Total Maximum Daily Loads for Bacteria and Sediment in the Christina River Basin, Pennsylvania, Delaware, and Maryland

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U.S. Environmental Protection Agency
Region III
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Philadelphia, Pennsylvania

_____*Signed*___________
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The Clean Water Act requires a Total Maximum Daily Load (TMDL) be developed for those waterbodies identified as impaired by the state where technology-based and other controls will not provide for attainment of water quality standards. A TMDL is a determination of the amount of a pollutant from point, nonpoint and natural background sources, including a margin of safety (MOS), which may be discharged to a water quality-limited waterbody without violating water quality standards.

This document revises the bacteria TMDLs established by the U.S. Environmental Protection Agency (EPA) on April 8, 2005. Although the sediment TMDLs is not being revised[a], this document supersedes the 2005 document in its entirety.

TMDLs are defined as the summation of the point source wasteload allocations (WLAs) plus the summation of the nonpoint source load allocations (LAs) plus a MOS and are often shown as:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

The TMDL is a written plan and analysis established to ensure that a waterbody will attain and maintain water quality standards. The TMDL is a scientifically-based strategy that considers current and foreseeable conditions, the best available data, and accounts for uncertainty with the inclusion of a MOS value.

The TMDLs are to achieve and maintain the States' existing water quality standards and must meet the following eight regulatory requirements pursuant to 40 CFR Part 130.

1. The TMDLs are designed to implement the applicable water quality standards.
2. The TMDLs include a total allowable load as well as individual WLAs and (LAs).
3. The TMDLs consider the impacts of background pollutant contributions.
4. The TMDLs consider critical environmental conditions.
5. The TMDLs consider seasonal environmental variations.
6. The TMDLs include a MOS.
7. There is reasonable assurance that the proposed TMDLs can be met.
8. The TMDLs have been subject to public participation.

As interstate TMDLs, both Pennsylvania and Maryland have the responsibility of meeting downstream Delaware's water quality standards.

[a] Although the sediment TMDLs are not revised, Table 4-7 was corrected.

The Pennsylvania Department of Environment Protection (PADEP) identified waterbodies within Pennsylvania's portion of the Christina River Watershed as impaired by bacteria and sediment, which are addressed in this TMDL Report. The Delaware Department of Natural Resources and Environmental Control (DNREC) identified waterbodies within Delaware's portion of the Christina River Basin as impaired by bacteria. Maryland's Department of the Environment has not identified waterbodies within the Christina River Watershed as impaired.

Both PADEP and DNREC have designated the primary contact recreation (swimming) and protection of aquatic life (fishing) uses for waterbodies in the Christina River Basin. The state agencies use different bacterial indicators in their respective water quality standards for pathogens. Pennsylvania uses fecal coliform bacteria as an indicator of bacteria contamination whereas Delaware uses *enterococcus* bacteria. Maryland uses either *E. coli* or *enterococcus* bacteria. While the states list waterbodies for bacteria impairments, only Pennsylvania and Maryland list waterbodies for sediment, suspended solids, or siltation impairments.

The bacteria TMDL endpoints are identified in Table 1-6 and 1-7. The sediment TMDL endpoint is based on the reference watershed method described in Section 3.2.1.

A customized modeling framework was developed to support determination of bacteria and sediment TMDLs for the Christina River Basin. The modeling framework used in this study consisted of three major components: (1) a watershed loading model Hydrologic Simulation Program Fortran (HSPF) developed for each of the four primary subwatersheds in the Christina River Basin by the U.S. Geological Survey (Senior and Koerkle, 2003a, 2003b, 2003c, 2003d), (2) a Combined Sewer Overflow flow model (XP-SWMM) developed by the City of Wilmington, and (3) a hydrodynamic model developed using the computational framework of the Environmental Fluid Dynamics Code (Hamrick, 1992). Development of inputs for these models involved the analyses of historical water quality and streamflow data to estimate point and nonpoint sources of bacteria and sediment.

The pathogen TMDLs are as follows:

Fecal coliform bacteria average annual TMDL allocations for the Christina River Basin

Subbasin	Baseline Load (cfu*/season)			TMDL Allocation (cfu/season)					Percent
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	Reduction
Swimming Season (May 1 - Sep 30)									
Red Clay (R01)	1.872E+12	2.914E+15	2.916E+15	8.734E+10	2.139E+14		1.126E+13	2.252E+14	92.28%
Red Clay (R02)	6.037E+12	1.319E+15	1.325E+15	1.274E+12	1.133E+14		6.031E+12	1.206E+14	90.90%
Red Clay (R03)	1.304E+12	1.435E+15	1.437E+15	1.738E+11	1.206E+14		6.359E+12	1.272E+14	91.15%
White Clay (W04)		1.726E+15	1.726E+15		1.040E+14		5.478E+12	1.095E+14	93.66%
White Clay (W07)	7.529E+10	3.140E+13	3.148E+13	7.529E+10	2.885E+12		1.557E+11	3.115E+12	90.10%
Non-swimming Season (Oct 1 - Apr 30)									
Red Clay (R01)	1.872E+12	6.404E+15	6.406E+15	8.734E+11	2.895E+15		1.524E+14	3.049E+15	52.40%
Red Clay (R02)	6.037E+12	3.406E+15	3.412E+15	1.274E+13	1.571E+15		8.338E+13	1.668E+15	51.12%
Red Clay (R03)	1.304E+12	3.704E+15	3.705E+15	1.738E+12	1.720E+15		9.062E+13	1.812E+15	51.08%

Subbasin	Baseline Load (cfu*/season)			TMDL Allocation (cfu/season)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
White Clay (W04)		2.499E+15	2.499E+15		2.370E+15		1.249E+14	2.495E+15	0.16%
White Clay (W07)	1.043E+11	6.899E+13	6.910E+13	7.529E+11	6.475E+13		3.450E+12	6.899E+13	0.15%

*****Colony forming units

Fecal coliform average annual TMDL allocations for MS4 municipalities

Town	Sub-Watershed	Swimming Season Baseline (cfu/season)	Swimming Season TMDL (cfu/season)	Percent Reduction
East Marlborough TWP	Red Clay	2.61E+15	2.06E+14	92.09%
Kennett Square Boro	Red Clay	2.35E+14	1.88E+13	91.98%
Kennett TWP	Red Clay	1.44E+15	1.24E+14	91.38%
New Garden TWP	Red Clay	1.12E+15	9.38E+13	91.60%
Avondale Boro	White Clay	3.81E+13	2.42E+12	93.64%
London Grove TWP	White Clay	1.54E+15	9.27E+13	93.99%
New Garden TWP	White Clay	3.00E+13	2.76E+12	90.82%
West Grove Boro	White Clay	8.48E+13	5.09E+12	93.99%
Town	**Sub-Watershed**	**Non-Swimming Season Baseline (cfu /season)**	**Non-Swimming Season TMDL (cfu/season)**	**Percent Reduction**
East Marlborough TWP	Red Clay	5.95E+15	2.85E+15	52.08%
Kennett Square Boro	Red Clay	5.45E+14	2.62E+14	51.95%
Kennett TWP	Red Clay	3.65E+15	1.78E+15	51.26%
New Garden TWP	Red Clay	2.76E+15	1.34E+15	51.52%
Avondale Boro	White Clay	5.83E+13	5.53E+13	5.06%
London Grove TWP	White Clay	2.23E+15	2.12E+15	5.04%
New Garden TWP	White Clay	6.59E+13	6.25E+13	5.15%
West Grove Boro	White Clay	1.23E+14	1.17E+14	5.04%

Average annual state line allocations for Christina River Basin *enterococci* bacteria TMDL

Location	Baseline (cfu/yr)	Allocation (cfu/yr)	Reduction
Allocations at the Pennsylvania-Delaware State Line			
Brandywine Cr. (at PA-DE Line)	3.12E+15	2.01E+14	93.56%
White Clay Cr. (at PA-DE Line)	6.86E+14	2.06E+14	70.03%
Red Clay Cr. (at PA-DE Line)	2.58E+14	1.08E+14	58.05%
Burroughs Run (at PA-DE Line)	1.85E+13	1.30E+13	29.32%
Allocations at the Maryland-Delaware State Line			
Christina River (at MD-DE Line)	1.86E+13	7.73E+12	58.40%

Neither the Pennsylvania nor the Delaware MS4 permits actually identify the extent of the systems. Therefore, the WLAs are for the whole municipal area and by subbasin. Appendix E contains sample calculations for determining WLAs for storm water permits within an MS4 permitted area. The same procedure should be used when converting the TMDL WLA into WLA and LA values when the actual extent of the MS4 system is known.

The non-MS4 point source permittee's allocations for fecal coliform, *enterococci*, and total suspended solids are not reduced from their permitted levels and are shown in Table 2-2.

Permit DE0020320-001, the City of Wilmington, is not shown in Table 2-2 because it discharges to the Delaware River. However, Wilmington has combined sewers with combined sewer overflows (CSOs) discharging to Brandywine Creek, Christina River, and Little Mill Creek. The CSO allocations are shown in the following table.

Table 4-5. Summary of average annual CSO enterococci baseline loads and WLA TMDL

Location	CSO ID Numbers	Baseline (cfu/yr)	WLA (cfu/yr)	Reduction
Little Mill Creek (C05)	27, 28, 29	1.56E+14	3.69E+13	76.32%
Christina River (C09)	5, 6, 7, 9a, 9c, 10, 11, 12, 13, 14, 15, 16, 17, 30	3.54E+14	9.75E+13	72.47%
Brandywine Creek (B34)	3, 4a, 4b, 4c, 4d, 4e, 4f, 18, 19, 20, 21a, 21b, 21c, 22b, 22c, 23, 24, 25, 26, RR	6.89E+14	2.55E+14	63.07%
Total CSO Loads	-	1.20E+15	3.89E+14	67.57%

All of New Castle County is covered by a MS4 permit and the allocations by subbasin are shown in the following table.

Average annual allocations for Christina River Basin *enterococci* bacteria TMDL

Location	Baseline (cfu/yr)	WLA (cfu/yr)	LA (cfu/yr)	MOS (cfu/yr)	TMDL (cfu/yr)	Reduction
Brandywine Creek in Delaware						
Brandywine Cr. (B18)	1.11E+14	0.00E+00	5.55E+12	2.92E+11	5.85E+12	94.75%
Brandywine Cr. (B19)	5.57E+13	3.45E+10	6.31E+12	3.32E+11	6.68E+12	88.00%
White Clay Creek in Delaware						
White Clay Cr. (W11)	4.07E+13	0.00E+00	9.96E+12	5.24E+11	1.05E+13	74.23%
White Clay Cr. (W12)	1.49E+14	4.15E+10	1.79E+13	9.44E+11	1.89E+13	87.31%
White Clay Cr. (W13)	3.01E+13	0.00E+00	3.91E+12	2.06E+11	4.11E+12	86.34%
White Clay Cr. (W14)	3.82E+13	0.00E+00	3.99E+12	2.10E+11	4.20E+12	89.00%
White Clay Cr. (W15)	2.85E+13	0.00E+00	8.95E+12	4.71E+11	9.42E+12	66.90%
White Clay Cr. (W16)	1.02E+14	0.00E+00	1.32E+13	6.95E+11	1.39E+13	86.41%
White Clay Cr. (W17)	2.41E+14	0.00E+00	3.34E+13	1.76E+12	3.52E+13	85.43%
Red Clay Creek in Delaware						
Red Clay Cr. (R04)	5.89E+13	3.00E+12	8.52E+12	4.48E+11	1.20E+13	79.67%
Red Clay Cr. (R05)	2.25E+13	2.07E+10	7.90E+12	4.16E+11	8.34E+12	63.01%
Red Clay Cr. (R06)	1.51E+13	6.22E+08	1.01E+13	5.34E+11	1.07E+13	29.32%
Red Clay Cr. (R07)	6.05E+12	0.00E+00	1.74E+12	9.16E+10	1.83E+12	69.75%
Red Clay Cr. (R08)	7.61E+13	4.84E+11	7.83E+12	4.12E+11	8.73E+12	88.54%
Red Clay Cr. (R09)	2.88E+13	0.00E+00	2.89E+12	1.52E+11	3.04E+12	89.44%
Christina River and Tidal Brandywine Creek						
Christina River (C01)	3.51E+13	0.00E+00	1.27E+13	6.69E+11	1.34E+13	61. 90%
Christina River (C02)	8.16E+13	0.00E+00	2.47E+13	1.30E+12	2.60E+13	68.15%
Christina River (C03)	6.64E+13	0.00E+00	9.35E+12	4.92E+11	9.84E+12	85.18%
Christina River (C04)	8.69E+13	0.00E+00	6.73E+12	3.54E+11	7.09E+12	91.84%
Christina River (C05) *	2.21E+14	3.69E+13	4.84E+12	2.55E+11	4.20E+13	81.01%

Location	Baseline (cfu/yr)	WLA (cfu/yr)	LA (cfu/yr)	MOS (cfu/yr)	TMDL (cfu/yr)	Reduction
Christina River (C06)	7.45E+13	0.00E+00	1.65E+13	8.70E+11	1.74E+13	76.66%
Christina River (C07)	7.16E+13	0.00E+00	1.08E+13	5.70E+11	1.14E+13	84.08%
Christina River (C08)	1.28E+14	0.00E+00	1.67E+13	8.79E+11	1.76E+13	86.29%
Christina River (C09) *	6.84E+14	9.75E+13	3.54E+13	1.87E+12	1.35E+14	80.30%
Tidal Brandywine Cr. (B34) *	8.23E+14	2.55E+14	1.33E+13	6.98E+11	2.68E+14	67.38%
Sunset Lake	6.39E+13	0.00E+00	1.41E+13	7.46E+11	1.49E+13	76.66%
Beck’s Pond	6.27E+13	0.00E+00	9.45E+12	4.99E+11	9.98E+12	84.08%
Smalley’s Pond	1.28E+14	0.00E+00	1.67E+13	8.79E+11	1.76E+13	86.29%
* CSO loads are included in the Baseline and WLA in these subbasins.						

For more detailed information, see the appendices.

Total Maximum Daily Loads for Bacteria and Sediment in the Christina River Watershed Pennsylvania, Delaware, and Maryland

I. Introduction

The Clean Water Act (CWA) requires a Total Maximum Daily Load (TMDL) be developed for those waterbodies identified as impaired by the state where technology-based and other controls will not provide for attainment of water quality standards. A TMDL is a determination of the amount of a pollutant from point, nonpoint and natural background sources, including a margin of safety (MOS), which may be discharged to a water quality-limited waterbody without violating water quality standards.

TMDLs are defined as the summation of the point source wasteload allocations (WLAs) plus the summation of the nonpoint source load allocations (LAs) plus a MOS and are often shown as:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

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The TMDLs are to achieve and maintain the states' existing water quality standards and must meet the following eight regulatory requirements pursuant to 40 CFR Part 130.

1. The TMDLs are designed to implement the applicable water quality standards.
2. The TMDLs include a total allowable load as well as individual WLAs and LAs.
3. The TMDLs consider the impacts of background pollutant contributions.
4. The TMDLs consider critical environmental conditions.
5. The TMDLs consider seasonal environmental variations.
6. The TMDLs include a MOS.
7. There is reasonable assurance that the proposed TMDLs can be met.
8. The TMDLs have been subject to public participation.

As interstate TMDLs, both Pennsylvania and Maryland have the responsibility of meeting downstream Delaware's water quality standards.

As a result of water quality and biological investigations conducted by the Pennsylvania Department of Environmental Protection (PADEP), Delaware Department of Natural Resources and Environmental Control (DNREC), and Maryland Department of Environment that identified observed impacts on aquatic life, many streams in the Christina River Basin have been listed on the states' Section 303(d) lists of impaired waters. Parts of the watershed are heavily impacted by urbanization and are listed as impaired due to problems associated with elevated bacteria levels and sediment (also referred to as siltation). This study will fulfill the requirements for bacteria and sediment TMDL development for waters in the Christina River Basin included in the Section 303(d) lists for Pennsylvania and Delaware. A related study addresses those impairments resulting from nutrients and low dissolved oxygen concentrations.

1.1 Historical Perspective

In 1991, at the request of DNREC and PADEP, the Delaware River Basin Commission (DRBC) agreed to mediate water management issues in the "interstate" Christina River Basin. The issues included interstate and intrastate coordination of monitoring, modeling, and pollution controls; balancing the conflicting demands for potable water while maintaining necessary minimum pass-by requirements to sustain aquatic life; protection of vulnerable, high quality scenic and recreational areas; restoration of wetlands and other critical habitats; and implementation of Delaware's Exceptional Recreational or Ecological Significance (ERES) objectives. A comprehensive basin approach was needed to address these management issues.

The DRBC facilitated a series of meetings with DNREC, PADEP, EPA, Chester County Water Resources Authority (CCWA), and the United States Geological Survey (USGS). EPA funded a study by Scientific Applications International Corporation for completion of an initial data assessment and problem identification study for the non-tidal portion of Brandywine Creek. The findings of this study, *Preliminary Study of the Brandywine Creek Sub-basin, Final Report, September 30, 1993*, provided a framework for use in a multi-step TMDL study for the entire Christina River Basin. The two States, DRBC and EPA, reached agreement in late 1993 to initiate a cooperative and coordinated monitoring and modeling approach to produce Christina River Basin TMDLs under low-flow conditions. EPA established the Christina River Basin Low-Flow TMDL on January 19, 2001 (later revised on October 8, 2002). See Region III web site at http://www.epa.gov/reg3wapd/tmdl/.

Even as the parties reached agreement on how best to address the impacts of pollutants during low-flow conditions, they recognized that additional efforts would be necessary to address the distinct water quality problems resulting from nonpoint sources of pollutants during high-flow or variable flow conditions. In 1993, EPA recommended that DRBC expand the effort to consider high-flow conditions. As a result, the Christina Basin Water Quality Management Committee (CBWQMC) was created with the purpose of addressing the applicable water quality problems and management policies on a watershed scale. The CBWQMC represents a variety of stakeholders and interested parties including the Brandywine Valley Association/Red Clay Valley Association, Chester County Conservation District, Chester County Health Department (CCHD), Chester County Planning Commission, CCWA, DNREC, Delaware Nature Society, DRBC, New Castle County Conservation District (NCCD), PADEP, EPA Region III, USGS, United States Natural Resources Conservation Service (USDA-NRCS) and the Water Resources Agency for New Castle County.

The CBWQMC developed a unified, multi-phased, five-year Water Quality Management Strategy (WQMS) that (1) addresses the water quality problems through voluntary watershed/water quality planning and management activities and (2), establishes appropriate TMDLs. The reason for separating the development of TMDLs to address water quality problems between low-flow and high-flow TMDLs is that each scenario has different and distinct pollutants and problems at different flow regimes.

Since 1995, the CBWQMC has been conducting activities set forth in the WQMS designed to implement programs aimed at protecting and improving water quality. These activities include Geographic Information System (GIS) watershed inventory, water quality assessment, watershed pollutant potential and prioritization, stormwater monitoring, best management practices (BMP) Implementation projects and public education/outreach. A summary of these activities can be found in *Phase I and II Report, Christina River Basin Water Quality Management Strategy, May 1998,* and *Phase III Report, Christina Basin Water Quality Management Strategy, August 5, 1999.* These reports describe ongoing efforts to provide pollution control and restore water quality within the Christina River Basin.

Both Pennsylvania and Delaware have identified multiple segments and pollutants in the Christina River Basin on their respective lists of impaired waters still requiring the development of a TMDL. Maryland has identified biological impairments in the West Branch Christina River. The CWA requires that upstream waters must meet the applicable water quality standard of the downstream state at or before the state line. In other words, both Maryland and Pennsylvania are required to meet Delaware's water quality standard at the Delaware State line.

Concurrent with the water quality improvement activities taking place within the Christina River Basin, EPA settled two civil lawsuits regarding EPA's oversight of the TMDL programs of Pennsylvania and Delaware. Both suits alleged violations of the CWA, the Endangered Species Act, and the Administrative Procedures Act. The settlement of the Pennsylvania matter, American Littoral Society and the Public Interest Research Group v. EPA, Civil No. 96-489 (E.D. Pa), effective date April 9, 1997, requires certain numbers of TMDLs by certain dates but gives discretion to Pennsylvania and EPA as to which TMDLs must be completed.

The settlement of the Delaware lawsuit, American Littoral Society and Sierra Club v. EPA, Civil Action No. 96-591 (SLR) (D.De), effective date August 9, 1997, sets forth specific deadlines for EPA relating to specific waters and TMDLs in the Christina River Basin. Under the schedule set forth the settlement, Delaware was to establish low-flow TMDLs for all water quality limited segments (except for those impaired by bacteria), including Brandywine Creek, Christina River, Red Clay Creek and White Clay Creek, by December 31, 1999. The Delaware settlement also expected Delaware to establish high-flow TMDLs by December 31, 2004. Pursuant to the Delaware agreement, EPA is required to establish TMDLs within one year should Delaware fail to do so.

1.2 Background Information

The Christina River Basin (Hydrologic Unit Code 02040205) covers an area of about 564 square miles and is located in Chester County, Pennsylvania, New Castle County, Delaware, and Cecil County, Maryland (Figure 1-1). Major streams include the Christina River (tidal and nontidal), Brandywine Creek (tidal and nontidal), Red Clay Creek and White Clay Creek (tidal and nontidal). These streams are designated as habitat for aquatic life, for municipal and industrial water supplies, and for recreational purposes. The Christina River Basin drains to the tidal Delaware River at Wilmington, Delaware.

The Christina River Basin is composed of diverse land uses including urban, rural and agricultural areas. Urban areas in the watershed include greater Wilmington and Newark, Delaware, and the Pennsylvania towns of West Chester, Downingtown, Kennett Square, Coatesville, Parkesburg, Honey Brook, Avondale and West Grove. The land use distribution within the basin is summarized in Table 1-1 and the Brandywine Creek Watershed subbasins are shown in Fingure 1-1 and identified in Table 1-2.

Table 1-1. Christina River Basin land use summary (square miles)

Land Use	DE/MD	Pennsylvania	Total	%
Urban/Suburban	87	108	195	34
Agricultural	18	160	178	31
Open Space or Protected Lands	21	5	26	5
Wooded	37	123	160	28
Water/other	3	3	6	2
Total	166	399	565	100

Source: Phase I/II Report Christina River Basin Water Quality Management Strategy (CBWQMC - May 1998)

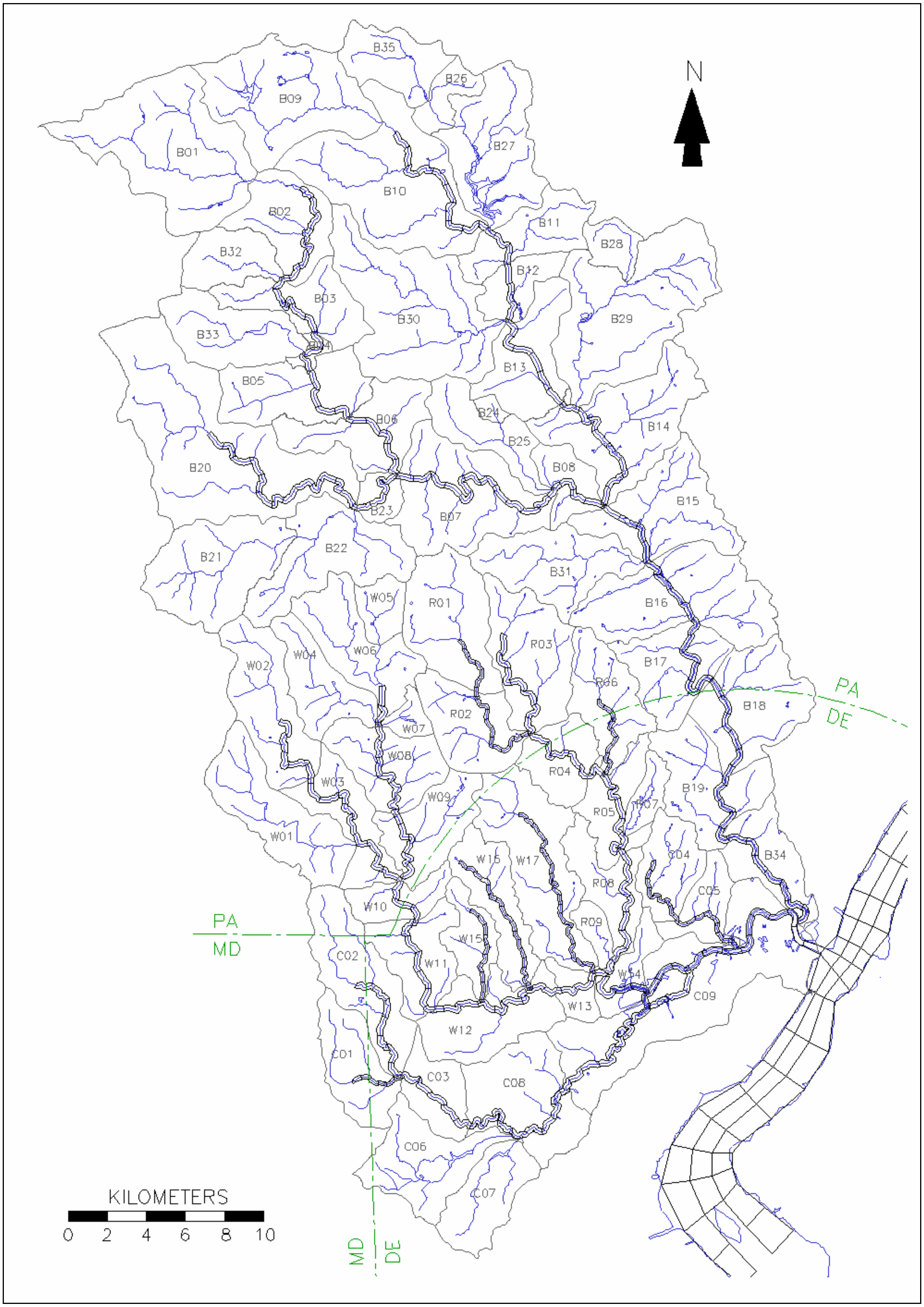

Figure 1-1. Christina River Basin delineation of HSPF model subbasins and EFDC model grid.

Table 1-2. Subbasins in the HSPF models of the Christina River Basin

Subbasin	Stream Name	Area (mi2)	Subbasin	Stream Name	Area (mi2)
	Brandywine Creek Watershed			*White Clay Creek Watershed*	
B01	Upper Brandywine Creek West Br.	18.39	W01	White Clay Creek West Br.	10.23
B02	Brandywine Creek West Branch	7.38	W02	Upper White Clay Creek Middle Br.	9.51
B03	Brandywine Creek West Branch	6.76	W03	White Clay Creek Middle Br.	6.35
B04	Brandywine Creek West Branch	0.80	W04	Trib. to White Clay Creek East Br.	6.20
B05	Brandywine Creek West Branch	8.82	W05	Trib. to White Clay Creek East Br.	2.65
B06	Brandywine Creek West Branch	8.06	W06	Upper White Clay Creek East Br.	8.57
B07	Brandywine Creek West Branch	13.46	W07	Trout Run	1.37
B08	Brandywine Creek West Branch	3.62	W08	White Clay Creek East Branch	7.47
B09	Upper Brandywine Creek East Br.	14.68	W09	White Clay Creek East Branch	6.85
B10	Brandywine Creek East Branch	18.31	W10	White Clay Creek	3.58
B11	Brandywine Creek East Branch	6.31	W11	White Clay Creek	6.53
B12	Brandywine Creek East Branch	3.70	W12	White Clay Creek	8.76
B13	Brandywine Creek East Branch	7.94	W13	White Clay Creek	2.08
B14	Brandywine Creek East Branch	12.92	W14	White Clay Creek	3.41
B15	Brandywine Creek	10.36	W15	Muddy Run	3.89
B16	Brandywine Creek	14.06	W16	Pike Creek	6.65
B17	Brandywine Creek	7.51	W17	Mill Creek	13.00
B18	Brandywine Creek	10.37		*Red Clay Creek Watershed*	
B19	Brandywine Creek	8.64	R01	Upper Red Clay Creek West Branch	10.08
B20	Upper Buck Run	25.54	R02	Red Clay Creek West Branch	7.39
B21	Upper Doe Run	11.05	R03	Red Clay Creek East Branch	9.90
B22	Lower Doe Run	10.96	R04	Red Clay Creek	5.11
B23	Lower Buck Run	1.95	R05	Red Clay Creek	5.24
B24	Tributary to Broad Run	0.60	R06	Burroughs Run	7.10
B25	Broad Run	5.83	R07	Hoopes Reservoir	2.10
B26	Marsh Creek	2.61	R08	Red Clay Creek	5.38
B27	Marsh Creek	11.54	R09	Red Clay Creek	1.72
B28	Tributary to Valley Creek	2.40		*Christina River Watershed*	
B29	Valley Creek	18.21	C01	Christina River West Branch	6.70
B30	Beaver Creek	18.08	C02	Upper Christina River	9.73
B31	Pocopson Creek	9.19	C03	Christine River	4.47
B32	Birch Run	4.66	C04	Upper Little Mill Creek	5.37
B33	Rock Run	8.03	C05	Little Mill Creek	3.84
B34	Brandywine Creek	6.05	C06	Muddy Run	8.64
B35	Upper Marsh Creek	5.80	C07	Belltown Run	6.37
			C08	Christina River	10.70
			C09	Lower Christina River	21.90

Both PADEP and DNREC identified the impaired stream segments based on historical monitoring data. The two state agencies use different bacterial indicators in their respective water quality standards for pathogens. Pennsylvania uses fecal coliform bacteria as an indicator of bacteria contamination whereas Delaware uses *enterococcus* bacteria. Fecal coliforms are a specific kind of coliform bacteria found primarily in the intestinal tracts of mammals and birds. These bacteria are usually released into the environment through human and animal feces. The presence of fecal coliform bacteria pollution may come from storm water runoff, pets, wildlife, and human sewage. If they are present in high concentrations in recreational waters and are ingested while swimming or enter the skin through a cut or sore, they may cause disease, infections, or rashes. *Enterococcus* is a common bacterium normally found in the intestinal tract of warm-blooded animals including humans. The presence of *enterococci* in surface water samples is used as an indicator of the presence of human sewage. *Enterococci* have a greater correlation with swimming-associated gastrointestinal illness in both marine and fresh waters than other bacterial indicator organisms, and are less likely to die off in saltwater.

1.3 Impairment Listing

TMDL development for this study is limited to bacteria and sediment impairments. Listings of the water segments in the Christina River Basin impaired by bacteria and sediment are provided in this section.

1.3.1 Bacteria Impairments

There are six subbasins containing stream segments on Pennsylvania's Section 303(d) list for bacteria impairment, and 19 waterbodies listed for bacteria impairment on Delaware's Section 303(d) list (see Table 1-3). There are no streams in the Maryland portion of the basin listed for bacteria impairment.

Table 1-3.   Segments impaired by bacteria in Christina River Basin.

Assessment ID	Waterbody Name	Size	Potential Source
Pennsylvania			
Subbasin R01	Mainstem and tributaries W. Br. Red Clay Creek	13.2 mi	NPS
Subbasin R02	Mainstem and tributaries W. Br. Red Clay Creek	18.9 mi	NPS
Subbasin R03	Mainstem and tributaries E. Br. Red Clay Creek	15.9 mi	NPS
Subbasin R04	Mainstem and tributaries Red Clay Creek	2.4 mi	NPS
Subbasin R06	Tributaries Red Clay Creek	8.6 mi	NPS
Subbasin W04	Tributaries E. Br. White Clay Creek	6.0 mi	PS
Delaware			
DE040-001	Lower Brandywine Creek	3.8 mi	PS, NPS
DE040-002	Upper Brandywine Creek	9.3 mi	PS, NPS
DE260-001	Red Clay Creek	12.8 mi	PS, NPS
DE260-002	Burroughs Run	2.6 mi	NPS
DE320-001	White Clay Creek (mainstem)	15.6 mi	PS, NPS
DE320-002	Mill Creek	8.3 mi	NPS
DE320-003	Pike Creek	5.4 mi	NPS
DE320-004	Middle Run	4.5 mi	NPS

Assessment ID	Waterbody Name	Size	Potential Source
DE120-003	Upper Christina River	6.3 mi	NPS
DE120-004-01	Lower Christina Creek	8.4 mi	NPS
DE120-004-02	Belltown Run	3.8 mi	NPS
DE120-004-03	Muddy Run	8.0 mi	NPS
DE120-005-01	West Branch Christina River	5.3 mi	NPS
DE120-006	Upper Christina Creek (mainstem)	8.3 mi	NPS
DE120-007-01	Little Mill Creek and Willow Run	5.1 mi	NPS
DE120-007-02	Chestnut Run	2.8 mi	NPS
DE120-L01	Smalleys Pond	30.0 ac	NPS
DE120-L02	Becks Pond	25.6 ac	NPS
DE120-L03	Sunset Pond	40.0 ac	NPS

1.3.2 Sediment Impairments

There are 14 stream segments on Pennsylvania's 1996 Section 303(d) list for sediment or siltation impairment (see Table 1-3). On Pennsylvania's 1998 Section 303(d) list 61 stream segments are listed for sediment or siltation impairments (see Table 1-4). There are no streams listed for sediment impairment in the Delaware or Maryland portions of the Christina River Basin.

Table 1-4. Pennsylvania streams requiring TMDLs for sediment on 1996 Section 303(d) list

Map ID	Segment ID	Stream Name	DEP 5-digit code	Downstr RM	Upstr RM	Assessment ID	Year listed
Watershed=03H (Brandywine Creek)							
5	64954_0.0_1.06	Unt E. Br. Brandywine Cr.	64954	0.0	1.06	970707-1120-GLW	1996
6	00229_24.5_27.3	E. Br. Brandywine Cr.	00229	24.46	27.3	970707-1120-GLW	1996
7	00371_0.0_1.46	Unt E. Br. Brandywine Cr.	00371	0.0	1.46	970707-1120-GLW	1996
8	00372_0.0_0.72	Unt E. Br. Brandywine Cr.	00372	0.0	0.72	970707-1120-GLW	1996
20	00085_10.52_16.4	W. Br. Brandywine Cr.	00085	10.52	16.4	19970925-1348-GLW	1996
Watershed=03I (White Clay Creek and Red Clay Creek)							
65	00465_0.0_7.78	W. Br. White Clay Cr.	00465	0.0	7.78	9408	1996*
SS1	00475_0.0_1.09	Indian Run	00475	0.0	1.09	115	1996
SS2	00462_2.56_14.08	Mid. Br. White Clay Cr.	00462	2.56	14.08	115	1996*
SS3	00462_6.53_8.76	Unt Mid. Br. White Clay Cr.	00462	6.53	8.76	115B	1996*
SS4	00476_0.0_1.56	Unt Mid. Br. White Clay Cr.	00476	0.0	1.56	115	1996
SS5	00477_0.0_1.80	Unt Mid. Br. White Clay Cr.	00477	0.0	1.80	115	1996
SS6	00478_0.0_1.26	Unt Mid. Br. White Clay Cr.	00478	0.0	1.26	115	1996
SS7	00479_0.0_0.63	Unt Mid. Br. White Clay Cr.	00479	0.0	0.63	115	1996
SS8	00480_0.0_0.56	Unt Mid. Br. White Clay Cr.	00480	0.0	0.56	115	1996

* Due to discrepancies between various Pennsylvania Section 303(d) lists, some listing dates may be in error. These marked listings were included on Pennsylvania's 1996 Section 303(d) list and are covered under the above-cited Consent Decree requirements for Pennsylvania.

Table 1-5. Pennsylvania streams requiring TMDLs for sediment (1998 Section 303(d) listings according to Pennsylvania's 2004 Section 303(d) list).

Map ID	Segment ID	Stream Name	DEP 5-digit code	Downstr RM	Upstr RM	Assessment ID	Year listed
Watershed=03H (Brandywine Creek)							
1	00185_0.0_3.31	Unt Buck Run	00185	0.0	3.31	19970710-1040-GLW	1998
2	00186_0.0_0.91	Unt Buck Run	00186	0.0	0.91	19970710-1040-GLW	1998
3	00187_0.0_1.04	Unt Buck Run	00187	0.0	1.04	970710-1340-GLW	1998
9	00076_0.0_3.42	Plum Run	00076	0.0	3.42	971023-1320-GLW	1998
10	00077_0.0_0.73	Unt Plum Run	00077	0.0	0.73	971023-1320-GLW	1998
67	00078_0.0_1.35	Unt Plum Run	00078	0.0	1.35	971023-1320-GLW	1998
11	00079_0.0_1.41	Unt Plum Run	00079	0.0	1.41	971023-1320-GLW	1998
12	00080_0.0_0.18	Unt Plum Run	00080	0.0	0.18	971023-1320-GLW	1998
13	00053_0.0_1.16	Pocopson Creek	00053	0.0	1.16	971021-1108-GLW	1998
14	00054_0.0_0.49	Unt Pocopson Creek	00054	0.0	0.49	971021-1108-GLW	1998
15	00071_0.0_2.22	Radley Run	00071	0.0	2.22	971024-1120-GLW	1998
16	00072_0.0_0.94	Unt Radley Run	00072	0.0	0.94	971024-1120-GLW	1998
17	00236_0.0_2.34	Taylor Run	00236	0.0	2.34	971006-1127-GLW	1998
18	00237_0.0_1.08	Unt Taylor Run	00237	0.0	1.08	971006-1127-GLW	1998
19	00238_0.0_0.34	Unt Taylor Run	00238	0.0	0.34	971006-1127-GLW	1998
	00239_0.0_0.97	Unt Taylor Run	00239	0.0	0.97	971006-1127-GLW	1998
21	00085_28.4_31.4	W. Br. Brandywine Cr.	00085	28.4	31.4	970618-1118-GLW	1998
22	00085_31.4_32.9	W. Br. Brandywine Cr.	00085	31.4	32.9	970618-1340-GLW	1998
23	00224_0.0_4.58	Unt W. Br. Brandywine Cr.	00224	0.0	4.58	970619-1222-GLW	1998
24	00224_4.58_7.16	Unt W. Br. Brandywine Cr.	00224	4.58	7.16	970619-1345-GLW	1998
25	00225_0.0_0.92	Unt W. Br. Brandywine Cr.	00225	0.0	0.92	970619-1222-GLW	1998
26	00226_0.0_1.41	Unt W. Br. Brandywine Cr.	00226	0.0	1.41	970619-1345-GLW	1998
27	00227_0.0_1.31	Unt W. Br. Brandywine Cr.	00227	0.0	1.31	970618-1340-GLW	1998
28	00228_0.0_0.78	Unt W. Br. Brandywine Cr.	00228	0.0	0.78	970618-1340-GLW	1998
Watershed=03I (White Clay Creek and Red Clay Creek)							
29	00434_0.24_3.49	Broad Run	00434	0.24	3.49	971029-1445-ACW	1998
30	00436_0.0_0.85	Unt Broad Run	00436	0.0	0.85	971029-1445-ACW	1998
31	00393_0.50_0.97	Bucktoe Creek	00393	0.50	0.97	971218-1300-ACW	1998
32	00394_0.0_1.12	Unt Bucktoe Creek	00394	0.0	1.12	971218-1300-ACW	1998
33	00395_0.0_1.09	Unt Bucktoe Creek	00395	0.0	1.09	971218-1300-ACW	1998
34	00413_0.0_5.29	E. Br. Red Clay Cr.	00413	0.0	5.29	971023-1050-MRB	1998
35	00414_0.03_3.28	Unt E. Br. Red Clay Cr.	00414	0.03	3.28	971204-1400-ACW	1998
36	00418_0.0_0.84	Unt E. Br. Red Clay Cr.	00418	0.0	0.84	971204-1400-ACW	1998
37	00419_0.0_1.24	Unt E. Br. Red Clay Cr.	00419	0.0	1.24	971203-1051-MRB	1998
38	00432_0.0_3.1	E. Br. White Clay Cr.	00432	0.0	3.1	971113-1335-GLW	1998
39	00432_3.1_5.77	E. Br. White Clay Cr.	00432	3.1	5.77	970506-1320-MRB	1998
40	00432_9.47_10.0	E. Br. White Clay Cr.	00432	9.47	10.0	971119-1116-GLW	1998

Map ID	Segment ID	Stream Name	DEP 5-digit code	Downstr RM	Upstr RM	Assessment ID	Year listed
41	00438_0.0_0.62	Unt E. Br. White Clay Cr.	00438	0.0	0.62	970506-1320-MRB	1998
42	00439_0.0_0.67	Unt E. Br. White Clay Cr.	00439	0.0	0.67	970506-1320-MRB	1998
43	00443_0.0_0.71	Unt E. Br. White Clay Cr.	00443	0.0	0.71	970506-1320-MRB	1998
44	00444_0.0_0.71	Unt E. Br. White Clay Cr.	00444	0.0	0.71	970506-1320-MRB	1998
45	00445_0.0_2.44	Unt E. Br. White Clay Cr.	00445	0.0	2.44	970508-1430-ACE	1998
46	00446_0.0_0.5	Unt E. Br. White Clay Cr.	00446	0.0	0.5	970506-1320-MRB	1998
47	00447_0.0_0.77	Unt E. Br. White Clay Cr.	00447	0.0	0.77	970506-1320-MRB	1998
48	00448_2.49_2.85	Unt E. Br. White Clay Cr.	00448	2.49	2.85	970409-1130-MRB	1998
49	00450_0.0_0.25	Unt E. Br. White Clay Cr.	00450	0.0	0.25	970409-1130-MRB	1998
50	00454_0.0_5.4	Unt E. Br. White Clay Cr.	00454	0.0	5.4	971120-1331-GLW	1998
51	00455_0.0_2.52	Unt E. Br. White Clay Cr.	00455	0.0	2.52	971120-1331-GLW	1998
52	00456_0.0_0.22	Unt E. Br. White Clay Cr.	00456	0.0	0.22	971120-1331-GLW	1998
53	00440_0.0_1.52	Egypt Run	00440	0.0	1.52	970508-1245-ACE	1998
54	00441_0.0_1.38	Unt Egypt Run	00441	0.0	1.38	970508-1245-ACE	1998
55	00442_0.0_0.76	Unt Egypt Run	00442	0.0	0.76	970508-1245-ACE	1998
56	63874_0.0_1.7	Trout Run	63874	0.0	1.7	970506-1425-MRB	1998
57	63875_0.0_0.82	Unt Trout Run	63875	0.0	0.82	970506-1425-MRB	1998
58	63876_0.0_0.21	Unt Trout Run	63876	0.0	0.21	970506-1425-MRB	1998
59	00435_0.0_1.39	Walnut Run	00435	0.0	1.39	971209-1445-ACW	1998
60	00391_0.0_4.6	W. Br. Red Clay Cr.	00391	0.0	4.6	971023-1145-MRB	1998
61	00396_0.0_1.8	Unt W. Br. Red Clay Cr.	00396	0.0	1.8	971023-1315-MRB	1998
66	00373_1.85_3.26	White Clay Creek	00373	1.85	3.26	971216-1230-GLW	1998

1.4 Water Quality Standards

1.4.1 Pennsylvania Water Quality Standards

Pennsylvania Code, Title 25, Chapter 93 sets forth water quality standards for surface waters of the Commonwealth. These standards are based upon water uses which are to be protected and will be considered by PADEP in implementing its authority under the Clean Streams Law and other Commonwealth statutes that authorize protection of surface water quality. With regard to bacteria, waters in the Christina River Basin are designated for contact recreation and potable water supply uses. Contact recreation is classified as swimming season (May 1 through September 30) and non-swimming season (October 1 through April 30). The water quality criteria for bacteria are more stringent during the swimming season. Statewide water uses in Pennsylvania include aquatic life, water supply, and recreation. Waters within the Christina River Basin include exceptional value and high quality waters. The applicable numeric water quality criteria for bacteria in the Pennsylvania portion of the Christina River Basin are shown in Table 1-6.

Implementation of the numeric water quality criteria in Pennsylvania are summarized in Table 1-6 and defined in PA Code, Title 25, Chapter 96.3 as follows:

Chapter 96.3(c): "To protect existing and designated surface water uses, the water quality criteria described in Chapter 93 (relating to water quality standards), including the criteria in Chapters 93.7 and 93.8a(b) (relating to specific water quality criteria; and toxic substances) shall be achieved in all surface waters at least 99 percent of the time, unless otherwise specified in this title. The general water quality criteria in Chapter 93.6 (relating to general water quality criteria) shall be achieved in surface waters at all times at design conditions."

Chapter 96.3(d): "As an exception to subsection (c), the water quality criteria for total dissolved solids, nitrite-nitrate nitrogen, phenolics and fluoride established for the protection of potable water supply shall be met at least 99 percnt of the time at the point of all existing or planned surface potable water supply withdrawals unless otherwise specified in this title."

In addition to numeric water quality criteria, waters in the Christina River Basin are also subject to narrative criteria stated in PA Code, Title 25, Chapter 93.6 as follows:

Chapter 93.6(a): "Water may not contain substances attributable to point or nonpoint source discharges in concentration or amounts sufficient to be inimical or harmful to the water uses to be protected or to human, animal, plant or aquatic life."

Chapter 93.6(b): "In addition to other substances listed within or addressed by this chapter, specific substances to be controlled include, but are not limited to, floating materials, oil, grease, scum and substances which produce color, tastes, odors, turbidity or settle to form deposits."

The TMDL developed for sediment rely on above narrative criteria for their endpoint. Because neither Pennsylvania nor EPA has numeric water quality criteria for sediment, a method was developed to determine water quality objectives that would result in the impaired stream segments attaining their designated uses. The method employed for these TMDLs is termed the "Reference Watershed Approach." The Reference Watershed Approach compares two watersheds, one attaining its uses and one that is impaired based on biological assessments. Both watersheds must have similar land use/cover distributions. Other features such as base geologic formation should be matched to the extent possible. However, most of the variations can be adjusted in the model. The objective of the process is to reduce the loading rate of pollutants in the impaired stream segment to a level equivalent to the loading rate in the non-impaired, reference stream segment. This load reduction will result in conditions favorable to the return of a healthy biological community to the impaired stream segments.

