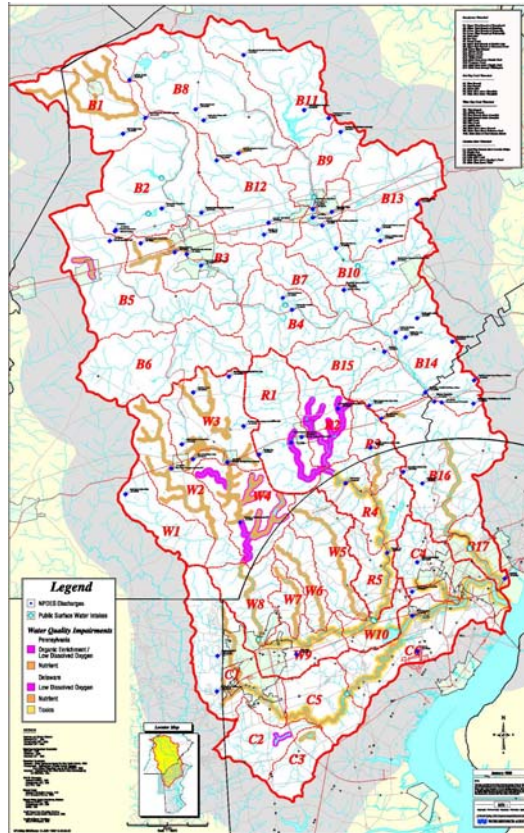
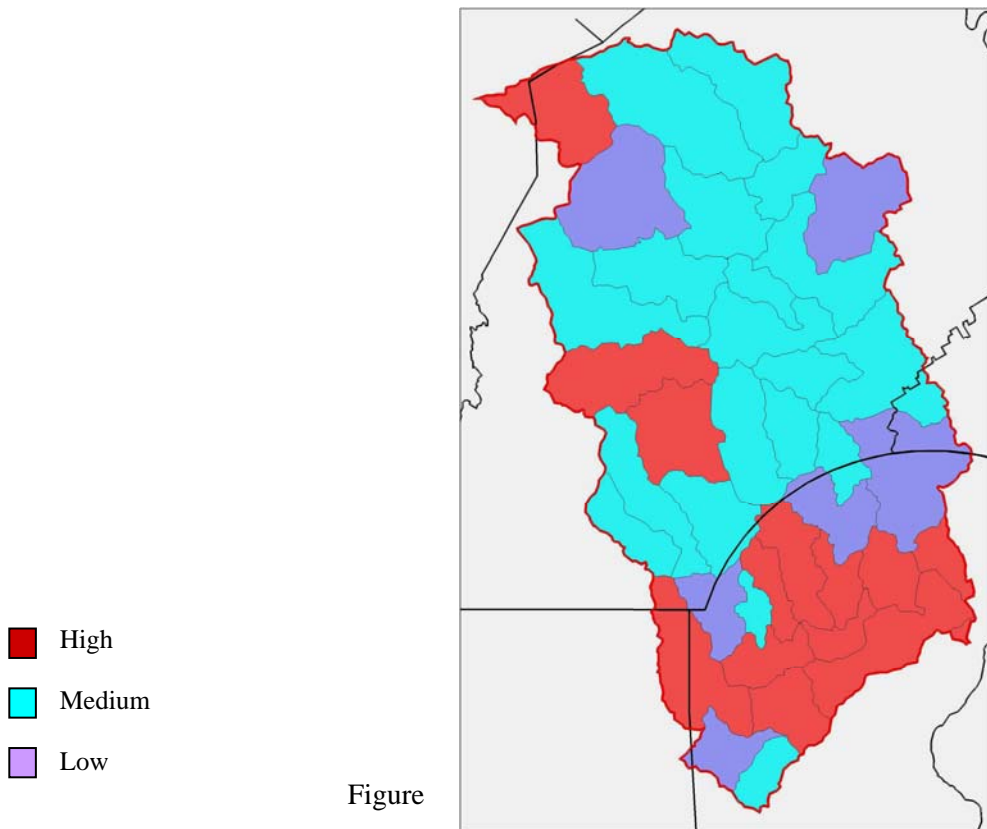


