Revisions to Total Maximum Daily Loads for Nutrient and Low Dissolved Oxygen Under High-Flow Conditions Christina River Basin, Pennsylvania, Delaware, and Maryland

September 2006

U.S. Environmental Protection Agency
Region 3
1650 Arch Street
Philadelphia, Pennsylvania

Errata

4/30/2007

The2005 and 2006 Total Maximum Daily Load of Nutrients and Low Dissolved Oxygen Under High-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland, *established April 8, 2005, and revised September 26, 2006, by EPA was not intended to modify wasteload allocations (WLAs)established in the* Total Maximum Daily Load of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland, *to the two WWTPs discharging to the West Branch Christina River in Maryland. The two WWTPs are:*

Highlands WWTP MD0065145
Meadowview WWTP MD0022641

The corrected portions of summary tables are shown in italics below.

Total nitrogen and total phosphorus allocations at MD-DE state line

Location	Baseline Load (kg/day)	Maryland Allocation (kg/day)	Reduction
Total Nitrogen			
Christina River West Branch (MD-DE Line)	*96.5*	26.2	*72.8%*
Total Phosphorus			
Christina River West Branch (MD-DE Line)	3.8	2.0	47.5%

TMDL summary for Christina River Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)					Percent
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	Reduction
Total Nitrogen									
C01	*57.781*	53.686	*110.467*	*57.781*	2.634	7.566	0.537	*67.718*	*38.9%*
C02	0.000	78.387	78.387	0.000	48.752	25.715	3.919	78.387	0.0%
C03	0.000	20.367	20.367	0.000	19.349	0.000	1.018	20.367	0.0%
C04	0.000	17.290	17.290	0.000	16.426	0.000	0.865	17.290	0.0%
C05	2.606	12.006	14.612	0.618	11.406	0.000	0.600	12.624	13.6%
C06	0.000	42.959	42.959	0.000	38.507	2.304	2.148	42.959	0.0%
C07	0.000	24.946	24.946	0.000	23.699	0.000	1.247	24.946	0.0%
C08	0.000	41.127	41.127	0.000	39.071	0.000	2.056	41.127	0.0%
C09	5.931	72.021	77.952	1.631	68.420	0.000	3.601	73.652	5.5%
Becks Pond	0.000	38.683	38.683	0.000	34.954	1.795	1.934	38.683	0.0%
Sunset Pond	0.000	22.557	22.557	0.000	21.429	0.000	1.128	22.557	0.0%

WLA summary for Christina River Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN Kg/day	TP Kg/day	TN Kg/day	TP Kg/day	TN	TP
C01	MD0022641	0.7000	*52.996*	2.650	*52.996*	2.650	0.0%	0.0%
C01	MD0065145	0.0500	*3.785*	0.189	*3.785*	0.189	0.0%	0.0%
C05	(DE CSO)	See Baseline and WLA nitrogen and phosphorus loads for CSO discharges table						
C09	(DE CSO)	See Baseline and WLA nitrogen and phosphorus loads for CSO discharges table						

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Executive Summary

Revisions to
Nutrient and Low dissolved Oxygen TMDL
Under High-Flow Conditions for
Christina River Watershed
Pennsylvania, Delaware, and Maryland

The Clean Water Act (CWA) requires a Total Maximum Daily Load (TMDL) be developed for those waterbodies identified as impaired by the states 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 WLAs plus the summation of the nonpoint source 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 Wasteload Allocations (WLAs) and Load Allocations (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.

The Pennsylvania Department of Environment Protection (PADEP) identified waterbodies within Pennsylvania's portion of the Christina River Watershed as impaired by nutrients, organic enrichment, or low dissolved oxygen, 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 nutrients or low dissolved oxygen. Maryland's Department of the Environment (MDE) 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. Applicable use designations and dissolved oxygen (DO) criteria are shown in Table 1-5 and a summary of nutrient criteria is shown in Table 1-6.

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 (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 (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 nutrients.

Total nitrogen and total phosphorus allocations at PA-DE state line

Location	Baseline Load (kg/day)	Pennsylvania Allocation (kg/day)	Reduction
Total Nitrogen			
Brandywine Creek (at PA-DE Line)	6849.8	3663.8	46.5%
White Clay Creek (at PA-DE Line)	956.2	685.0	28.4%
Red Clay Creek (at PA-DE Line)	466.7	320.4	31.3%
Burroughs Run (at PA-DE Line)	43.4	43.4	0.0%
Total Phosphorus			
Brandywine Creek (at PA-DE Line)	423.8	250.8	40.8%
White Clay Creek (at PA-DE Line)	110.6	65.9	40.4%
Red Clay Creek (at PA-DE Line)	62.8	17.2	72.6%
Burroughs Run (at PA-DE Line)	0.8	0.8	0.0%

Total nitrogen and total phosphorus allocations at MD-DE state line

Location	Baseline Load (kg/day)	Maryland Allocation (kg/day)	Reduction
Total Nitrogen			
Christina River West Branch (MD-DE Line)	68.7	26.2	61.9%
Total Phosphorus			
Christina River West Branch (MD-DE Line)	3.8	2.0	47.5%

TMDL summary for Brandywine Creek Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)					Percent
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	Reduction
Total Nitrogen									
B01	31.559	362.174	393.733	31.559	170.416	36.023	10.865	248.863	36.8%
B02	0.000	114.369	114.369	0.000	65.191	0.000	3.431	68.622	40.0%
B03	2.167	89.226	91.393	2.167	67.779	8.510	4.015	82.471	9.8%
B04	0.000	5.369	5.369	0.000	5.101	0.000	0.268	5.369	0.0%
B05	558.690	77.512	636.202	558.690	34.049	10.133	2.325	605.197	4.9%
B06	0.156	123.362	123.518	0.156	80.940	1.095	4.318	86.509	30.0%
B09	0.078	252.455	252.533	0.078	97.148	99.515	10.351	207.092	18.0%
B10	3.721	252.455	256.176	3.721	179.343	17.320	10.351	210.735	17.7%
B17	1.013	83.890	84.903	1.013	43.626	30.491	3.901	79.031	6.9%
B18	0.000	103.795	103.795	0.000	98.605	0.000	5.190	103.795	0.0%
B19	0.946	64.711	65.657	0.946	61.475	0.000	3.236	65.657	0.0%
B32	0.000	29.001	29.001	0.000	24.796	0.000	1.305	26.101	10.0%
B33	1.799	95.092	96.891	1.799	80.541	0.763	4.279	87.382	9.8%
B34	11.443	33.958	45.401	4.107	32.260	0.000	1.698	38.065	16.2%
Total Phosphorus									
B01	6.360	6.920	13.280	6.360	3.256	0.688	0.208	10.512	20.8%
B02	0.000	2.185	2.185	0.000	1.245	0.000	0.066	1.311	40.0%
B03	0.540	16.229	16.769	0.540	12.328	1.548	0.730	15.146	9.7%
B04	0.000	0.988	0.988	0.000	0.939	0.000	0.049	0.988	0.0%
B05	35.524	14.615	50.139	35.524	6.420	1.911	0.438	44.293	11.7%
B06	0.040	25.254	25.294	0.040	16.570	0.224	0.884	17.718	30.0%
B09	0.020	3.849	3.869	0.020	1.481	1.517	0.158	3.176	17.9%
B10	0.429	3.848	4.277	0.429	2.734	0.264	0.158	3.585	16.2%
B17	0.221	7.508	7.729	0.221	3.904	2.729	0.349	7.203	6.8%
B18	0.000	8.586	8.586	0.000	8.157	0.000	0.429	8.586	0.0%
B19	0.189	2.376	2.565	0.189	2.257	0.000	0.119	2.565	0.0%
B32	0.000	2.147	2.147	0.000	1.836	0.000	0.097	1.933	10.0%
B33	0.115	1.729	1.844	0.115	1.465	0.014	0.078	1.672	9.3%
B34	1.966	2.843	4.809	0.730	2.701	0.000	0.142	3.573	25.7%

WLA summary for Brandywine Creek Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN kg/day	TP kg/day	TN kg/day	TP kg/day	TN	TP
B01	PA0036412	0.0550	2.682	0.559	2.682	0.559	0.0%	0.0%
B01	PA0044776	0.6000	28.799	5.781	28.799	5.781	0.0%	0.0%
B01	PA0057339	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B03	PA0052728	0.0004	0.036	0.015	0.036	0.015	0.0%	0.0%
B03	PA0055697	0.0490	2.131	0.525	2.131	0.525	0.0%	0.0%
B05	PA0011568-001	0.6400	14.045	1.029	14.045	1.029	0.0%	0.0%
B05	PA0011568-016	0.5045	23.868	0.811	23.868	0.811	0.0%	0.0%
B05	PA0026859	3.8500	466.237	29.508	466.237	29.508	0.0%	0.0%
B05	PA0036897	0.3900	54.54	4.176	54.54	4.176	0.0%	0.0%
B06	PA0053228	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B06	PA0053236	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B09	PA0054691	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B10	PA0050458	0.0351	1.724	0.188	1.724	0.188	0.0%	0.0%

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN kg/day	TP kg/day	TN kg/day	TP kg/day	TN	TP
B10	PA0050547	0.0375	1.841	0.201	1.841	0.201	0.0%	0.0%
B10	PA0055492	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B10	PA0057827	0.0050	0.078	0.02	0.078	0.02	0.0%	0.0%
B17	PA0053082	0.0206	1.013	0.221	1.013	0.221	0.0%	0.0%
B19	DE0021768	0.0250	0.947	0.189	0.947	0.189	0.0%	0.0%
B33	PA0012416	0.1400	1.643	0.075	1.643	0.075	0.0%	0.0%
B33	PA0052990	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B33	PA0056073	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B34	(DE CSO)	See Table 4-11						

TMDL summary for Red Clay Creek Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)					Percent
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	Reduction
Total Nitrogen									
R01	3.677	126.926	130.603	3.677	54.709	5.581	3.173	67.140	48.6%
R02	49.825	104.678	154.503	49.825	49.722	0.000	2.617	102.164	33.9%
R03	6.807	120.151	126.958	6.807	57.071	0.000	3.004	66.882	47.3%
R04	2.197	39.984	42.181	2.197	18.992	0.000	1.000	22.189	47.4%
R05	0.568	34.713	35.281	0.568	16.489	0.000	0.868	17.925	49.2%
R06	0.078	67.015	67.093	0.078	63.664	0.000	3.351	67.093	0.0%
R07	0.000	3.012	3.012	0.000	2.861	0.000	0.151	3.012	0.0%
R08	0.318	23.882	24.200	0.318	22.688	0.000	1.194	24.200	0.0%
R09	0.000	7.346	7.346	0.000	6.979	0.000	0.367	7.346	0.0%
Total Phosphorus									
R01	0.914	2.277	3.191	0.914	0.982	0.100	0.057	2.053	35.7%
R02	7.506	45.473	52.979	7.506	4.320	0.000	0.227	12.053	77.2%
R03	1.606	2.845	4.451	1.606	1.352	0.000	0.071	3.029	31.9%
R04	1.699	6.407	8.106	1.699	1.887	0.000	0.099	3.685	54.5%
R05	0.114	4.249	4.363	0.114	4.037	0.000	0.212	4.363	0.0%
R06	0.020	1.269	1.289	0.020	1.206	0.000	0.063	1.289	0.0%
R07	0.000	0.424	0.424	0.000	0.403	0.000	0.021	0.424	0.0%
R08	0.133	1.383	1.516	0.133	1.314	0.000	0.069	1.516	0.0%
R09	0.000	0.360	0.360	0.000	0.342	0.000	0.018	0.360	0.0%

WLA summary for Red Clay Creek Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN Kg/day	TP Kg/day	TN Kg/day	TP Kg/day	TN	TP
R01	PA0050679	0.2500	0.321	0.134	0.321	0.134	0.0%	0.0%
R01	PA0057720-001	0.0720	3.240	0.732	3.240	0.732	0.0%	0.0%
R01	PA0057720-002	0.0900	0.116	0.048	0.116	0.048	0.0%	0.0%
R02	PA0024058	1.1000	49.825	7.506	49.825	7.506	0.0%	0.0%
R03	PA0055107	0.1500	6.807	1.606	6.807	1.606	0.0%	0.0%
R04	DE0000451	2.1700	1.972	1.643	1.972	1.643	0.0%	0.0%
R04	DE0050067	0.0015	0.225	0.056	0.225	0.056	0.0%	0.0%
R05	DE0021709	0.0150	0.568	0.114	0.568	0.114	0.0%	0.0%
R06	PA0055425	0.0005	0.078	0.020	0.078	0.020	0.0%	0.0%
R08	DE0000230	0.3500	0.318	0.133	0.318	0.133	0.0%	0.0%

TMDL summary for White Clay Creek Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)					Percent
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	Reduction
Total Nitrogen									
W01	0.981	157.038	158.019	0.981	74.593	0.000	3.926	79.500	49.7%
W02	15.503	133.766	149.269	15.503	47.807	9.378	3.010	75.697	49.3%
W03	0.000	87.269	87.269	0.000	41.453	0.000	2.182	43.635	50.0%
W04	0.000	83.361	83.361	0.000	38.121	1.476	2.084	41.681	50.0%
W06	59.718	168.665	228.383	59.718	50.433	29.683	4.217	144.051	36.9%
W07	8.868	29.463	38.331	8.868	13.994	0.000	0.737	23.599	38.4%
W08	1.164	129.466	130.630	1.164	61.496	0.000	3.237	65.897	49.6%
W09	0.113	79.504	79.617	0.113	37.764	0.000	1.988	39.865	49.9%
W10	0.000	32.949	32.949	0.000	15.651	0.000	0.824	16.475	50.0%
W11	0.000	39.714	39.714	0.000	37.728	0.000	1.986	39.714	0.0%
W12	0.027	52.612	52.639	0.027	49.981	0.000	2.631	52.639	0.0%
W13	0.000	12.866	12.866	0.000	12.223	0.000	0.643	12.866	0.0%
W14	0.000	13.572	13.572	0.000	12.893	0.000	0.679	13.572	0.0%
W15	0.000	34.796	34.796	0.000	33.056	0.000	1.740	34.796	0.0%
W16	0.000	39.019	39.019	0.000	37.068	0.000	1.951	39.019	0.0%
W17	0.000	84.250	84.250	0.000	80.038	0.000	4.213	84.250	0.0%
Total Phosphorus									
W01	0.214	1.921	2.135	0.214	0.821	0.000	0.043	1.078	49.5%
W02	2.676	1.418	4.094	2.676	0.507	0.100	0.032	3.315	19.0%
W03	0.000	16.736	16.736	0.000	7.155	0.000	0.377	7.532	55.0%
W04	0.000	1.170	1.170	0.000	0.482	0.019	0.026	0.527	55.0%
W06	6.493	2.203	8.696	6.493	0.330	0.194	0.028	7.044	19.0%
W07	0.105	1.890	1.995	0.105	0.808	0.000	0.043	0.955	52.1%
W08	0.084	59.994	60.078	0.084	15.958	0.000	0.840	16.882	71.9%
W09	0.046	15.519	15.565	0.046	6.635	0.000	0.349	7.030	54.8%
W10	0.000	4.907	4.907	0.000	2.098	0.000	0.110	2.208	55.0%
W11	0.000	5.474	5.474	0.000	5.200	0.000	0.274	5.474	0.0%
W12	0.011	4.122	4.133	0.011	3.916	0.000	0.206	4.133	0.0%
W13	0.000	1.074	1.074	0.000	1.020	0.000	0.054	1.074	0.0%
W14	0.000	0.637	0.637	0.000	0.605	0.000	0.032	0.637	0.0%
W15	0.000	0.494	0.494	0.000	0.469	0.000	0.025	0.494	0.0%
W16	0.000	0.831	0.831	0.000	0.789	0.000	0.042	0.831	0.0%
W17	0.000	2.152	2.152	0.000	2.044	0.000	0.108	2.152	0.0%

WLA summary for White Clay Creek Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN kg/day	TP kg/day	TN kg/day	TP kg/day	TN	TP
W01	PA0053783	0.0200	0.981	0.214	0.981	0.214	0.0%	0.0%
W02	PA0024066	0.2500	15.503	2.676	15.503	2.676	0.0%	0.0%
W06	PA0025488	0.3000	59.038	6.425	59.038	6.425	0.0%	0.0%
W06	PA0040436	0.0090	0.680	0.068	0.680	0.068	0.0%	0.0%
W07	PA0056898	0.0650	8.868	0.105	8.868	0.105	0.0%	0.0%
W08	PA0057029	0.1440	1.164	0.084	1.164	0.084	0.0%	0.0%
W09	PA0052451	0.0012	0.113	0.046	0.113	0.046	0.0%	0.0%
W12	DE0000191	0.0300	0.027	0.011	0.027	0.011	0.0%	0.0%

TMDL summary for Christina River Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)					Percent
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	Reduction
Total Nitrogen									
C01	28.965	53.686	82.651	28.965	2.634	7.566	0.537	39.702	52.0%
C02	0.000	78.387	78.387	0.000	48.752	25.715	3.919	78.387	0.0%
C03	0.000	20.367	20.367	0.000	19.349	0.000	1.018	20.367	0.0%
C04	0.000	17.290	17.290	0.000	16.426	0.000	0.865	17.290	0.0%
C05	2.606	12.006	14.612	0.618	11.406	0.000	0.600	12.624	13.6%
C06	0.000	42.959	42.959	0.000	38.507	2.304	2.148	42.959	0.0%
C07	0.000	24.946	24.946	0.000	23.699	0.000	1.247	24.946	0.0%
C08	0.000	41.127	41.127	0.000	39.071	0.000	2.056	41.127	0.0%
C09	5.931	72.021	77.952	1.631	68.420	0.000	3.601	73.652	5.5%
Becks Pond	0.000	38.683	38.683	0.000	34.954	1.795	1.934	38.683	0.0%
Sunset Pond	0.000	22.557	22.557	0.000	21.429	0.000	1.128	22.557	0.0%
Total Phosphorus									
C01	2.839	1.334	4.173	2.839	0.065	0.188	0.013	3.106	25.6%
C02	0.000	1.584	1.584	0.000	0.985	0.520	0.079	1.584	0.0%
C03	0.000	2.610	2.610	0.000	2.480	0.000	0.131	2.610	0.0%
C04	0.000	0.438	0.438	0.000	0.416	0.000	0.022	0.438	0.0%
C05	0.441	0.826	1.267	0.104	0.785	0.000	0.041	0.930	26.6%
C06	0.000	1.211	1.211	0.000	1.085	0.065	0.061	1.211	0.0%
C07	0.000	1.000	1.000	0.000	0.950	0.000	0.050	1.000	0.0%
C08	0.000	4.202	4.202	0.000	3.992	0.000	0.210	4.202	0.0%
C09	1.003	6.688	7.691	0.276	6.354	0.000	0.334	6.964	9.5%
Becks Pond	0.000	1.090	1.090	0.000	0.985	0.051	0.055	1.090	0.0%
Sunset Pond	0.000	0.904	0.904	0.000	0.859	0.000	0.045	0.904	0.0%

WLA summary for Christina River Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN Kg/day	TP Kg/day	TN Kg/day	TP Kg/day	TN	TP
C01	MD0022641	0.7000	26.503	2.650	26.503	2.650	0.0%	0.0%
C01	MD0065145	0.0500	2.462	0.189	2.462	0.189	0.0%	0.0%
C05	(DE CSO)	See Baseline and WLA nitrogen and phosphorus loads for CSO discharges table						
C09	(DE CSO)	See Baseline and WLA nitrogen and phosphorus loads for CSO discharges table						

Neither the Pennsylvania nor the Delaware MS4 permits actually identify the extent of the systems. Since these systems have not yet been delineated, the TMDL includes nonpoint source loadings into the WLA portion of the TMDL. Once these delineations are available, the nonpoint source loadings can then be separated out of the WLAs and moved under the LA. 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.

The non-MS4 point source permittee's allocations for five-day carbon biological oxygen demand, ammonia, and total phosphorus are not reduced from their permitted levels and are shown in Table 2-2.

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.

Baseline and WLA nitrogen and phosphorus loads for CSO discharges

Location	CSO ID numbers	Baseline (kg/day)	WLA (kg/day)	Reduction
Total Nitrogen				
Little Mill Creek (C05)	27, 28, 29	2.606	0.618	76.3%
Christina River (C09)	5, 6, 7, 9a, 9c, 10, 11, 12, 13, 14, 15, 16, 17, 30	5.931	1.631	72.5%
Brandywine Cr. (B34)	3, 4a, 4b, 4c, 4d, 4e, 4f, 18, 19, 20, 21a, 21b, 21c, 22b, 22c, 23, 24, 25, 26, RR	11.443	4.107	64.1%
Total CSO load	-	19.980	6.356	68.2%
Total Phosphorus				
Little Mill Creek (C05)	27, 28, 29	0.441	0.104	76.4%
Christina River (C09)	5, 6, 7, 9a, 9c, 10, 11, 12, 13, 14, 15, 16, 17, 30	1.003	0.276	72.5%
Brandywine Cr. (B34)	3, 4a, 4b, 4c, 4d, 4e, 4f, 18, 19, 20, 21a, 21b, 21c, 22b, 22c, 23, 24, 25, 26, RR	1.966	0.730	62.9%
Total CSO load	-	3.410	1.110	67.4%

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting their designated uses even though pollutant sources have implemented technology-based controls. A TMDL establishes the allowable load of a pollutant or other quantifiable parameter based on the relationship between pollutant sources and in-stream water quality. A TMDL provides the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources and restore and maintain the quality of the state's water resources (USEPA, 1991).

As a result of water quality and biological investigations conducted by the Pennsylvania Department of Environmental Protection (PADEP) and Delaware Department of Natural Resources and Environmental Control (DNREC) 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 resulting from problems associated with elevated nutrient levels, including low dissolved oxygen (DO). These TMDLs, in conjunction with the low-flow Christina TMDL (USEPA, 2002), fulfill the requirements for nutrient and low dissolved oxygen TMDL development for waters in the Christina River basin included in the Section 303(d) lists for Pennsylvania and Delaware. A related study is underway to address impairments resulting from elevated bacteria and sediment loads.

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 (SAIC) 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.

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 primarily nonpoint sources of pollutants during high-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 (BVA/RCVA), Chester County Conservation District (CCCD), Chester County Health Department (CCHD), Chester County Planning Commission (CCPC), CCWA, DNREC, Delaware Nature Society (DNS), DRBC, New Castle County Conservation District (NCCD), DEP, EPA Region III, USGS, United States Natural Resources Conservation Service (USDA-NRCS) and the Water Resources Agency for New Castle County (WRANCC).

The CBWQMC developed a unified, multi-phased, 5-year Water Quality Management Strategy (WQMS) that first addresses the water quality problems through voluntary watershed/water quality planning and management activities and second, 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 requiring the development of a TMDL. The Clean Water Act (CWA) requires that upstream waters must meet the applicable WQS of the downstream state at or before the state line. In other words, Pennsylvania and Maryland waters are required to meet Delaware's WQS at the 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 (ESA) and the Administrative Procedures Act (APA). The settlement of the Pennsylvania matter, American Littoral Society and the Public Interest Research Group v. EPA, Civil No. 96-489 (E.D. Pa), was entered on April 9, 1997. The Pennsylvania TMDL settlement 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), was entered on August 9, 1997. The Delaware TMDL settlement sets forth specific deadlines for EPA relating to specific waters and TMDLs in the Christina River Basin. Under the schedule set forth in 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 was 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 565 square miles and is located in Chester County, Pennsylvania, New Castle County, Delaware, and Cecil County, Maryland (see Figure 1-1 and Table 1-2). 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 used 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.

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)

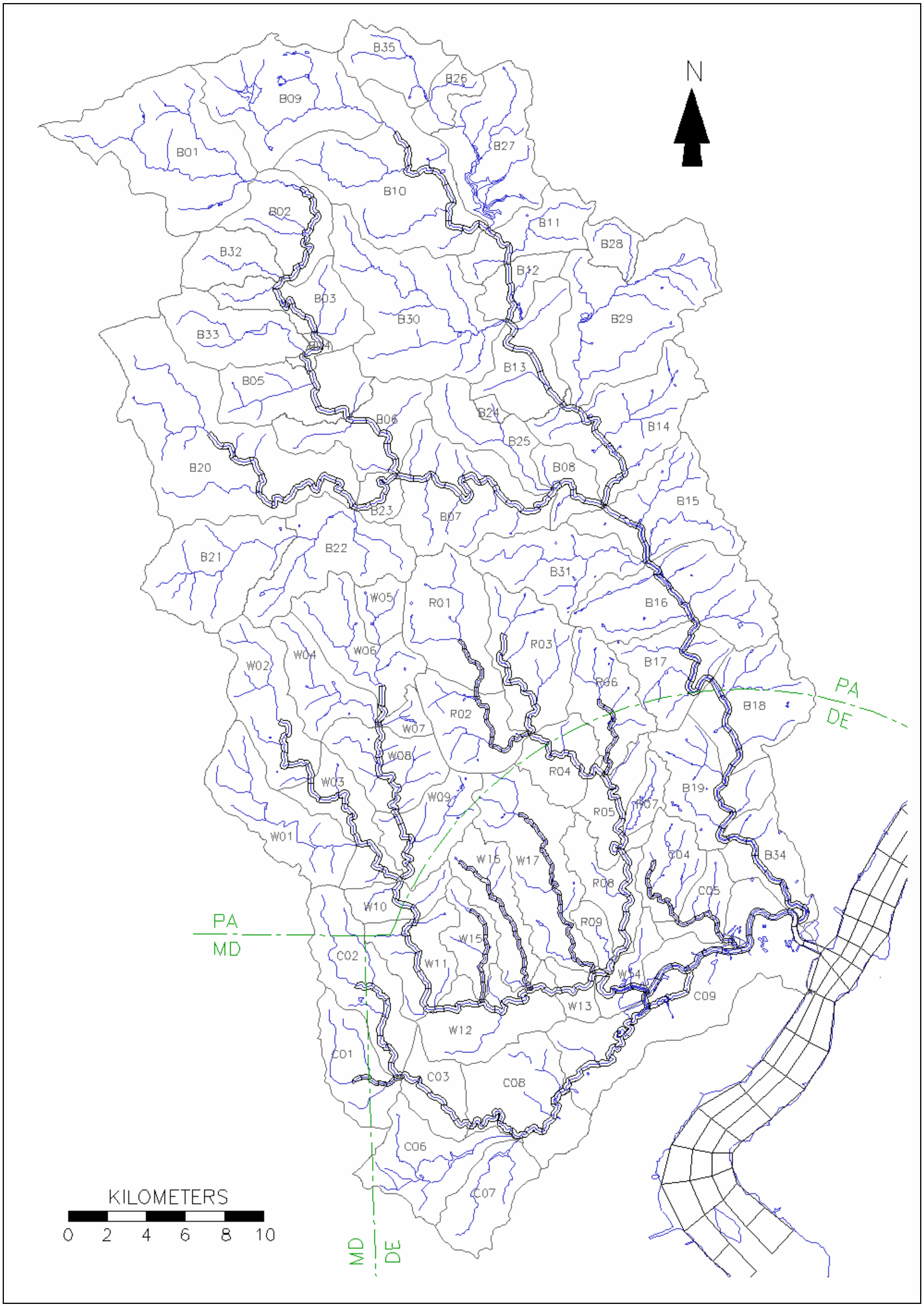

Figure 1-1. Christina River Basin delineation of HSPF model subbasins and EFDC model grid

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

Subbasin	Stream Name	Area (sq.mi)	Subbasin	Stream Name	Area (sq.mi)
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	Christina River	4.47
B32	Birch Run	4.66	C04	Upper Little Mill Creek	5.37
B33	Rock Run	8.03	C05	Lower Little Mill Creek	3.84
B34	Lower 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 (tidal)	21.90

1.3 Impairment Listing

In response to the requirements of Section 303(d) of the CWA, PADEP and DNREC listed multiple Christina River Basin waterbodies on the 1996 and 1998 Section 303(d) lists of impaired waterbodies based on available information. Pennsylvania identified a total of 60 stream segments as impaired by nutrients, organic enrichment, or low dissolved oxygen. Of that total, 14 stream segments were first listed in 1996 and 46 stream segments were listed in 1998 (Table 1-3). Delaware identified 15 stream segments on the 1998 Section 303(d) list (Table 1-4) as not meeting WQS for nutrients and low DO within the Christina River Basin. Pursuant to the TMDL Consent Decree in Delaware, those 15 stream segments were given high priority. Likewise, Pennsylvania identified 23 of the listed segments as high priority. A number of monitoring stations are located throughout the Christina River Basin within the listed waters. Data from these stations as well as biological assessments were used to determine the impairment and inclusion on the Section 303(d) lists. Excessive nutrients, organic enrichment and low DO are specified as the causes of impairment in the various listed stream segments. The pollutant sources are varied and include industrial and municipal point sources, agriculture, and Superfund sites.

Table 1-3. Christina River Basin stream segments on the PA 1998 Section 303(d) List

Watershed	Stream ID	Segment ID	Miles	Year Listed	Source of Impairment	Cause of Impairment	HSPF Subbasin
Trib to Brandywine Cr.	00026	27	1.3	1996	Other	Nutrients	B17
East Br. Brandywine Cr.	64954	970707-120-HLW	1.1	1996	Agriculture	Nutrients	B09
East Br. Brandywine Cr.	00229	970703-1500-ACE	0.6	1996	Agriculture	Nutrients	B09
East Br. Brandywine Cr.	00229	970707-1120-GLW	2.9	1996	Agriculture	Nutrients	B09
East Br. Brandywine Cr.	00371	970707-1120-GLW	1.5	1996	Agriculture	Nutrients	B09
East Br. Brandywine Cr.	00372	970707-1120-GLW	0.7	1996	Agriculture	Nutrients	B09
Indian Run	00360	360	3.3	1996	Agriculture, hydromodification	Nutrients, low DO, organic enrichment	B10
Sucker Run	00202	970930-1437-GLW	3.6	1998	Agriculture	Nutrients	B05
Sucker Run	00203	970930-1437-GLW	1.6	1998	Agriculture	Nutrients	B05
Sucker Run	00204	970930-1437-GLW	0.9	1998	Agriculture	Nutrients	B05
Sucker Run	00205	970930-1437-GLW	0.7	1998	Agriculture	Nutrients	B05
West Br. Brandywine Cr.	00085	9700925-1348-GLW	4.7	1996	Agriculture	Nutrients	B04, B05, B06
West Br. Brandywine Cr.	00085	970618-1118-GLW	3.0	1998	Agriculture	Nutrients	B01
West Br. Brandywine Cr.	00085	970618-1340-GLW	1.5	1998	Agriculture	Nutrients	B01
West Br. Brandywine Cr.	00224	970619-1222-GLW	4.6	1998	Agriculture	Nutrients	B01
West Br. Brandywine Cr.	00224	970619-1345-GLW	2.6	1998	Agriculture	Nutrients	B01
West Br. Brandywine Cr.	00225	970619-1322-GLW	0.9	1998	Agriculture	Nutrients	B01
West Br. Brandywine Cr.	00226	970619-1345-GLW	1.4	1998	Agriculture	Nutrients	B01
West Br. Brandywine Cr.	00227	970618-1340-GLW	1.3	1998	Agriculture	Nutrients	B01
West Br. Brandywine Cr.	00228	970618-1340-GLW	0.8	1998	Agriculture	Nutrients	B01
Broad Run	00434	971209-1445-ACW	3.2	1998	Agriculture, hydromodification	Nutrients, low DO, organic enrichment	W09
Broad Run	00436	971209-1445-ACW	0.8	1998	Agriculture, hydromodification	Nutrients, low DO, organic enrichment	W09
East Br. Red Clay Cr.	00413	971023-1050-MRB	5.3	1996	Agriculture	Organic enrichment, low DO	R03
East Br. Red Clay Cr.	00414	971204-1400-ACW	3.2	1998	Agriculture	Organic enrichment, low DO	R03
East Br. Red Clay Cr.	00417	971204-1403-ACW	1.0	1998	Agriculture	Organic enrichment, low DO	R03
East Br. Red Clay Cr.	00418	971204-1400-ACW	0.8	1998	Agriculture	Organic enrichment, low DO	R03
East Br. Red Clay Cr.	00419	971023-1050-MRB	1.2	1996	Agriculture	Organic enrichment, low DO	R03
East Br. White Clay Cr.	00432	971113-1335-GLW	3.1	1998	Agriculture	Organic enrichment, low DO	W09
East Br. White Clay Cr.	00432	970506-1320-MRB	2.7	1998	Agriculture	Nutrients	W08
East Br. White Clay Cr.	00432	9417	2.0	1996	Municipal PS	Nutrients, low DO, organic enrichment	W08
East Br. White Clay Cr.	00432	971119-1116-GLW	1.2	1998	Agriculture	Organic enrichment, low DO	W06
East Br. White Clay Cr.	00438	970506-1320-MRB	0.6	1998	Agriculture	Nutrients	W08
East Br. White Clay Cr.	00439	970506-1320-MRB	0.7	1998	Agriculture	Nutrients	W08
East Br. White Clay Cr.	00443	970506-1320-MRB	0.7	1998	Agriculture	Nutrients	W08
East Br. White Clay Cr.	00444	970506-1320-MRB	0.7	1998	Agriculture	Nutrients	W08
East Br. White Clay Cr.	00445	970508-1430-ACE	2.4	1998	Agriculture	Organic enrichment, low DO	W08
East Br. White Clay Cr.	00446	970506-1320-MRB	0.5	1998	Agriculture	Nutrients	W08

Watershed	Stream ID	Segment ID	Miles	Year Listed	Source of Impairment	Cause of Impairment	HSPF Subbasin
East Br. White Clay Cr.	00447	970506-1320-MRB	0.8	1998	Agriculture	Nutrients	W06
East Br. White Clay Cr.	00448	970409-1130-MRB	0.8	1998	Agriculture	Nutrients	W04
East Br. White Clay Cr.	00450	970409-1130-MRB	0.2	1998	Agriculture	Nutrients	W04
East Br. White Clay Cr.	00454	971120-1331-GLW	5.4	1998	Agriculture	Nutrients	W06
East Br. White Clay Cr.	00455	971120-1331-GLW	2.5	1998	Agriculture	Nutrients	W06
East Br. White Clay Cr.	00456	971120-1331-GLW	0.2	1998	Agriculture	Nutrients	W06
Egypt Run	00440	970508-1245-ACE	1.5	1998	Agriculture	Nutrients, low DO, organic enrichment	W08
Egypt Run	00441	970508-1245-ACE	1.4	1998	Agriculture	Nutrients, low DO, organic enrichment	W08
Egypt Run	00442	970508-1245-ACE	0.8	1998	Agriculture	Nutrients, low DO, organic enrichment	W08
Indian Run	00475	115	1.1	1998	Agriculture	Nutrients	W03
Middle Br. White Clay Cr.	00462	115	9.3	1998	Agriculture	Nutrients	W02, W03
Middle Br. White Clay Cr.	00462	115B	2.2	1996	Agriculture, Municipal PS	Nutrients	W02
Middle Br. White Clay Cr.	00476	115	1.6	1998	Agriculture	Nutrients	W02
Middle Br. White Clay Cr.	00477	115	1.8	1998	Agriculture	Nutrients	W02
Middle Br. White Clay Cr.	00478	115	1.3	1998	Agriculture	Nutrients	W02
Middle Br. White Clay Cr.	00479	115	0.6	1998	Agriculture	Nutrients	W02
Middle Br. White Clay Cr.	00480	115	0.6	1998	Agriculture	Nutrients	W02
Red Clay Creek	00374	971203-1400-ACW	0.1	1998	Agriculture	Organic enrichment, low DO	R04
Trout Run	63874	970506-1425-MRB	1.7	1998	Agriculture	Nutrients	W07
Trout Run	63875	970506-1425-MRB	0.8	1998	Agriculture	Nutrients	W07
Trout Run	63876	970506-1425-MRB	0.2	1998	Agriculture	Nutrients	W07
Walnut Run	00435	971209-1445-ACW	1.4	1998	Agriculture, hydromodification	Nutrients, low DO, organic enrichment	W09
West Br. Red Clay Cr.	00391	971023-1145-MRB	4.6	1998	Agriculture	Organic enrichment, low DO	R02
West Br. Red Clay Cr.	00396	971023-1315-MRB	1.8	1996	Agriculture	Nutrients	R02
West Br. White Clay Cr.	00465	9408	7.8	1996	Agriculture	Nutrients	W01
White Clay Creek	00373	971216-1230-GLW	1.4	1998	Agriculture	Nutrients	W10

Table 1-4. Christina River Basin stream segments on the DE 1998 Section 303(d) List

Waterbody ID	Watershed Name	Segment	Miles	Year Listed	Pollutants/Stressor	Probable Sources	HSPF Subbasin
DE040-001	Brandywine Creek	Lower Brandywine	3.8	1996	nutrients	PS, NPS, SF	B34
DE040-002	Brandywine Creek	Upper Brandywine	9.3	1996	nutrients	PS, NPS, SF	B18, B19
DE260-001	Red Clay Creek	Main Stem	12.8	1996	nutrients	PS, NPS, SF	R04, R05, R08, R09
DE260-002	Red Clay Creek	Burroughs Run	2.6	1996	nutrients	NPS	R06
DE320-001	White Clay Creek	Main Stem	15.6	1996	nutrients	PS, NPS	W10, W11, W12, W13, W14
DE320-002	White Clay Creek	Mill Creek	8.3	1996	nutrients	NPS	W17
DE320-003	White Clay Creek	Pike Creek	9.4	1996	nutrients	NPS	W16
DE320-004	White Clay Creek	Muddy Run	5.8	1996	nutrients	NPS	W15
DE120-001	Christina River	Lower Christina	1.5	1996	nutrients, DO	NPS, SF	C09
DE120-002	Christina River	Middle Christina River	7.5	1996	nutrients	NPS, SF	C09
DE120-003	Christina River	Upper Christina River	6.3	1996	nutrients	NPS, SF	C09
DE120-003-02	Christina River	Lower Christina Creek	8.4	1996	nutrients	NPS	C03, C08
DE120-005-01	Christina River	West Branch	5.3	1996	nutrients	NPS	C01
DE120-006	Christina River	Upper Christina Creek	8.3	1996	nutrients	NPS	C02
DE120-007-01	Christina River	Little Mill Creek	5.1	1996	nutrients, DO	NPS, SF	C04, C05
DE120-L01	Christina River	Smalleys Pond	30 Ac.	1996	Nutrients	NPS	C08
DE120-L02	Christina River	Becks Pond	25.6 ac	1996	Nutrients*	NPS	C07

PS= point source; NPS = nonpoint source; SF=superfund site, *delisted for nutrients in 2002

1.4 Water Quality Standards

The CWA requires states to adopt WQS to define the water goals for a waterbody by designating the use or uses to be made of the water, by setting criteria necessary to protect the uses and by protecting water quality through antidegradation provisions. These standards serve dual purposes: they establish water quality goals for a specific waterbody, and they serve as the regulatory basis for establishing water quality-based controls and strategies beyond the technology-based levels of treatment required by sections 301(b) and 306 of the CWA. Within the Christina River Basin, there are four regulatory agencies that have applicable WQS. The PADEP, DNREC, and MDE have WQS that apply to those stream segments of the Christina River Basin located in the respective state. The DRBC is an interstate agency that has the authority to establish WQS and regulate pollution activities within the tidal Delaware River Basin including the Christina River Basin, one of the Delaware River's tributary basins. Tables 1-5 and 1-6 below summarize the applicable WQS relating to DO and nutrients.