Table 1-6. Pennsylvania water quality standards (PA Code, Title 25, Chapter 93.7)

<table>
<tr><th>Pollutant</th><th>Designated Use</th><th colspan="2">Criteria</th><th>Period</th></tr>
<tr><td rowspan="3">Fecal Coliform Bacteria (cfu/100 mL)</td><td rowspan="2">Water Contact Recreation (statewide)</td><td>Maximum geometric mean of 200 cfu per 100 mL, based on a minimum of 5 consecutive samples each sample collected on different days during a 30-day period.</td><td>No more than 10% of the total samples taken during a 30-day period may exceed 400 cfu per 100 mL</td><td>May 1 to Sep 30</td></tr>
<tr><td colspan="2">Maximum geometric mean of 2,000 cfu per 100 mL, based on a minimum of 5 consecutive samples each sample collected on different days during a 30-day period</td><td>Oct 1 to Apr 30</td></tr>
<tr><td>Potable Water Supply (statewide)</td><td colspan="2">Maximum of 5,000 cfu per 100 mL as a monthly average value, no more than this number in more than 20 samples collected during a month, nor more than 20,000 cfu per 100 mL in more than 5% of the samples</td><td>year round</td></tr>
<tr><td>Total Dissolved Solids TDS (mg/L)</td><td>Potable Water Supply (statewide)</td><td>maximum = 750</td><td>monthly avg. = 500</td><td>year round</td></tr>
</table>

cfu – colony forming units

1.4.2 Delaware Water Quality Standards

Delaware amended its water quality standards on July 11, 2004. EPA approved the revised standards for *enterococci* bacteria in November 2004. The Christina River and Brandywine Creek are designated as public and industrial water supply, primary and secondary contact recreation, and for fish, aquatic and wildlife. Portions of the Brandywine Creek are also designated as ERES waters.

The Delaware water quality standards contain criteria for bacteria for primary and secondary contact waters as well as shellfish harvesting waters. There are no shellfish harvesting waters in the Christina River Basin. Waters in the Christina River Basin within Delaware are designated for both primary and secondary contact recreation uses as shown in Table 1-6.

Table 1-7. Delaware bacteria water quality standards, *enterococcus* bacteria (cfu/100 mL).

Waterbody Use Designation	Criteria	
	Single-Sample Value	Geometric Mean
Primary contact recreation fresh waters	185	100
Primary contact recreation marine waters	104	35
Secondary contact recreation fresh waters	925	500
Secondary contact recreation marine waters	520	175

Delaware is committed to bacteria source tracking to be able to determine the source of bacteria causing impairments under the supposed assumption that bacteria from wildlife sources does not pay as great a threat to human health as bacteria from human sources does. However, DNREC does not have information from the Christina River and Brandywine Creek Watersheds on which to estimate the wildlife contribution to the bacteria impairment. Therefore, no reductions to monitoring data will be taken.

"Marine waters" are defined as waters of the state that contain natural levels of salinity greater than five parts per thousand (ppt). All waters within the Christina River Basin have natural salinity levels less than five ppt. Therefore, the primary contact fresh-water criteria for *enterococcus* bacteria were used as the target end points for this TMDL.

1.4.3 Maryland Water Quality Standards

All surface waters shall be protected for water contact recreation, fishing, and protection of aquatic life and wildlife. For fresh waters, Maryland uses either *enterococci* or *E. coli* as the bacteria indicator. For waters not designated as beaches, only the steady state geometric mean indicator density for *enterococci* is 33 counts/100 mL and for *E. coli* 126 counts/100 mL is the applicable criterion.

2.0 SOURCE ASSESSMENT

Waters of the Christina River Basin are used for recreation, public water supply, and to support aquatic life. Some of these uses are threatened due to impairment caused by point and nonpoint sources of bacteria and sediment. PADEP and DNREC identified the impaired stream segments based on historical monitoring data and biological integrity field surveys. The two state agencies use different bacterial indicators in their respective water quality standards for pathogens. Pennsylvania uses fecal coliform bacteria as an indicator of bacteria contamination whereas, Delaware uses enterococcus bacteria. While both states list waterbodies for bacteria impairments, only Pennsylvania lists waterbodies for sediment, suspended solids, or siltation impairments.

Fecal coliform is a specific kind of coliform bacteria found primarily in the intestinal tracts of mammals and birds. These bacteria are usually released into the environment through human and animal feces. The presence of fecal coliform bacteria pollution may come from storm water runoff, pets, wildlife, and human sewage. If present in high concentrations in recreational waters and are ingested while swimming or enter the skin through a cut or sore, fecal coliform may cause disease, infections, or rashes.

Enterococcus is a common bacterium normally found in the intestinal tract of warm-blooded animals including humans. The presence of enterococci in surface water samples is used as an indicator of the presence of human sewage. Enterococci have a greater correlation with swimming-associated gastrointestinal illness in both marine and fresh waters than other bacterial indicator organisms, and are less likely to die off in saltwater.

A customized modeling framework was developed to support determination of bacteria and sediment TMDLs for the Christina River Basin. The modeling framework used in this study consisted of three major components: (1) a watershed loading model (Hydrolic Systems Program Fortran (HSPF) developed for each of the four primary subwatersheds in the Christina River Basin by the USGS (Senior and Koerkle, 2003a, 2003b, 2003c, 2003d), (2) a Combined Sewer Overflow (CSO) flow model (XP-SWMM) developed by the City of Wilmington, and (3) a hydrodynamic model developed using the computational framework of the Environmental Fluid Dynamics Code (EFDC) (Hamrick, 1992). Development of inputs for these models involved the analyses of historical water quality and streamflow data to estimate point and nonpoint sources of bacteria and sediment.

2.1 Point Sources

The term "point source" refers to any discernible, confined, and discrete conveyance, such as a pipe, ditch, channel, tunnel, conduit, discrete fissure, or container including vessels or other floating craft from which pollutants are or may be discharged. The point source also includes concentrated animal feeding operations, places where animals are confined and fed. Storm water runoff from certain areas may also be considered a point source because the water is transported through a pipe or ditch.

Estimating the transport of sediments and pathogens into a surface waterbody from most point sources is a fairly straightforward matter. Wastewater treatment plants (WWTPs), CSOs, and municipal separate storm sewer systems (MS4s) discharge though a constructed conveyance to a waterbody. Many of the pathogen organisms transported to WWTPs are removed during the treatment process, and permit limits are established to ensure that WWTPs meet water quality standards. However, in some instances failures or leaks may occur, or a wet weather event may create flows that exceed the capacity of the WWTP or CSO. This can lead to a discharge of contaminated water exceeding the permitted limits into the river system. MS4s discharge to waterbodies without being treated by a WWTP.

2.1.1 Wastewater Treatment Plants

Treated industrial and municipal sewage can be a point source of sediment and bacterial contamination. Not all human pathogens or sediment are removed or rendered harmless by treatment processes. Periodic effluent overflows and high-flow bypass in WWTPs can cause occasional high loading of pathogens. Raw sewage entering the WWTP typically has a total coliform count ranging from 10^7 to 10^9 cfu/100 mL (Novotny et al., 1989). Associated with raw sewage are proportionally high concentrations of pathogenic bacteria, viruses and protozoans. A typical wastewater treatment plant reduces the total coliform count by about three orders of magnitude. The magnitude of reduction, however, varies with the treatment process.

Treatment of municipal waste is generally identified as primary, secondary or advanced (also called tertiary) treatment, although the distinctions are somewhat arbitrary. Primary treatment involves removing suspended solids with screens and the use of gravity settling ponds followed by disinfection. Most protozoan cysts settle out in ponds after 11 days due to their size (EPA, 2001). Secondary treatment uses biological treatment to decompose organic matter to cell material and by-products, and the subsequent removal of cell matter, usually by gravity settling. Activated sludge processes involve the production of an activated mass of microorganisms capable of stabilizing waste aerobically. Secondary treatment by activated sludge typically reduces bacteria concentrations by 90 to 99 percent.

Tertiary treatment is any practice beyond secondary treatment and is very effective in destroying most pathogens. Tertiary treatment can include disinfection, filtration, and coagulation. Disinfection is the most common treatment technique to combat waterborne diseases, and the most frequently used disinfectant is chlorine (EPA, 2001). Chlorine kills many microbes, including most pathogens, except protozoan cysts, which are resistant to chlorine. Other disinfectants used are ozone, ultraviolet light, and iodine.

As authorized by the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. The locations of NPDES facilities in the Christina River Basin are shown in Figure 2-1 and listed in Table 2-1. The fecal coliform bacteria, enterococci bacteria, and total suspended solids loads for each of the NPDES facilities, based on permit flow rate, are provided in Table 2-2. Note that fecal coliform bacteria were not simulated for the Delaware or Maryland NPDES facilities.

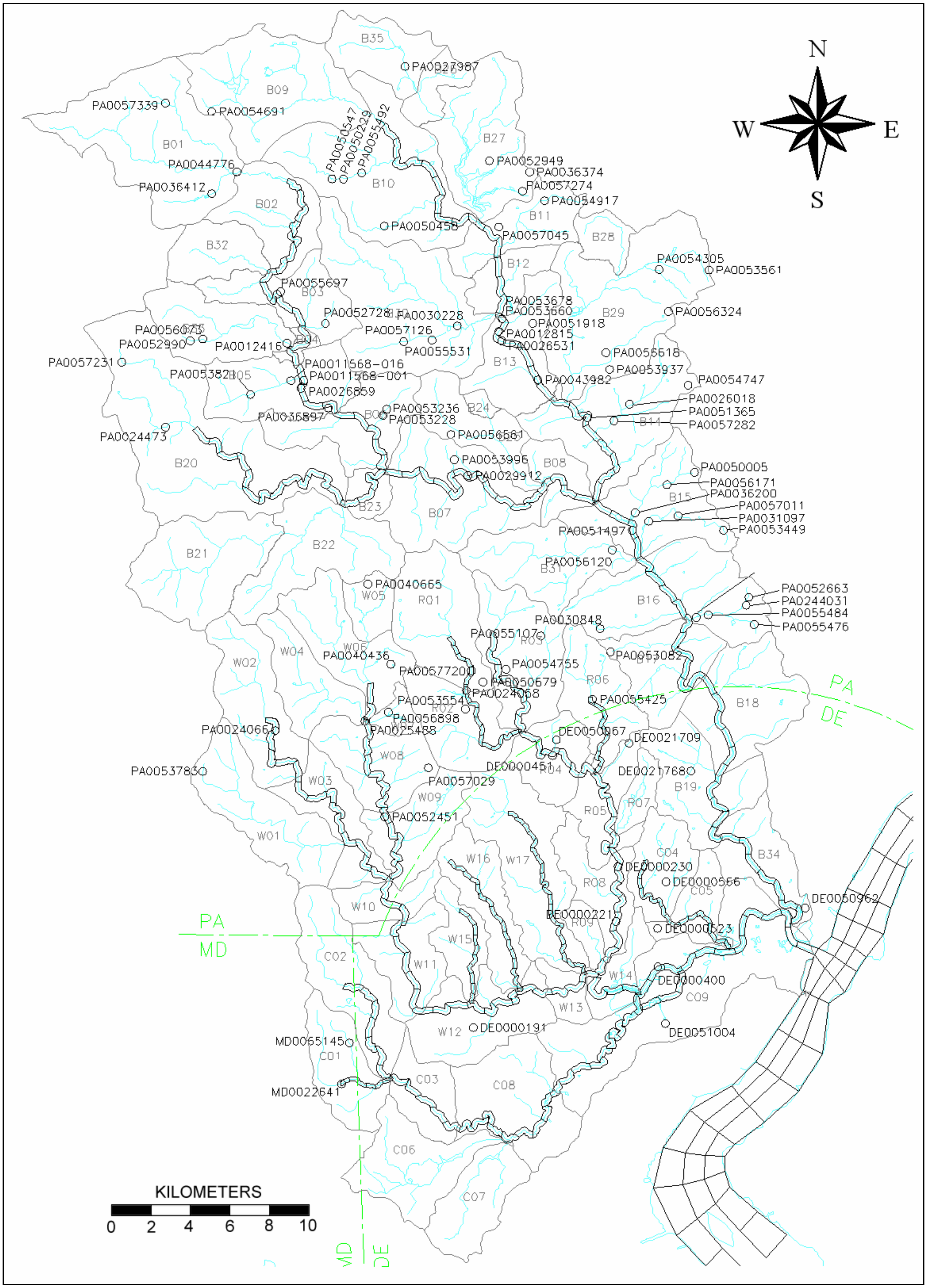

Figure 2-1. NPDES discharges in Christina River Basin

Table 2-1. NPDES point source discharges in Christina River Basin

RIVER MILE	CELL I, J	NPDES NUMBER	FLOWLIM MGD	CODE	OWNER	STREAM	TYPE	DESCRIPTION
Brandywine Creek (main stem)								
76.610	54,15	DE0050962	0.0000	SWR	AMTRAK	TB-Brandywine Creek	Industrial	Stormwater
83.554	54,27	DE0021768	0.0250	STP	Winterthur Museum	Clenney Run	Municipal	Small STP
88.644	54,37	PA0053082	0.0206	STP	Mendenhall Inn	TB Brandywine Creek	Commercial	Small STP
89.917	54,38	PA0052663	0.0900	STP	Knight's Bridge Co/Villages at Painters	Harvey Run	Commercial	Small STP
89.917	54,38	PA0055476	0.0400	STP	Birmingham TSA/Ridings at Chadds Ford	TB Harvey Creek	Municipal	Small STP
89.917	54,38	PA0055484	0.0005	SRD	Keating Herbert & Elizabeth	TB Brandywine Creek	Municipal	Single Residence STP
89.917	54,38	PA0244031	0.1500	STP	Chadds Ford Township	Harvey Run		
90.553	54,39	PA0030848	0.0063	STP	Unionville - Chadds Ford Elem. School	Ring Run	Municipal	Small STP
93.098	54,42	PA0056120	0.0005	SRD	Schindler	Pocopson Creek	Municipal	Single Residence STP
92.462	54,43	PA0031097	0.0170	STP	Radley Run C.C.	Radley Run	Municipal	Small STP
92.462	54,43	PA0053449	0.1500	STP	Birmingham Twp. STP	Radley Run	Municipal	Small STP
93.735	54,43	PA0057011	0.0773	STP	Thornbury Twp./Bridlewood Farms STP	Radley Run		
92.462	54,44	PA0036200	0.0320	STP	Radley Run Mews	Plum Run	Municipal	Small STP
94.371	54,44	PA0056171	0.0005	SRD	McGlaughlin Jeffrey	Plum Run	Municipal	Single Residence STP
94.371	54,44	PAG050005	0.1400	GWC	Sun Company	TB Brandywine Creek	GWCleanup	New permit 03/27/98
94.371	54,44	PA0051497	0.0300	NCW	Lenape Forge	Brandywine Creek	Industrial	Cooling Water
Brandywine Creek East Branch								
98.647	54,52	PA0026018	1.8000	MUN	West Chester Borough MUA/Taylor Run	Taylor Run	Municipal	Large STP
98.647	54,52	PA0057282	0.0005	SRD	Jonathan & Susan Pope	TB Valley Creek	Municipal	Single Residence STP
99.276	54,53	PA0051365	0.3690	WFP	PA American Water	EB Brandywine Creek	Municipal	Ingram's Mill-Filter Backwash
100.535	54,55	PA0053937	0.0005	SRD	William and Patricia Kratz	Broad Run Creek	Municipal	Single Residence STP
100.535	54,55	PA0056324	0.0440	GWC	Mobil SS#16-GPB	TB-WB Valley Run	Commercial	DP
100.535	54,55	PA0056618	0.0005	SRD	O'Cornwell David & Jeanette	Broad Run	Municipal	Single Residence STP
100.535	54,55	PA0054305	0.0000	IND	Sun Co, Inc. (R&M)	TB Valley Creek	Industrial	
100.535	54,55	PA0053561	0.0360	GWC	Johnson Matthey	Valley Creek	GWCleanup	Permitted 03/12/96
101.794	54,57	PA0043982	0.4000	ATP2	Broad Run Sew Co.	EB Brandywine Creek	Municipal	Large STP
103.682	54,61	PA0012815	1.0280	IND	Sonoco Products	EB Brandywine Creek	Industrial	Paper Company - Mill Raceway
103.682	54,60	PA0026531	7.5000	ATP2	Downingtown Area Regional Authority	EB Brandywine Creek	Municipal	Large STP
104.312	54,61	PA0051918	0.1440	NCW	Pepperidge Farms	Parke Run Creek	Industrial	Cooling Water
103.682	54,61	PA0055531	0.0007	STP	Khalife Paul	TB Valley Run	Commercial	Small STP
104.312	54,61	PA0057126	0.0000	IND	Hess Oil - SS #38291	Valley Run	Commercial	DP
104.312	54,61	PA0030228	0.0225	STP	Downingtown I&A School	Beaver Creek	Municipal	No flow since Feb 1994
104.312	54,61	PA0053678	0.0000	IND	Lambert Earl R.	EB Brandywine Creek	Industrial	DP
104.312	54,61	PA0053660	0.0000	IND	Mobil Oil Company #016	EB Brandywine Creek	Commercial	Air stripper at Service Sta
106.830	54,65	PA0054917	0.4750	STP	Uwchlan Twp. Municipal Authority	Shamona Creek	Municipal	Eagleview CC STP
107.459	54,66	PA0057045	0.0000	SWR	Shyrock Brothers, Inc.	EB Brandywine Creek	Commercial	Stormwater
108.088	54,67	PA0027987	0.0500	STP	Pennsylvania Tpk./Caruiel Service Plaza	Marsh Creek	Commercial	Small STP
108.088	54,67	PA0036374	0.0150	STP	Eaglepoint Dev. Assoc.	TB Marsh Creek	Municipal	Small STP
108.088	54,67	PA0052949	0.0000	IND	Phila. Suburban Water Co.	Marsh Creek	Industrial	Uwchlan DP
108.088	54,67	PA0057274	0.0005	SRD	Michael & Antionette Hughes	TB Marsh Creek	Municipal	Single Residence STP
109.977	54,70	PA0050458	0.0531	STP	Little Washington Drainage Co.	Culbertson Run	Municipal	Small STP
112.495	54,74	PA0057827	0.0005	SRD	McKenna	Indian Run	Municipal	Single Residence STP
112.495	54,74	PA0050547	0.0375	STP	Indian Run Village MHP	Indian Run	Municipal	Small STP
112.495	54,74	PA0055492	0.0005	SRD	Andrew and Gail Woods	Indian Run	Municipal	Single Residence STP
113.753	54,76	PA0054691	0.0005	SRD	Stoltzfus Ben Z.	TB Brandywine Creek	Municipal	Single Residence STP

Table 2-1. NPDES point source discharges in Christina River Basin (continued).

RIVER MILE	CELL I, J	NPDES NUMBER	FLOWLIM MGD	CODE	OWNER	STREAM	TYPE	DESCRIPTION
Brandywine Creek West Branch								
97.976	46,79	PA0056561	0.0000	SWR	Richard M. Armstrong Co.	Broad Run	Commercial	Stormwater
101.708	40,79	PA0029912	0.1000	STP	Embreeville Hospital	WB Brandywine Creek	Municipal	Large STP
102.330	39,79	PA0053996	0.0005	SRD	Redmond Michael	TB-WB Brandywine Creek	Municipal	Single Residence STP
107.306	29,79	PA0053228	0.0005	SRD	Gramm Jeffery	WB Brandywine Creek	Municipal	Single Residence STP
107.306	29,79	PA0053236	0.0005	SRD	Woodward Raymond Sr. STP	WB Brandywine Creek	Municipal	Single Residence STP
110.416	24,79	PA0036897	0.3900	ATP1	South Coatesville Borough	WB Brandywine Creek	Municipal	Large STP
111.038	23,79	PA0026859	3.8500	ATP1	Coatesville City Authority	WB Brandywine Creek	Municipal	Large STP
111.038	23,79	PA0011568-001	0.5000	IND	ISG Plate LLC	Sucker Run	Industrial	Large STP
111.038	23,79	PA0011568-016	0.5000	IND	ISG Plate LLC	Sucker Run	Industrial	Large STP
111.038	23,79	PA0053821	0.0000	SWR	Chester County Aviation Inc.	Sucker Run	Commercial	Stormwater
112.282	20,79	PA0012416	0.1400	WFP	PA American Water	Rock Run	Industrial	Water Filtration Plant-Backwash
112.282	20,79	PA0052990	0.0005	SRD	Mitchell Rodney	Rock Run	Municipal	Single Residence STP
112.282	20,79	PA0056073	0.0005	SRD	Vreeland Russell Dr.	TB Rock Run	Municipal	Single Residence STP
113.526	18,79	PA0052728	0.0004	STP	Farmland Industries Inc./Turkey Hill	WB Brandywine Creek	Industrial	Small STP
114.770	16,79	PA0055697	0.0490	STP	Spring Run Estates	WB Brandywine Creek	Commercial	Small STP
120.368	06,79	PA0036412	0.0550	STP	Tel Hai Retirement Community	TB-WB Brandywine Creek	Municipal	Small STP
120.368	06,79	PA0044776	0.6000	STP	NW Chester Co. Municipal Authority	WB Brandywine Creek	Municipal	Large STP
120.368	06,79	PA0057339	0.0005	SRD	Brian & Cheryl Davidson	TB-WB Brandywine Creek	Municipal	Single Residence STP
Buck Run								
117.041	33,61	PA0024473	0.7000	STP	Parkersburg Borough Authority WWTP	TB-Buck Run	Municipal	Small STP-discontinued 06/10/97
117.041	33,61	PA0057231	0.0005	SRD	Archie & Cloria Shearer	TB-Buck Run	Municipal	Single Residence STP
Christina River (tidal)								
82.274	45,13	DE0000400-001	0.0000	NCW	Ciba-Geigy Corp.	Christina River	Industrial	Cooling Water
83.561	43,09	DE0051004	0.0000	SWR	Boeing	Nonesuch Creek	Industrial	Stormwater
Christina River West Branch								
99.587	16,09	MD0065145	0.0500	STP	Highlands WWTP	WB Christina River	Municipal	Small STP
100.209	14,09	MD0022641	0.4500	STP	Meadowview Utilities, Inc.	WB Christina River	Municipal	Small STP
Red Clay Creek								
89.828	43,26	DE0000221-001	0.0060	NCW	HAVEG/AMTEK (eliminated July 1996)	Red Clay Creek	Industrial	Cooling Water
89.828	43,26	DE0000221-003	0.0040	NCW	HAVEG/AMTEK (eliminated July 1996)	Red Clay Creek	Industrial	Cooling Water
91.746	43,29	DE0000230-001	0.3500	NCW	Hercules Inc.	Red Clay Creek	Industrial	Cooling Water
95.583	43,35	DE0021709-001	0.0150	STP	Greenville Country Club	TB-Red Clay Creek	Municipal	Small STP
96.861	43,37	PA0055425	0.0005	SRD	D'Ambro Anthony Jr.-Lot #22	TB-EB Red Clay Creek	Municipal	Single Residence STP
98.780	43,40	DE0050067	0.0015	STP	Center for Creative Arts	TB-Red Clay Creek	Municipal	Small STP
98.780	43,40	DE0000451-002	2.1700	NCW	NVF Yorklyn	Red Clay Creek	Industrial	Stormwater/Cooling Water
101.337	43,44	PA0055107	0.1500	STP	East Marlborough Township STP	TB-EB Red Clay Creek	Municipal	Large STP
Red Clay Creek West Branch								
103.313	32,43	PA0053554	0.0000	SWR	Earthgro Inc.	WB Red Clay Creek	Industrial	Stormwater
103.950	30,43	PA0024058	1.1000	STP	Kennett Square Boro. WWTP	WB Red Clay Creek	Municipal	Large STP
104.268	29,43	PA0050679	0.2500	NCW	National Vulcanized Fiber (NVF)	TB-WB Red Clay Creek	Industrial	Cooling Water
104.579	28,43	PA0057720-001	0.0720	STP	Sunny Dell Foods, Inc.	WB-Red Clay Creek	Industrial	Mushroom Canning/Process Water
104.579	28,43	PA0057720-002	0.0900	NCW	Sunny Dell Foods, Inc.	WB-Red Clay Creek	Industrial	Mushroom Canning/Cooling Water
White Clay Creek								
93.090	32,18	DE0000191-001	0.0300	NCW	FMC Corp.	Cool Run	Industrial	Stormwater/Cooling Water
102.824	15,18	PA0053783	0.0200	STP	Avon Grove School Dist	TB-WB White Clay Creek	Commercial	Small STP
108.696	06,18	PA0024066	0.2500	STP	West Grove Borough Authority STP	MB White Clay Creek	Municipal	Large STP

Table 2-1. NPDES point source discharges in Christina River Basin (continued).

RIVER MILE	CELL I, J	NPDES NUMBER	FLOWLIM MGD	CODE	OWNER	STREAM	TYPE	DESCRIPTION
White Clay Creek East Branch								
102.750	19,24	PA0052451	0.0012	STP	Frances L. Hamilton Oates STP	EB White Clay Creek	Municipal	Small STP
104.020	19,26	PA0057029	0.1440	GWC	Hewlett Packard Co.	Egypt Run	GWCleanup	Groundwater Cleanup
106.560	19,30	PA0025488	0.3000	ATP2	Avondale Borough Sewer Authority	Indian Run	Municipal	Large STP
106.560	19,30	PA0056898	0.0650	IND	To-Jo Mushrooms Inc.	Trout Run	Industrial	Small STP-online Jan 98
107.830	19,32	PA0040436	0.0090	STP	Chadds Ford Investment Co./Red Fox GC	TB-EB White Clay Creek	Municipal	Small STP
107.830	19,32	PA0040665	0.0100	STP	Stone Barn Restuarantand Apt. Cplx	EB White Clay Creek	Commercial	Small STP
Little Mill Creek								
82.441	41,55	DE0000523-001	0.0000	SWR	General Motors Assembly	Little Mill Creek	Industrial	Stormwater
83.373	38,55	DE0000566	0.0000	SWR	DuPont Chestnut Run	Little Mill Creek	Industrial	Stormwater/Cooling Water
Delaware River								
63.839	57,04	DE0021555-001	0.5500	MUN	Delaware City STP	Delaware River	Municipal	
65.272	57,05	DE0000256-601	13.0000	IND	Star Enterprises	Delaware River	Industrial	
65.272	57,05	DE0000612-001	0.8000	IND	Formosa Plastics Corp.	Delaware River	Industrial	
65.272	57,05	DE0020001-001	0.6800	MUN	Standard Chlorine	Delaware River	Municipal	
65.272	57,05	DE0050911-001	0.3000	MUN	Occidental Chemical Corp.	Delaware River	Municipal	
75.237	57,15	DE0020320-001	90.0000	MUN	City of Wilmington	Delaware River	Municipal	
77.162	57,17	DE0000051-001	5.2000	IND	Dupont-Edgemoor	Delaware River	Industrial	
77.162	57,17	DE0000051-002	3.0000	IND	Dupont-Edgemoor	Delaware River	Industrial	
77.162	57,17	DE0000051-003	6.0000	IND	Dupont-Edgemoor	Delaware River	Industrial	
81.307	57,20	DE0000655-001	33.3000	IND	General Chemical Corporation	Delaware River	Industrial	
83.907	57,22	PA0012637-002	52.3500	IND	Bayway Manufacturing	Delaware River	Industrial	SEE NOTE 1
83.907	57,22	PA0012637-101	69.8000	IND	Bayway Manufacturing	Delaware River	Industrial	SEE NOTE 1
83.907	57,22	PA0012637-201	3.3400	IND	Bayway Manufacturing	Delaware River	Industrial	SEE NOTE 1
85.199	57,23	PA0027103-001	44.0000	MUN	Delcora	Delaware River	Municipal	
82.639	58,21	NJ0005045-001	0.5000	IND	Monsanto	Delaware River	Industrial	SEE NOTE 2
63.839	59,04	NJ0024856-001	1.4450	MUN	City of Salem	Delaware River	Municipal	SEE NOTE 1
69.534	59,09	NJ0021598-001	2.4650	MUN	Pennsville Sewage Authority	Delaware River	Municipal	SEE NOTE 1
73.339	59,12	NJ0005100-661	22.9000	IND	Dupont-Chambers Works	Delaware River	Industrial	SEE NOTE 1
75.237	59,15	NJ0021601-001	1.7290	MUN	Carneys Pt. Sewage Authority	Delaware River	Municipal	SEE NOTE 1
76.045	59,16	NJ0024023-001	0.9500	MUN	Penns Grove Sewage Authority	Delaware River	Municipal	SEE NOTE 1
77.162	59,17	NJ0024635-001	0.0366	MUN	Fort Dix/Pedricktown Facility	Delaware River	Municipal	SEE NOTE 1
79.919	59,19	NJ0004286-001	2.1000	IND	Geon	Delaware River	Industrial	
82.639	59,21	NJ0027545-001	0.9860	MUN	Logan Township MUA	Delaware River	Municipal	SEE NOTE 1

NOTES:

[1] No flow limit available in PCS data base; flow limit shown is maximum reported flow during 01/01/95 to 12/31/98

[2] No flow limit or reported flow available in PCS data base; flow limit shown is an estimate

Table 2-2. Fecal coliform, *enterococci*, and TSS loads for NPDES facilities

NPDES Number	HSPF Subbasin	Flow (mgd)	TSS (mg/L)	Fecal Coliform (cfu/100mL)	Enterococci (cfu/100mL)	TSS (kg/day)	Fecal Coliform (cfu/day)	Enterococci (cfu/day)
Brandywine Creek main stem								
DE0021768	B19	0.0250	15		100	1.42		9.464E+07
PA0053082	B17	0.0206	10	200	100	0.78	1.560E+08	7.798E+07
PA0052663	B16	0.0900	10	200	100	3.41	6.814E+08	3.407E+08
PA0055476	B16	0.0400	10	200	100	1.51	3.028E+08	1.514E+08
PA0244031	B16	0.1500	30	200	100	17.03	1.136E+09	5.678E+08
PA0055484	B16	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0030848	B16	0.0063	30	200	100	0.72	4.770E+07	2.385E+07
PA0056120	B31	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0031097	B15	0.0170	20	200	100	1.29	1.287E+08	6.435E+07
PA0053449	B15	0.1500	30	200	100	17.03	1.136E+09	5.678E+08
PA0057011	B15	0.0773	30	200	100	8.78	5.852E+08	2.926E+08
PA0036200	B15	0.0320	30	200	100	3.63	2.423E+08	1.211E+08
PAG0050005	B15	0.1400	10	2	2	5.30	1.060E+07	1.060E+07
PA0051497	B15	0.0300	10	2	2	1.14	2.271E+06	2.271E+06
PA0056171	B15	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
Brandywine Creek East Branch								
PA0026018	B14	1.5000	30	200	100	170.34	1.136E+10	5.678E+09
PA0057282	B14	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0051365	B14	0.3690	20	2	2	27.94	2.794E+07	2.794E+07
PA0053937	B29	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0056324	B29	0.0440	10	2	2	1.67	3.331E+06	3.331E+06
PA0056618	B29	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0053561	B29	0.0360	10	2	2	1.36	2.725E+06	2.725E+06
PA0043982	B13	0.4000	30	200	100	45.42	3.028E+09	1.514E+09
PA0012815	B13	1.0280	50	200	100	194.57	7.783E+09	3.891E+09
PA0026531	B13	7.5000	30	200	100	810.15	5.687E+10	2.839E+10
PA0030228	B30	0.0225	20	200	100	1.70	1.703E+08	8.517E+07
PA0051918	B13	0.1440	10	2	2	5.45	1.090E+07	1.090E+07
PA0055531	B30	0.0007	30	200	100	0.08	5.300E+06	2.650E+06
PA0054917	B11	0.4750	20	200	100	35.96	3.596E+09	1.798E+09
PA0036374	B27	0.0150	30	200	100	1.70	1.136E+08	5.678E+07
PA0057274	B27	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0050458	B10	0.0351	20	200	100	2.66	2.657E+08	1.329E+08
PA0057827	B10	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0050547	B10	0.0375	20	200	100	2.84	2.839E+08	1.420E+08
PA0055492	B10	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0052949	B10	0.0030	20	2	2	0.23	2.271E+05	2.271E+05
PA0027987	B10	0.0050	20	200	100	0.38	3.785E+07	1.893E+07
PA0054691	B09	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
Brandywine Creek West Branch								
PA0029912	B07	0.1000	30	200	100	11.36	7.571E+08	3.785E+08
PA0053996	B07	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0053228	B06	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0053236	B06	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0036897	B05	0.3900	30	200	100	44.29	2.953E+09	1.476E+09
PA0026859	B05	3.8500	30	200	100	437.22	2.915E+10	1.457E+10
PA0011568-001	B05	0.6400	30	200	100	72.68	4.845E+09	2.423E+09
PA0011568-016	B05	0.5045	30	200	100	57.29	3.819E+09	1.910E+09
PA0056073	B33	0.0005	20	200	100	0.04	3.785E+06	1.893E+06

NPDES Number	HSPF Subbasin	Flow (mgd)	TSS (mg/L)	Fecal Coliform (cfu/100mL)	Enterococci (cfu/100mL)	TSS (kg/day)	Fecal Coliform (cfu/day)	Enterococci (cfu/day)
PA0012416	B33	0.1400	20	2	2	10.60	1.060E+07	1.060E+07
PA0052990	B33	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0052728	B03	0.0004	30	200	100	0.05	3.028E+06	1.514E+06
PA0055697	B03	0.0490	30	200	100	5.56	3.710E+08	1.855E+08
PA0036412	B01	0.0550	28	200	100	5.83	4.164E+08	2.082E+08
PA0044776	B01	0.6000	30	200	100	68.14	4.542E+09	2.271E+09
PA0057339	B01	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
PA0057231	B20	0.0005	20	200	100	0.04	3.785E+06	1.893E+06
Christina River								
MD0022641	C01	0.7000	30		100	79.49		2.650E+09
MD0065145	C01	0.0500	30		100	5.68		1.893E+08
DE0020230	C09	0.3500	7		2	9.27		2.650E+07
Red Clay Creek								
DE0021709	R05	0.0150	15		100	0.85		5.678E+07
PA0055425	R06	0.0005	20	200		0.04	3.785E+06	0.000E+00
DE0050067	R04	0.0015	30		100	0.17		5.678E+06
DE0000451	R04	2.1700	20		2	164.29		1.643E+08
PA0055107	R03	0.1500	30	200	100	17.03	1.136E+09	5.678E+08
PA0053554	R02	0.0000	100	200	100	0.00	0.000E+00	0.000E+00
PA0024058	R02	1.1000	30	200	100	124.92	8.328E+09	4.164E+09
PA0050679	R01	0.2500	10	2	2	9.46	1.893E+07	1.893E+07
PA0057720-001	R01	0.0720	30	200	100	8.18	5.451E+08	2.725E+08
PA0057720-002	R01	0.0900	10	2	2	3.41	6.814E+06	6.814E+06
White Clay Creek								
DE0000191	W12	0.0300	10		2	1.14		2.271E+06
PA0053783	W01	0.0200	10	200	100	0.76	1.514E+08	7.571E+07
PA0024066	W02	0.2500	30	200	100	28.39	1.893E+09	9.464E+08
PA0052451	W09	0.0012	30	200	100	0.14	9.085E+06	4.542E+06
PA0057029	W08	0.1440	10	2	2	5.45	1.090E+07	1.090E+07
PA0025488	W06	0.3000	30	200	100	34.07	2.271E+09	1.136E+09
PA0056898	W07	0.0650	30	200	100	7.38	4.921E+08	2.461E+08
PA0040436	W06	0.0090	20	200	100	0.68	6.814E+07	3.407E+07
PA0040665	W05	0.0100	20	200	100	0.76	7.571E+07	3.785E+07

2.1.2 Combined Sewer Overflows

Combined sewer systems (CSSs) are sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. Most of the time, CSSs transport all of their wastewater to a sewage treatment plant, where it is treated and then discharged to a waterbody. However, during periods of heavy rainfall or snowmelt (wet weather) the combined storm water and wastewater volume can exceed the capacity of the sewer system or treatment plant. For this reason, CSSs are designed to overflow occasionally and discharge excess wastewater directly to nearby streams, rivers, or other waterbodies. These overflows, referred to as combined sewer overflows (CSOs), contains storm water and untreated human and industrial waste, toxic materials, and debris. CSOs typically discharge for short periods of time at random intervals due to their association with wet weather events.

There are 38 CSO outfalls in the vicinity of the city of Wilmington. Bacteria loads from these CSOs were determined using the flow rates calculated by the XP-SWMM model and event mean concentrations measured during two storm events in 2003.

2.1.3 Storm Water Phase II Communities

Storm water runoff can contribute bacteria and other pollutants to a waterbody. Material can collect on streets, rooftops, parking lots, sidewalks, yards and parks and then during a precipitation event this material can be flushed into gutters, drains and culverts and be discharged into a waterbody.

As part of the 1987 amendments to the CWA, Congress added Section 402(p) to the Act to cover discharges composed entirely of storm water. Section 402(p)(2) of the CWA requires permit coverage for discharges associated with industrial activity and discharges from large and medium municipal separate storm sewer systems (MS4s). Large MS4s serve populations over 250,000 and medium MS4s serve populations between 100,000 and 250,000. These discharges are referred to as Phase I MS4 discharges. EPA issued regulations on December 8, 1999 (64 FR 68722), expanding the NPDES storm water program to include discharges from smaller MS4s, including all systems within urbanized areas and other systems serving populations less than 100,000 as well as storm water discharges from construction sites that disturb one to five acres, with opportunities for area-specific exclusions. This expansion is referred to as Phase II of the MS4 program.

Storm water discharges that are regulated under Phase I and Phase II of the NPDES MS4 program are point sources that must be included in the WLA portion of a TMDL. Storm water discharges not currently subject to Phase I or Phase II of the MS4 program are not required to obtain NPDES permits. Therefore, for regulatory purposes, are analogous to nonpoint sources and are included in the LA portion of a TMDL.

An EPA Memorandum from Robert Wayland and James Hanlon, Water Division Directors, dated November 22, 2002, (see Appendix B) clarified existing regulatory requirements for MS4s connected with TMDLs). The key points are:

- NPDES-regulated MS4 discharges must be included in the WLA component of the TMDL and may not be addressed by the LA component of TMDL.

- The stormwater allotment can be a gross allotment and does not need to be apportioned to specific outfalls.

- Industrial storm water permits need to reflect technology-based and water quality-based requirements.

Most of the townships and boroughs within the Christina River Basin in Chester County and all of New Castle County are covered by the Phase II MS4 program regulations. The delineation of the storm water collection system contributing areas within each municipality has not been completed at the present time. Therefore, it is not possible to assign a WLA specific to the storm sewer collection areas within each MS4 municipality. Instead, the TMDL will be presented as a WLA for the entire land area of the township, borough, or county. In the future, when the storm sewer collection systems have been delineated, it is anticipated that the State’s storm water program will revise the WLA into the appropriate WLA and LA as part of the storm water permit reissuance. Note that the overall reductions in the TMDL will not change.

Runoff from urban areas may carry significant loads of bacteria and sediment and increased storm runoff flows may cause streambed and bank erosion. To assess the relative loads of bacteria and sediment from different land uses within municipal boundaries, it was important to have an inventory of municipal land use data as a proportion of the HSPF subbasins in which the municipality resides. Since the 1995 land use data available for assessing the municipalities is different than the land use categories used by the USGS to develop their HSPF models of Christina River Basin, an aggregated land use was developed for this purpose as shown in Table 2-3. A list of MS4 municipalities in the study area is provided in Table 2-4 and their locations are shown in Figure 2-2.

Table 2-3. Aggregated land use categories used for MS4 assessments

Aggregated Land Use for MS4 Assessments	HSPF Land Use	1995 Land Use
Residential	Residential-septic Residential-sewer	Single family Multi-family
Agricultural	Agricultural-cows Agricultural-crops Agricultural-mushroom	Agriculture
Open Land	Open land	Public/private open space
Forest	Forest	Wooded
Water	Wetlands, water	Water
Urban	Commercial/industry Undesignated use Roads, building-residential Roads, building-urban	Vacant Transportation/utility Unknown Institutional Industrial Commercial Mining

Table 2-4. Municipalities with MS4 permits in the Christina River Basin

Permit Number	Municipality Name	HSPF Model Subbasins
PAG130079	Avondale Borough	W04, W06, W07, W08
PAG130047	Birmingham Township	B15, B16
PAG130053	Caln Township	B03, B30, B12
PAG130142	Chadds Ford Township	B16, B17, B18
PAG130066	City of Coatesville	B05
PAG130140	Downingtown Borough	B12, B13, B30
PAI130523	East Bradford Township	B08, B14, B15, B29
PAI130524	East Brandywine Township	B10, B11, B12, B30
PAI130536	East Caln Township	B13, B29
PAI130512	East Fallowfield Township	B05, B06, B20, B23
PAG130123	East Marlborough Township	B07, B22, B31, R01, R03
PAG130058	Franklin Township Chester County	W01, W03, W08, C02
PAI130535	Honey Brook Township	B01, B02, B09
PAG130037	Kennett Square Borough	R01, R03
PAG130146	Kennett Township	B16, B17, R01, R02, R03,R04, R06, W17
PAG130062	London Britain Township	W03, W09, W10, W11, C02

Permit Number	Municipality Name	HSPF Model Subbasins
PAI130503	London Grove Township	W02, W03, W04, W05, W06,W08
PAI130516	New Garden Township	W06, W07, W08, W09, R01, R02
PAI130526	New London Township	W01, W02
PAI130539	Penn Township	W01, W02
PAG130134	Pennsbury Township	B16, B17, B31, R06
PAG130113	Pocopson Township	B07, B08, B15, B31
PAG130101	Sadsbury Township	B20
PAG130163	South Coatesville Borough	B05, B06
PAG130067	Thornbury Township	B15, B16
PAI130527	Upper Uwchlan Township	B10, B11, B27
PAI130505	Uwchlan Township	B11, B12, B27, B29
PAG130150	Valley Township	B03, B04, B05, B33
PAI130529	Wallace Township	B09, B10, B26, B27, B35
PAI130511	West Bradford Township	B06, B07, B08, B13, B14, B24, B25, B30
PAG130100, PAI130544	West Brandywine Township	B02, B03, B10, B30
PAG130145	West Caln Township	B01, B02, B03, B20, B32, B33
PAG130002	West Chester Borough	B14, B15
PAG130144	West Grove Borough	W02, W04
PAI130530	West Whiteland Township	B28, B29
DE0051071	City of Wilmington, DE	B34, C05
DE0051071	Elsmere, DE	C04, C05
DE0051071	Newport, DE	C09
DE0051071	City of Newark, DE	W11, W12, C01, C02, C03
DE0051071	New Castle County, DE	B17, B18, B19, B34, R04, R05, R06, R07, R08, R09, W09, W10, W11, W12, W13, W14, W15, W16, W17, C01, C02, C03, C04, C05, C06, C07, C08, C09

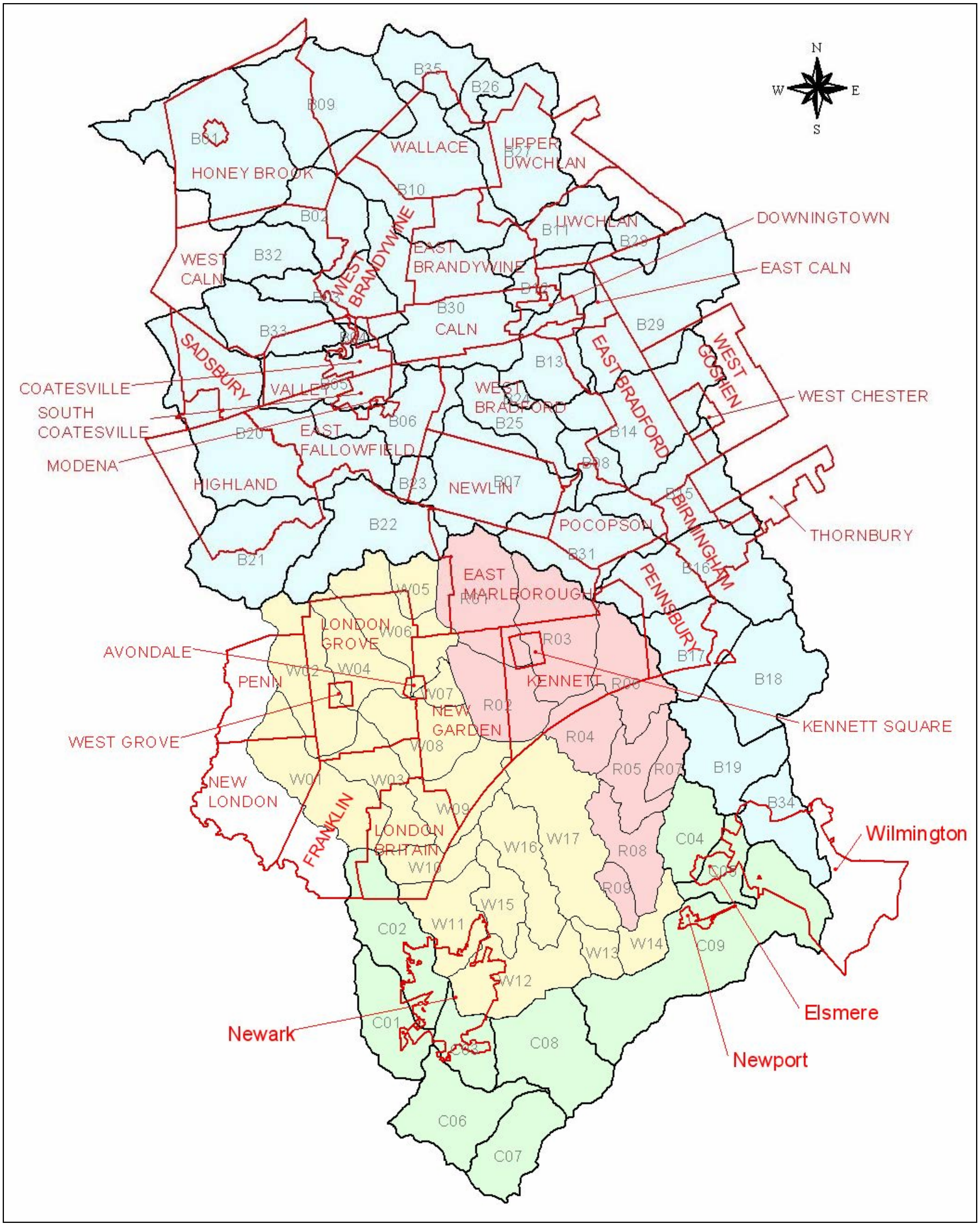

Figure 2-2. Municipalities with MS4 permits in Christina River Basin

2.2 **Nonpoint Sources**

Nonpoint sources of sediment and bacteria are generally much more difficult to identify and quantify than are point sources. In residential and urban areas, nonpoint sources can include leaking or faulty septic systems, landfill seepage, pet waste, storm water runoff (outside of Phase II communities) and other sources. In more rural areas, major contributors can be pasture runoff, manure storage and spreading, concentrated animal feedlots, and wildlife.