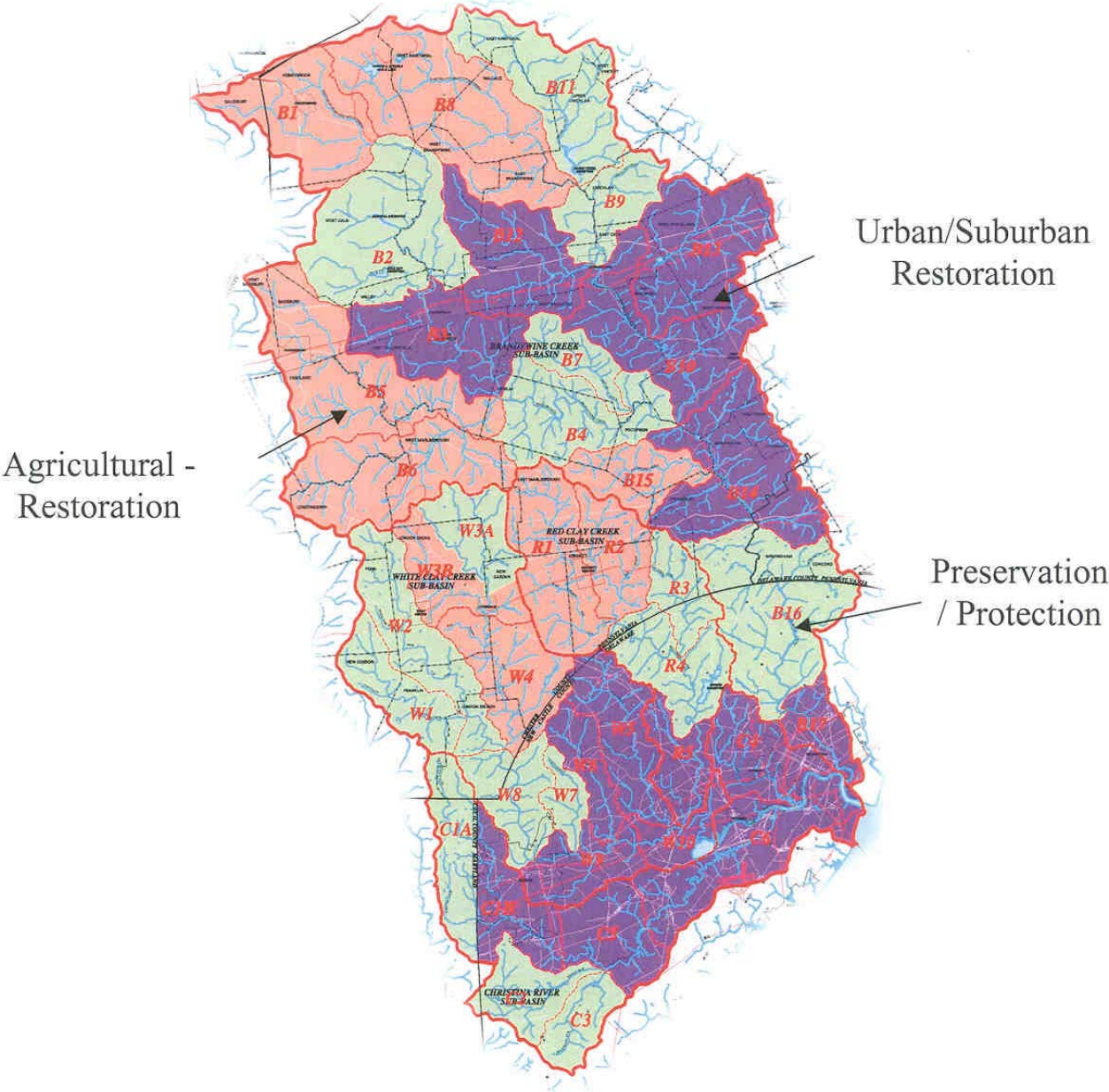
Figure 14. Watershed Pollution Potential