1.4.1 Pennsylvania WQS

Pennsylvania Code, Title 25, Chapter 93 sets forth water quality standards for surface waters of the state. These standards are based upon water uses which are to be protected and will be considered by PADEP in its regulation of discharges. Implementation of the numeric water quality criteria in Pennsylvania are summarized in Table 1-5 and 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% 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% 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."

Chapter 93.9(g): Drainage List G contains the designated uses for the waters within the Brandywine Creek, Red Clay Creek, and White Clay Creek watersheds. Protected uses include cold water fishes, warm water fishes, migratory fishes, trout stocking fishes, high quality, and exceptional quality waters.

1.4.2 Delaware WQS

Delaware's water quality criteria for DO and nutrients are listed in Table 1-5 and Table 1-6. Marine waters are defined as waters of the state that contain natural levels of salinity greater than 5 parts per thousand (ppt). All waters within the Christina River Basin have natural salinity levels less than 5 ppt. Therefore, the fresh water designated use shall apply for this TMDL.

Table 1-5. Summary of applicable use designations and DO criteria

Agency	Designated Use	D.O. Criteria (mg/L)		Comments
		Daily avg.	Minimum	
PADEP	Warm water fish (WWF)	5.0	4.0	
	Cold water fish (CWF)	6.0	5.0	
	Trout stocking fishery (TSF)	6.0 5.0	5.0 4.0	Feb 15 - Jul 31 Aug 01 - Feb 14
	High Quality CWF		7.0	Special Protection Waters
	High Quality TSF	6.0	5.0	Special Protection Waters
	Exceptional value			Special Protection Waters
DNREC	Fresh waters	5.5	4.0	Year round
	Cold water fish	6.5	5.0	Seasonal
	Marine waters	5.0	4.0	Salinity greater than 5.0 ppt
	Exceptional recreation or ecological significance			Existing or natural water quality
MDE	Fresh waters	5.0	5.0	Use I waters, DO must not be less than 5.0 mg/L at any time
DRBC	Resident game fish	5.0	4.0	
	Trout	6.0	5.0 7.0	 During spawning season
	Tidal: resident or anadromous fish	4.5		6.5 mg/L seasonal average during Apr 01 - Jun 15 and Sep 16 - Dec 31

Table 1-6. Summary of nutrient criteria

Parameter	Agency	Comments
Ammonia-Nitrogen*		
	PADEP	1-day and 30-day average ambient criteria are a function of pH and temperature for toxicity; Implementation Guidance document for Ammonia allocations for NBOD and Toxicity.
	DNREC	No specific numeric criteria; Narrative statement for prevention of toxicity.
	DRBC	NPDES effluents limited to a 30-day average of 20 mg/L as N.
Nitrate-Nitrogen		
	PADEP	Ambient criteria is maximum of 10 mg/L as N applied at the point of water supply intake, not at the point of an effluent discharge. For the case of an interstate stream, the state line shall be considered a point of water supply intake.
	DNREC	Ambient nitrate criteria is maximum of 10 mg/L as N; provision for site-specific nutrient controls. The DNREC Section 303(d) rationale document cites 3.0 mg/L total nitrogen as guidance for determining impairment.
	DRBC	No specific numeric criteria.
Phosphorus		
	PADEP	No specific numeric criteria are specified in the Pennsylvania Code, Title 25, Chapter 93 (Water Quality Standards). According to Chapter 95 (Wastewater Treatment Requirements), phosphorus effluent limits are set to a maximum of 2 mg/L whenever the Department determines that instream phosphorus alone or in combination with other pollutants contributes to impairment of designated stream uses.
	DNREC	No specific numeric criteria; provision for site-specific controls. The Section 303(d) rationale document cites 0.2 mg/L of total phosphorus as guidance for use impairment.
	DRBC	No specific numerical criteria.

* Maryland adopted the EPA water quality criteria for ammonia nitrogen in January 2001 (effective April 2001 - Title 26 Maryland Department of the Environment Subtitle 08 Water Pollution Chapter 02 Water Quality). This was approved by EPA in June 2001.

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 by impairments caused by point and nonpoint sources of nutrients and oxygen demanding material. PADEP and DNREC identified the impaired stream segments based on historical water quality monitoring data and biological integrity field surveys. EPA characterizes the past and current condition of water quality in the Christina River Basin, and assesses available data, as part of the basis for these TMDLs. A data report prepared by Davis (1999) for the low-flow study describes the existing water quality in the basin. This data was used, in part, for developing these TMDLs.

A customized modeling framework was developed to support determination of nutrient and low DO TMDLs for the Christina River Basin. The modeling framework used in this study consisted of three major components: (1) a watershed loading model (HSPF) developed for each of the four primary subwatersheds in the Christina River Basin (Senior and Koerkle, 2003a, 2003b, 2003c, 2003d), (2) a 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 nutrients and oxygen demanding substances.

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. It also includes vessels or other floating craft from which pollutants are or may be discharged. The term “point source” also includes concentrated animal feeding operations, which are places where animals are confined and fed. Storm water runoff from certain areas is also considered a point source because the water is transported through a pipe or ditch.

Estimating the transport of nutrients into a surface water body from most point sources is a fairly straightforward matter. Both wastewater treatment plants (WWTP) and combined sewer overflows (CSOs) discharge though a constructed conveyance to a waterbody. Many of the nutrients transported in this way are removed through 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 combined sewer systems. This can lead to a discharge of contaminated water into the river system.

2.1.1 Wastewater Treatment Plants

Treated industrial and municipal sewage can be a point source of nutrients. 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 summer season nutrient and CBOD5 loads for each of the NPDES facilities, based on permit flow rate, are provided in Table 2-2 (see table footnote).

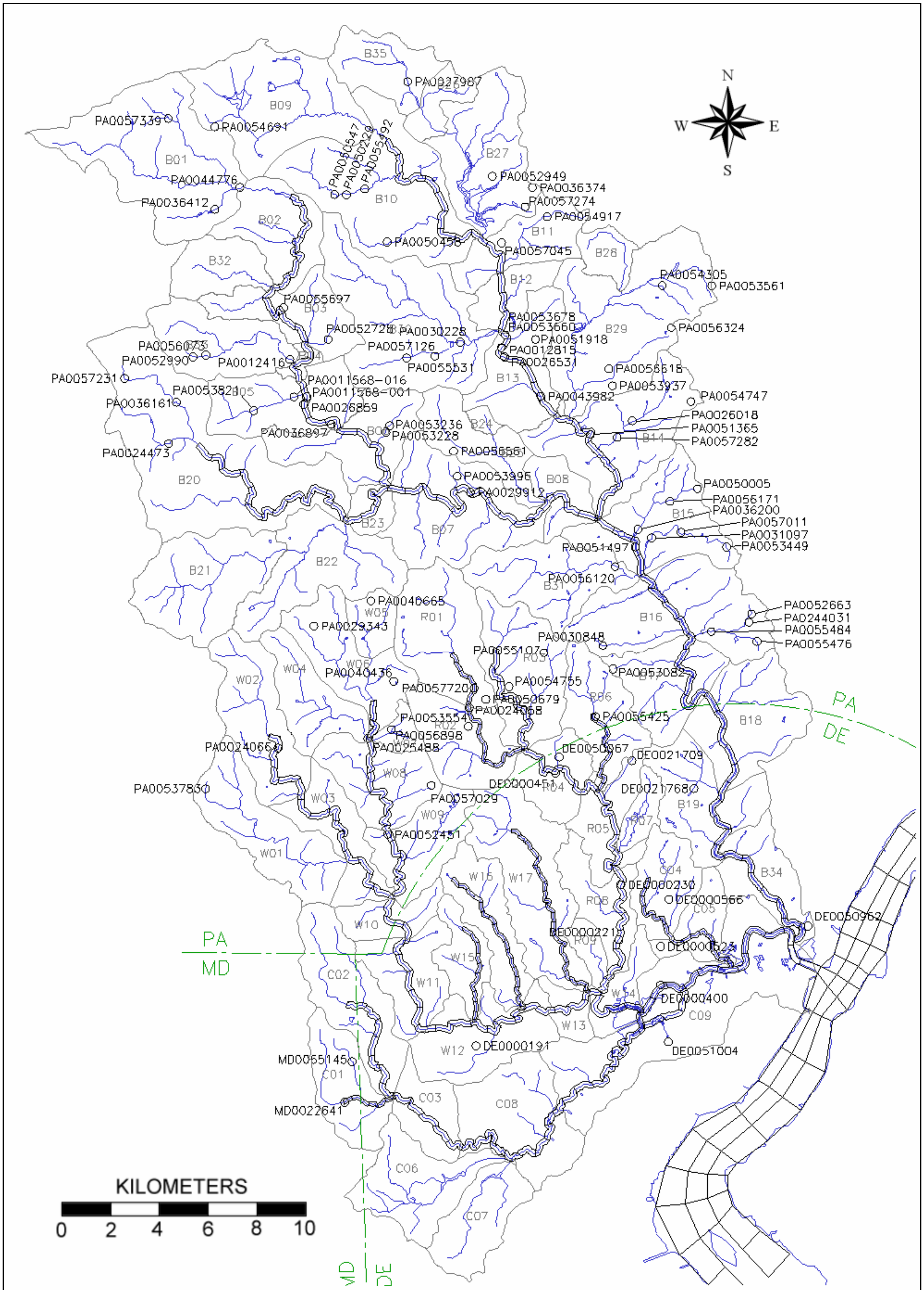

Figure 2-1. NPDES discharges in Christina River Basin

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	0.0300	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. NPDES permit flows and loads for nutrients and CBOD5

NPDES Number	HSPF Subbasin	Flow (mgd)	CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5 (kg/day)	NH3-N (kg/day)	TP (kg/day)
Brandywine Creek main stem								
DE0021768	B19	0.0250	15.00	1.50	2.00	1.42	0.14	0.19
PA0053082	B17	0.0206	10.00	3.00	2.00	0.78	0.23	0.16
PA0052663	B16	0.0900	10.00	1.00	2.00	3.41	0.34	0.68
PA0055476	B16	0.0400	10.00	3.00	2.00	1.51	0.45	0.30
PA0244031	B16	0.1500	10.00	1.50	0.50	5.68	0.85	0.28
PA0055484	B16	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0030848	B16	0.0063	25.00	80.00	20.00	0.60	1.91	0.48
PA0056120	B31	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0031097	B15	0.0170	25.00	20.00	2.00	1.61	1.29	0.13
PA0053449	B15	0.1500	15.00	1.50	2.00	8.52	0.85	1.14
PA0057011	B15	0.0773	25.00	3.50	2.00	7.32	1.02	0.59
PA0036200	B15	0.0320	25.00	20.00	2.00	3.03	2.42	0.24
PA0050005	B15	0.1400	2.00	0.04	0.11	1.06	0.02	0.06
PA0051497	B15	0.0300	2.00	0.10	0.10	0.23	0.01	0.01
PA0056171	B15	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
Brandywine Creek East Branch								
PA0026018	B14	1.5000	25.00	2.50	2.00	141.95	14.20	11.36
PA0057282	B14	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0051365	B14	0.3690	2.00	0.10	0.10	2.79	0.14	0.14
PA0053937	B29	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0056324	B29	0.0440	2.00	0.04	0.11	0.33	0.01	0.02
PA0056618	B29	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0053561	B29	0.0360	2.00	0.04	0.11	0.27	0.01	0.01
PA0043982	B13	0.4000	22.95	2.00	1.88	34.75	3.03	2.85
PA0012815	B13	1.0280	25.14	4.44	0.74	97.83	17.28	2.88
PA0026531	B13	7.5000	7.00	1.50	2.00	198.73	42.59	56.78
PA0030228	B30	0.0225	7.00	1.00	3.00	0.60	0.09	0.26
PA0051918	B13	0.1440	2.00	0.10	0.10	1.09	0.05	0.05
PA0055531	B30	0.0007	25.00	10.00	10.00	0.07	0.03	0.03
PA0054917	B11	0.4750	5.89	0.78	0.78	10.59	1.40	1.40
PA0036374	B27	0.0150	10.00	0.50	0.50	0.57	0.03	0.03
PA0057274	B27	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0050458	B10	0.0351	10.00	3.00	1.00	1.33	0.40	0.13
PA0057827	B10	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0050547	B10	0.0375	10.00	3.00	1.00	1.42	0.43	0.14
PA0055492	B10	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0052949	B10	0.0030	10.00	0.10	0.10	0.11	0.001	0.001
PA0027987	B10	0.0050	10.00	3.90	2.00	0.19	0.07	0.04
PA0054691	B09	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
Brandywine Creek West Branch								
PA0029912	B07	0.1000	25.00	20.00	2.00	9.46	7.57	0.76
PA0053996	B07	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0053228	B06	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0053236	B06	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0036897	B05	0.3900	25.00	7.00	2.00	36.91	10.33	2.95
PA0026859	B05	3.8500	11.07	2.00	1.48	161.33	29.15	21.57
PA0011568-001	B05	0.6400	5.00	0.50	0.30	12.11	1.21	0.73
PA0011568-016	B05	0.5045	5.00	0.50	0.30	9.55	0.95	0.57
PA0056073	B33	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0012416	B33	0.1400	10.00	0.10	0.10	5.30	0.05	0.05

NPDES Number	HSPF Subbasin	Flow (mgd)	CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5 (kg/day)	NH3-N (kg/day)	TP (kg/day)
PA0052990	B33	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0052728	B03	0.0004	25.00	10.00	10.00	0.04	0.02	0.02
PA0055697	B03	0.0490	25.00	1.50	2.00	4.64	0.28	0.37
PA0036412	B01	0.0550	10.00	2.90	1.90	2.08	0.60	0.40
PA0044776	B01	0.6000	13.50	2.70	1.80	30.66	6.13	4.09
PA0057339	B01	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
PA0057231	B20	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
Christina River								
MD0022641	C01	0.7000	12.22	2.00	1.00	32.38	5.30	2.65
MD0065145	C01	0.0500	10.00	4.52	1.00	1.89	0.86	0.19
Red Clay Creek								
DE0000230	R08	0.3500	7.00	0.10	0.10	9.27	0.13	0.13
DE0021709	R05	0.0150	20.00	1.50	2.00	1.14	0.09	0.11
PA0055425	R06	0.0005	25.00	10.00	10.00	0.05	0.02	0.02
DE0050067	R04	0.0015	30.00	10.00	10.00	0.17	0.06	0.06
DE0000451	R04	2.1700	3.00	0.10	4.00	24.64	0.82	32.86
PA0055107	R03	0.1500	25.00	2.00	2.00	14.20	1.14	1.14
PA0024058	R02	1.1000	16.63	2.00	1.28	69.25	8.33	5.33
PA0050679	R01	0.2500	2.00	0.10	0.10	1.89	0.09	0.09
PA0057720-001	R01	0.0720	9.50	1.90	1.90	2.59	0.52	0.52
PA0057720-002	R01	0.0900	2.00	0.10	0.10	0.68	0.03	0.03
White Clay Creek								
DE0000191	W12	0.0300	3.00	0.10	0.10	0.34	0.01	0.01
PA0053783	W01	0.0200	10.00	3.00	2.00	0.76	0.23	0.15
PA0024066	W02	0.2500	25.00	4.80	2.00	23.66	4.54	1.89
PA0052451	W09	0.0012	25.00	10.00	10.00	0.11	0.05	0.05
PA0057029	W08	0.1440	2.00	0.04	0.11	1.09	0.02	0.06
PA0025488	W06	0.3000	25.00	2.00	4.00	28.39	2.27	4.54
PA0056898	W07	0.0650	25.00	3.50	0.30	6.15	0.86	0.07
PA0040436	W06	0.0090	25.00	10.00	2.00	0.85	0.34	0.07
PA0040665	W05	0.0100	25.00	10.00	2.00	0.95	0.38	0.08

For facilities with flow greater than 10,000 gpd, the CBOD5 and NH3-N limits above are summer limits and apply from May 1 to Oct 31 and the summer TP limits apply from Apr 1 to Oct 31. During the winter season from Nov 1 to Apr 30, the CBOD5 limit is 2 times the summer limit and the NH3-N limit is 3 times the summer limit. The winter TP limit is 2 times the summer limit and applies from Nov 1 to Mar 31. For small facilities with flow less than 10,000 gpd, the above limits apply year round.

2.1.2 Combined Sewer Overflows

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

There are 38 CSO outfalls[1] in the vicinity of the city of Wilmington. Nutrient loads from these CSOs were determined using the flow rates calculated by the XP-SWMM model and event mean concentrations calculated from storm events monitored in 2003 and 2004 (see Appendix E for storm monitoring data).

2.1.3 Stormwater Phase II Communities

Storm water runoff can contribute nutrients 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 Clean Water Act (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 and, 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 wasteload allocation component of the TMDL and may not be addressed by the load allocation 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

[1] Though currently there are 40 CSO locations in the City of Wilmington, the XP-SWMM model results provided by the City indicated only 38 CSO outfall locations with 37 of these discharging within the Christina River Basin.

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 nutrients that reach surface waters. To assess the relative loads of nutrients 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 in the HSPF model, 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-resid 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

Permit Number	Municipality Name	HSPF Model Subbasins
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
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

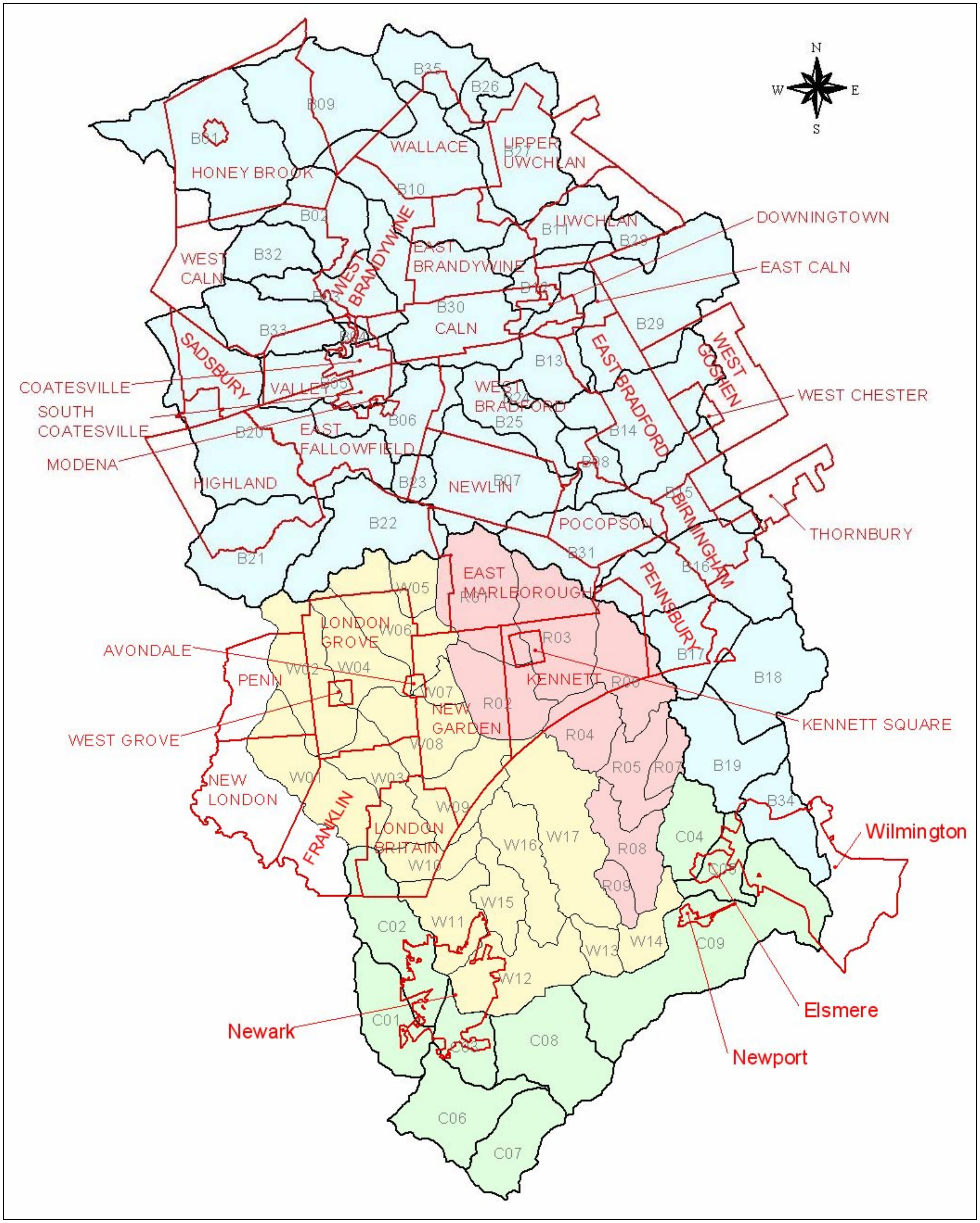

Figure 2-2. Municipalities with MS4 permits in Christina River Basin

2.2 Nonpoint Sources

Nonpoint sources of nutrients 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 water table levels, compact glacial till, bedrock, and coarse sand and gravel outwash. When these 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 the Christina River Basin was not available. Therefore, estimates of the nutrient loads from septic systems were based on the assumptions outlined below:

- Number of septic systems (based on US Census 1990 and 2000)
- 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 total nitrogen load of 26 g/person/day (Thomann and Mueller, 1987)
- Septic effluent total phosphorus load of 1.3 g/person/day
- Septic effluent CBODu load of 180 g/person/day (Thomann and Mueller, 1987)
- Average annual septic malfunction rate (1% of all septic systems)

The number of septic tanks in Chester County and New Castle County were 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 nitrogen load (kg/day)	3.6	119.8
2005 Estimated potential phosphorus load (kg/day)	0.2	6.0
2005 Estimated potential CBODu load (kg/day)	24.8	829.1

The potential annual nutrient and CBODu 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. It was assumed that the delivery ratio for malfunctioning systems was 1.0 and for properly functioning systems was 0.02.

2.2.2 Agriculture Activities

Land used for agricultural purposes can be a source of nutrients. 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 nutrient 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 (USEPA, 2001).

The application of manure that has been improperly composted can contribute nutrients that are conveyed into surface waters during runoff events. Animal wastes must be handled, stored, utilized and/or disposed of in an efficient way to avoid this problem. Grazing animals, confined animal operations and manure application are all potential sources of nutrients 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.

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

Category	Chester County, PA			New Castle County, DE		
	1992	**1997**	**2002**	**1992**	**1997**	**2002**
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

2.2.3 Wildlife

Wildlife also contribute nutrients to land surface and in streams. A precise estimate of the number of wild animals in the Christina River Basin is not available. Literature and empirical values were used to estimate wild animal population densities for different land use categories as shown in Table 2-7.

Table 2-7. 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 Representation of Nonpoint Sources in the HSPF Model

Nonpoint source flows and loads for the Christina River Basin nutrient and dissolved oxygen TMDLs were simulated using four HSPF watershed models, one for each of the four main watersheds in the basin (Brandywine Creek watershed, White Clay Creek watershed, Red Clay Creek watershed, and Christina River watershed). Under the HSPF model framework, each watershed was numerous subbasins with each subbasin having 12 land use categories. Loads for septic systems, livestock, and wildlife were not explicitly incorporated into the HSPF models. Instead they were implicitly lumped into the HSPF land use categories, and the overall load from a subbasin was approximated through comparison of model output to instream monitoring data during the calibration process (Senior and Koerkle, 2003a, 2003b, 2003d, 2003d). The data shown in Section 2.2 for septic systems, livestock, and wildlife are for information purposes and can be used during the implementation phase of the TMDL to target likely sources requiring load reduction.

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).

Once the applicable use designation and water quality criteria is identified, the numeric water quality target or goal for the TMDL is determined. These targets represent a number where applicable water quality is achieved and maintained. In these TMDLs, the target is to attain and maintain the applicable DO water quality criteria at all flow conditions. Figure 3-1 below shows the applicable use designations for stream segments included in the Christina River Basin TMDL. Using Tables 1-4 and 1-5 and Figure 3-1, the numeric water quality targets for DO can be identified for each segment. Table 3-1 below identifies the general water quality targets or endpoints for the Christina River Basin TMDLs.

Table 3-1. Summary of TMDL Endpoints

Parameter	Target Limit	Reference
Daily Average DO, warm water fish (PA)	5.0 mg/L	Pennsylvania Water Quality Standards
Daily Average DO, cold water fish (PA)	6.0 mg/L	Pennsylvania Water Quality Standards
Daily Average DO, fresh waters (DE)	5.5 mg/L	Delaware Water Quality Standards
Daily Average DO, cold water fish (DE)	6.5 mg/L	Delaware Water Quality Standards
Daily Average DO, tidal fresh waters (DE)	5.5 mg/L	Delaware Water Quality Standards
DO at any time, freshwater (MD)	5.0 mg/L	Maryland Water Quality Standards
Minimum DO, warm water fish (PA)	4.0 mg/L	Pennsylvania Water Quality Standards
Minimum DO, cold water fish (PA)	5.0 mg/L	Pennsylvania Water Quality Standards
Minimum DO, fresh waters (DE)	4.0 mg/L	Delaware Water Quality Standards
Minimum DO, cold water fish (DE)	5.0 mg/L	Delaware Water Quality Standards
Nitrate-Nitrogen	10 mg/L	PA and DE Water Quality Standards
Ammonia-Nitrogen	function(Temp, pH)	PA and EPA Water Quality Criteria
Total Nitrogen guideline (DE)	3.0 mg/L	DE 303(d) rationale document
Total Phosphorus guideline (DE)	0.2 mg/L	DE 303(d) rationale document

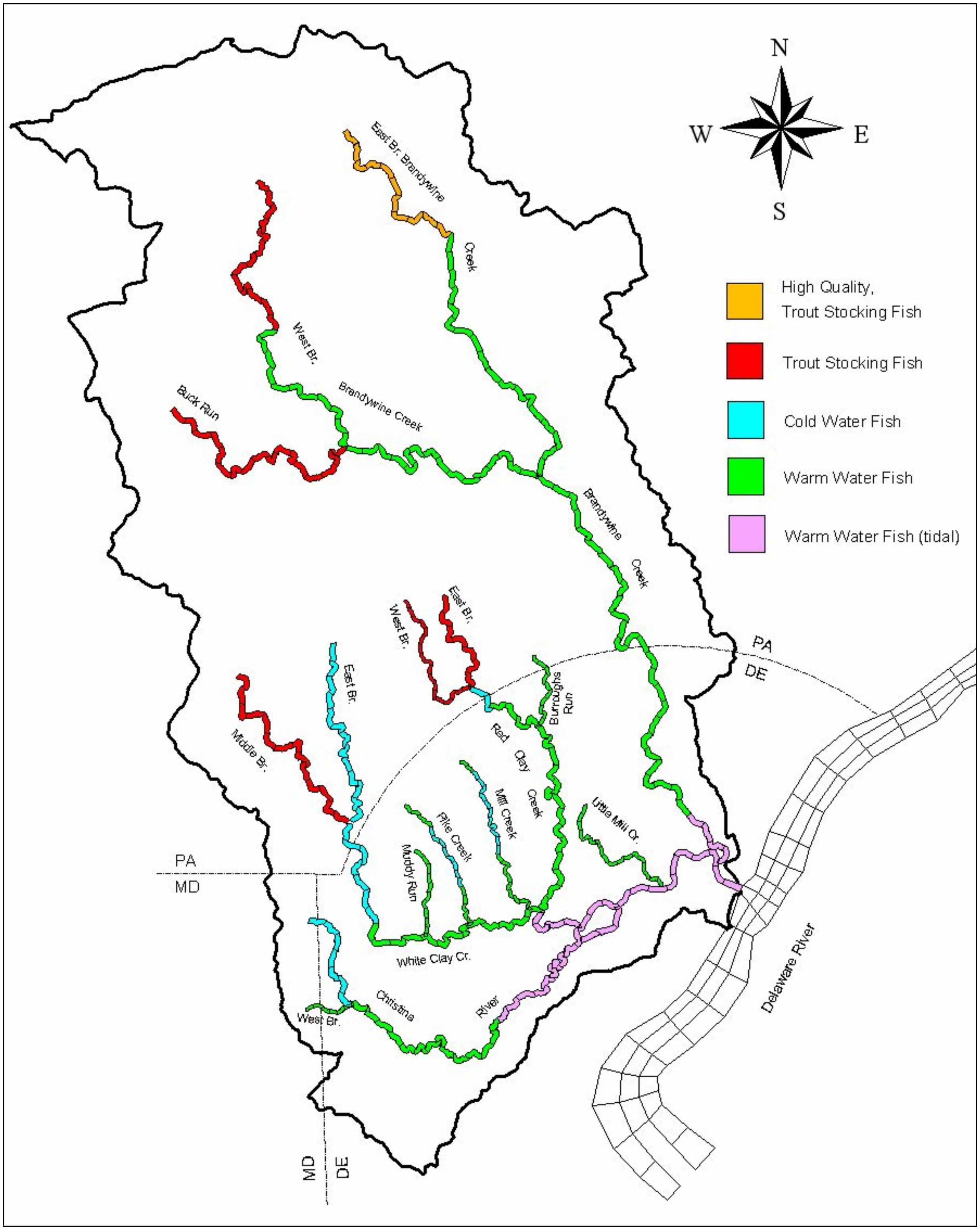

Figure 3-1. Use designations of streams included in the Christina River Basin water quality model

These TMDLs have also identified the pollutants and sources of pollutants that cause or contribute to the impairment of the DO criteria and allocate appropriate loadings to the various sources. Given our scientific knowledge regarding the interrelationship of nutrients, BOD, SOD and their impact on DO, EPA determined it necessary and appropriate to establish numeric targets for total nitrogen and total phosphorus based on applicable state narrative criteria to support the attainment of the numeric DO criterion and protection of aquatic habitat. Establishing numeric water quality endpoints or goals also provides the ability to measure the progress toward attainment of the WQS and to identify the amount or degree of deviation from the allowable pollutant load.

While the ultimate endpoint for the previous low-flow TMDL analysis was to ensure that the WQS for DO were maintained throughout the Christina River Basin, it is necessary to determine if other applicable water quality criteria are met and maintained. Specifically, this applies to the Pennsylvania WQS for nitrate-nitrogen of 10 mg/L and ammonia-nitrogen, which is based on temperature and pH. The Maryland WQS for ammonia-nitrogen adopted the EPA water quality criteria in January 2001 (see Table 1-6). As a result of the pollutant load reductions necessary to maintain the water quality criteria for DO, the WQS for nitrate-nitrogen and ammonia-nitrogen of Pennsylvania and Maryland were also evaluated. The ammonia-nitrogen standard is met throughout the Pennsylvania portion of the Christina River Basin. The only instances where the nitrate nitrogen value of 10 mg/L is exceeded are small distances on the East Branch Brandywine Creek and West Branch Brandywine Creek. As there are no drinking water withdrawals at these locations, the standard is not applicable and additional reduction is not necessary.

The Delaware WQS also set a numeric water quality criterion of 10 mg/L for nitrate-nitrogen. The WQS for nitrate-nitrogen of Delaware are met throughout the Delaware portion of the Christina River Basin. Delaware does not have numeric water quality criteria for ammonia nitrogen; however, the analysis indicates that ammonia-nitrogen levels throughout the Delaware portion of the Christina River Basin are consistent with the recommended EPA water quality criterion from Section 304(a) of the CWA.

Achieving these in-stream numeric water quality targets will ensure that the designated uses (aquatic life and human health uses) of waters in Pennsylvania, Delaware, and Maryland are supported during critical conditions.

Errata

4/30/2007

The2005 and 2006 Total Maximum Daily Load of Nutrients and Low Dissolved Oxygen Under High-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland*, established April 8, 2005, and revised September 26, 2006, by EPA was not intended to modify wasteload allocations (WLAs)established in the* Total Maximum Daily Load of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland*, to the two WWTPs discharging to the West Branch Christina River in Maryland. The two WWTPs are:*

Highlands WWTP MD0065145
Meadowview WWTP MD0022641

The corrected portions of Section 4 are shown in italics below.

4.5.2 Maryland Allocations at MD-DE State Line

Water flowing into Delaware from Maryland must meet Delaware WQS at the Delaware state line. There are two streams that enter Delaware from Maryland: the upper Christina River and Christina River West Branch. The results from the linked HSPF-EFDC models for these two streams were used to determine whether the Delaware guideline endpoints for total nitrogen (3.0 mg/L) and total phosphorus (0.2 mg/L) were satisfied at the state line. The TMDL endpoints at the MD-DE state line for the upper Christina River were achieved under baseline conditions. Therefore, no load reductions were necessary to the portion of the watershed feeding the upper Christina River. The Maryland allocations for nutrients at the Delaware state line for the Christina River West Branch are shown in Table 4-2. The baseline and allocation loads in Table 4-2 represent the average daily nitrogen and phosphorus loads over the four-year model simulation period (October 1, 1994 to October 1, 1998) necessary to achieve the endpoint concentration over that same period. The model simulations indicate the load reductions from baseline conditions were *72.8%* for total nitrogen, and 47.5% for total phosphorus.

Table 4-2. Total nitrogen and total phosphorus allocations at MD-DE state line

Location	Baseline Load (kg/day)	Maryland Allocation (kg/day)	Reduction
Total Nitrogen			
Christina River West Branch (MD-DE Line)	*95.5*	26.2	*72.8%*
Total Phosphorus			
Christina River West Branch (MD-DE Line)	3.8	2.0	47.5%

TMDL summary for Christina River Watershed

Subbasin	Baseline Loads (kg/day)	Allocations (kg/day)	Percent

	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	Reduction
Total Nitrogen									
C01	*57.781*	53.686	*110.467*	*57.781*	2.634	7.566	0.537	*67.718*	*38.9%*
C02	0.000	78.387	78.387	0.000	48.752	25.715	3.919	78.387	0.0%
C03	0.000	20.367	20.367	0.000	19.349	0.000	1.018	20.367	0.0%
C04	0.000	17.290	17.290	0.000	16.426	0.000	0.865	17.290	0.0%
C05	2.606	12.006	14.612	0.618	11.406	0.000	0.600	12.624	13.6%
C06	0.000	42.959	42.959	0.000	38.507	2.304	2.148	42.959	0.0%
C07	0.000	24.946	24.946	0.000	23.699	0.000	1.247	24.946	0.0%
C08	0.000	41.127	41.127	0.000	39.071	0.000	2.056	41.127	0.0%
C09	5.931	72.021	77.952	1.631	68.420	0.000	3.601	73.652	5.5%
Becks Pond	0.000	38.683	38.683	0.000	34.954	1.795	1.934	38.683	0.0%
Sunset Pond	0.000	22.557	22.557	0.000	21.429	0.000	1.128	22.557	0.0%

WLA summary for Christina River Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN Kg/day	TP Kg/day	TN Kg/day	TP Kg/day	TN	TP
C01	MD0022641	0.7000	*52.996*	2.650	*52.996*	2.650	0.0%	0.0%
C01	MD0065145	0.0500	*3.785*	0.189	*3.785*	0.189	0.0%	0.0%
C05	(DE CSO)	See Baseline and WLA nitrogen and phosphorus loads for CSO discharges table						
C09	(DE CSO)	See Baseline and WLA nitrogen and phosphorus loads for CSO discharges table						

TMDL METHODOLOGY AND CALCULATION

4.1 Methodology

This section discusses the methodology used for TMDL development and results in terms of TMDLs and required load reductions for the stream segments listed on Pennsylvania's and Delaware's Section 303(d) lists as impaired due to nutrients and low DO (see Figures 4-1 and 4-2).

To determine nutrient TMDLs for the Christina River Basin listed waters, three models were used: the HSPF watershed loading model, the XP-SWMM CSO discharge model, and the EFDC receiving water model. The HSPF and EFDC models were calibrated using the four-year period October 1, 1994 to October 1, 1998. All three models were run using this same four-year simulation period to calculate the baseline and allocation loads. The HSPF model was used to estimate nonpoint source loads from 70 subbasins in the Christina River Basin. The nonpoint source loads were then input to the EFDC receiving water model for more detailed analysis of instream water quality conditions. The HSPF model was also used to calculate nutrient loads at the Pennsylvania-Delaware state line since the Delaware WQS applies to Pennsylvania at their common border. The calculation at the state line affected four streams: Brandywine Creek, White Clay Creek, Red Clay Creek, and Burroughs Run in the Red Clay Creek watershed. In addition, the HSPF model was used to calculate nutrient loads for several smaller listed stream segments that were not included in the EFDC model. The XP-SWMM model was used to calculate nutrient 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 receiving water model to simulate nutrient concentrations in the tidal waters of the Christina River and Brandywine Creek.

Baseline conditions for the TMDL included meteorology and hydrology for the October 1, 1994, to October 1, 1998, calibration period. NPDES flows were set to their permit limits for the entire four-year simulation period. The Pennsylvania NPDES facilities operated with seasonal permit concentrations for CBOD, ammonia nitrogen, and total phosphorus. During the winter periods from November 1 to April 30, the concentration of 5-day CBOD (CBOD5) was set to two times the summer concentration and ammonia-nitrogen concentration was set to three times the summer value. During the period November 1 to March 31, the total phosphorus concentrations were set to twice of the summer permit concentration. CSO loads from the City of Wilmington were estimated using simulated flow rates from the XP-SWMM model and event mean concentrations from a storm-water monitoring program. Septic loads and land use coverage from 1995 were used for the baseline conditions in the HSPF watershed model.