2.2.1 Septic Systems

Septic systems that are properly designed and maintained should not serve as a source of contamination to surface waters. However, septic systems do fail for a variety of reasons. Common soil-type limitations that contribute to septic system failure include seasonal high water table levels, compact glacial till, bedrock, and coarse sand and gravel outwash. When septic systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration) there can be adverse effects to surface waters down gradient (Horsely and Witten, 1996).

Site-specific information on the locations or numbers of septic systems in Chester County was not available. A GIS database maintained by DNREC contained information on the number of septic systems in the New Castle County portion of the Christina River Basin for the years 1997 and 2004. This inventory was interpolated and extrapolated to estimate the number of septic systems in 1990, 1995, and 2005 (see Table 2-3). Estimates of the bacteria loads from septic systems will be based on the assumptions outlined below:

- Number of septic systems (based on US Census 1990 and 2000 and DNREC GIS database)
- Estimated population served by the septic systems (an average of 2.8 people per septic system, US Census 1990)
- An average daily discharge of 70 gallons/person/day (Horsley and Witten, 1996)
- Septic effluent fecal coliform concentration of 1.0E+07 cfu/100mL bacteria concentration (Powelson and Mills, 2001) from malfunctioning septic systems
- Septic effluent enterococcus concentration of 8.0E+05 cfu/100mL from malfunctioning septic systems
- Septic effluent concentrations of 200 cfu/100mL (fecal coliform) and 100 cfu/100mL (*enterococci*) from properly functioning septic systems

The number of septic tanks in Chester County was estimated from US Census data (obtained online from http://factfinder.census.gov/). Examination of the number of housing units in rural areas in the two counties reported in the 1990 U.S. Census revealed that approximately each rural housing unit has a septic system (see Table 2-5). Since no septic system information was available from the 2000 US Census data, estimates were made based on information from the Chester County Health Department (CCHD, 2005). In Chester County, approximately 1,500 permits for septic systems are issued every year of which about 600 of are for repair work and 1,100 are for new permits. The total number of septic systems in Chester County in 2005 was estimated as about 69,000 based on the number in 1990 plus 1,100 new systems per year. Since about 80 percent of the septic systems in Chester County are within the Christina River Basin, there were about 55,200 septic systems in the Chester County portion of the basin in 2005.

Table 2-5. Census data related to septic system estimation

Category	New Castle County	Chester County
1990 Census: Number of rural housing units in County	10,335	50,396
1990 Census: Number septic systems in County	12,142	52,493
1990 Census: Rural population in County	29,468	146,612
1990 Estimated number septic systems in Christina River Basin	10,500	42,000
1995 Estimated number septic systems in Christina River Basin	7,041	46,400
1997 DNREC Inventory of septic systems in Christina River Basin	5,455	-
2004 DNREC Inventory of septic systems in Christina River Basin	1,713	-
2005 Estimated number septic systems in Christina River Basin	1,650	55,200
2005 Estimated number of malfunctioning septic systems	17	552
2005 Estimated potential bacteria load (cfu/year)	3.6E+11	1.5E+14

The potential annual bacteria load from malfunctioning as well as properly functioning septic systems was estimated using the data in Table 2-5. According to CCHD (2005), 600 permits are issued for repair work, which is approximately one percent of the total number of septic systems in Chester County. Therefore, it was assumed that at any given time one percent of the septic systems were malfunctioning. The same failure rate was applied to New Castle County.

2.2.2 Agriculture Activities

Land used for agricultural purposes can be a significant source of sediment and bacteria. Runoff from pastures, livestock operations, improper land application of animal wastes, and livestock with access to waterbodies are all potential agricultural sources. Animals grazing in pasturelands deposit manure directly upon the land surface. Even though a pasture may be relatively large, and animal densities low, manure will often be concentrated near the feeding and watering areas in the field. These areas can quickly become barren of plant cover, increasing the possibility of contaminated runoff during a storm event. The occurrence and degree of bacteria loads from livestock are linked to temporally and spatially variable hydrologic factors, such as precipitation and runoff, except when manure is directly deposited into a waterbody (EPA, 2001).

The application of manure that has been improperly composted can contribute bacteria that are conveyed into surface waters during runoff events. The bacterial content of animal waste varies with collection, storage, and application method. Therefore, animal wastes must be handled, stored, utilized and/or disposed of in an efficient way to minimize waterbody impacts. Grazing animals, confined animal operations and manure application are all potential sources of nutrients and bacteria in the Christina River Basin. The inventories of livestock in Chester County and New Castle County from the last three agricultural census periods are shown in Table 2-6.

The monthly-varying fecal coliform bacteria accumulation rates used in the watershed-loading model categorized by land use in Chester County are provided in Table 2-7. The enterococci bacteria accumulation rates broken down by land use for enterococci bacteria for Chester County and New Castle County are given in Tables 2-8 and 2-9, respectively.

Table 2-6. Livestock inventories from 1992, 1997, and 2002 USDA Agriculture Census

Category	Chester County, PA			New Castle County, DE		
	1992	1997	2002	1992	1997	2002
Cattle and calves	50,795	48,897	41,878	3,446	2,628	2,665
Hogs and pigs	11,855	2,357	12,860	630	51	86
Poultry (layers, broilers, turkeys)	734,087	599,360	696,361	209,195	220,308	NA
Horses and ponies	4,330	5,293	8,597	770	737	833
Sheep and lambs	3,421	2,154	2,856	238	222	366

NA = not available

Table 2-7. Fecal coliform bacteria accumulation rates (cfu/acre/day) for Chester County

Land Use	JAN	FEB	MAR	APR	MAY	JUN
RESIDENTIAL-SEPTIC	1.7E+07	1.7E+07	1.7E+07	1.7E+07	1.7E+07	1.7E+07
RESIDENTIAL-SEWER	2.3E+07	2.3E+07	2.3E+07	2.3E+07	2.3E+07	2.3E+07
COMMERCIAL/INDUSTRY	6.2E+06	6.2E+06	6.2E+06	6.2E+06	6.2E+06	6.2E+06
AGRICULTURAL-COWS	5.1E+09	5.1E+09	2.0E+10	2.0E+10	2.0E+10	2.0E+10
AGRICULTURAL-CROPS	6.1E+09	6.1E+09	9.5E+09	1.0E+10	1.0E+10	1.0E+10
AGRICULTURAL-MUSHROOM	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07
FOREST	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07
OPEN LAND	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
WETLANDS, WATER	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
undesignated use	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
ROADS,BUILDING-residential	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07
ROADS,BUILDING-urban	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07
Land Use	JUL	AUG	SEP	OCT	NOV	DEC
RESIDENTIAL-SEPTIC	1.7E+07	1.7E+07	1.7E+07	1.7E+07	1.7E+07	1.7E+07
RESIDENTIAL-SEWER	2.3E+07	2.3E+07	2.3E+07	2.3E+07	2.3E+07	2.3E+07
COMMERCIAL/INDUSTRY	6.2E+06	6.2E+06	6.2E+06	6.2E+06	6.2E+06	6.2E+06
AGRICULTURAL-COWS	2.0E+10	2.0E+10	2.0E+10	2.0E+10	1.0E+10	5.1E+09
AGRICULTURAL-CROPS	1.0E+10	1.0E+10	1.0E+10	1.0E+10	9.3E+09	6.1E+09
AGRICULTURAL-MUSHROOM	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07
FOREST	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07	7.0E+07
OPEN LAND	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
WETLANDS, WATER	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
undesignated use	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07	1.0E+07
ROADS,BUILDING-residential	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07
ROADS,BUILDING-urban	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07	5.0E+07

Table 2-8. ***Enterococci*** **accumulation rates (cfu/acre/day) for Chester County**

Land Use	JAN	FEB	MAR	APR	MAY	JUN
RESIDENTIAL-SEPTIC	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05
RESIDENTIAL-SEWER	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05
COMMERCIAL/INDUSTRY	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05
AGRICULTURAL-COWS	8.90E+07	8.90E+07	2.50E+08	3.30E+08	3.10E+08	2.90E+08
AGRICULTURAL-CROPS	3.00E+07	3.00E+07	9.00E+07	2.40E+08	2.20E+08	1.20E+08
AGRICULTURAL-MUSHROOM	3.40E+05	3.40E+05	3.40E+06	3.40E+05	3.40E+05	3.40E+05
FOREST	5.10E+06	5.10E+06	5.10E+07	5.10E+06	5.10E+06	5.10E+06
OPEN LAND	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
WETLANDS, WATER	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
undesignated use	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
ROADS,BUILDING-residential	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
ROADS,BUILDING-urban	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
Land Use	JUL	AUG	SEP	OCT	NOV	DEC
RESIDENTIAL-SEPTIC	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05
RESIDENTIAL-SEWER	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05
COMMERCIAL/INDUSTRY	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05
AGRICULTURAL-COWS	2.80E+08	2.80E+08	3.30E+08	2.70E+08	1.90E+08	8.90E+07
AGRICULTURAL-CROPS	1.20E+08	1.20E+08	1.40E+08	4.90E+08	4.60E+08	3.00E+07
AGRICULTURAL-MUSHROOM	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
FOREST	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06
OPEN LAND	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
WETLANDS, WATER	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
undesignated use	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
ROADS,BUILDING-residential	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
ROADS,BUILDING-urban	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07

Table 2-9. ***Enterococci*** **accumulation rates (cfu/acre/day) for New Castle County**

Land Use	JAN	FEB	MAR	APR	MAY	JUN
RESIDENTIAL-SEPTIC	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05
RESIDENTIAL-SEWER	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05
COMMERCIAL/INDUSTRY	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05
AGRICULTURAL-COWS	6.10E+08	6.10E+08	2.00E+09	2.00E+09	2.00E+09	2.00E+09
AGRICULTURAL-CROPS	1.20E+07	1.20E+07	2.50E+07	1.30E+08	1.30E+08	3.30E+07
AGRICULTURAL-MUSHROOM	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
FOREST	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06
OPEN LAND	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
WETLANDS, WATER	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
undesignated use	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
ROADS,BUILDING-residential	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
ROADS,BUILDING-urban	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
Land Use	JUL	AUG	SEP	OCT	NOV	DEC
RESIDENTIAL-SEPTIC	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05	5.50E+05
RESIDENTIAL-SEWER	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05	7.70E+05
COMMERCIAL/INDUSTRY	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05	2.00E+05

Land Use	JUL	AUG	SEP	OCT	NOV	DEC
AGRICULTURAL-COWS	2.00E+09	2.00E+09	2.00E+09	2.00E+09	1.00E+09	6.10E+08
AGRICULTURAL-CROPS	3.20E+07	3.20E+07	3.60E+07	4.00E+08	4.00E+08	1.20E+07
AGRICULTURAL-MUSHROOM	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
FOREST	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06
OPEN LAND	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
WETLANDS, WATER	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
undesignated use	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05	3.40E+05
ROADS,BUILDING-residential	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
ROADS,BUILDING-urban	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07

2.2.3 Wildlife

Wildlife also generates bacteria on the land surfaces and in streams. Wild animals are also assumed to be the only source of bacteria on forested land. A precise estimate of the number of wild animals in the Christina River Basin is not available. Literature and empirical values are used in this study, as shown in Table 2-10, to estimate wild animal population densities for different land use categories. Monthly adjustment factors were used to account for seasonal variations in wild animal populations.

Table 2-10. Estimated wildlife density for associated land uses in Christina River Basin

Wild Animals	Agricutlure-Rowcrop (Animals/sq mile)	Agricutlure-Livestock (Animals/sq mile)	Forest Animals/sq mile)
Ducks	30	30	10
Geese	50	50	0
Deer	0	35	35
Beaver	5	5	10
Raccoons	2.5	2.5	5
Other	320	160	160

2.2.4 Domestic Pets

Domestic pets are potential sources of bacteria in a similar way as wildlife. Cats and dogs can contribute fecal material within the watershed that may find its way into surface waters. This source is more likely in more populated areas where large numbers of pets tend to be found.

A 1999 national study American Pet Products Manufactures Association (APPMA, 1999) reported that 39.1 percent of households own at least one dog and 32.1 percent own at least one cat. The average number of dogs per dog-owning household is 1.41, and the average number for cats is 2.40 per cat-owning household. There are an estimated 149,812 households in the Christina River Basin (US Census Bureau, 2000). Based on the APPMA national study, approximately 58,576 households own dogs and 48,090 households own cats. Using these values results in an estimate of 82,593 dogs and 115,415 cats within the Christina River Basin. The bacteria load from these animals was estimated in the HSPF watershed model runoff from urban and residential areas.

3.0 TMDL ENDPOINT DETERMINATION

To meet the designated uses in the Christina River Basin, water quality targets, or endpoints, must be achieved under the variable flow conditions. The selection of these endpoints considers the water quality standards prescribed by those designated uses (Section 1.3), but where no numeric criteria were found in the standards, interpretations of the narrative standard or site-specific endpoints were applied.

3.1 Bacteria TMDL Endpoints

In Pennsylvania, the TMDL target endpoints for bacteria are the fecal coliform bacteria water quality standards presented in Table 1-6. These targets represent numbers where the applicable water quality is achieved and maintained to protect designated uses. In these TMDLs, the targets were selected to maintain recreational contact uses during both the swimming and non-swimming seasons. During the swimming season, from May 1 through September 30, the 30-day geometric mean fecal coliform bacteria levels must be less than the target value of 200 cfu/100mL and not more than 10 percent of fecal bacteria concentrations within a 30-day period can exceed 400 cfu/100mL. During the non-swimming season (October 1 through April 30), the 30-day geometric mean target level is 2,000 cfu/100mL.

In Delaware, the TMDL target endpoint for bacteria is the *enterococcus* bacteria geometric mean water quality standard presented in Table 1-7. The target were selected to protect the primary contact recreation designated use in freshwaters in Delaware. The TMDL target endpoint for *enterococcus* bacteria is the geometric mean concentration of 100 cfu/100mL. The proposed *enterococcus* bacteria TMDLs in Delaware used both the geometric mean and the single sample maximum. However, based on the Environmental Protection Agency's 2004 explanation[1] of the appropriate (see below) use of the single sample maximum criterion, these established *enterococcus* bacteria TMDLs in Delaware are based on the geometric mean criterion only. It should be noted that the TMDL, WLA, and LA values remain unchanged from the proposed values.

In promulgating the 2004 final rule, *Water quality Standards for Coastal and Great Lakes Recreational Waters* rule, the preamble to the final rule discusses comments received regarding the implementation of the single sample maximum criterion and the intent of EPA's *Ambient Water Quality Criteria for Bacteria –1986*[2]. The 1986 bacteria criteria document did not discuss using the single sample maximum as a never-to-be-surpassed value for all applications under the CWA. The geometric mean is the more relevant value for describing the risk of contact recreation uses and the single sample maximum criterion is best used for making beach notification and closure decisions based on limited data. In the future, DNREC intends to limit the use of the single sample maximum to beach closures or to where decisions must be made with limited data. Because the daily simulations from October 1, 1994, through

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[1] 69 *FR* 67218-67243
[2] EPA 440/5-84-002, January 1986

October 1, 1998, provide adequate data for use of the geometric mean as the indicator of attainment of water quality standards, the single sample maximum criterion is not used for these TMDLs.

3.2 Sediment TMDL Endpoints

Pennsylvania's narrative standard, Chapter 93.6(a), must be interpreted with respect to sediment. PADEP uses a reference watershed approach to develop TMDL endpoints for the allowable sediment loading rates in the impaired watersheds.

3.2.1 Reference Watershed Approach

The reference watershed approach was used to estimate the necessary sediment load reduction required to restore a healthy aquatic community and allow the streams in the impaired watershed to achieve their designated uses. In the reference watershed approach, two watersheds are used, one attaining its uses and the other being impaired. Both watersheds must have similar land cover and land use characteristics. Other features such as base geologic formation, soils, percent slope, and geographic eco-region should be matched to the extent possible. The objective of this process is to reduce the loading rate of sediment in the impaired watershed to a level equivalent to or slightly lower than the loading rate in the unimpaired reference watershed. Achieving the sediment loadings recommended in the TMDLs will ensure protection of the designated aquatic life of the impaired watershed.

3.2.2 Considerations for Reference Watershed Selection

Two factors form the basis for selecting a suitable reference watershed. First, the watershed must have been assessed by PADEP and determined to be attaining water quality standards and meeting designated uses. Second, the watershed should closely resemble the impaired watershed in physical properties such as land cover, land use, physiographic province, size and geology. The 35 subbasins used in the modeling were screened for an unimpaired subbasin.

There are four steps in matching a reference watershed to an impaired watershed (see Figure 3-1). The first step is to locate watersheds that have been recently assessed and are not impaired. Step 2 is to identify a pool of unimpaired watersheds similar in size and geology to the impaired watersheds. Step 3 involves comparing the land cover data of the watersheds and selecting unimpaired watersheds that had land cover characteristics similar to those of the impaired watersheds. Land use distributions were compared on a percentage basis as calculated from HSPF land use input data. It is important to have a good match between the sizes of the reference and impaired watersheds so that reasonable comparisons could be made. As a result, the Step 4 is to resize the reference watersheds to produce a load that reasonably matches the impaired watersheds.

Once the reference watersheds were selected, their existing sediment loads were estimated based on the HSPF watershed model simulation. The estimated existing reference watershed sediment loads were then considered as the target endpoints the impaired watersheds.

3.2.3 Selected Reference Watershed and Endpoints

The TMDL endpoints established for this study were determined using the reference watersheds listed in Table 3-2 and shown in Figure 3-2. The methodology used for identification of candidate reference watersheds and final selection of reference watersheds for the TMDL target is outlined in Appendix K of the model report (USEPA, 2005). The listed segments in the Brandywine Creek watershed were grouped as either a predominately residential/urban watershed or a rural/agricultural watershed based on the land use characteristics of their associated HSPF model subbasin (see Table 3-1). The TMDL sediment endpoints (as unit area loads) for each of the reference watersheds are presented in Table 3-2. The TMDL process uses these loading rates in the non-impaired watersheds as targets for loading reductions in the impaired watersheds.

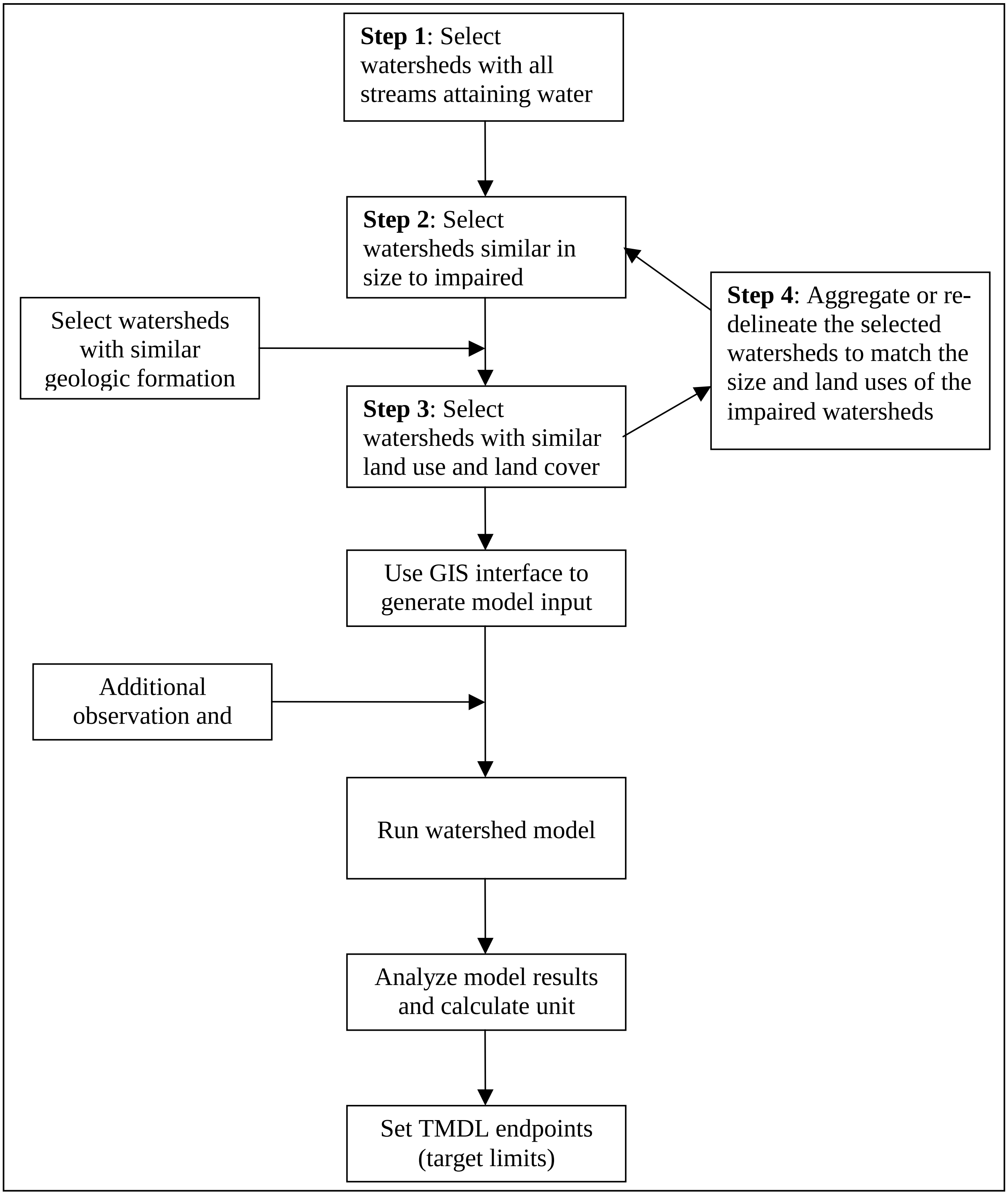

Figure 3-1. Reference watershed approach for derivation of TMDL target limits

Table 3-1. Land use characteristics of impaired subbasins and reference watersheds

HSPF Subbasin	Area (sq.mi.)	Land uses (percent)			Predominate Watershed Type
		Residential-Urban	Agriculture-Rural	Forested-Wetland	
Subbasins impaired by siltation in Brandywine Creek watershed:					
B01	18.39	7.9	68.1	20.6	Rural
B05	8.82	38.6	19.1	36.3	Residential-Urban
B06	8.06	22.7	39.6	35.9	Residential-Urban
B09	14.68	8.3	54.0	35.4	Rural
B14	12.92	32.3	31.9	31.2	Residential-Urban
B15	10.36	33.6	40.7	17.8	Residential-Urban
B20	25.54	13.3	58.8	25.9	Rural
B31	9.19	26.8	48.8	22.4	Residential-Urban
Subbasins impaired by siltation in White Clay Creek watershed:					
W01	10.23	19.4	51.8	26.2	Rural
W02	9.51	16.7	63.4	17.9	Rural
W03	6.35	18.3	44.7	36.4	Rural
W04	6.20	14.1	57.5	24.0	Rural
W06	8.57	5.4	67.5	22.0	Rural
W07	1.37	16.8	62.0	19.0	Rural
W08	7.47	14.6	50.4	32.9	Rural
W09	6.85	31.1	32.7	33.3	Residential-Urban
Subbasins impaired by siltation in Red Clay Creek watershed:					
R01	10.08	18.2	58.6	18.8	Rural
R02	7.39	15.2	58.4	25.4	Rural
R03	9.90	21.4	47.3	23.1	Residential-Urban
Reference Watersheds:					
B25	5.83	26.8	40.7	30.5	Brandywine Cr. – Urban
B32	4.66	14.2	31.6	53.0	Brandywine Cr. – Rural
R04	5.11	44.7	17.8	29.2	Red Clay Creek
W10	3.58	18.8	27.1	53.7	White Clay Creek

Table 3-2. Sediment endpoints for Christina River Basin TMDL

Reference Watershed ID	Watershed Name	Unit Area Sediment Load (tons/acre/year)
B25	Broad Run (Brandywine Creek)	0.089
B32	Birch Run (Brandywine Creek)	0.045
R04	Red Clay Creek	0.635
W10	White Clay Creek	1.043

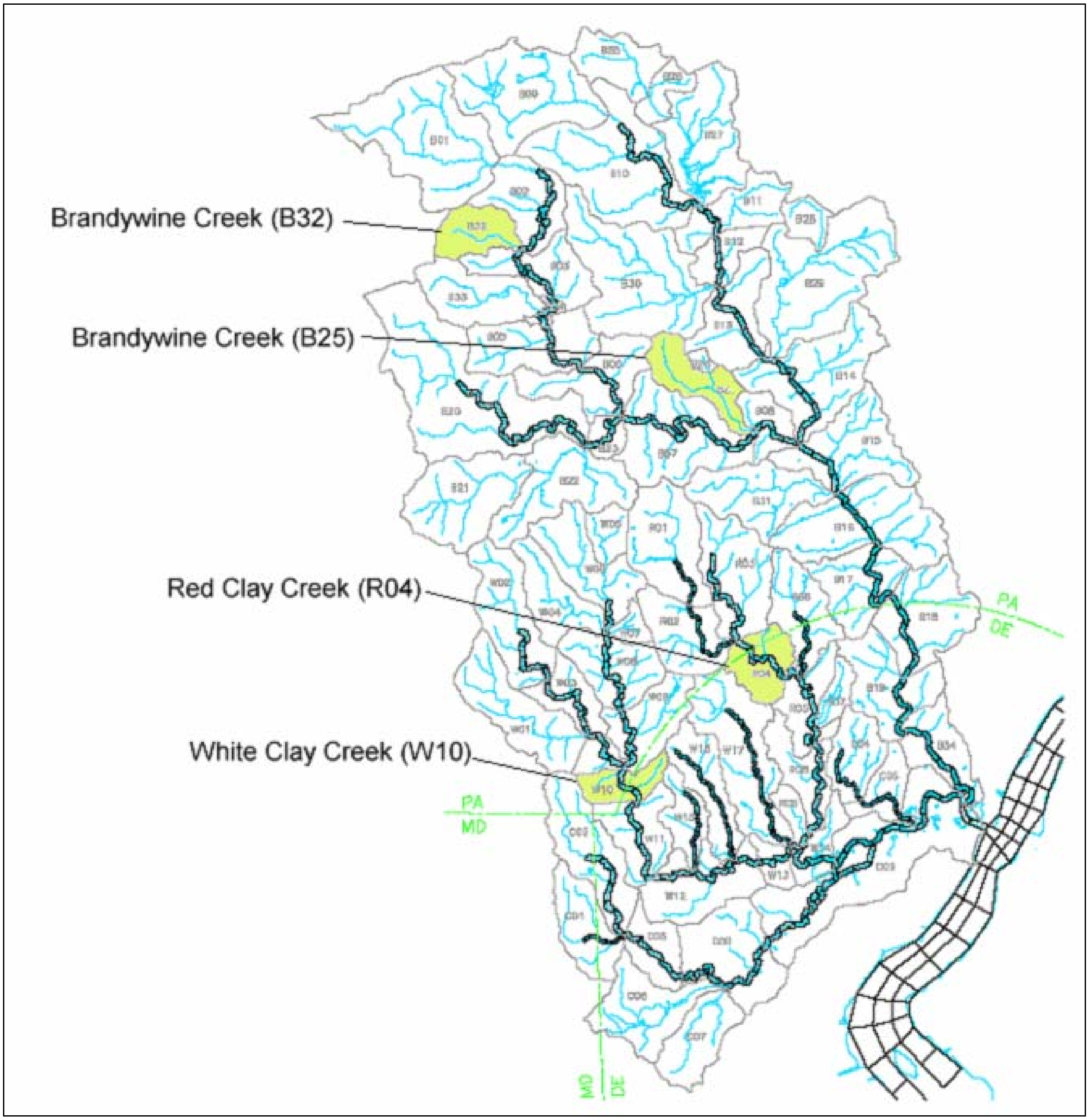

Figure 3-2. Locations of reference watersheds in Christina River Basin

4.0 TMDL METHODOLOGY AND CALCULATION

4.1 Bacteria TMDLs

The following sections discuss the methods used for developing the April 2005 TMDLs and the 2006 CSO allocations. TMDLs, allocated loads, and percent reductions were developed for the stream segments listed on Pennsylvania's and Delaware's Section 303(d) lists of impaired waters for bacteria shown in Figure 4-1.

4.1.1 Methodology

The HSPF watershed models were used to calculate the baseline and allocation loads for fecal coliform bacteria for the TMDLs for the Pennsylvania listed waters. The models were calibrated over a four-year period (October 1, 1994 through October 1, 1998) to include both low and high streamflow. Following calibration, the same four-year period was used for the baseline and TMDL allocation simulations. For the baseline condition, all NPDES point sources were set to their permitted flow and bacteria levels (see Table 2-2). Estimates of septic system loads and bacteria accumulation and storage on different land uses in the watersheds were also incorporated into the models. A series of model runs were made in which the bacteria loads from failed septic systems and land sources were reduced until insteam water quality standards were met. A detailed description of the background, configuration, and calibration of the modeling system is provided in the modeling report (EPA, 2005).

Three models were used to determine *enterococcus* bacteria TMDLs for the Delaware listed waters: the HSPF watershed loading model, the XP-SWMM[1] CSO discharge model, and the EFDC[2] receiving water model. All three models were run for the October 1, 1994, through October 1, 1998, period and the baseline and allocation loads were determined. Since Pennsylvania and Maryland have the responsibility to meet the Delaware water quality standards at the state line, the HSPF models were used to calculate *enterococcus* bacteria loads at the Pennsylvania-Delaware state line for Brandywine Creek, White Clay Creek, Red Clay Creek, and Burroughs Run in the Red Clay Creek Watershed. A Maryland allocation was used to calculate *enterococcus* bacteria loads at the Maryland/Delaware state line for the Christina River.

The XP-SWMM model was used to calculate *enterococcus* loads from the CSO discharge points in the City of Wilmington. The daily time-series loads from the HSPF model and from the XP-SWMM model were then input to the EFDC[3] receiving water model to calculate *enterococcus* concentrations in the tidal waters of the Christina River, Brandywine Creek, and Little Mill Creek. More detailed descriptions of the calibration and application of these models are provided in the modeling report (EPA, 2005).

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[1] The City of Wilmington provided the CSO discharges based on their XP-SWMM model runs.
[2] In reviewing the April 2005 TMDLs, it was discovered that Little Mill watershed was inadvertently left out the EDFC model.
[3] EDFC was used because HSPF is not applicable to tidal waters.

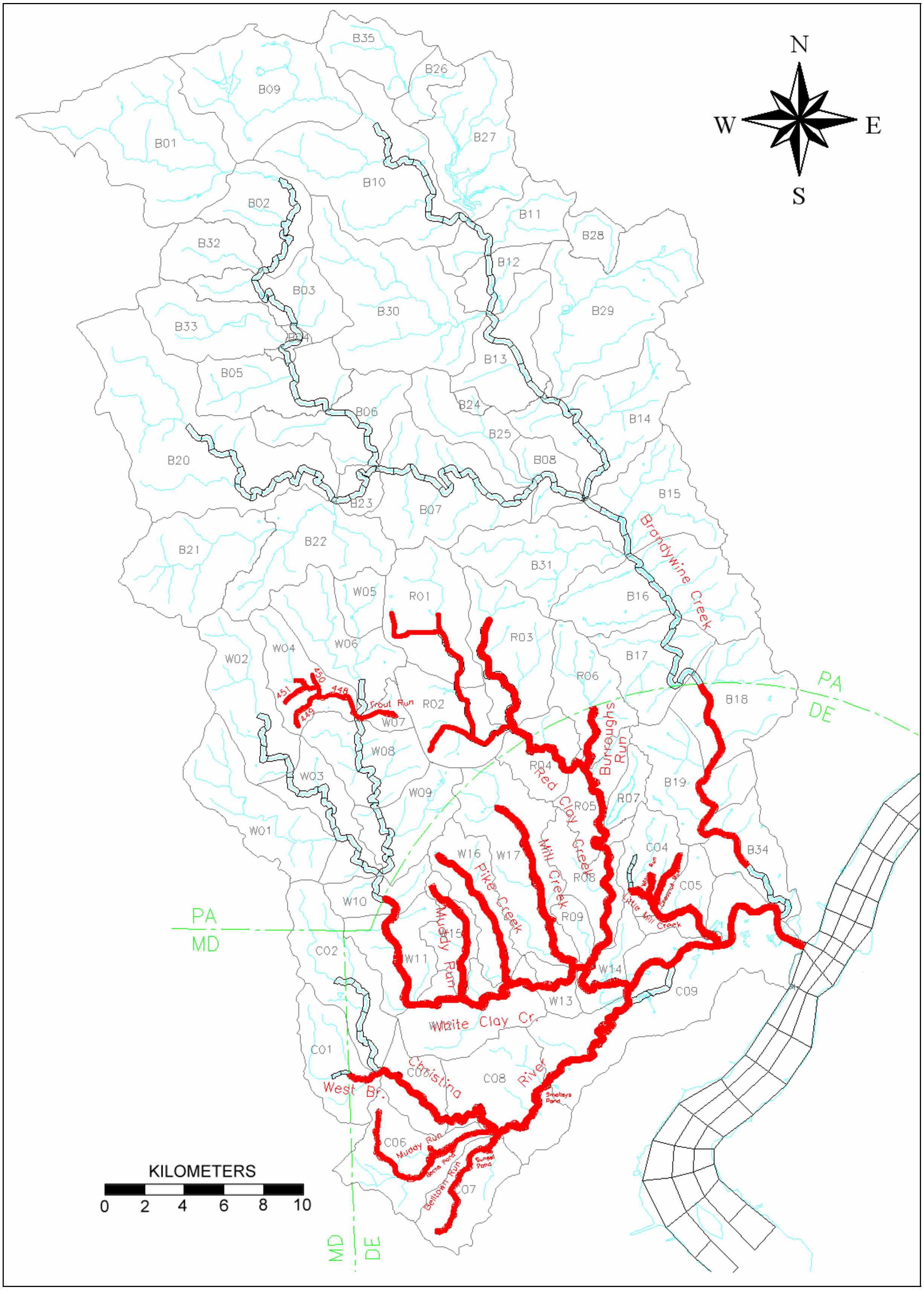

Figure 4-1. Locations of stream segments impaired by bacteria

4.1.2 TMDL Calculation

TMDLs were established for each fecal coliform bacteria-listed stream on Pennsylvania's Section 303(d) list. Each TMDL is the sum of the point source WLAs and the nonpoint source LAs, and a MOS. These TMDLs identify the sources of pollutants that cause or contribute to the impairment of the fecal coliform bacteria criteria and allocate appropriate loadings to the various sources. The basic equation used for TMDLs and allocations to sources is:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

The WLA portion of this equation is the total loading assigned to point sources permitted under the NPDES program. The LA portion is the loading assigned to nonpoint sources. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis. An explicit five percent MOS was used for this TMDL.

4.1.3 Wasteload Allocations

Federal regulations (40 CFR § 130.7) require TMDLs to include individual WLAs for each point source. None of the NPDES permitted dischargers, except as noted below, in the impaired subbasins were required to reduce their present NPDES permit limits of 200 cfu/100mL for fecal coliform bacteria or 100 cfu/100mL for *enterococcus* bacteria.

The City of Wilmington's CSOs are NPDES permitted discharges that currently have no permit limits. Future permits will contain permit limits and require reductions in loads discharged to the Christina River, Little Mill Creek, and Brandywine Creek.

EPA's storm water permitting regulations require municipalities to obtain permit coverage for all storm water discharges from municipal separate storm sewer systems (MS4) as described in Section 2.1.3. MS4s within the Christina River watershed receive allocations expressed as WLAs, enforceable through the NPDES permitting process.

Most of the townships/municipalities within the watershed have been designated by PADEP as covered under the NPDES Phase II Storm Water Regulations, and comprise the almost the entire watershed area. DNREC has issued MS4 permits covering all of New Castle County. MS4 bacteria baseline and allocation loadings were estimated based on drainage areas of each municipality, and the area-weighted WLAs were further allocated by the land use distribution of each municipality (see Appendix C, Tables C-1, C-2, C-3, C-4, C-8, C-9, C-10, C-11, C-12, and C13). MS4 permits issued to date require gathering information regarding the systems.

4.1.4 Load Allocations

According to Federal regulations (40 CFR § 130.2(g)), LAs are best estimates of the nonpoint source or background loading. These allocations may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading.

As explained in Section 2.1.3, once a municipality delineates its MS4 sewershed area, the loads associated with nonpoint sources may be parsed out of the WLA and moved to the LA portion of the TMDL. Note that the total allocation will be unchanged. Example calculations are shown in Appendix E.

4.1.5 CSO Overflows

One of the key principles of the 1994 CSO Control Policy[4] is to provide levels of control that are presumed to meet appropriate health and environmental criteria. After the nine minimum controls, technology-based measures, were implemented, permittees were to develop long-term control plans. The permittees could use one of two approaches: (1) demonstrate its plan was adequate to meet the water quality-based requirements of the CWA or (2) implement a minimum level of treatment presumed to meet the water quality-based requirements. Wilmington selected the presumptive approach which requires capture for treatment of 85 percent of the combined sewage flows and limiting CSO discharges to less than an average of four to six events per year. Guidance[5] defines the required capture as:

> The elimination or the capture for treatment of no less than 85% by volume of the combined sewage collected in the CSS during precipitation events on a system-wide annual average basis.

The CSO loads are equal to the volume multiplied by the event mean concentration. See Appendix D for a discussion of the event mean concentration.

TMDLs and WLAs are generally expressed as loads, mass per unit time. When the TMDLs and WLAs are storm water related, as these TMDLs are, they are often expressed as average annual loads. This means that the analysis (or computer modeling) indicates that instream water quality standards are met each and every day (or as required by the water quality standards) over the predictive time-frame used when all loads are reduced as specified, and the loads entering the waterbody from each source are added together and divided by the number of years in the predictive time-frame used. Because Pennsylvania's bacteria criteria are based on the swimming/non-swimming seasons, the TMDLs and WLAs are average annual seasonal loads. TMDLs, WLAs, and LAs shown in following Tables 4-3 to 4-10 in average annual units are also shown in Appendix F in terms of units per day.

4.1.6 TMDL Results and Allocations

4.1.6.1 Fecal Coliform Bacteria

The fecal coliform bacteria impaired stream segments on Pennsylvania's Section 303(d) list are located in the East Branch White Clay Creek in subbasins W04 and W07 and the Red Clay Watershed in subbasins R01, R02, and R03. The HSPF models for the White Clay Creek and Red Clay Creek were run for the four-year period October 1, 1994, through October 1, 1998, for both the baseline (current) conditions and for the TMDL allocation conditions. Bacteria watershed loads were adjusted in the TMDL allocation scenario until the fecal coliform bacteria 30-day geometric mean water quality standards were achieved for both the swimming season (200 cfu/100mL from May 1 through September 30) and non-swimming season (2,000 cfu/100mL from October 1 to April 30). Watershed loads include domestic and wild animals, and failed septic systems.

The TMDLs and allocations are presented in Tables 4-1 through 4-3. A five percent MOS was used, which means the model instream fecal coliform bacteria concentrations were

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[4] 59*FR*18688
[5] *Combined Sewer Overflows – Guidance For Long-Term Control Plan,* September 1995, EPA 832-B-95-005.

compared to 190 cfu/100mL and 1900 cfu/100mL instead of the water criteria of 200 cfu/100mL and 2000 cfu/100mL.

The non-MS4 point sources in both the Red Clay Creek and White Clay Creek where not reduced. See Table 2-2 for point source WLAs. The septic system loads were reduced by elimination of failed systems.

The baseline and TMDL allocation loads shown in Table 4-1 represent the average seasonal loads calculated from the HSPF model simulation during the period October 1, 1994, through October 1, 1998. In addition to the load allocations at the subbasin scale, the bacteria loads were allocated to the MS4 townships. Four municipalities including Avondale, London Grove, New Garden, and West Grove are located in subbasins W04 and W07. Four municipalities including East Marlborough Township, Kennett Square, Kennett Township and New Garden Townships are located in subbasins R01, R02, and R04. The TMDL allocations for the affected municipalities are shown in Table 4-2. Allocations for fecal coliform bacteria loads for septic systems in each of the impaired subbasins are provided in Table 4-3.

Table 4-1. Average annual seasonal fecal coliform bacteria TMDL allocations for the Christina River Basin

	Baseline Load (cfu/season)			TMDL Allocation (cfu/season)					Percent
Subbasin	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	Reduction
Swimming Season (May 1 - Sep 30)									
Red Clay (R01)	1.872E+12	2.914E+15	2.916E+15	8.734E+10	2.139E+14		1.126E+13	2.252E+14	92.28%
Red Clay (R02)	6.037E+12	1.319E+15	1.325E+15	1.274E+12	1.133E+14		6.031E+12	1.206E+14	90.90%
Red Clay (R03)	1.304E+12	1.435E+15	1.437E+15	1.738E+11	1.206E+14		6.359E+12	1.272E+14	91.15%
White Clay (W04)		1.726E+15	1.726E+15		1.040E+14		5.478E+12	1.095E+14	93.66%
White Clay (W07)	7.529E+10	3.140E+13	3.148E+13	7.529E+10	2.885E+12		1.557E+11	3.115E+12	90.10%
Non-swimming Season (Oct 1 - Apr 30)									
Red Clay (R01)	1.872E+12	6.404E+15	6.406E+15	8.734E+11	2.895E+15		1.524E+14	3.049E+15	52.40%
Red Clay (R02)	6.037E+12	3.406E+15	3.412E+15	1.274E+13	1.571E+15		8.338E+13	1.668E+15	51.12%
Red Clay (R03)	1.304E+12	3.704E+15	3.705E+15	1.738E+12	1.720E+15		9.062E+13	1.812E+15	51.08%
White Clay (W04)		2.499E+15	2.499E+15		2.370E+15		1.249E+14	2.495E+15	0.16%
White Clay (W07)	1.043E+11	6.899E+13	6.910E+13	7.529E+11	6.475E+13		3.450E+12	6.899E+13	0.15%

Table 4-2. Average annual seasonal fecal coliform TMDL allocations for MS4 municipalities

Town	Sub-Watershed	Swimming Season Baseline (cfu/season)	Swimming Season TMDL (cfu/season)	Percent Reduction
East Marlborough TWP	Red Clay	2.61E+15	2.06E+14	92.09%
Kennett Square Boro	Red Clay	2.35E+14	1.88E+13	91.98%
Kennett TWP	Red Clay	1.44E+15	1.24E+14	91.38%
New Garden TWP	Red Clay	1.12E+15	9.38E+13	91.60%
Avondale Boro	White Clay	3.81E+13	2.42E+12	93.64%
London Grove TWP	White Clay	1.54E+15	9.27E+13	93.99%
New Garden TWP	White Clay	3.00E+13	2.76E+12	90.82%
West Grove Boro	White Clay	8.48E+13	5.09E+12	93.99%

Town	Sub-Watershed	Non-Swimming Season Baseline (cfu /season)	Non-Swimming Season TMDL (cfu/season)	Percent Reduction
East Marlborough TWP	Red Clay	5.95E+15	2.85E+15	52.08%
Kennett Square Boro	Red Clay	5.45E+14	2.62E+14	51.95%
Kennett TWP	Red Clay	3.65E+15	1.78E+15	51.26%
New Garden TWP	Red Clay	2.76E+15	1.34E+15	51.52%
Avondale Boro	White Clay	5.83E+13	5.53E+13	5.06%
London Grove TWP	White Clay	2.23E+15	2.12E+15	5.04%
New Garden TWP	White Clay	6.59E+13	6.25E+13	5.15%
West Grove Boro	White Clay	1.23E+14	1.17E+14	5.04%

Table 4-3. Average annual seasonal septic system TMDL allocations of fecal coliform bacteria

Sub-Watershed	Estimated number of septic systems	Swimming Season Baseline (cfu/season)	Swimming Season TMDL (cfu/season)	Percent Reduction
Red Clay (R01)	553	6.13E+13	1.26E+11	99.79%
Red Clay (R02)	460	5.09E+13	1.05E+11	99.79%
Red Clay (R03)	779	8.63E+13	1.77E+11	99.79%
White Clay (W04)	224	2.48E+13	5.10E+10	99.79%
White Clay (W07)	42	4.69E+12	9.63E+09	99.79%
Sub-Watershed	**Estimated number of septic systems**	**Non Swimming Season Baseline (cfu/season)**	**Non Swimming Season TMDL (cfu/season)**	**Percent Reduction**
Red Clay (R01)	553	8.79E+13	1.75E+11	99.80%
Red Clay (R02)	460	7.31E+13	1.45E+11	99.80%
Red Clay (R03)	779	1.24E+14	2.46E+11	99.80%
White Clay (W04)	224	3.56E+13	7.06E+10	99.80%
White Clay (W07)	42	6.72E+12	1.33E+10	99.80%

4.1.6.2 *Enterococci* Bacteria

The locations of the stream segments listed as impaired for *enterococci* bacteria in Delaware are shown in Figure 4-1, and comprise most of the Christina River Basin within Delaware. Pennsylvania TMDL allocations for *enterococci* bacteria were determined at the PA-DE state line for Brandywine Creek, White Clay Creek, Red Clay Creek, and Burroughs Run and for Maryland at the MD-DE State line for the East and West Branches of the Christina River.

In Delaware, TMDL allocations were determined for each HSPF model subbasin to ensure protection of both the 30-day geometric mean criterion (100 cfu/100mL) also using a five percent MOS. The model run results were compared to a 30-day geometric mean of 95 cfu/100mL. All Delaware loads are average annual loads because Delaware does not have seasonal bacteria criteria.

In Pennsylvania, TMDL allocation results indicate that reductions in bacteria loading from land accumulation and from livestock's direct bacteria loading to streams on the order of 29 to 93 percent, respectively, are necessary to protect the water quality standards for *enterococci* bacteria at the PA-DE state line on Brandywine Creek, White Clay Creek, Red Clay Creek, and Burroughs Run. Approximately a 58 percent reduction is required at the MD-DE state line. Allocations are shown in Table 4-4.