Figure

15. Watershed

Restoration Action Strategy (WRAS) Map



Chapter 5: Recommended Watershed Restoration Action Strategy

Protection and restoration of the waters of the Christina Basin is a big job that will take years of work by many. Various members of the Christina Basin Clean Water Partnership will be appointed as "BMP Champions" to take the lead on implementing the various BMP strategies discussed below. BMP Champions will be requested to develop a schedule with milestones and report back quarterly to the committee regarding the progress of the BMP initiatives. The following Watershed Restoration Action Strategy (WRAS) is recommended to protect and restore the waters and the watersheds of the Christina Basin in Delaware by the year 2015.

Preservation/Protection Watershed BMPs

These relatively undeveloped "green" watersheds generally have healthy water quality due to low amounts of impervious surfaces, few contaminant sources, and high overall amounts of forested and open spaces. The strategy for these areas is to keep "green" watersheds as they are and maintain existing good water quality through the following preservation/protection Best Management Practices:

P-1. Acquire and Conserve Open Space: Prioritize funding to acquire 6,000 acres of public open space, particularly forested tracts and headwater streams adjacent to the Brandywine Creek State Park, White Clay Creek State Park, Middle Run Preserve, Sunset Lake and Becks Pond. Representatives from the Delaware DNREC - Division of Parks and Recreation, the New Castle County Department of Special Services, and the City of Newark Department of Parks and Recreation would be appointed as the Open Space BMP champions for this initiative.

P-2. Retain Conservation Easements: Continue to seek opportunities to acquire 2000 acres of conservation easements for the preservation of open space especially near the Woodlawn Trustees parcels in the Brandywine Valley, near the White Clay Creek State Park, and near the Delaware Nature Society in the Red Clay Valley. The Brandywine Valley Association/Red Clay Valley Association and the Delaware Nature Society would be appointed as the Conservation Easement BMP champions for this initiative.

P-3. Minimize Impervious Cover: Amend the existing New Castle County Unified Development Code to establish an impervious cover threshold of 15 to 20 percent in watershed zoning districts for any new development in the Brandywine, Red Clay, White Clay Creeks and Christina River watersheds that are upstream from the only four drinking water intakes in New Castle County and hold the only six trout streams in Delaware. The University of Delaware Water Resources Agency and New Castle County would be appointed as the Impervious Cover BMP champions. The following subwatersheds would be included as water resource protection areas under the provisions of the Unified Development Code:

Subwatershed	Existing Impervious
B16 - Brandywine Creek above Wilmington	13%
R3 - Burroughs Run	9%
R4 - Red Clay Creek above Wooddale	16%
W7 - Middle Run	10%
W8 - White Clay Creek above Newark	9%
C2 - Muddy Run	16%

P-4. Amend Stormwater Ordinances: To be consistent with upstream townships in Pennsylvania, amend the New Castle County and City of Newark Drainage Codes to assume a predevelopment "meadow" condition (curve number) for stormwater calculations for new subdivisions. The University of Delaware Water Resources Agency, New Castle County, and City of Newark would be appointed as the Stormwater Ordinance BMP champions.

P-5. Implement Agricultural Conservation BMPs: Prioritize existing U.S. Department of Agriculture, Conservation Reserve Enhancement Program (CREP), WHIP, WRP, and EQIP funds for nutrient management, grassed waterways, crop rotation and filter strips, manure storage and stream fencing at 15 farms in the remaining agricultural watersheds of the Christina Basin in Delaware. The Delaware Nutrient Management Commission requires development of a nutrient management plan for any business operation that applies nutrients to greater than 10 acres of land or manages 8,000 pounds of animals. The USDA Natural Resources Conservation Service, New Castle Conservation District, and the Delaware Nutrient Management Commission would be appointed as the Agricultural BMP champions. The following subwatersheds have agricultural lands that exceed 10% of the watershed area:

Subwatershed	Agricultural Land
B16 - Brandywine Creek above Wilmington	17%
R3 - Burroughs Run	15%
W7 - Middle Run	30%
W8 - White Clay Creek above Newark	20%
C2 - Muddy Run	15%

P-6. Coordinate with Nonprofit Watershed Organizations: Coordinate with the stewardship and stream watch programs of the nonprofit watershed organizations such as:

- Delaware Nature Society - Soil Watch and Stream Watch
- Brandywine Valley Association - Stream Watch
- Brandywine Conservancy - Land Stewardship
- Red Clay Valley Association - Advocacy
- White Clay Watershed Association - Stream Watch
- Christina Conservancy - Advocacy
- Coalition for Natural Stream Valleys

The Delaware Nature Society and Brandywine Valley Association would be appointed as Nonprofit Watershed Organization BMP champions.

P-7. SMARTYARD Home Lawn Care Program: Work with landscape designers and the Delaware Nature Society to provide incentive to and assist homeowners to plant water friendly native landscaping to conserve water and reduce fertilizer and pesticide use. The SMARTYARD program would include delivery of rain barrels to interested and qualified homeowners according to the following goals:

Watershed	SMARTYARDS	Rain Barrels
Brandywine Creek	100	300
Red Clay Creek	100	250
White Clay Creek	100	250
Christina River	200	200

The Delaware Nature Society and the University of Delaware Water Resources Agency would be appointed as SMARTYARD BMP champions.

P-8. Public Education and Outreach: Expand the public outreach program through the following techniques:

- Water bill and brochure inserts to the Newark, Wilmington, Artesian Water Company, and United Water Delaware water bills
- Watershed road signs at 18 locations entering the Christina Basin along DELDOT highways
- Watershed brochures delivered at University of Delaware Football Games (capacity 22,000), U of D basketball games (capacity 5,000) and Wilmington Blue Rock Minor League Baseball games (capacity 5,000)
- Update the Christina Basin website at the U of D homepage (www.wr.udel.edu)
- Obtain or develop an email mailing list to broadcast word about the Christina Basin
- Develop press releases to the Wilmington News Journal and the Philadelphia Inquirer, TV Channel 12, and WILM radio
- Sponsor a 5k race through the White Clay Creek State Park highlighting the watershed
- Watershed Education Module - Accomplished with Middle School Teachers by the DE Department of Education and the UD Math and Science Education and Research Center.

Figure 16. Protection/Preservation Watershed BMPs for the Christina Basin WRAS

WRAS Implementation BMP	Goal	BMP Champions	Timing
P1. Acquire/Conserve Open Space	6000 acres	DNREC, New Castle County, City of Newark	TBD
P2. Retain Conservation Easements	2000 acres	Delaware Nature Society Brandywine Valley Association	TBD
P3. Minimize Impervious Cover	1 ordinance 6 subwatersheds	UD Water Resources Agency, New Castle County	TBD
P4. Amend Stormwater Ordinances	2 ordinances	UD Water Resources Agency, New Castle County, City of Newark	TBD
P5. Implement Agricultural Conservation BMPs	15 Farms 6 subwatersheds	USDA NRCS, New Castle Conservation District, Delaware Nutrient Management Commission	TBD
P6. Coordinate w/ Nonprofit Watershed Organizations	7 organizations	Delaware Nature Society Brandywine Valley Association	TBD
P7. Administer SMARTYARD Program for Homeowners	500 lawns 1000 rainbarrels	UD Water Resources Agency Delaware Nature Society	TBD
P8. Expand Public Outreach Program	9 components	Delaware Nature Society Brandywine Valley Association UD Water Resources Agency	TBD

TBD – To be determined by individual watershed BMP champions

Restoration/Retrofitting Watershed BMPs

These developed watersheds have generally poor water quality due to higher amounts of impervious surfaces, low overall amounts of forested and open space, and higher densities of contaminant sources.

Restoration subwatersheds have characteristics of (a) low percentages (< 10%) of wooded land, (b) high percentages (> 20%) of impervious cover, (c) relatively poor water quality, and (d) many contaminant sources such as wastewater discharges and hazardous waste sites.