4.2 TMDL Calculation

TMDLs were established for each individual stream segment listed for nutrients on the Pennsylvania and Delaware Section 303(d) lists. Each TMDL consists of a point source waste load allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS). These TMDLs identify the sources of pollutants that cause or contribute to the impairment and allocate appropriate loadings to the various sources. The basic equation used for TMDLs and allocations to sources is:

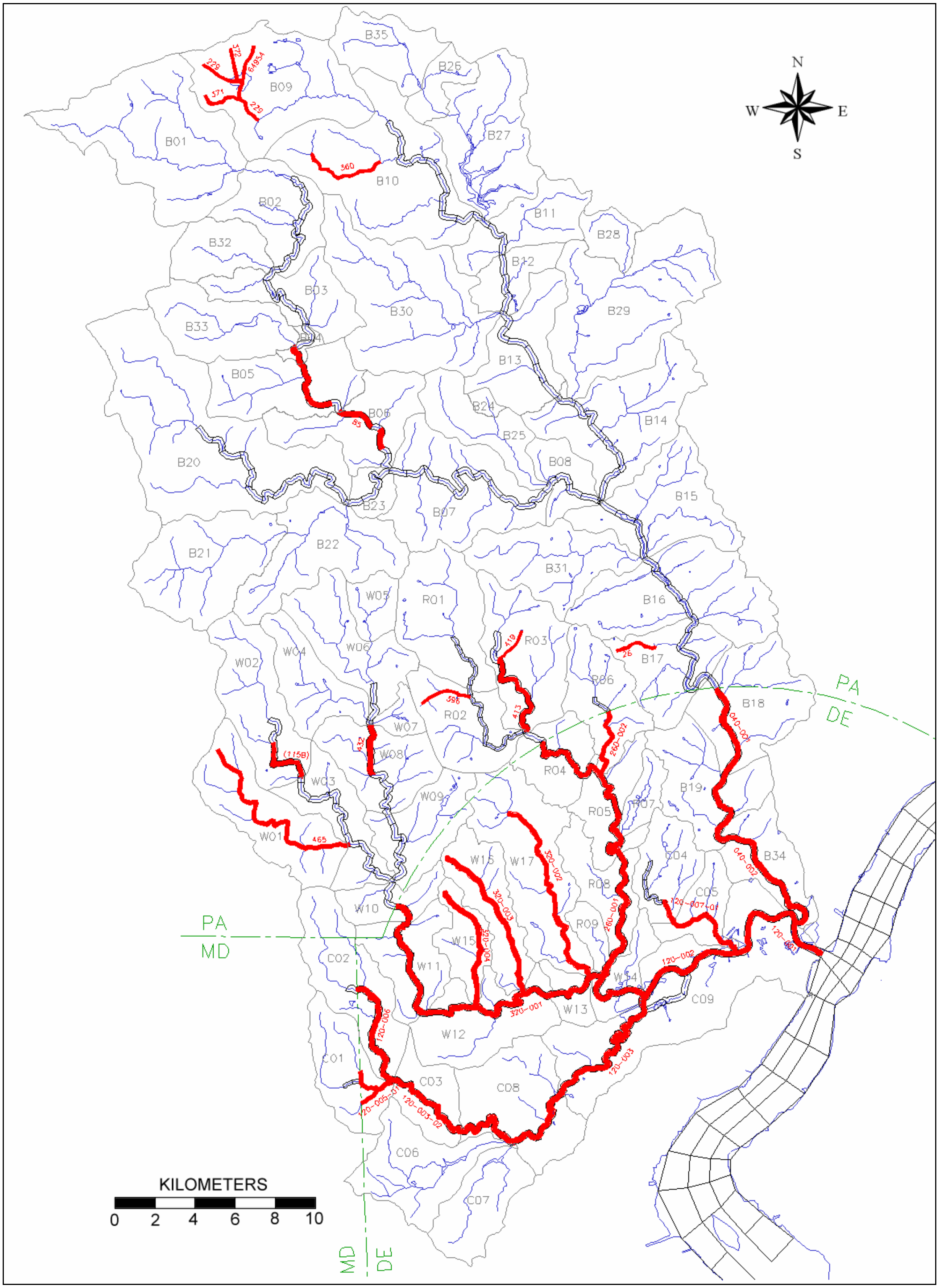

Figure 0-1. Stream segments impaired by nutrients and low DO on 1996 Section 303(d) lists

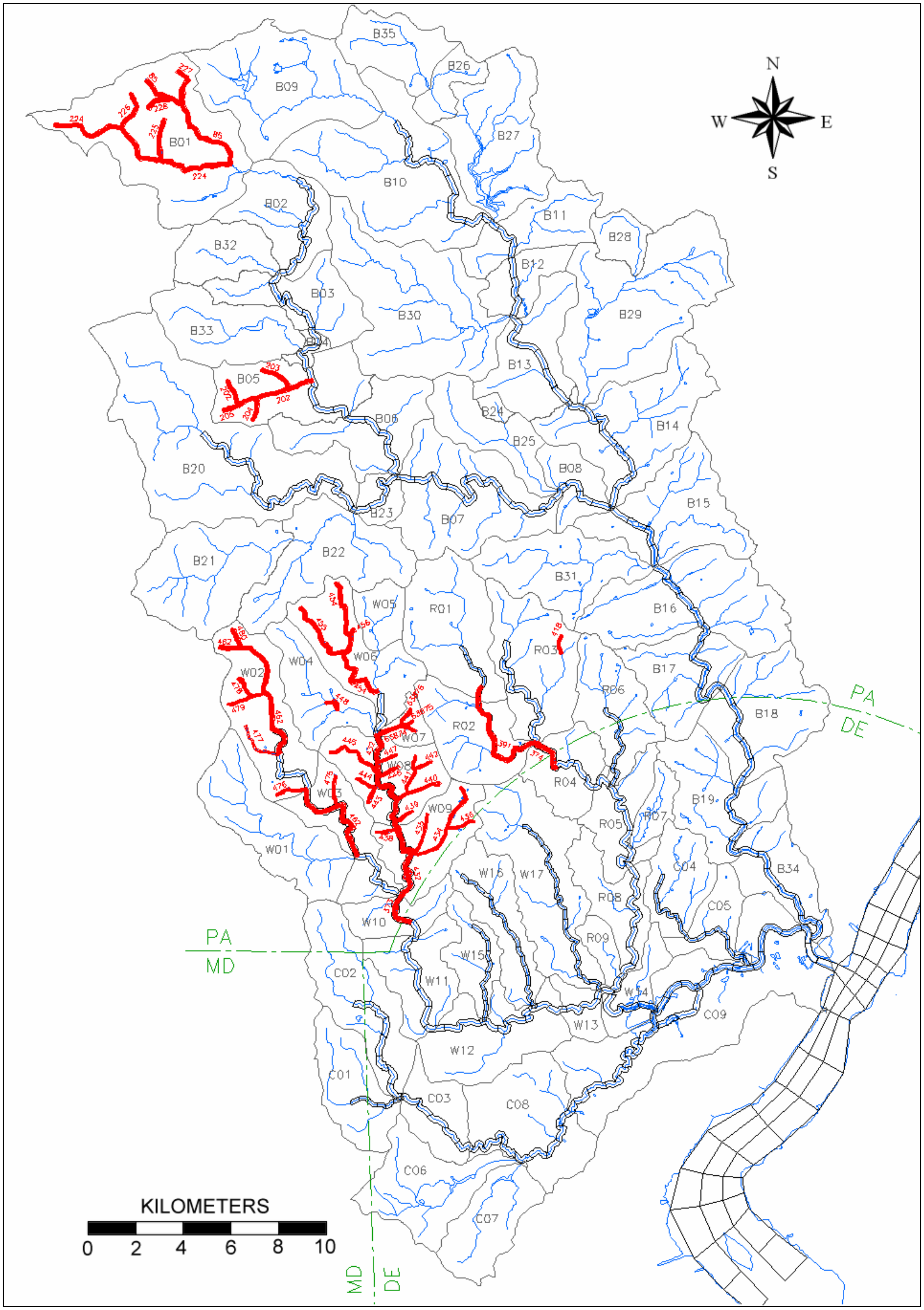

Figure 0-2. Stream segments impaired by nutrients and low DO on 1998 Section 303(d) lists

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

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 of MOS was used for this TMDL.

4.3 Waste Load Allocations

Federal regulations (40 CFR 130.7) require TMDLs to include individual WLAs for each point source. Based on the water quality model simulations, none of the non-MS4 NPDES permitted dischargers in the impaired subbasins were required to reduce their present NPDES permit limits for CBOD, nitrogen, or phosphorus.

The wasteload allocation (WLA) portion of the TMDL equation is the total loading of a pollutant that is assigned to point sources. EPA's stormwater permitting regulations require municipalities to obtain permit coverage for all stormwater discharges from municipal separate storm sewer systems (MS4). On November 22, 2002, an EPA Memorandum from Robert Wayland and James Hanlon, Water Division Directors (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 wasteload allocation component of the TMDL and may not be addressed by the load allocation 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

Based on this memorandum, MS4s within the Christina River watershed are treated as point sources for TMDL and NPDES permitting purposes, and the nutrient loading generated within the boundary of an MS4 area was assigned a WLA. Each of the townships/municipalities within the watershed has been designated by PADEP as needing coverage under NPDES Phase II Stormwater Regulations, and comprises almost the entire watershed area. To determine the nutrient loading associated with each MS4, the township boundary GIS layer was overlaid with the land-use coverage. Nutrient 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).

At this time, EPA cannot determine what portion of the municipalities are designated/used for collection or conveying stormwater, as opposed to portions that are truly nonpoint sources. As part of the Phase II process, MS4s will be responsible for evaluating and mapping out areas that are contributing to or collected in storm sewers. Since these systems have not yet been delineated, the TMDL includes nonpoint source loadings into the WLA portion of the TMDL. Once these delineations are available, the nonpoint source loadings can then be separated out of the WLAs and moved under the LA. Until that time, the WLAs have been broken down by land uses. These areas should not be precluded from nonpoint source funding, such as Growing Greener and Section 319 grants.

The TMDL loads 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. In the future, the States may allow an alternate reduction scenario, which also demonstrates that water quality standards are met throughout the length of impaired waterbody, or may redistribute the wateload allocations within an impaired waterbody segment. It is anticipated that any re-allocation of the wasteload allocation would be done as part of the NPDES permitting to allow for public participation.

4.4 Load Allocations

According to federal regulations (40 CFR 130.2(g)), load allocations 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 4.2, once a municipality delineates its MS4 area, the nutrient 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 allocation will be unchanged.

4.5 TMDL Results and Allocations

The impaired stream segments on the Section 303(d) list for nutrients and low DO in the Pennsylvania portion of the Christina River Basin are located in the Brandywine Creek, White Clay Creek, and Red Clay Creek watersheds. The HSPF and EFDC models for were run for the period October 1, 1994, to October 1, 1998, for both the baseline (current) conditions and for the TMDL allocation conditions. The WLA from the low-flow TMDL (USEPA, 2002) was used as the baseline conditions for the NPDES facilities in this high-flow TMDL. Watershed nutrient loads were adjusted in the TMDL allocation scenarios until the target endpoints described in Section 3.0 were achieved. The allocation process included the following steps.

(1) For the impaired Pennsylvania subbasins, the nutrient loads were reduced as necessary to protect the DO water quality standards.

(2) At the Delaware-Pennsylvania state line, the simulated TN and TP concentrations were used to determine the Pennsylvania allocations for TN and TP necessary to achieve Delaware's guidance of 3.0 mg/L and 0.2 mg/L, respectively.

(3) At the Maryland-Delaware state line, the simulated TN and TP concentrations were used to calculate the Maryland allocations for TN and TP necessary to achieve Delaware's guidance of 3.0 mg/L and 0.2 mg/L, respectively.

(4) For Delaware's upper subbasins, the TN and TP guidance concentrations were used to adjust nutrient loads, as necessary, in each subbasin. Also, protection of the WQS for DO, nitrate-nitrogen, and ammonia-nitrogen was determined and additional load reductions were made, as necessary, to achieve the WQS.

(5) For the tidal Christina River near the mouth of the basin, the model was run with reductions stipulated in steps (1) to (3) above and the TMDL endpoints pertaining to Delaware (see Table 3-1) were evaluated to determine if reductions were necessary to CSO loads from the City of Wilmington.

4.5.1 Pennsylvania Allocations at PA-DE State Line

Water flowing into Delaware from Pennsylvania must meet Delaware WQS at the Delaware state line. There are four streams that enter Delaware from Pennsylvania: Brandywine Creek, White Clay Creek, Red Clay Creek, and Burroughs Run. The results from the linked HSPF-EFDC models for these four streams were used to determine whether the Delaware guideline endpoints for total nitrogen (3.0 mg/L) and total phosphorus (0.2 mg/L) were satisfied at the state line. The Pennsylvania allocations for nutrients at the state line are shown in Table 4-1. The baseline and allocation loads in Table 4-1 represent the average nitrogen and phosphorus loads over the four-year model simulation period (October 1, 1994 to October 1, 1998) necessary to achieve an average endpoint concentration over that same period. Model results indicate the load reductions from baseline conditions range from about 0% to 46% for total nitrogen, and from 0% to 73% for total phosphorus.

Table 4-1. Total nitrogen and total phosphorus allocations at PA-DE state line

Location	Baseline Load (kg/day)	Pennsylvania Allocation (kg/day)	Reduction
Total Nitrogen			
Brandywine Creek (at PA-DE Line)	6849.8	3663.8	46.5%
White Clay Creek (at PA-DE Line)	956.2	685.0	28.4%
Red Clay Creek (at PA-DE Line)	466.7	320.4	31.3%
Burroughs Run (at PA-DE Line)	43.4	43.4	0.0%
Total Phosphorus			
Brandywine Creek (at PA-DE Line)	423.8	250.8	40.8%
White Clay Creek (at PA-DE Line)	110.6	65.9	40.4%
Red Clay Creek (at PA-DE Line)	62.8	17.2	72.6%
Burroughs Run (at PA-DE Line)	0.8	0.8	0.0%

4.5.2 Maryland Allocations at MD-DE State Line

Water flowing into Delaware from Maryland must meet Delaware WQS at the Delaware state line. There are two streams that enter Delaware from Maryland: the upper Christina River and Christina River West Branch. The results from the linked HSPF-EFDC models for these two streams were used to determine whether the Delaware guideline endpoints for total nitrogen (3.0 mg/L) and total phosphorus (0.2 mg/L) were satisfied at the state line. The TMDL endpoints at the MD-DE state line for the upper Christina River were achieved under baseline conditions. Therefore, no load reductions were necessary to the portion of the watershed feeding the upper Christina River. The Maryland allocations for nutrients at the Delaware state line for the Christina River West Branch are shown in Table 4-2. The baseline and allocation loads in Table 4-2 represent the average daily nitrogen and phosphorus loads over the four-year model simulation period (October 1, 1994 to October 1, 1998) necessary to achieve the endpoint concentration over that same period. The model simulations indicate the load reductions from baseline conditions were 61.9% for total nitrogen, and 47.5% for total phosphorus.

Table 4-2. Total nitrogen and total phosphorus allocations at MD-DE state line

Location	Baseline Load (kg/day)	Maryland Allocation (kg/day)	Reduction
Total Nitrogen			
Christina River West Branch (MD-DE Line)	68.7	26.2	61.9%
Total Phosphorus			
Christina River West Branch (MD-DE Line)	3.8	2.0	47.5%

4.5.3 Nitrate-Nitrogen and Ammonia-Nitrogen Allocations

Under baseline conditions, the model indicated that the daily average nitrate concentrations were less than 10 mg/L at all grid cell locations within the listed impaired water segments. Therefore, no reductions in nitrogen loads were necessary to achieve compliance with the nitrate-nitrogen WQS of 10 mg/L. Ammonia-nitrogen, which is based on pH and temperature, was investigated during the low-flow study (USEPA, 2002) and it was determined that the ammonia-nitrogen standard was protected throughout the Christina River Basin. Since the critical period for potential violations of the ammonia-nitrogen standard occur during low-flow summer months, no additional investigation was deemed necessary for this high-flow study.

4.5.4 Nitrogen and Phosphorus Allocations

In Pennsylvania, it was necessary to reduce nitrogen and phosphorus loads from both point and nonpoint sources in a number of subbasins in order to protect the minimum and daily average DO water quality standards. The models were run in an iterative fashion to determine the load reductions required from point and nonpoint sources to protect the DO criteria. The load allocations and WLAs are summarized by impaired subbasin in Tables 4-3 to 4-10 below. An explicit 5% margin of safety (MOS) is included in the TMDL allocation. The baseline and preliminary TMDL allocation loads shown in Table 4-3 to 4-10 represent the average daily loads calculated from the HSPF and EFDC model simulations covering the period October 1, 1994, to October 1, 1998. The model results for the baseline condition and TMDL allocations are presented in the graphs in Appendix D. These graphs represent transects along the impaired stream segments included in the water quality model and show the model results in relation to the TMDL target endpoints.

4.5.5 Dissolved Oxygen Allocations

Under the low-flow study (USEPA, 2002), an analysis was performed to investigate potential dissolved oxygen WQS violations during critical conditions. The NPDES point source discharges were set to their maximum permitted flows and concentrations and the model was run under 7Q10 (minimum 7-day flow expected to occur every 10 years) stream flow conditions. As a result of the low-flow study, WLAs were established for several NPDES discharges on East Branch Brandywine Creek, West Branch Brandywine Creek, West Branch Red Clay Creek, and West Branch Christina River to protect the dissolved oxygen WQS. For the baseline conditions of this high-flow TMDL, the NPDES discharges in the Christina River Basin were set to the recommended WLA values from the low-flow study during the summer season. During the winter season, the permitted concentrations of ammonia nitrogen, total phosphorus, and CBOD were increased as described in Section 4.1. The model results for the high-flow TMDL allocations presented in Tables 4-1 to 4-10, indicate that no additional reductions to the non-MS4 NPDES discharges over and above those recommended in the low-flow TMDL are necessary to protect the dissolved oxygen WQS. However, nonpoint sources, including MS4s, and CSO load reductions were necessary to achieve the TMDL targets related to dissolved oxygen, total nitrogen, and total phosphorus.

Table 4-3. TMDL summary for Brandywine Creek Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
Total Nitrogen									
B01	31.559	362.174	393.733	31.559	170.416	36.023	10.865	248.863	36.8%
B02	0.000	114.369	114.369	0.000	65.191	0.000	3.431	68.622	40.0%
B03	2.167	89.226	91.393	2.167	67.779	8.510	4.015	82.471	9.8%
B04	0.000	5.369	5.369	0.000	5.101	0.000	0.268	5.369	0.0%
B05	558.690	77.512	636.202	558.690	34.049	10.133	2.325	605.197	4.9%
B06	0.156	123.362	123.518	0.156	80.940	1.095	4.318	86.509	30.0%
B09	0.078	252.455	252.533	0.078	97.148	99.515	10.351	207.092	18.0%
B10	3.721	252.455	256.176	3.721	179.343	17.320	10.351	210.735	17.7%
B17	1.013	83.890	84.903	1.013	43.626	30.491	3.901	79.031	6.9%
B18	0.000	103.795	103.795	0.000	98.605	0.000	5.190	103.795	0.0%
B19	0.946	64.711	65.657	0.946	61.475	0.000	3.236	65.657	0.0%
B32	0.000	29.001	29.001	0.000	24.796	0.000	1.305	26.101	10.0%
B33	1.799	95.092	96.891	1.799	80.541	0.763	4.279	87.382	9.8%
B34	11.443	33.958	45.401	4.107	32.260	0.000	1.698	38.065	16.2%
Total Phosphorus									
B01	6.360	6.920	13.280	6.360	3.256	0.688	0.208	10.512	20.8%
B02	0.000	2.185	2.185	0.000	1.245	0.000	0.066	1.311	40.0%
B03	0.540	16.229	16.769	0.540	12.328	1.548	0.730	15.146	9.7%
B04	0.000	0.988	0.988	0.000	0.939	0.000	0.049	0.988	0.0%
B05	35.524	14.615	50.139	35.524	6.420	1.911	0.438	44.293	11.7%
B06	0.040	25.254	25.294	0.040	16.570	0.224	0.884	17.718	30.0%
B09	0.020	3.849	3.869	0.020	1.481	1.517	0.158	3.176	17.9%
B10	0.429	3.848	4.277	0.429	2.734	0.264	0.158	3.585	16.2%
B17	0.221	7.508	7.729	0.221	3.904	2.729	0.349	7.203	6.8%
B18	0.000	8.586	8.586	0.000	8.157	0.000	0.429	8.586	0.0%
B19	0.189	2.376	2.565	0.189	2.257	0.000	0.119	2.565	0.0%
B32	0.000	2.147	2.147	0.000	1.836	0.000	0.097	1.933	10.0%
B33	0.115	1.729	1.844	0.115	1.465	0.014	0.078	1.672	9.3%
B34	1.966	2.843	4.809	0.730	2.701	0.000	0.142	3.573	25.7%

Table 4-4. WLA summary for Brandywine Creek Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN kg/day	TP kg/day	TN kg/day	TP kg/day	TN	TP
B01	PA0036412	0.0550	2.682	0.559	2.682	0.559	0.0%	0.0%
B01	PA0044776	0.6000	28.799	5.781	28.799	5.781	0.0%	0.0%
B01	PA0057339	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B03	PA0052728	0.0004	0.036	0.015	0.036	0.015	0.0%	0.0%
B03	PA0055697	0.0490	2.131	0.525	2.131	0.525	0.0%	0.0%
B05	PA0011568-001	0.6400	14.045	1.029	14.045	1.029	0.0%	0.0%

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN kg/day	TP kg/day	TN kg/day	TP kg/day	TN	TP
B05	PA0011568-016	0.5045	23.868	0.811	23.868	0.811	0.0%	0.0%
B05	PA0026859	3.8500	466.237	29.508	466.237	29.508	0.0%	0.0%
B05	PA0036897	0.3900	54.54	4.176	54.54	4.176	0.0%	0.0%
B06	PA0053228	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B06	PA0053236	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B09	PA0054691	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B10	PA0050458	0.0351	1.724	0.188	1.724	0.188	0.0%	0.0%
B10	PA0050547	0.0375	1.841	0.201	1.841	0.201	0.0%	0.0%
B10	PA0055492	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B10	PA0057827	0.0050	0.078	0.02	0.078	0.02	0.0%	0.0%
B17	PA0053082	0.0206	1.013	0.221	1.013	0.221	0.0%	0.0%
B19	DE0021768	0.0250	0.947	0.189	0.947	0.189	0.0%	0.0%
B33	PA0012416	0.1400	1.643	0.075	1.643	0.075	0.0%	0.0%
B33	PA0052990	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B33	PA0056073	0.0005	0.078	0.02	0.078	0.02	0.0%	0.0%
B34	(DE CSO)	See Table 4-11						

Table 4-5. TMDL summary for Red Clay Creek Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)					Percent
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	Reduction
Total Nitrogen									
R01	3.677	126.926	130.603	3.677	54.709	5.581	3.173	67.140	48.6%
R02	49.825	104.678	154.503	49.825	49.722	0.000	2.617	102.164	33.9%
R03	6.807	120.151	126.958	6.807	57.071	0.000	3.004	66.882	47.3%
R04	2.197	39.984	42.181	2.197	18.992	0.000	1.000	22.189	47.4%
R05	0.568	34.713	35.281	0.568	16.489	0.000	0.868	17.925	49.2%
R06	0.078	67.015	67.093	0.078	63.664	0.000	3.351	67.093	0.0%
R07	0.000	3.012	3.012	0.000	2.861	0.000	0.151	3.012	0.0%
R08	0.318	23.882	24.200	0.318	22.688	0.000	1.194	24.200	0.0%
R09	0.000	7.346	7.346	0.000	6.979	0.000	0.367	7.346	0.0%
Total Phosphorus									
R01	0.914	2.277	3.191	0.914	0.982	0.100	0.057	2.053	35.7%
R02	7.506	45.473	52.979	7.506	4.320	0.000	0.227	12.053	77.2%
R03	1.606	2.845	4.451	1.606	1.352	0.000	0.071	3.029	31.9%
R04	1.699	6.407	8.106	1.699	1.887	0.000	0.099	3.685	54.5%
R05	0.114	4.249	4.363	0.114	4.037	0.000	0.212	4.363	0.0%
R06	0.020	1.269	1.289	0.020	1.206	0.000	0.063	1.289	0.0%
R07	0.000	0.424	0.424	0.000	0.403	0.000	0.021	0.424	0.0%
R08	0.133	1.383	1.516	0.133	1.314	0.000	0.069	1.516	0.0%
R09	0.000	0.360	0.360	0.000	0.342	0.000	0.018	0.360	0.0%

Table 4-6. WLA summary for Red Clay Creek Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN Kg/day	TP Kg/day	TN Kg/day	TP Kg/day	TN	TP
R01	PA0050679	0.2500	0.321	0.134	0.321	0.134	0.0%	0.0%
R01	PA0057720-001	0.0720	3.240	0.732	3.240	0.732	0.0%	0.0%
R01	PA0057720-002	0.0900	0.116	0.048	0.116	0.048	0.0%	0.0%
R02	PA0024058	1.1000	49.825	7.506	49.825	7.506	0.0%	0.0%
R03	PA0055107	0.1500	6.807	1.606	6.807	1.606	0.0%	0.0%
R04	DE0000451	2.1700	1.972	1.643	1.972	1.643	0.0%	0.0%

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN Kg/day	TP Kg/day	TN Kg/day	TP Kg/day	TN	TP
R04	DE0050067	0.0015	0.225	0.056	0.225	0.056	0.0%	0.0%
R05	DE0021709	0.0150	0.568	0.114	0.568	0.114	0.0%	0.0%
R06	PA0055425	0.0005	0.078	0.020	0.078	0.020	0.0%	0.0%
R08	DE0000230	0.3500	0.318	0.133	0.318	0.133	0.0%	0.0%

Table 4-7. TMDL summary for White Clay Creek Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
Total Nitrogen									
W01	0.981	157.038	158.019	0.981	74.593	0.000	3.926	79.500	49.7%
W02	15.503	133.766	149.269	15.503	47.807	9.378	3.010	75.697	49.3%
W03	0.000	87.269	87.269	0.000	41.453	0.000	2.182	43.635	50.0%
W04	0.000	83.361	83.361	0.000	38.121	1.476	2.084	41.681	50.0%
W06	59.718	168.665	228.383	59.718	50.433	29.683	4.217	144.051	36.9%
W07	8.868	29.463	38.331	8.868	13.994	0.000	0.737	23.599	38.4%
W08	1.164	129.466	130.630	1.164	61.496	0.000	3.237	65.897	49.6%
W09	0.113	79.504	79.617	0.113	37.764	0.000	1.988	39.865	49.9%
W10	0.000	32.949	32.949	0.000	15.651	0.000	0.824	16.475	50.0%
W11	0.000	39.714	39.714	0.000	37.728	0.000	1.986	39.714	0.0%
W12	0.027	52.612	52.639	0.027	49.981	0.000	2.631	52.639	0.0%
W13	0.000	12.866	12.866	0.000	12.223	0.000	0.643	12.866	0.0%
W14	0.000	13.572	13.572	0.000	12.893	0.000	0.679	13.572	0.0%
W15	0.000	34.796	34.796	0.000	33.056	0.000	1.740	34.796	0.0%
W16	0.000	39.019	39.019	0.000	37.068	0.000	1.951	39.019	0.0%
W17	0.000	84.250	84.250	0.000	80.038	0.000	4.213	84.250	0.0%
Total Phosphorus									
W01	0.214	1.921	2.135	0.214	0.821	0.000	0.043	1.078	49.5%
W02	2.676	1.418	4.094	2.676	0.507	0.100	0.032	3.315	19.0%
W03	0.000	16.736	16.736	0.000	7.155	0.000	0.377	7.532	55.0%
W04	0.000	1.170	1.170	0.000	0.482	0.019	0.026	0.527	55.0%
W06	6.493	2.203	8.696	6.493	0.330	0.194	0.028	7.044	19.0%
W07	0.105	1.890	1.995	0.105	0.808	0.000	0.043	0.955	52.1%
W08	0.084	59.994	60.078	0.084	15.958	0.000	0.840	16.882	71.9%
W09	0.046	15.519	15.565	0.046	6.635	0.000	0.349	7.030	54.8%
W10	0.000	4.907	4.907	0.000	2.098	0.000	0.110	2.208	55.0%
W11	0.000	5.474	5.474	0.000	5.200	0.000	0.274	5.474	0.0%
W12	0.011	4.122	4.133	0.011	3.916	0.000	0.206	4.133	0.0%
W13	0.000	1.074	1.074	0.000	1.020	0.000	0.054	1.074	0.0%
W14	0.000	0.637	0.637	0.000	0.605	0.000	0.032	0.637	0.0%
W15	0.000	0.494	0.494	0.000	0.469	0.000	0.025	0.494	0.0%
W16	0.000	0.831	0.831	0.000	0.789	0.000	0.042	0.831	0.0%
W17	0.000	2.152	2.152	0.000	2.044	0.000	0.108	2.152	0.0%

Table 4-8. WLA summary for White Clay Creek Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN kg/day	TP kg/day	TN kg/day	TP kg/day	TN	TP
W01	PA0053783	0.0200	0.981	0.214	0.981	0.214	0.0%	0.0%
W02	PA0024066	0.2500	15.503	2.676	15.503	2.676	0.0%	0.0%
W06	PA0025488	0.3000	59.038	6.425	59.038	6.425	0.0%	0.0%

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN kg/day	TP kg/day	TN kg/day	TP kg/day	TN	TP
W06	PA0040436	0.0090	0.680	0.068	0.680	0.068	0.0%	0.0%
W07	PA0056898	0.0650	8.868	0.105	8.868	0.105	0.0%	0.0%
W08	PA0057029	0.1440	1.164	0.084	1.164	0.084	0.0%	0.0%
W09	PA0052451	0.0012	0.113	0.046	0.113	0.046	0.0%	0.0%
W12	DE0000191	0.0300	0.027	0.011	0.027	0.011	0.0%	0.0%

Table 4-9. TMDL summary for Christina River Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
Total Nitrogen									
C01	28.965	53.686	82.651	28.965	2.634	7.566	0.537	39.702	52.0%
C02	0.000	78.387	78.387	0.000	48.752	25.715	3.919	78.387	0.0%
C03	0.000	20.367	20.367	0.000	19.349	0.000	1.018	20.367	0.0%
C04	0.000	17.290	17.290	0.000	16.426	0.000	0.865	17.290	0.0%
C05	2.606	12.006	14.612	0.618	11.406	0.000	0.600	12.624	13.6%
C06	0.000	42.959	42.959	0.000	38.507	2.304	2.148	42.959	0.0%
C07	0.000	24.946	24.946	0.000	23.699	0.000	1.247	24.946	0.0%
C08	0.000	41.127	41.127	0.000	39.071	0.000	2.056	41.127	0.0%
C09	5.931	72.021	77.952	1.631	68.420	0.000	3.601	73.652	5.5%
Becks Pond	0.000	38.683	38.683	0.000	34.954	1.795	1.934	38.683	0.0%
Sunset Pond	0.000	22.557	22.557	0.000	21.429	0.000	1.128	22.557	0.0%
Total Phosphorus									
C01	2.839	1.334	4.173	2.839	0.065	0.188	0.013	3.106	25.6%
C02	0.000	1.584	1.584	0.000	0.985	0.520	0.079	1.584	0.0%
C03	0.000	2.610	2.610	0.000	2.480	0.000	0.131	2.610	0.0%
C04	0.000	0.438	0.438	0.000	0.416	0.000	0.022	0.438	0.0%
C05	0.441	0.826	1.267	0.104	0.785	0.000	0.041	0.930	26.6%
C06	0.000	1.211	1.211	0.000	1.085	0.065	0.061	1.211	0.0%
C07	0.000	1.000	1.000	0.000	0.950	0.000	0.050	1.000	0.0%
C08	0.000	4.202	4.202	0.000	3.992	0.000	0.210	4.202	0.0%
C09	1.003	6.688	7.691	0.276	6.354	0.000	0.334	6.964	9.5%
Becks Pond	0.000	1.090	1.090	0.000	0.985	0.051	0.055	1.090	0.0%
Sunset Pond	0.000	0.904	0.904	0.000	0.859	0.000	0.045	0.904	0.0%

Table 4-10. WLA summary for Christina River Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads		WLA		Percent Reduction	
			TN Kg/day	TP Kg/day	TN Kg/day	TP Kg/day	TN	TP
C01	MD0022641	0.7000	26.503	2.650	26.503	2.650	0.0%	0.0%
C01	MD0065145	0.0500	2.462	0.189	2.462	0.189	0.0%	0.0%
C05	(DE CSO)	See Table 4-11						
C09	(DE CSO)	See Table 4-11						

4.5.6 CSO Allocations

The City of Wilmington has 38 combined sewer overflows (CSOs) that discharge within the Christina River Basin study area. A summary of the baseline and allocated annual average nitrogen and phosphorus for CSOs grouped by EFDC model grid cell is provided in Appendix E,

Table E-5. After applying the TMDL allocations listed in Tables 4-1 to 4-10, the water quality model indicated that the TP target of 0.2 mg/L was protected in lower Brandywine Creek and lower Christina River where the CSOs discharge. However, the model indicated that the TN target of 3.0 mg/L and the water quality standards for DO were not protected; therefore, the CSO loads were reduced to meet these endpoints. The combined reduction of nutrients from the watershed loads and the CSO loads resulted in achievement of the TN target and protection of the DO water quality standards in lower Brandywine Creek and lower Christina River. The baseline and allocated annual average loads for CSO discharges from the City of Wilmington are shown in Table 4-11.

Please note that the TMDL CSO load reductions shown in Appendix E, Table E-5, 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.

Table 4-11. Baseline and WLA nitrogen and phosphorus loads for CSO discharges

Location	CSO ID numbers	Baseline (kg/day)	WLA (kg/day)	Reduction
Total Nitrogen				
Little Mill Creek (C05)	27, 28, 29	2.606	0.618	76.3%
Christina River (C09)	5, 6, 7, 9a, 9c, 10, 11, 12, 13, 14, 15, 16, 17, 30	5.931	1.631	72.5%
Brandywine Cr. (B34)	3, 4a, 4b, 4c, 4d, 4e, 4f, 18, 19, 20, 21a, 21b, 21c, 22b, 22c, 23, 24, 25, 26, RR	11.443	4.107	64.1%
Total CSO load	-	19.980	6.356	68.2%
Total Phosphorus				
Little Mill Creek (C05)	27, 28, 29	0.441	0.104	76.4%
Christina River (C09)	5, 6, 7, 9a, 9c, 10, 11, 12, 13, 14, 15, 16, 17, 30	1.003	0.276	72.5%
Brandywine Cr. (B34)	3, 4a, 4b, 4c, 4d, 4e, 4f, 18, 19, 20, 21a, 21b, 21c, 22b, 22c, 23, 24, 25, 26, RR	1.966	0.730	62.9%
Total CSO load	-	3.410	1.110	67.4%

4.6 Consideration of Critical Conditions

Federal Regulations (40 CFR 130.7(c)(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. Critical conditions include combinations of environmental factors that result in attaining and maintaining the water quality criteria and have an acceptably low frequency of occurrence

(USEPA, 2001). The nutrient and low DO 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 extremes in the basin.

4.7 Consideration of Seasonal Variation

The critical conditions for nutrient impairments of aquatic life habitat cannot be defined with a fixed flow rate. A long-term continuous simulation is the one way to determine when the nutrient concentrations are above the target endpoints. Therefore, the models were run for a four-year period (October 1, 1994 to 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.

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.

Reasonable assurance indicates a high degree of confidence that each waste load allocation (WLA) and load allocation in a TMDL can be implemented. 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 load allocations 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 Best Management Practices for nonpoint source pollutants.

Implementation of best management practices (BMPs) in the affected areas should achieve the loading reduction goals established in the TMDLs. Substantial reductions in the amount of nutrients 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 nutrient reduction. 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 nutrient 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 baseflow 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 adaptive 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 to meet interstate instream water quality standards. 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* (Nov 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 PADEP 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 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.

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 publicly held 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 2005 *Nutrient and Low Dissolved Oxygen TMDL Under High-Flow Conditions for Christina River Basin, Pennsylvania-Delaware-Maryland* was open for public comment on January 20, 2005, with a notice in the *Philadelphia Inquirer* and the *Wilmington New Journal*. On January 6, 2005, a public meeting was held at the Red Clay Room in Kennett Square. Two additional public meetings were held on February 10, 2005, in Newark, DE, and February 17, 2005, in West Chester, PA.

Following the public comment period, the Christina River Basin watershed and receiving water models used for development of nutrient and low dissolved oxygen 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 to 11 am in the Red Clay Room, 423 Dalmatian Street, Kennett Square, Pa. 19348. Public notice announcements were published in the *Philadelphia Inquirer* and the *Wilmington News Journal* on January 20, 2006.