The WLA portion of the TMDL allocation includes the contributions from CSO outfalls in the City of Wilmington (see Figure 4-2). The baseline loading for the CSO outfalls was determined using flow rates simulated by the XP-SWMM model and event mean concentrations (EMC) from CSO monitoring during storm events. Allocation model runs reduced the CSO loads by reducing the EMC but not the CSO volume except for CSOs 27, 28, and 29 on Little Mill Creek. For those three CSOs, the flows were routed through a storage tank to reduce the volume and load. The required total CSO load reduction from baseline conditions is approximately 68 percent as shown in Table 4-5. These reductions are based on the assumption that the Delaware River also meets applicable water quality criteria. See Appendix D for details.

The TMDL CSO load reductions shown in Appendix D, Table D-3, are one scenario of load reductions which, together with other sources' reductions, result in achieving instream water quality criteria throughout the length of the impaired waterbody. It should be noted that other scenarios are possible. In the future DNREC may allow an alternate CSO load reduction scenario, which also demonstrates that water quality standards are met throughout the length of the impaired waterbody.

In 2005 construction of a 2.3 million gallon (mgal) storage tank at Canby Park was completed to help capture overflows from CSOs 27, 28, and 29. Model runs indicate that the 2.3 mgal tank will reduce the average annual *enterococc*i load by 9.90E+13 cfu of the required 1.19E+14 cfu reduction specified by the TMDL. Thus, an additional annual reduction of 1.99E+13 cfu is needed to meet the TMDL in Little Mill Creek.

The non-MS4 point sources in Delaware where not reduced. See Table 2-2 for point source WLAs. Septic system loads were reduced by elimination of failed systems. In the Delaware subbasins, the overall reductions in *enterococci* bacteria from the baseline conditions range from about 29 percent to over 90 percent as shown in Table 4-6. The WLAs include non-MS4 point sources (Table 2-2) and CSO point sources.

Table 4-4. State line average annual allocations for Christina River Basin *enterococci* bacteria TMDL

Location	Baseline (cfu/yr)	Allocation (cfu/yr)	Reduction
Allocations at the Pennsylvania-Delaware State Line			
Brandywine Cr. (at PA-DE Line)	3.12E+15	2.01E+14	93.56%
White Clay Cr. (at PA-DE Line)	6.86E+14	2.06E+14	70.03%
Red Clay Cr. (at PA-DE Line)	2.58E+14	1.08E+14	58.05%
Burroughs Run (at PA-DE Line)	1.85E+13	1.30E+13	29.32%
Allocations at the Maryland-Delaware State Line			
Christina River (at MD-DE Line)	1.86E+13	7.73E+12	58.40%

Table 4-5. Summary of average annual CSO *enterococci* baseline loads and WLA TMDL

Location	CSO ID Numbers	Baseline (cfu/yr)	WLA (cfu/yr)	Reduction
Little Mill Creek (C05)	27, 28, 29	1.56E+14	3.69E+13	76.32%
Christina River (C09)	5, 6, 7, 9a, 9c, 10, 11, 12, 13, 14, 15, 16, 17, 30	3.54E+14	9.75E+13	72.47%
Brandywine Creek (B34)	3, 4a, 4b, 4c, 4d, 4e, 4f, 18, 19, 20, 21a, 21b, 21c, 22b, 22c, 23, 24, 25, 26, RR	6.89E+14	2.55E+14	63.07%
Total CSO Loads	-	1.20E+15	3.89E+14	67.57%

Table 4-6. Average annual allocations for Christina River Basin *enterococci* bacteria TMDL

Location	Baseline (cfu/yr)	WLA (cfu/yr)	LA (cfu/yr)	MOS (cfu/yr)	TMDL (cfu/yr)	Reduction
Brandywine Creek in Delaware						
Brandywine Cr. (B18)	1.11E+14	0.00E+00	5.55E+12	2.92E+11	5.85E+12	94.75%
Brandywine Cr. (B19)	5.57E+13	3.45E+10	6.31E+12	3.32E+11	6.68E+12	88.00%
White Clay Creek in Delaware						
White Clay Cr. (W11)	4.07E+13	0.00E+00	9.96E+12	5.24E+11	1.05E+13	74.23%
White Clay Cr. (W12)	1.49E+14	4.15E+10	1.79E+13	9.44E+11	1.89E+13	87.31%
White Clay Cr. (W13)	3.01E+13	0.00E+00	3.91E+12	2.06E+11	4.11E+12	86.34%
White Clay Cr. (W14)	3.82E+13	0.00E+00	3.99E+12	2.10E+11	4.20E+12	89.00%
White Clay Cr. (W15)	2.85E+13	0.00E+00	8.95E+12	4.71E+11	9.42E+12	66.90%
White Clay Cr. (W16)	1.02E+14	0.00E+00	1.32E+13	6.95E+11	1.39E+13	86.41%
White Clay Cr. (W17)	2.41E+14	0.00E+00	3.34E+13	1.76E+12	3.52E+13	85.43%
Red Clay Creek in Delaware						
Red Clay Cr. (R04)	5.89E+13	3.00E+12	8.52E+12	4.48E+11	1.20E+13	79.67%
Red Clay Cr. (R05)	2.25E+13	2.07E+10	7.90E+12	4.16E+11	8.34E+12	63.01%
Red Clay Cr. (R06)	1.51E+13	6.22E+08	1.01E+13	5.34E+11	1.07E+13	29.32%
Red Clay Cr. (R07)	6.05E+12	0.00E+00	1.74E+12	9.16E+10	1.83E+12	69.75%
Red Clay Cr. (R08)	7.61E+13	4.84E+11	7.83E+12	4.12E+11	8.73E+12	88.54%
Red Clay Cr. (R09)	2.88E+13	0.00E+00	2.89E+12	1.52E+11	3.04E+12	89.44%
Christina River and Tidal Brandywine Creek						
Christina River (C01)	3.51E+13	0.00E+00	1.27E+13	6.69E+11	1.34E+13	61. 90%
Christina River (C02)	8.16E+13	0.00E+00	2.47E+13	1.30E+12	2.60E+13	68.15%
Christina River (C03)	6.64E+13	0.00E+00	9.35E+12	4.92E+11	9.84E+12	85.18%
Christina River (C04)	8.69E+13	0.00E+00	6.73E+12	3.54E+11	7.09E+12	91.84%
Christina River (C05) *	2.21E+14	3.69E+13	4.84E+12	2.55E+11	4.20E+13	81.01%
Christina River (C06)	7.45E+13	0.00E+00	1.65E+13	8.70E+11	1.74E+13	76.66%
Christina River (C07)	7.16E+13	0.00E+00	1.08E+13	5.70E+11	1.14E+13	84.08%
Christina River (C08)	1.28E+14	0.00E+00	1.67E+13	8.79E+11	1.76E+13	86.29%
Christina River (C09) *	6.84E+14	9.75E+13	3.54E+13	1.87E+12	1.35E+14	80.30%
Tidal Brandywine Cr. (B34) *	8.23E+14	2.55E+14	1.33E+13	6.98E+11	2.68E+14	67.38%
Sunset Lake	6.39E+13	0.00E+00	1.41E+13	7.46E+11	1.49E+13	76.66%
Beck's Pond	6.27E+13	0.00E+00	9.45E+12	4.99E+11	9.98E+12	84.08%
Smalley's Pond	1.28E+14	0.00E+00	1.67E+13	8.79E+11	1.76E+13	86.29%

* CSO loads are included in the Baseline and WLA in these subbasins.

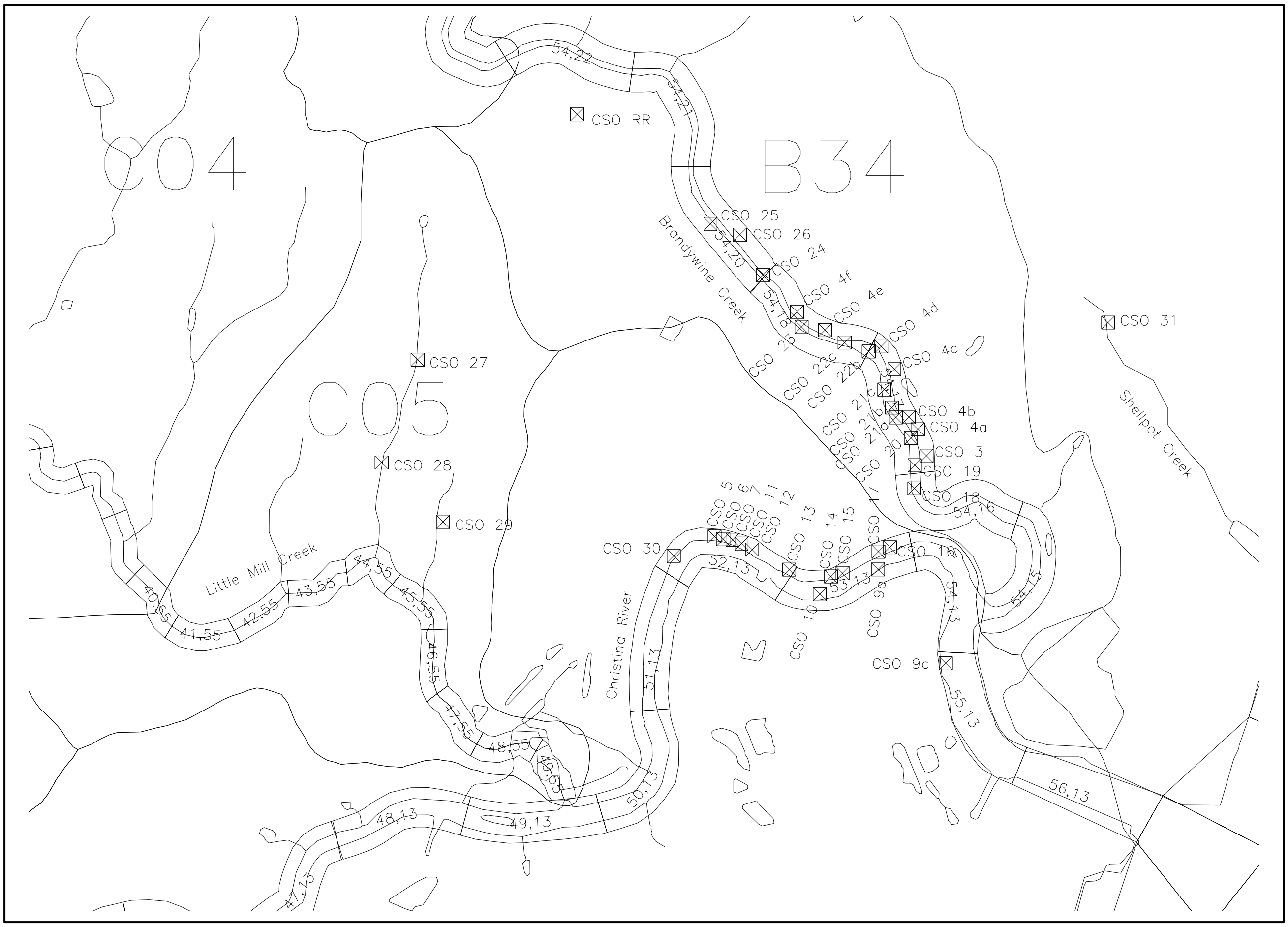

Figure 4-2. Location of CSO discharges in relation to EFDC model grid cells

4.1.7 Consideration of Critical Conditions

Federal Regulations (40 CFR § 130.7c(1)) require TMDLs to consider critical conditions for streamflow, loading, and water quality parameters. The intent of this requirement is to ensure protection of water quality in waterbodies during periods when they are most vulnerable. There may be multiple critical conditions depending on the different sources of bacteria. The four-year dynamic modeling addresses varying rainfall, flow, and seasonal variations of bacteria (EPA, 2001). The bacteria TMDLs for Christina River Basin adequately address critical conditions for flow and loading through analysis of a four-year hydrologic simulation that includes typical low and high flow variations in the basin.

The model calibration results for fecal coliform and *enterococci* bacteria show that the bacteria concentrations tend to be higher during the warm weather months. The bacteria concentrations appear to be correlated with cattle grazing behavior and storm events. The calibration results suggest that the highest bacteria concentration in terms of 30-day geometric mean may occur in warm weather following a storm event preceded by a long dry-weather period.

4.1.8 Consideration of Seasonal Variation

The critical conditions for bacteria, or any pollutant washed off the land surface by rainfall runoff, cannot be defined with a fixed flow rate. A long-term continuous simulation is one way to determine when the bacteria concentrations are highest. Therefore, the models were run for a four-year period (October 1, 1994, through October 1, 1998). This period is characterized by both extreme low flows during the summers of 1995 and 1997 as well as high-flow events during storms. This simulation period covered the range of typical critical hydrological conditions expected in the Christina River Basin.

4.1.9 Margin of Safety

The CWA and Federal regulations require TMDLs to include a MOS to take into account the relationship between effluent limitations and water quality. EPA guidance suggests two approaches to satisfy the MOS requirement. First, it can be met implicitly by using conservative model assumptions to develop the allocations. Alternately, it can be met explicitly by allocating a portion of the allowable load to the MOS. These TMDLs use an explicit five percent MOS.

4.2 Sediment TMDLs

The following sections discuss the methods used for TMDL development and the LAs, and percent reductions for the sediment-listed Pennsylvania waters. No stream segments are listed as impaired due to sediment in Delaware or Maryland. The stream segments listed for sediment impairment on Pennsylvania's 1996 Section 303(d) list are shown in Figure 4-3, and those on the 1998 Section 303(d) list are shown in Figure 4-4.

4.2.1 Methodology

Sediment and siltation problems tend to occur during wet weather periods when sediment washes off land surfaces and when high flows cause erosion of streambeds and stream banks. Sediment TMDL endpoints for the impaired reaches were developed using a reference watershed approach (see Section 3.2). After the impaired and reference watersheds were matched, the HSPF models were used to simulate the sediment loads from different sources for both the impaired and reference watersheds. The sediment loads calculated for the reference watersheds were used as endpoints for the impaired watersheds. A general description of the approach was previously shown in Figure 3-1.

The HSPF watershed models were used to calculate the TMDL sediment baseline and LAs for the Pennsylvania listed waters. The models were calibrated over a four-year period (October 1, 1994, through October 1, 1998) to include both low and high streamflow. Following calibration, the same four-year period was used for the baseline and TMDL allocation simulations. For the baseline condition, all NPDES point sources were set to their permitted flow and sediment (total suspended solids (TSS)) levels (see Table 2-2). No sediment loads were assigned to septic systems. Sediment yields from different land uses in the watersheds were incorporated into the models. A series of model runs were made in which the sediment loads from land sources were reduced until water quality standards were met. A detailed description of the background, configuration, and calibration of the modeling system is provided in the Modeling Report (EPA, 2005).

4.2.2 TMDL Calculation

TMDLs were established for the stream segments listed on Pennsylvania's Section 303(d) list. Each TMDL consists of point source WLAs, nonpoint source LAs, and a MOS. The basic equation used for TMDLs and allocations to sources is:

$$\text{TMDL} = \sum \text{WLAs} + \sum \text{LAs} + \text{MOS}$$

The WLA portion of this equation is the total loading assigned to point sources. The LA portion is the loading assigned to nonpoint sources. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis. An explicit five percent MOS was used for this TMDL.

4.2.3 Waste Load Allocations

Federal regulations (40 CFR § 130.7) require TMDLs to include individual WLAs for each point source. None of the non-MS4 NPDES permitted dischargers in the impaired subbasins was required to reduce their present TSS NPDES permit limits shown in Table 2-2. Based on the available discharge monitoring reports the average discharge of sediment from such facilities in the watershed was usually well below the permitted TSS concentration.

EPA's storm water permitting regulations require municipalities to obtain permit coverage for all storm water discharges from municipal separate storm sewer systems (MS4) as described in Section 2.1.3. MS4s within the Christina River Watershed receive allocations expressed as WLAs, enforceable through the NPDES permitting process.

Sediment loadings were estimated based on drainage areas of each municipality, and the area-weighted WLAs were further allocated by the land use distribution of each municipality (see Appendix C, Tables C-5, 6, and 7).

4.2.4 Load Allocations

According to Federal regulations (40 CFR § 130.2(g)), LAs are best estimates of the nonpoint source and background loading. These allocations may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint sources should be distinguished (EPA, 2001). Model output for the impaired subbasins includes sediment loads from each of the contributing land uses as well as a total sediment load from streambed erosion.

As explained in Section 4.1.3, once a municipality delineates its MS4 area, the sediment loads associated with nonpoint sources may be parsed out of the WLA and moved under the LA portion of the TMDL. Note that the total LA will be unchanged. See Appendix E, Storm Water Permits, Sample Calculations.

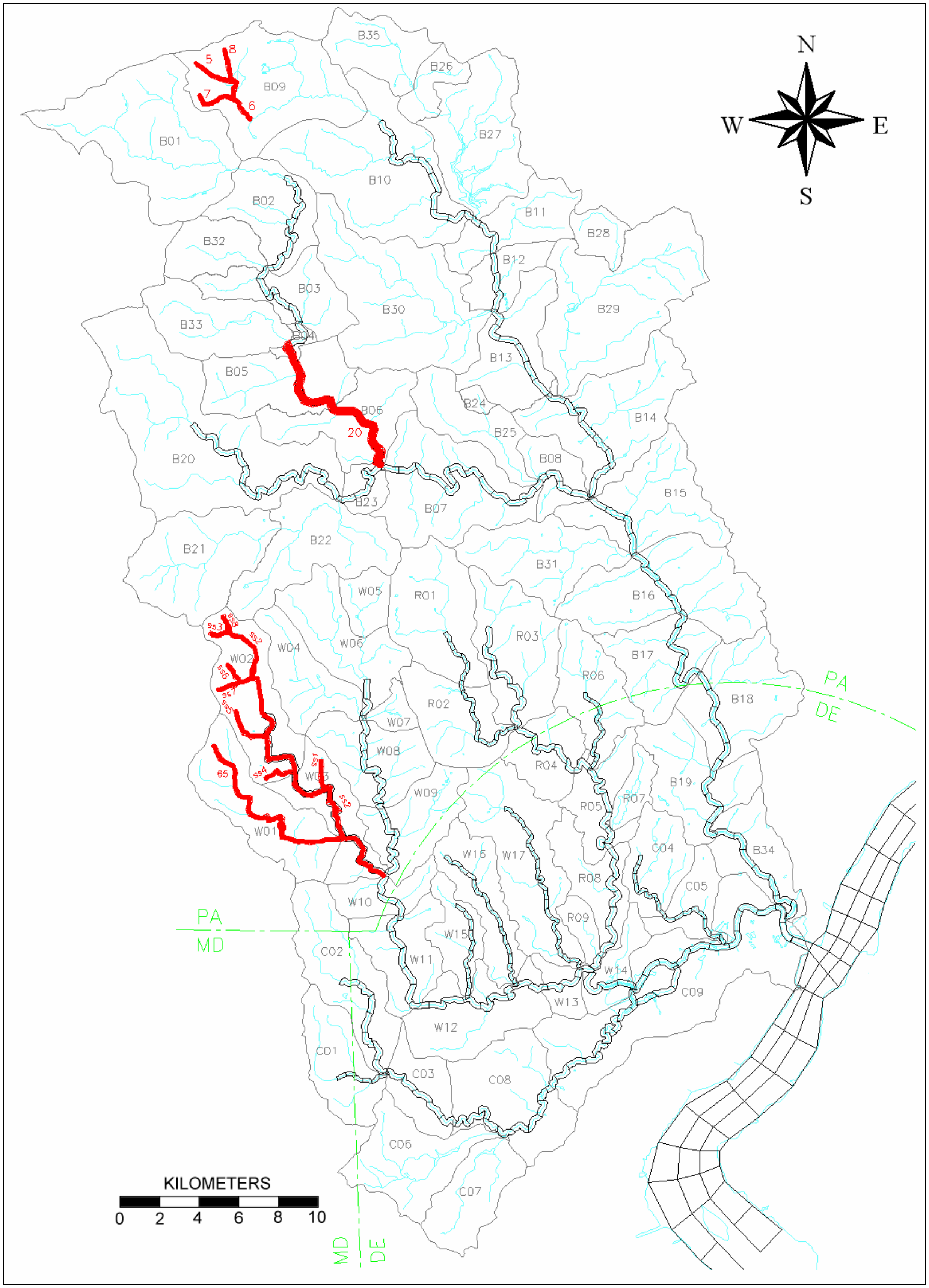

Figure 4-3. Stream segments impaired by sediment on Pennsylvania 1996 Section 303(d) list

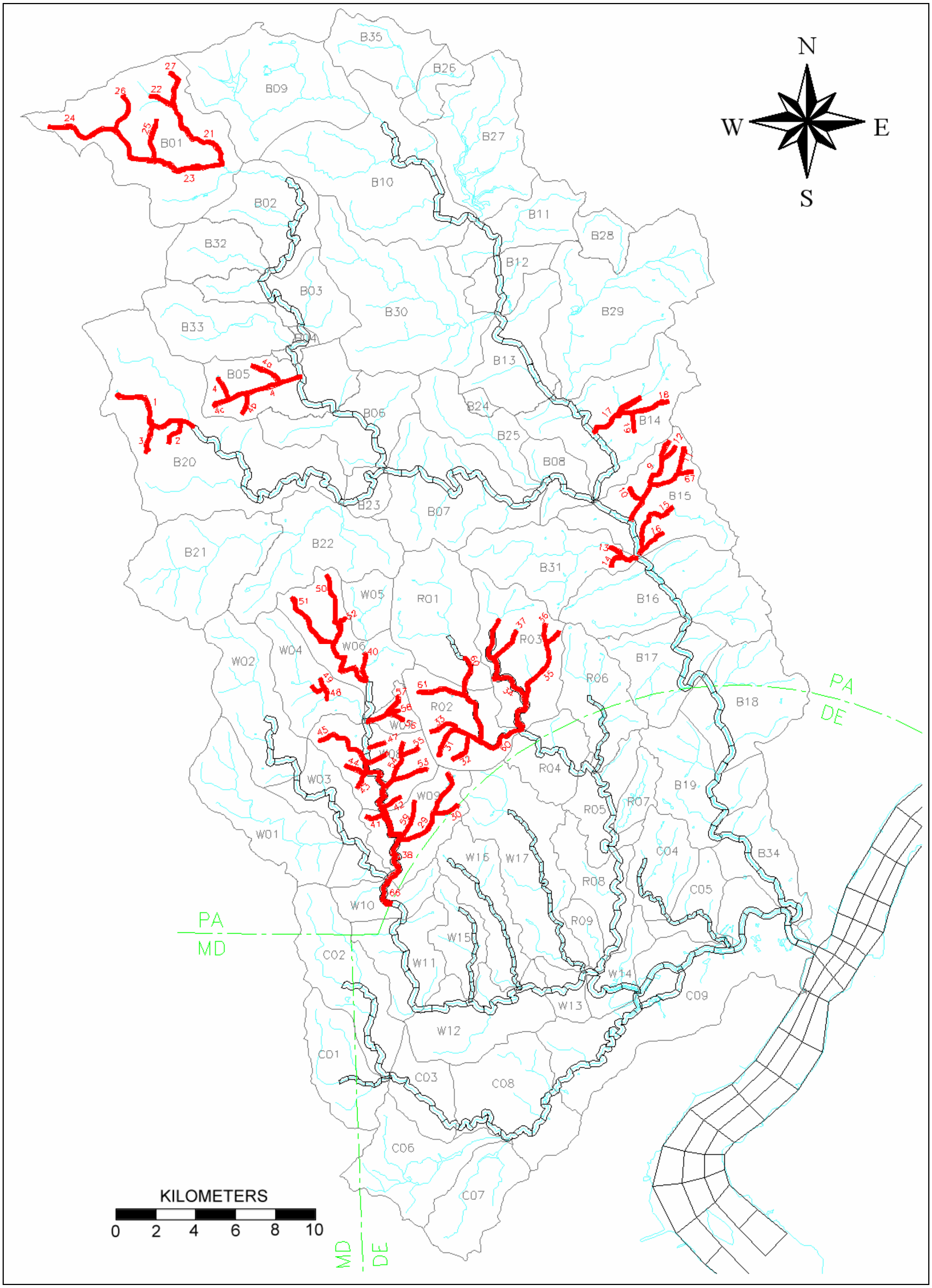

Figure 4-4. Stream segments impaired by sediment on Pennsylvania 1998 Section 303(d) list

4.2.5 TMDL Results and Allocations

The TMDL allocations for sediment in the Christina River Basin are presented in Table 4-7. The NPDES permitted point sources shown in Table 2-2 are summed by subbasin in Table 4-7. The TMDL allocations for the MS4 municipalities in Brandywine Creek, Red Clay Creek, and White Clay Creek Watersheds are listed in Table 4-8, 4-9, and 4-10, respectively.

Table 4-7. Average annual[6] allocations for Christina River Basin sediment TMDL

Subbasin	Baseline Load (ton/yr)			TMDL Allocation (ton/yr)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
Brandywine Creek									
B01	29.80	776.03	805.83	29.80	414.16	84.82	27.83	556.61	30.9%
B04	0.00	42.63	42.63	0.00	21.77	-	1.15	22.92	46.2%
B05	246.02	1278.65	1524.67	246.02	421.74	-	35.15	702.91	53.9%
B06	0.08	340.20	340.28	0.08	219.34		11.55	230.97	32.1%
B09	0.04	498.86	498.89	0.04	180.75	218.75	21.03	420.57	15.7%
B14	79.81	1637.50	1717.31	79.81	631.82	-	37.45	749.08	56.4%
B15	9.19	1214.60	1223.79	9.19	509.37	-	27.29	545.85	55.4%
B20	1.68	1119.58	1121.26	1.68	645.94	49.03	36.67	733.31	34.6%
B31	0.04	1189.38	1189.42	0.04	452.25	-	23.80	476.09	60.0%
White Clay Creek									
W01	0.30	5353.56	5353.87	0.30	2940.17	-	154.76	3095.23	42.2%
W02	11.42	7999.18	8010.60	11.42	2283.47	449.21	144.43	2888.53	63.9%
W03	0.00	3168.54	3168.54	0.00	1825.04	-	96.05	1921.10	39.4%
W04	0.00	5187.94	5187.94	0.00	1722.66	58.57	94.49	1875.72	63.8%
W06	2.83	8114.08	8116.92	2.83	1795.34	667.6	129.78	2595.55	68.0%
W07	2.97	1414.61	1417.58	2.97	393.60	-	20.87	417.44	70.6%
W08	2.19	4606.80	4609.00	2.19	2146.83	-	113.11	2262.13	50.9%
W09	0.05	2808.89	2808.95	0.05	1968.74	-	103.62	2072.42	26.2%
Red Clay Creek									
R01	8.45	8424.04	8432.49	8.45	3500.39	329.31	201.96	4040.11	52.1%
R02	50.26	6252.12	6302.38	50.26	2805.45	-	150.30	3006.01	52.3%
R03	6.85	7218.12	7224.97	6.85	3761.33	-	198.33	3966.51	45.1%

The TMDLs in Table 4-7 were not revised. However, where a subbasin is not completely within a MS4 jurisdiction, the TMDL is divided into the MS4 WLA and LA.

[6] See Appendix F for loads in terms of units per day.

Table 4-8. Average annual sediment allocations for towns in Brandywine Creek Watershed

Township	Baseline (ton/yr)	TMDL (ton/yr)	Percent Reduction
BIRMINGHAM TWP	310.81	130.35	58.06%
COATESVILLE CITY	231.29	79.76	65.52%
EAST BRADFORD TWP	1185.00	467.17	60.58%
EAST FALLOWFIELD TWP	803.23	426.42	46.91%
EAST MARLBOROUGH TWP	366.70	139.44	61.98%
HIGHLAND TWP	384.80	238.86	37.93%
HONEY BROOK BORO	20.58	13.23	35.70%
HONEY BROOK TWP	813.84	558.76	31.34%
MODENA BORO	27.96	12.46	55.43%
NEWLIN TWP	144.18	59.59	58.67%
PARKESBURG BORO	52.11	32.35	37.93%
PENNSBURY TWP	113.98	43.48	61.85%
POCOPSON TWP	821.21	320.79	60.94%
SADSBURY TWP	289.73	172.13	40.59%
THORNBURY TWP	82.17	34.46	58.06%
VALLEY TWP	485.14	164.64	66.06%
WALLACE TWP	21.74	17.41	19.92%
WEST BRADFORD TWP	283.22	121.60	57.07%
WEST CALN TWP	68.28	43.07	36.92%
WEST GOSHEN TWP	461.32	180.51	60.87%

Table 4-9. Average annual sediment allocations for towns in Red Clay Creek Watershed

Township	Baseline (ton/yr)	TMDL (ton/yr)	Percent Reduction
EAST MARLBOROUGH TWP	8791.41	4193.24	52.30%
KENNETT SQUARE BORO	840.10	405.41	51.74%
KENNETT TWP	6751.63	3312.06	50.94%
NEW GARDEN TWP	4709.65	2118.72	55.01%

Table 4-10. Average annual sediment allocations for towns in White Clay Creek Watershed

Township	Baseline (ton/yr)	TMDL (ton/yr)	Percent Reduction
AVONDALE BORO	463.65	140.02	69.80%
FRANKLIN TWP	4220.43	2305.87	45.36%
LONDON BRITAIN TWP	2634.66	1620.44	38.50%
LONDON GROVE TWP	13616.33	4842.81	64.43%
NEW GARDEN TWP	6746.50	2986.66	55.73%
NEW LONDON TWP	1913.97	1008.60	47.30%
PENN TWP	3584.76	1410.29	60.66%
WEST GROVE BORO	562.29	192.63	65.74%

4.2.6 Critical Conditions

The HSPF model is a continuous-simulation model that uses daily time steps for weather data and water balance calculations. The average annual yearly calculations made for the sediment loads shown in the average annual TMDL allocation tables in the previous section were based on the daily model simulation output and summed to get yearly values. Therefore, all flow conditions are taken into account for loading calculations. Because there is usually a significant lag time between the introduction of sediment to a waterbody and the resulting impact on beneficial uses, establishing these TMDLs using average annual loads is protective of the waterbody.

4.2.7 Seasonal Variation

The continuous-simulation model used for this analysis considers seasonal variation through a number of mechanisms. Daily time steps are used for weather data and water balance calculations. The HSPF model had for a four-year period (October 1, 1994, through October 1, 1998). This period is characterized by both extreme low flows during the summers of 1995 and 1997, as well as high-flow events during storms. This simulation period covered the range of typical critical hydrological conditions expected in the Christina River Basin. The combination of these model features accounts for seasonal variability.

4.2.8 Margin of Safety

The CWA and Federal regulations require TMDLs to include a MOS to take into account any lack of knowledge concerning the relationship between effluent limitations and water quality. EPA guidance suggests two approaches to satisfy the MOS requirement. First, it can be met implicitly by using conservative model assumptions to develop the allocations. Alternately, it can be met explicitly by allocating a portion of the allowable load to the MOS. These TMDLs use an explicit five percent MOS.

5.0 REASONABLE ASSURANCE AND IMPLEMENTATION

EPA's regulations require that there is reasonable assurance that TMDLs can be implemented. Reasonable assurance indicates a high degree of confidence that the goals outlined in the TMDL, whether in the form of WLAs or LAs, can be achieved. In terms of the Christina River High-flow TMDL, various programs exist that can be utilized to help implement TMDLs.

For point sources, Federal regulations at 40 CFR 122.44(d)(1)(vii)(B), require effluent limitations for an NPDES permit to be consistent with the assumptions and requirements of any available WLA for the discharge prepared by the state and approved by EPA. Furthermore, EPA has authority to object to issuance of a NPDES permit that is inconsistent with the WLAs established for that point source. Additionally, according to 40 CFR 130.7(d)(2), approved TMDL loadings shall be incorporated into the states' current water quality management plans. These plans are used to direct implementation and draw upon the water quality assessments to identify priority point and nonpoint source water quality problems, consider alternative solutions, and recommend control measures.

With regard to LAs for nonpoint sources, programs including Section 319 programs are available. Pennsylvania's Growing Greener funding has provided more than $65 million dollars to environmental initiatives throughout the Commonwealth of Pennsylvania. Section 319 grant funding, supported by the Unified Watershed Assessment and the Watershed Restoration Action Strategies, is designed to focus resources towards the implementation of BMPs for nonpoint source pollutants.

Implementation of BMPs in the affected areas should achieve the loading reduction goals established in the TMDLs. Substantial reductions in the amount of bacteria and sediment reaching the streams can be made through the planning of riparian buffer zones, contour strips, cover crops, or stormwater retention techniques. These BMPs range in efficiency from 20% to 70% for sediment and bacteria reduction. Reductions in instream loads resulting from bank erosion can be made through two plans: (1) stream restoration plans that seek to stabilize stream banks and provide better transport of high storm flows associated with urban areas, and (2) implementation of urban BMPs that reduce peak storm flow through retention or increased infiltration. Such management practices will also address those stream segments listed as impaired due to water/flow variability. Further investigations should be performed in order to assess both the extent of existing BMPs, and to determine the most cost-effective and environmentally protective combination of BMPs required for meeting the bacteria and sediment reductions outlined in this report.

There are state and local policies and regulations in place to help ensure implementation of BMPs. At the state level, PADEP has developed a Proposed Comprehensive Stormwater Management Policy (Appendix A) that encourages implementation of BMPs for stormwater control to reduce pollutant loadings, recharge groundwater tables, enhance stream base flow during drought periods, and reduce the threat of stream bank erosion and flooding. This policy seeks to integrate watershed management plans with permitting programs. Therefore incorporation of TMDL targets at this stage is essential for setting goals for future watershed management plans. Such watershed management plans should be consistent with Stormwater Management Plans developed by counties and implemented by municipalities on a watershed basis, as required by the Pennsylvania Stormwater Management Act (Act 167).

At the Federal level, EPA's storm water permitting regulations require municipalities to obtain permit coverage for all storm water discharges from separate storm sewer systems (MS4s). Due to the variability of storm events and discharges from storm sewer system discharges, it is difficult to establish numeric limits on stormwater discharges that accurately address projected loadings. As a result, EPA regulations and guidance recommend expressing NPDES permit limits for MS4s as BMPs, and only using numeric limits in unique instances. Such BMP plans should accompany monitoring plans that test the performance of BMPs and provide a basis for revised management techniques. This iterative strategy is consistent with the watershed management approach discussed above, and allows an implementation plan where realistic goals can be set to improve the water quality of the streams through the use of BMPs throughout the watershed. The intention is to implement BMPs as required through the Federal and state policies and regulations described above with the ultimate goal of achieving the WLA. For more information, see the EPA memorandum titled *Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs* (November 22, 2002) in Appendix B.

For purposes of this TMDL, WLAs were developed for each municipality holding MS4 permits. Distribution of loads was estimated using land use data within municipal boundaries and application of unit area loadings (lbs/acre/year) determined for subbasins defined in the HSPF model and used for TMDL development. As additional data are collected by the States' storm water programs regarding drainage areas of each storm sewer system in the basin, these WLAs can be refined to more detailed representation of WLAs for each stormwater permit and LAs for areas not bound by such permits. To do this, the drainage area of each storm sewer should be delineated so that the area and distributions of land use can be determined. The land use areas within the stormwater drainage areas can be multiplied by the unit area loadings reported herein to determine the WLA for each MS4 permit and to calculate the load reduction necessary to meet the TMDL. The remaining load in each respective township can then be assigned to LAs. Until such storm water drainage area data are available, the WLAs and required load reductions reported herein are applicable.

The development of TMDLs is only the beginning of the process for stream restoration and watershed management. Load allocations to point and nonpoint sources serve as targets for improvement, but success is determined by the level of effort put forth in making sure that those goals are achieved. The load reductions proposed by the bacteria and sediment TMDLs require specific watershed management measures to ensure successful implementation.

For the Delaware portion of the Christina Basin, the Christina Basin Clean Water Partnership has developed a Watershed Restoration Action Strategy (WRAS), which is intended to provide a guideline for future watershed protection and restoration actions. The WRAS, developed in June 2003, is also designed to interconnect with EPA's earlier low-flow, point source TMDL for the Christina Basin and this high-flow, nonpoint source TMDL. 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." To do so, the Christina Basin WRAS identifies some goals and objectives that are related to this sediment and bacteria TMDL. One goal is to reduce bacteria loads in the streams to meet the Delaware swimmable primary recreation water quality standards of less than 100 cfu/100 mL. Another goal is to reduce sediment loads from land and stream erosion sources to less than 250 pounds per acre per year. And, regarding stream habitat, the WRAS hopes to 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.

There are many active watershed groups, in addition to various local and government organizations, that provide watershed stewardship in the Christina Basin. These include: the Brandywine Conservancy, Brandywine Valley Association, Red Clay Valley Association, Delaware Nature Society, White Clay Watershed Association, Stroud White Clay Creek Laboratory, and Christina Conservancy, and Wilmington River-City Steering Committee. Additionally, the Chester County Water Resources Authority and Chester County Conservation District in Pennsylvania, and the University of Delaware, Water Resources Authority, play an active role in coordinating watershed activities and initiatives for the Christina Basin. It is also important to mention that the Chester County and New Castle Conservation Districts have and hopefully will continue to install BMP implementation projects that are in line with the goals of the TMDL. Many of these organizations serve as local co-coordinators or as members of the Christina Basin Clean Water Partnership mentioned above.

6.0 PUBLIC PARTICIPATION

Public participation is not only a requirement of the TMDL process, but is essential to its success. At a minimum, the public must be allowed at least 30 days to review and comment prior to establishing a TMDL. Also, EPA must provide a summary of all public comments and responses to those comments to indicate how the comments were considered in the final decision.

Multiple public meetings have been provided throughout all stages of the project to inform and update the public on all aspects of the project as it evolved. The public was encouraged to participate in data collection efforts and provide comments on a report of the data review and proposed TMDL methodology prior to TMDL development.

A first draft of the *Bacteria and Sediment TMDL Under High-Flow Conditions for Christina River Basin, Pennsylvania-Delaware-Maryland* was open for public comment on January 20, 2005. On January 6, 2005, a public meeting was held at the Red Clay Room in Kennett Square, Pennsylvania. Two additional public meetings were held on February 10, 2005, in Newark, Delaware, and February 17, 2005, in West Chester, Pennsylvania.

Following the public comment period, the Christina River Basin Watershed and receiving water models used for development of the bacteria and sediment TMDLs were revised to address the concerns of stakeholders.

For these revised TMDLs EPA held one informational meeting to present details and answer questions regarding the Christina River TMDLs on February 3, 2006, from 9 am to noon in the Red Clay Room, 423 Dalmatian Street, Kennett Square, Pa. 19348. Public notice announcements were published in the *Philadelphia Inquirer* on January 20, 2006, and in the *Wilmington News-Journal* on January 20, 2006. The public notice announcement was also put on the EPA Region III, together will all relevant documents.

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Appendix A

Pennsylvania Comprehensive Stormwater Management Policy

EXECUTIVE SUMMARY
COMPREHENSIVE STORMWATER MANAGEMENT POLICY
DOCUMENT NUMBER: 392-0300-002

At the 15 water forums held throughout the Commonwealth in 2001, stormwater management was a consistent issue identified by the forum participants. In addition, stormwater management is a priority issue identified in the Environmental Futures Planning process throughout the 34 watershed planning areas within the Commonwealth. Stormwater runoff has also been identified as one of the top three causes of water quality impairment in the Department's Clean Water Act Section 303(d) listing process. Finally, DEP must implement the federal Clean Water Act Phase II NPDES stormwater permit program by December 2002.

In response to the forums, the Environmental Futures Planning process, stream impairment listings and federal program requirements, on October 27, 2001, the Department published a proposed comprehensive stormwater management policy to more fully integrate post construction stormwater planning requirements, emphasizing the use of ground water infiltration and volume and rate control best management practices (BMPs), into the existing and proposed NPDES permitting programs and the Stormwater Management Act ("Act 167") Planning Program. Specifically, the Department proposed the following:

- The consistent application of existing legal requirements to protect water quality in all stormwater programs, including the protection and maintenance of existing uses and the physical, chemical and biological characteristics of surface waters.

- The integration of the municipally implemented Act 167 stormwater management programs into the NPDES permitting process for urbanized areas requiring Municipal Separate Storm Sewer System (MS4) NPDES Permits for Stormwater Discharges.

- The integration of consistent post construction stormwater management planning processes emphasizing, and sometimes requiring, water quality and quantity infiltration and volume and rate control BMPs into the permit process for NPDES Stormwater Discharges Associated with Construction Activity.

- The use of a Chapter 91 Water Quality Management Part II Permit to ensure the maintenance and operation of the post construction stormwater BMPs after the earth disturbance activities are completed.

More than 600 comments were received from 234 individuals and organizations during the public comment period on the draft policy. Comments ranged from strong support to strong opposition. The major comments focused on the following areas:

Use of existing authority: Many commentators support the use of exiting authority. Others object to portions of the policy asserting that the Department should instead undertake a formal rulemaking subject to public review and comment, as well as review and approval by the Environmental Quality Board and the Independent Regulatory Review Commission.

Use of the Part II WQM permit for post construction stormwater: While many commentators generally support this approach, there are numerous requests for more clarification on the administration of this proposed permit requirement. Others question the legal authority for the permit. A few commentators suggest the existing NPDES permit process should be used because it is already in place and also provides federal EPA oversight.

Best Management Practice Manual: Many commentators suggest that the Department develop a technical manual accompanied by training to ensure consistent program administration and implementation.

Consistency with the Department's Antidegradation Policy: Many commentators suggest that the use of current regulations prohibiting degradation of existing uses of waterways needs to be emphasized and clarified.

Funding and Staffing: Some commentators question the absence of an analysis relative to the costs of implementing the suggested BMPs. Many commentators express concerns relative to costs and staffing within the Department and County Conservation Districts to support the implementation of the policy. Commentators also request clarification regarding various funding resources such as PennVEST and Act 167 to support the policy.

Science, Foundation, and Technical Feasibility for the Policy: Many commentators raise concerns that the objectives stated in the policy relative to infiltration BMPs, and groundwater recharge were not fully developed, practical or in some cases feasible. Some commentators question the Department's scientific foundation for the development of the policy while many other commentators clearly believe that streams have been severely impacted by poor or inadequate stormwater management practices and support the proposed policy.

Compensation (mitigation) for stormwater impacts: Several commentators question the proposed compensation option for sites in EV wetlands where infiltration cannot be achieved. Some express concerns that compensation provides a way out for persons affected by the policy and may be abused. Others are concerned about the lack of guidance in determining how someone compensates for potential impacts.

Expand the Policy: Many commentators suggest that the requirement to infiltrate stormwater should be expanded to all waterways regardless of their designated or existing use. Many are concerned that waters other than special protection receive no or limited protection under the proposed policy.

SUMMARY OF RELATED ACTIONS

Since announcement of the Proposed Comprehensive Stormwater Management Policy in October 2001, the Department has proposed, revised or otherwise finalized the following related documents:

- Renewal of NPDES Stormwater Construction General Permit (5 acres or greater)
- Proposed NPDES Stormwater Construction General Permit (1-5 acres)
- Proposed MS4 General Permit

- Renewal of NPDES Industrial General Permit
- Revised Act 167 Model Ordinance
- EPA has approved funding to support the development of a Post Construction Stormwater Technical BMP Manual

SUMMARY OF THE FINAL POLICY

The final policy sets forth the Department's general framework for implementing its stormwater management programs, using existing legal authority. In particular, the policy promotes and integrates the following into the Department's existing stormwater management programs:

- A clarification of the application of existing antidegradation provisions in 25 Pa. Code Section 93.4a to the BMP-based stormwater programs to protect and maintain existing uses and maintain water quality necessary to support those uses in all streams and to protect and maintain water quality in special protection streams.

- A uniform approach to post construction stormwater management that emphasizes ground water recharge through infiltration, water quality treatment and discharge volume and rate control with a goal of replicating infiltration and runoff characteristics of the site prior to development.

- The proposed Part II Water Quality Management permit is not included in the final policy. Instead, post construction stormwater management planning has been integrated into the NPDES stormwater permitting programs.

- The promotion of a comprehensive watershed approach to stormwater management through the Act 167 stormwater management planning program.

- The final policy clarifies that existing Department policies and programs related to flood protection and combined sewer overflows are not affected by this policy.

Fundamentally, the policy emphasizes the reduction of stormwater runoff generated by development and other activities by encouraging the minimization of impervious cover, use of low impact development designs, and the use of innovative stormwater BMPs that provide infiltration, water quality treatment, and otherwise more effectively manage the volume and rate of stormwater discharges. These stormwater BMPs and planning practices will be advanced through increased emphasis on the Department's Act 167 stormwater management planning program and implementation of the new (Phase II) and existing (Phase I) NPDES Stormwater Discharge Associated with Construction Activity Permit programs, and the new NPDES MS4 permits.

Administratively the Department is advancing a consistent approach to stormwater management in all NPDES stormwater permits and in the Act 167 stormwater planning processes. Department-approved Act 167 stormwater management plans and NPDES permits required under the federal Clean Water Act will include the same planning objectives to protect and maintain existing uses and maintain the level of water quality necessary to protect those uses in all streams, and to protect and maintain water quality in special protection streams. For instance, municipalities who follow the recommended stormwater planning protocol in the MS4 General Permit described in this policy can satisfy those planning objectives in both the applicable NPDES permits and the Act 167 stormwater planning requirements. In addition, persons implementing post construction stormwater plans under Act 167 that emphasize infiltration, water quality treatment and other volume and rate controls can also satisfy the post construction stormwater management planning requirements of the NPDES Stormwater Discharge Associated with Construction Activity Permit and the MS4 Permit.

The terms stormwater and stormwater management as utilized throughout the policy refer to increased volumes and rates of runoff resulting from construction and land development activities. Stormwater management as recommended in this policy is not intended to address over bank flooding resulting from major storm events. Stream and river flooding from major storm events is addressed through the Department's Flood Protection and Stream Improvement Programs.