The strategy is to restore the "brown" watersheds and improve existing impaired water quality through the implementation of the following restoration and retrofitting Best Management Practices:

R-1. Cleanup Superfund, Hazardous Waste and LUST Sites: Establish an abatement schedule to prioritize the remediation of 40 Superfund, Hazardous Waste, and LUST sites in the Delaware portion of the watershed. First priority for remediation should be given to the hazardous waste sites above the 4 drinking water intakes in the watersheds of the Brandywine, Red Clay Creek, White Clay Creek, and Christina River. The Delaware DNREC -Division of Air and Waste Management is identified as the BMP Champion for this initiative.

Watershed	Existing Superfund, Hazardous Waste and LUST Sites
Brandywine Creek above Wilmington	311
White Clay Creek above Newark	16
Red Clay/White Clay Creeks above Stanton	513
Christina River above Smalley's Pond	333

R-2. Abate the Combined Sewer Overflows (CSOs): In accordance with the recommendations of the Wilmington CSO Task Force and the Christina Basin High Flow TMDLs (due 2004), implement storage, conveyance, and treatment strategies to remove 85% of the combined sewer overflows at 37 locations along the Brandywine Creek and Christina River. The City of Wilmington Department of Public Works is identified as the BMP Champion for this initiative.

R-3. Riverfront Development Efforts: Coordinate with Riverfront Development Corporation efforts to clean up and restore the riverfront and revitalize with the waterfront park, path, offices, restaurants, and shops along the Brandywine Creek and Christina River in Wilmington. A representative of the state/private funded Riverfront Development Corporation will be requested to act as the BMP Champion for this initiative.

R-4. Continue Sewer Repair/Septic Elimination Projects: Continue ongoing program to repair 30 miles of sanitary sewers and eliminate 500 failing septic systems in the New Castle County regional wastewater system. The New Castle County Department of Special Services will be requested to act as the BMP Champion for this initiative.

R-5. Restore Stream and Riparian Corridors: Restore 20 miles of stream and riparian corridors using techniques such as bioengineering and wetland restoration. The Delaware DNREC Division of Soil and Water Conservation and Whole Basin Program will be requested to act as the BMP Champions for stream restoration.

R-6. Reforest Watersheds and Headwaters: Reforest 2000 acres of watershed land and headwater streams in the Delaware portion of the Christina Basin. The Delaware Nature Society and the New Castle Conservation District will be requested to act as the BMP Champions for the reforestation initiative.

R-7. Retrofit Stormwater Quality Basins: Amend the City of Wilmington, City of Newark and New Castle County Development Codes to require retrofitting of stormwater management ponds for water quality functions during urban redevelopment projects. Find opportunities to retrofit existing stormwater basins and convert them into stormwater quality ponds. The New Castle County Department of Land Use and City of Newark Department of Public Works are identified as the BMP Champions.

R-8. Eliminate Remaining NPDES Discharges: Seek opportunities to eliminate or consolidate the 10 remaining NPDES wastewater discharges in Delaware and the 2 remaining discharges in the Maryland portions of the Christina Basin. The Delaware DNREC - Division of Water Resources, Discharges Section is identified as the BMP Champion.

Figure 17. Restoration Watershed BMPs in the Christina Basin WRAS.

WRAS Implementation BMP	Goal	BMP Champion	Timing
R1. Clean-up Superfund, Hazardous Waste, and LUST Sites	40 sites	DNREC Division of Air and Waste Management	TBD
R2. Abate Combined Sewer Overflows	37 CSOs	City of Wilmington	TBD
R3. Continue Riverfront Development Efforts	5 acres	Riverfront Development Corporation	TBD
R4. Continue Sewer Repair/Septic Elimination Projects	30 miles	New Castle County Dept. of Special Services	TBD
R5. Restore Stream and Riparian Corridors	6 miles	DNREC Division of Soil and Water Conservation and DNREC Whole Basin Program	TBD
R6. Reforest Watersheds and Headwaters	1,200 acres	Delaware Nature Society New Castle Cons. District	TBD
R7. Retrofit Stormwater Quality Basins	10 Ponds	City of Newark New Castle County	TBD
R8. Eliminate Remaining NPDES Discharges	10 Discharges	Delaware DNREC Division of Water Resources	TBD