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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

NPDES Stormwater Discharge Associated with Construction Activity Permit Program

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

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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

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
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

HSPF Subbasin	MS4 Municipality	Residential	Agriculture	Open Land	Forest	Water	Urban	MS4 Total	Subbasin Total	MS4 Ratio
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
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

HSPF Subbasin	MS4 Municipality	Residential	Agriculture	Open Land	Forest	Water	Urban	MS4 Total	Subbasin Total	MS4 Ratio
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

HSPF Subbasin	MS4 Municipality	Residential	Agriculture	Open Land	Forest	Water	Urban	MS4 Total	Subbasin Total	MS4 Ratio
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

HSPF Subbasin	MS4 Municipality	Residential	Agriculture	Open Land	Forest	Water	Urban	MS4 Total	Subbasin Total	MS4 Ratio
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. Total nitrogen MS4 baseline loads for Brandywine Creek watershed (kg/day)

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
COATESVILLE CITY	B03	0.00	0.00	0.00	0.80	0.00	0.00	0.80	16.08
COATESVILLE CITY	B04	0.20	0.00	0.00	1.81	0.00	0.40	2.42	
COATESVILLE CITY	B05	6.70	0.00	0.27	1.61	0.00	4.29	12.86	
EAST BRANDYWINE TWP	B10	17.64	17.64	0.42	17.64	0.42	0.42	54.19	54.19
EAST FALLOWFIELD TWP	B05	1.88	4.55	0.00	7.77	0.00	2.14	16.34	110.54
EAST FALLOWFIELD TWP	B06	21.92	33.58	0.93	34.51	0.00	3.26	94.20	
HONEY BROOK BORO	B01	5.40	3.60	0.00	0.00	0.00	0.60	9.61	9.61
HONEY BROOK TWP	B01	13.21	203.52	0.00	46.23	0.60	11.41	274.96	421.64
HONEY BROOK TWP	B02	6.14	1.89	0.00	19.85	0.00	0.47	28.35	
HONEY BROOK TWP	B09	7.86	72.83	0.00	24.63	7.34	1.05	113.70	
HONEY BROOK TWP	B10	1.26	0.42	0.00	1.26	0.84	0.84	4.62	
KENNETT TWP	B17	1.36	0.00	0.00	1.02	0.00	0.00	2.38	2.38
MODENA BORO	B05	0.27	0.00	0.00	0.54	0.27	0.00	1.07	4.80
MODENA BORO	B06	0.47	0.93	0.00	0.93	0.00	1.40	3.73	
NEWLIN TWP	B06	0.00	1.40	0.00	4.20	0.00	0.93	6.53	6.53
PENNSBURY TWP	B17	6.47	16.35	0.00	23.16	1.02	0.00	47.00	47.00
SADSBURY TWP	B05	0.27	0.80	0.00	0.27	0.00	0.27	1.61	3.05
SADSBURY TWP	B33	0.72	0.36	0.00	0.36	0.00	0.00	1.44	
UPPER UWCHLAN TWP	B10	2.10	4.20	0.00	4.20	0.00	0.42	10.92	10.92
VALLEY TWP	B03	0.40	1.21	0.00	1.21	0.00	1.21	4.02	57.57
VALLEY TWP	B04	0.20	0.40	0.00	2.15	0.00	0.20	2.95	
VALLEY TWP	B05	4.55	8.04	0.27	8.30	0.27	6.43	27.86	
VALLEY TWP	B33	3.97	6.14	0.36	9.02	0.00	3.25	22.74	
WALLACE TWP	B09	1.05	2.62	0.00	6.29	0.00	1.05	11.00	126.53
WALLACE TWP	B10	15.12	38.65	1.26	56.72	0.00	3.78	115.53	
WEST BRADFORD TWP	B06	3.26	8.39	0.00	5.60	0.00	0.00	17.25	17.25
WEST BRANDYWINE TWP	B02	10.87	15.61	0.00	17.96	0.47	1.89	46.80	136.01
WEST BRANDYWINE TWP	B03	15.69	14.49	0.00	13.68	0.00	0.40	44.26	
WEST BRANDYWINE TWP	B10	8.82	17.64	0.42	15.96	0.42	1.68	44.95	
WEST CALN TWP	B01	2.40	0.00	0.00	11.41	0.00	0.60	14.41	183.72
WEST CALN TWP	B02	8.51	15.12	0.47	14.18	0.47	0.47	39.22	
WEST CALN TWP	B03	5.23	10.06	0.40	13.28	0.40	0.80	30.18	
WEST CALN TWP	B32	4.17	10.05	0.00	14.20	0.00	0.57	29.00	
WEST CALN TWP	B33	11.91	34.10	1.80	18.77	2.17	2.17	70.91	
WILMINGTON, DE	B19	0.04	0.00	0.08	0.17	0.02	0.04	0.36	22.43

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
WILMINGTON, DE	B34	7.16	0.00	3.16	1.35	0.87	9.53	22.07	
NEW CASTLE CO., DE	B17	10.56	19.25	5.13	36.99	1.07	1.69	74.70	217.66
NEW CASTLE CO., DE	B18	8.47	14.18	9.73	25.50	0.74	8.11	66.73	
NEW CASTLE CO., DE	B19	13.47	2.68	25.96	10.51	0.63	11.10	64.35	
NEW CASTLE CO., DE	B34	1.34	0.53	0.08	1.95	0.01	7.98	11.89	

Table C-5b. Total nitrogen MS4 allocations for Brandywine Creek watershed (kg/day)

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
COATESVILLE CITY	B03	0.00	0.00	0.00	0.72	0.00	0.00	0.72	10.86
COATESVILLE CITY	B04	0.20	0.00	0.00	1.81	0.00	0.40	2.42	
COATESVILLE CITY	B05	4.02	0.00	0.16	0.96	0.00	2.57	7.71	
EAST BRANDYWINE TWP	B10	14.47	14.47	0.34	14.47	0.34	0.34	44.44	44.44
EAST FALLOWFIELD TWP	B05	1.13	2.73	0.00	4.66	0.00	1.29	9.80	75.74
EAST FALLOWFIELD TWP	B06	15.34	23.50	0.65	24.16	0.00	2.29	65.94	
HONEY BROOK BORO	B01	3.24	2.16	0.00	0.00	0.00	0.36	5.76	5.76
HONEY BROOK TWP	B01	7.92	122.11	0.00	27.74	0.36	6.84	164.98	279.02
HONEY BROOK TWP	B02	3.69	1.13	0.00	11.91	0.00	0.28	17.01	
HONEY BROOK TWP	B09	6.45	59.72	0.00	20.19	6.02	0.86	93.24	
HONEY BROOK TWP	B10	1.03	0.34	0.00	1.03	0.69	0.69	3.79	
KENNETT TWP	B17	1.27	0.00	0.00	0.95	0.00	0.00	2.22	2.22
MODENA BORO	B05	0.16	0.00	0.00	0.32	0.16	0.00	0.64	3.25
MODENA BORO	B06	0.33	0.65	0.00	0.65	0.00	0.98	2.61	
NEWLIN TWP	B06	0.00	0.98	0.00	2.94	0.00	0.65	4.57	4.57
PENNSBURY TWP	B17	6.02	15.20	0.00	21.54	0.95	0.00	43.71	43.71
SADSBURY TWP	B05	0.16	0.48	0.00	0.16	0.00	0.16	0.96	2.26
SADSBURY TWP	B33	0.65	0.32	0.00	0.32	0.00	0.00	1.30	
UPPER UWCHLAN TWP	B10	1.72	3.44	0.00	3.44	0.00	0.34	8.96	8.96
VALLEY TWP	B03	0.36	1.09	0.00	1.09	0.00	1.09	3.62	43.75
VALLEY TWP	B04	0.20	0.40	0.00	2.15	0.00	0.20	2.95	
VALLEY TWP	B05	2.73	4.82	0.16	4.98	0.16	3.86	16.71	
VALLEY TWP	B33	3.57	5.52	0.32	8.12	0.00	2.92	20.46	
WALLACE TWP	B09	0.86	2.15	0.00	5.16	0.00	0.86	9.02	103.76
WALLACE TWP	B10	12.40	31.69	1.03	46.51	0.00	3.10	94.74	
WEST BRADFORD TWP	B06	2.29	5.88	0.00	3.92	0.00	0.00	12.08	12.08
WEST BRANDYWINE TWP	B02	6.52	9.37	0.00	10.77	0.28	1.13	28.08	104.78
WEST BRANDYWINE TWP	B03	14.12	13.04	0.00	12.31	0.00	0.36	39.84	
WEST BRANDYWINE TWP	B10	7.23	14.47	0.34	13.09	0.34	1.38	36.86	
WEST CALN TWP	B01	1.44	0.00	0.00	6.84	0.00	0.36	8.65	149.26
WEST CALN TWP	B02	5.10	9.07	0.28	8.51	0.28	0.28	23.53	
WEST CALN TWP	B03	4.71	9.05	0.36	11.95	0.36	0.72	27.16	
WEST CALN TWP	B32	3.76	9.05	0.00	12.78	0.00	0.51	26.10	
WEST CALN TWP	B33	10.72	30.69	1.62	16.89	1.95	1.95	63.82	
WILMINGTON, DE	B19	0.04	0.00	0.08	0.17	0.02	0.04	0.36	22.43
WILMINGTON, DE	B34	7.16	0.00	3.16	1.35	0.87	9.53	22.07	
NEW CASTLE CO., DE	B17	9.82	17.90	4.77	34.40	1.00	1.57	69.47	212.43
NEW CASTLE CO., DE	B18	8.47	14.18	9.73	25.50	0.74	8.11	66.73	
NEW CASTLE CO., DE	B19	13.47	2.68	25.96	10.51	0.63	11.10	64.35	
NEW CASTLE CO., DE	B34	1.34	0.53	0.08	1.95	0.01	7.98	11.89	

Table C-6a. Total phosphorus MS4 baseline loads for Brandywine Creek watershed (kg/day)

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
COATESVILLE CITY	B03	0.000	0.000	0.000	0.146	0.000	0.000	0.146	3.015
COATESVILLE CITY	B04	0.037	0.000	0.000	0.334	0.000	0.074	0.445	
COATESVILLE CITY	B05	1.263	0.000	0.051	0.303	0.000	0.808	2.424	
EAST BRANDYWINE TWP	B10	0.269	0.269	0.006	0.269	0.006	0.006	0.826	0.826
EAST FALLOWFIELD TWP	B05	0.354	0.859	0.000	1.465	0.000	0.404	3.081	22.365
EAST FALLOWFIELD TWP	B06	4.487	6.874	0.191	7.065	0.000	0.668	19.284	
HONEY BROOK BORO	B01	0.103	0.069	0.000	0.000	0.000	0.011	0.184	0.184
HONEY BROOK TWP	B01	0.252	3.889	0.000	0.883	0.011	0.218	5.254	7.599
HONEY BROOK TWP	B02	0.117	0.036	0.000	0.379	0.000	0.009	0.542	
HONEY BROOK TWP	B09	0.120	1.110	0.000	0.375	0.112	0.016	1.734	
HONEY BROOK TWP	B10	0.019	0.006	0.000	0.019	0.013	0.013	0.070	
KENNETT TWP	B17	0.122	0.000	0.000	0.091	0.000	0.000	0.213	0.213
MODENA BORO	B05	0.051	0.000	0.000	0.101	0.051	0.000	0.202	0.966
MODENA BORO	B06	0.095	0.191	0.000	0.191	0.000	0.286	0.764	
NEWLIN TWP	B06	0.000	0.286	0.000	0.859	0.000	0.191	1.337	1.337
PENNSBURY TWP	B17	0.579	1.463	0.000	2.073	0.091	0.000	4.206	4.206
SADSBURY TWP	B05	0.051	0.152	0.000	0.051	0.000	0.051	0.303	0.329
SADSBURY TWP	B33	0.013	0.007	0.000	0.007	0.000	0.000	0.026	
UPPER UWCHLAN TWP	B10	0.032	0.064	0.000	0.064	0.000	0.006	0.166	0.166
VALLEY TWP	B03	0.073	0.220	0.000	0.220	0.000	0.220	0.732	6.941
VALLEY TWP	B04	0.037	0.074	0.000	0.395	0.000	0.037	0.543	
VALLEY TWP	B05	0.859	1.515	0.051	1.566	0.051	1.212	5.253	
VALLEY TWP	B33	0.072	0.112	0.007	0.164	0.000	0.059	0.413	
WALLACE TWP	B09	0.016	0.040	0.000	0.096	0.000	0.016	0.168	1.929
WALLACE TWP	B10	0.231	0.589	0.019	0.864	0.000	0.058	1.761	
WEST BRADFORD TWP	B06	0.668	1.718	0.000	1.146	0.000	0.000	3.532	3.532
WEST BRANDYWINE TWP	B02	0.208	0.298	0.000	0.343	0.009	0.036	0.894	9.630
WEST BRANDYWINE TWP	B03	2.854	2.635	0.000	2.489	0.000	0.073	8.051	
WEST BRANDYWINE TWP	B10	0.134	0.269	0.006	0.243	0.006	0.026	0.685	
WEST CALN TWP	B01	0.046	0.000	0.000	0.218	0.000	0.011	0.275	9.950
WEST CALN TWP	B02	0.162	0.289	0.009	0.271	0.009	0.009	0.749	
WEST CALN TWP	B03	0.951	1.830	0.073	2.415	0.073	0.146	5.489	
WEST CALN TWP	B32	0.309	0.744	0.000	1.052	0.000	0.042	2.147	
WEST CALN TWP	B33	0.217	0.620	0.033	0.341	0.039	0.039	1.289	
WILMINGTON, DE	B19	0.002	0.000	0.003	0.006	0.001	0.002	0.013	1.861
WILMINGTON, DE	B34	0.600	0.000	0.265	0.113	0.072	0.797	1.848	
NEW CASTLE CO., DE	B17	0.945	1.723	0.459	3.311	0.096	0.151	6.685	15.563
NEW CASTLE CO., DE	B18	0.701	1.173	0.805	2.110	0.061	0.671	5.520	
NEW CASTLE CO., DE	B19	0.495	0.098	0.953	0.386	0.023	0.408	2.363	
NEW CASTLE CO., DE	B34	0.112	0.044	0.007	0.163	0.001	0.668	0.995	

Table C-6b. Total phosphorus MS4 allocations for Brandywine Creek watershed (kg/day)

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
COATESVILLE CITY	B03	0.000	0.000	0.000	0.132	0.000	0.000	0.132	2.031
COATESVILLE CITY	B04	0.037	0.000	0.000	0.334	0.000	0.074	0.445	
COATESVILLE CITY	B05	0.758	0.000	0.030	0.182	0.000	0.485	1.455	
EAST BRANDYWINE TWP	B10	0.221	0.221	0.005	0.221	0.005	0.005	0.677	0.677

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
EAST FALLOWFIELD TWP	B05	0.212	0.515	0.000	0.879	0.000	0.242	1.849	15.348
EAST FALLOWFIELD TWP	B06	3.141	4.812	0.134	4.945	0.000	0.468	13.499	
HONEY BROOK BORO	B01	0.062	0.041	0.000	0.000	0.000	0.007	0.110	0.110
HONEY BROOK TWP	B01	0.151	2.333	0.000	0.530	0.007	0.131	3.152	4.956
HONEY BROOK TWP	B02	0.070	0.022	0.000	0.227	0.000	0.005	0.325	
HONEY BROOK TWP	B09	0.098	0.911	0.000	0.308	0.092	0.013	1.421	
HONEY BROOK TWP	B10	0.016	0.005	0.000	0.016	0.011	0.011	0.058	
KENNETT TWP	B17	0.113	0.000	0.000	0.085	0.000	0.000	0.198	0.198
MODENA BORO	B05	0.030	0.000	0.000	0.061	0.030	0.000	0.121	0.656
MODENA BORO	B06	0.067	0.134	0.000	0.134	0.000	0.200	0.535	
NEWLIN TWP	B06	0.000	0.200	0.000	0.601	0.000	0.134	0.936	0.936
PENNSBURY TWP	B17	0.539	1.360	0.000	1.927	0.085	0.000	3.911	3.911
SADSBURY TWP	B05	0.030	0.091	0.000	0.030	0.000	0.030	0.182	0.205
SADSBURY TWP	B33	0.012	0.006	0.000	0.006	0.000	0.000	0.024	
UPPER UWCHLAN TWP	B10	0.026	0.053	0.000	0.053	0.000	0.005	0.137	0.137
VALLEY TWP	B03	0.066	0.198	0.000	0.198	0.000	0.198	0.659	4.726
VALLEY TWP	B04	0.037	0.074	0.000	0.395	0.000	0.037	0.543	
VALLEY TWP	B05	0.515	0.909	0.030	0.939	0.030	0.727	3.152	
VALLEY TWP	B33	0.065	0.100	0.006	0.148	0.000	0.053	0.372	
WALLACE TWP	B09	0.013	0.033	0.000	0.079	0.000	0.013	0.138	1.582
WALLACE TWP	B10	0.189	0.483	0.016	0.709	0.000	0.047	1.444	
WEST BRADFORD TWP	B06	0.468	1.203	0.000	0.802	0.000	0.000	2.473	2.473
WEST BRANDYWINE TWP	B02	0.125	0.179	0.000	0.206	0.005	0.022	0.536	8.344
WEST BRANDYWINE TWP	B03	2.569	2.371	0.000	2.240	0.000	0.066	7.246	
WEST BRANDYWINE TWP	B10	0.110	0.221	0.005	0.200	0.005	0.021	0.562	
WEST CALN TWP	B01	0.028	0.000	0.000	0.131	0.000	0.007	0.165	8.649
WEST CALN TWP	B02	0.097	0.173	0.005	0.162	0.005	0.005	0.450	
WEST CALN TWP	B03	0.856	1.647	0.066	2.174	0.066	0.132	4.940	
WEST CALN TWP	B32	0.278	0.670	0.000	0.947	0.000	0.038	1.933	
WEST CALN TWP	B33	0.195	0.558	0.030	0.307	0.035	0.035	1.161	
WILMINGTON, DE	B19	0.002	0.000	0.003	0.006	0.001	0.002	0.013	1.861
WILMINGTON, DE	B34	0.600	0.000	0.265	0.113	0.072	0.797	1.848	
NEW CASTLE CO., DE	B17	0.879	1.602	0.427	3.079	0.089	0.141	6.217	15.095
NEW CASTLE CO., DE	B18	0.701	1.173	0.805	2.110	0.061	0.671	5.520	
NEW CASTLE CO., DE	B19	0.495	0.098	0.953	0.386	0.023	0.408	2.363	
NEW CASTLE CO., DE	B34	0.112	0.044	0.007	0.163	0.001	0.668	0.995	

Table C-7a. Total nitrogen MS4 baseline loads for Red Clay Creek watershed (kg/day)

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
EAST MARLBOROUGH TWP	R01	11.13	56.05	0.77	16.51	0.38	3.07	87.92	137.13
EAST MARLBOROUGH TWP	R03	10.36	25.53	4.44	5.92	0.00	2.96	49.21	
KENNETT SQUARE BORO	R01	2.69	1.92	0.38	0.00	0.00	1.92	6.91	13.26
KENNETT SQUARE BORO	R02	0.00	0.43	0.00	0.00	0.00	0.00	0.43	
KENNETT SQUARE BORO	R03	3.33	0.74	0.00	1.11	0.00	0.74	5.92	
KENNETT TWP	R01	1.15	1.54	0.38	1.54	0.00	1.92	6.53	157.97
KENNETT TWP	R02	12.96	13.82	0.00	14.25	0.00	0.00	41.03	
KENNETT TWP	R03	12.21	31.82	0.00	17.39	0.37	2.59	64.38	
KENNETT TWP	R04	2.38	2.38	0.00	3.58	0.00	0.00	8.34	

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
KENNETT TWP	R06	9.21	13.52	0.29	13.23	0.00	1.44	37.69	
NEW GARDEN TWP	R01	2.30	6.53	0.00	3.07	0.00	1.92	13.82	77.03
NEW GARDEN TWP	R02	5.18	41.62	0.00	13.39	0.00	3.02	63.21	
PENNSBURY TWP	R06	1.15	1.15	0.00	0.86	0.00	1.15	4.32	4.32
NEW CASTLE CO., DE	R04	12.73	4.64	3.15	7.79	0.32	3.01	31.64	125.61
NEW CASTLE CO., DE	R05	11.95	5.09	2.07	13.11	0.42	2.08	34.71	
NEW CASTLE CO., DE	R06	4.63	13.77	3.15	2.72	0.09	0.66	25.01	
NEW CASTLE CO., DE	R07	0.79	0.22	0.09	1.34	0.43	0.15	3.01	
NEW CASTLE CO., DE	R08	8.80	0.38	3.30	3.22	0.33	7.85	23.88	
NEW CASTLE CO., DE	R09	3.34	0.00	0.28	0.75	0.03	2.94	7.35	

Table C-7b. Total nitrogen MS4 allocations for Red Clay Creek watershed (kg/day)

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
EAST MARLBOROUGH TWP	R01	5.57	28.03	0.38	8.25	0.19	1.54	43.96	68.56
EAST MARLBOROUGH TWP	R03	5.18	12.76	2.22	2.96	0.00	1.48	24.60	
KENNETT SQUARE BORO	R01	1.34	0.96	0.19	0.00	0.00	0.96	3.46	6.63
KENNETT SQUARE BORO	R02	0.00	0.22	0.00	0.00	0.00	0.00	0.22	
KENNETT SQUARE BORO	R03	1.66	0.37	0.00	0.55	0.00	0.37	2.96	
KENNETT TWP	R01	0.58	0.77	0.19	0.77	0.00	0.96	3.26	97.83
KENNETT TWP	R02	6.48	6.91	0.00	7.13	0.00	0.00	20.52	
KENNETT TWP	R03	6.10	15.91	0.00	8.69	0.18	1.29	32.19	
KENNETT TWP	R04	1.19	1.19	0.00	1.79	0.00	0.00	4.17	
KENNETT TWP	R06	9.21	13.52	0.29	13.23	0.00	1.44	37.69	
NEW GARDEN TWP	R01	1.15	3.26	0.00	1.54	0.00	0.96	6.91	38.52
NEW GARDEN TWP	R02	2.59	20.81	0.00	6.69	0.00	1.51	31.61	
PENNSBURY TWP	R06	1.15	1.15	0.00	0.86	0.00	1.15	4.32	4.32
NEW CASTLE CO., DE	R04	6.37	2.32	1.57	3.89	0.16	1.50	15.82	92.43
NEW CASTLE CO., DE	R05	5.97	2.55	1.03	6.55	0.21	1.04	17.36	
NEW CASTLE CO., DE	R06	4.63	13.77	3.15	2.72	0.09	0.66	25.01	
NEW CASTLE CO., DE	R07	0.79	0.22	0.09	1.34	0.43	0.15	3.01	
NEW CASTLE CO., DE	R08	8.80	0.38	3.30	3.22	0.33	7.85	23.88	
New Castle Co., DE	R09	3.34	0.00	0.28	0.75	0.03	2.94	7.35	

Table C-8a. Total phosphorus MS4 baseline loads for Red Clay Creek watershed (kg/day)

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
EAST MARLBOROUGH TWP	R01	0.200	1.006	0.014	0.296	0.007	0.055	1.577	2.742
EAST MARLBOROUGH TWP	R03	0.245	0.605	0.105	0.140	0.000	0.070	1.165	
KENNETT SQUARE BORO	R01	0.048	0.034	0.007	0.000	0.000	0.034	0.124	0.452
KENNETT SQUARE BORO	R02	0.000	0.188	0.000	0.000	0.000	0.000	0.188	
KENNETT SQUARE BORO	R03	0.079	0.018	0.000	0.026	0.000	0.018	0.140	
KENNETT TWP	R01	0.021	0.028	0.007	0.028	0.000	0.034	0.117	21.517
KENNETT TWP	R02	5.629	6.004	0.000	6.192	0.000	0.000	17.825	
KENNETT TWP	R03	0.289	0.753	0.000	0.412	0.009	0.061	1.524	
KENNETT TWP	R04	0.382	0.382	0.000	0.573	0.000	0.000	1.337	
KENNETT TWP	R06	0.174	0.256	0.005	0.251	0.000	0.027	0.714	
NEW GARDEN TWP	R01	0.041	0.117	0.000	0.055	0.000	0.034	0.248	27.708
NEW GARDEN TWP	R02	2.252	18.078	0.000	5.817	0.000	1.313	27.460	

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
PENNSBURY TWP	R06	0.022	0.022	0.000	0.016	0.000	0.022	0.082	0.082
NEW CASTLE CO., DE	R04	2.041	0.744	0.504	1.248	0.052	0.482	5.070	11.960
NEW CASTLE CO., DE	R05	1.462	0.624	0.253	1.605	0.051	0.254	4.249	
NEW CASTLE CO., DE	R06	0.088	0.261	0.060	0.052	0.002	0.012	0.474	
NEW CASTLE CO., DE	R07	0.111	0.031	0.013	0.188	0.061	0.021	0.424	
NEW CASTLE CO., DE	R08	0.509	0.022	0.191	0.187	0.019	0.455	1.383	
NEW CASTLE CO., DE	R09	0.164	0.000	0.014	0.037	0.002	0.144	0.360	

Table C-8b. Total phosphorus MS4 allocations for Red Clay Creek watershed (kg/day)

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
EAST MARLBOROUGH TWP	R01	0.100	0.503	0.007	0.148	0.003	0.028	0.789	1.372
EAST MARLBOROUGH TWP	R03	0.123	0.302	0.053	0.070	0.000	0.035	0.583	
KENNETT SQUARE BORO	R01	0.024	0.017	0.003	0.000	0.000	0.017	0.062	0.151
KENNETT SQUARE BORO	R02	0.000	0.019	0.000	0.000	0.000	0.000	0.019	
KENNETT SQUARE BORO	R03	0.039	0.009	0.000	0.013	0.000	0.009	0.070	
KENNETT TWP	R01	0.010	0.014	0.003	0.014	0.000	0.017	0.059	3.731
KENNETT TWP	R02	0.563	0.600	0.000	0.619	0.000	0.000	1.782	
KENNETT TWP	R03	0.145	0.377	0.000	0.206	0.004	0.031	0.762	
KENNETT TWP	R04	0.118	0.118	0.000	0.178	0.000	0.000	0.414	
KENNETT TWP	R06	0.174	0.256	0.005	0.251	0.000	0.027	0.714	
NEW GARDEN TWP	R01	0.021	0.059	0.000	0.028	0.000	0.017	0.124	2.870
NEW GARDEN TWP	R02	0.225	1.808	0.000	0.582	0.000	0.131	2.746	
PENNSBURY TWP	R06	0.022	0.022	0.000	0.016	0.000	0.022	0.082	0.082
NEW CASTLE CO., DE	R04	0.633	0.231	0.156	0.387	0.016	0.149	1.572	8.461
NEW CASTLE CO., DE	R05	1.462	0.624	0.253	1.605	0.051	0.254	4.249	
NEW CASTLE CO., DE	R06	0.088	0.261	0.060	0.052	0.002	0.012	0.474	
NEW CASTLE CO., DE	R07	0.111	0.031	0.013	0.188	0.061	0.021	0.424	
NEW CASTLE CO., DE	R08	0.509	0.022	0.191	0.187	0.019	0.455	1.383	
NEW CASTLE CO., DE	R09	0.164	0.000	0.014	0.037	0.002	0.144	0.360	

Table C-9a. Total nitrogen MS4 baseline loads for White Clay Creek watershed (kg/day)

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
AVONDALE BORO	W04	0.82	0.41	0.00	0.41	0.00	0.00	1.64	9.16
AVONDALE BORO	W06	1.80	0.00	0.00	1.80	0.00	0.00	3.60	
AVONDALE BORO	W07	0.65	1.96	0.00	0.65	0.00	0.65	3.93	
FRANKLIN TWP	W01	7.96	36.16	0.00	22.96	0.00	3.28	70.36	122.01
FRANKLIN TWP	W03	5.03	17.31	0.00	12.57	0.00	0.00	34.91	
FRANKLIN TWP	W08	3.17	9.52	0.00	3.70	0.00	0.00	16.39	
FRANKLIN TWP	W09	0.00	0.35	0.00	0.00	0.00	0.00	0.35	
KENNETT TWP	W17	0.20	1.78	0.00	0.20	0.00	0.00	2.17	2.17
LONDON BRITAIN TWP	W01	1.87	3.28	0.00	5.15	0.00	0.00	10.31	96.47
LONDON BRITAIN TWP	W03	9.63	13.41	0.00	14.66	0.42	0.00	38.12	
LONDON BRITAIN TWP	W09	4.95	8.48	0.00	11.67	0.35	0.00	25.45	
LONDON BRITAIN TWP	W10	4.18	6.14	0.00	8.65	0.00	0.28	19.25	
LONDON BRITAIN TWP	W11	0.56	1.11	0.00	1.48	0.00	0.19	3.34	
LONDON GROVE TWP	W02	10.28	35.56	0.43	11.14	0.43	0.43	58.27	262.76
LONDON GROVE TWP	W03	4.19	5.45	0.00	4.19	0.00	0.42	14.24	

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
LONDON GROVE TWP	W04	6.55	45.04	0.41	19.24	0.41	2.87	74.52	
LONDON GROVE TWP	W06	1.20	58.19	0.00	10.80	0.00	1.20	71.38	
LONDON GROVE TWP	W08	5.82	17.91	1.06	19.03	0.00	0.53	44.34	
NEW GARDEN TWP	W06	1.80	13.80	4.20	8.40	0.00	3.00	31.19	167.06
NEW GARDEN TWP	W07	4.58	15.72	0.00	3.27	0.65	1.31	25.54	
NEW GARDEN TWP	W08	10.57	35.42	0.00	21.15	0.00	1.59	68.73	
NEW GARDEN TWP	W09	9.90	15.91	0.00	10.96	0.71	3.53	41.00	
NEW GARDEN TWP	W17	0.00	0.59	0.00	0.00	0.00	0.00	0.59	
NEW LONDON TWP	W01	12.18	24.36	0.00	9.84	0.00	3.75	50.13	53.56
NEW LONDON TWP	W02	0.86	1.29	0.00	1.29	0.00	0.00	3.43	
PENN TWP	W01	4.22	16.40	0.00	5.15	0.00	0.47	26.24	71.23
PENN TWP	W02	6.00	28.71	0.00	9.00	0.43	0.86	44.99	
WEST GROVE BORO	W02	3.43	0.43	0.00	0.00	0.00	1.29	5.14	9.24
WEST GROVE BORO	W04	1.23	0.82	0.41	0.82	0.00	0.82	4.09	
NEW CASTLE CO., DE	W10	2.98	4.37	0.00	6.16	0.00	0.20	13.70	260.24
NEW CASTLE CO., DE	W11	0.24	3.95	1.67	17.91	0.23	3.65	27.65	
NEW CASTLE CO., DE	W12	8.27	3.09	3.67	4.46	0.36	17.40	37.26	
NEW CASTLE CO., DE	W13	0.88	1.43	0.92	1.47	0.20	7.96	12.87	
NEW CASTLE CO., DE	W14	1.44	0.00	2.94	1.89	1.95	5.34	13.57	
NEW CASTLE CO., DE	W15	4.95	10.26	1.13	14.68	0.00	3.67	34.70	
NEW CASTLE CO., DE	W16	15.21	3.28	3.56	5.03	0.00	11.94	39.02	
NEW CASTLE CO., DE	W17	28.83	6.81	8.55	9.64	0.00	27.66	81.48	
NEWARK, DE	W11	2.94	1.09	1.16	2.39	0.09	1.06	8.73	24.18
NEWARK, DE	W12	4.41	1.85	1.46	1.18	0.13	6.31	15.36	
NEWARK, DE	W15	0.10	0.00	0.00	0.00	0.00	0.00	0.10	

Table C-9b. Total nitrogen MS4 allocations for White Clay Creek watershed (kg/day)

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
AVONDALE BORO	W04	0.41	0.20	0.00	0.20	0.00	0.00	0.82	4.58
AVONDALE BORO	W06	0.90	0.00	0.00	0.90	0.00	0.00	1.80	
AVONDALE BORO	W07	0.33	0.98	0.00	0.33	0.00	0.33	1.96	
FRANKLIN TWP	W01	3.98	18.08	0.00	11.48	0.00	1.64	35.18	61.01
FRANKLIN TWP	W03	2.51	8.66	0.00	6.28	0.00	0.00	17.45	
FRANKLIN TWP	W08	1.59	4.76	0.00	1.85	0.00	0.00	8.20	
FRANKLIN TWP	W09	0.00	0.18	0.00	0.00	0.00	0.00	0.18	
KENNETT TWP	W17	0.20	1.78	0.00	0.20	0.00	0.00	2.17	2.17
LONDON BRITAIN TWP	W01	0.94	1.64	0.00	2.58	0.00	0.00	5.15	49.90
LONDON BRITAIN TWP	W03	4.82	6.70	0.00	7.33	0.21	0.00	19.06	
LONDON BRITAIN TWP	W09	2.47	4.24	0.00	5.83	0.18	0.00	12.73	
LONDON BRITAIN TWP	W10	2.09	3.07	0.00	4.32	0.00	0.14	9.63	
LONDON BRITAIN TWP	W11	0.56	1.11	0.00	1.48	0.00	0.19	3.34	
LONDON GROVE TWP	W02	4.63	16.00	0.19	5.01	0.19	0.19	26.22	128.47
LONDON GROVE TWP	W03	2.09	2.72	0.00	2.09	0.00	0.21	7.12	
LONDON GROVE TWP	W04	3.28	22.52	0.20	9.62	0.20	1.43	37.26	
LONDON GROVE TWP	W06	0.60	29.09	0.00	5.40	0.00	0.60	35.69	
LONDON GROVE TWP	W08	2.91	8.95	0.53	9.52	0.00	0.26	22.17	
NEW GARDEN TWP	W06	0.90	6.90	2.10	4.20	0.00	1.50	15.60	83.83
NEW GARDEN TWP	W07	2.29	7.86	0.00	1.64	0.33	0.65	12.77	

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
NEW GARDEN TWP	W08	5.29	17.71	0.00	10.57	0.00	0.79	34.37	
NEW GARDEN TWP	W09	4.95	7.95	0.00	5.48	0.35	1.77	20.50	
NEW GARDEN TWP	W17	0.00	0.59	0.00	0.00	0.00	0.00	0.59	
NEW LONDON TWP	W01	6.09	12.18	0.00	4.92	0.00	1.87	25.07	26.61
NEW LONDON TWP	W02	0.39	0.58	0.00	0.58	0.00	0.00	1.54	
PENN TWP	W01	2.11	8.20	0.00	2.58	0.00	0.23	13.12	33.36
PENN TWP	W02	2.70	12.92	0.00	4.05	0.19	0.39	20.24	
WEST GROVE BORO	W02	1.54	0.19	0.00	0.00	0.00	0.58	2.31	4.36
WEST GROVE BORO	W04	0.61	0.41	0.20	0.41	0.00	0.41	2.05	
NEW CASTLE CO., DE	W10	1.49	2.18	0.00	3.08	0.00	0.10	6.85	253.39
NEW CASTLE CO., DE	W11	0.24	3.95	1.67	17.91	0.23	3.65	27.65	
NEW CASTLE CO., DE	W12	8.27	3.09	3.67	4.46	0.36	17.40	37.26	
NEW CASTLE CO., DE	W13	0.88	1.43	0.92	1.47	0.20	7.96	12.87	
NEW CASTLE CO., DE	W14	1.44	0.00	2.94	1.89	1.95	5.34	13.57	
NEW CASTLE CO., DE	W15	4.95	10.26	1.13	14.68	0.00	3.67	34.70	
NEW CASTLE CO., DE	W16	15.21	3.28	3.56	5.03	0.00	11.94	39.02	
NEW CASTLE CO., DE	W17	28.83	6.81	8.55	9.64	0.00	27.66	81.48	
NEWARK, DE	W11	2.94	1.09	1.16	2.39	0.09	1.06	8.73	24.18
NEWARK, DE	W12	4.41	1.85	1.46	1.18	0.13	6.31	15.36	
NEWARK, DE	W15	0.10	0.00	0.00	0.00	0.00	0.00	0.10	

Table C-10a. Total phosphorus MS4 baseline loads for White Clay Creek watershed (kg/day)

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
AVONDALE BORO	W04	0.011	0.006	0.000	0.006	0.000	0.000	0.023	0.322
AVONDALE BORO	W06	0.024	0.000	0.000	0.024	0.000	0.000	0.047	
AVONDALE BORO	W07	0.042	0.126	0.000	0.042	0.000	0.042	0.252	
FRANKLIN TWP	W01	0.097	0.442	0.000	0.281	0.000	0.040	0.861	15.219
FRANKLIN TWP	W03	0.964	3.320	0.000	2.410	0.000	0.000	6.694	
FRANKLIN TWP	W08	1.470	4.410	0.000	1.715	0.000	0.000	7.595	
FRANKLIN TWP	W09	0.000	0.069	0.000	0.000	0.000	0.000	0.069	
KENNETT TWP	W17	0.005	0.045	0.000	0.005	0.000	0.000	0.055	0.055
LONDON BRITAIN TWP	W01	0.023	0.040	0.000	0.063	0.000	0.000	0.126	15.732
LONDON BRITAIN TWP	W03	1.848	2.571	0.000	2.812	0.080	0.000	7.311	
LONDON BRITAIN TWP	W09	0.966	1.656	0.000	2.277	0.069	0.000	4.968	
LONDON BRITAIN TWP	W10	0.623	0.914	0.000	1.288	0.000	0.042	2.867	
LONDON BRITAIN TWP	W11	0.077	0.153	0.000	0.205	0.000	0.026	0.460	
LONDON GROVE TWP	W02	0.109	0.377	0.005	0.118	0.005	0.005	0.618	25.875
LONDON GROVE TWP	W03	0.803	1.044	0.000	0.803	0.000	0.080	2.731	
LONDON GROVE TWP	W04	0.092	0.632	0.006	0.270	0.006	0.040	1.046	
LONDON GROVE TWP	W06	0.016	0.760	0.000	0.141	0.000	0.016	0.932	
LONDON GROVE TWP	W08	2.695	8.298	0.490	8.820	0.000	0.245	20.548	
NEW GARDEN TWP	W06	0.024	0.180	0.055	0.110	0.000	0.039	0.407	41.916
NEW GARDEN TWP	W07	0.294	1.008	0.000	0.210	0.042	0.084	1.638	
NEW GARDEN TWP	W08	4.900	16.415	0.000	9.800	0.000	0.735	31.851	
NEW GARDEN TWP	W09	1.932	3.105	0.000	2.139	0.138	0.690	8.004	
NEW GARDEN TWP	W17	0.000	0.015	0.000	0.000	0.000	0.000	0.015	
NEW LONDON TWP	W01	0.149	0.298	0.000	0.120	0.000	0.046	0.613	0.650
NEW LONDON TWP	W02	0.009	0.014	0.000	0.014	0.000	0.000	0.036	

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
PENN TWP	W01	0.052	0.201	0.000	0.063	0.000	0.006	0.321	0.798
PENN TWP	W02	0.064	0.304	0.000	0.095	0.005	0.009	0.477	
WEST GROVE BORO	W02	0.036	0.005	0.000	0.000	0.000	0.014	0.055	0.112
WEST GROVE BORO	W04	0.017	0.011	0.006	0.011	0.000	0.011	0.057	
NEW CASTLE CO., DE	W10	0.444	0.651	0.000	0.917	0.000	0.029	2.040	13.886
NEW CASTLE CO., DE	W11	0.033	0.545	0.230	2.468	0.032	0.504	3.811	
NEW CASTLE CO., DE	W12	0.648	0.242	0.288	0.350	0.028	1.363	2.919	
NEW CASTLE CO., DE	W13	0.074	0.120	0.077	0.122	0.017	0.665	1.074	
NEW CASTLE CO., DE	W14	0.068	0.000	0.138	0.089	0.092	0.251	0.637	
NEW CASTLE CO., DE	W15	0.070	0.146	0.016	0.208	0.000	0.052	0.493	
NEW CASTLE CO., DE	W16	0.324	0.070	0.076	0.107	0.000	0.254	0.831	
NEW CASTLE CO., DE	W17	0.736	0.174	0.218	0.246	0.000	0.706	2.081	
NEWARK, DE	W11	0.405	0.151	0.160	0.330	0.012	0.146	1.203	2.408
NEWARK, DE	W12	0.346	0.145	0.115	0.092	0.011	0.495	1.203	
NEWARK, DE	W15	0.001	0.000	0.000	0.000	0.000	0.000	0.001	

Table C-10b. Total phosphorus MS4 allocations for White Clay Creek watershed (kg/day)

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
AVONDALE BORO	W04	0.005	0.003	0.000	0.003	0.000	0.000	0.010	0.135
AVONDALE BORO	W06	0.006	0.000	0.000	0.006	0.000	0.000	0.012	
AVONDALE BORO	W07	0.019	0.057	0.000	0.019	0.000	0.019	0.113	
FRANKLIN TWP	W01	0.044	0.199	0.000	0.126	0.000	0.018	0.387	5.557
FRANKLIN TWP	W03	0.434	1.494	0.000	1.085	0.000	0.000	3.013	
FRANKLIN TWP	W08	0.412	1.235	0.000	0.480	0.000	0.000	2.127	
FRANKLIN TWP	W09	0.000	0.031	0.000	0.000	0.000	0.000	0.031	
KENNETT TWP	W17	0.005	0.045	0.000	0.005	0.000	0.000	0.055	0.055
LONDON BRITAIN TWP	W01	0.010	0.018	0.000	0.028	0.000	0.000	0.057	7.333
LONDON BRITAIN TWP	W03	0.832	1.157	0.000	1.265	0.036	0.000	3.290	
LONDON BRITAIN TWP	W09	0.435	0.745	0.000	1.025	0.031	0.000	2.236	
LONDON BRITAIN TWP	W10	0.280	0.411	0.000	0.580	0.000	0.019	1.290	
LONDON BRITAIN TWP	W11	0.077	0.153	0.000	0.205	0.000	0.026	0.460	
LONDON GROVE TWP	W02	0.049	0.170	0.002	0.053	0.002	0.002	0.278	7.965
LONDON GROVE TWP	W03	0.362	0.470	0.000	0.362	0.000	0.036	1.229	
LONDON GROVE TWP	W04	0.041	0.285	0.003	0.122	0.003	0.018	0.471	
LONDON GROVE TWP	W06	0.004	0.190	0.000	0.035	0.000	0.004	0.233	
LONDON GROVE TWP	W08	0.755	2.323	0.137	2.470	0.000	0.069	5.753	
NEW GARDEN TWP	W06	0.006	0.045	0.014	0.027	0.000	0.010	0.102	13.374
NEW GARDEN TWP	W07	0.132	0.453	0.000	0.094	0.019	0.038	0.737	
NEW GARDEN TWP	W08	1.372	4.596	0.000	2.744	0.000	0.206	8.918	
NEW GARDEN TWP	W09	0.869	1.397	0.000	0.963	0.062	0.311	3.602	
NEW GARDEN TWP	W17	0.000	0.015	0.000	0.000	0.000	0.000	0.015	
NEW LONDON TWP	W01	0.067	0.134	0.000	0.054	0.000	0.021	0.276	0.292
NEW LONDON TWP	W02	0.004	0.006	0.000	0.006	0.000	0.000	0.016	
PENN TWP	W01	0.023	0.090	0.000	0.028	0.000	0.003	0.144	0.359
PENN TWP	W02	0.029	0.137	0.000	0.043	0.002	0.004	0.215	
WEST GROVE BORO	W02	0.016	0.002	0.000	0.000	0.000	0.006	0.025	0.050
WEST GROVE BORO	W04	0.008	0.005	0.003	0.005	0.000	0.005	0.026	
NEW CASTLE CO., DE	W10	0.200	0.293	0.000	0.413	0.000	0.013	0.918	12.764