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION

COMPREHENSIVE STORMWATER MANAGEMENT POLICY

Document ID # 392-0300-002

September 28, 2002

DOCUMENT NUMBER: 392-0300-002

TITLE: Comprehensive Stormwater Management Policy

EFFECTIVE DATE: September 28, 2002

AUTHORITY:

Pennsylvania Clean Streams Law (35 P.S. §§ 691.1-691.1001); Pennsylvania Stormwater Management Act (32 P.S. §§ 680.1-680.17); Federal Clean Water Act (33 U.S.C.A § 1342), 40 CFR Part 122 and 25 Pa Code Chapters 92, 93, 96, 102, 105, and 111.

POLICY:

The Department will ensure activities and plans approved under its authority will employ stormwater management plans utilizing best management practices to protect and maintain ground water resources, preserve ground water supplies, maintain stream base flows, and protect, preserve, and maintain the physical stability, and environmental integrity of waters of the Commonwealth.

PURPOSE:

Clean, reliable ground water and surface water resources are critical for sustaining the environmental health of our natural resources, protecting the public's health and safety, and maintaining the economic vitality of the Commonwealth. The purpose of this policy is to ensure effective stormwater management to minimize the adverse impacts of stormwater on ground water and surface water resources to support and sustain the social, economic and environmental quality of the Commonwealth, and to integrate federal Clean Water Act Stormwater Management requirements.

APPLICABILITY:

This policy applies to all Department programs implementing stormwater management.

DISCLAIMER:

The policies and procedures outlined in this guidance document are intended to supplement existing requirements. Nothing in the policies or procedures shall affect regulatory requirements. The policies and procedures herein are not adjudications or regulations. There is no intent on the part of DEP to give the rules in these policies that weight or deference. This document establishes the framework within which DEP will exercise its administrative discretion in the future. DEP reserves the discretion to deviate from this policy statement if circumstances warrant.

PAGE LENGTH: 8 pages

LOCATION: Volume 15, Tab 21

COMPREHENSIVE STORMWATER MANAGEMENT POLICY

This policy document describes the Department's update of its stormwater management programs, using existing authority, to improve water quality, sustain water quantity including ground water recharge and stream base flow, and to implement federal stormwater management obligations.

This policy provides a framework for the integration of all Department stormwater management programs and promotes a comprehensive watershed approach to stormwater management in the Commonwealth. This policy identifies and integrates existing legal requirements and post construction stormwater management planning goals, objectives, and recommended procedures into the various Department stormwater management programs.

Unmanaged or poorly managed stormwater can result in stream bank scour, stream destabilization, sedimentation, loss of groundwater recharge, loss of base flow, localized flooding, habitat modification and water quality and quantity impairment. Conversely, properly managed stormwater through properly constructed and maintained best management practices (BMPs) can remove pollutants, facilitate ground water recharge through retention and infiltration, provide base flow for surface waters, and maintain the stability and the environmental integrity of waterways and wetlands. To provide long-term protection and sustainability of ground and surface water resources, stormwater should be managed at the source or origin as an environmental resource to be protected rather than as a waste to be quickly discharged and moved downstream.

Fundamentally, the goals of the policy are to improve and sustain ground and surface water quality and quantity through the use of planning practices and BMPs that minimize the generation of stormwater runoff, provide ground water recharge and minimize the adverse effects of stormwater discharges on ground and surface water resources. This policy also supports the fulfillment of the state's obligation under 25 Pa. Code Section 93.4a to protect and maintain existing uses and the level of water quality necessary to protect those uses in all surface waters and to protect and maintain water quality in "special protection" waters. Special protection waters are Pennsylvania's highest quality surface waters and include Exceptional Value (EV) and High Quality (HQ) waters.

RECOMMENDED POST CONSTRUCTION STORMWATER MANAGEMENT PROCESS TO MEET REGULATORY STANDARDS

Procedurally, post construction stormwater management plans required under the NPDES Stormwater Discharges Associated with Construction Activities permit program and the NPDES Municipal Separate Storm Sewer System (MS4) permit program, as well as stormwater management plans developed under the Act 167 program, must demonstrate compliance with the antidegradation requirements at 25 Pa. Code Section 93.4a to protect and maintain existing uses and the level of water quality necessary to protect those uses in all surface waters and protect and maintain water quality in special protection waters.

This policy recommends that in order to meet the regulatory requirements of 25 Pa. Code Section 93.4a, persons involved in the development of post construction stormwater management plans should prepare a comparative pre and post construction stormwater management analysis.

In watersheds other than special protection, based upon the comparative stormwater management analysis, planners and applicants should evaluate and utilize infiltration BMPs to manage the net change in stormwater generated or otherwise replicate to the maximum extent possible preconstruction stormwater infiltration and runoff conditions so that post construction stormwater discharges do not degrade the physical, chemical or biological characteristics of the receiving waters. Additionally, water quality treatment BMPs must be employed where necessary to ensure protection of existing uses and the level of water quality necessary to protect those existing uses. Finally, the volume and rate of stormwater discharges must be managed to prevent the physical degradation of receiving waters, such as scour and streambank destabilization.

In special protection watersheds, based upon the comparative stormwater management analysis, planners and applicants can ensure that existing water quality will be protected and maintained by demonstrating that post construction infiltration equals or exceeds preconstruction infiltration and that any post construction discharge will not degrade the physical, chemical or biological characteristics of the special protection surface water. In these special protection watersheds, infiltration BMPs should be used to the maximum extent possible. To the extent that planners and applicants cannot totally infiltrate stormwater to pre construction volumes due to site conditions or limitations, off-site compensation projects in the same watershed and preferably upstream of the project site should be evaluated and employed to protect and maintain water quality. Additionally, water quality treatment BMPs must be employed where necessary to ensure the protection and maintenance of water quality. Finally, the volume and rate of stormwater discharges must be managed to prevent the physical degradation of receiving waters, such as scour and streambank destabilization.

Overall, the implementation of these stormwater management approaches will meet the requirements of 25 Pa. Code Section 93.4a by reducing pollutant loads to streams, recharging aquifers, protecting stream base flows, preventing stream bank erosion and streambed scour, and protecting the environmental integrity of receiving waters.

INTEGRATION OF POST CONSTRUCTION STORMWATER MANAGEMENT PLANNING INTO EXISTING STORMWATER PROGRAMS

<u>NPDES Stormwater Discharge Associated with Construction Activity Permit Program</u>

Pennsylvania regulates stormwater impacts occurring during construction under the Erosion and Sediment Pollution Control Program. All earth disturbances of 5000 square feet or greater require the development and implementation of an erosion and sediment control plan under 25 Pa. Code Chapter 102. Erosion and sediment control BMPs are used to minimize the potential for accelerated erosion and sediment pollution from these activities. The Department has developed a manual, “Erosion and Sediment Pollution Control Program Manual,” that identifies BMPs, provides recommended site design standards and specifications as well as their applicability to various situations. For High Quality (HQ) and Exceptional Value (EV) watersheds, there are more protective BMP requirements contained in Chapter 102. Beyond these planning and implementation requirements persons conducting earth disturbance activities are required to secure the appropriate NPDES permit as follows:

Phase I Earth Disturbances 5 Acres or Greater

EPA regulations implementing the Clean Water Act require NPDES permits for construction activities of five (5) acres or greater (Phase I). Using its existing authority pursuant to the Department's regulations found in 25 Pa. Code Chapters 92, 93, 96 and 102, Pennsylvania began to implement the Phase I Stormwater NPDES program in 1992. Under the Department's regulations, any earth disturbance 5 acres or greater (including earth disturbances of less than 5 acres that occur as a part of a larger common plan of development or sale consisting of 5 acres or more) requires a permit prior to the commencement of the earth disturbance. An individual NPDES permit is required for projects located in HQ and EV watersheds and in most circumstances a general permit is available for use in all other watersheds. The Department has delegated the primary functions and responsibilities of the program to County Conservation Districts under the authority contained in the Conservation District Law.

Phase II Earth Disturbance between 1 and 5 acres

In 1999, EPA promulgated Phase II stormwater regulations establishing NPDES permit requirements for construction activities with between 1 and 5 acres of earth (including earth disturbances less than 1 acre that occur as part of a larger common plan of development or sale between 1 and 5 acres), with a point source discharge. Pennsylvania is required to implement the Phase II requirements by December 8, 2002.

An NPDES Phase II permit is not required for earth disturbance activities of between 1 and 5 acres unless there is point source discharge of stormwater to surface waters of the Commonwealth. For activities that do not have a point source discharge, the erosion and sediment pollution control plan requirements in Chapter 102 described above will be used as the substantive environmental control requirements for those projects. Earth disturbance activities of between 1 and 5 acres (small construction sites) that include a point source discharge and which are located in HQ and EV watersheds require an individual NPDES permit. In most circumstances a general permit is available for use in all other watersheds.

Integration of Post Construction Stormwater Management Plans into NPDES Stormwater Discharge Associated with Construction Activity Permits

Since 1990, the Federal NPDES regulations have required the identification of post construction stormwater management BMPs in the permit application or Notice of Intent for General Permit users. To further advance effective stormwater management and to support the regulatory requirements found at 25 Pa. Code Section 93.4a, the Department has amended the permit application and Notice of Intent for General Permits to require the identification of post construction stormwater management BMPs within a site specific post construction stormwater management plan. Post Construction Stormwater Management Plans should be developed in accordance with the process described above and supported by references listed in Appendix A of this policy.

NPDES Municipal Separate Storm Sewer System (MS4) Discharge Permit Program

The federal Phase II stormwater regulations also established NPDES permit requirements for MS4 discharges from Municipal Separate Storm Sewer Systems (MS4s). Pennsylvania is required to implement these MS4 requirements by December 2002. Based on 1990 census data there are approximately 700 municipalities and other facilities within the Commonwealth that must meet the Phase II permit requirements.

In general terms, the MS4 permit requirements are to develop, implement and enforce a BMP based stormwater program with these six elements:

1. implement a public education program;
2. include public involvement in decision making;
3. eliminate or treat discharges not composed entirely of stormwater;
4. require erosion and sediment controls for construction activities;
5. require BMPs to manage post-construction stormwater for new development and redevelopment; and
6. require pollution prevention/good housekeeping for municipal operations.

EPA's Phase II regulations allow existing state and local regulatory programs to be used to meet the MS4 requirements. The Department will use a general permit to cover the required program elements in watersheds other than special protection. Pennsylvania will use the Stormwater Management Act ("Act 167") Program as a centerpiece of the MS4 program for Pennsylvania. In general, municipalities that have developed and are implementing an Act 167 Plan developed on a watershed basis that includes the water quality protective measures, including an MS4 module, will be able to meet the EPA MS4 NPDES requirements through the Act 167 process.

Municipalities that are required to obtain an MS4 permit but which have discharges to watersheds without an approved Act 167 Plan that meets the water quality requirements of 25 Pa. Code Section 93.4a, will be encouraged to work with their county to develop a stormwater plan that meets the requirements of Act 167 and the Phase II MS4 permit. Financial assistance for that effort is authorized under Act 167, and a special MS4 module is available for this purpose. Municipalities that do not want to participate in the Act 167 process will be required to develop a separate municipal plan to meet the MS4 requirements, without the use of state cost-sharing funding under Act 167.

Integration of Post Construction Stormwater Management Plans into Act 167 Stormwater Management Plans and MS4 permits

Under the Stormwater Management Act (Act 167), counties are required to develop a watershed based stormwater management plan that is implemented by affected municipalities through municipal ordinances. Both the statute and implementation guidelines require these plans to include provisions to protect water quality, existing uses and the level of water quality necessary to protect those existing uses in all surface waters and to protect and maintain water quality in special protection waters. Funding has generally been available from the Department to cover

75% of the cost to develop the plan. Act 167 also authorizes funding to support municipal implementation of ordinances adopted under the Act 167 plan.

This program has evolved since it began in 1979. Watershed based stormwater management plans developed under Act 167 approved by the Department will include water quality and quantity protection requirements to be implemented by municipalities at the local level as discussed above. Where Act 167 plans implement these water quality and quantity requirements, individuals and the Department may rely on those Act 167 plans and implementing municipal ordinances to meet the relevant MS4 NPDES permitting requirements for municipalities under the Clean Water Act Phase II stormwater program.

The Department will encourage the use of Act 167 plans to facilitate implementation of the new MS4 NPDES permit program, described above, by including an "MS4 module" in the planning process. In this way, municipalities required to meet the MS4 requirement will be able to do so using the watershed plans, cost-share funds and municipal ordinances available under Act 167.

NPDES Industrial Stormwater Permit Program

The existing Phase I of the federal NPDES stormwater permitting regulations for industrial facilities includes eleven (11) categories of industrial activity that are required to be permitted, including the construction activities discussed previously in this policy (5 acres or more).

A permit exception is incorporated in the Phase II program. This exception is referred to as the "no exposure certification" exception. The exception allows all but 1 (construction) of the 11 industrial activities to bypass the permitting process and requirements if their industrial activities and materials are not "exposed to stormwater." A similar exception, under Phase I, only applied to one industrial activity, commonly referred to as "light industry." "Light industry" operators were not required to submit any information supporting their claim for the exception.

The Phase II program covers the same industrial categories but expands the "no exposure" permit exception. The exception previously enjoyed by "light industry" activities is now available for all categories (except for construction activity) listed under the definition of "industrial activity." The new rule allows for a simple and cost-effective way to comply with permitting provisions when industrial activities and materials are completely sheltered from stormwater. Under the EPA rule, operators now have the option of either applying for a permit, or submitting a "no exposure certification" form, conditioned on the discharge not contributing "to the violation of, or interfering with the attainment or maintenance of, water quality standards, including designated uses."

The Department will implement the no exposure certification by amending its existing stormwater discharge general permit for industrial activities. The next permit revision will provide all permittees with an option to either submit the Notice of Intent for coverage under the statewide general permit, or to submit a "no exposure certification" statement. The certifications must be made on a facility wide basis and are required every five years.

Flood Protection and Combined Sewer Overflow Programs

While stormwater management is related to flood protection this policy is not intended to address major flood events on streams and rivers or modify existing flood protection programs and policies of the Department. Additionally, this policy is not intended to modify or otherwise affect existing policies and programs of the Department related to combined sewer overflows.

TECHNICAL SUPPORT AND GUIDANCE

There are numerous sources of technical support and guidance available in print and electronically which provide an array of development planning options and post construction stormwater BMPs that can be used to meet the objectives of this policy and underlying legal requirements. A list of recently developed manuals and reference materials is included in Appendix A of this policy. The Department is in the process of developing a Pennsylvania specific post construction stormwater BMP manual that is expected to be available in 2004.

Appendix A

Stormwater Management BMP Manuals

Delaware Conservation Design For Stormwater Management Guidance Manual (1997)
Address: DNREC
Division of Soil and Water Conservation
Sediment and Stormwater Program
89 Kings Highway
Dover, DE 19901
Website: http://www.dnrec.state.de.us/dnrec2000/Divisions/Soil/Stormwater/Apps/DesignManualRequest.htm
Cost: $25

2000 Maryland Stormwater Design Manual (10/2000)
Address: Maryland Department of the Environment
Water Management Administration
Nonpoint Source Program
2500 Broening Highway
Baltimore, MD 21224
(410) 631-3543 or 1-800-633-6101
Website: http://www.mde.state.md.us/environment/wma/stormwatermanual/Manual_CD/Introduction.pdf
http://www.mde.state.md.us/environment/wma/stormwatermanual/publist2.htm
Cost: October 2000 edition, web download – free
April 2000 edition, printed version - $25

Revised Manual for New Jersey: Best Management Practices for Control of Nonpoint Source Pollution from Stormwater (5/2000, 5th draft)
Address: NJDEP
Division of Watershed Management
Sandra A. Blick
PO Box 418
Trenton, NJ 08625-0418
H2Oshed@dep.state.nj.us
Website: http://www.state.nj.us/dep/watershedmgt/bmpmanual.htm
Cost: web download - free

New York State Stormwater Management Design Manual (10/2001)
Address: New York State
Department of Environmental Conservation
625 Broadway
Albany, NY 12233
Webpage: http://www.dec.state.ny.us/website/dow/swmanual/swmanual.html
Cost: web download - free

Pennsylvania Handbook of Best Management Practices for Developing Areas (1997)

Address: PACD
225 Pine St.
Harrisburg, PA 17101
(717) 236-1006
(717) 236-6410 - fax

Website: http://www.pacd.org/products/bmp/bmp_handbook.htm
http://www.pacd.org/products/bmp/bmp_orderform.htm

Cost: web download – free (limited browser version)
printed version - $20-30

Center for Watershed Protection

Address: 8391 Main Street
Ellicott City, MD 21043-4605
(410) 461-8323
(410) 461-8324 - fax

Website: http://www.cwp.org/

Pennsylvania Department of Environmental Protection

Address: Division of Waterways, Wetlands and Erosion Control
P. O. Box 8775
Harrisburg, PA 17105-8775
(717) 787-6827
(717) 787-5986 – fax

Website: http://www.dep.state.pa.us/dep/deputate/watermgt/wc/subjects/stormwatermanagement.htm
http://www.dep.state.pa.us/dep/deputate/watermgt/wc/subjects/WWEC/StrmH2O_Home.htm

Address: Southeast Regional Office
Lee Park, Suite 6010
555 North Lane
Conshohocken, PA 19428
(610) 832-6130
(610) 832-6133 – fax

Website: http://www.dep.state.pa.us/dep/deputate/fieldops/se/water/PCSWM.htm

Appendix B

EPA Memorandum

Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs

Stormwater Runoff Water Quality Science/Engineering Newsletter
Devoted to Urban/Rural Stormwater Runoff
Water Quality Management Issues

* * * * *

Volume 5 Number 5
December 2, 2002

Editor: Anne Jones-Lee, PhD
Contributor to this Issue:
G. Fred Lee, PhD, PE, DEE

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This issue of the Newsletter is primarily devoted to a presentation of a recent US EPA headquarters memorandum, "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs." This memo establishes the Bush Administration US EPA policy for including NPDES permitted urban and highway stormwater runoff in TMDLs. There are still some important unresolved issues concerning how the US EPA approach will be implemented with respect to the BMP ratcheting down process to ultimately achieve water quality standards (see NLs 1-2, 1-5). As discussed in previous Newsletters (see NLs 1-2, 1-3, 1-5, and 2-2) all NPDES permitted discharges must not cause or contribute to violations of water quality standards. In the past and under this recently announced policy for incorporating NPDES permitted urban and highway stormwater runoff in TMDLs, this requirement still stands. However, the timetable for controlling violations of water quality standards caused by urban stormwater runoff still has not been established. This situation is not surprising since, as discussed in previous Newsletters (see NL 3-3), compliance with water quality standards associated with urban stormwater runoff from developed areas will cost the public served by the storm sewer system from $5 to $10 per person per day. Previous issues of this Newsletter that discuss these issues are available from www.gfredlee.com.

The Water Environment Federation (WEF) has recently held a three day conference in Phoenix, AZ devoted to WEF 2002 TMDL Science and Policy. The proceedings from this conference will be of interest to all of those interested in TMDL issues. About 100 papers were presented on various TMDL science/policy issues. There were over 450 attendees including US EPA HQ and Regional senior staff in the TMDL program and other programs. Based on the discussions, major changes are likely in the national TMDL program in the next year. There were sessions of about six papers each on each of the major TMDL topics including water quality monitoring, water quality modeling, uncertainty in modeling of water quality, reasonable assurance, water quality standards, relationship between water quality standards and beneficial uses, nutrients and N and P water quality standards, urban stormwater quality standards/variances, clean sediment management issues, narrative standard implementation in TMDLs, biological impact and assessment issues, stakeholder involvement, BMP effectiveness, revised use attainability analysis, NPS load allocation issues, pollutant trading, pathogens, human vs animal fecal coliform source tracing, etc. There were several papers presented at this conference devoted to how states are addressing the regulation of urban stormwater runoff causing violations of water quality standards.

According to the WEF website, www.wef.org, papers are now available for purchase and download from the 2002 National TMDL Science and Policy Conference. The WEF has established a link from its website to view abstracts for individual papers.

US EPA Washington DC

November 22, 2002

MEMORANDUM

SUBJECT: Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs

FROM: Robert H. Wayland, III, Director /S/

Office of Wetlands, Oceans and Watersheds

James A. Hanlon, Director /S/

Office of Wastewater Management

TO: Water Division Directors

Regions 1 - 10

This memorandum clarifies existing EPA regulatory requirements for, and provides guidance on, establishing wasteload allocations (WLAs) for storm water discharges in total maximum daily loads (TMDLs) approved or established by EPA. It also addresses the establishment of water quality-based effluent limits (WQBELs) and conditions in National Pollutant Discharge Elimination System (NPDES) permits based on the WLAs for storm water discharges in TMDLs. The key points presented in this memorandum are as follows:

- NPDES-regulated storm water discharges must be addressed by the wasteload allocation component of a TMDL. See 40 C.F.R. § 130.2(h).
- NPDES-regulated storm water discharges may not be addressed by the load allocation (LA) component of a TMDL. See 40 C.F.R. § 130.2 (g) & (h).
- Storm water discharges from sources that are not currently subject to NPDES regulation may be addressed by the load allocation component of a TMDL. See 40 C.F.R. § 130.2(g).
- It may be reasonable to express allocations for NPDES-regulated storm water discharges from multiple point sources as a single categorical wasteload allocation when data and information are insufficient to assign each source or outfall individual WLAs. See 40 C.F.R. § 130.2(i). In cases where wasteload allocations are developed for categories of discharges, these categories should be defined as narrowly as available information allows.
- The WLAs and LAs are to be expressed in numeric form in the TMDL. See 40 C.F.R. § 130.2(h) & (i). EPA expects TMDL authorities to make separate allocations to NPDES- regulated storm water discharges (in the form of WLAs) and unregulated storm water (in the form of LAs). EPA recognizes that these allocations might be fairly rudimentary because of data limitations and variability in the system.

- NPDES permit conditions must be consistent with the assumptions and requirements of available WLAs. See 40 C.F.R. § 122.44(d)(1)(vii)(B).
- WQBELs for NPDES-regulated storm water discharges that implement WLAs in TMDLs may be expressed in the form of best management practices (BMPs) under specified circumstances. See 33 U.S.C. §1342(p)(3)(B)(iii); 40 C.F.R. §122.44(k)(2)&(3). If BMPs alone adequately implement the WLAs, then additional controls are not necessary.
- EPA expects that most WQBELs for NPDES-regulated municipal and small construction storm water discharges will be in the form of BMPs, and that numeric limits will be used only in rare instances.
- When a non-numeric water quality-based effluent limit is imposed, the permit's administrative record, including the fact sheet when one is required, needs to support that the BMPs are expected to be sufficient to implement the WLA in the TMDL. See 40 C.F.R. §§ 124.8, 124.9 & 124.18.
- The NPDES permit must also specify the monitoring necessary to determine compliance with effluent limitations. See 40 C.F.R. § 122.44(i). Where effluent limits are specified as BMPs, the permit should also specify the monitoring necessary to assess if the expected load reductions attributed to BMP implementation are achieved (e.g., BMP performance data).
- The permit should also provide a mechanism to make adjustments to the required BMPs as necessary to ensure their adequate performance.

This memorandum is organized as follows:

(I). Regulatory basis for including NPDES-regulated storm water discharges in WLAs in TMDLs;

(II). Options for addressing storm water in TMDLs; and

(III). Determining effluent limits in NPDES permits for storm water discharges consistent with the WLA

(I). Regulatory Basis for Including NPDES-regulated Storm Water Discharges in WLAs in TMDLs

As part of the 1987 amendments to the CWA, Congress added Section 402(p) to the Act to cover discharges composed entirely of storm water. Section 402(p)(2) of the Act requires permit coverage for discharges associated with industrial activity and discharges from large and medium municipal separate storm sewer systems (MS4), i.e., systems serving a population over 250,000 or systems serving a population between 100,000 and 250,000, respectively. These discharges are referred to as Phase I MS4 discharges.

In addition, the Administrator was directed to study and issue regulations that designate additional storm water discharges, other than those regulated under Phase I, to be regulated in order to protect water quality. EPA issued regulations on December 8, 1999 (64 FR 68722), expanding the NPDES storm water program to include discharges from smaller MS4s (including all systems within "urbanized areas" and other systems serving populations less than 100,000) and storm water discharges from construction sites that disturb one to five acres, with opportunities for area-specific exclusions. This program expansion is referred to as Phase II.

Section 402(p) also specifies the levels of control to be incorporated into NPDES storm water permits depending on the source (industrial versus municipal storm water). Permits for storm water discharges associated with industrial activity are to require compliance with all applicable provisions of Sections 301 and 402 of the CWA, i.e., all technology-based and water quality-based requirements. See 33 U.S.C. §1342(p)(3)(A). Permits for discharges from MS4s, however, "shall require controls to reduce the discharge of pollutants to the maximum extent practicable ... and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants." See 33 U.S.C. §1342(p)(3)(B)(iii).

Storm water discharges that are regulated under Phase I or Phase II of the NPDES storm water program are point sources that must be included in the WLA portion of a TMDL. See 40 C.F.R. § 130.2(h). Storm water discharges that are not currently subject to Phase I or Phase II of the NPDES storm water program are not required to obtain NPDES permits. 33 U.S.C. §1342(p)(1) & (p)(6). Therefore, for regulatory purposes, they are analogous to nonpoint sources and may be included in the LA portion of a TMDL. See 40 C.F.R. § 130.2(g).

(II). Options for Addressing Storm Water in TMDLs

Decisions about allocations of pollutant loads within a TMDL are driven by the quantity and quality of existing and readily available water quality data. The amount of storm water data available for a TMDL varies from location to location. Nevertheless, EPA expects TMDL authorities will make separate aggregate allocations to NPDES-regulated storm water discharges (in the form of WLAs) and unregulated storm water (in the form of LAs). It may be reasonable to quantify the allocations through estimates or extrapolations, based either on knowledge of land use patterns and associated literature values for pollutant loadings or on actual, albeit limited, loading information. EPA recognizes that these allocations might be fairly rudimentary because of data limitations.

EPA also recognizes that the available data and information usually are not detailed enough to determine waste load allocations for NPDES-regulated storm water discharges on an outfall-specific basis. In this situation, EPA recommends expressing the wasteload allocation in the TMDL as either a single number for all NPDES-regulated storm water discharges, or when information allows, as different WLAs for different identifiable categories, e.g., municipal storm water as distinguished from storm water discharges from construction sites or municipal storm water discharges from City A as distinguished from City B. These categories should be defined as narrowly as available information allows (e.g., for municipalities, separate WLAs for each municipality and for industrial sources, separate WLAs for different types of industrial storm water sources or dischargers).

(III). Determining Effluent Limits in NPDES Permits for Storm Water Discharges Consistent with the WLA

Where a TMDL has been approved, NPDES permits must contain effluent limits and conditions consistent with the requirements and assumptions of the wasteload allocations in the TMDL. See 40 CFR § 122.44(d)(1)(vii)(B). Effluent limitations to control the discharge of pollutants generally are expressed in numerical form. However, in light of 33 U.S.C. §1342(p)(3)(B)(iii), EPA recommends that for NPDES-regulated municipal and small construction storm water discharges effluent limits should be expressed as best management practices (BMPs) or other similar requirements, rather than as numeric effluent limits. See *Interim Permitting Approach for Water Quality-Based Effluent Limitations in Storm Water Permits,* 61 FR 43761 (Aug. 26, 1996). The Interim Permitting Approach Policy recognizes the need for an iterative approach to control pollutants in storm water discharges. Specifically, the policy anticipates that a suite of BMPs will be used in the initial rounds of permits and that these BMPs will be tailored in subsequent rounds.

EPA's policy recognizes that because storm water discharges are due to storm events that are highly variable in frequency and duration and are not easily characterized, only in rare cases will it be feasible or appropriate to establish numeric limits for municipal and small construction storm water discharges. The variability in the system and minimal data generally available make it difficult to determine with precision or certainty actual and projected loadings for individual dischargers or groups of dischargers. Therefore, EPA believes that in these situations, permit limits typically can be expressed as BMPs, and that numeric limits will be used only in rare instances.

Under certain circumstances, BMPs are an appropriate form of effluent limits to control pollutants in storm water. See 40 CFR § 122.44(k)(2) & (3). If it is determined that a BMP approach (including an iterative BMP approach) is appropriate to meet the storm water component of the TMDL, EPA recommends that the TMDL reflect this.

EPA expects that the NPDES permitting authority will review the information provided by the TMDL, see 40 C.F.R. § 122.44(d)(1)(vii)(B), and determine whether the effluent limit is appropriately expressed using a BMP approach (including an iterative BMP approach) or a numeric limit. Where BMPs are used, EPA recommends that the permit provide a mechanism to require use of expanded or better-tailored BMPs when monitoring demonstrates they are necessary to implement the WLA and protect water quality.

Where the NPDES permitting authority allows for a choice of BMPs, a discussion of the BMP selection and assumptions needs to be included in the permit's administrative record, including the fact sheet when one is required. 40 C.F.R.§§ 124.8, 124.9 & 124.18. For general permits, this may be included in the storm water pollution prevention plan required by the permit. See 40 C.F.R. § 122.28. Permitting authorities may require the permittee to provide supporting information, such as how the permittee designed its management plan to address the WLA(s). See 40 C.F.R. § 122.28. The NPDES permit must require the monitoring necessary to assure compliance with permit limitations, although the permitting authority has the discretion under EPA's regulations to decide the frequency of such monitoring. See 40 CFR § 122.44(i). EPA recommends that such permits require collecting data on the actual performance of the BMPs. These additional data may provide a basis for revised management measures. The monitoring data are likely to have other uses as well. For example, the monitoring data might indicate if it is necessary to adjust the BMPs. Any monitoring for storm water required as part of the permit should be consistent with the state's overall assessment and monitoring strategy.

The policy outlined in this memorandum affirms the appropriateness of an iterative, adaptive management BMP approach, whereby permits include effluent limits (e.g., a combination of structural and non-structural BMPs) that address storm water discharges, implement mechanisms to evaluate the performance of such controls, and make adjustments (i.e., more stringent controls or specific BMPs) as necessary to protect water quality. This approach is further supported by the recent report from the National Research Council (NRC), *Assessing the TMDL Approach to Water Quality Management* (National Academy Press, 2001). The NRC report recommends an approach that includes "adaptive implementation," i.e., "a cyclical process in which TMDL plans are periodically assessed for their achievement of water quality standards" . . . and adjustments made as necessary. *NRC Report* at ES-5.

This memorandum discusses existing requirements of the Clean Water Act (CWA) and codified in the TMDL and NPDES implementing regulations. Those CWA provisions and regulations contain legally binding requirements. This document describes these requirements; it does not substitute for those provisions or regulations. The recommendations in this memorandum are not binding; indeed, there may be other approaches that would be appropriate in particular situations. When EPA makes a TMDL or permitting decision, it will make each decision on a case-by-case basis and will be guided by the applicable requirements of the CWA and implementing regulations, taking into account comments and information presented at that time by interested persons regarding the appropriateness of applying these recommendations to the particular situation. EPA may change this guidance in the future.

If you have any questions please feel free to contact us or Linda Boornazian, Director of the Water Permits Division or Charles Sutfin, Director of the Assessment and Watershed Protection Division.

cc: Water Quality Branch Chiefs Regions 1 - 10

Permit Branch Chiefs Regions 1 - 10

Appendix C

Subbasin Tables

Appendix C

Land Use Areas and Allocations for MS4 Municipalities in Christina River Basin

Table C-1. Land Use Areas (acres) for MS4 Municipalities in Brandywine Creek Watershed

HSPF Subbasin	MS4 Municipality	Residential	Agriculture	Open Land	Forest	Water	Urban	MS4 Total	Subbasin Total	MS4 Ratio
B01	HONEY BROOK BORO	175.55	117.03	0.00	0.00	0.00	19.51	312.08	11766.82	0.0265
B01	HONEY BROOK TWP	429.11	6612.23	0.00	1501.89	19.51	370.60	8933.33	11766.82	0.7592
B01	WEST CALN TWP	78.02	0.00	0.00	370.60	0.00	19.51	468.12	11766.82	0.0398
B02	HONEY BROOK TWP	253.57	78.02	0.00	819.21	0.00	19.51	1170.31	4720.88	0.2479
B02	WEST BRANDYWINE TWP	448.62	663.17	0.00	741.19	19.51	78.02	1950.51	4720.88	0.4132
B02	WEST CALN TWP	351.09	624.16	19.51	585.15	19.51	19.51	1618.92	4720.88	0.3429
B03	COATESVILLE CITY	0.00	0.00	0.00	39.01	0.00	0.00	39.01	4324.94	0.0090
B03	VALLEY TWP	19.51	58.52	0.00	58.52	0.00	58.52	195.05	4324.94	0.0451
B03	WEST BRANDYWINE TWP	760.70	702.18	0.00	663.17	0.00	19.51	2145.56	4324.94	0.4961
B03	WEST CALN TWP	253.57	487.63	19.51	643.67	19.51	39.01	1462.88	4324.94	0.3382
B04	COATESVILLE CITY	19.51	0.00	0.00	175.55	0.00	39.01	234.06	519.99	0.4501
B04	VALLEY TWP	19.51	39.01	0.00	234.06	0.00	19.51	312.08	519.99	0.6002
B05	COATESVILLE CITY	487.63	0.00	19.51	117.03	0.00	312.08	936.24	5644.14	0.1659
B05	EAST FALLOWFIELD TWP	136.54	331.59	0.00	565.65	0.00	156.04	1189.81	5644.14	0.2108
B05	MODENA BORO	19.51	0.00	0.00	39.01	19.51	0.00	78.02	5644.14	0.0138
B05	SADSBURY TWP	19.51	58.52	0.00	19.51	0.00	19.51	117.03	5644.14	0.0207
B05	VALLEY TWP	331.59	585.15	19.51	604.66	19.51	468.12	2028.53	5644.14	0.3594
B06	EAST FALLOWFIELD TWP	916.74	1404.37	39.01	1443.38	0.00	136.54	3940.03	5159.73	0.7636
B06	MODENA BORO	19.51	39.01	0.00	39.01	0.00	58.52	156.04	5159.73	0.0302
B06	NEWLIN TWP	0.00	58.52	0.00	175.55	0.00	39.01	273.07	5159.73	0.0529
B06	WEST BRADFORD TWP	136.54	351.09	0.00	234.06	0.00	0.00	721.69	5159.73	0.1399
B07	EAST MARLBOROUGH TWP	39.01	429.11	0.00	156.04	0.00	0.00	624.16	8616.54	0.0724
B07	NEWLIN TWP	292.58	2867.25	0.00	2594.18	97.53	273.07	6124.60	8616.54	0.7108
B07	POCOPSON TWP	39.01	195.05	0.00	117.03	0.00	19.51	370.60	8616.54	0.0430
B07	WEST BRADFORD TWP	195.05	507.13	0.00	546.14	0.00	175.55	1423.87	8616.54	0.1652
B08	EAST BRADFORD TWP	78.02	429.11	0.00	214.56	19.51	0.00	741.19	2314.42	0.3203
B08	POCOPSON TWP	0.00	526.64	0.00	195.05	19.51	0.00	741.19	2314.42	0.3203
B08	WEST BRADFORD TWP	136.54	487.63	0.00	195.05	0.00	39.01	858.22	2314.42	0.3708
B09	HONEY BROOK TWP	292.58	2711.21	0.00	916.74	273.07	39.01	4232.60	9397.55	0.4504
B09	WALLACE TWP	39.01	97.53	0.00	234.06	0.00	39.01	409.61	9397.55	0.0436
B10	EAST BRANDYWINE TWP	819.21	819.21	19.51	819.21	19.51	19.51	2516.16	11721.04	0.2147
B10	HONEY BROOK TWP	58.52	19.51	0.00	58.52	39.01	39.01	214.56	11721.04	0.0183
B10	UPPER UWCHLAN TWP	97.53	195.05	0.00	195.05	0.00	19.51	507.13	11721.04	0.0433
B10	WALLACE TWP	702.18	1794.47	58.52	2633.19	0.00	175.55	5363.90	11721.04	0.4576
B10	WEST BRANDYWINE TWP	409.61	819.21	19.51	741.19	19.51	78.02	2087.04	11721.04	0.1781
B11	EAST BRANDYWINE TWP	214.56	331.59	0.00	546.14	0.00	0.00	1092.29	4039.89	0.2704
B11	UPPER UWCHLAN TWP	0.00	19.51	0.00	78.02	0.00	0.00	97.53	4039.89	0.0241
B11	UWCHLAN TWP	663.17	916.74	39.01	936.24	0.00	253.57	2808.73	4039.89	0.6952
B12	DOWNINGTOWN BORO	156.04	39.01	39.01	39.01	19.51	58.52	351.09	2369.53	0.1482
B12	EAST BRANDYWINE TWP	156.04	58.52	0.00	136.54	19.51	19.51	390.10	2369.53	0.1646

HSPF Subbasin	MS4 Municipality	Residential	Agriculture	Open Land	Forest	Water	Urban	MS4 Total	Subbasin Total	MS4 Ratio
B12	EAST CALN TWP	195.05	39.01	0.00	292.58	0.00	19.51	546.14	2369.53	0.2305
B12	UWCHLAN TWP	312.08	0.00	0.00	331.59	0.00	19.51	663.17	2369.53	0.2799
B13	DOWNINGTOWN BORO	253.57	136.54	0.00	117.03	0.00	234.06	741.19	5084.19	0.1458
B13	EAST BRADFORD TWP	39.01	136.54	0.00	409.61	19.51	0.00	604.66	5084.19	0.1189
B13	EAST CALN TWP	273.07	234.06	117.03	351.09	0.00	214.56	1189.81	5084.19	0.2340
B13	WEST BRADFORD TWP	702.18	253.57	0.00	1404.37	0.00	156.04	2516.16	5084.19	0.4949
B14	EAST BRADFORD TWP	1072.78	1931.00	97.53	1131.30	97.53	156.04	4486.17	8268.16	0.5426
B14	WEST BRADFORD TWP	97.53	526.64	0.00	487.63	0.00	78.02	1189.81	8268.16	0.1439
B14	WEST GOSHEN TWP	663.17	214.56	19.51	838.72	19.51	195.05	1950.51	8268.16	0.2359
B15	BIRMINGHAM TWP	546.14	741.19	117.03	136.54	19.51	136.54	1696.94	6631.34	0.2559
B15	EAST BRADFORD TWP	526.64	604.66	19.51	351.09	0.00	117.03	1618.92	6631.34	0.2441
B15	PENNSBURY TWP	0.00	19.51	0.00	0.00	0.00	0.00	19.51	6631.34	0.0029
B15	POCOPSON TWP	136.54	663.17	0.00	234.06	97.53	58.52	1189.81	6631.34	0.1794
B15	THORNBURY TWP	0.00	331.59	0.00	97.53	0.00	19.51	448.62	6631.34	0.0677
B15	WEST GOSHEN TWP	253.57	0.00	58.52	78.02	0.00	19.51	409.61	6631.34	0.0618
B16	BIRMINGHAM TWP	585.15	780.20	0.00	780.20	39.01	58.52	2243.09	8996.74	0.2493
B16	KENNETT TWP	351.09	214.56	0.00	117.03	0.00	58.52	741.19	8996.74	0.0824
B16	PENNSBURY TWP	975.25	760.70	0.00	1228.82	39.01	78.02	3081.80	8996.74	0.3425
B16	THORNBURY TWP	0.00	0.00	0.00	19.51	0.00	0.00	19.51	8996.74	0.0022
B17	KENNETT TWP	78.02	0.00	0.00	58.52	0.00	0.00	136.54	4804.91	0.0284
B17	PENNSBURY TWP	370.60	936.24	0.00	1326.35	58.52	0.00	2691.70	4804.91	0.5602
B18	PENNSBURY TWP	0.00	19.51	0.00	19.51	19.51	0.00	58.52	6636.33	0.0088
B18	New Castle Co., DE	541.70	906.34	622.35	1630.53	47.00	518.45	4266.37	6636.33	0.6429
B19	Wilmington, DE	3.59	0.00	7.18	14.36	1.80	3.59	30.53	5534.18	0.0055
B19	New Castle Co., DE	1152.14	228.80	2220.40	898.84	54.03	949.45	5503.65	5534.18	0.9945
B20	EAST FALLOWFIELD TWP	585.15	2165.07	0.00	1111.79	19.51	117.03	3998.54	16344.14	0.2446
B20	HIGHLAND TWP	136.54	3744.98	0.00	1482.39	19.51	234.06	5617.47	16344.14	0.3437
B20	PARKESBURG BORO	429.11	97.53	0.00	97.53	0.00	136.54	760.70	16344.14	0.0465
B20	SADSBURY TWP	507.13	2048.03	0.00	975.25	0.00	312.08	3842.50	16344.14	0.2351
B20	WEST CALN TWP	58.52	273.07	0.00	195.05	0.00	19.51	546.14	16344.14	0.0334
B21	HIGHLAND TWP	78.02	2594.18	0.00	253.57	19.51	58.52	3003.78	7074.39	0.4246
B22	EAST FALLOWFIELD TWP	0.00	19.51	0.00	0.00	0.00	0.00	19.51	7013.14	0.0028
B22	EAST MARLBOROUGH TWP	0.00	234.06	0.00	97.53	0.00	0.00	331.59	7013.14	0.0473
B23	EAST FALLOWFIELD TWP	0.00	351.09	0.00	273.07	0.00	0.00	624.16	1245.87	0.5010
B23	NEWLIN TWP	0.00	331.59	0.00	292.58	0.00	0.00	624.16	1245.87	0.5010
B24	WEST BRADFORD TWP	364.17	19.51	0.00	0.00	0.00	0.00	383.68	383.68	1.0000
B25	NEWLIN TWP	39.01	39.01	0.00	0.00	0.00	0.00	78.02	3733.70	0.0209
B25	WEST BRADFORD TWP	936.24	1443.38	19.51	1111.79	0.00	175.55	3686.46	3733.70	0.9873
B26	WALLACE TWP	78.02	97.53	0.00	273.07	0.00	39.01	487.63	1673.35	0.2914
B27	UPPER UWCHLAN TWP	1404.37	1306.84	78.02	1599.42	565.65	273.07	5227.36	6837.84	0.7645
B27	UWCHLAN TWP	0.00	0.00	0.00	39.01	0.00	0.00	39.01	6837.84	0.0057
B27	WALLACE TWP	175.55	195.05	0.00	292.58	19.51	19.51	702.18	6837.84	0.1027
B28	UWCHLAN TWP	741.19	19.51	39.01	136.54	0.00	58.52	994.76	1537.60	0.6470
B29	EAST BRADFORD TWP	526.64	448.62	39.01	1228.82	0.00	97.53	2340.61	11653.36	0.2009
B29	EAST CALN TWP	39.01	39.01	78.02	214.56	39.01	273.07	682.68	11653.36	0.0586
B29	UWCHLAN TWP	156.04	19.51	0.00	78.02	0.00	19.51	273.07	11653.36	0.0234

HSPF Subbasin	MS4 Municipality	Residential	Agriculture	Open Land	Forest	Water	Urban	MS4 Total	Subbasin Total	MS4 Ratio
B29	WEST GOSHEN TWP	409.61	78.02	0.00	195.05	0.00	39.01	721.69	11653.36	0.0619
B30	DOWNINGTOWN BORO	214.56	19.51	0.00	39.01	0.00	19.51	292.58	11568.11	0.0253
B30	EAST BRANDYWINE TWP	936.24	1404.37	0.00	780.20	0.00	136.54	3257.35	11568.11	0.2816
B30	EAST FALLOWFIELD TWP	39.01	117.03	0.00	39.01	0.00	19.51	214.56	11568.11	0.0185
B30	WEST BRADFORD TWP	273.07	214.56	0.00	546.14	0.00	39.01	1072.78	11568.11	0.0927
B30	WEST BRANDYWINE TWP	351.09	1287.34	39.01	507.13	0.00	39.01	2223.58	11568.11	0.1922
B31	EAST MARLBOROUGH TWP	663.17	799.71	78.02	253.57	0.00	19.51	1813.97	5883.50	0.3083
B31	NEWLIN TWP	39.01	468.12	0.00	97.53	0.00	19.51	624.16	5883.50	0.1061
B31	PENNSBURY TWP	58.52	351.09	0.00	136.54	0.00	0.00	546.14	5883.50	0.0928
B31	POCOPSON TWP	780.20	1365.36	0.00	741.19	19.51	78.02	2984.28	5883.50	0.5072
B32	WEST CALN TWP	429.11	1033.77	0.00	1460.59	0.00	58.52	2981.99	2981.99	1.0000
B33	SADSBURY TWP	39.01	19.51	0.00	19.51	0.00	0.00	78.02	5139.05	0.0152
B33	VALLEY TWP	214.56	331.59	19.51	487.63	0.00	175.55	1228.82	5139.05	0.2391
B33	WEST CALN TWP	643.67	1794.47	97.53	1014.26	117.03	117.03	3783.99	5139.05	0.7363
B34	Wilmington, DE	817.01	0.00	360.92	154.42	98.76	1086.4	2517.46	3873.14	0.6500
B34	New Castle Co., DE	152.60	60.27	9.58	222.06	1.52	909.65	1355.68	3873.14	0.3500
B35	WALLACE TWP	58.52	156.04	0.00	351.09	0.00	39.01	604.66	3713.47	0.1628

Note: MS4 Total = total land area in MS4 municipality
Subbasin Total = total land area of HSPF subbasin
MS4 Ratio = MS4 Total / Subbasin Total

Table C-2. Land Use Areas (acres) for MS4 Municipalities in Red Clay Creek Watershed