TBD – To be determined by individual watershed BMP champions

Figure 18. Relationship of WRAS BMPs to Watershed Goals

RELATIONSHIP OF BMPS TO WATERSHED GOALS	GOAL 1 NUTRIENTS	GOAL 2 TOXICS	GOAL 3 BACTERIA	GOAL 4 FISH CONSUMPT. ADVISORY	GOAL 5 SEDIMENT	GOAL 6 STREAM HABITAT
PROTECTION/PRESERVATION WATERSHEDS						
P1. Acquire/Conserve Open Space						
P2. Retain Conservation Easements						
P3. Minimize Impervious Cover						
P4. Amend Stormwater Ordinances						
P5. Implement Agricultural Conservation BMPs						
P6. Coordinate w/ Nonprofit Watershed Organizations						
P7. Administer SMARTYARD Program for Homeowners						
P8. Expand Public Outreach Program						
RESTORATION WATERSHEDS						
R1. Clean-up Superfund, Hazardous Waste, and LUST Sites						
R2. Abate Combined Sewer Overflows						
R3. Continue Riverfront Development Efforts						
R4. Continue Sewer Repair/Septic Elimination Projects						
R5. Restore Stream and Riparian Corridors						
R6. Reforest Watersheds and Headwaters						
R7. Retrofit Stormwater Quality Basins						
R8. Eliminate Remaining NPDES Discharges						

Chapter 6: WRAS Progress in Delaware

While the recommendations of the Watershed Restoration Action Strategy (WRAS) for the Delaware portion of the Christina Basin are new, progress on these BMPs is not. For years, many agencies and entities have implemented WRAS BMPs in the Christina Basin under the auspices of individual programs. The Delaware DNREC owns many acres of open space at the Brandywine Creek and White Clay Creek State Parks and is cleaning up Superfund and hazardous waste sites along with the Christina Riverfront revitalization effort at Wilmington. The Delaware Nature Society holds many acres of conservation easements in the Red Clay Creek watershed donated by the public. The New Castle Conservation District has funded many streamside restoration and stormwater pond retrofitting projects. While these BMP projects and programs were conducted incrementally, they count as "progress" toward the implementation of an overall Christina Basin WRAS Strategy in anticipation of the upcoming, high flow, stormwater TMDLs in 2004.

Preservation/Protection Watershed BMPs

These relatively undeveloped "green" watersheds have generally healthy water quality due to low amounts of impervious surfaces and contaminant sources, and high overall amounts of forested and open spaces. The strategy for these areas is to keep the "green" watersheds "green" as they are and maintain existing high water quality through preservation/protection Best Management Practices. The following BMPs have been installed in the DE portion of the Christina Basin:

P1. Acquire and Conserve Open Space

- White Clay Creek State Park
- Brandywine Creek State Park
- Dayett Mills, Upper Christina River
- Middle Run Natural Area
- Carousel Park
- Valley Garden Park, Hoopes Reservoir .
- DNREC Parks Open Space Inventory
 - Brandywine Creek sub-basin - 380 acres
 - Christina River sub-basin - 341 acres
 - White Clay Creek sub-basin - 2231 acres

P2. Retain Conservation Easements

- Woodlawn Trustees Preserve
- Delaware Nature Society Burrows Run Preserve.
- Frederick Family/Whitely Farms Natural Area
- Lefren Family Conservation Area
- Lunger Family Conservation Easement
- Flint Woods Preserve
- University of Delaware Laird Campus, Agriculture Farm, and Judge Morris tracts.
- DuPont Corporation Haskell Research Center and the Experimental Station
- Sophie du Pont May conservation easement along Smith Bridge Road
- Winterthur easement – Brandywine Conservancy.