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
NEW CASTLE CO., DE	W11	0.033	0.545	0.230	2.468	0.032	0.504	3.811	
NEW CASTLE CO., DE	W12	0.648	0.242	0.288	0.350	0.028	1.363	2.919	
NEW CASTLE CO., DE	W13	0.074	0.120	0.077	0.122	0.017	0.665	1.074	
NEW CASTLE CO., DE	W14	0.068	0.000	0.138	0.089	0.092	0.251	0.637	
NEW CASTLE CO., DE	W15	0.070	0.146	0.016	0.208	0.000	0.052	0.493	
NEW CASTLE CO., DE	W16	0.324	0.070	0.076	0.107	0.000	0.254	0.831	
NEW CASTLE CO., DE	W17	0.736	0.174	0.218	0.246	0.000	0.706	2.081	
NEWARK, DE	W11	0.405	0.151	0.160	0.330	0.012	0.146	1.203	2.408
NEWARK, DE	W12	0.346	0.145	0.115	0.092	0.011	0.495	1.203	
NEWARK, DE	W15	0.001	0.000	0.000	0.000	0.000	0.000	0.001	

Table C-11a. Total nitrogen MS4 baseline loads for Christina River Creek watershed (kg/day)

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
FRANKLIN TWP	C02	1.35	1.35	0.18	0.81	0.00	0.64	4.34	4.34
LONDON BRITTAIN TWP	C02	4.05	4.05	0.54	2.43	0.01	1.93	13.01	13.01
NEW CASTLE CO., DE	C01	1.19	4.48	1.13	3.20	0.00	0.48	10.48	224.96
NEW CASTLE CO., DE	C02	0.34	6.59	0.08	3.25	0.02	1.75	12.04	
NEW CASTLE CO., DE	C03	1.95	1.16	0.67	2.82	0.04	4.72	11.36	
NEW CASTLE CO., DE	C04	5.08	0.24	1.58	3.15	0.04	7.15	17.25	
NEW CASTLE CO., DE	C05	0.89	0.00	1.56	0.90	0.13	6.08	9.55	
NEW CASTLE CO., DE	C06	6.11	6.35	4.38	15.73	0.47	8.05	41.09	
NEW CASTLE CO., DE	C07	5.16	2.11	2.01	8.56	0.21	6.90	24.95	
NEW CASTLE CO., DE	C08	9.89	2.06	2.74	10.62	0.21	15.60	41.13	
NEW CASTLE CO., DE	C09	4.30	1.29	11.65	8.98	1.69	29.20	57.12	
NEWARK, DE	C01	0.36	0.49	0.16	0.29	0.00	2.11	3.42	33.75
NEWARK, DE	C02	13.79	0.00	2.19	2.08	0.00	3.19	21.25	
NEWARK, DE	C03	2.53	0.69	0.86	0.86	0.08	3.99	9.01	
NEWARK, DE	C06	0.00	0.00	0.00	0.08	0.00	0.00	0.08	
NEWPORT, DE	C09	0.25	0.00	0.09	0.00	0.08	1.08	1.51	1.51
WILMINGTON, DE	C04	0.02	0.00	0.01	0.00	0.00	0.01	0.04	15.89
WILMINGTON, DE	C05	1.63	0.00	0.25	0.15	0.00	0.42	2.45	
WILMINGTON, DE	C09	3.23	0.00	2.67	0.00	1.31	6.19	13.40	

Table C-11b. Total nitrogen MS4 allocations forChristina River watershed (kg/day)

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
FRANKLIN TWP	C02	1.35	1.35	0.18	0.81	0.00	0.64	4.34	4.34
LONDON BRITTAIN TWP	C02	4.05	4.05	0.54	2.43	0.01	1.93	13.01	13.01
NEW CASTLE CO., DE	C01	0.24	0.90	0.23	0.64	0.00	0.10	2.10	216.57
NEW CASTLE CO., DE	C02	0.34	6.59	0.08	3.25	0.02	1.75	12.04	
NEW CASTLE CO., DE	C03	1.95	1.16	0.67	2.82	0.04	4.72	11.36	
NEW CASTLE CO., DE	C04	5.08	0.24	1.58	3.15	0.04	7.15	17.25	
NEW CASTLE CO., DE	C05	0.89	0.00	1.56	0.90	0.13	6.08	9.55	
NEW CASTLE CO., DE	C06	6.11	6.35	4.38	15.73	0.47	8.05	41.09	
NEW CASTLE CO., DE	C07	5.16	2.11	2.01	8.56	0.21	6.90	24.95	
NEW CASTLE CO., DE	C08	9.89	2.06	2.74	10.62	0.21	15.60	41.13	
NEW CASTLE CO., DE	C09	4.30	1.29	11.65	8.98	1.69	29.20	57.12	
NEWARK, DE	C01	0.07	0.10	0.03	0.06	0.00	0.42	0.68	31.02

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
NEWARK, DE	C02	13.79	0.00	2.19	2.08	0.00	3.19	21.25	
NEWARK, DE	C03	2.53	0.69	0.86	0.86	0.08	3.99	9.01	
NEWARK, DE	C06	0.00	0.00	0.00	0.08	0.00	0.00	0.08	
NEWPORT, DE	C09	0.25	0.00	0.09	0.00	0.08	1.08	1.51	1.51
WILMINGTON, DE	C04	0.02	0.00	0.01	0.00	0.00	0.01	0.04	15.89
WILMINGTON, DE	C05	1.63	0.00	0.25	0.15	0.00	0.42	2.45	
Wilmington, DE	C09	3.23	0.00	2.67	0.00	1.31	6.19	13.40	

Table C-12a. Total phosphorus MS4 baseline loads for Christina River Creek watershed (kg/day)

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
FRANKLIN TWP	C02	0.027	0.027	0.004	0.016	0.000	0.013	0.088	0.088
LONDON BRITTAIN TWP	C02	0.082	0.082	0.011	0.049	0.000	0.039	0.263	0.263
NEW CASTLE CO., DE	C01	0.030	0.111	0.028	0.080	0.000	0.012	0.260	14.718
NEW CASTLE CO., DE	C02	0.007	0.133	0.002	0.066	0.000	0.035	0.243	
NEW CASTLE CO., DE	C03	0.250	0.148	0.086	0.362	0.005	0.605	1.456	
NEW CASTLE CO., DE	C04	0.129	0.006	0.040	0.080	0.001	0.181	0.437	
NEW CASTLE CO., DE	C05	0.061	0.000	0.107	0.062	0.009	0.418	0.657	
NEW CASTLE CO., DE	C06	0.172	0.179	0.124	0.443	0.013	0.227	1.158	
NEW CASTLE CO., DE	C07	0.207	0.085	0.081	0.343	0.008	0.277	1.000	
NEW CASTLE CO., DE	C08	1.011	0.210	0.280	1.085	0.022	1.593	4.202	
NEW CASTLE CO., DE	C09	0.399	0.120	1.082	0.834	0.157	2.711	5.304	
NEWARK, DE	C01	0.009	0.012	0.004	0.007	0.000	0.053	0.085	1.671
NEWARK, DE	C02	0.279	0.000	0.044	0.042	0.000	0.064	0.429	
NEWARK, DE	C03	0.324	0.089	0.110	0.110	0.010	0.512	1.154	
NEWARK, DE	C06	0.000	0.000	0.000	0.002	0.000	0.000	0.002	
NEWPORT, DE	C09	0.023	0.000	0.009	0.000	0.008	0.100	0.140	0.140
WILMINGTON, DE	C04	0.000	0.000	0.000	0.000	0.000	0.000	0.001	1.414
WILMINGTON, DE	C05	0.112	0.000	0.017	0.010	0.000	0.029	0.169	
WILMINGTON, DE	C09	0.300	0.000	0.248	0.000	0.122	0.575	1.244	

Table C-12b. Total phosphorus MS4 allocations forChristina River watershed (kg/day)

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
FRANKLIN TWP	C02	0.027	0.027	0.004	0.016	0.000	0.013	0.088	0.088
LONDON BRITTAIN TWP	C02	0.082	0.082	0.011	0.049	0.000	0.039	0.263	0.263
NEW CASTLE CO., DE	C01	0.006	0.022	0.006	0.016	0.000	0.002	0.052	14.509
NEW CASTLE CO., DE	C02	0.007	0.133	0.002	0.066	0.000	0.035	0.243	
NEW CASTLE CO., DE	C03	0.250	0.148	0.086	0.362	0.005	0.605	1.456	
NEW CASTLE CO., DE	C04	0.129	0.006	0.040	0.080	0.001	0.181	0.437	
NEW CASTLE CO., DE	C05	0.061	0.000	0.107	0.062	0.009	0.418	0.657	
NEW CASTLE CO., DE	C06	0.172	0.179	0.124	0.443	0.013	0.227	1.158	
NEW CASTLE CO., DE	C07	0.207	0.085	0.081	0.343	0.008	0.277	1.000	
NEW CASTLE CO., DE	C08	1.011	0.210	0.280	1.085	0.022	1.593	4.202	
NEW CASTLE CO., DE	C09	0.399	0.120	1.082	0.834	0.157	2.711	5.304	
NEWARK, DE	C01	0.002	0.002	0.001	0.001	0.000	0.011	0.017	1.603
NEWARK, DE	C02	0.279	0.000	0.044	0.042	0.000	0.064	0.429	
NEWARK, DE	C03	0.324	0.089	0.110	0.110	0.010	0.512	1.154	
NEWARK, DE	C06	0.000	0.000	0.000	0.002	0.000	0.000	0.002	

MS4 Municipality	Subbasin	Residential	Agriculture	OpenLand	Forest	Water	Urban	Subtotal	Total
NEWPORT, DE	C09	0.023	0.000	0.009	0.000	0.008	0.100	0.140	0.140
WILMINGTON, DE	C04	0.000	0.000	0.000	0.000	0.000	0.000	0.001	1.414
WILMINGTON, DE	C05	0.112	0.000	0.017	0.010	0.000	0.029	0.169	
WILMINGTON, DE	C09	0.300	0.000	0.248	0.000	0.122	0.575	1.244	

Appendix D

EFDC Water Quality Model
Baseline and TMDL Allocation Results

Transect graphics are presented in this appendix showing the EFDC model calculated concentrations of daily average dissolved oxygen, minimum dissolved oxygen, total nitrogen, and total phosphorus for the impaired stream segments in the Christina River Basin. In Delaware waters, the 80^{th} percentile model concentrations of total nitrogen and total phosphorus are compared with the TMDL endpoint targets of 3.0 mg/L and 0.2 mg/L, respectively. In Pennsylvania, the minimum and daily average dissolved oxygen concentrations are compared with the water quality standards.

Table D-1. Stream reaches included in EFDC water quality model.

Stream Reach	River Mile at Mouth	River Mile at Upstream Extent
Christina River (lower)	74.2	89.6
Christina River (upper)	89.6	103.0
Christina River West Branch	98.5	100.4
Brandywine Creek (main stem)	76.3	95.8
Brandywine Creek East Branch	95.8	113.7
Brandywine Creek West Branch	95.8	120.7
Buck Run	106.6	117.3
Red Clay Creek and East Branch	87.6	104.9
Red Clay Creek West Branch	100.3	104.9
Burroughs Run	97.1	100.2
White Clay Creek and Middle Branch	85.6	109.7
White Clay Creek East Branch	99.9	107.1
Little Mill Creek	79.8	85.4
Mill Creek	87.9	94.7
Pike Creek	90.6	95.9
Muddy Run	93.2	95.9
Delaware River	62.6	86.5

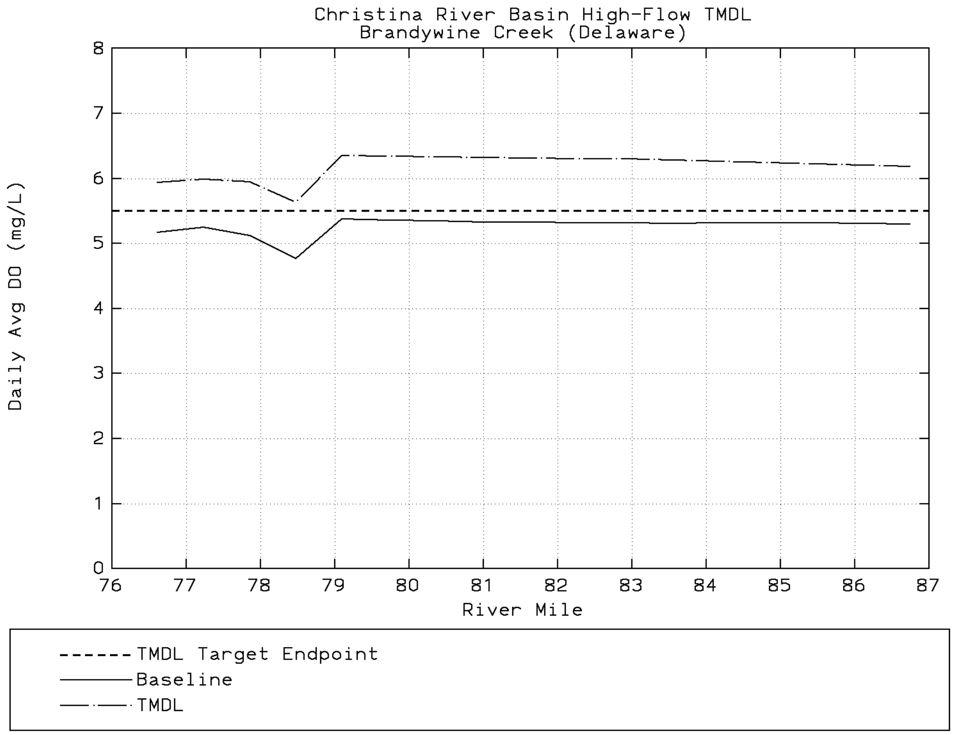

Figure D-1. Baseline and TMDL Daily Average DO, Brandywine Creek (Delaware)

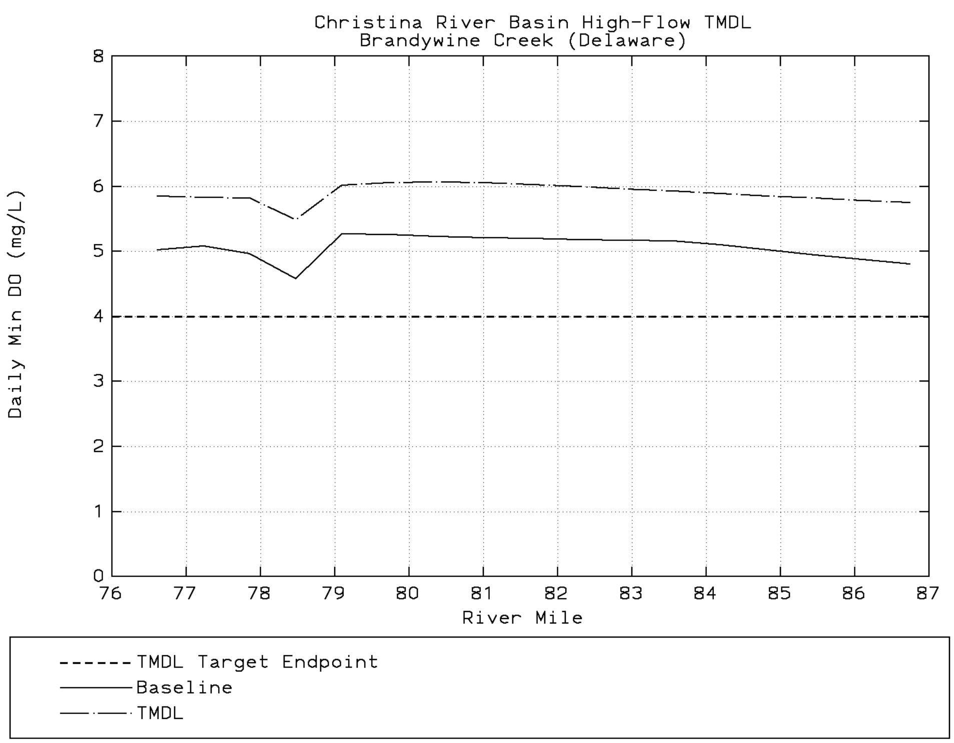

Figure D-2. Baseline and TMDL Minimum DO, Brandywine Creek (Delaware)

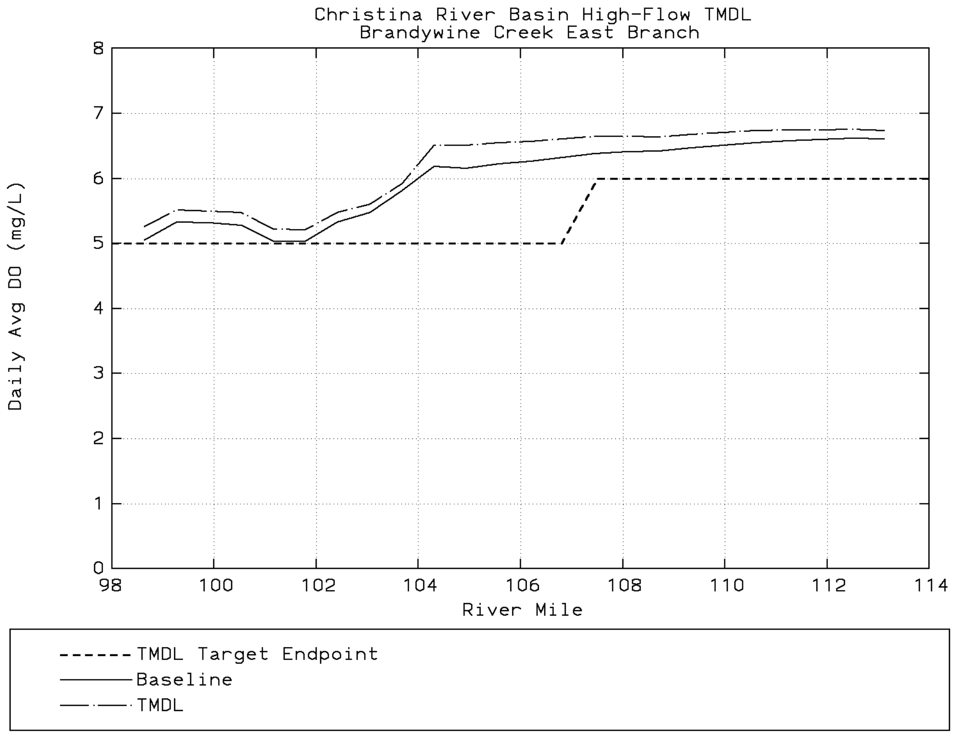

Figure D-3. Baseline and TMDL Daily Average DO, Brandywine Creek East Branch

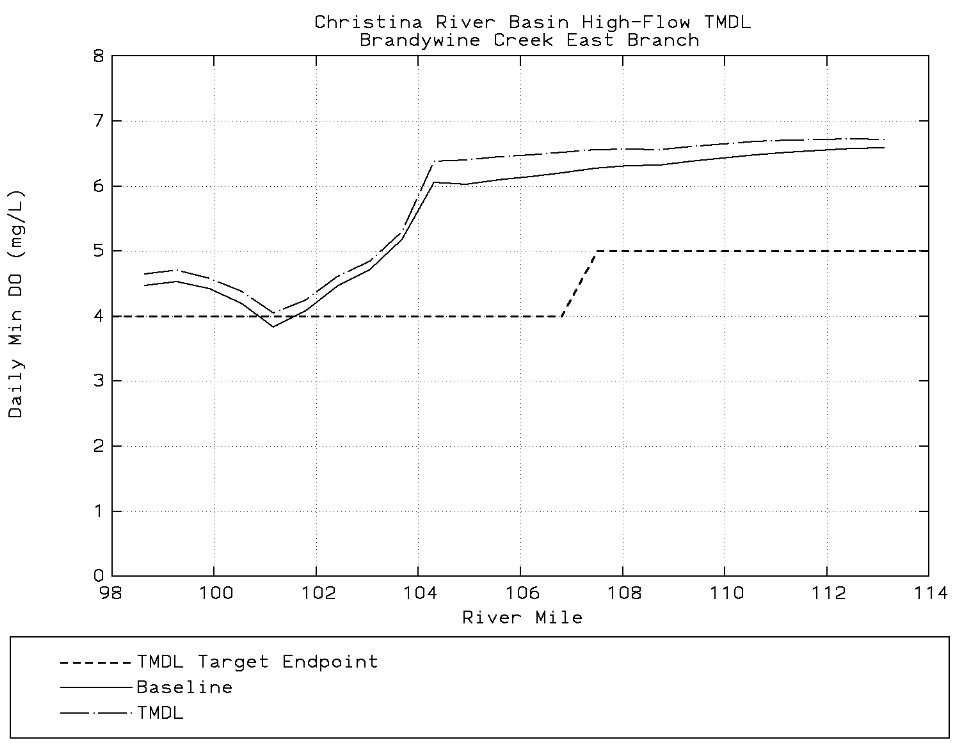

Figure D-4. Baseline and TMDL Minimum DO, Brandywine Creek East Branch

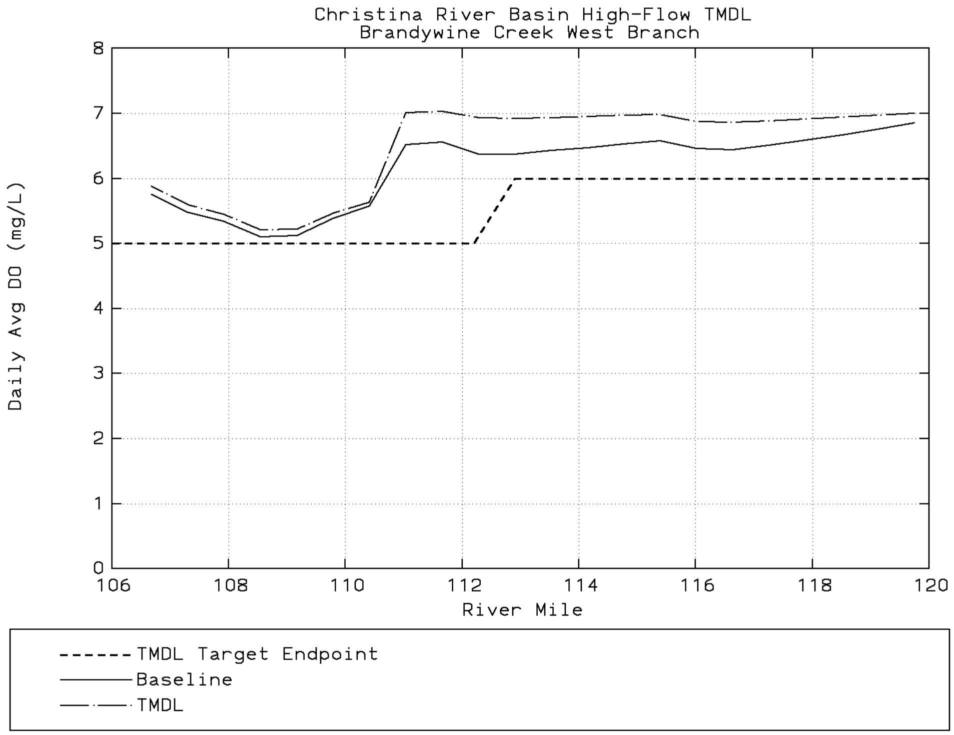

Figure D-5. Baseline and TMDL Daily Average DO, Brandywine Creek West Branch

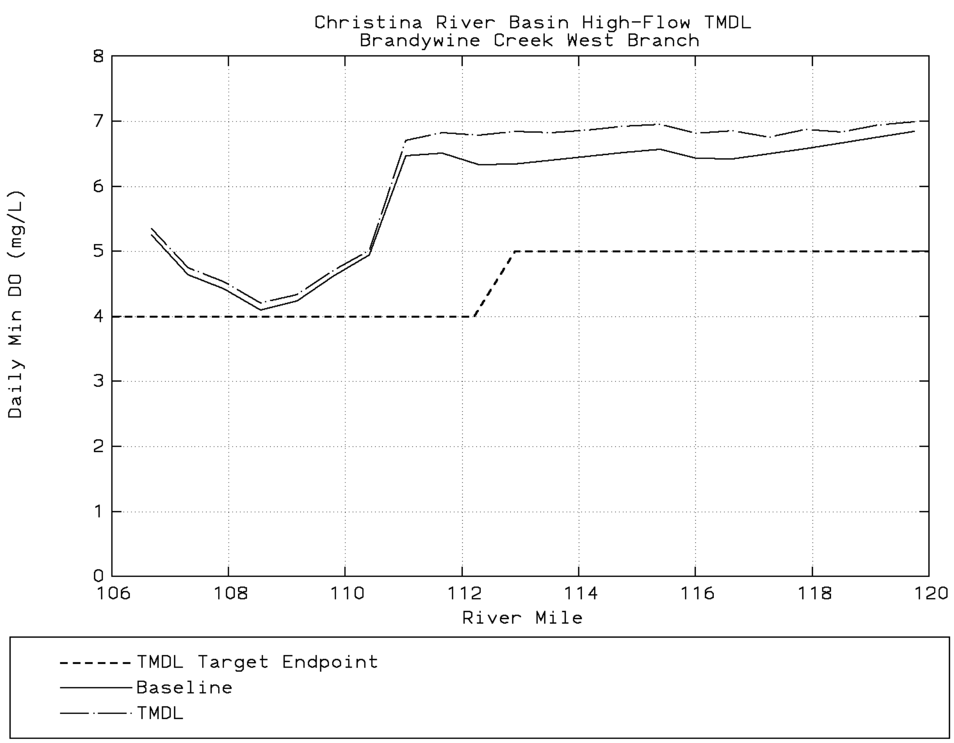

Figure D-6. Baseline and TMDL Minimum DO, Brandywine Creek West Branch

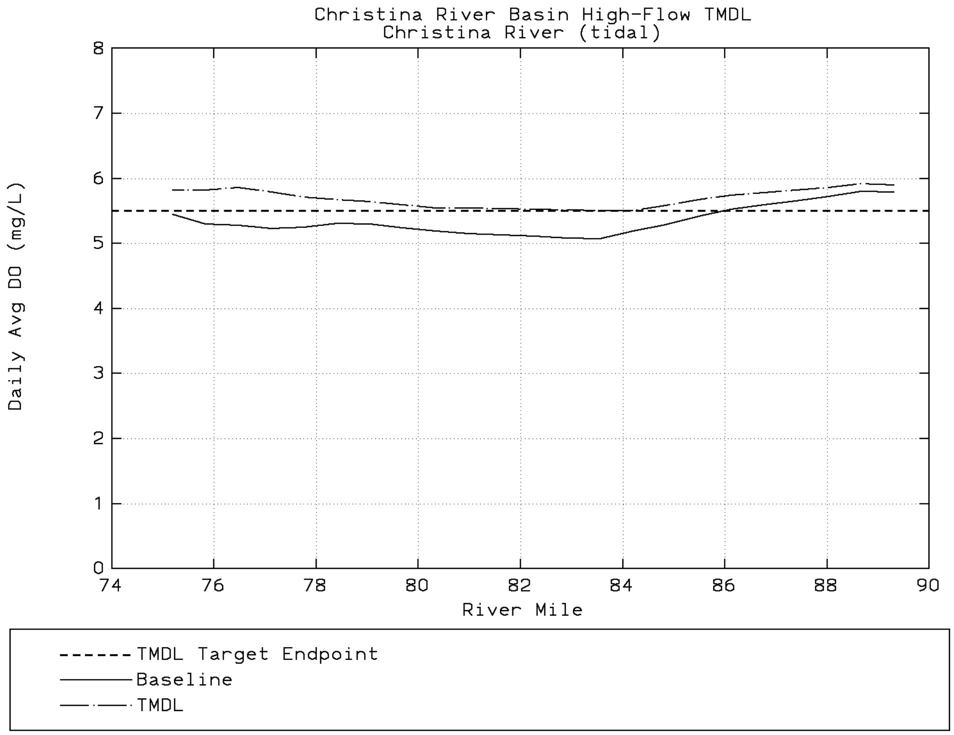

Figure D-7. Baseline and TMDL Daily Average DO, Christina River (tidal)

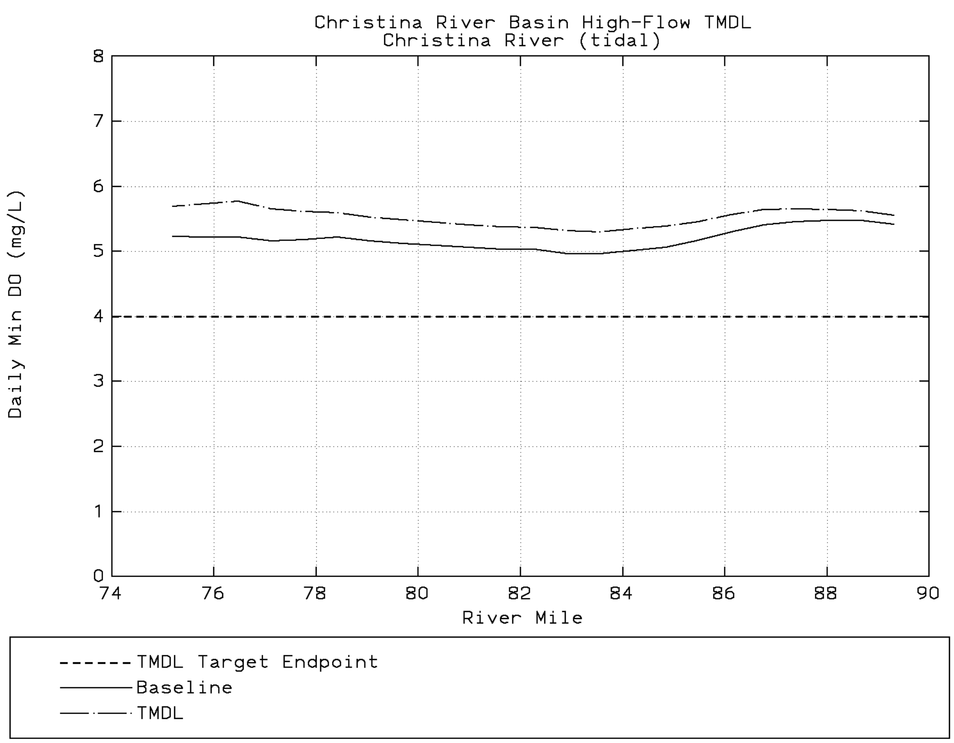

Figure D-8. Baseline and TMDL Minimum DO, Christina River (tidal)

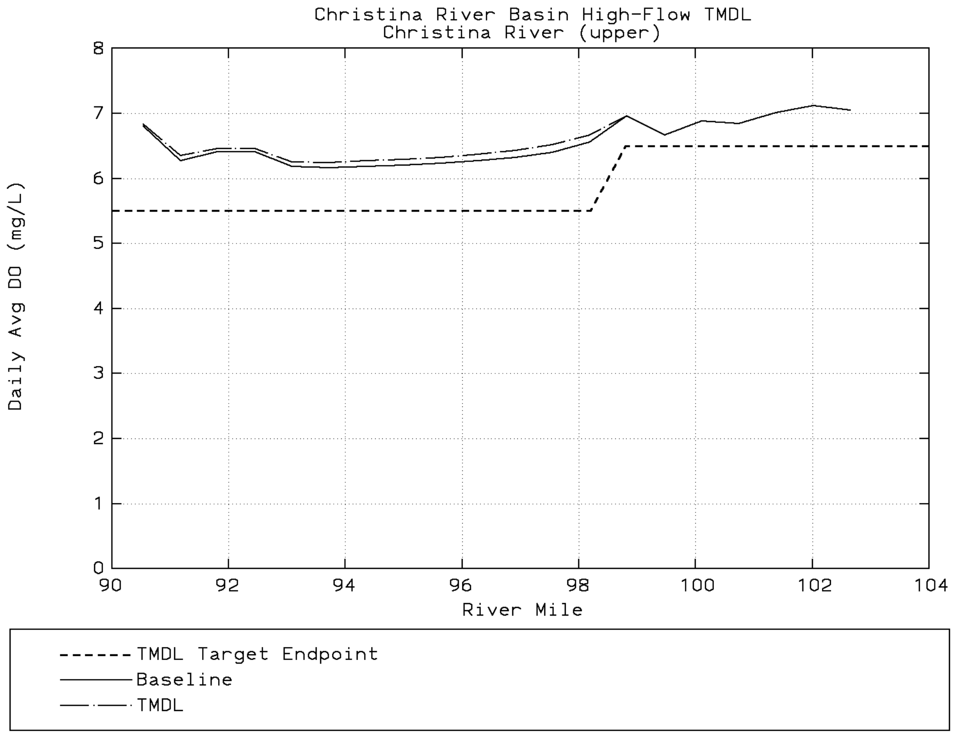

Figure D-9. Baseline and TMDL Daily Average DO, Christina River (upper)

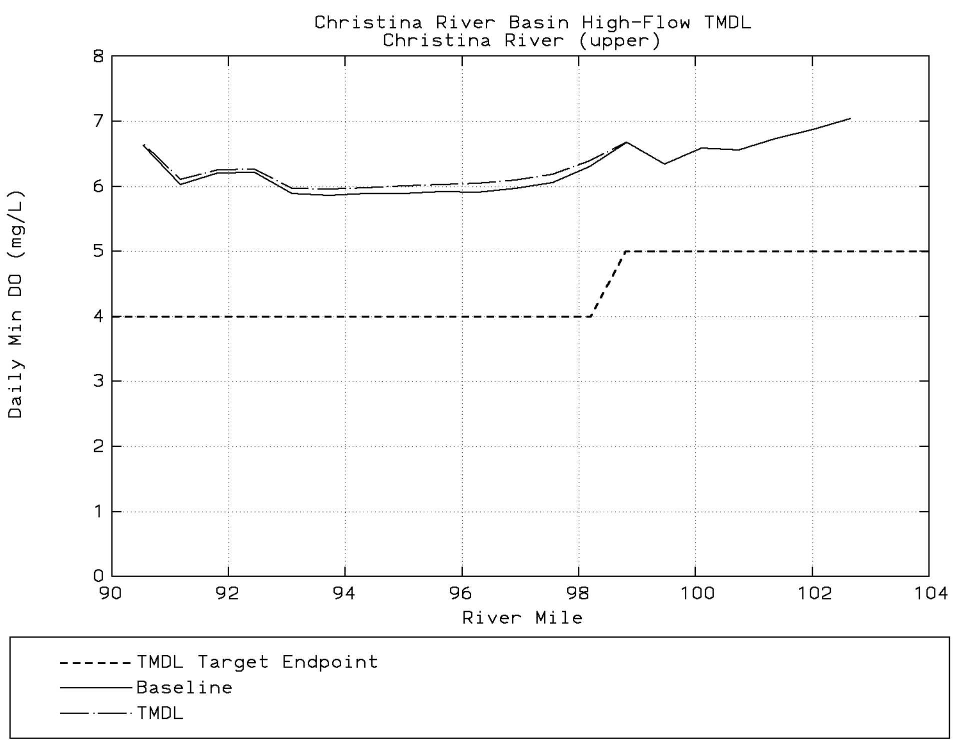

Figure D-10. Baseline and TMDL Minimum DO, Christina River (upper)