HSPF Subbasin	MS4 Municipality	Residential	Agriculture	Open Land	Forest	Water	Urban	MS4 Total	Subbasin Total	MS4 Ratio
R01	EAST MARLBOROUGH TWP	565.65	2847.74	39.01	838.72	19.51	156.04	4466.67	6448.43	0.6927
R01	KENNETT SQUARE BORO	136.54	97.53	19.51	0.00	0.00	97.53	351.09	6448.43	0.0544
R01	KENNETT TWP	58.52	78.02	19.51	78.02	0.00	97.53	331.59	6448.43	0.0514
R01	NEW GARDEN TWP	117.03	331.59	0.00	156.04	0.00	97.53	702.18	6448.43	0.1089
R02	KENNETT SQUARE BORO	0.00	19.51	0.00	0.00	0.00	0.00	19.51	4727.00	0.0041
R02	KENNETT TWP	585.15	624.16	0.00	643.67	0.00	0.00	1852.98	4727.00	0.3920
R02	NEW GARDEN TWP	234.06	1891.99	0.00	604.66	0.00	136.54	2867.25	4727.00	0.6066
R03	EAST MARLBOROUGH TWP	546.14	1345.85	234.06	312.08	0.00	156.04	2594.18	6333.99	0.4096
R03	KENNETT SQUARE BORO	175.55	39.01	0.00	58.52	0.00	39.01	312.08	6333.99	0.0493
R03	KENNETT TWP	643.67	1677.44	0.00	916.74	19.51	136.54	3393.89	6333.99	0.5358
R04	KENNETT TWP	195.05	195.05	0.00	292.58	0.00	0.00	682.68	3272.23	0.2086
R04	New Castle Co., DE	1042.15	379.99	257.52	637.52	26.44	245.93	2589.55	3272.23	0.7914
R05	New Castle Co., DE	1153.92	492.06	199.56	1266.25	40.64	200.64	3353.07	3353.07	1.0000
R06	KENNETT TWP	624.16	916.74	19.51	897.23	0.00	97.53	2555.17	4543.71	0.5624
R06	PENNSBURY TWP	78.02	78.02	0.00	58.52	0.00	78.02	292.58	4543.71	0.0644
R06	New Castle Co., DE	313.61	933.77	213.39	184.51	6.01	44.67	1695.96	4543.71	0.3733
R07	New Castle Co., DE	350.82	97.20	39.98	596.30	192.37	66.92	1343.59	1343.59	1.0000
R08	New Castle Co., DE	1268.17	54.61	475.64	464.55	47.93	1132.1	3442.99	3442.99	1.0000
R09	New Castle Co., DE	501.89	0.00	41.68	112.89	4.86	441.99	1103.31	1103.31	1.0000

Note: MS4 Total = total land area in MS4 municipality
Subbasin Total = total land area of HSPF subbasin
MS4 Ratio = MS4 Total / Subbasin Total

Table C-3. Land Use Areas (acres) for MS4 Municipalities in White Clay Creek Watershed

HSPF Subbasin	MS4 Municipality	Residential	Agriculture	Open Land	Forest	Water	Urban	MS4 Total	Subbasin Total	MS4 Ratio
W01	FRANKLIN TWP	331.59	1423.87	0.00	955.75	0.00	136.54	2847.74	6537.83	0.4356
W01	LONDON BRITAIN TWP	78.02	136.54	0.00	214.56	0.00	0.00	429.11	6537.83	0.0656
W01	NEW LONDON TWP	507.13	1014.26	0.00	409.61	0.00	156.04	2087.04	6537.83	0.3192
W01	PENN TWP	175.55	682.68	0.00	214.56	0.00	19.51	1092.29	6537.83	0.1671
W02	LONDON GROVE TWP	468.12	1618.92	19.51	507.13	19.51	19.51	2652.69	6089.44	0.4356
W02	NEW LONDON TWP	39.01	58.52	0.00	58.52	0.00	0.00	156.04	6089.44	0.0256
W02	PENN TWP	273.07	1306.84	0.00	409.61	19.51	39.01	2048.03	6089.44	0.3363
W02	WEST GROVE BORO	156.04	19.51	0.00	0.00	0.00	58.52	234.06	6089.44	0.0384
W03	FRANKLIN TWP	234.06	838.72	0.00	585.15	0.00	0.00	1657.93	4063.37	0.4080
W03	LONDON BRITAIN TWP	448.62	624.16	0.00	682.68	19.51	0.00	1774.96	4063.37	0.4368
W03	LONDON GROVE TWP	195.05	253.57	0.00	195.05	0.00	19.51	663.17	4063.37	0.1632
W04	AVONDALE BORO	39.01	19.51	0.00	19.51	0.00	0.00	78.02	3971.00	0.0196
W04	LONDON GROVE TWP	312.08	2145.56	19.51	916.74	19.51	136.54	3549.93	3971.00	0.8940
W04	WEST GROVE BORO	58.52	39.01	19.51	39.01	0.00	39.01	195.05	3971.00	0.0491
W05	LONDON GROVE TWP	0.00	136.54	0.00	58.52	0.00	0.00	195.05	1705.95	0.1143
W06	AVONDALE BORO	58.52	0.00	0.00	58.52	0.00	0.00	117.03	5484.38	0.0213
W06	LONDON GROVE TWP	39.01	1891.99	0.00	351.09	0.00	39.01	2321.11	5484.38	0.4232
W06	NEW GARDEN TWP	58.52	448.62	136.54	273.07	0.00	97.53	1014.26	5484.38	0.1849
W07	AVONDALE BORO	19.51	58.52	0.00	19.51	0.00	19.51	117.03	877.92	0.1333
W07	NEW GARDEN TWP	136.54	546.14	0.00	97.53	19.51	39.01	838.72	877.92	0.9553
W08	FRANKLIN TWP	117.03	351.09	0.00	136.54	0.00	0.00	604.66	4776.15	0.1266
W08	LONDON GROVE TWP	214.56	624.16	39.01	702.18	0.00	19.51	1599.42	4776.15	0.3349
W08	NEW GARDEN TWP	390.10	1306.84	0.00	780.20	0.00	58.52	2535.66	4776.15	0.5309
W09	FRANKLIN TWP	0.00	19.51	0.00	0.00	0.00	0.00	19.51	4386.93	0.0044
W09	LONDON BRITAIN TWP	273.07	468.12	0.00	643.67	19.51	0.00	1404.37	4386.93	0.3201
W09	NEW GARDEN TWP	546.14	877.73	0.00	604.66	39.01	195.05	2262.59	4386.93	0.5158
W10	LONDON BRITAIN TWP	292.58	429.11	0.00	604.66	0.00	19.51	1345.85	2303.61	0.5842
W10	New Castle Co., DE	208.24	305.42	0.00	430.36	0.00	13.82	957.84	2303.61	0.4158
W11	LONDON BRITAIN TWP	58.52	117.03	0.00	156.04	0.00	19.51	351.09	4175.09	0.0841
W11	Newark, DE	308.85	114.92	122.10	251.39	8.98	111.33	917.56	4175.09	0.2198
W11	New Castle Co., DE	25.21	415.38	175.09	1882.36	24.17	384.21	2906.43	4175.09	0.6961
W12	Newark, DE	470.45	197.52	156.22	125.69	14.36	673.36	1637.60	5610.56	0.2919
W12	New Castle Co., DE	881.65	329.92	391.80	476.03	38.16	1855.4	3972.96	5610.56	0.7081
W13	New Castle Co., DE	92.06	149.15	95.56	152.54	20.96	828.58	1338.85	1338.85	1.0000
W14	New Castle Co., DE	232.26	0.00	473.83	304.83	314.16	859.76	2184.84	2184.84	1.0000
W15	Newark, DE	7.18	0.00	0.00	0.00	0.00	0.00	7.18	2489.61	0.0029
W15	New Castle Co., DE	354.20	734.14	81.03	1050.46	0.00	262.60	2482.43	2489.61	0.9971
W16	New Castle Co., DE	1656.07	357.50	387.82	547.53	0.00	1300.9	4249.78	4249.78	1.0000
W17	KENNETT TWP	19.51	175.55	0.00	19.51	0.00	0.00	214.56	8320.77	0.0258
W17	NEW GARDEN TWP	0.00	58.52	0.00	0.00	0.00	0.00	58.52	8320.77	0.0070
W17	New Castle Co., DE	2847.08	672.52	844.32	952.36	0.03	2731.4	8047.68	8320.77	0.9672

Note: MS4 Total = total land area in MS4 municipality
Subbasin Total = total land area of HSPF subbasin
MS4 Ratio = MS4 Total / Subbasin Total

Table C-4. Land Use Areas (acres) for MS4 Municipalities in Christina River Watershed

HSPF Subbasin	MS4 Municipality	Residential	Agriculture	Open Land	Forest	Water	Urban	MS4 Total	Subbasin Total	MS4 Ratio
C01	Newark, DE	28.73	39.50	12.57	23.34	0.00	168.79	272.93	4288.78	0.0636
C01	New Castle Co., DE	94.94	357.76	90.37	255.93	0.00	38.18	837.18	4288.78	0.1952
C02	Newark, DE	1095.33	0.00	174.18	165.20	0.00	253.18	1687.88	6227.34	0.2710
C02	New Castle Co., DE	27.32	523.32	6.57	258.56	1.32	139.09	956.18	6227.34	0.1535
C03	Newark, DE	360.92	98.76	122.10	122.10	10.77	569.21	1283.87	2903.23	0.4422
C03	New Castle Co., DE	277.57	164.73	95.85	402.58	5.23	673.40	1619.36	2903.23	0.5578
C04	Wilmington, DE	3.59	0.00	1.80	0.00	0.00	1.80	7.18	3443.61	0.0021
C04	New Castle Co., DE	1012.41	48.63	315.16	627.61	8.45	1424.17	3436.43	3443.61	0.9979
C05	Wilmington, DE	333.99	0.00	52.07	30.53	0.00	86.19	502.77	2459.29	0.2044
C05	New Castle Co., DE	181.40	0.00	319.94	183.63	27.03	1244.51	1956.51	2459.29	0.7956
C06	Newark, DE	0.00	0.00	0.00	10.77	0.00	0.00	10.77	5532.47	0.0019
C06	New Castle Co., DE	786.46	817.40	564.42	2025.95	59.89	1037.13	5291.24	5532.47	0.9564
C07	New Castle Co., DE	843.87	344.68	328.54	1398.69	34.25	1127.56	4077.59	4077.59	1.0000
C08	New Castle Co., DE	1716.70	357.44	476.20	1843.67	36.71	2706.49	7137.21	7137.21	1.0000
C09	Newport, DE	48.48	0.00	17.96	0.00	16.16	210.09	292.69	14002.93	0.0209
C09	Wilmington, DE	628.47	0.00	518.93	0.00	254.98	1203.06	2605.44	14002.93	0.1861
C09	New Castle Co., DE	836.12	251.48	2265.00	1746.20	329.18	5676.83	11104.80	14002.93	0.7930

Note: MS4 Total = total land area in MS4 municipality
Subbasin Total = total land area of HSPF subbasin
MS4 Ratio = MS4 Total / Subbasin Total

Table C-5a. Sediment MS4 load allocations in Brandywine Creek Watershed

Township	Subbasin	Residential (ton/yr)	Agricultural (ton/yr)	Open (ton/yr)	Forested (ton/yr)	Wetland (ton/yr)	Urban (ton/yr)	Sub-Total (ton/yr)	Total (ton/yr)
BIRMINGHAM TWP	B15	15.64	104.33	3.35	3.11	0.00	3.91	130.35	130.35
COATESVILLE CITY	B04	1.00	0.00	0.00	13.88	0.00	1.00	15.88	86.06
COATESVILLE CITY	B05	33.82	0.00	1.60	9.25	0.00	25.52	70.19	
EAST BRADFORD TWP	B14	33.05	279.61	3.00	29.47	0.03	4.81	349.98	467.17
EAST BRADFORD TWP	B15	16.23	87.61	0.60	9.15	0.00	3.61	117.19	
EAST FALLOWFIELD TWP	B05	3.57	48.10	0.00	6.69	0.00	3.94	62.30	426.42
EAST FALLOWFIELD TWP	B06	18.72	154.29	0.73	17.08	0.00	3.30	194.12	
EAST FALLOWFIELD TWP	B20	11.02	143.62	0.00	13.15	0.00	2.20	170.00	
EAST MARLBOROUGH TWP	B31	19.09	111.14	2.25	6.40	0.00	0.56	139.44	139.44
HIGHLAND TWP	B20	1.66	224.63	0.00	9.71	0.00	2.85	238.86	238.86
HONEY BROOK BORO	B01	2.98	9.93	0.00	0.00	0.00	0.33	13.23	13.23
HONEY BROOK TWP	B01	4.94	377.82	0.00	8.39	0.00	4.26	395.42	558.76
HONEY BROOK TWP	B09	3.37	154.39	0.00	5.12	0.02	0.45	163.34	
MODENA BORO	B05	0.13	0.00	0.00	1.14	0.01	0.00	1.27	12.46
MODENA BORO	B06	0.76	7.00	0.00	1.14	0.00	2.29	11.19	
NEWLIN TWP	B06	0.00	4.42	0.00	2.99	0.00	0.82	8.24	59.59
NEWLIN TWP	B31	0.82	48.45	0.00	1.66	0.00	0.41	51.35	
PARKESBURG BORO	B20	12.78	13.93	0.00	1.56	0.00	4.07	32.35	32.35
PENNSBURY TWP	B15	0.00	2.17	0.00	0.00	0.00	0.00	2.17	43.48
PENNSBURY TWP	B31	1.30	37.36	0.00	2.65	0.00	0.00	41.31	
POCOPSON TWP	B15	3.80	88.92	0.00	5.56	0.02	1.63	99.93	320.79
POCOPSON TWP	B31	21.72	179.34	0.00	17.61	0.00	2.17	220.85	
SADSBURY TWP	B05	0.29	4.23	0.00	0.16	0.00	0.29	4.96	172.13
SADSBURY TWP	B20	7.45	147.10	0.00	8.03	0.00	4.58	167.17	
THORNBURY TWP	B15	0.00	32.50	0.00	1.56	0.00	0.39	34.46	34.46
VALLEY TWP	B04	0.75	1.67	0.00	8.89	0.00	0.75	12.07	164.64
VALLEY TWP	B05	12.82	97.94	0.75	22.96	0.01	18.10	152.58	
WALLACE TWP	B09	1.06	12.67	0.00	2.64	0.00	1.06	17.41	17.41
WEST BRADFORD TWP	B06	3.36	40.65	0.00	4.47	0.00	0.00	48.48	121.60
WEST BRADFORD TWP	B14	2.40	59.48	0.00	9.32	0.00	1.92	73.12	
WEST CALN TWP	B01	0.14	0.00	0.00	4.88	0.00	0.49	5.51	43.07
WEST CALN TWP	B20	1.46	33.06	0.00	2.57	0.00	0.49	37.57	
WEST GOSHEN TWP	B14	46.26	44.49	1.36	49.84	0.01	13.61	155.57	180.51
WEST GOSHEN TWP	B15	14.87	0.00	4.08	4.64	0.00	1.36	24.94	

Table C-5b. Sediment baseline MS4 loads in Brandywine Creek Watershed

Township	Subbasin	Residential (ton/yr)	Agricultural (ton/yr)	Open (ton/yr)	Forested (ton/yr)	Wetland (ton/yr)	Urban (ton/yr)	Sub-Total (ton/yr)	Total (ton/yr)
BIRMINGHAM TWP	B15	37.30	253.09	7.99	3.11	0.00	9.32	310.81	310.81
COATESVILLE CITY	B04	4.63	0.00	0.00	13.88	0.00	9.25	27.75	231.29
COATESVILLE CITY	B05	115.65	0.00	4.63	9.25	0.00	74.01	203.54	
EAST BRADFORD TWP	B14	83.84	754.59	7.62	29.47	0.03	12.20	887.74	1185.00
EAST BRADFORD TWP	B15	41.16	236.28	1.52	9.15	0.00	9.15	297.26	

Township	Subbasin	Residential (ton/yr)	Agricultural (ton/yr)	Open (ton/yr)	Forested (ton/yr)	Wetland (ton/yr)	Urban (ton/yr)	Sub-Total (ton/yr)	Total (ton/yr)
EAST FALLOWFIELD TWP	B05	6.72	96.52	0.00	6.69	0.00	7.42	117.36	803.23
EAST FALLOWFIELD TWP	B06	35.26	305.72	1.38	17.08	0.00	6.22	365.66	
EAST FALLOWFIELD TWP	B20	20.77	282.15	0.00	13.15	0.00	4.15	320.23	
EAST MARLBOROUGH TWP	B31	50.21	302.72	5.91	6.40	0.00	1.48	366.70	366.70
HIGHLAND TWP	B20	2.68	367.81	0.00	9.71	0.00	4.60	384.80	384.80
HONEY BROOK BORO	B01	4.63	15.44	0.00	0.00	0.00	0.51	20.58	20.58
HONEY BROOK TWP	B01	7.19	554.14	0.00	8.39	0.00	6.21	575.94	813.84
HONEY BROOK TWP	B09	4.90	227.21	0.00	5.12	0.02	0.65	237.91	
MODENA BORO	B05	1.71	0.00	0.00	1.14	0.01	0.00	2.86	27.96
MODENA BORO	B06	1.71	17.12	0.00	1.14	0.00	5.14	25.10	
NEWLIN TWP	B06	0.00	14.95	0.00	2.99	0.00	1.99	19.93	144.18
NEWLIN TWP	B31	1.99	119.60	0.00	1.66	0.00	1.00	124.25	
PARKESBURG BORO	B20	20.59	23.40	0.00	1.56	0.00	6.55	52.11	52.11
PENNSBURY TWP	B15	0.00	5.68	0.00	0.00	0.00	0.00	5.68	113.98
PENNSBURY TWP	B31	3.41	102.24	0.00	2.65	0.00	0.00	108.30	
POCOPSON TWP	B15	9.73	236.35	0.00	5.56	0.02	4.17	255.83	821.21
POCOPSON TWP	B31	55.61	486.59	0.00	17.61	0.00	5.56	565.38	
SADSBURY TWP	B05	0.48	7.23	0.00	0.16	0.00	0.48	8.36	289.73
SADSBURY TWP	B20	12.53	253.09	0.00	8.03	0.00	7.71	281.37	
THORNBURY TWP	B15	0.00	79.67	0.00	1.56	0.00	0.94	82.17	82.17
VALLEY TWP	B04	2.22	22.22	0.00	8.89	0.00	2.22	35.55	485.14
VALLEY TWP	B05	37.77	333.30	2.22	22.96	0.01	53.33	449.59	
WALLACE TWP	B09	1.32	16.47	0.00	2.64	0.00	1.32	21.74	21.74
WEST BRADFORD TWP	B06	7.83	100.62	0.00	4.47	0.00	0.00	112.92	283.22
WEST BRADFORD TWP	B14	5.59	150.93	0.00	9.32	0.00	4.47	170.31	
WEST CALN TWP	B01	3.08	0.00	0.00	4.88	0.00	0.77	8.73	68.28
WEST CALN TWP	B20	2.31	53.91	0.00	2.57	0.00	0.77	59.56	
WEST GOSHEN TWP	B14	118.22	191.25	3.48	49.84	0.01	34.77	397.57	461.32
WEST GOSHEN TWP	B15	45.20	0.00	10.43	4.64	0.00	3.48	63.75	

Table C-5c. Sediment MS4 reductions for Brandywine Creek Watershed

Township	Subbasin	Residential	Agricultural	Open	Forested	Wetland	Urban	Sub-Total	Total
BIRMINGHAM TWP	B15	58.06%	58.78%	58.06%	0.00%	0.00%	58.06%	58.06%	58.06%
COATESVILLE CITY	B04	78.38%			0.00%		89.19%	42.79%	62.79%
COATESVILLE CITY	B05	70.76%		65.52%	0.00%		65.52%	65.52%	
EAST BRADFORD TWP	B14	60.58%	62.94%	60.58%	0.00%	0.00%	60.58%	60.58%	60.58%
EAST BRADFORD TWP	B15	60.58%	62.92%	60.58%	0.00%		60.58%	60.58%	
EAST FALLOWFIELD TWP	B05	46.91%	50.16%		0.00%		46.91%	46.91%	46.91%
EAST FALLOWFIELD TWP	B06	46.91%	49.53%	46.91%	0.00%		46.91%	46.91%	
EAST FALLOWFIELD TWP	B20	46.91%	49.10%		0.00%	0.00%	46.91%	46.91%	
EAST MARLBOROUGH TWP	B31	61.98%	63.29%	61.98%	0.00%		61.98%	61.98%	61.98%
HIGHLAND TWP	B20	37.93%	38.93%		0.00%	0.00%	37.93%	37.93%	37.93%
HONEY BROOK BORO	B01	35.70%	35.70%				35.70%	35.70%	35.70%
HONEY BROOK TWP	B01	31.34%	31.82%		0.00%	0.00%	31.34%	31.34%	31.34%
HONEY BROOK TWP	B09	31.34%	32.05%		0.00%	0.00%	31.34%	31.34%	
MODENA BORO	B05	92.57%			0.00%	0.00%		55.43%	55.43%

Township	Subbasin	Residential	Agricultural	Open	Forested	Wetland	Urban	Sub-Total	Total
MODENA BORO	B06	55.43%	59.13%		0.00%		55.43%	55.43%	
NEWLIN TWP	B06		70.41%		0.00%		58.67%	58.67%	58.67%
NEWLIN TWP	B31	58.67%	59.49%		0.00%		58.67%	58.67%	
PARKESBURG BORO	B20	37.93%	40.45%		0.00%		37.93%	37.93%	37.93%
PENNSBURY TWP	B15		61.85%					61.85%	61.85%
PENNSBURY TWP	B31	61.85%	63.46%		0.00%			61.85%	
POCOPSON TWP	B15	60.94%	62.38%		0.00%	0.00%	60.94%	60.94%	60.94%
POCOPSON TWP	B31	60.94%	63.14%		0.00%	0.00%	60.94%	60.94%	
SADSBURY TWP	B05	40.59%	41.49%		0.00%		40.59%	40.59%	40.59%
SADSBURY TWP	B20	40.59%	41.88%		0.00%		40.59%	40.59%	
THORNBURY TWP	B15		59.20%		0.00%		58.06%	58.06%	58.06%
VALLEY TWP	B04	66.06%	92.49%		0.00%		66.06%	66.06%	66.06%
VALLEY TWP	B05	66.06%	70.62%	66.06%	0.00%	0.00%	66.06%	66.06%	
WALLACE TWP	B09	19.92%	23.10%		0.00%		19.92%	19.92%	19.92%
WEST BRADFORD TWP	B06	57.07%	59.60%		0.00%			57.07%	57.07%
WEST BRADFORD TWP	B14	57.07%	60.59%		0.00%		57.07%	57.07%	
WEST CALN TWP	B01	95.38%			0.00%		36.92%	36.92%	36.92%
WEST CALN TWP	B20	36.92%	38.68%		0.00%		36.92%	36.92%	
WEST GOSHEN TWP	B14	60.87%	76.74%	60.87%	0.00%	0.00%	60.87%	60.87%	60.87%
WEST GOSHEN TWP	B15	67.11%		60.87%	0.00%		60.87%	60.87%	

Table C-6a. Sediment MS4 load allocations in Red Clay Creek Watershed

Township	Subbasin	Residential (ton/yr)	Agricultural (ton/yr)	Open (ton/yr)	Forested (ton/yr)	Wetland (ton/yr)	Urban (ton/yr)	Sub-Total (ton/yr)	Total (ton/yr)
EAST MARLBOROUGH TWP	R01	87.56	2616.45	6.04	54.44	0.01	24.15	2788.652	4193.24
EAST MARLBOROUGH TWP	R03	84.54	1239.40	36.23	20.26	0.00	24.15	1404.588	
KENNETT SQUARE BORO	R01	39.09	167.52	5.58	0.00	0.00	27.92	240.1189	405.41
KENNETT SQUARE BORO	R02	0.00	33.50	0.00	0.00	0.00	0.00	33.50496	
KENNETT SQUARE BORO	R03	50.26	63.42	0.00	6.94	0.00	11.17	131.7862	
KENNETT TWP	R01	12.00	92.70	4.00	6.52	0.00	20.01	135.2348	3312.06
KENNETT TWP	R02	120.03	740.77	0.00	53.83	0.00	0.00	914.6353	
KENNETT TWP	R03	132.03	2025.47	0.00	76.67	0.02	28.01	2262.19	
NEW GARDEN TWP	R01	17.61	293.66	0.00	10.44	0.00	14.68	336.3886	2118.72
NEW GARDEN TWP	R02	35.22	1686.11	0.00	40.45	0.00	20.55	1782.331	

Table C-6b. Sediment baseline MS4 loads for Red Clay Creek Watershed

Township	Subbasin	Residential (ton/yr)	Agricultural (ton/yr)	Open (ton/yr)	Forested (ton/yr)	Wetland (ton/yr)	Urban (ton/yr)	Sub-Total (ton/yr)	Total (ton/yr)
EAST MARLBOROUGH TWP	R01	183.58	5545.26	12.66	54.44	0.01	50.64	5846.59	8791.40
EAST MARLBOROUGH TWP	R03	177.25	2620.70	75.96	20.26	0.00	50.64	2944.81	
KENNETT SQUARE BORO	R01	81.00	347.15	11.57	0.00	0.00	57.86	497.58	840.09
KENNETT SQUARE BORO	R02	0.00	69.43	0.00	0.00	0.00	0.00	69.43	
KENNETT SQUARE BORO	R03	104.14	138.86	0.00	6.94	0.00	23.14	273.09	
KENNETT TWP	R01	24.47	195.75	8.16	6.52	0.00	40.78	275.68	6751.62
KENNETT TWP	R02	244.68	1565.97	0.00	53.83	0.00	0.00	1864.48	
KENNETT TWP	R03	269.15	4208.54	0.00	76.67	0.02	57.09	4611.46	

Township	Subbasin	Residential (ton/yr)	Agricultural (ton/yr)	Open (ton/yr)	Forested (ton/yr)	Wetland (ton/yr)	Urban (ton/yr)	Sub-Total (ton/yr)	Total (ton/yr)
NEW GARDEN TWP	R01	39.15	665.54	0.00	10.44	0.00	32.62	747.75	4709.65
NEW GARDEN TWP	R02	78.30	3797.47	0.00	40.45	0.00	45.67	3961.90	

Table C-6c. Sediment MS4 reductions for Red Clay Creek Watershed

Township	Subbasin	Residential	Agricultural	Open	Forested	Wetland	Urban	Sub-Total	Total
EAST MARLBOROUGH TWP	R01	52.30%	52.82%	52.30%	0.00%	0.00%	52.30%	52.30%	52.30%
EAST MARLBOROUGH TWP	R03	52.30%	52.71%	52.30%	0.00%		52.30%	52.30%	
KENNETT SQUARE BORO	R01	51.74%	51.74%	51.74%			51.74%	51.74%	51.74%
KENNETT SQUARE BORO	R02		51.74%					51.74%	
KENNETT SQUARE BORO	R03	51.74%	54.33%		0.00%		51.74%	51.74%	
KENNETT TWP	R01	50.94%	52.64%	50.94%	0.00%		50.94%	50.94%	50.94%
KENNETT TWP	R02	50.94%	52.70%		0.00%			50.94%	
KENNETT TWP	R03	50.94%	51.87%		0.00%	0.00%	50.94%	50.94%	
NEW GARDEN TWP	R01	55.01%	55.88%		0.00%		55.01%	55.01%	55.01%
NEW GARDEN TWP	R02	55.01%	55.60%		0.00%		55.01%	55.01%	

Table C-7a. Sediment MS4 load allocations in White Clay Creek Watershed

Township	Subbasin	Residential (ton/yr)	Agricultural (ton/yr)	Open (ton/yr)	Forested (ton/yr)	Wetland (ton/yr)	Urban (ton/yr)	Sub-Total (ton/yr)	Total (ton/yr)
AVONDALE BORO	W04	8.75	24.23	0.00	2.90	0.00	0.00	35.88	140.02
AVONDALE BORO	W06	7.06	0.00	0.00	8.69	0.00	0.00	15.75	
AVONDALE BORO	W07	4.38	76.74	0.00	2.90	0.00	4.38	88.39	
FRANKLIN TWP	W01	45.10	1140.37	0.00	47.58	0.00	18.57	1251.62	2305.87
FRANKLIN TWP	W03	31.83	671.22	0.00	29.13	0.00	0.00	732.19	
FRANKLIN TWP	W08	15.92	283.43	0.00	6.80	0.00	0.00	306.14	
FRANKLIN TWP	W09	0.00	15.92	0.00	0.00	0.00	0.00	15.92	
LONDON BRITAIN TWP	W01	14.91	151.40	0.00	13.33	0.00	0.00	179.63	1620.44
LONDON BRITAIN TWP	W03	85.72	699.22	0.00	42.42	0.01	0.00	827.36	
LONDON BRITAIN TWP	W09	52.18	521.26	0.00	39.99	0.01	0.00	613.44	
LONDON GROVE TWP	W02	54.92	1117.97	2.29	33.46	0.01	2.29	1210.93	4842.81
LONDON GROVE TWP	W03	22.88	170.19	0.00	12.87	0.00	2.29	208.23	
LONDON GROVE TWP	W04	36.61	1471.25	2.29	60.48	0.01	16.02	1586.66	
LONDON GROVE TWP	W06	4.58	1316.82	0.00	23.16	0.00	4.58	1349.14	
LONDON GROVE TWP	W08	25.17	409.49	4.58	46.32	0.00	2.29	487.85	
NEW GARDEN TWP	W06	8.29	371.53	19.34	17.47	0.00	13.81	430.45	2986.66
NEW GARDEN TWP	W07	19.34	460.67	0.00	6.24	0.01	5.53	491.79	
NEW GARDEN TWP	W08	55.26	1082.84	0.00	49.93	0.00	8.29	1196.32	
NEW GARDEN TWP	W09	77.36	724.39	0.00	38.69	0.02	27.63	868.10	
NEW LONDON TWP	W01	70.72	838.41	0.00	21.68	0.00	21.76	952.57	1008.60
NEW LONDON TWP	W02	5.44	47.50	0.00	3.10	0.00	0.00	56.03	
PENN TWP	W01	19.70	452.17	0.00	12.24	0.00	2.19	486.29	1410.29
PENN TWP	W02	30.64	865.61	0.00	23.36	0.01	4.38	924.00	
WEST GROVE BORO	W02	43.53	32.65	0.00	0.00	0.00	16.32	92.51	192.63
WEST GROVE BORO	W04	16.32	61.12	5.44	6.35	0.00	10.88	100.12	

Table C-7b. Sediment baseline MS4 loads for White Clay Creek Watershed

Township	Subbasin	Residential (ton/yr)	Agricultural (ton/yr)	Open (ton/yr)	Forested (ton/yr)	Wetland (ton/yr)	Urban (ton/yr)	Sub-Total (ton/yr)	Total (ton/yr)
AVONDALE BORO	W04	28.98	86.93	0.00	2.90	0.00	0.00	118.81	463.65
AVONDALE BORO	W06	43.47	0.00	0.00	8.69	0.00	0.00	52.16	
AVONDALE BORO	W07	14.49	260.80	0.00	2.90	0.00	14.49	292.67	
FRANKLIN TWP	W01	82.54	2126.73	0.00	47.58	0.00	33.99	2290.84	4220.43
FRANKLIN TWP	W03	58.27	1252.73	0.00	29.13	0.00	0.00	1340.13	
FRANKLIN TWP	W08	29.13	524.40	0.00	6.80	0.00	0.00	560.33	
FRANKLIN TWP	W09	0.00	29.13	0.00	0.00	0.00	0.00	29.13	
LONDON BRITAIN TWP	W01	24.24	254.50	0.00	13.33	0.00	0.00	292.06	2634.66
LONDON BRITAIN TWP	W03	139.37	1163.41	0.00	42.42	0.01	0.00	1345.21	
LONDON BRITAIN TWP	W09	84.83	872.56	0.00	39.99	0.01	0.00	997.40	
LONDON GROVE TWP	W02	154.41	3203.99	6.43	33.46	0.01	6.43	3404.73	13616.33
LONDON GROVE TWP	W03	64.34	501.83	0.00	12.87	0.00	6.43	585.47	
LONDON GROVE TWP	W04	102.94	4246.25	6.43	60.48	0.01	45.04	4461.14	
LONDON GROVE TWP	W06	12.87	3744.42	0.00	23.16	0.00	12.87	3793.31	
LONDON GROVE TWP	W08	70.77	1235.27	12.87	46.32	0.00	6.43	1371.67	
NEW GARDEN TWP	W06	18.72	861.25	43.69	17.47	0.00	31.20	972.34	6746.50
NEW GARDEN TWP	W07	43.69	1048.48	0.00	6.24	0.01	12.48	1110.90	
NEW GARDEN TWP	W08	124.82	2508.86	0.00	49.93	0.00	18.72	2702.33	
NEW GARDEN TWP	W09	174.75	1685.06	0.00	38.69	0.02	62.41	1960.93	
NEW LONDON TWP	W01	134.20	1610.46	0.00	21.68	0.00	41.29	1807.64	1913.97
NEW LONDON TWP	W02	10.32	92.91	0.00	3.10	0.00	0.00	106.33	
PENN TWP	W01	50.07	1168.21	0.00	12.24	0.00	5.56	1236.08	3584.76
PENN TWP	W02	77.88	2236.30	0.00	23.36	0.01	11.13	2348.68	
WEST GROVE BORO	W02	127.07	95.31	0.00	0.00	0.00	47.65	270.03	562.29
WEST GROVE BORO	W04	47.65	190.61	15.88	6.35	0.00	31.77	292.27	

Table C-7c. Sediment MS4 reductions for White Clay Creek Watershed

Township	Subbasin	Residential	Agricultural	Open	Forested	Wetland	Urban	Sub-Total	Total
AVONDALE BORO	W04	69.80%	72.13%		0.00%			69.80%	69.80%
AVONDALE BORO	W06	83.76%			0.00%			69.80%	
AVONDALE BORO	W07	69.80%	70.58%		0.00%		69.80%	69.80%	
FRANKLIN TWP	W01	45.36%	46.38%		0.00%		45.36%	45.36%	45.36%
FRANKLIN TWP	W03	45.36%	46.42%		0.00%			45.36%	
FRANKLIN TWP	W08	45.36%	45.95%		0.00%			45.36%	
FRANKLIN TWP	W09		45.36%					45.36%	
LONDON BRITAIN TWP	W01	38.50%	40.51%		0.00%			38.50%	38.50%
LONDON BRITAIN TWP	W03	38.50%	39.90%		0.00%	0.00%		38.50%	
LONDON BRITAIN TWP	W09	38.50%	40.26%		0.00%	0.00%		38.50%	
LONDON GROVE TWP	W02	64.43%	65.11%	64.43%	0.00%	0.00%	64.43%	64.43%	64.43%
LONDON GROVE TWP	W03	64.43%	66.09%		0.00%		64.43%	64.43%	
LONDON GROVE TWP	W04	64.43%	65.35%	64.43%	0.00%	0.00%	64.43%	64.43%	
LONDON GROVE TWP	W06	64.43%	64.83%		0.00%		64.43%	64.43%	
LONDON GROVE TWP	W08	64.43%	66.85%	64.43%	0.00%		64.43%	64.43%	

Township	Subbasin	Residential	Agricultural	Open	Forested	Wetland	Urban	Sub-Total	Total
NEW GARDEN TWP	W06	55.73%	56.86%	55.73%	0.00%		55.73%	55.73%	55.73%
NEW GARDEN TWP	W07	55.73%	56.06%		0.00%	0.00%	55.73%	55.73%	
NEW GARDEN TWP	W08	55.73%	56.84%		0.00%		55.73%	55.73%	
NEW GARDEN TWP	W09	55.73%	57.01%		0.00%	0.00%	55.73%	55.73%	
NEW LONDON TWP	W01	47.30%	47.94%		0.00%		47.30%	47.30%	47.30%
NEW LONDON TWP	W02	47.30%	48.88%		0.00%			47.30%	
PENN TWP	W01	60.66%	61.29%		0.00%		60.66%	60.66%	60.66%
PENN TWP	W02	60.66%	61.29%		0.00%	0.00%	60.66%	60.66%	
WEST GROVE BORO	W02	65.74%	65.74%				65.74%	65.74%	65.74%
WEST GROVE BORO	W04	65.74%	67.93%	65.74%	0.00%		65.74%	65.74%	

Table C-8a. Fecal coliform allocations during swimming season in White Clay Creek Basin

Township	Subbasin	Residential (cfu/season)	Agricultural (cfu/season)	Open (cfu/season)	Forested (cfu/season)	Wetland (cfu/season)	Urban (cfu/season)	Sub-Total (cfu/season)	Total load (cfu/season)
AVONDALE BORO	W04	2.99E+09	5.89E+11	0.00E+00	9.97E+09	0.00E+00	0.00E+00	6.02E+11	2.42E+12
AVONDALE BORO	W07	1.50E+09	1.79E+12	0.00E+00	9.97E+09	0.00E+00	1.99E+10	1.82E+12	
LONDON GROVE TWP	W04	3.36E+10	9.18E+13	7.00E+08	6.58E+11	1.40E+10	1.96E+11	9.27E+13	9.27E+13
NEW GARDEN TWP	W07	1.72E+09	2.74E+12	0.00E+00	8.19E+09	1.64E+09	6.55E+09	2.76E+12	2.76E+12
WEST GROVE BORO	W04	1.84E+10	4.82E+12	2.04E+09	8.16E+10	0.00E+00	1.63E+11	5.09E+12	5.09E+12

Table C-8b. Fecal coliform baseline loads during swimming season in White Clay Creek Basin

Township	Subbasin	Residential (cfu/season)	Agricultural (cfu/season)	Open (cfu/season)	Forested (cfu/season)	Wetland (cfu/season)	Urban (cfu/season)	Sub-Total (cfu/season)	Total load (cfu/season)
AVONDALE BORO	W04	1.80E+10	9.45E+12	0.00E+00	9.97E+09	0.00E+00	0.00E+00	9.48E+12	3.81E+13
AVONDALE BORO	W07	8.98E+09	2.84E+13	0.00E+00	9.97E+09	0.00E+00	2.19E+11	2.86E+13	
LONDON GROVE TWP	W04	2.02E+11	1.53E+15	7.00E+09	6.58E+11	1.40E+10	2.16E+12	1.54E+15	1.54E+15
NEW GARDEN TWP	W07	1.03E+10	2.99E+13	0.00E+00	8.19E+09	1.64E+09	7.20E+10	3.00E+13	3.00E+13
WEST GROVE BORO	W04	1.10E+11	8.28E+13	2.04E+10	8.16E+10	0.00E+00	1.80E+12	8.48E+13	8.48E+13

Table C-8c. Fecal coliform percent reductions during swimming season in White Clay Creek Basin

Township	Subbasin	Residential	Agricultural	Open	Forested	Wetland	Urban	Sub-Total	Total load
AVONDALE BORO	W04	83.33%	93.77%		0.00%			93.65%	93.65%
AVONDALE BORO	W07	83.33%	93.70%		0.00%		90.91%	93.65%	
LONDON GROVE TWP	W04	83.33%	94.02%	90.00%	0.00%	0.00%	90.91%	93.97%	93.97%
NEW GARDEN TWP	W07	83.33%	90.82%		0.00%	0.00%	90.91%	90.79%	90.79%
WEST GROVE BORO	W04	83.33%	94.17%	90.00%	0.00%		90.91%	93.99%	93.99%

Table C-9a. Fecal coliform allocation, non-swimming season in White Clay Creek Basin

Township	Sub-basin	Residential (cfu/season)	Agricultural (cfu/season)	Open (cfu/season)	Forested (cfu/season)	Wetland (cfu/season)	Urban (cfu/season)	Sub-Total (cfu/season)	Total load (cfu/season)
AVONDALE BORO	W04	4.48E+10	1.34E+13	0.00E+00	4.48E+10	0.00E+00	0.00E+00	1.35E+13	5.53E+13
AVONDALE BORO	W07	2.24E+10	4.03E+13	0.00E+00	4.48E+10	0.00E+00	1.34E+12	4.18E+13	
LONDON GROVE TWP	W04	5.10E+11	2.10E+15	6.37E+10	3.00E+12	6.37E+10	1.34E+13	2.12E+15	2.12E+15
NEW GARDEN TWP	W07	2.58E+10	6.20E+13	0.00E+00	3.69E+10	7.38E+09	4.43E+11	6.25E+13	6.25E+13
WEST GROVE BORO	W04	2.64E+11	1.06E+14	1.76E+11	3.52E+11	0.00E+00	1.06E+13	1.17E+14	1.17E+14

Table C-9b. Fecal coliform baseline loads, non-swimming season in White Clay Creek Basin

Township	Subbasin	Residential (cfu/season)	Agricultural (cfu/season)	Open (cfu/season)	Forested (cfu/season)	Wetland (cfu/season)	Urban (cfu/season)	Sub-Total (cfu/season)	Total load (cfu/season)
AVONDALE BORO	W04	4.48E+10	1.42E+13	0.00E+00	4.48E+10	0.00E+00	0.00E+00	1.43E+13	5.83E+13
AVONDALE BORO	W07	2.24E+10	4.26E+13	0.00E+00	4.48E+10	0.00E+00	1.34E+12	4.40E+13	
LONDON GROVE TWP	W04	5.10E+11	2.21E+15	6.37E+10	3.00E+12	6.37E+10	1.34E+13	2.23E+15	2.23E+15
NEW GARDEN TWP	W07	2.58E+10	6.54E+13	0.00E+00	3.69E+10	7.38E+09	4.43E+11	6.59E+13	6.59E+13
WEST GROVE BORO	W04	2.64E+11	1.12E+14	1.76E+11	3.52E+11	0.00E+00	1.06E+13	1.23E+14	1.23E+14

Table C-9c. Fecal coliform percent reductions, non-swimming season in White Clay Creek Basin

Township	Subbasin	Residential	Agricultural	Open	Forested	Wetland	Urban	Sub-Total	Total load
AVONDALE BORO	W04	0.00%	5.28%		0.00%			5.25%	5.06%
AVONDALE BORO	W07	0.00%	5.28%		0.00%		0.00%	5.11%	
LONDON GROVE TWP	W04	0.00%	5.05%	0.00%	0.00%	0.00%	0.00%	5.04%	5.04%
NEW GARDEN TWP	W07	0.00%	5.20%		0.00%	0.00%	0.00%	5.15%	5.15%
WEST GROVE BORO	W04	0.00%	5.37%	0.00%	0.00%		0.00%	5.04%	5.04%

Table C-10a. Fecal coliform allocations during swimming season in Red Clay Creek Basin

Township	Subbasin	Residential (cfu/season)	Agricultural (cfu/season)	Open (cfu/season)	Forested (cfu/season)	Wetland (cfu/season)	Urban (cfu/season)	Sub-Total (cfu/season)	Total load (cfu/season)
EAST MARLBOROUGH TWP	R01	7.56E+10	1.53E+14	1.45E+09	1.32E+12	0.00E+00	2.62E+11	1.55E+14	2.06E+14
EAST MARLBOROUGH TWP	R03	4.49E+10	5.11E+13	5.35E+09	3.02E+11	0.00E+00	1.43E+11	5.16E+13	
KENNETT SQUARE BORO	R01	4.10E+10	1.18E+13	1.63E+09	0.00E+00	0.00E+00	3.27E+11	1.22E+13	1.88E+13
KENNETT SQUARE BORO	R03	5.82E+10	5.77E+12	0.00E+00	2.28E+11	0.00E+00	1.45E+11	6.20E+12	
KENNETT SQUARE BORO	R02	0.00E+00	4.73E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.73E+11	
KENNETT TWP	R01	2.06E+10	1.08E+13	1.91E+09	3.23E+11	0.00E+00	3.84E+11	1.15E+13	1.24E+14
KENNETT TWP	R03	5.55E+10	6.63E+13	0.00E+00	9.30E+11	0.00E+00	1.50E+11	6.74E+13	
KENNETT TWP	R02	9.12E+10	4.36E+13	0.00E+00	1.18E+12	0.00E+00	0.00E+00	4.49E+13	
NEW GARDEN TWP	R01	2.10E+10	2.38E+13	0.00E+00	3.29E+11	0.00E+00	1.96E+11	2.43E+13	9.38E+13
NEW GARDEN TWP	R02	1.87E+10	6.88E+13	0.00E+00	5.67E+11	0.00E+00	1.22E+11	6.95E+13	

Table C-10b. Fecal coliform baseline loads during swimming season in Red Clay Creek Basin

Township	Subbasin	Residential (cfu/season)	Agricultural (cfu/season)	Open (cfu/season)	Forested (cfu/season)	Wetland (cfu/season)	Urban (cfu/season)	Sub-Total (cfu/season)	Total load (cfu/season)
EAST MARLBOROUGH TWP	R01	7.56E+11	2.01E+15	1.59E+10	1.32E+12	0.00E+00	2.62E+12	2.02E+15	2.61E+15
EAST MARLBOROUGH TWP	R03	4.49E+11	5.86E+14	5.88E+10	3.02E+11	0.00E+00	1.43E+12	5.88E+14	
KENNETT SQUARE BORO	R01	4.10E+11	1.55E+14	1.79E+10	0.00E+00	0.00E+00	3.27E+12	1.59E+14	2.35E+14
KENNETT SQUARE BORO	R03	5.82E+11	6.85E+13	0.00E+00	2.28E+11	0.00E+00	1.45E+12	7.07E+13	
KENNETT SQUARE BORO	R02	0.00E+00	5.44E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.44E+12	
KENNETT TWP	R01	2.06E+11	1.45E+14	2.10E+10	3.23E+11	0.00E+00	3.84E+12	1.50E+14	1.44E+15
KENNETT TWP	R03	5.55E+11	7.66E+14	0.00E+00	9.30E+11	0.00E+00	1.50E+12	7.69E+14	
KENNETT TWP	R02	9.12E+11	5.15E+14	0.00E+00	1.18E+12	0.00E+00	0.00E+00	5.17E+14	
NEW GARDEN TWP	R01	2.10E+11	3.15E+14	0.00E+00	3.29E+11	0.00E+00	1.96E+12	3.17E+14	1.12E+15
NEW GARDEN TWP	R02	1.87E+11	7.98E+14	0.00E+00	5.67E+11	0.00E+00	1.22E+12	8.00E+14	

Table C-10c. Fecal coliform percent reductions during swimming season in Red Clay Creek Basin

Township	Subbasin	Residential	Agricultural	Open	Forested	Wetland	Urban	Sub-Total	Total load
EAST MARLBOROUGH TWP	R01	90.00%	92.40%	90.91%	0.00%		90.00%	92.34%	92.09%
EAST MARLBOROUGH TWP	R03	90.00%	91.28%	90.91%	0.00%		90.00%	91.23%	
KENNETT SQUARE BORO	R01	90.00%	92.39%	90.91%			90.00%	92.34%	91.98%
KENNETT SQUARE BORO	R03	90.00%	91.57%		0.00%		90.00%	91.23%	
KENNETT SQUARE BORO	R02		91.31%					91.31%	
KENNETT TWP	R01	90.00%	92.61%	90.91%	0.00%		90.00%	92.34%	91.38%
KENNETT TWP	R03	90.00%	91.34%		0.00%		90.00%	91.23%	
KENNETT TWP	R02	90.00%	91.53%		0.00%			91.31%	
NEW GARDEN TWP	R01	90.00%	92.45%		0.00%		90.00%	92.34%	91.60%
NEW GARDEN TWP	R02	90.00%	91.38%		0.00%		90.00%	91.31%	