P3. Minimize Impervious Cover in New Developments

New Castle County Water Resource Protection Area (WRPA) Ordinance - Impervious Cover Thresholds (adopted 1990)

- Cockeysville Limestone Aquifer
- Cockeysville Drainage Area
- Wellhead Areas
- Recharge Areas
- Hoopes Reservoir Watershed

P4. Amend the Stormwater Ordinances

- DNREC Stormwater and Sediment Ordinance (1991)
- DNREC Conservation Design Manual (2001)
- New Castle County Unified Development Code (1997)

P5. Implement Agricultural Conservation BMPs

- USDA-NRCS and NCD Agriculture BMPs
- Red/White Clay Creeks PL83-566 Program
- EQIP
- Conservation Reserve Program
- District Cost-share Program
- Conservation Practices
- Delaware Nutrient Management Commission
- Hy-point Dairy Waste Storage System
- UD Farm Stream Fencing Conservation Cost-Share
- Cool Run Tributary to the White Clay Creek at the University of Delaware farm in Newark
- Conservation Management Plans - Piedmont Whole Basin Management Program

P6. Coordinate with Nonprofit Watershed Organizations

- Annual Christina River Cleanup by Christina Conservancy
- Delaware Nature Society Soil Watch Program
- DNS Reforestation
- DNS Macroinvertebrate Surveys
- White Clay Watershed Association- Stream Watch
- Red Clay Valley Association
- Delaware Nature Society Stream Watch

P7. Administer SMARTYARD Program for Homeowners

- New Castle Conservation District Backyard Conservation Kit-
- SMARTYARDS Native Landscaping (2002)– The University of Delaware Water Resources Agency, Delaware Nature Society, and URS Inc.
- Christina Basin Rain Barrel Program

P8. Expand Public Education Outreach Programs

- Christina Basin Task Force
- Christina Basin Bus Tour
- Christina Basin Brochure/Newsletter
- Basin Scapes Homeowners Guides
- Christina Basin Conference - June 1999 .
- Christina Basin Web Site - (www.wr.udel.edu)
- Christina Basin Road Signs -18 DELDOT road signs.
- Christina Basin Poster
- Storm Drain Stenciling – The Partnership for the Delaware Estuary, city of Wilmington and DNREC, City of Newark
- Kalmar Nyckel Shipyard Challenge Program
- 7th Grade Watershed Training Module

Restoration/Retrofitting Watershed BMPs

These developed watersheds have generally poor water quality due to high amounts of impervious surfaces, high densities of contaminant sources, and low overall amounts of forested and open spaces. The strategy for these watersheds is to restore the "brown" watersheds and improve existing impaired water quality through the implementation of the following restoration and retrofitting Best Management Practices.

R-1. Cleanup Superfund, Hazardous Waste and LUST Sites

- DNREC Superfund Program in the Christina Basin include:
- DE 1084. AMTRAK Operations Center
- DE 1085. Madison Street Ext
- DE 1116. Riverfront Park
- DE 1044. CSX Railroad Yard
- DE 244 Rogers Corner Dump Route 13 and I-495
- DE-199. NVF-Newark Company Site

- DE-0163. Del Chapel Place (University Courtyard)
- Dupont Co. Cleanup Christina River in Newport.
- PCBs in Piedmont Streams – Delaware Piedmont Whole Basin Management Program
- DNREC Site Index Database - Statewide identification of potential contaminant sources

R-2. Abate the Combined Sewer Overflows (CSOs)

Wilmington CSO Abatement Strategy -

- 19 CSOs to Brandywine Creek
- 15 CSOs to Christina River
- 2 CSOs to Silverbrook Run
- 1 CSO to Little Mill Creek

The City has implemented CSO control such as:

- USEPA nine minimum controls such as daily inspection of CSOs, street cleanup programs, and nets at CSO 30 to catch floatables
- Upgrade the Wilmington Wastewater Treatment plant from 90 mgd to 134 mgd
- Improve the capacity and modify pump controls at the 11th Street pump station
- Develop West Side facility plans to reduce discharge from CSOs 27, 28, and 29
- Install a netting system and raise the regulating weir at CSO 30

Long Term CSO Control Plan (LTCP) - The City prepared a long term plan to control 85% of the CSO volume by 2010. The LTCP recommends:

Nonstructural Improvements

- Inspect and repair tide gates city wide
- Assess performance of floatables control
- Initiate GIS mapping of sewers.