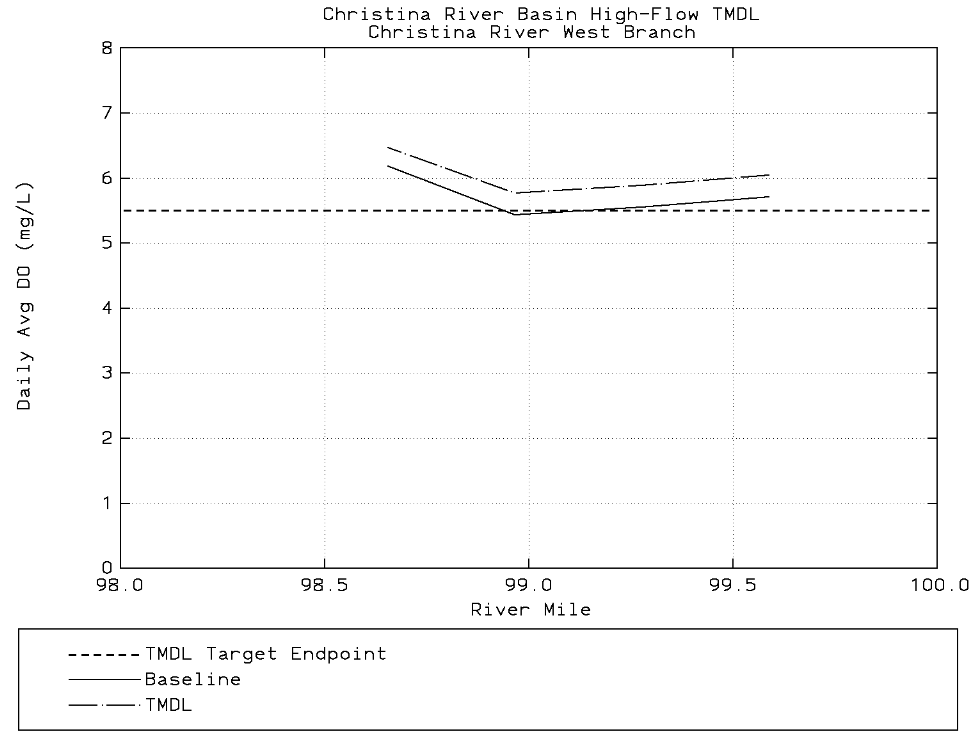

Figure D-11. Baseline and TMDL Daily Average DO, Christina River West Branch

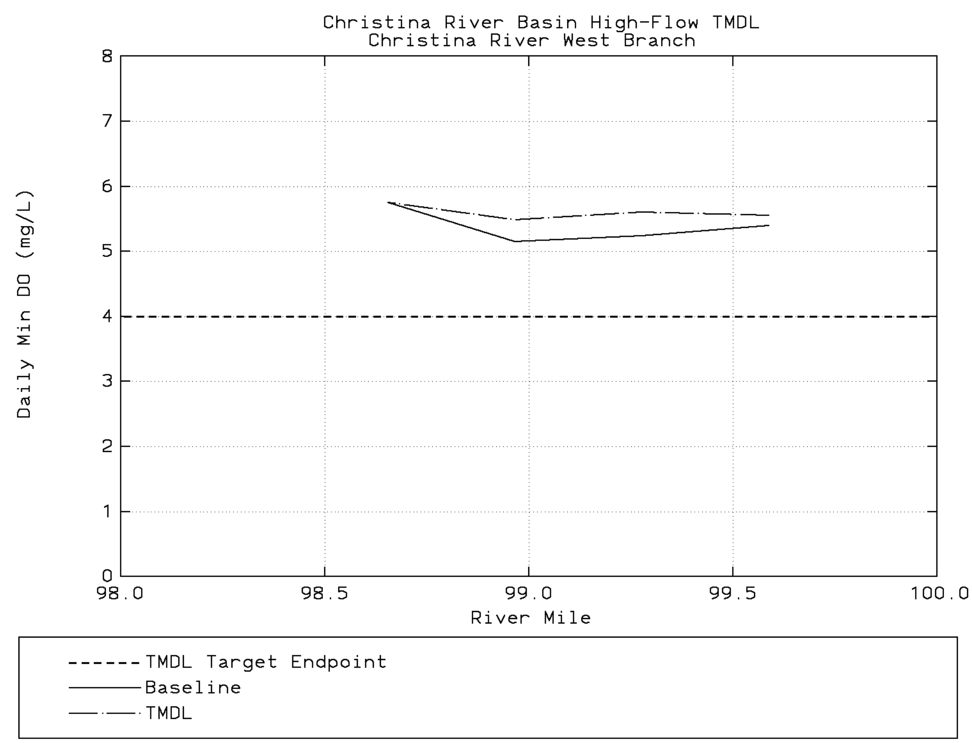

Figure D-12. Baseline and TMDL Minimum DO, Christina River West Branch

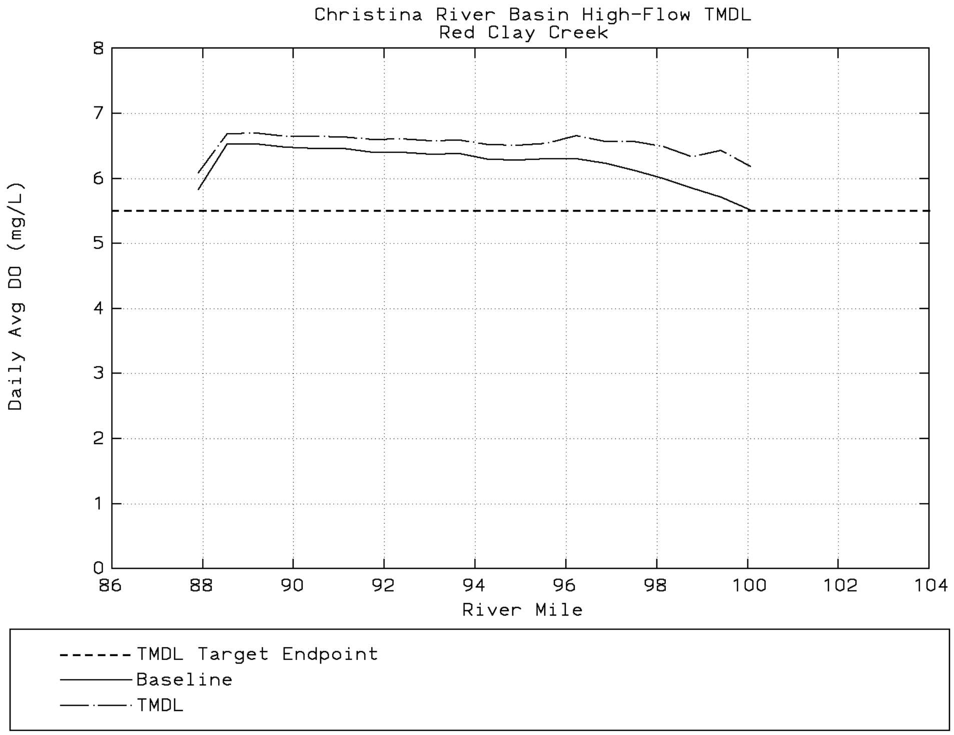

Figure D-13. Baseline and TMDL Daily Average DO, Red Clay Creek

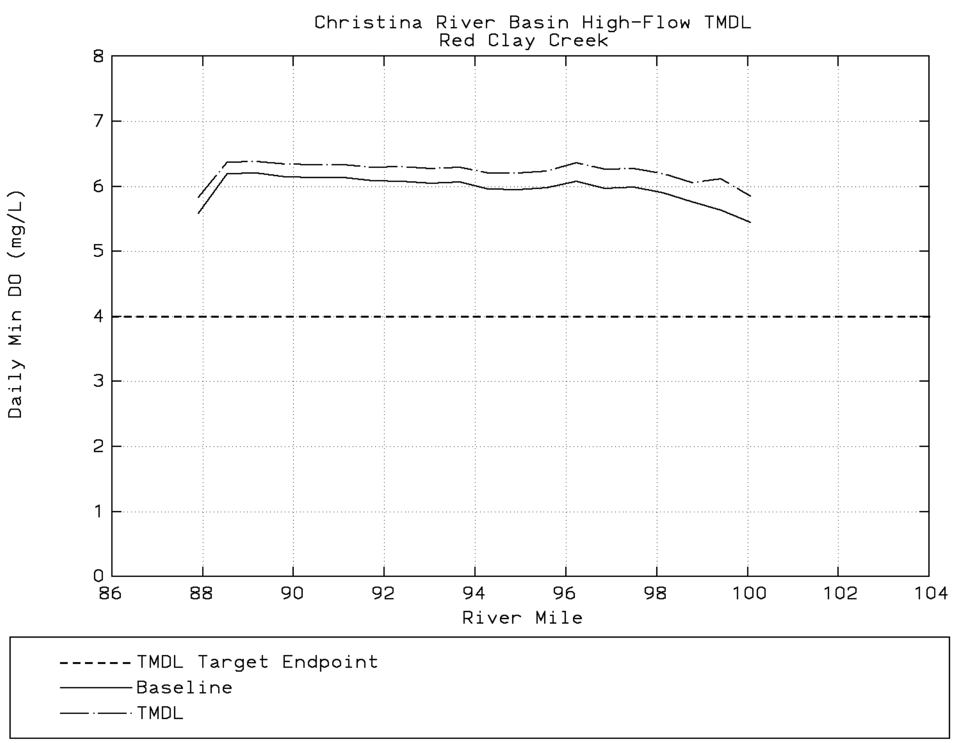

Figure D-14. Baseline and TMDL Minimum DO, Red Clay Creek

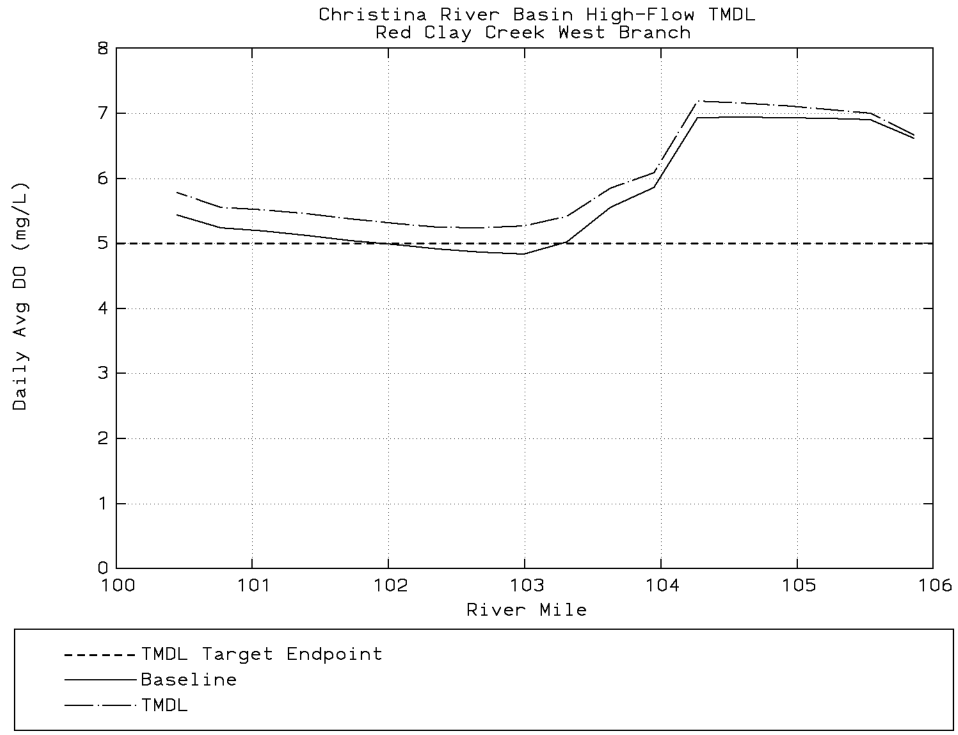

Figure D-15. Baseline and TMDL Daily Average DO, Red Clay Creek West Branch

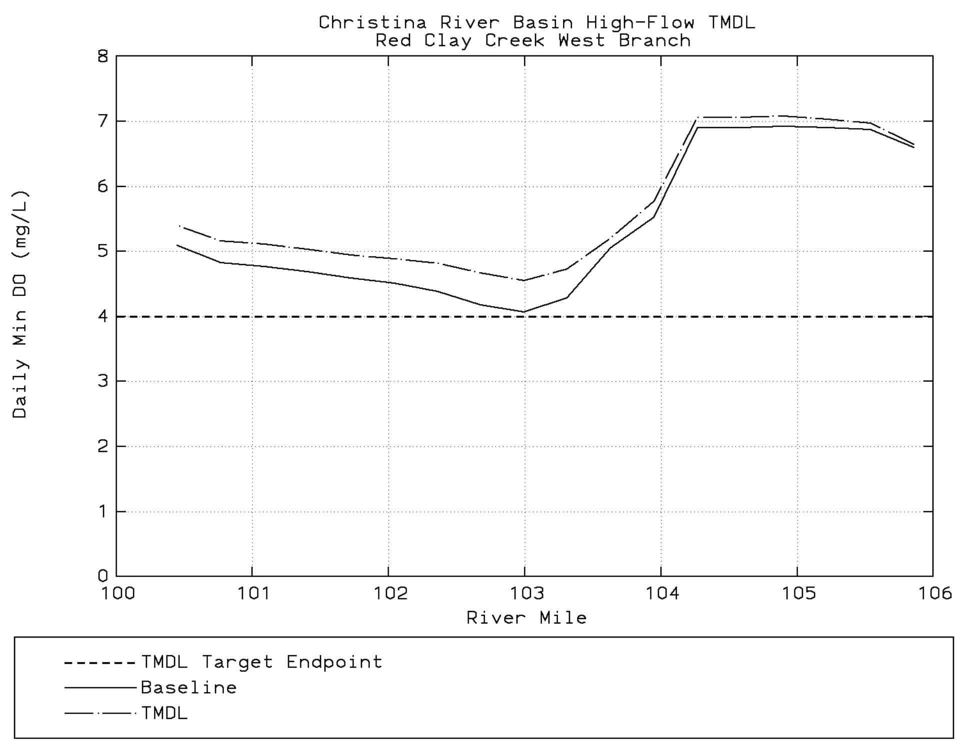

Figure D-16. Baseline and TMDL Minimum DO, Red Clay Creek West Branch

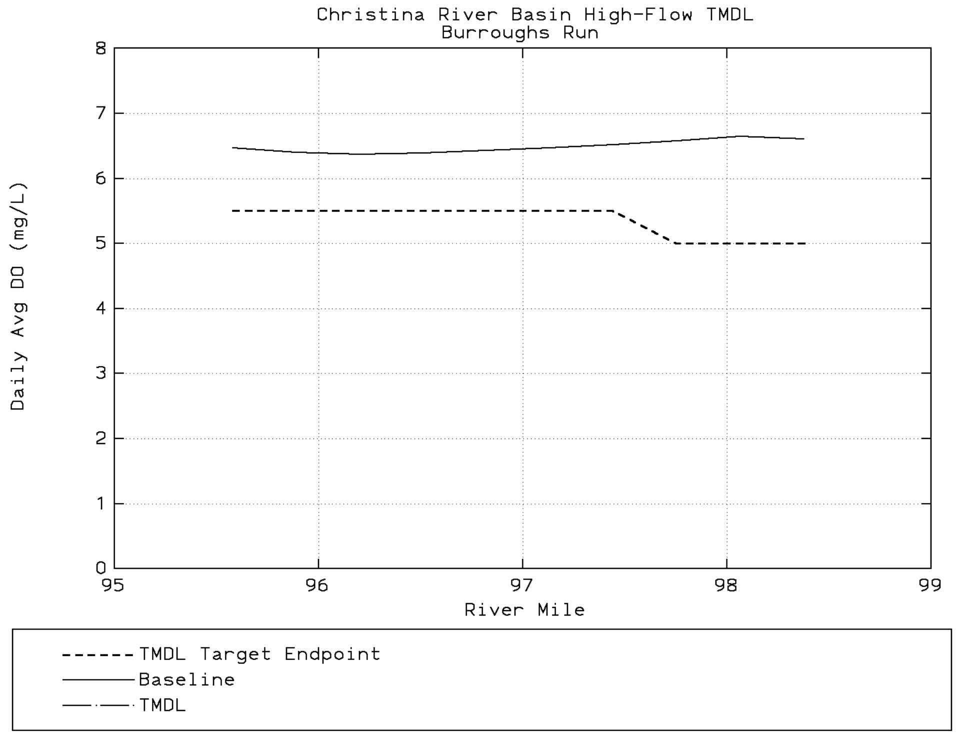

Figure D-17. Baseline and TMDL Daily Average DO, Burroughs Run

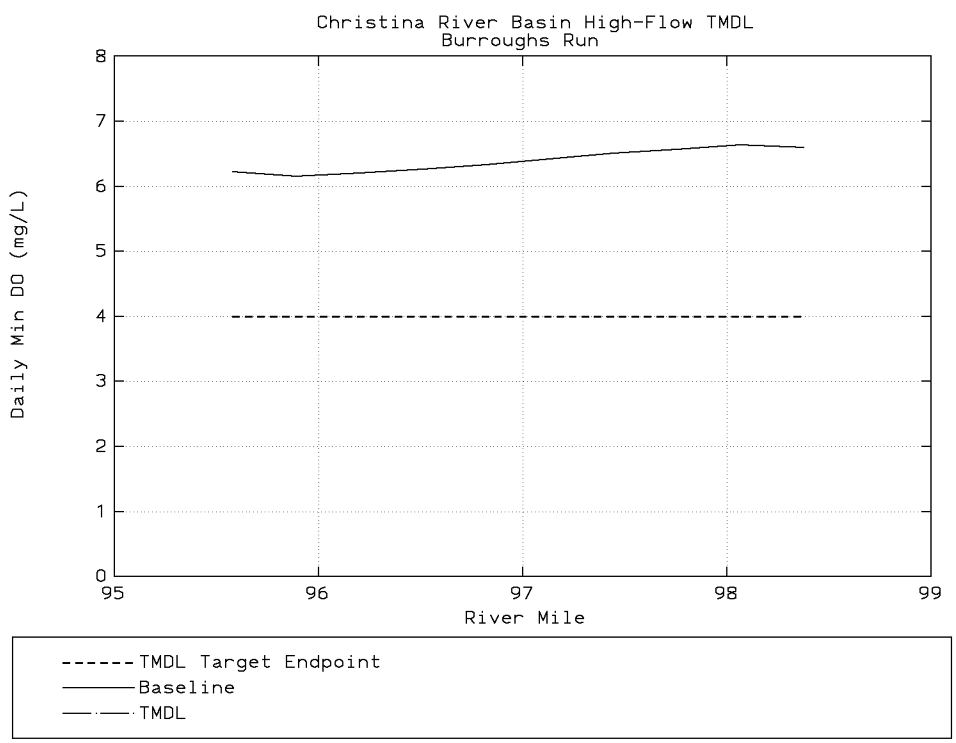

Figure D-18. Baseline and TMDL Minimum DO, Burroughs Run

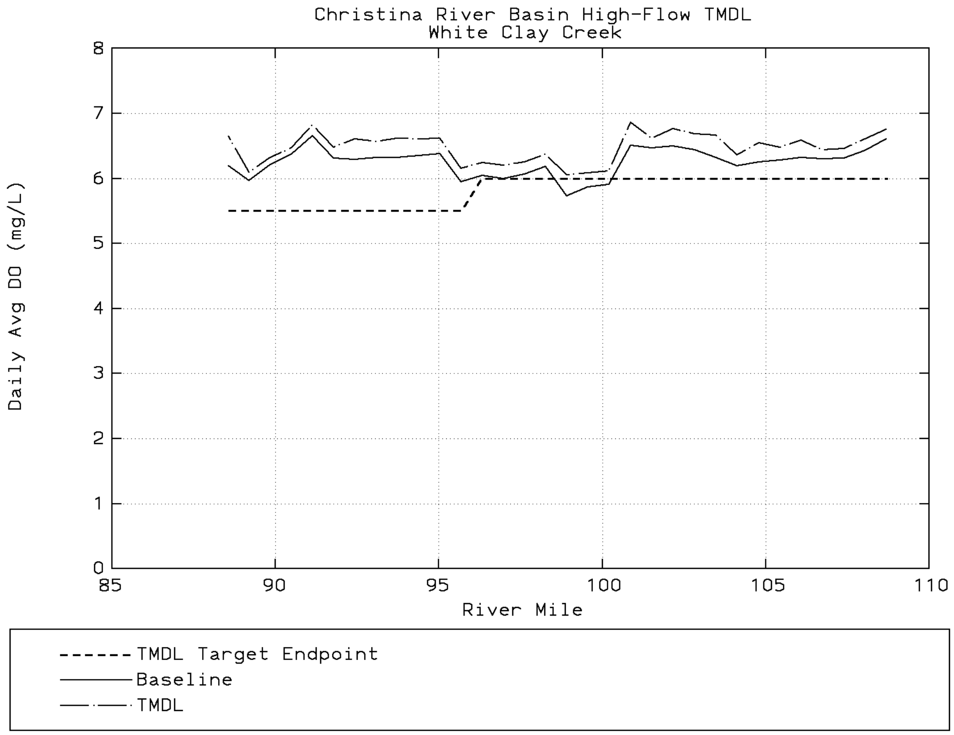

Figure D-19. Baseline and TMDL Daily Average DO, White Clay Creek

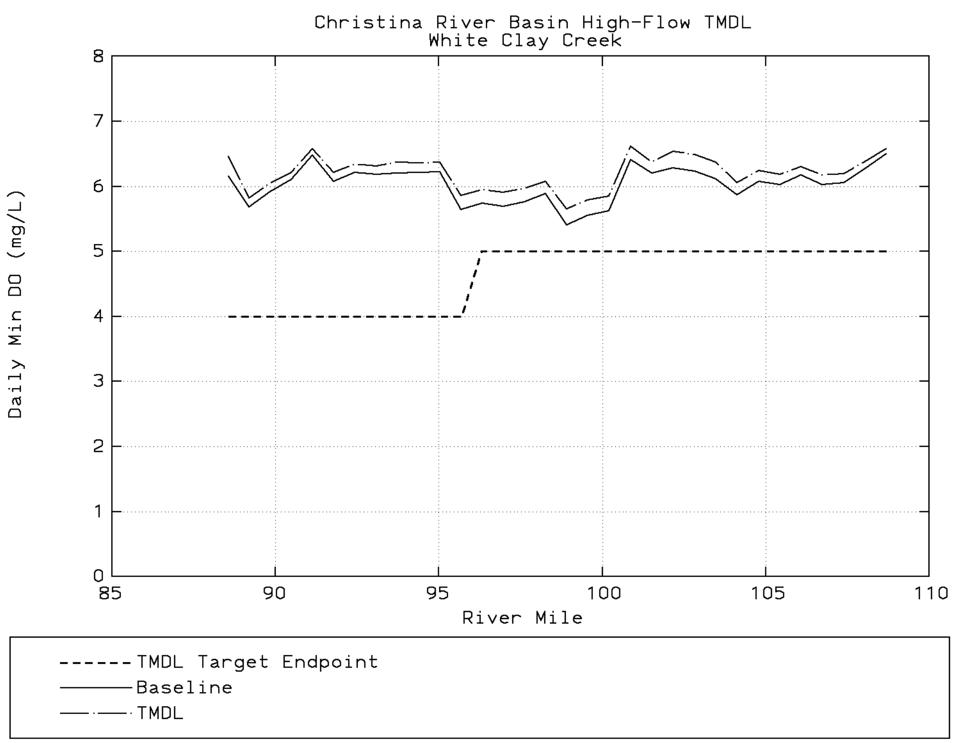

Figure D-20. Baseline and TMDL Minimum DO, White Clay Creek

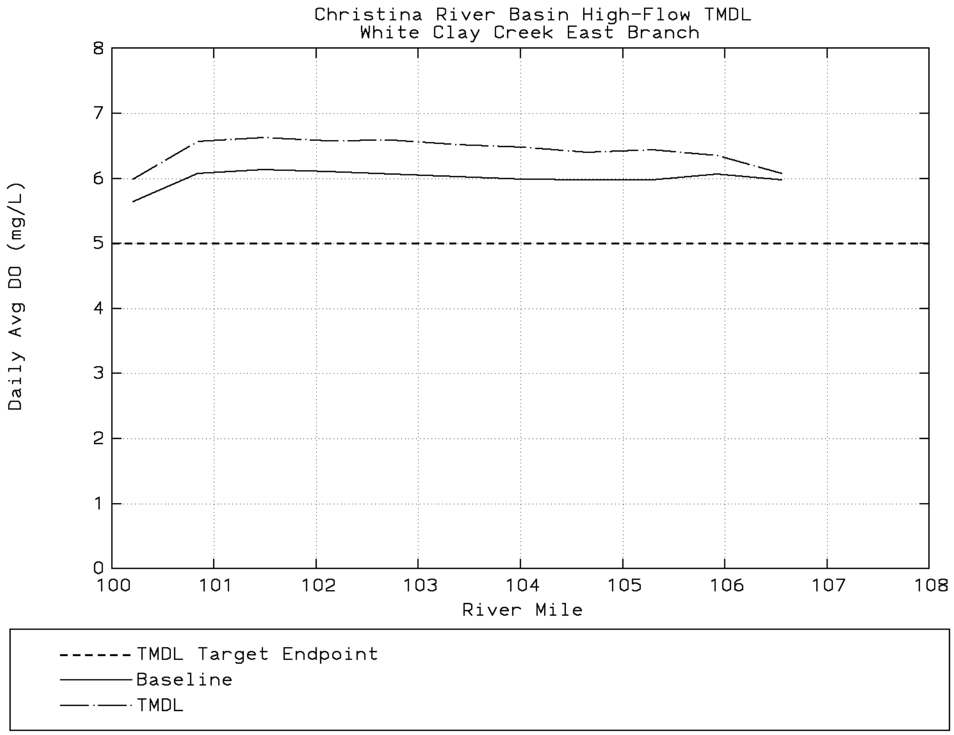

Figure D-21. Baseline and TMDL Daily Average DO, White Clay Creek East Branch

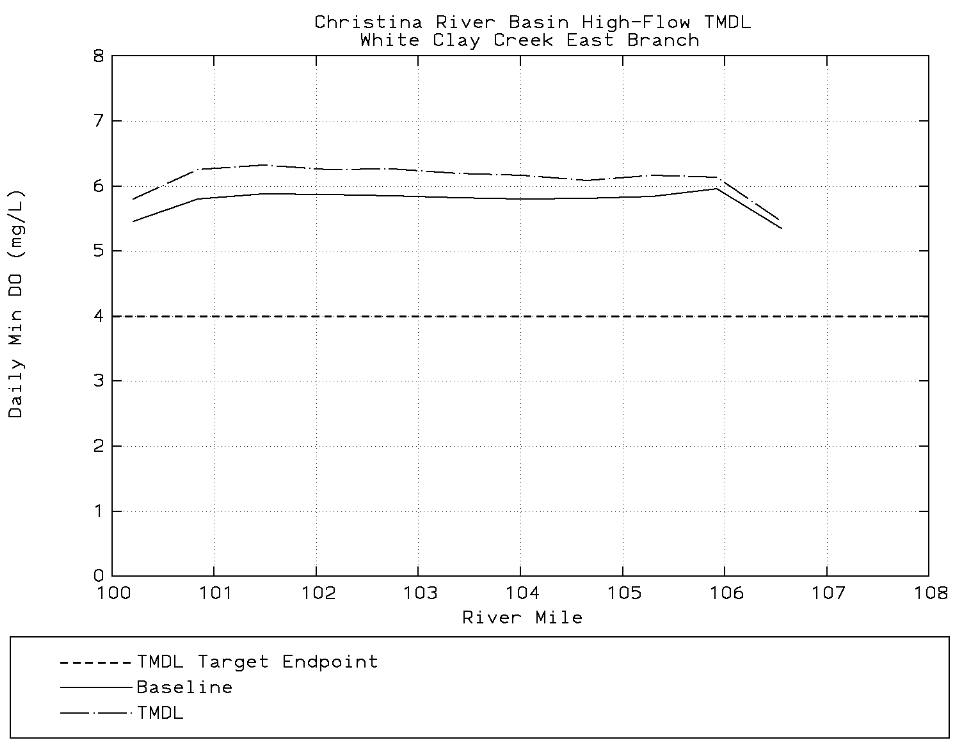

Figure D-22. Baseline and TMDL Minimum DO, White Clay Creek East Branch

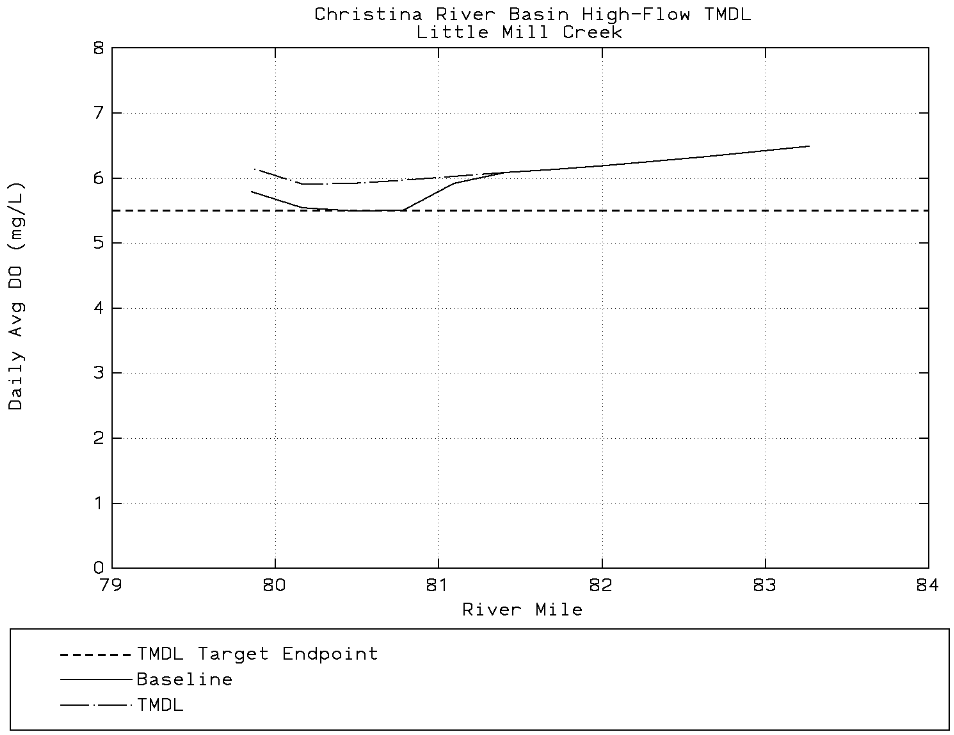

Figure D-23. Baseline and TMDL Daily Average DO, Little Mill Creek