Table C-11a. Fecal coliform allocations, non-swimming season in Red Clay Creek Basin

Township	Subbasin	Residential (cfu/season)	Agricultural (cfu/season)	Open (cfu/season)	Forested (cfu/season)	Wetland (cfu/season)	Urban (cfu/season)	Sub-Total (cfu/season)	Total load (cfu/season)
EAST MARLBOROUGH TWP	R01	8.54E+11	2.10E+15	2.26E+10	4.65E+12	0.00E+00	3.70E+12	2.11E+15	2.85E+15
EAST MARLBOROUGH TWP	R03	5.96E+11	7.37E+14	9.81E+10	1.25E+12	0.00E+00	2.38E+12	7.42E+14	
KENNETT SQUARE BORO	R01	4.66E+11	1.61E+14	2.56E+10	0.00E+00	0.00E+00	4.65E+12	1.66E+14	2.62E+14
KENNETT SQUARE BORO	R03	7.75E+11	8.51E+13	0.00E+00	9.49E+11	0.00E+00	2.40E+12	8.92E+13	
KENNETT SQUARE BORO	R02	0.00E+00	6.86E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.86E+12	
KENNETT TWP	R01	2.35E+11	1.50E+14	3.01E+10	1.15E+12	0.00E+00	5.46E+12	1.57E+14	1.78E+15
KENNETT TWP	R03	7.37E+11	9.63E+14	0.00E+00	3.86E+12	0.00E+00	2.49E+12	9.70E+14	
KENNETT TWP	R02	1.21E+12	6.45E+14	0.00E+00	4.89E+12	0.00E+00	0.00E+00	6.51E+14	
NEW GARDEN TWP	R01	2.38E+11	3.28E+14	0.00E+00	1.16E+12	0.00E+00	2.77E+12	3.32E+14	1.34E+15
NEW GARDEN TWP	R02	2.48E+11	1.00E+15	0.00E+00	2.35E+12	0.00E+00	2.02E+12	1.01E+15	

Table C-11b. Fecal coliform baseline loads, non-swimming season in Red Clay Creek Basin

Township	Subbasin	Residential (cfu/season)	Agricultural (cfu/season)	Open (cfu/season)	Forested (cfu/season)	Wetland (cfu/season)	Urban (cfu/season)	Sub-Total (cfu/season)	Total load (cfu/season)
EAST MARLBOROUGH TWP	R01	2.13E+12	4.43E+15	4.98E+10	4.65E+12	0.00E+00	3.70E+12	4.44E+15	5.95E+15
EAST MARLBOROUGH TWP	R03	1.49E+12	1.51E+15	2.16E+11	1.25E+12	0.00E+00	2.38E+12	1.52E+15	
KENNETT SQUARE BORO	R01	1.17E+12	3.43E+14	5.63E+10	0.00E+00	0.00E+00	4.65E+12	3.49E+14	5.45E+14
KENNETT SQUARE BORO	R03	1.94E+12	1.77E+14	0.00E+00	9.49E+11	0.00E+00	2.40E+12	1.82E+14	
KENNETT SQUARE BORO	R02	0.00E+00	1.41E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.41E+13	
KENNETT TWP	R01	5.87E+11	3.22E+14	6.61E+10	1.15E+12	0.00E+00	5.46E+12	3.29E+14	3.65E+15
KENNETT TWP	R03	1.84E+12	1.98E+15	0.00E+00	3.86E+12	0.00E+00	2.49E+12	1.98E+15	
KENNETT TWP	R02	3.02E+12	1.33E+15	0.00E+00	4.89E+12	0.00E+00	0.00E+00	1.33E+15	
NEW GARDEN TWP	R01	5.94E+11	6.93E+14	0.00E+00	1.16E+12	0.00E+00	2.77E+12	6.97E+14	2.76E+15
NEW GARDEN TWP	R02	6.19E+11	2.06E+15	0.00E+00	2.35E+12	0.00E+00	2.02E+12	2.07E+15	

Table C-11c. Fecal coliform percent reductions, non-swimming season in Red Clay Creek Basin

Township	Subbasin	Residential	Agricultural	Open	Forested	Wetland	Urban	Sub-Total	Total load
EAST MARLBOROUGH TWP	R01	60.00%	52.52%	54.55%	0.00%		0.00%	52.42%	52.08%
EAST MARLBOROUGH TWP	R03	60.00%	51.21%	54.55%	0.00%		0.00%	51.10%	
KENNETT SQUARE BORO	R01	60.00%	53.11%	54.55%			0.00%	52.42%	51.95%
KENNETT SQUARE BORO	R03	60.00%	51.97%		0.00%		0.00%	51.10%	
KENNETT SQUARE BORO	R02		51.21%					51.21%	
KENNETT TWP	R01	60.00%	53.48%	54.55%	0.00%		0.00%	52.42%	51.26%
KENNETT TWP	R03	60.00%	51.26%		0.00%		0.00%	51.10%	
KENNETT TWP	R02	60.00%	51.38%		0.00%			51.21%	
NEW GARDEN TWP	R01	60.00%	52.71%		0.00%		0.00%	52.42%	51.52%
NEW GARDEN TWP	R02	60.00%	51.32%		0.00%		0.00%	51.21%	

Table C-12a. Enterococci allocations for MS4 municipalities in New Castle County

Town	Subbasin	Residential (cfu/yr)	Agricultural (cfu/yr)	Open (cfu/yr)	Forested (cfu/yr)	Wetland (cfu/yr)	Urban (cfu/yr)	Sub-Total (cfu/yr)	Total (cfu/yr)
Newark	C02	2.19E+11	0.00E+00	2.61E+10	2.48E+10	0.00E+00	1.90E+11	4.60E+11	1.28E+13
Newark	C01	5.75E+09	9.88E+10	1.89E+09	3.50E+09	0.00E+00	1.27E+11	2.36E+11	
Newark	C03	7.22E+10	2.47E+11	1.83E+10	1.83E+10	1.62E+09	4.27E+11	7.84E+11	
Newark	C06	0.00E+00	0.00E+00	0.00E+00	1.62E+09	0.00E+00	0.00E+00	1.62E+09	
Newark	W15	1.62E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.62E+09	
Newark	W12	1.06E+11	5.93E+12	3.09E+10	5.34E+10	2.41E+09	1.35E+12	7.46E+12	
Newark	W11	6.95E+10	3.45E+12	2.41E+10	1.07E+11	1.50E+09	2.23E+11	3.87E+12	
Newport	C09	9.70E+09	0.00E+00	2.69E+09	0.00E+00	2.42E+09	1.58E+11	1.72E+11	1.72E+11
Wilmington	C04	5.39E+08	0.00E+00	2.02E+08	0.00E+00	0.00E+00	1.01E+09	1.75E+09	3.01E+12
Wilmington	C05	4.96E+10	0.00E+00	5.79E+09	4.58E+09	0.00E+00	4.79E+10	1.08E+11	
Wilmington	C09	1.26E+11	0.00E+00	7.78E+10	0.00E+00	3.82E+10	9.02E+11	1.14E+12	
Wilmington	B19	9.67E+08	0.00E+00	1.98E+09	4.07E+09	3.88E+08	4.36E+09	1.18E+10	

Town	Subbasin	Residential (cfu/yr)	Agricultural (cfu/yr)	Open (cfu/yr)	Forested (cfu/yr)	Wetland (cfu/yr)	Urban (cfu/yr)	Sub-Total (cfu/yr)	Total (cfu/yr)
Wilmington	B34	2.20E+11	0.00E+00	9.93E+10	4.37E+10	2.14E+10	1.36E+12	1.74E+12	
New Castle County	*	1.06E+13	1.56E+14	5.60E+12	2.35E+13	1.13E+12	9.11E+13	2.87E+14	2.87E+14

* Including New Castle County within the Christina River Basin, excluding Newark, Newport, and Wilmington. Subbasins include B17, B18, B19, B34, R04, R05, R06, R07, R08, R09, W09, W10, W11, W12, W13, W14, W15, W16, W17, C01, C02, C03, C04, C05, C06, C07, C08, and C09

Table C-12b. Enterococci baseline loads for MS4 municipalities in New Castle County.

Town	Subbasin	Residential (cfu/yr)	Agricultural (cfu/yr)	Open (cfu/yr)	Forested (cfu/yr)	Wetland (cfu/yr)	Urban (cfu/yr)	Sub-Total (cfu/yr)	Total (cfu/yr)
Newark	C02	2.19E+11	0.00E+00	2.61E+10	2.48E+10	0.00E+00	1.90E+12	2.17E+12	4.34E+13
Newark	C01	5.75E+09	6.91E+12	1.89E+09	3.50E+09	0.00E+00	1.27E+12	8.19E+12	
Newark	C03	7.22E+10	1.73E+13	1.83E+10	1.83E+10	1.62E+09	4.27E+12	2.17E+13	
Newark	C06	0.00E+00	0.00E+00	0.00E+00	1.62E+09	0.00E+00	0.00E+00	1.62E+09	
Newark	W15	1.62E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.62E+09	
Newark	W12	1.06E+11	5.93E+12	3.09E+10	5.34E+10	2.41E+09	1.35E+12	7.46E+12	
Newark	W11	6.95E+10	3.45E+12	2.41E+10	1.07E+11	1.50E+09	2.23E+11	3.87E+12	
Newport	C09	9.70E+09	0.00E+00	2.69E+09	0.00E+00	2.42E+09	1.58E+11	1.72E+11	1.72E+11
Wilmington	C04	7.18E+08	0.00E+00	2.69E+08	0.00E+00	0.00E+00	1.35E+09	2.33E+09	3.09E+12
Wilmington	C05	6.68E+10	0.00E+00	7.81E+09	4.58E+09	0.00E+00	6.46E+10	1.44E+11	
Wilmington	C09	1.26E+11	0.00E+00	7.78E+10	0.00E+00	3.82E+10	9.02E+11	1.14E+12	
Wilmington	B19	9.96E+08	0.00E+00	2.03E+09	4.07E+09	3.88E+08	4.62E+09	1.21E+10	
Wilmington	B34	2.27E+11	0.00E+00	1.02E+11	4.37E+10	2.14E+10	1.40E+12	1.79E+12	
New Castle County	*	1.83E+13	2.28E+15	1.36E+13	2.35E+13	1.13E+12	1.72E+15	4.05E+15	4.05E+15

* Including New Castle County within the Christina River Basin, excluding Newark, Newport, and Wilmington. Subbasins include B17, B18, B19, B34, R04, R05, R06, R07, R08, R09, W09, W10, W11, W12, W13, W14, W15, W16, W17, C01, C02, C03, C04, C05, C06, C07, C08, and C09

Table C-12c. Enterococci percent reductions for MS4 municipalities in New Castle County

Town	Subbasin	Residential	Agricultural	Open	Forested	Wetland	Urban	Sub-Total	Total
Newark	C02	0.00%		0.00%	0.00%		90.00%	78.80%	70.43%
Newark	C01	0.00%	98.57%	0.00%	0.00%		90.00%	97.11%	
Newark	C03	0.00%	98.57%	0.00%	0.00%	0.00%	90.00%	96.38%	
Newark	C06				0.00%			0.00%	
Newark	W15	0.00%						0.00%	
Newark	W12	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Newark	W11	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Newport	C09	0.00%		0.00%		0.00%	0.00%	0.00%	0.00%
Wilmington	C04	25.00%		25.00%			0.00%	0.00%	2.60%
Wilmington	C05	25.82%		25.82%	0.00%		25.82%	0.00%	
Wilmington	C09	0.00%		0.00%		0.00%	0.00%	0.00%	
Wilmington	B19	2.91%		2.91%	0.00%	0.00%	5.72%	2.91%	
Wilmington	B34	2.91%		2.91%	0.00%	0.00%	3.05%	2.91%	
New Castle County	*	41.92%	93.17%	58.80%	0.00%	0.00%	94.70%	92.91%	92.91%

* Including New Castle County within the Christina River Basin, excluding Newark, Newport, and Wilmington. Subbasins include B17, B18, B19, B34, R04, R05, R06, R07, R08, R09, W09, W10, W11, W12, W13, W14, W15, W16, W17, C01, C02, C03, C04, C05, C06, C07, C08, and C09

Table C-13a. MS4 enterococci baseline loads for New Castle County, DE

Location	Residential (cfu/yr)	Agricultural (cfu/yr)	Open (cfu/yr)	Forested (cfu/yr)	Wetland (cfu/yr)	Urban (cfu/yr)	Total (cfu/yr)
Brandywine Cr. (B18)	3.55E+11	9.42E+13	4.04E+11	1.06E+12	2.33E+10	1.53E+13	1.11E+14
Brandywine Cr. (B19)	7.68E+11	2.42E+13	1.47E+12	5.99E+11	2.78E+10	2.86E+13	5.56E+13
Tidal Brandywine Cr. (B34)	1.41E+12	9.37E+12	1.02E+11	4.77E+11	5.30E+10	1.21E+14	1.32E+14
Red Clay Cr. (R04)	1.34E+12	4.14E+13	2.35E+11	7.48E+11	2.06E+10	1.21E+13	5.59E+13
Red Clay Cr. (R05)	5.87E+11	1.67E+13	8.58E+10	4.80E+11	1.49E+10	4.65E+12	2.25E+13
Red Clay Cr. (R06)	1.19E+11	1.41E+13	2.16E+10	9.32E+10	4.76E+08	7.51E+11	1.51E+13
Red Clay Cr. (R07)	2.02E+11	3.74E+12	1.95E+10	2.56E+11	8.01E+10	1.76E+12	6.05E+12
Red Clay Cr. (R08)	1.68E+12	4.81E+12	5.31E+11	4.57E+11	4.57E+10	6.81E+13	7.56E+13
Red Clay Cr. (R09)	6.96E+11	0.00E+00	4.88E+10	1.17E+11	4.87E+09	2.79E+13	2.88E+13
White Clay Cr. (W11)	4.71E+10	2.22E+13	5.34E+10	1.18E+12	5.83E+09	1.33E+13	3.68E+13
White Clay Cr. (W12)	5.72E+11	2.93E+13	2.10E+11	5.16E+11	1.72E+10	1.11E+14	1.42E+14
White Clay Cr. (W13)	2.95E+10	6.38E+12	2.69E+10	9.25E+10	5.01E+09	2.36E+13	3.01E+13
White Clay Cr. (W14)	1.14E+11	0.00E+00	2.05E+11	2.83E+11	1.15E+11	3.75E+13	3.82E+13
White Clay Cr. (W15)	8.16E+10	2.26E+13	1.64E+10	4.57E+11	0.00E+00	5.36E+12	2.85E+13
White Clay Cr. (W16)	1.02E+12	2.94E+13	2.10E+11	6.37E+11	0.00E+00	7.10E+13	1.02E+14
White Clay Cr. (W17)	1.88E+12	7.92E+13	4.86E+11	1.20E+12	1.46E+07	1.59E+14	2.41E+14
Christina River (C01)	1.05E+12	4.03E+13	5.36E+11	9.92E+10	0.00E+00	2.54E+12	4.45E+13
Christina River (C02)	2.08E+12	7.27E+13	1.00E+12	1.11E+11	3.65E+08	3.51E+12	7.94E+13
Christina River (C03)	1.40E+12	2.00E+13	1.62E+11	2.11E+11	1.01E+09	2.29E+13	4.47E+13
Christina River (C04)	1.31E+12	1.57E+13	3.06E+11	6.07E+11	8.18E+09	6.90E+13	8.69E+13
Christina River (C05)	5.95E+11	0.00E+00	3.51E+11	2.02E+11	2.60E+10	6.41E+13	6.52E+13
Christina River (C06)	1.24E+12	6.00E+13	1.03E+12	4.61E+11	1.36E+10	1.18E+13	7.45E+13
Christina River (C07)	1.46E+12	4.60E+13	3.35E+11	5.75E+11	1.41E+10	2.32E+13	7.16E+13
Christina River (C08)	2.13E+12	5.77E+13	4.36E+11	9.12E+11	1.82E+10	6.69E+13	1.28E+14
Christina River (C09)	2.36E+12	6.01E+13	3.00E+12	1.29E+12	4.04E+11	2.62E+14	3.29E+14

Table C-13b. MS4 enterococci allocations for New Castle County, DE

Location	Residential (cfu/yr)	Agricultural (cfu/yr)	Open (cfu/yr)	Forested (cfu/yr)	Wetland (cfu/yr)	Urban (cfu/yr)	Total (cfu/yr)
Brandywine Cr. (B18)	1.26E+11	3.63E+12	1.48E+11	1.06E+12	2.33E+10	5.62E+11	5.55E+12
Brandywine Cr. (B19)	5.39E+11	2.01E+12	1.06E+12	5.99E+11	2.78E+10	2.06E+12	6.30E+12
Tidal Brandywine Cr. (B34)	2.89E+10	1.23E+12	8.81E+10	4.77E+11	5.30E+10	9.64E+12	1.15E+13
Red Clay Cr. (R04)	2.04E+11	5.67E+12	3.58E+10	7.48E+11	2.06E+10	1.85E+12	8.52E+12
Red Clay Cr. (R05)	2.06E+11	5.54E+12	3.01E+10	4.80E+11	1.49E+10	1.63E+12	7.90E+12
Red Clay Cr. (R06)	8.00E+10	9.45E+12	1.45E+10	9.32E+10	4.76E+08	5.04E+11	1.01E+13
Red Clay Cr. (R07)	5.82E+10	8.35E+11	5.60E+09	2.56E+11	8.01E+10	5.05E+11	1.74E+12
Red Clay Cr. (R08)	1.51E+11	6.94E+10	5.49E+10	4.57E+11	4.57E+10	7.05E+12	7.83E+12
Red Clay Cr. (R09)	6.99E+10	0.00E+00	4.90E+09	1.17E+11	4.87E+09	2.69E+12	2.89E+12
White Clay Cr. (W11)	2.13E+10	4.68E+12	2.98E+09	1.18E+12	5.83E+09	1.97E+11	6.09E+12
White Clay Cr. (W12)	1.47E+11	6.87E+12	5.92E+10	5.16E+11	1.72E+10	2.86E+12	1.05E+13
White Clay Cr. (W13)	1.30E+10	2.75E+12	1.18E+10	9.25E+10	5.01E+09	1.04E+12	3.91E+12

Location	Residential (cfu/yr)	Agricultural (cfu/yr)	Open (cfu/yr)	Forested (cfu/yr)	Wetland (cfu/yr)	Urban (cfu/yr)	Total (cfu/yr)
White Clay Cr. (W14)	1.02E+11	0.00E+00	1.82E+11	2.83E+11	1.15E+11	3.31E+12	3.99E+12
White Clay Cr. (W15)	2.99E+10	8.25E+12	6.20E+09	4.57E+11	0.00E+00	2.04E+11	8.95E+12
White Clay Cr. (W16)	3.51E+11	9.69E+12	7.22E+10	6.37E+11	0.00E+00	2.45E+12	1.32E+13
White Clay Cr. (W17)	6.36E+11	2.60E+13	1.64E+11	1.20E+12	1.46E+07	5.39E+12	3.34E+13
Christina River (C01)	3.77E+11	1.58E+13	2.37E+11	9.92E+10	0.00E+00	2.27E+12	1.88E+13
Christina River (C02)	1.34E+12	2.01E+13	1.31E+11	1.11E+11	3.65E+08	2.60E+12	2.42E+13
Christina River (C03)	5.79E+11	3.29E+12	1.56E+11	2.11E+11	1.01E+09	4.33E+12	8.56E+12
Christina River (C04)	8.93E+11	4.89E+11	2.08E+11	6.07E+11	8.18E+09	4.69E+12	6.89E+12
Christina River (C05)	3.68E+11	0.00E+00	2.21E+11	2.02E+11	2.60E+10	3.98E+12	4.79E+12
Christina River (C06)	7.70E+11	1.11E+13	4.14E+11	4.61E+11	1.36E+10	3.81E+12	1.65E+13
Christina River (C07)	8.54E+11	4.86E+12	2.49E+11	5.75E+11	1.41E+10	4.28E+12	1.08E+13
Christina River (C08)	1.58E+12	4.49E+12	3.29E+11	9.12E+11	1.82E+10	9.36E+12	1.67E+13
Christina River (C09)	1.39E+12	3.21E+12	2.04E+12	1.29E+12	4.04E+11	2.58E+13	3.41E+13

Table C-13c. MS4 enterococci percent reductions for New Castle County, DE

Location	Residential	Agricultural	Open	Forested	Wetland	Urban	Total
Brandywine Cr. (B18)	64.39%	96.14%	63.32%	0.00%	0.00%	96.33%	95.01%
Brandywine Cr. (B19)	29.83%	91.68%	27.72%	0.00%	0.00%	92.78%	88.67%
Tidal Brandywine Cr. (B34)	97.95%	86.87%	13.91%	0.00%	0.00%	92.00%	91.27%
Red Clay Cr. (R04)	84.75%	86.32%	84.75%	0.00%	0.00%	84.75%	84.75%
Red Clay Cr. (R05)	64.92%	66.84%	64.92%	0.00%	0.00%	64.92%	64.92%
Red Clay Cr. (R06)	32.85%	33.07%	32.85%	0.00%	0.00%	32.85%	32.85%
Red Clay Cr. (R07)	71.26%	77.67%	71.26%	0.00%	0.00%	71.26%	71.26%
Red Clay Cr. (R08)	90.96%	98.56%	89.65%	0.00%	0.00%	89.65%	89.65%
Red Clay Cr. (R09)	89.97%		89.97%	0.00%	0.00%	90.36%	89.97%
White Clay Cr. (W11)	54.82%	78.90%	94.42%	0.00%	0.00%	98.52%	83.46%
White Clay Cr. (W12)	74.23%	76.55%	71.83%	0.00%	0.00%	97.42%	92.60%
White Clay Cr. (W13)	56.12%	56.98%	56.12%	0.00%	0.00%	95.60%	87.03%
White Clay Cr. (W14)	10.85%		10.85%	0.00%	0.00%	91.17%	89.55%
White Clay Cr. (W15)	63.37%	63.40%	62.14%	0.00%		96.20%	68.56%
White Clay Cr. (W16)	65.59%	67.01%	65.59%	0.00%		96.55%	87.09%
White Clay Cr. (W17)	66.14%	67.15%	66.14%	0.00%	0.00%	96.60%	86.16%
Christina River (C01)	64.27%	60.75%	55.78%	0.00%		10.43%	57.77%
Christina River (C02)	35.76%	72.42%	86.94%	0.00%	0.00%	26.11%	69.50%
Christina River (C03)	58.64%	83.57%	3.34%	0.00%	0.00%	81.14%	80.85%
Christina River (C04)	31.87%	96.89%	32.11%	0.00%	0.00%	93.21%	92.07%
Christina River (C05)	38.11%		37.18%	0.00%	0.00%	93.80%	92.66%
Christina River (C06)	37.85%	81.57%	59.71%	0.00%	0.00%	67.70%	77.83%
Christina River (C07)	41.62%	89.45%	25.60%	0.00%	0.00%	81.55%	84.88%
Christina River (C08)	25.73%	92.22%	24.35%	0.00%	0.00%	86.01%	86.97%
Christina River (C09)	41.01%	94.66%	31.89%	0.00%	0.00%	90.15%	89.63%

Appendix D

Revisions to April 2005 Bacteria TMDL for Christina River Basin

Appendix D

Revisions to April 2005 Bacteria TMDL for Christina River Basin

On April 8, 2005, the United States Environmental Protection Agency Region III established Total Maximum Daily Loads (TMDLs) for bacteria and sediment for the portions of the Christina River Basin listed on the Clean Water Act Section 303(d) lists for the Commonwealth of Pennsylvania and the State of Delaware. Additional information has become available for combined sewer overflow (CSO) and National Pollutant Discharge Elimination System (NPDES) discharges that prompted this revision to the April 2005 TMDLs. The updated information is described in this appendix.

D.1 Event Mean Concentrations for Wilmington CSO Discharges

Following the establishment of the Christina River Basin bacteria and sediment TMDLs, the City of Wilmington and Delaware Department of Natural Resources and Environmental Control completed a storm-monitoring program. The goal of the storm-monitoring program was to collect nutrient and bacteria data from four storm events to establish characteristic concentrations for the CSO discharges in the City of Wilmington. Two storm events had been completed prior to the April 2005 TMDL. After April 2005, the monitoring data from two additional storm events were available. This proposed TMDL revision incorporates data from the four storm events to establish updated event mean concentrations (EMCs) for the Wilmington CSO discharges as shown in Table D-1.

Table D-1. Revised EMCs for City of Wilmington CSOs

CSO ID	EMC April 2005 TMDL (cfu/100mL)	EMC for Revised TMDL (cfu/100mL)
CSO 4b	56,117	34,917
CSO 25	235,333	57,885
CSO 3	113,833	121,635
All other CSOs	113,833	45,888

The data from the individual storm events are summarized in Table D-2. The revised event mean concentrations were calculated using a geometric mean of the data associated with a given CSO. The event mean concentrations for the April 2005 TMDL were calculated using an arithmetic mean of the data associated with a particular CSO. For the April 2005 TMDL, data from the 11th Street Pumping Station were used to establish EMCs for CSO3 and all other CSOs except for CSO 4b, and CSO 25. For the revised TMDL, data from the 11th Street Pumping Station was used to establish the EMC only for CSO 3 because of its close proximity to the pumping station. The EMCs for the other CSOs were calculated as the geometric mean from the combined storm monitoring data from CSO 4b and CSO 25.

Stormwater runoff sometimes exhibits high pollutant concentrations during the initial stages of a storm. This is referred to as the “first flush.” Examination of the CSO storm monitoring data in Table D-2 did not indicate any strong first-flush tendency. Larger concentrations were just as likely to occur several hours into the storm event rather than at the beginning. Also, in many of the storms, the concentrations were relatively constant over time. Due to the absence of any definitive evidence in the monitoring data, the first-flush phenomenon was not included in this analysis. Event-mean concentrations were considered appropriate for characterizing the mass loadings from the CSO outfalls.

Table D-2. Wilmington CSO *enterococci* storm monitoring data

CSO4b		CSO25		CSO3 (11th St. Pump Station)	
Date	**cfu/100mL**	**Date**	**cfu/100mL**	**Date**	**cfu/100mL**
10/27/2003 11:40	90,000	10/27/2003 11:00	230,000	10/27/2003 11:20	280,000
10/27/2003 12:10	90,000	10/27/2003 11:30	70,000	10/27/2003 11:50	400,000
10/27/2003 12:40	110,000	10/27/2003 12:00	40,000	10/27/2003 12:10	130,000
10/27/2003 13:10	110,000	10/27/2003 12:30	80,000	10/27/2003 12:50	140,000
10/27/2003 13:40	130,000	10/27/2003 13:30	30,000	10/27/2003 13:20	130,000
10/27/2003 14:10	50,000	10/27/2003 14:00	50,000	10/27/2003 13:50	110,000
12/17/2003 09:00	25,000	12/17/2003 08:45	18,000	12/17/2003 08:50	36,000
12/17/2003 09:30	18,000	12/17/2003 09:15	1,500,000	12/17/2003 09:20	32,000
12/17/2003 10:00	20,000	12/17/2003 09:45	100,000	12/17/2003 09:50	24,000
12/17/2003 10:30	15,000			12/17/2003 10:20	27,000
12/17/2003 11:00	11,000	11/04/2004 13:20	27,000	12/17/2003 10:50	23,000
12/17/2003 11:30	4,400	11/04/2004 13:50	27,000	12/17/2003 11:20	34,000
		11/04/2004 14:20	25,000		
11/04/2004 13:33	33,000	11/04/2004 14:50	42,000	11/04/2004 13:25	370,000
11/04/2004 14:03	26,000			11/04/2004 13:55	360,000
11/04/2004 14:33	39,000	10/08/2005 07:55	70,000	11/04/2004 14:25	380,000
11/04/2004 15:03	36,000	10/08/2005 08:25	218,182	11/04/2004 14:55	290,000
11/04/2004 15:33	34,000	10/08/2005 08:55	96,396	11/04/2004 15:25	400,000
		10/08/2005 09:25	101,802	11/04/2004 15:55	340,000
		10/08/2005 09:55	61,818		
		10/08/2005 10:15	510		
		10/08/2005 10:25	236,364		
EMC	34,917		57,885		121,635
EMC (4b and 25)	45,888				

D.2 Summary of Annual Baseline and TMDL CSO *Enterococci* Loads

A summary of the baseline and TMDL CSO *enterococci* loads grouped by Environmental Fluid Dynamics Code (EFDC) model grid cell location is presented in Table D-3. The locations of the CSO discharges and the EFDC model grid cells are shown in Figure D-1. Note that CSO 31 discharges to Shellpot Creek, which flows into the Delaware River and is outside the Christina River Basin, therefore it is not included in the CSO load totals for the baseline and TMDL columns in Table D-3. The following CSOs were assigned zero flow (i.e., 100% load reduction) for the TMDL allocation: 4b, 4c, 4f, 12, 14, 15, 18, 20, and Rockford Road based on information provided by the City of Wilmington. A comparison of the baseline and TMDL *enterococci* loads for the April 2005 TMDL and this revised TMDL is presented in Table D-4.

Table D-3. Average annual baseline and TMDL CSO loads grouped by EFDC grid cell

Location - EFDC [I,J]	CSO ID numbers	Baseline (cfu/yr)	TMDL (cfu/yr)	Percent Reduction
Little Mill Creek. - [44,55]	27, 28	1.120E+14	2.652E+13	76.32%
Little Mill Creek - [45,55]	29	4.379E+13	1.037E+13	76.32%
Christina River - [52,13]	5, 6, 7, 11, 12, 13, 30	1.730E+14	5.961E+13	65.55%
Christina River - [53,13]	9a, 10, 14, 15, 16, 17	1.725E+14	3.745E+13	78.29%
Christina River - [55,13]	9c	8.585E+12	4.384E+11	94.89%
Brandywine Creek - [54,16]	18	5.377E+10	0.000E+00	100.00%
Brandywine Creek - [54,17]	3, 4a, 4b, 4c, 4d, 19, 20, 21a, 21b, 21c	3.340E+14	6.301E+13	81.14%
Brandywine Creek - [54,18]	4e, 4f, 22b, 22c, 23, 24	1.342E+14	1.157E+14	13.83%
Brandywine Creek - [54,20]	25, 26	2.109E+14	7.586E+13	64.04%
Brandywine Creek - [54,21]	RR	9.951E+12	0.000E+00	100.00%
Shellpot Creek - [57,15] *	31	4.247E+13	2.991E+13	29.59%
Total CSO load		1.199E+15	3.889E+14	67.57%

*CSO31 not included in total CSO load since it discharges outside of Christina River Basin

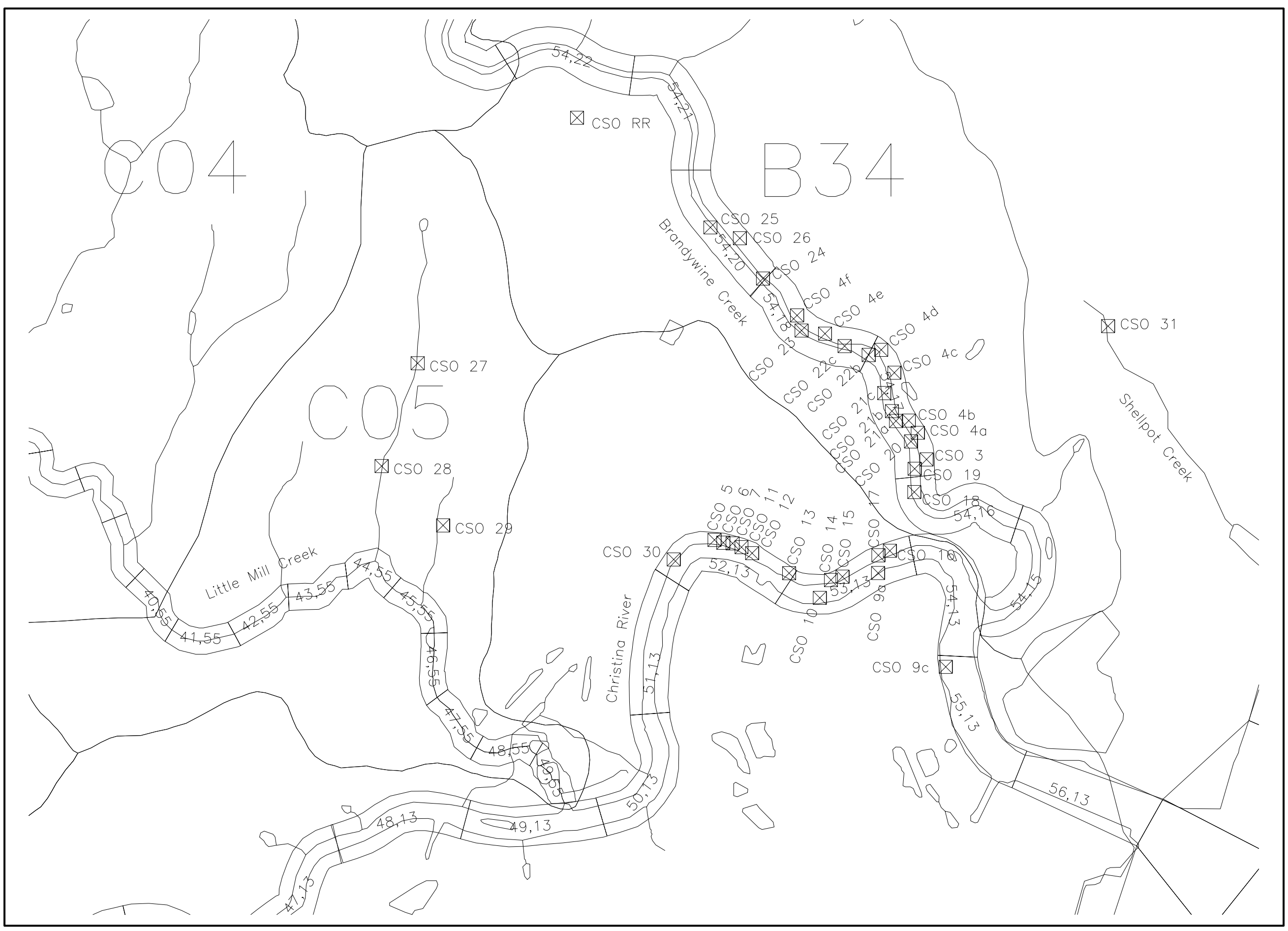


Figure D-1. Location of CSO discharges in relation to EFDC model grid cells

Table D-4. Comparison of revised CSO *enterococci* average annual loads with April 2005 TMDL

Location - EFDC [I,J]	CSO ID numbers	Revised TMDL		April 2005 TMDL	
		Baseline (cfu/yr)	WLA (cfu/yr)	Baseline (cfu/yr)	WLA (cfu/yr)
Little Mill Ceek. - [44,55]	27, 28	1.120E+14	2.652E+13	2.778E+14	4.167E+13
Little Mill Creek - [45,55]	29	4.379E+13	1.037E+13	1.086E+14	1.630E+13
Christina River - [52,13]	5, 6, 7, 11, 12, 13, 30	1.730E+14	5.961E+13	4.293E+14	6.439E+13
Christina River - [53,13]	9a, 10, 14, 15, 16, 17	1.725E+14	3.745E+13	4.279E+14	6.419E+13
Christina River - [55,13]	9c	8.585E+12	4.384E+11	2.130E+13	3.195E+12
Brandywine Creek - [54,16]	18	5.377E+10	0.000E+00	1.334E+11	2.001E+10
Brandywine Creek - [54,17]	3, 4a, 4b, 4c, 4d, 19, 20, 21a, 21b, 21c	3.340E+14	6.301E+13	6.652E+14	9.977E+13
Brandywine Creek - [54,18]	4e, 4f, 22b, 22c, 23, 24	1.342E+14	1.157E+14	3.330E+14	4.995E+13
Brandywine Creek - [54,20]	25, 26	2.109E+14	7.586E+13	8.538E+14	1.281E+14
Brandywine Creek - [54,21]	RR	9.951E+12	0.000E+00	2.468E+13	3.703E+12
Shellpot Creek - [57,15] *	31	4.247E+13	2.991E+13	1.054E+14	1.580E+13
Total CSO load		1.199E+15	3.889E+14	3.142E+15	4.713E+14

*CSO31 discharges outside of Christina River Basin

D.3 Addition of Little Mill Creek to EFDC Model

Little Mill Creek receives loading from CSOs 27, 28, and 29 located in subbasin C05. In the April 2005 TMDL, Little Mill Creek was not explicitly included in the EFDC model domain for the *enterococci* bacteria analysis. Instead, the flow and load from these three CSOs were assigned to Christina River grid cell [49,13]. In this revised TMDL, 10 grid cells representing Little Mill Creek were added into the model domain. CSO 27 and CSO 28 discharge to EFDC grid cells [44,55] and CSO 29 discharges to grid cell [45,55] as indicated in Table D-3 and shown in Figure D-1.

D.4 Updated NPDES Information

The Hydrologic Simulation Program Fortran (HSPF) and EFDC models were calibrated using information for the 1994-1998 period, including NPDES facilities that were in existence at that time. The NPDES facilities were updated prior to the April 2005 TMDL. Additional information on the NPDES discharges has become available since issuance of the April 2005 TMDL and has been incorporated into this revised TMDL. The changes to the NPDES discharges are listed in Table D-5.

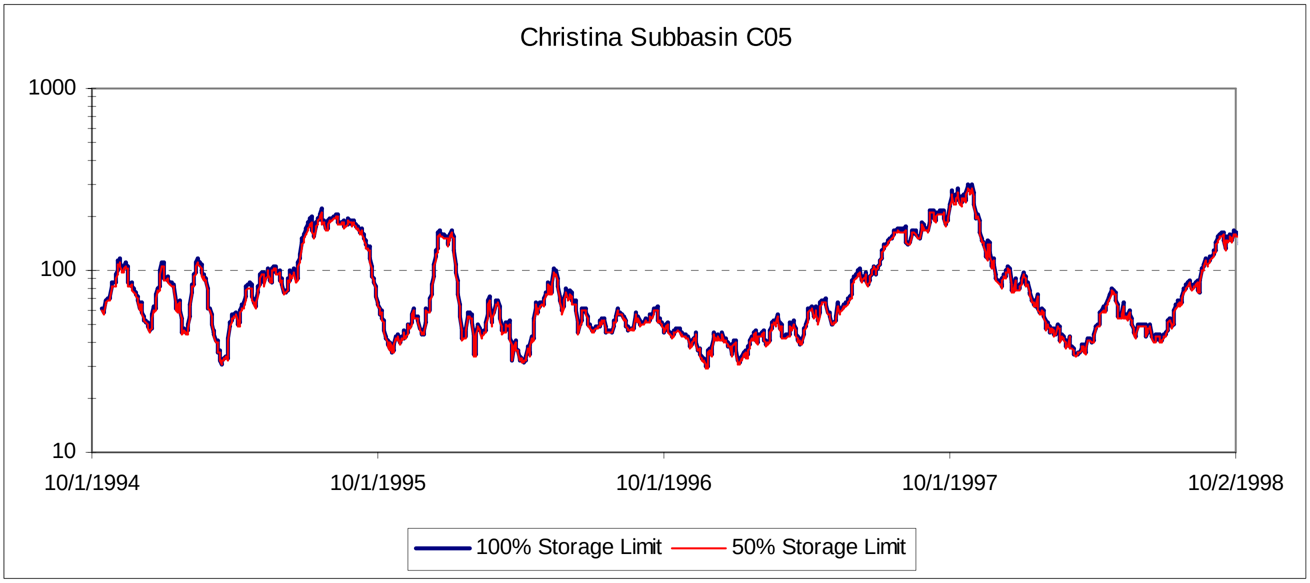
Table D-5. List of updated NPDES information for Christina River Basin

NPDES Permit	HSPF subbasin	Name	Description of Change
PA0012416	B03	PA American Water (Rock Run)	New owner (previously owned by Coatesville)
PA0011568-001	B05	ISG Plate LLC (Sucker Run, W. Br. Brandywine Cr.)	New owner (previously owned by Lukens Steel)

NPDES Permit	HSPF subbasin	Name	Description of Change
PA0011560-016	B05	ISG Plate LLC (Sucker Run, W. Br. Brandywine Cr.)	New owner (previously owned by Lukens Steel)
PA0055492	B10	Andrew and Gail Woods (Indian Run)	New owners (previously owned by John and Jane Topp
PA0051365	B11	PA American Water (E. Br. Brandywine Cr.)	New owner (previously owned by West Chester Area Municipal Authority)
PA0026531	B13	Downingtown Area WWTP (E. Br. Brandywine Cr.)	Flow increase from 7.134 to 7.500 mgd
PA0244031	B16	Chadds Ford Township (Brandywine Cr.)	Replaces PA0047252 (Pantos Corp.). Flow increase from 0.07 to 0.15 mgd
PA0055085	B16	Nancy Winslow (Brandywine Cr.)	Active during 1994-98 calibration period. No longer exists.
PA0036161	B20	Lincoln Crest MHP (Buck Run)	Active during 1994-98 calibration period. No longer exists.
PA0053937	B29	William and Patricia Kratz (Broad Creek)	New owners (previously owned by Ralph and Gayla Johnson)
PA0056952	W04	Sun Company, Inc. (E. Br. White Clay Cr.)	Active during 1994-98 calibration period. No longer exists.
PA0052019	W04	Avon Grove Trailer Court (E. Br. White Clay Cr.)	Active during 1994-98 calibration period. No longer exists.
PA0029343	W06	Chatham Acres (E.Br. White Clay Cr.)	Active during 1994-98 calibration period. No longer exists.
PA0057720-001	R01	Sunny Dell Foods, Inc. (W. Br. Red Clay Cr.)	Flow increase from 0.05 to 0.072 mgd

D.5 Sensitivity to *Enterococci* Storage Limit

During dry periods, *enterococci* bacteria accumulate at a specified rate on the land surface and eventually reach a maximum accumulated limit, called the storage limit in the HSPF model. A rain event following a dry period then washes the accumulated bacteria from the land surfaces into the receiving streams. During model calibration, the *enterococci* storage limit was set to 15 times the accumulation rate based on previous modeling experience. As a sensitivity test, the storage limit was reduced by 50% to evaluate whether this parameter would have a significant impact on model results. The test indicated the resulting *enterococci* concentrations would be reduced by only about 3% on average as a result of a 50% reduction in *enterococci* storage limit. The time series of model concentrations for the baseline run in HSPF subbasin C05 (Little Mill Creek) indicates that both the 100% and 50% storage limit scenarios are nearly identical (see Figure D-2). Since the model was relatively insensitive to a large reduction in the storage limit parameter, no change to that parameter was made for this revised TMDL model application.



D.6 EFDC Model Calibration Results

Following the updates to the CSO loading described in section D.1, the addition of Little Mill Creek described in section D.3, and the changes to the NPDES facilities described in section D.4, the EFDC *enterococci* bacteria model was recalibrated. Model-data agreement was visually assessed by use of probability distributions for the six monitoring stations listed in Table D-6. The model-data probability distribution graphics are presented in Figures D-3 through D-8. The model probability distribution was derived using the daily average results from the four-year calibration period (October 1, 1994, through October 1, 1998) and was comprised of 1461 data points. The probability distributions for the monitoring stations were based on available monitoring data from July 1986 through November 1998. Sample sizes ranged from 35 data points at station 106291 to 125 data points at station 104011 (see Table D-6). Considering the discrepancy between the model and observed sample sizes, the model results compare reasonably well with the observations.