Structural Improvements

- Construct underground retention basins at
CSOs 28 and 29 (Silverbrook), CSOs 24 and 25 (Brandywine Creek)
CSO 27 (Silverbrook), CSOs 4a and 4b (Brandywine Creek)
- Partial separation of combined sewers
- Expand pumping capacity
- Use inflatable dams for in-pipe storage.

R-3. Coordinate with Wilmington Riverfront Development Efforts

- Brandywine Creek Vessel Removal
- Russell W. Peterson Urban Wildlife Refuge
- Riverfront Development Corporation - The riverfront revitalization plan includes such completed amenities as:
- Riverfront Arts Center
- Factory Discount Shopping
- Restaurants
- Riverfront Park
- River Walk
- Wildlife Wetland Refuge
- Kalmar Nyckel Shipyard
- Wilmington Blue Rocks Baseball Stadium
- Wilmington Rowing Club Boathouse

R-4. Continue Sewer Repair/Septic Elimination Projects

New Castle County Sewer Rehabilitation - Since 1990, the New Castle County Department of Special Services has rehabilitated 18 miles of sanitary sewer in the following watersheds:

- Brandywine Creek 10 miles
- Red Clay Creek 8 miles
- White Clay Creek 0 miles
- Christina River 0 miles

New Castle County Septic Relief - The New Castle County Department of Special Services has eliminated over 200 failing septic systems in the following Christina Basin watersheds:

- Brandywine Creek
- Red Clay Creek
- White Clay Creek
- Christina River

Domestic Septic Mapping- Identification of non-point pollutant septic sources and locations of all domestic septic systems through the Piedmont Whole Basin Management Program.

R-5. Restore Stream and Riparian Corridors

- Newark Bioengineering Project - Upper Christina River
- Wilmington Rattlesnake Run Project
- Mill Creek Stream Bioengineering Project
- Ball Run at All Saints Cemetery
- Mill Creek Greenway
- Three Little Bakers Pike Creek Restoration

R-6. Reforest Watersheds and Headwaters

- Pike Creek Christian School - Middle Run
- Terraces at Iron Hill Open Space
- Girl Scouts Restore Birch Run Meadow -.
- Pike Creek Stream Buffer Initiative - Yorktowne and Thistleberry Farms subdivisions
- Winterthur - native landscaped meadow along Wilson Run.
- Burrows Run Preserve Reforestation
- Middle Run Preserve Reforestation Effort -
- Friends of White Clay Creek State Park Wildlife Habitat Restoration
- Wilmington/Newark Urban Forest Management - Delaware Center for Horticulture

R-7. Retrofit Stormwater Quality Basins

- Dayett Mills Christina River Dam Stabilization
- DNREC Stormwater Contractor Certification
- DNREC Sediment and Stormwater Certified Construction Reviewer
- White Chapel Storm Water Basin.
- Brader Elementary School Pond Independence School Wetland
- Carousel Pond Rehabilitation
- Hockessin Glen Stormwater Basin Retrofit
- Coverdale Farm Restoration

R-8. Eliminate Remaining NPDES Discharges

These point source discharges in the Delaware portion of the Christina Basin have declined by 70% from 34 discharges in 1977 to 10 in 1999 due to regional wastewater plans implemented by the Delaware DNREC, City of Wilmington, and New Castle County governments. The remaining Delaware discharges in the Christina Basin include:

Brandywine Creek

- Amtrak Stormwater Winterthur Museum Wastewater

Red Clay Creek

- Haveg/Amtek Cooling Water Hercules Cooling Water
- Greenville Country Club Wastewater

White Clay Creek

- FMC Corp Stormwater

Christina River

- General Motors Stormwater DuPont Chestnut Run Stormwater
- Ciba Geigy Corp. Cooling Water Boeing Stormwater

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