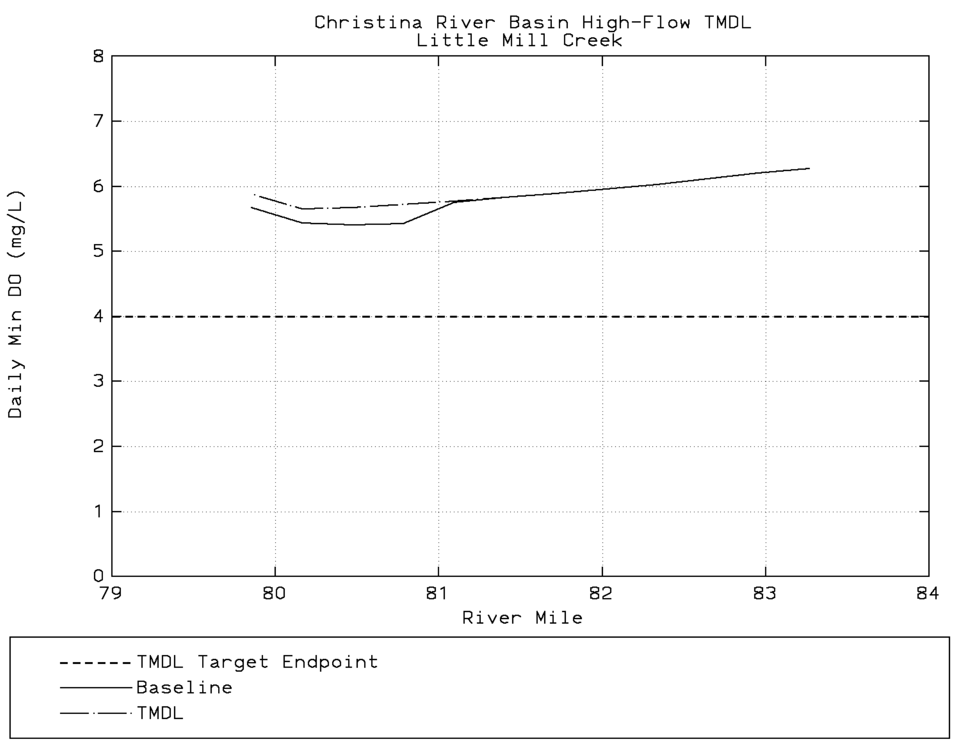

Figure D-24. Baseline and TMDL Minimum DO, Little Mill Creek

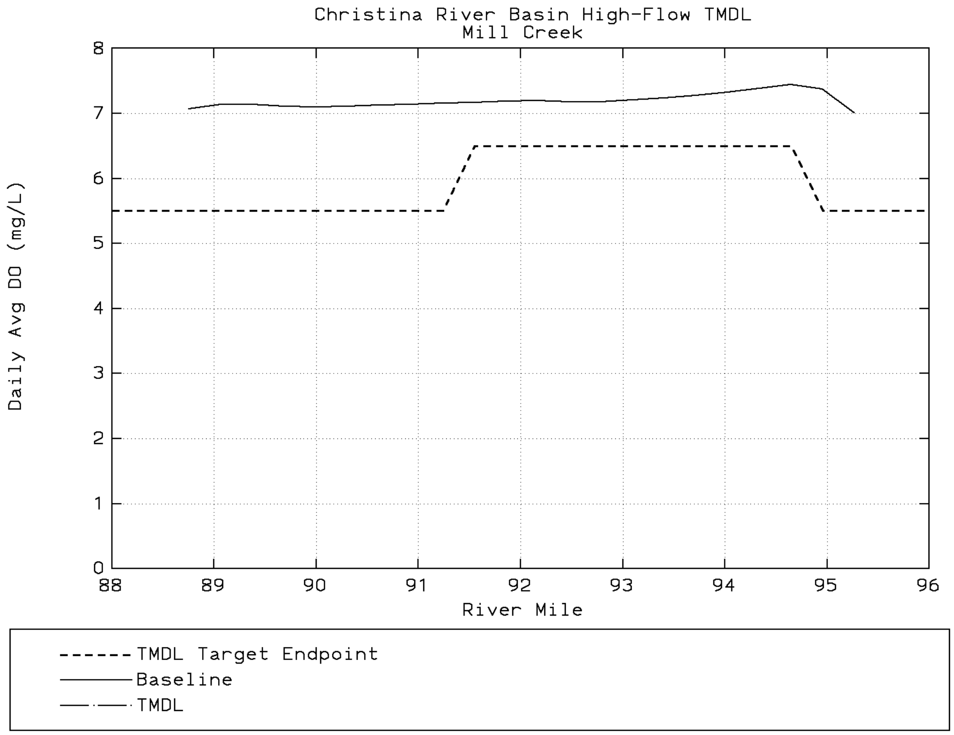

Figure D-25. Baseline and TMDL Daily Average DO, Mill Creek

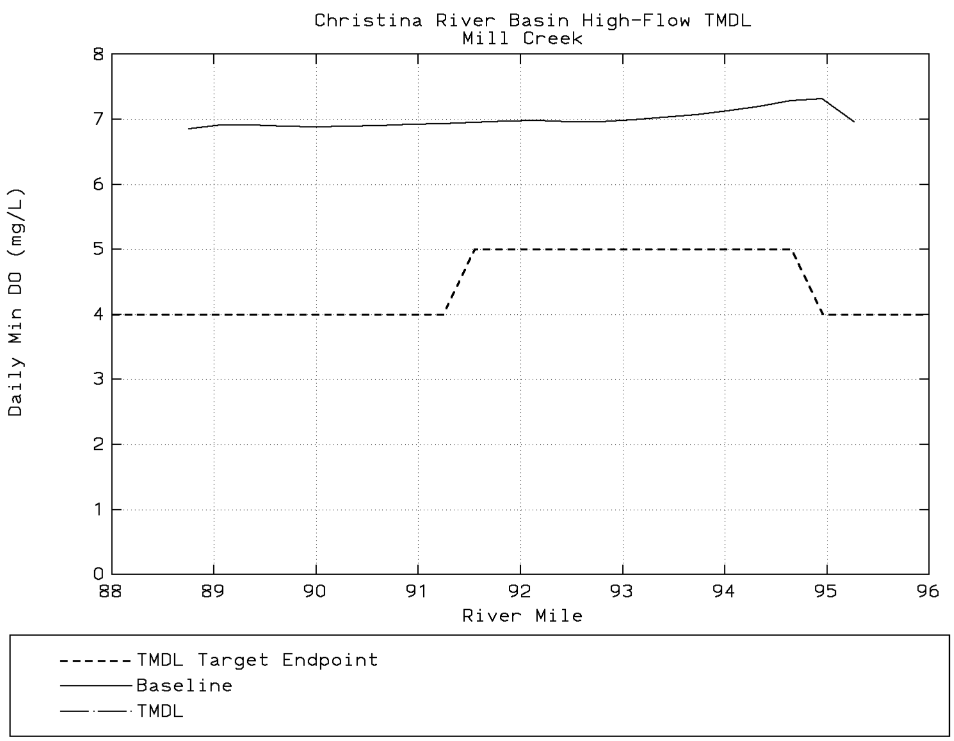

Figure D-26. Baseline and TMDL Minimum DO, Mill Creek

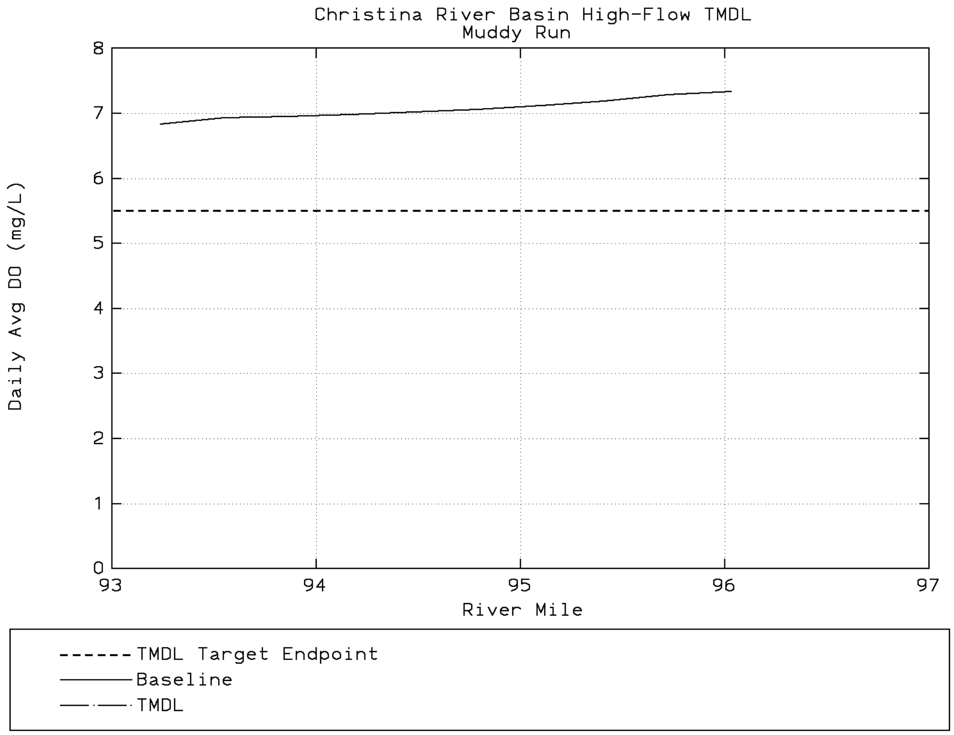

Figure D-27. Baseline and TMDL Daily Average DO, Muddy Run

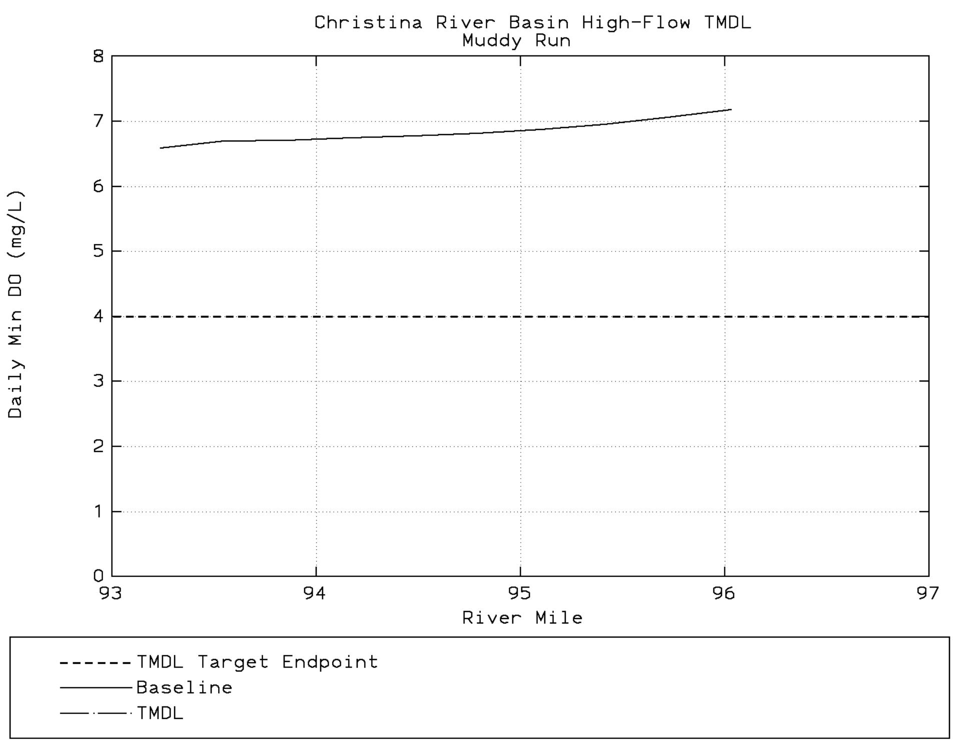

Figure D-28. Baseline and TMDL Minimum DO, Muddy Run

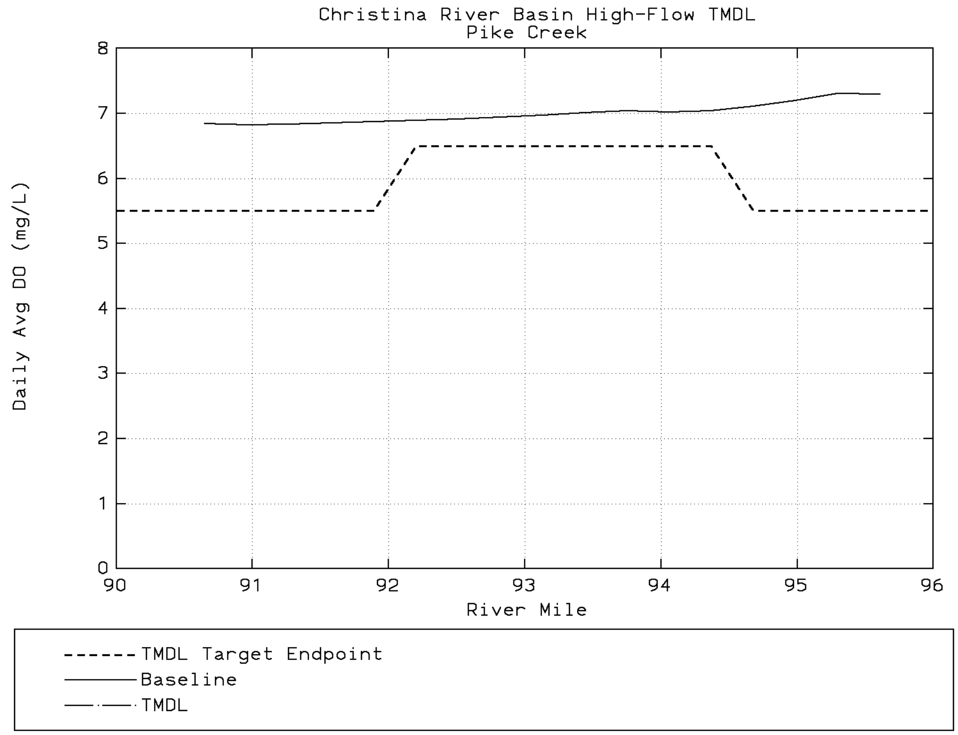

Figure D-29. Baseline and TMDL Daily Average DO, Pike Creek

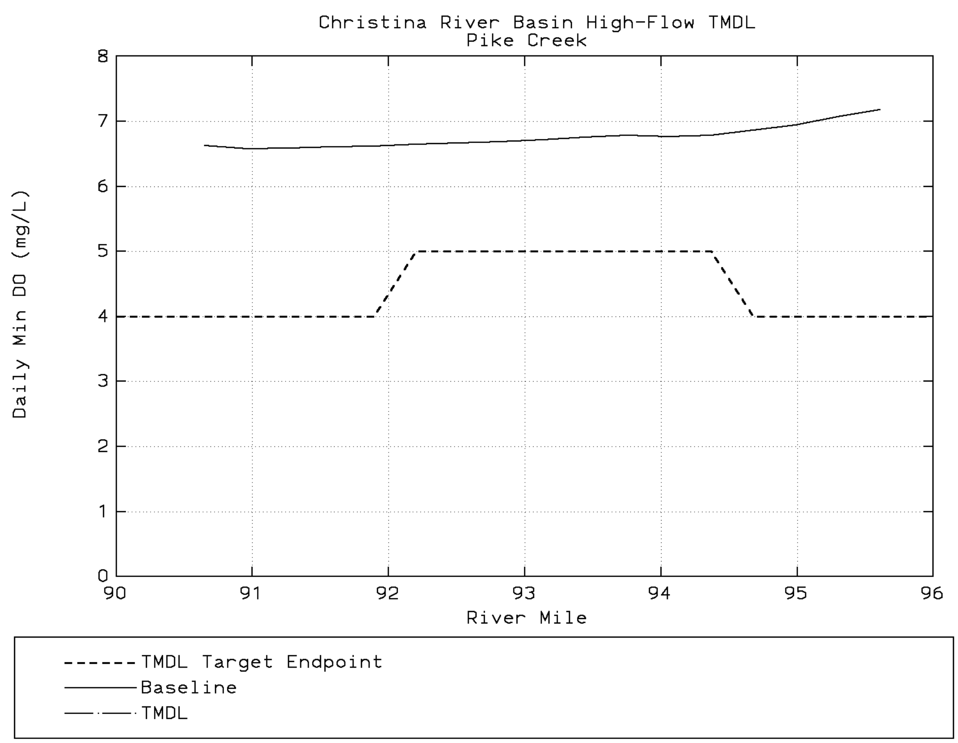

Figure D-30. Baseline and TMDL Minimum DO, Pike Creek

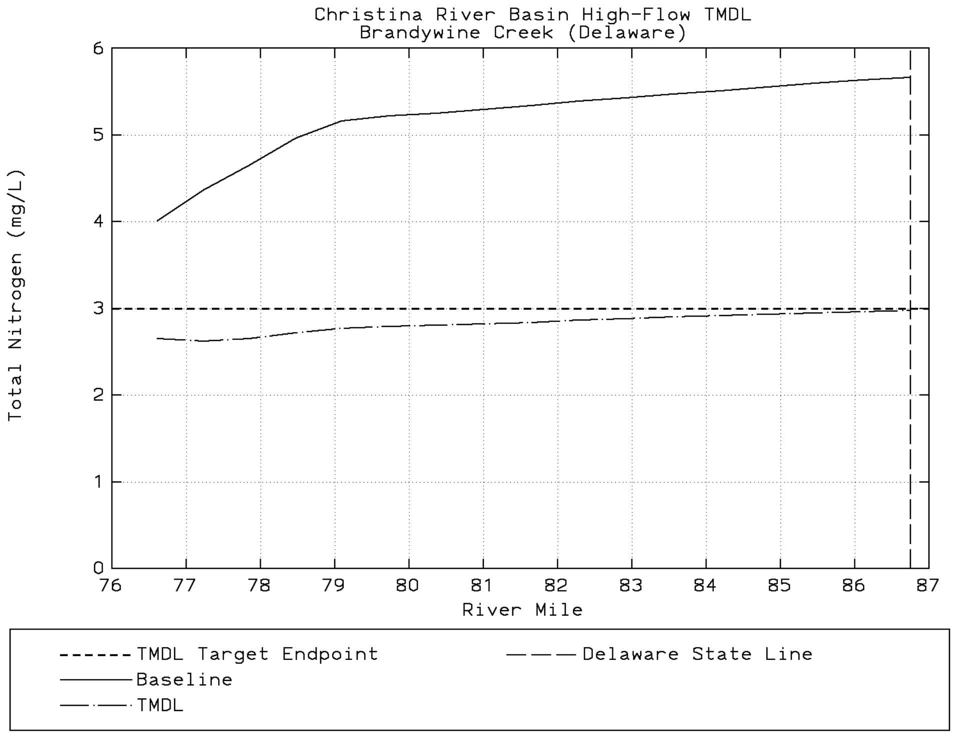

Figure D-31. Baseline and TMDL Total Nitrogen, Brandywine Creek (Delaware)

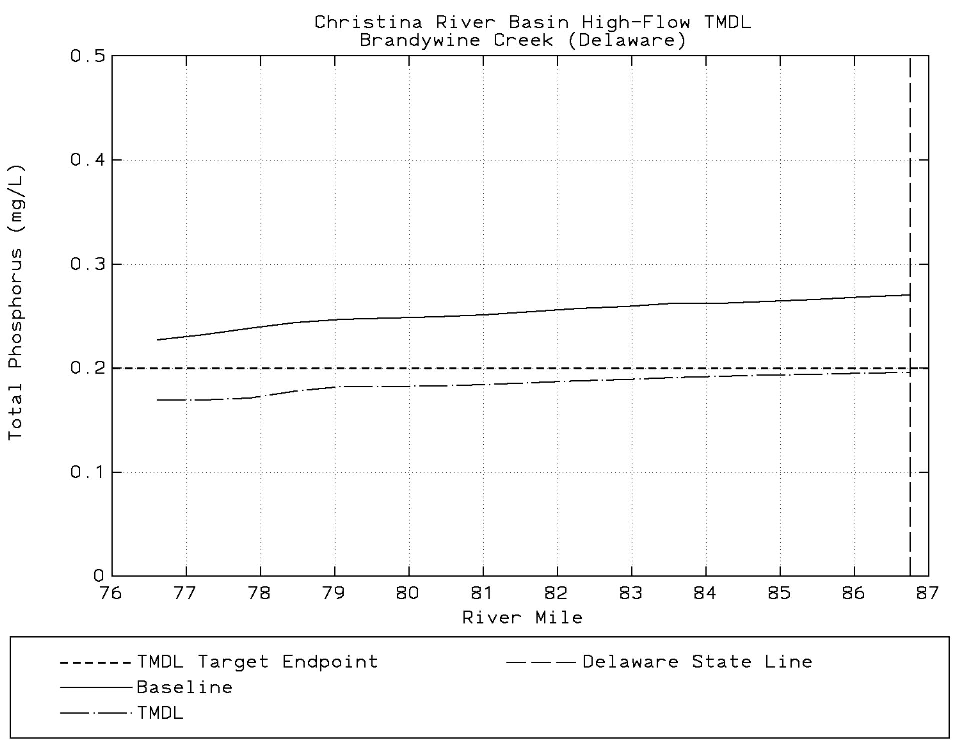

Figure D-32. Baseline and TMDL Total Phosphorus, Brandywine Creek (Delaware)

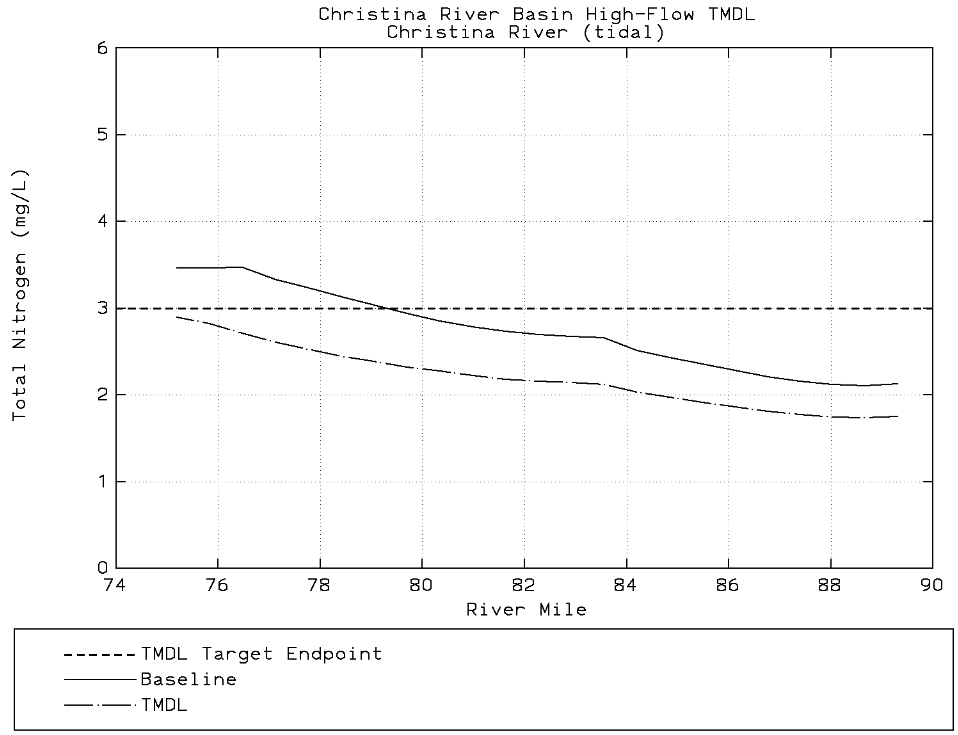

Figure D-33. Baseline and TMDL Total Nitrogen, Christina River (tidal)

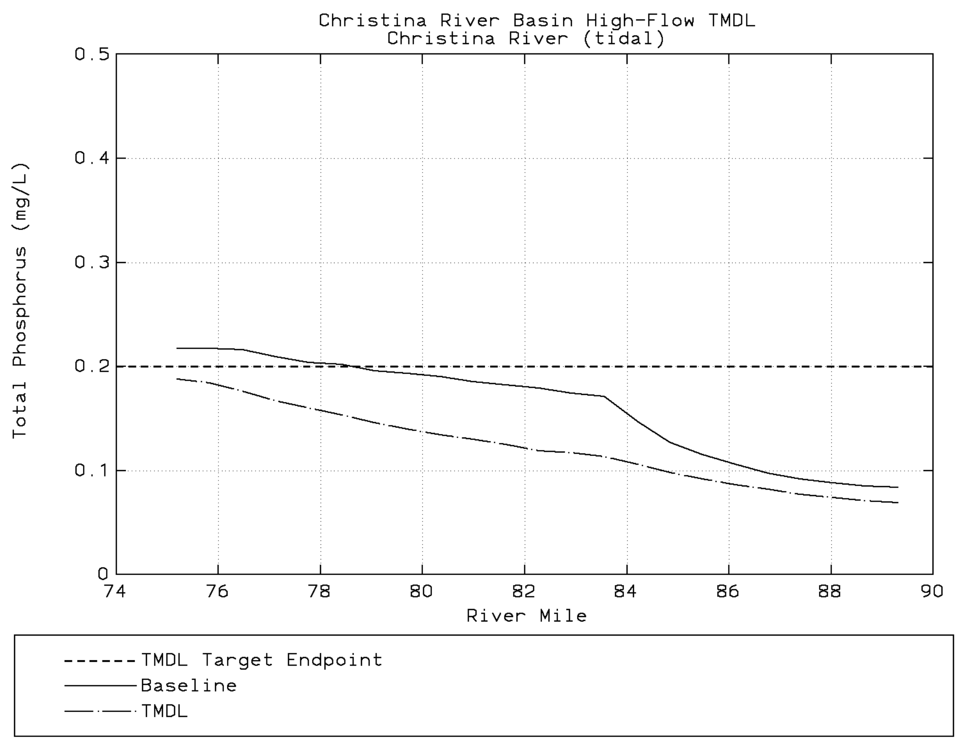

Figure D-34. Baseline and TMDL Total Phosphorus, Christina River (tidal)

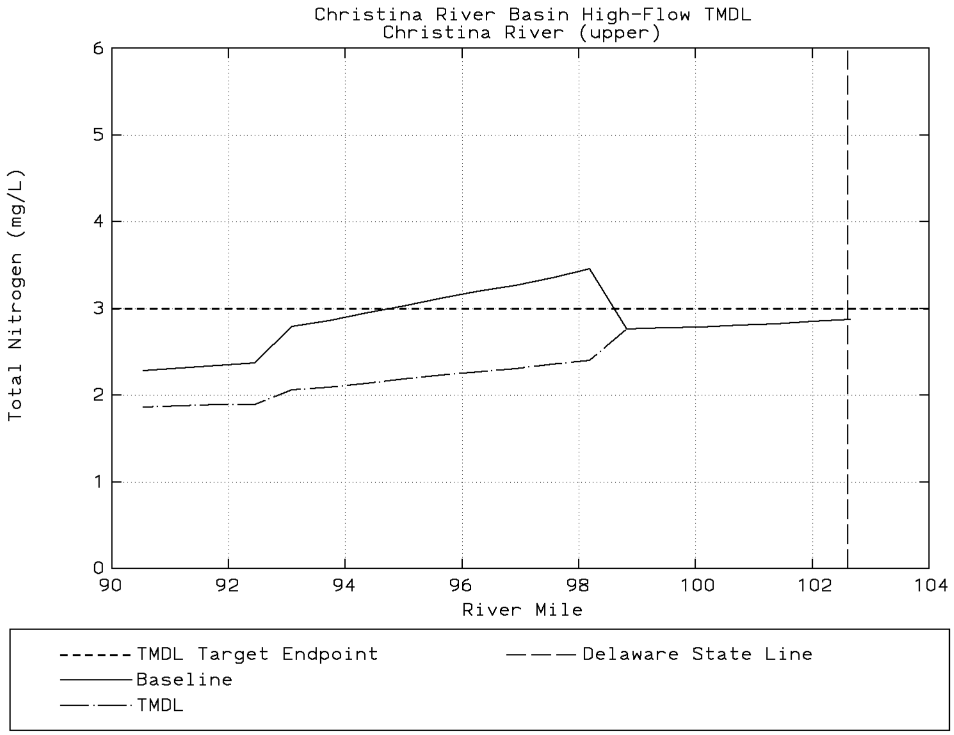

Figure D-35. Baseline and TMDL Total Nitrogen, Christina River (upper)

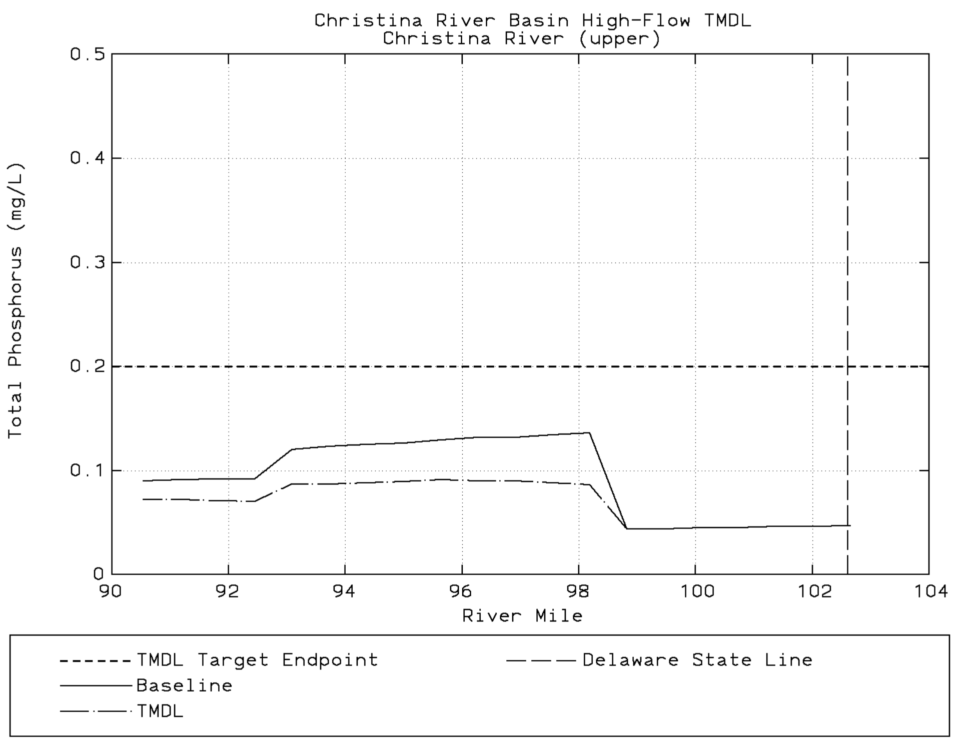

Figure D-36. Baseline and TMDL Total Phosphorus, Christina River (upper)