Table D-6. Locations of Monitoring stations used for EFDC model calibration

Monitoring Station	Sample Size	EFDC grid cell [I,J]	Description
104011	125	[43,55]	Brandywine Creek, footbridge in Brandywine Park
106281	37	[54,20]	Little Mill Creek at Atlantic Avenue
106291	35	[55,13]	Christina River, railroad bridge near Port of Wilmington
106011	117	[53,13]	Christina River, US Rt. 13 at Third Street bridge
106021	116	[47,13]	Christina River, Rt. 141 drawbridge in Newport, DE
106031	97	[34,13]	Christina River at Smalleys Dam

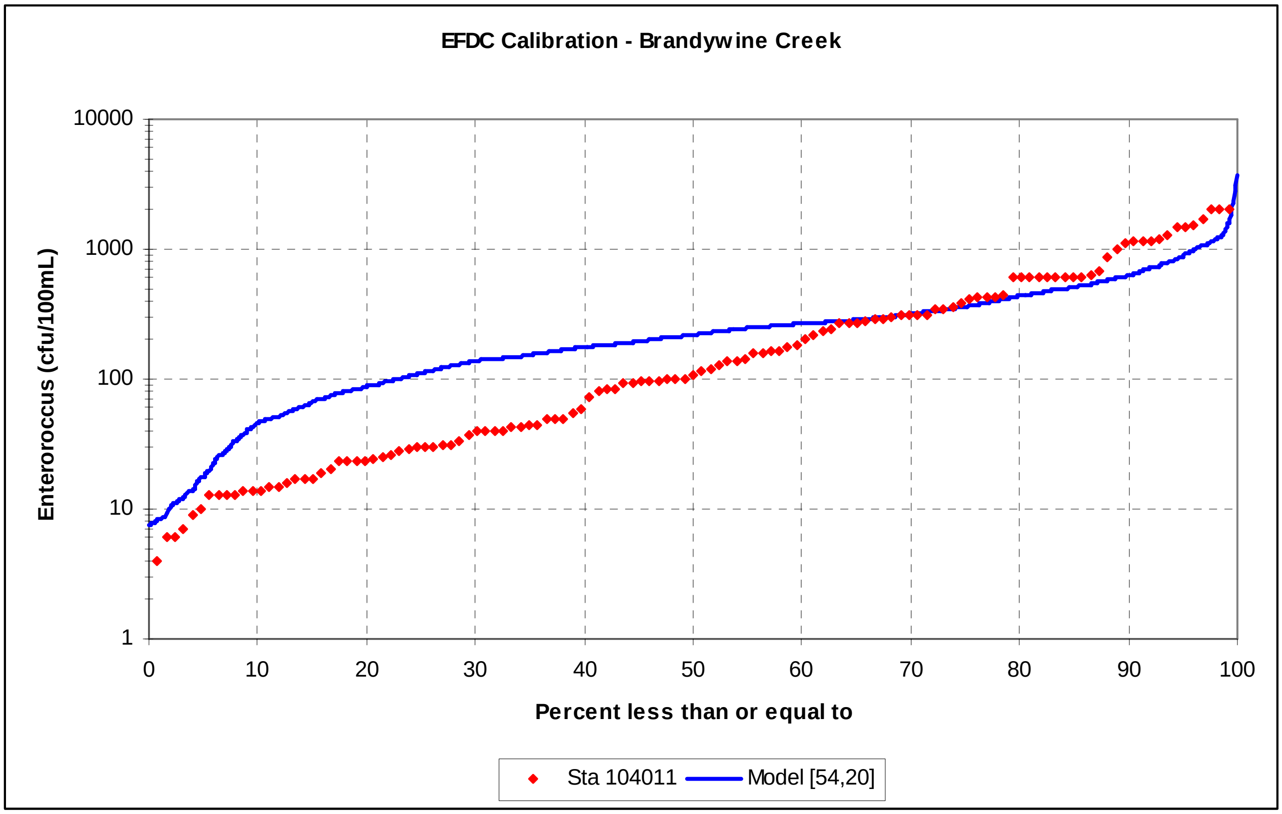


Figure D-3. Model-data probability distribution at station 104011, Brandywine Creek

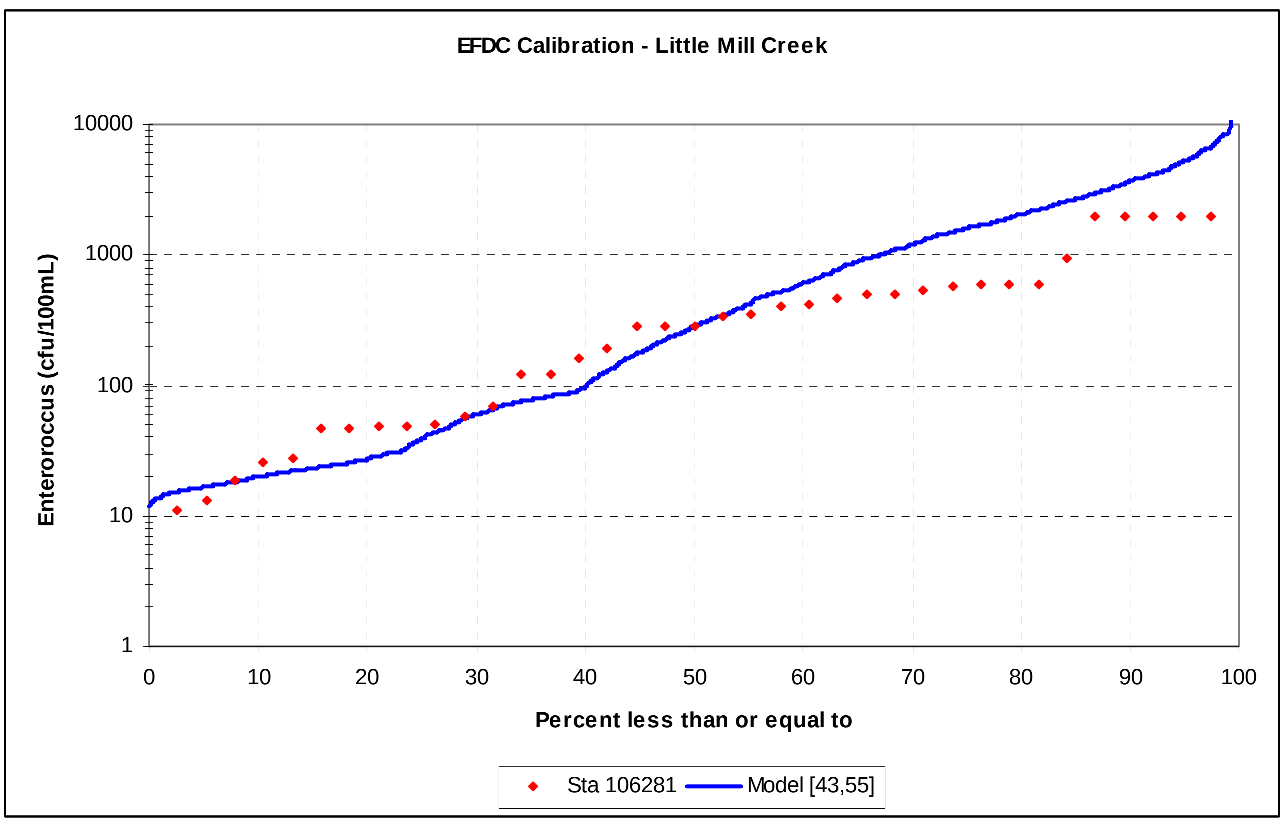


Figure D-4. Model-data probability distribution at station 106281, Little Mill Creek

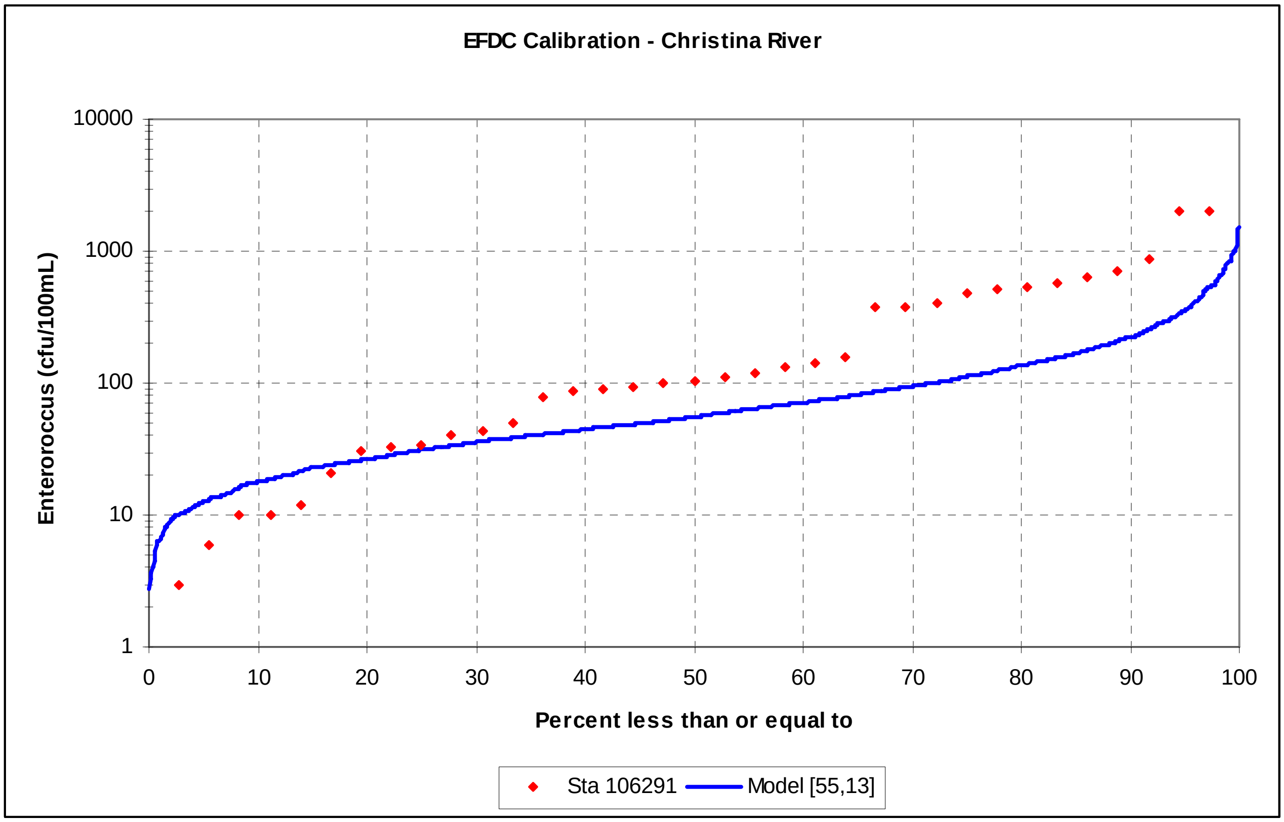


Figure D-5. Model-data probability distribution at station 106291, Christina River

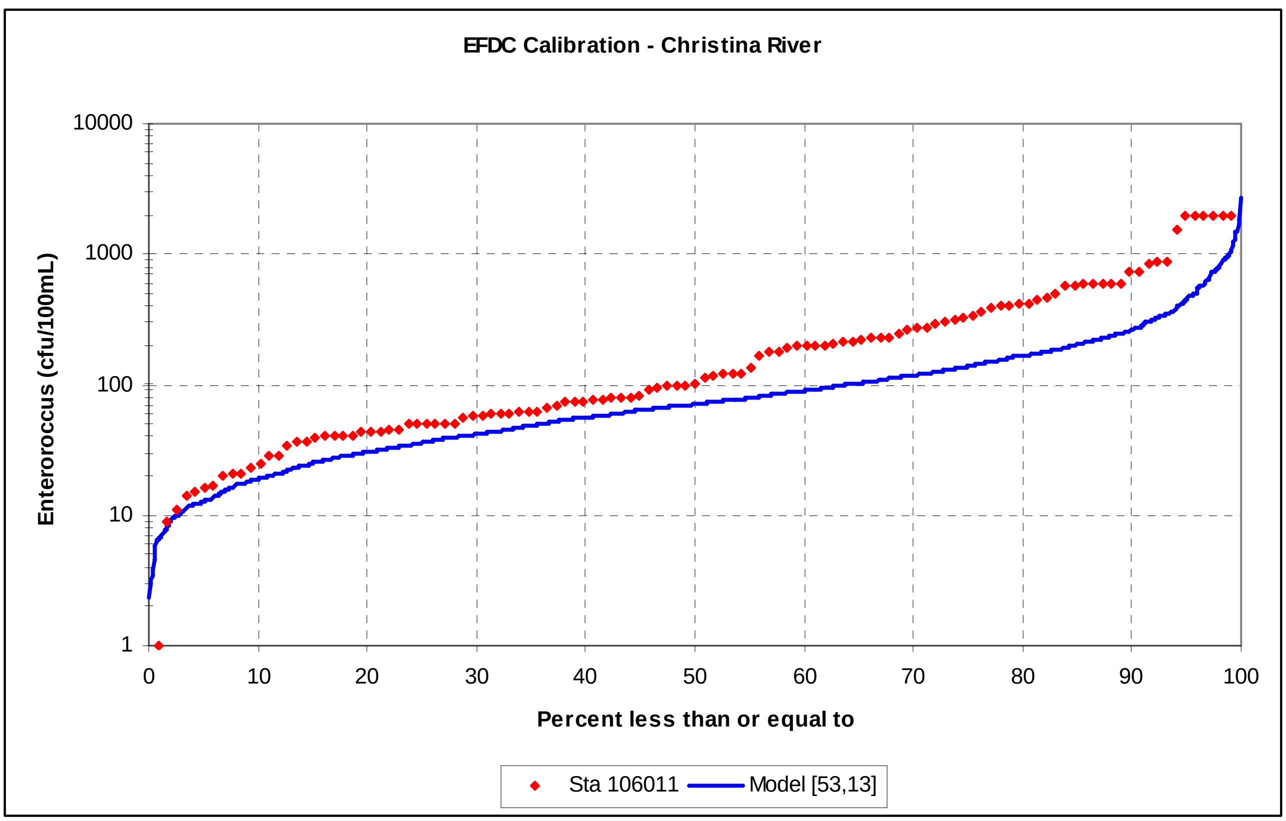


Figure D-6. Model-data probability distribution at station 106011, Christina River

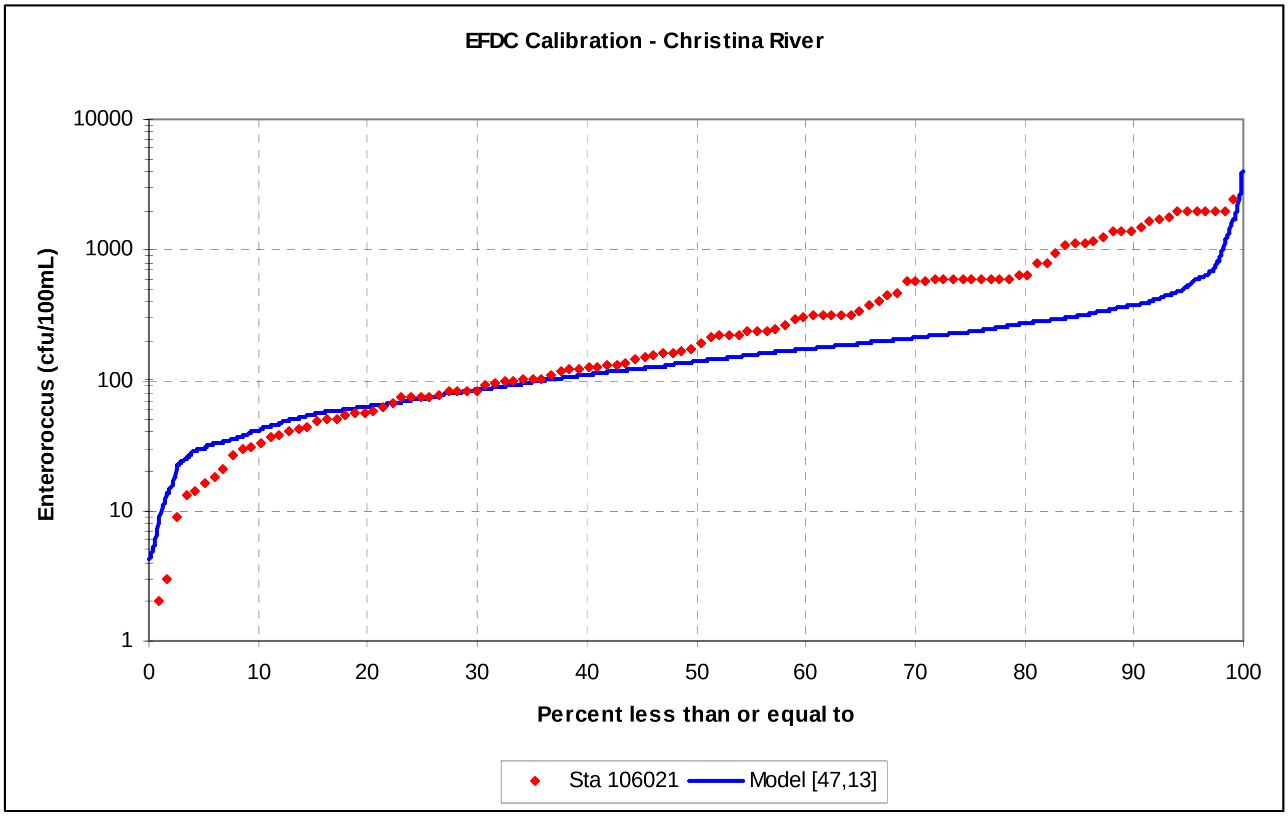


Figure D-7. Model-data probability distribution at station 106021, Christina River

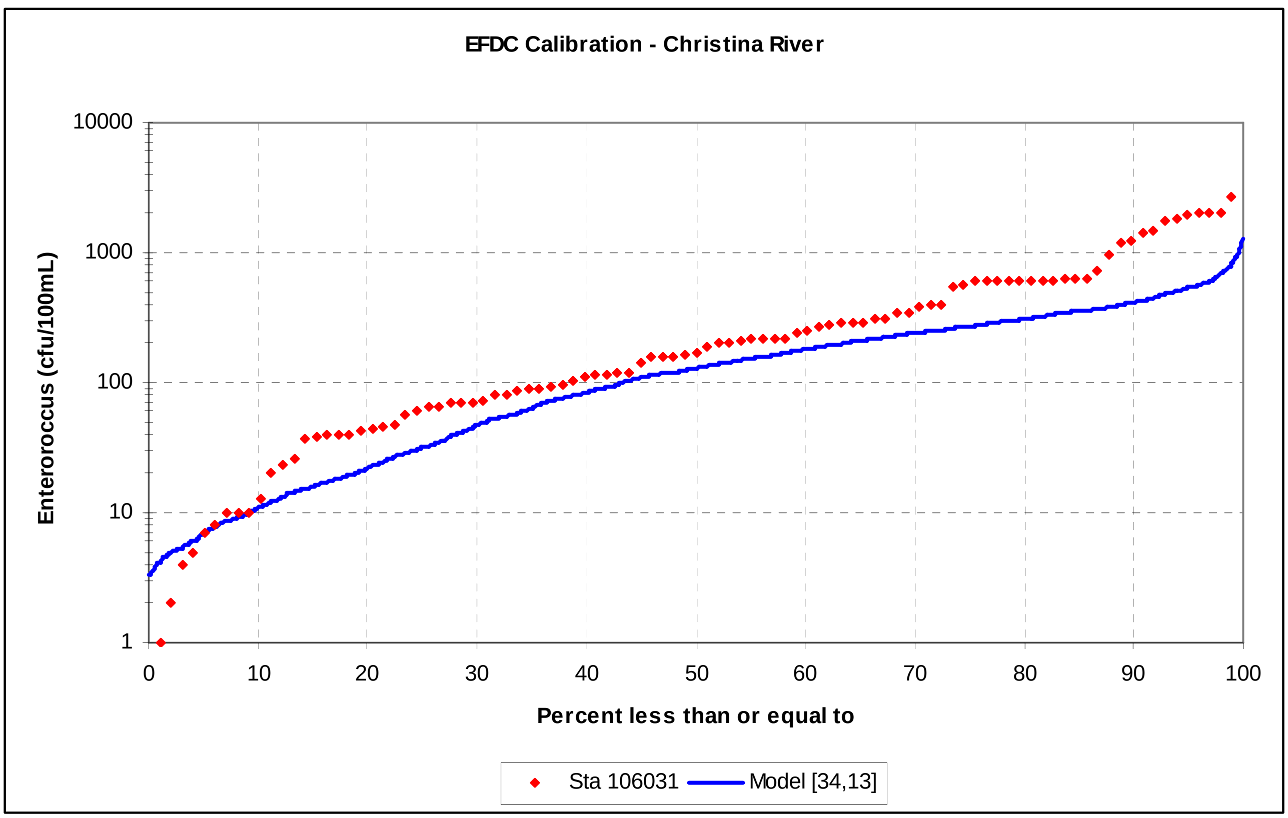


Figure D-8. Model-data probability distribution at station 106031, Christina River

D.7 Baseline and TMDL *Enterococci* Model Results

The EFDC model results for the baseline and revised *enterococci* TMDL are shown in Figures D-9 to D-14. These graphs represent the longitudinal transect of the three impaired water segments (Christina River, lower Brandywine Creek, and Little Mill Creek). The river mile notation for each stream reach is defined in Table D-7. The model results in Figures D-9, D-10, and D-11 represent the maximum of the running 30-day geometric mean concentration at each model grid cell along a given transect. The 30-day geometric mean *enterococci* water quality standard (100 cfu/100mL) is also shown on each graph.

Table D-7. Stream reaches included in EFDC *enterococci* bacteria model

Stream Reach	River Mile at Mouth	River Mile at Upstream Extent
Christina River	74.2	89.6
Brandywine Creek	76.3	80.4
Little Mill Creek	79.8	82.6

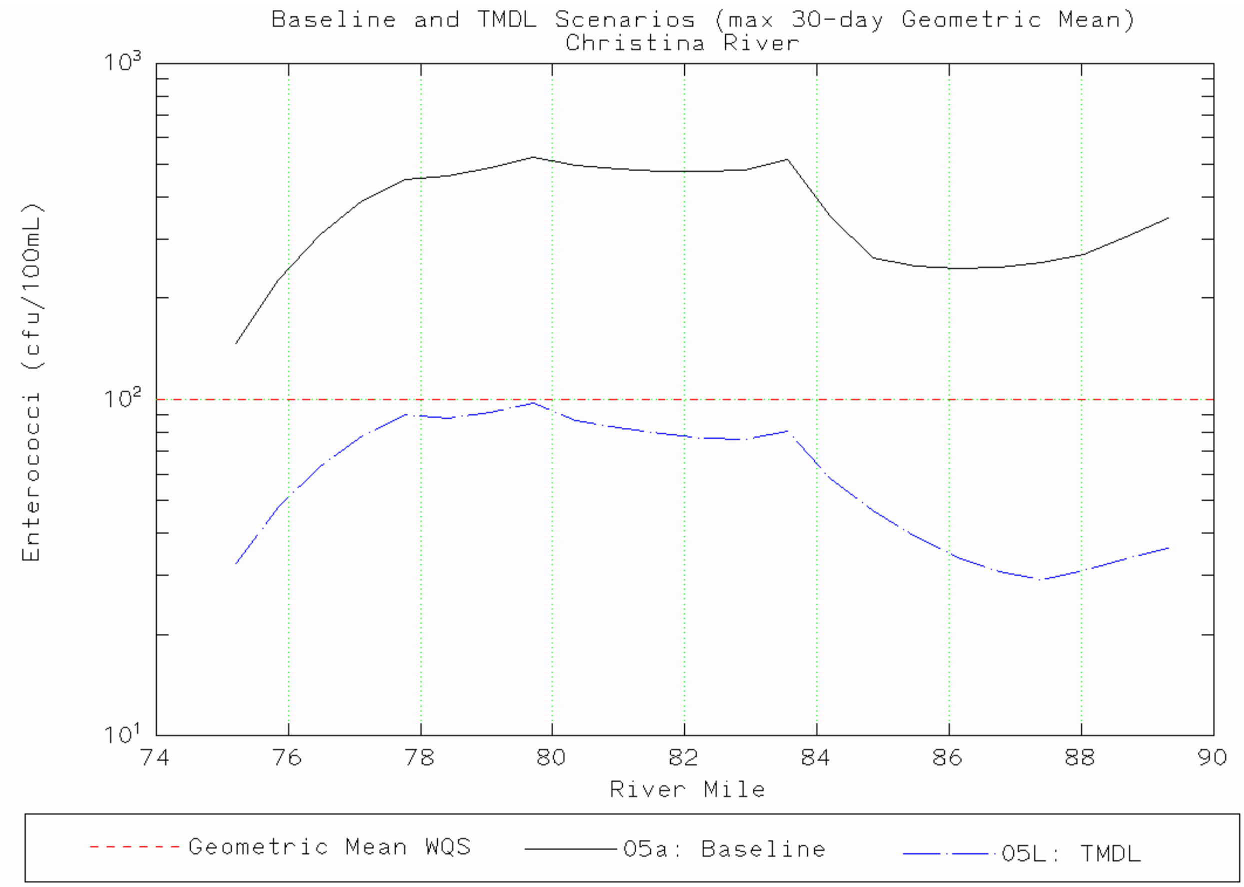


Figure D-9. Christina River, comparison to 30-day geometric mean WQS

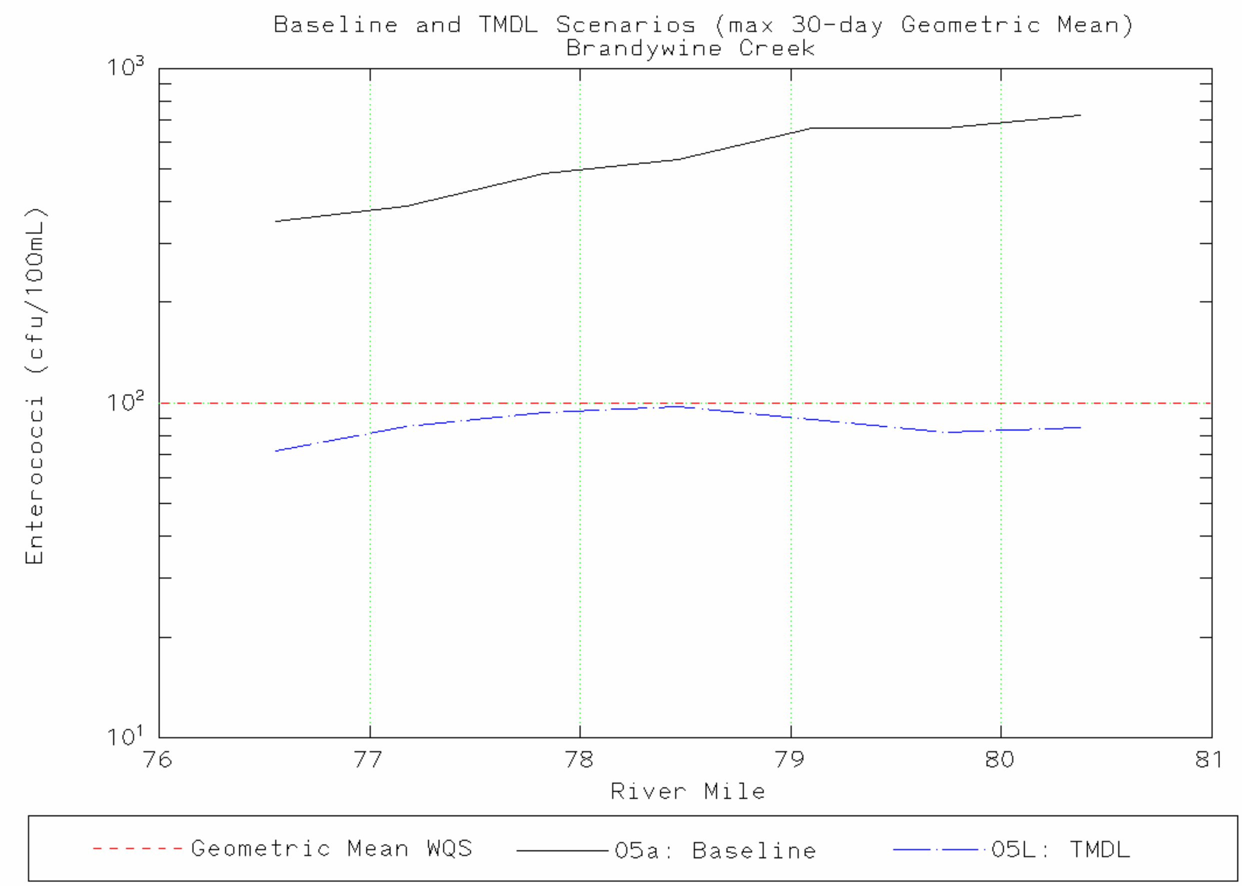


Figure D-10. Brandywine Creek, comparison to 30-day geometric mean WQS

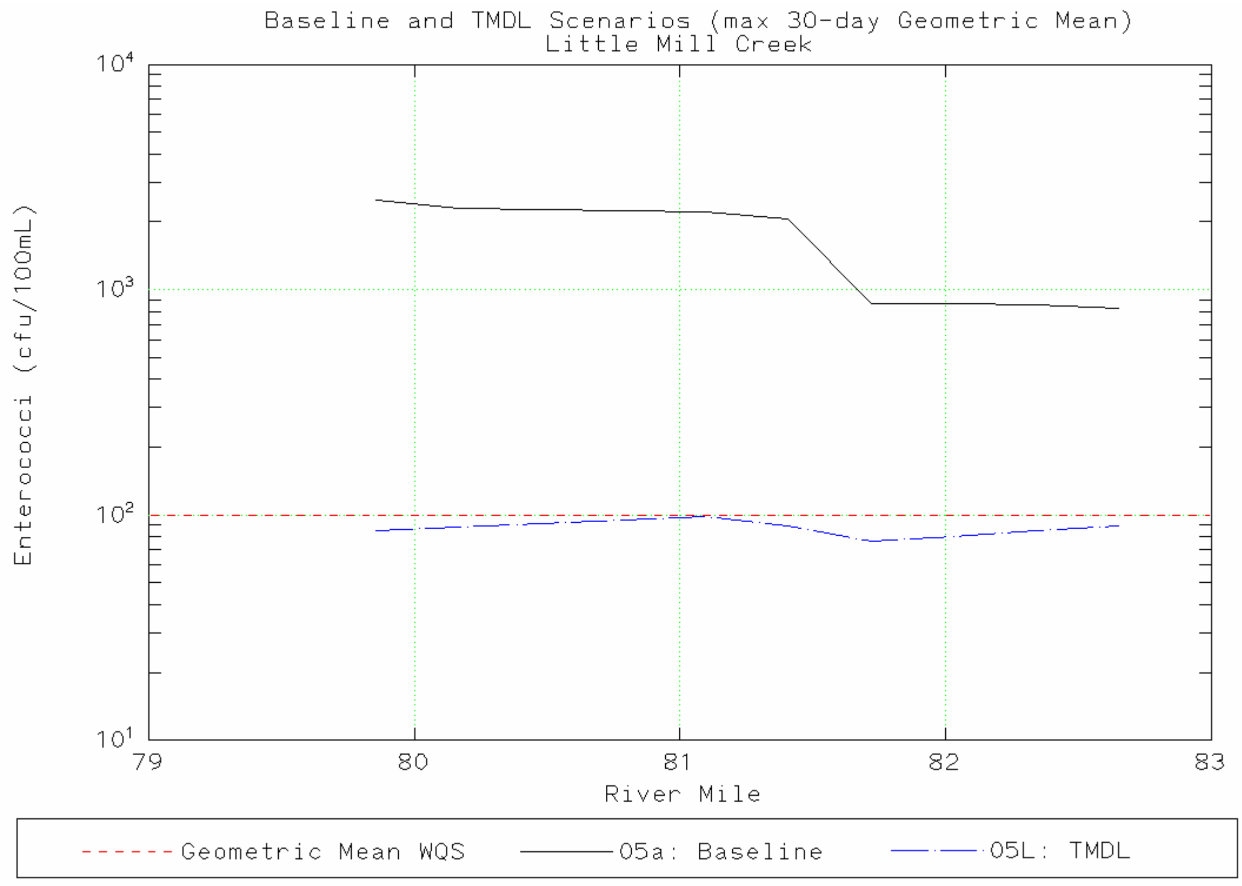


Figure D-11. Little Mill Creek, comparison to 30-day geometric mean WQS

Appendix E

Storm Water Permits
Sample Calculations

Permitted Storm Water Facility
Sample Calculations

A permitted industrial facility is located within the City of Wilmington west of I-495 and north of E. 12th Street in subbasin B34 (Figure 1-1). All of New Castle County and the City of Wilmington are covered by MS4 permits. The facility's storm water WLAs should be based on the MS4 unit area loads.

Storm water permits are not impacted by the Christina River Basin low-flow TMDLs. Pollutants of concern for storm water permits in Delaware are bacteria, total nitrogen (TN), and total phosphorus (TP). little

Table 2-3 describes land use categories. "Urban" land use is considered appropriate for this facility.

From Table C-12b, *enterococci* baseline loads, the tidal Brandywine Creek – Wilmington (B34) urban area average annual baseline load is 1.40E+12 colony forming units (cfu)/year.

From Table C-12a, *enterococci* allocations, the tidal Brandywine Creek – Wilmington (B34) urban area average annual allocation is 1.36E+12 cfu/year.

From Table C-12c, *enterococci* percent reductions required, the tidal Brandywine Creek – Wilmington (B34) reduction is 3.05%.

From Table C-1, land use areas for MS4 municipalities, the tidal Brandywine Creek (B34) urban area is Wilmington 1086.40 acres. The average annual *enterococci* unit load is equal to Wilmington B34 urban average annual allocation divided by the Wilmington B34 urban area or 1.29E+09 cfu/acre/year. The permit writer just needs to multiply the unit area load by the area of interest to obtain the storm water average annual loads.

APPENDI X F

TMDLs, WLAs and LAs in Units per Day

Table 4-1. Fecal coliform bacteria TMDL allocations for the Christina River Basin

Subbasin	Baseline Load (cfu/day)			TMDL Allocation (cfu/day)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
Swimming Season (May 1 - Sep 30)									
Red Clay (R01)	1.25E+10	1.94E+13	1.94E+13	5.82E+08	1.43E+12		7.51E+10	1.50E+12	92.28%
Red Clay (R02)	4.02E+10	8.79E+12	8.83E+12	8.49E+09	7.55E+11		4.02E+10	8.04E+11	90.90%
Red Clay (R03)	8.69E+09	9.57E+12	9.58E+12	1.16E+09	8.04E+11		4.24E+10	8.48E+11	91.15%
White Clay (W04)		1.15E+13	1.15E+13		6.93E+11		3.65E+10	7.30E+11	93.66%
White Clay (W07)	5.02E+08	2.09E+11	2.10E+11	5.02E+08	1.92E+10		1.04E+09	2.08E+10	90.10%
Non-swimming Season (Oct 1 - Apr 30)									
Red Clay (R01)	8.91E+09	3.05E+13	3.05E+13	4.16E+09	1.38E+13		7.26E+11	1.45E+13	52.40%
Red Clay (R02)	2.87E+10	1.62E+13	1.62E+13	6.07E+10	7.48E+12		3.97E+11	7.94E+12	51.12%
Red Clay (R03)	6.21E+09	1.76E+13	1.76E+13	8.28E+09	8.19E+12		4.32E+11	8.63E+12	51.08%
White Clay (W04)		1.19E+13	1.19E+13		1.13E+13		5.95E+11	1.19E+13	0.16%
White Clay (W07)	4.97E+08	3.29E+11	3.29E+11	3.59E+09	3.08E+11		1.64E+10	3.29E+11	0.15%

Table 4-2. Fecal coliform TMDL allocations for MS4 municipalities

Town	Sub-Watershed	Non-Swimming Season Baseline (cfu /day)	Non-Swimming Season TMDL (cfu/day)	Percent Reduction
East Marlborough TWP	Red Clay	2.83E+13	1.36E+13	52.08%
Kennett Square Boro	Red Clay	2.60E+12	1.25E+12	51.95%
Kennett TWP	Red Clay	1.74E+13	8.48E+12	51.26%
New Garden TWP	Red Clay	1.31E+13	6.38E+12	51.52%
Avondale Boro	White Clay	2.78E+11	2.63E+11	5.06%
London Grove TWP	White Clay	1.06E+13	1.01E+13	5.04%
New Garden TWP	White Clay	3.14E+11	2.98E+11	5.15%
West Grove Boro	White Clay	5.86E+11	5.57E+11	5.04%

Town	Sub-Watershed	Non-Swimming Season Baseline (cfu /day)	Non-Swimming Season TMDL (cfu/day)	Percent Reduction
East Marlborough TWP	Red Clay	2.83E+13	1.36E+13	52.08%
Kennett Square Boro	Red Clay	2.60E+12	1.25E+12	51.95%
Kennett TWP	Red Clay	1.74E+13	8.48E+12	51.26%
New Garden TWP	Red Clay	1.31E+13	6.38E+12	51.52%
Avondale Boro	White Clay	2.78E+11	2.63E+11	5.06%
London Grove TWP	White Clay	1.06E+13	1.01E+13	5.04%
New Garden TWP	White Clay	3.14E+11	2.98E+11	5.15%

Table 4-3. Septic system TMDL allocations of fecal coliform bacteria

Sub-Watershed	Estimated number of septic systems	Swimming Season Baseline (cfu/day)	Swimming Season TMDL (cfu/day)	Percent Reduction
Red Clay (R01)	553	4.09E+11	8.40E+08	99.79%
Red Clay (R02)	460	3.39E+11	7.00E+08	99.79%
Red Clay (R03)	779	5.75E+11	1.18E+09	99.79%
White Clay (W04)	224	1.65E+11	3.40E+08	99.79%
White Clay (W07)	42	3.13E+10	6.42E+07	99.79%
Sub-Watershed	**Estimated number of septic systems**	**Non Swimming Season Baseline (cfu/day)**	**Non Swimming Season TMDL (cfu/day)**	**Percent Reduction**
Red Clay (R01)	553	4.19E+11	8.33E+08	99.80%
Red Clay (R02)	460	3.48E+11	6.90E+08	99.80%
Red Clay (R03)	779	5.90E+11	1.17E+09	99.80%
White Clay (W04)	224	1.70E+11	3.36E+08	99.80%
White Clay (W07)	42	3.20E+10	6.33E+07	99.80%

Table 4-4. State line allocations for Christina River Basin *enterococci* bacteria TMDL

Location	Baseline (cfu/day)	Allocation (cfu/day)	Reduction
Allocations at the Pennsylvania-Delaware State Line			
Brandywine Cr. (at PA-DE Line)	8.55E+12	5.51E+11	93.56%
White Clay Cr. (at PA-DE Line)	1.88E+12	5.64E+11	70.03%
Red Clay Cr. (at PA-DE Line)	7.07E+11	2.96E+11	58.05%
Burroughs Run (at PA-DE Line)	5.07E+10	3.56E+10	29.32%
Allocations at the Maryland-Delaware State Line			
Christina River (at MD-DE Line)	5.10E+10	2.12E+10	58.40%

Table 4-5. Summary of CSO *enterococci* baseline loads and WLA TMDL

Location	CSO ID Numbers	Baseline (cfu/day)	WLA (cfu/day)	Reduction
Little Mill Creek (C05)	27, 28, 29	4.27E+11	1.01E+11	2.09E-03
Christina River (C09)	5, 6, 7, 9a, 9c, 10, 11, 12, 13, 14, 15, 16, 17, 30	9.70E+11	2.67E+11	1.99E-03
Brandywine Creek (B34)	3, 4a, 4b, 4c, 4d, 4e, 4f, 18, 19, 20, 21a, 21b, 21c, 22b, 22c, 23, 24, 25, 26, RR	1.89E+12	6.99E+11	1.73E-03
Total CSO Loads	-	3.29E+12	1.07E+12	1.85E-03

Table 4-6. Allocations for Christina River Basin *enterococci* bacteria TMDL

Location	Baseline (cfu/yr)	WLA (cfu/day)	LA (cfu/day)	MOS (cfu/day)	TMDL (cfu/day)	Reduction
Brandywine Creek in Delaware						
Brandywine Cr. (B18)	3.04E+11	0.00E+00	1.52E+10	8.00E+08	1.60E+10	94.75%
Brandywine Cr. (B19)	1.53E+11	9.45E+07	1.73E+10	9.10E+08	1.83E+10	88.00%
White Clay Creek in Delaware						
White Clay Cr. (W11)	1.12E+11	0.00E+00	2.73E+10	1.44E+09	2.88E+10	74.23%
White Clay Cr. (W12)	4.08E+11	1.14E+08	4.90E+10	2.59E+09	5.18E+10	87.31%
White Clay Cr. (W13)	8.25E+10	0.00E+00	1.07E+10	5.64E+08	1.13E+10	86.34%
White Clay Cr. (W14)	1.05E+11	0.00E+00	1.09E+10	5.75E+08	1.15E+10	89.00%
White Clay Cr. (W15)	7.81E+10	0.00E+00	2.45E+10	1.29E+09	2.58E+10	66.90%
White Clay Cr. (W16)	2.79E+11	0.00E+00	3.62E+10	1.90E+09	3.81E+10	86.41%
White Clay Cr. (W17)	6.60E+11	0.00E+00	9.15E+10	4.82E+09	9.64E+10	85.43%
Red Clay Creek in Delaware						
Red Clay Cr. (R04)	1.61E+11	8.22E+09	2.33E+10	1.23E+09	3.29E+10	79.67%
Red Clay Cr. (R05)	6.16E+10	5.67E+07	2.16E+10	1.14E+09	2.28E+10	63.01%
Red Clay Cr. (R06)	4.14E+10	1.70E+06	2.77E+10	1.46E+09	2.93E+10	29.32%
Red Clay Cr. (R07)	1.66E+10	0.00E+00	4.77E+09	2.51E+08	5.01E+09	69.75%
Red Clay Cr. (R08)	2.08E+11	1.33E+09	2.15E+10	1.13E+09	2.39E+10	88.54%
Red Clay Cr. (R09)	7.89E+10	0.00E+00	7.92E+09	4.16E+08	8.33E+09	89.44%
Christina River and Tidal Brandywine Creek						
Christina River (C01)	9.62E+10	0.00E+00	3.48E+10	1.83E+09	3.67E+10	61. 90%
Christina River (C02)	2.24E+11	0.00E+00	6.77E+10	3.56E+09	7.12E+10	68.15%
Christina River (C03)	1.82E+11	0.00E+00	2.56E+10	1.35E+09	2.70E+10	85.18%
Christina River (C04)	2.38E+11	0.00E+00	1.84E+10	9.70E+08	1.94E+10	91.84%
Christina River (C05) *	6.05E+11	1.01E+11	1.33E+10	6.99E+08	1.15E+11	81.01%
Christina River (C06)	2.04E+11	0.00E+00	4.52E+10	2.38E+09	4.77E+10	76.66%
Christina River (C07)	1.96E+11	0.00E+00	2.96E+10	1.56E+09	3.12E+10	84.08%
Christina River (C08)	3.51E+11	0.00E+00	4.58E+10	2.41E+09	4.82E+10	86.29%
Christina River (C09) *	1.87E+12	2.67E+11	9.70E+10	5.12E+09	3.70E+11	80.30%
Tidal Brandywine Cr. (B34) *	2.25E+12	6.99E+11	3.64E+10	1.91E+09	7.34E+11	67.38%
Sunset Lake	1.75E+11	0.00E+00	3.86E+10	2.04E+09	4.08E+10	76.66%
Beck's Pond	1.72E+11	0.00E+00	2.59E+10	1.37E+09	2.73E+10	84.08%
Smalley's Pond	3.51E+11	0.00E+00	4.58E+10	2.41E+09	4.82E+10	86.29%
* CSO loads are included in the Baseline and WLA in these subbasins.						

Table 4-7. Allocations for Christina River Basin sediment TMDL

Subbasin	Baseline Load (ton/day)			TMDL Allocation (ton/day)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
Brandywine Creek									
B01	0.0816	2.1261	2.2078	0.0816	1.1347	0.2324	0.0762	1.5250	30.90%
B04	0.0000	0.1168	0.1168	0.0000	0.0596	-	0.0032	0.0628	46.20%
B05	0.6740	3.5032	4.1772	0.6740	1.1555	-	0.0963	1.9258	53.90%
B06	0.0002	0.9321	0.9323	0.0002	0.6009		0.0316	0.6328	32.10%
B09	0.0001	1.3667	1.3668	0.0001	0.4952	0.5993	0.0576	1.1522	15.70%
B14	0.2187	4.4863	4.7050	0.2187	1.7310	-	0.1026	2.0523	56.40%
B15	0.0252	3.3277	3.3528	0.0252	1.3955	-	0.0748	1.4955	55.40%
B20	0.0046	3.0673	3.0719	0.0046	1.7697	0.1343	0.1005	2.0091	34.60%
B31	0.0001	3.2586	3.2587	0.0001	1.2390	-	0.0652	1.3044	60.00%
White Clay Creek									
W01	0.0008	14.6673	14.6681	0.0008	8.0553	-	0.4240	8.4801	42.20%
W02	0.0313	21.9156	21.9468	0.0313	6.2561	1.2307	0.3957	7.9138	63.90%
W03	0.0000	8.6809	8.6809	0.0000	5.0001	-	0.2632	5.2633	39.40%
W04	0.0000	14.2135	14.2135	0.0000	4.7196	0.1605	0.2589	5.1390	63.80%
W06	0.0078	22.2304	22.2381	0.0078	4.9187	1.8290	0.3556	7.1111	68.00%
W07	0.0081	3.8756	3.8838	0.0081	1.0784	-	0.0572	1.1437	70.60%
W08	0.0060	12.6214	12.6274	0.0060	5.8817	-	0.3099	6.1976	50.90%
W09	0.0001	7.6956	7.6958	0.0001	5.3938	-	0.2839	5.6779	26.20%
Red Clay Creek									
R01	0.0232	23.0796	23.1027	0.0232	9.5901	0.9022	0.5533	11.0688	52.10%
R02	0.1377	17.1291	17.2668	0.1377	7.6862	-	0.4118	8.2356	52.30%
R03	0.0188	19.7757	19.7944	0.0188	10.3050	-	0.5434	10.8672	45.10%

Table 4-8. Sediment allocations for towns in Brandywine Creek Watershed

Township	Baseline (ton/day)	TMDL (ton/day)	Percent Reduction
BIRMINGHAM TWP	0.85153	0.35712	58.06%
COATESVILLE CITY	0.63367	0.21852	65.52%
EAST BRADFORD TWP	3.24658	1.27992	60.58%
EAST FALLOWFIELD TWP	2.20063	1.16827	46.91%
EAST MARLBOROUGH TWP	1.00466	0.38203	61.98%
HIGHLAND TWP	1.05425	0.65441	37.93%
HONEY BROOK BORO	0.05638	0.03625	35.70%
HONEY BROOK TWP	2.22970	1.53085	31.34%
MODENA BORO	0.07660	0.03414	55.43%
NEWLIN TWP	0.39501	0.16326	58.67%
PARKESBURG BORO	0.14277	0.08863	37.93%
PENNSBURY TWP	0.31227	0.11912	61.85%
POCOPSON TWP	2.24989	0.87888	60.94%
SADSBURY TWP	0.79378	0.47159	40.59%
THORNBURY TWP	0.22512	0.09441	58.06%
VALLEY TWP	1.32915	0.45107	66.06%
WALLACE TWP	0.05956	0.04770	19.92%
WEST BRADFORD TWP	0.77595	0.33315	57.07%
WEST CALN TWP	0.18707	0.11800	36.92%
WEST GOSHEN TWP	1.26389	0.49455	60.87%

Table 4-9. Sediment allocations for towns in Red Clay Creek Watershed

Township	Baseline (ton/day)	TMDL (ton/day)	Percent Reduction
EAST MARLBOROUGH TWP	24.0861	11.4883	52.30%
KENNETT SQUARE BORO	2.3016	1.1107	51.74%
KENNETT TWP	18.4976	9.0741	50.94%
NEW GARDEN TWP	12.9032	5.8047	55.01%

Table 4-10. Sediment allocations for towns in White Clay Creek Watershed

Township	Baseline (ton/day)	TMDL (ton/day)	Percent Reduction
AVONDALE BORO	1.2703	0.3836	69.80%
FRANKLIN TWP	11.5628	6.3175	45.36%
LONDON BRITAIN TWP	7.2182	4.4396	38.50%
LONDON GROVE TWP	37.3050	13.2680	64.43%
NEW GARDEN TWP	18.4836	8.1826	55.73%
NEW LONDON TWP	5.2438	2.7633	47.30%
PENN TWP	9.8213	3.8638	60.66%
WEST GROVE BORO	1.5405	0.5278	65.74%