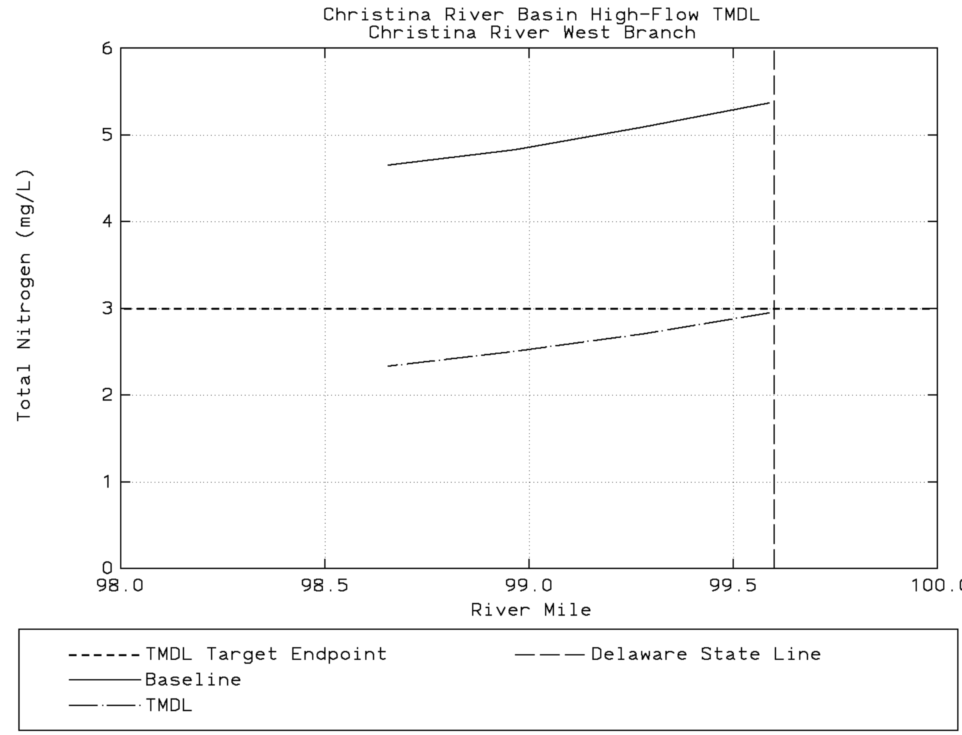

Figure D-37. Baseline and TMDL Total Nitrogen, Christina River West Branch

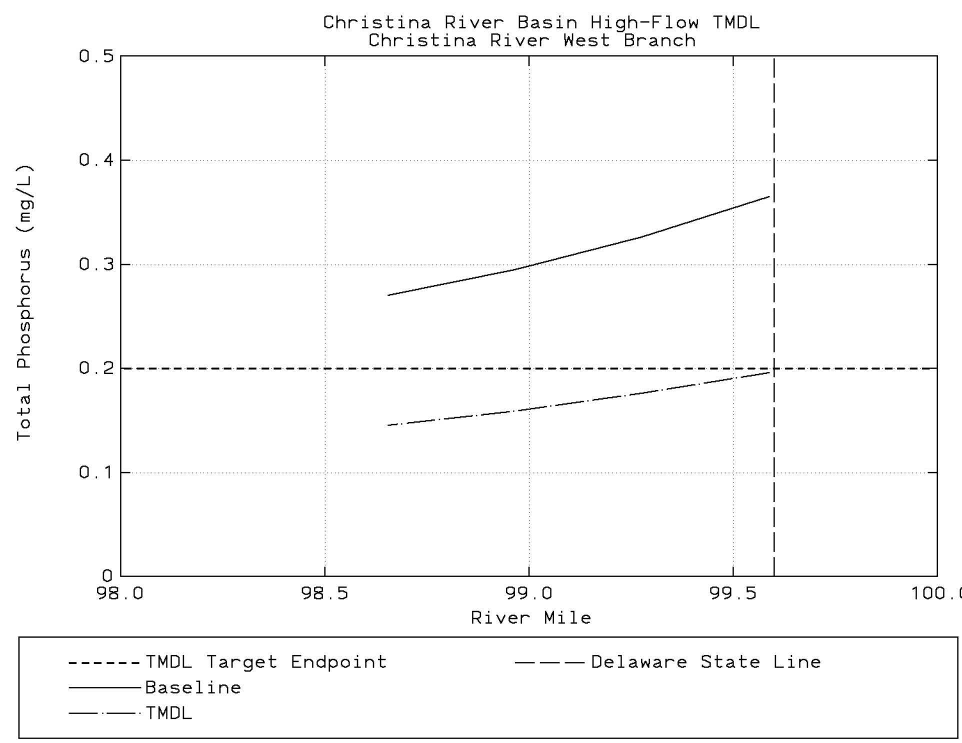

Figure D-38. Baseline and TMDL Total Phosphorus, Christina River West Branch

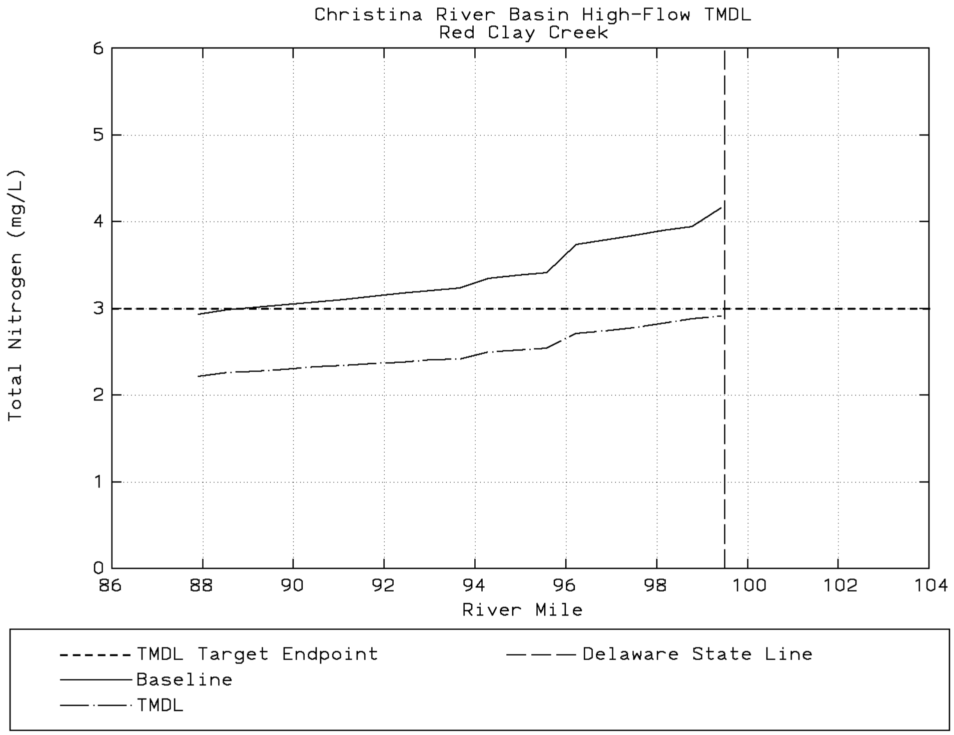

Figure D-39. Baseline and TMDL Total Nitrogen, Red Clay Creek

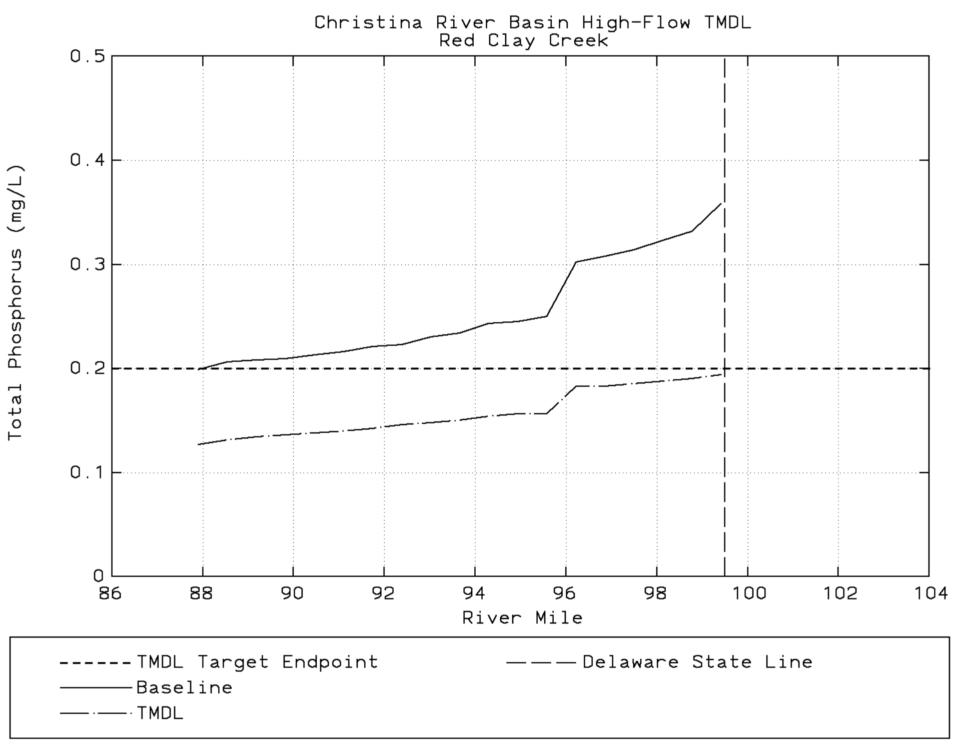

Figure D-40. Baseline and TMDL Total Phosphorus, Red Clay Creek

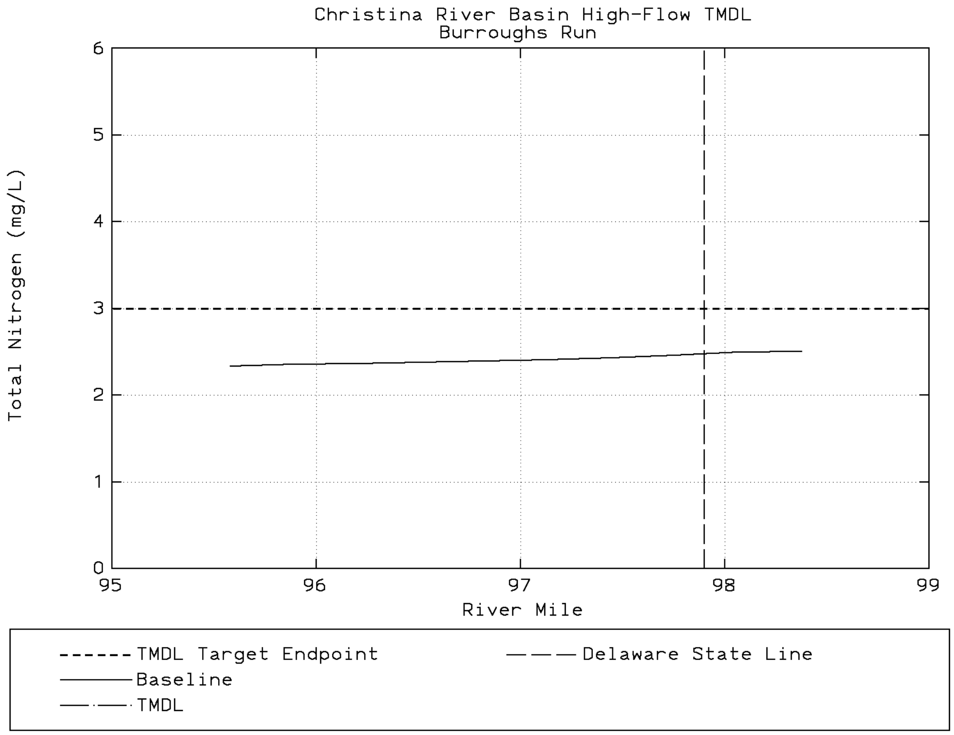

Figure D-41. Baseline and TMDL Total Nitrogen, Burroughs Run

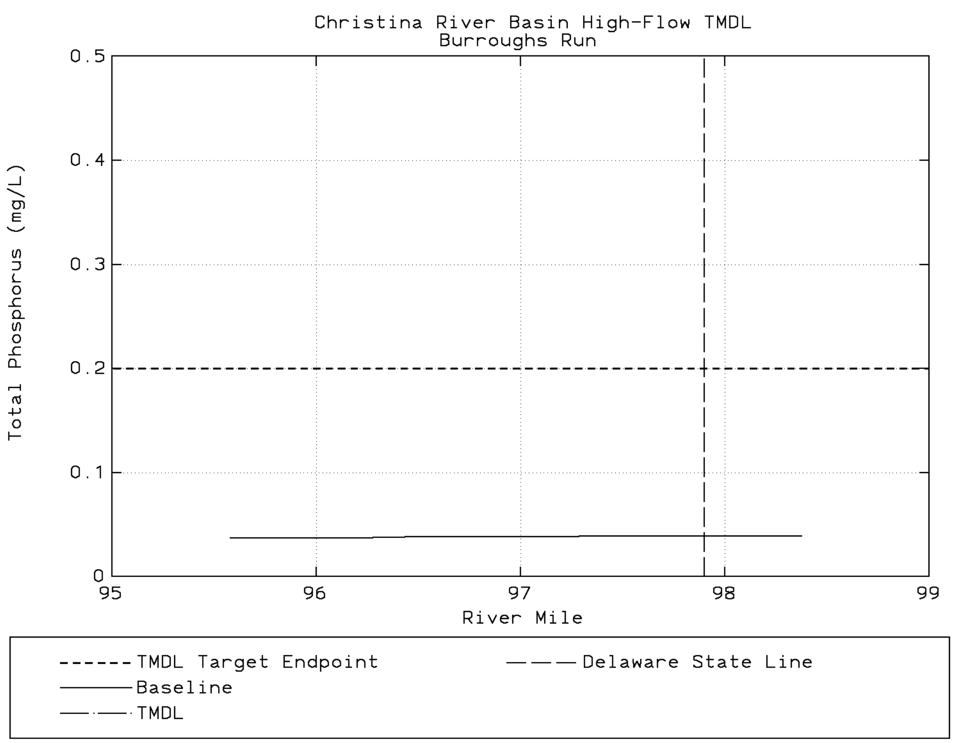

Figure D-42. Baseline and TMDL Total Phosphorus, Burroughs Run

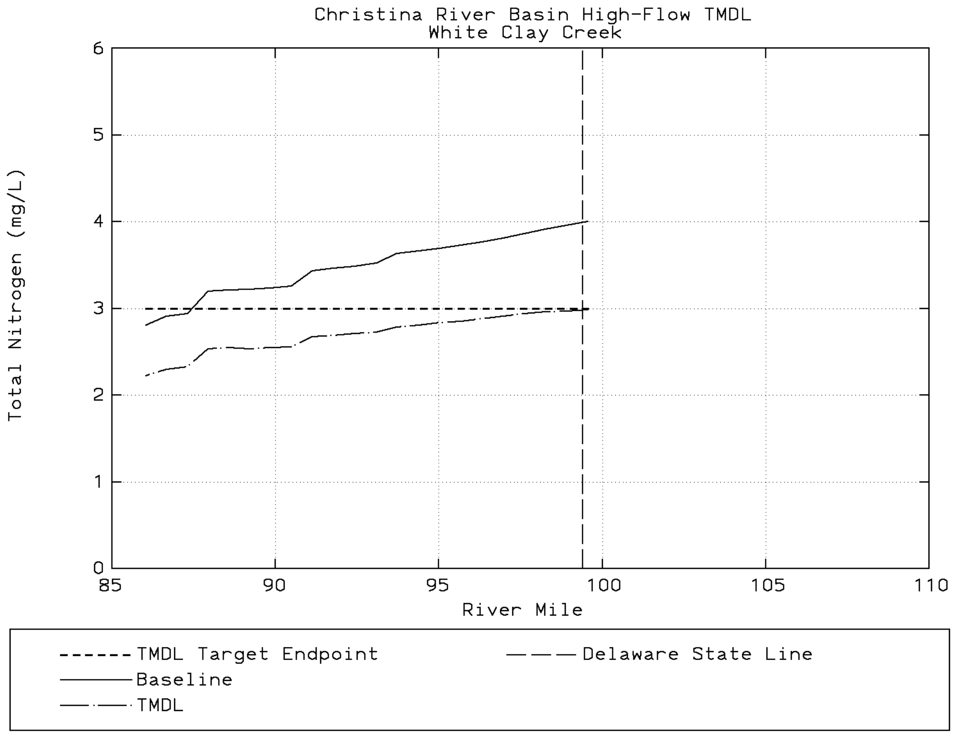

Figure D-43. Baseline and TMDL Total Nitrogen, White Clay Creek

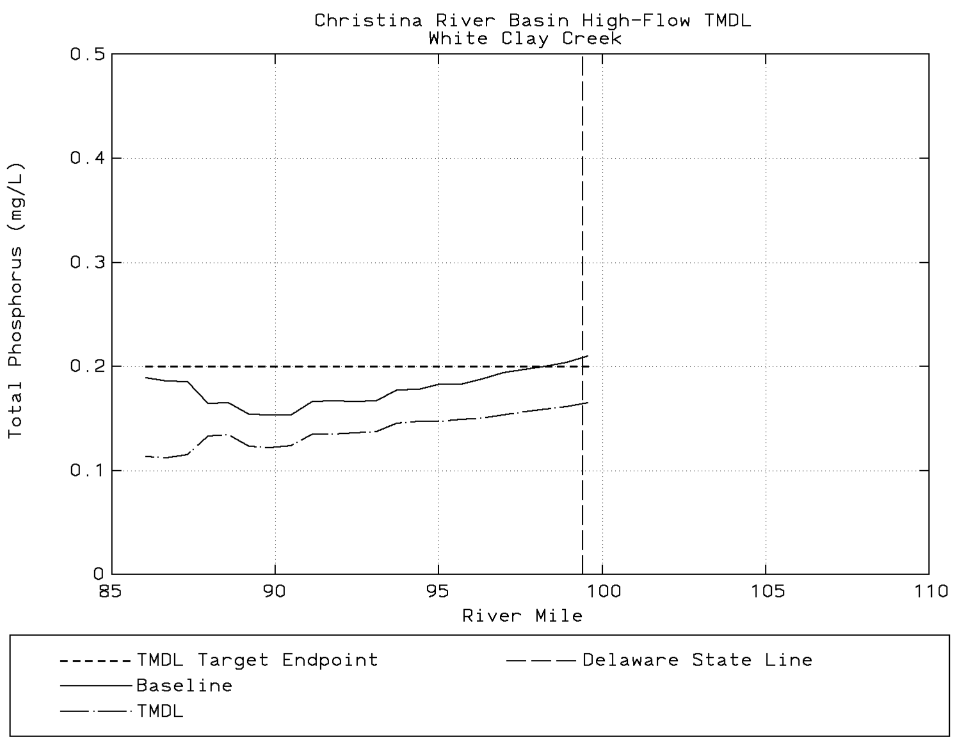

Figure D-44. Baseline and TMDL Total Phosphorus, White Clay Creek

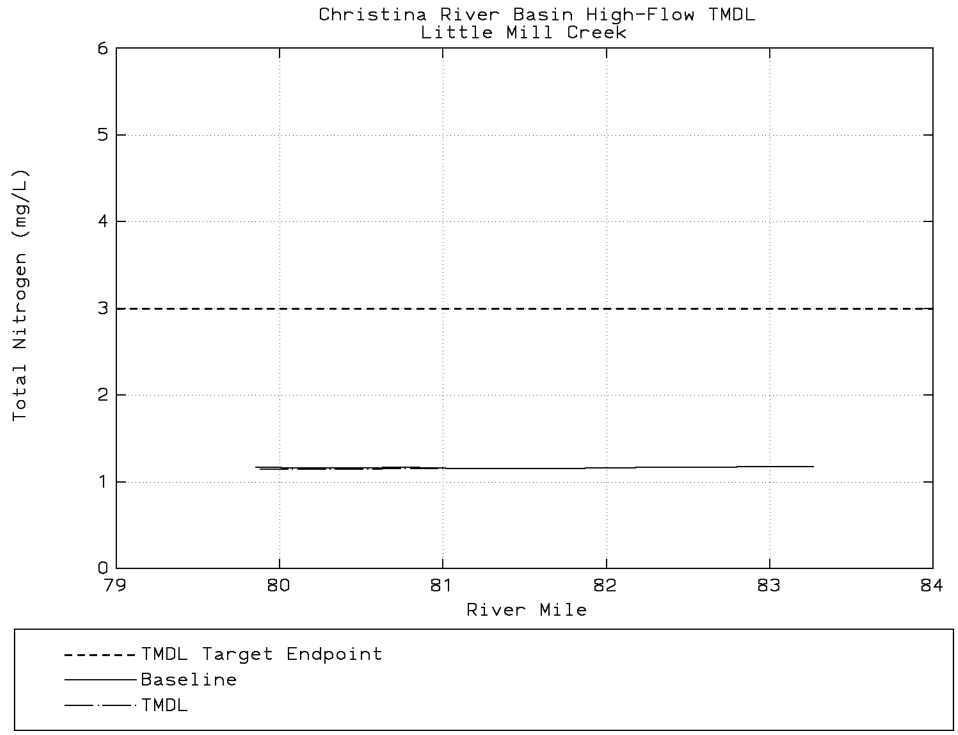

Figure D-45. Baseline and TMDL Total Nitrogen, Little Mill Creek

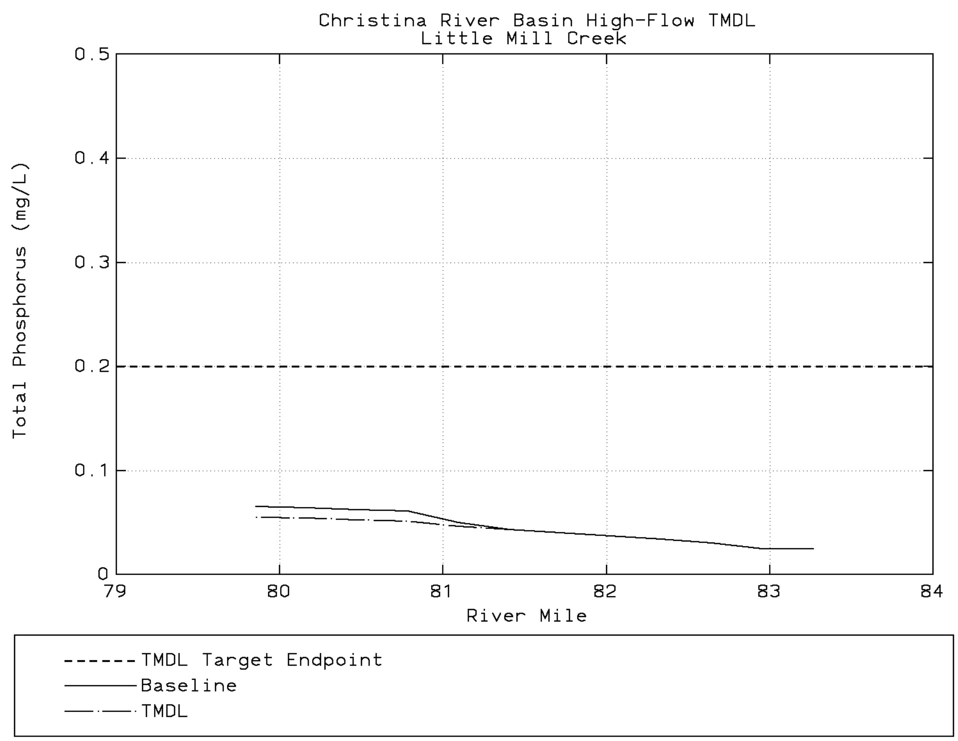

Figure D-46. Baseline and TMDL Total Phosphorus, Little Mill Creek

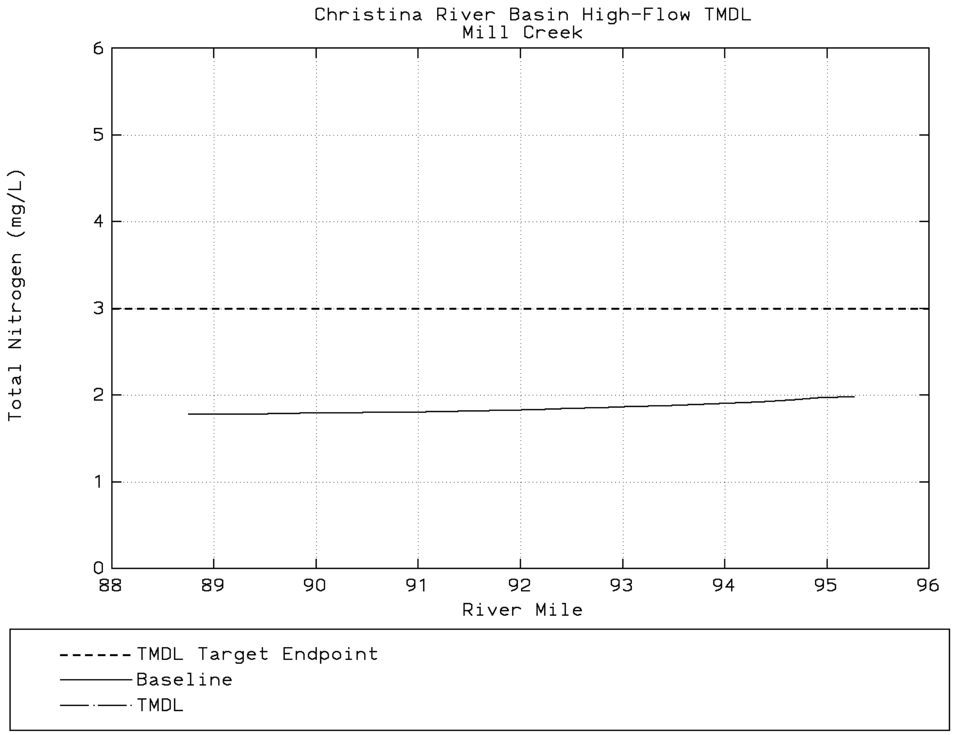

Figure D-47. Baseline and TMDL Total Nitrogen, Mill Creek

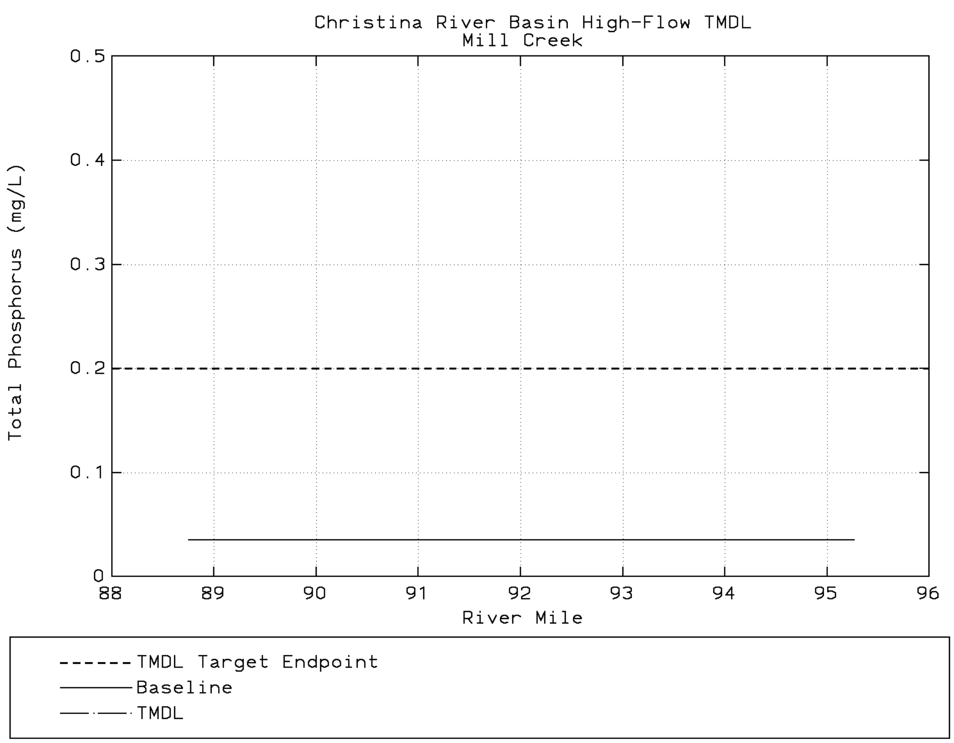

Figure D-48. Baseline and TMDL Total Phosphorus, Mill Creek

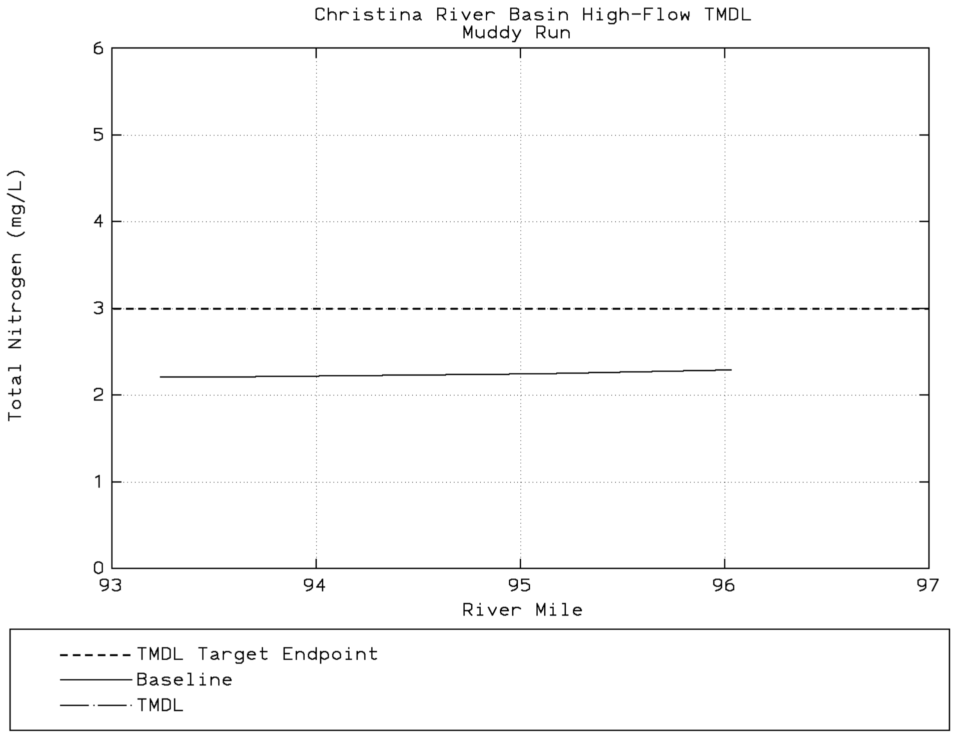

Figure D-49. Baseline and TMDL Total Nitrogen, Muddy Run

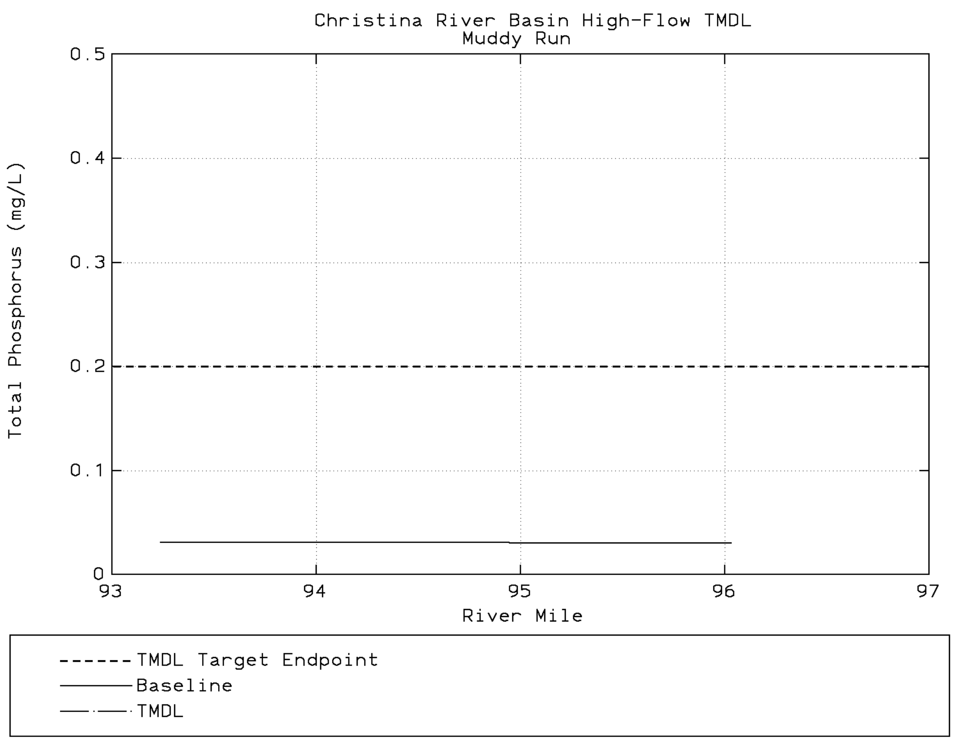

Figure D-50. Baseline and TMDL Total Phosphorus, Muddy Run

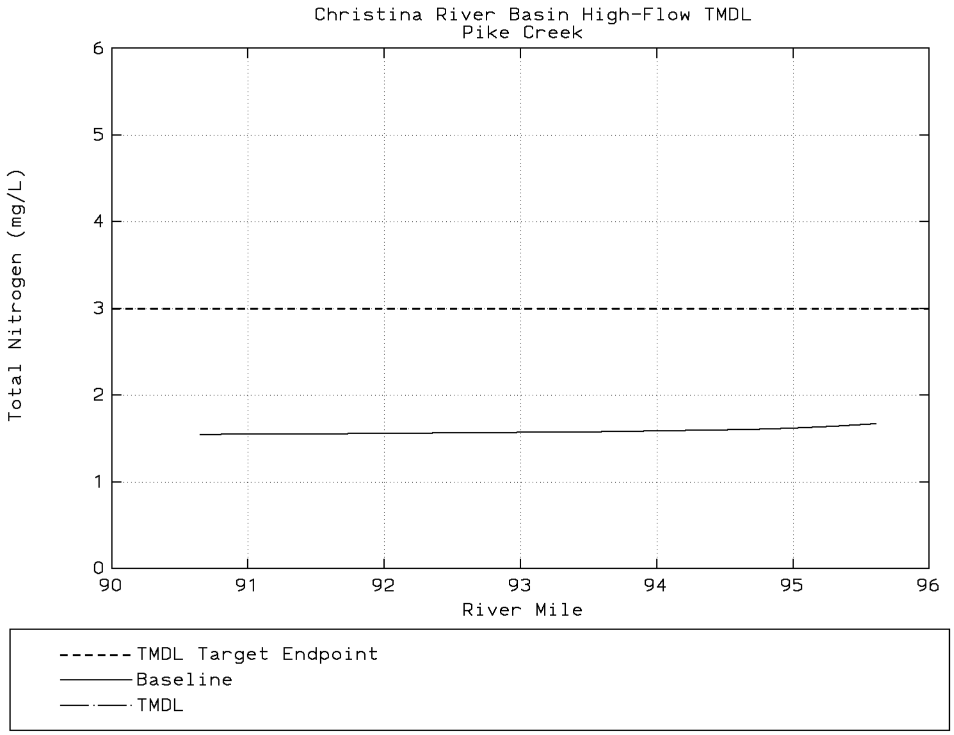

Figure D-51. Baseline and TMDL Total Nitrogen, Pike Creek

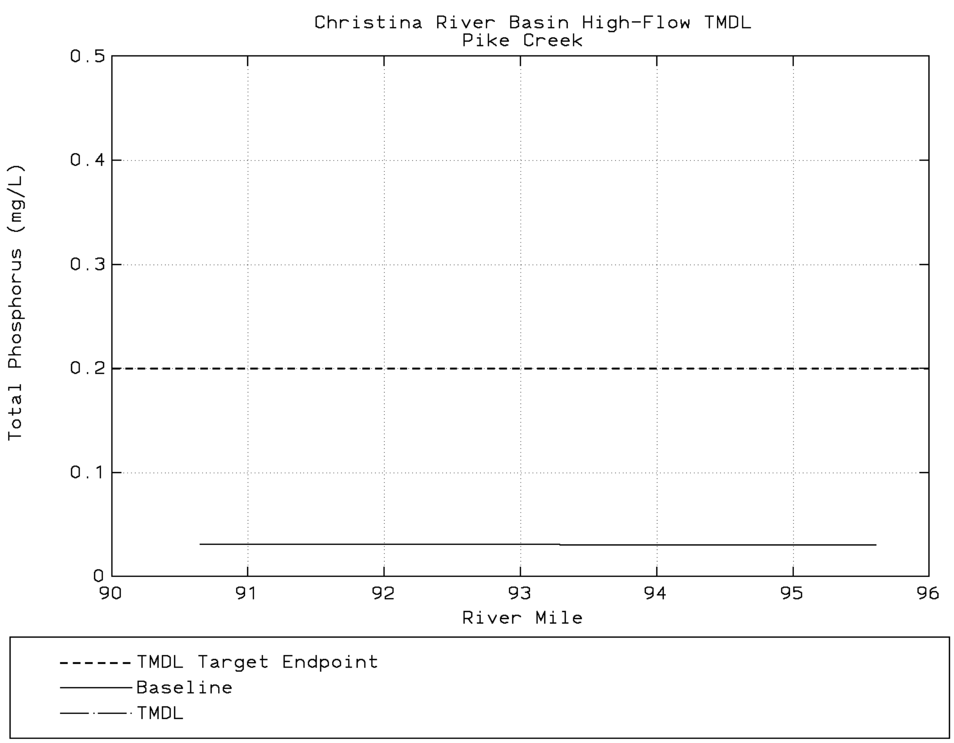

Figure D-52. Baseline and TMDL Total Phosphorus, Pike Creek

Appendix E

Revisions to April 2005 Nutrient and DO High-Flow TMDL for Christina River Basin

Appendix E

Revisions to April 2005 Nutrient and DO High-Flow TMDL for Christina River Basin

On April 8, 2005, the Region III (Philadelphia, PA) office of the Environmental Protection Agency (EPA) established Total Maximum Daily Loads (TMDLs) for nutrients and dissolved oxygen (DO) under high-flow conditions 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 CSO and NPDES discharges that prompted this revision to the April 2005 TMDLs. The updated information is described in this appendix.

E.1 Event Mean Concentrations for Wilmington CSO Discharges

Following the establishment of the Christina River Basin nutrient and DO high-flow TMDLs, the City of Wilmington and Delaware DNREC 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 additional storm events to establish updated total nitrogen (TN), total phosphorus (TP), and total organic carbon (TOC) event mean concentrations (EMCs) for the Wilmington CSO discharges as shown in Table E-1.

Table E-1. Revised EMCs for TN, TP, and TOC City of Wilmington CSOs

CSO ID	EMC April 2005 TMDL (mg/L)			EMC for Revised TMDL (mg/L)		
	TN	TP	TOC	TN	TP	TOC
CSO 4b	2.966	0.310	6.92	2.619	0.334	11.94
CSO 25	2.947	0.618	21.70	2.928	0.655	20.58
CSO 3	4.451	0.690	12.63	7.591	1.041	15.84
All other CSOs	4.451	0.690	12.63	2.753	0.339	15.68

The data from the individual storm events are summarized in Tables E-2, E-3, and E-4. The revised event mean concentrations were calculated using an arithmetic mean of all data associated with a given 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 for CSO 3 only. The EMCs for the other CSOs were calculated as the arithmetic mean from the combined storm monitoring data of 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 Tables E-2, E-3, and E-4 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 E-2. Storm monitoring data for CSO 4b

Date	Time	CBOD20 mg/L 80087	CBOD5 mg/L 80082	DOC mg/L 00681	TOC mg/L 00680	NH3-N mg/L 00610	NOxN mg/L 00630	TKN mg/L 00625	TN mg/L ****	DOrthP mg/L 00671	TP mg/L 00665	TSS mg/L 00530
10/27/2003	11:40	14.62	11.70	6.6	9.1	0.362	0.969	1.400	2.369	0.004	0.238	298
10/27/2003	12:10	13.60	5.82	2.9	3.7	0.137	0.248	0.275	0.248	0.020	0.320	278
10/27/2003	12:40	10.20	5.64	6.1	6.2	0.189	0.502	0.644	0.502	0.100	0.219	195
10/27/2003	13:10	14.48	7.85	5.9	7.1	0.238	0.831	1.080	1.911	0.126	0.270	177
10/27/2003	13:40	13.98	7.65	6.8	8.3	0.244	1.070	1.210	2.280	0.141	0.219	75
10/27/2003	14:10	13.50	10.60	7.3	8.9	0.238	1.290	1.370	2.660	0.159	0.216	32
12/17/2003	09:00	16.20	9.20	4.9	6.8	0.403	0.627	2.650	3.277	0.203	0.388	35
12/17/2003	09:30	16.10	8.65	4.7	6.2	0.480	0.855	2.790	3.645	0.180	0.382	34
12/17/2003	10:00	23.80	12.80	6.8	8.4	4.520	1.210	4.830	6.040	0.222	0.546	25
12/17/2003	10:30	16.20	10.60	5.9	6.1	0.504	1.360	3.060	4.420	0.192	0.416	17
12/17/2003	11:00	12.10	8.18	5.5	6.0	0.486	1.710	2.610	4.320	0.138	0.306	19
12/17/2003	11:30	10.60	6.86	5.0	6.2	0.357	1.970	1.950	3.920	0.112	0.194	19
11/4/2004	13:33	25.10	13.10	22.9	24.4	0.206	0.391	1.250	1.641	0.308	0.489	174
11/4/2004	14:03	28.40	15.20	18.3	20.2	0.154	0.337	0.937	1.274	0.256	0.376	31
11/4/2004	14:33	27.40	15.00	20.6	22.8	0.145	0.540	1.060	1.600	0.268	0.386	14
11/4/2004	15:03	24.50	15.60	22.2	23.5	0.113	0.748	1.080	1.828	0.250	0.314	11
11/4/2004	15:33	23.60	13.60	22.5	29.1	0.197	0.710	1.870	2.580	0.218	0.407	27
EMC		17.90	10.47	10.29	11.94	0.528	0.904	1.769	2.619	0.170	0.334	86

Table E-3. Storm monitoring data for CSO 25

Date	Time	CBOD20 mg/L 80087	CBOD5 mg/L 80082	DOC mg/L 00681	TOC mg/L 00680	NH3-N mg/L 00610	NOxN mg/L 00630	TKN mg/L 00625	TN mg/L ****	DOrthP mg/L 00671	TP mg/L 00665	TSS mg/L 00530
10/27/2003	11:00	13.88	13.88	11.8	14.4	0.325	0.516	1.270	1.786	0.234	0.296	32
10/27/2003	11:30	14.76	14.76	10.3	11.6	0.294	0.503	1.050	1.553	0.286	0.397	33
10/27/2003	12:00	7.83	5.36	3.8	4.3	0.136	0.215	0.392	0.215	0.113	0.178	51
10/27/2003	12:30	12.14	12.14	70.5	80.0	0.421	0.634	3.070	3.704	1.870	1.620	39
10/27/2003	13:30	14.10	14.10	10.6	11.6	0.352	0.820	1.900	2.720	0.249	0.450	26
10/27/2003	14:00	14.26	14.26	10.8	12.0	0.455	1.160	2.480	3.640	0.354	0.642	15
12/17/2003	08:45	15.00	9.48	6.3	6.6	0.350	0.547	1.850	2.397	0.202	0.102	27
12/17/2003	09:15	28.30	19.60	9.1	10.2	0.500	0.839	3.140	3.979	0.317	0.296	22
12/17/2003	09:45	28.76	28.76	40.8	44.6	3.720	1.030	5.500	6.530	1.560	1.580	14
11/4/2004	13:20	28.50	14.90	15.4	18.3	0.476	0.272	1.990	2.262	0.277	0.505	42
11/4/2004	13:50	27.74	15.30	14.0	15.2	0.559	0.315	2.220	2.535	1.000	1.100	39
11/4/2004	14:20	28.00	14.10	17.2	19.1	0.606	0.422	2.630	3.052	0.385	0.637	19
11/4/2004	14:50	26.10	15.10	16.4	19.6	0.712	0.513	3.180	3.693	0.436	0.706	16
EMC		19.95	14.75	18.24	20.58	0.685	0.599	2.359	2.928	0.560	0.655	29

Table E-4. Storm monitoring data for CSO 3 (11th Street Pumping Station)

Date	Time	CBOD20 mg/L 80087	CBOD5 mg/L 80082	DOC mg/L 00681	TOC mg/L 00680	NH3-N mg/L 00610	NOxN mg/L 00630	TKN mg/L 00625	TN mg/L ****	DOrthP mg/L 00671	TP mg/L 00665	TSS mg/L 00530
10/27/2003	11:20	11.76	11.76	23.5	29.6	4.040	0.467	7.250	7.717	0.262	1.470	454
10/27/2003	11:50	10.88	10.88	9.5	11.9	3.070	1.100	3.820	4.920	0.433	0.520	71
10/27/2003	12:10	10.88	10.88	7.7	9.6	1.520	0.545	1.450	1.995	0.202	0.357	166
10/27/2003	12:50	12.98	9.02	4.6	5.8	2.200	0.517	1.400	1.917	0.003	0.366	144
10/27/2003	13:20	11.82	11.82	13.9	15.3	1.720	0.646	0.964	1.610	0.167	0.289	104
10/27/2003	13:50	11.66	11.66	6.8	8.5	2.340	0.753	1.880	0.753	0.311	0.420	106
12/17/2003	08:50	82.32	29.30	8.5	10.4	3.040	0.682	6.790	7.472	0.157	1.160	143
12/17/2003	09:20	26.50	13.80	5.3	6.3	4.520	0.732	4.880	0.732	0.129	0.630	86
12/17/2003	09:50	29.60	15.40	6.0	8.2	1.650	0.820	4.900	5.720	0.004	0.632	91
12/17/2003	10:20	20.80	14.30	6.7	9.1	3.530	0.842	4.670	5.512	0.019	0.645	73
12/17/2003	10:50	42.40	23.70	7.3	11.3	2.940	1.200	5.910	7.110	0.004	0.883	106
12/17/2003	11:20	82.05	82.05	21.4	25.5	1.150	1.140	6.810	7.950	0.341	0.909	64
11/4/2004	13:25	26.82	13.58	20.1	22.6	4.340	0.460	23.200	23.660	0.007	3.400	553
11/4/2004	13:55	30.00	13.70	16.0	23.2	3.080	0.463	12.300	12.763	0.210	1.650	189
11/4/2004	14:25	29.50	12.96	15.6	20.0	2.780	0.506	10.600	11.106	0.182	1.130	181
11/4/2004	14:55	24.36	13.40	14.6	21.5	3.140	0.430	12.600	13.030	0.274	1.470	122
11/4/2004	15:25	20.70	12.40	16.7	21.2	3.050	0.533	11.200	11.733	0.605	1.480	128
11/4/2004	15:55	23.50	12.80	20.9	25.2	2.800	0.630	10.300	10.930	0.644	1.320	104
EMC		28.25	17.97	12.51	15.84	2.828	0.693	7.274	7.591	0.220	1.041	160

E.2 Summary of Annual Baseline and TMDL CSO Nitrogen and Phosphorus Loads

A summary of the baseline and TMDL CSO nitrogen and phosphorus annual average loads grouped by EFDC model grid cell location is presented in Table E-5. The locations of the CSO discharges and the EFDC model grid cells are shown in Figure E-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 E-5. 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 (RR).

Table E-5. Baseline and TMDL average annual loads for CSOs grouped by EFDC grid cell

Location (subbasin)	EFDC Cell [I,J]	CSO ID numbers	Baseline (kg/yr)	TMDL (kg/yr)	Reduction
Total Nitrogen					
Little Mill Creek (C05)	[44,55]	27, 28	683.6	162.1	76.3%
Little Mill Creek (C05)	[45,55]	29	267.5	63.5	76.3%
Christina River (C09)	[52,13]	5, 6, 7, 11, 12, 13, 30	1055.2	363.2	65.6%
Christina River (C09)	[53,13]	9a, 10, 14, 15, 16, 17	1057.4	229.6	78.3%
Christina River (C09)	[55,13]	9c	52.2	2.6	95.1%
Brandywine Cr. (B34)	[54,16]	18	0.4	0.0	100.0%
Brandywine Cr. (B34)	[54,17]	3, 4a, 4b, 4c, 4d, 19, 20, 21a, 21b, 21c	2210.1	398.2	82.0%
Brandywine Cr. (B34)	[54,18]	4e, 4f, 22b, 22c, 23, 24	262.1	261.0	0.4%
Brandywine Cr. (B34)	[54,20]	25, 26	1643.6	839.9	48.9%
Brandywine Cr. (B34)	[54,21]	RR	60.6	0.0	100.0%
Shellpot Creek - CSO 31*	[57,15]	31	258.8	182.1	29.6%
Total Average Annual Nitrogen Load			7292.7	2319.9	68.2%
Total Phosphorus					
Little Mill Creek (C05)	[44,55]	27, 28	115.7	27.4	76.3%
Little Mill Creek (C05)	[45,55]	29	45.3	10.6	76.6%
Christina River (C09)	[52,13]	5, 6, 7, 11, 12, 13, 30	178.5	61.7	65.4%
Christina River (C09)	[53,13]	9a, 10, 14, 15, 16, 17	178.9	38.7	78.4%
Christina River (C09)	[55,13]	9c	8.8	0.4	95.8%
Brandywine Cr. (B34)	[54,16]	18	0.0	0.0	0.0%
Brandywine Cr. (B34)	[54,17]	3, 4a, 4b, 4c, 4d, 19, 20, 21a, 21b, 21c	328.9	60.2	81.7%
Brandywine Cr. (B34)	[54,18]	4e, 4f, 22b, 22c, 23, 24	44.9	44.5	0.8%
Brandywine Cr. (B34)	[54,20]	25, 26	333.6	161.7	51.5%
Brandywine Cr. (B34)	[54,21]	RR	10.2	0.0	100.0%
Shellpot Creek - CSO 31*	[57,15]	31	43.8	30.7	30.0%
Total Average Annual Phosphorus Load			1244.7	405.2	67.4%

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

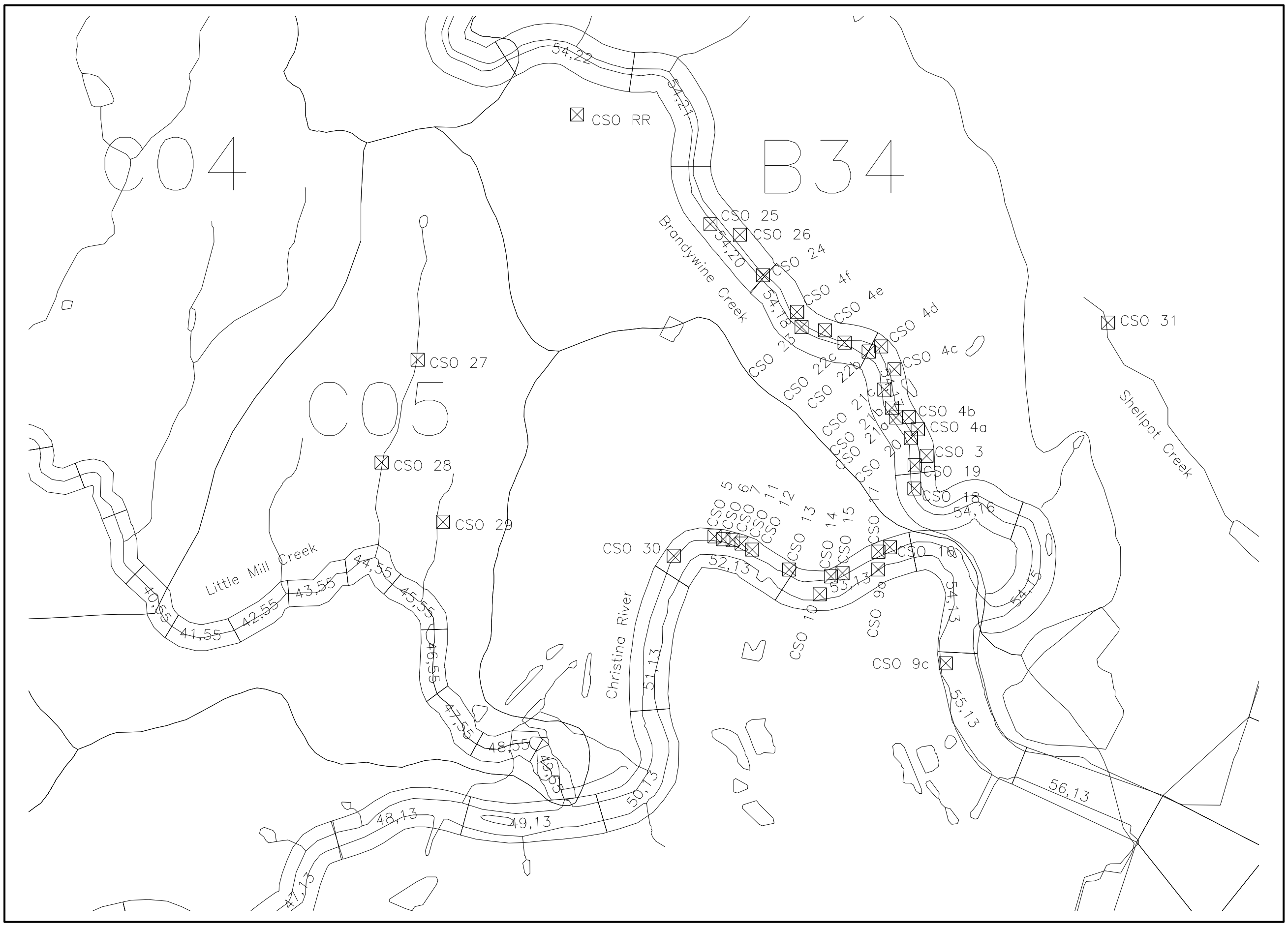

Figure E-1. Location of CSO discharges in relation to EFDC model grid cells

E.3 Revision of Groundwater Flows and Loads

Groundwater flows and nutrient loads for some of the HSPF subbasins were incorrectly added twice to the EFDC water quality model for the April 2005 TMDL. This problem with the HSPF-EFDC linkage was corrected and the proper groundwater flows and loads are used for this revised TMDL. The EFDC water quality model was re-calibrated following the correction of the groundwater flows and loads.

E.4 Updated NPDES Information

The 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 E-6. In addition to the changes listed in Table E-6, the April 2005 model used permit limits for ammonia nitrogen of 10 mg/L and total nitrogen of 20 mg/L for the small residence discharges (flow rate of 500 gpd). For this revised TMDL, the permit limits for ammonia nitrogen and total nitrogen were changed to 30 and 40 mg/L, respectively, which are more appropriate for these types of small discharges. This change in nitrogen loading from the small residence discharges had negligible impact on receiving water quality.

Table E-6. 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)
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

Appendix F

Tables from the 2005 TMDL Report Revised by this TMDL Report

Appendix F

The following tables are from the April 2005 Christina River Basin Nutrient/DO TMDL report for which revisions are proposed.

Table 4-1. Total nitrogen and total phosphorus allocations at PA-DE state line

Location	Baseline Load (kg/day)	Pennsylvania Allocation (kg/day)	Reduction
Total Nitrogen			
Brandywine Creek (at PA-DE Line)	6981.0	4002.7	42.7%
White Clay Creek (at PA-DE Line)	1166.7	818.4	29.9%
Red Clay Creek (at PA-DE Line)	438.9	320.6	27.0%
Burroughs Run (at PA-DE Line)	34.2	34.2	0.0%
Total Phosphorus			
Brandywine Creek (at PA-DE Line)	368.2	355.2	3.5%
White Clay Creek (at PA-DE Line)	111.1	111.1	0.0%
Red Clay Creek (at PA-DE Line)	57.6	34.4	40.2%
Burroughs Run (at PA-DE Line)	0.7	0.7	0.0%

Table 4-2. Total nitrogen and total phosphorus allocations at MD-DE state line

Location	Baseline Load (kg/day)	Maryland Allocation (kg/day)	Reduction
Total Nitrogen			
Christina River West Branch (MD-DE Line)	65.1	34.6	46.9%
Total Phosphorus			
Christina River West Branch (MD-DE Line)	3.6	1.8	48.0%

Table 4-3. TMDL summary for Brandywine Creek Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)				Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	MOS	TMDL	
Total Nitrogen								
B01	0.038	379.770	379.808	0.038	216.467	11.395	227.900	40.0%
B02	16.295	63.651	79.946	16.295	35.466	2.724	54.486	31.8%
B03	0.704	156.047	156.751	0.704	133.385	7.057	141.146	10.0%
B04	0.000	9.380	9.380	0.000	9.380	0.000	9.380	0.0%
B05	517.319	134.617	651.936	517.319	50.866	29.904	598.090	8.3%
B06	0.076	213.433	213.509	0.076	141.929	7.474	149.479	30.0%
B09	0.038	224.511	224.549	0.038	174.892	9.207	184.137	18.0%
B10	1.077	465.938	467.015	1.077	362.912	19.157	383.146	18.0%
B17	0.566	158.854	159.420	0.566	147.865	7.812	156.243	2.0%
B32	0.000	29.010	29.010	0.000	24.804	1.305	26.109	10.0%

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)				Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	MOS	TMDL	
B33	0.203	95.181	95.384	0.203	81.370	4.293	85.866	10.0%
Total Phosphorus								
B01	0.019	7.408	7.427	0.019	4.222	0.223	4.464	39.9%
B02	4.484	0.433	4.917	4.484	0.023	0.237	4.744	3.5%
B03	0.386	16.693	17.079	0.386	14.253	0.770	15.410	9.8%
B04	0.000	1.020	1.020	0.000	1.020	0.000	1.020	0.0%
B05	25.825	15.089	40.914	25.825	7.309	1.744	34.878	14.8%
B06	0.038	25.876	25.914	0.038	17.206	0.908	18.151	30.0%
B09	0.019	2.873	2.892	0.019	2.237	0.119	2.375	17.9%
B10	0.161	34.096	34.257	0.161	26.553	1.406	28.120	17.9%
B17	0.156	8.071	8.227	0.156	7.506	0.403	8.066	2.0%
B32	0.000	2.148	2.148	0.000	1.837	0.097	1.933	10.0%
B33	0.091	1.732	1.823	0.091	1.476	0.082	1.650	9.5%

Table 4-4. WLA summary for Brandywine Creek Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads				WLA				Percent Reduction	
			TN mg/L	TP mg/L	TN kg/day	TP kg/day	TN mg/L	TP mg/L	TN kg/day	TP kg/day	TN	TP
B01	PA0057339	0.0005	20.00	10.00	0.038	0.019	20.00	10.00	0.038	0.019	0.0%	0.0%
B02	PA0036412	0.0550	7.02	1.90	1.462	0.396	7.02	1.90	1.462	0.396	0.0%	0.0%
B02	PA0044776	0.6000	6.53	1.80	14.833	4.089	6.53	1.80	14.833	4.089	0.0%	0.0%
B03	PA0052728	0.0004	20.00	10.00	0.030	0.015	20.00	10.00	0.030	0.015	0.0%	0.0%
B03	PA0055697	0.0490	3.63	2.00	0.673	0.371	3.63	2.00	0.673	0.371	0.0%	0.0%
B05	PA0011568-001	0.6400	5.30	0.30	12.842	0.727	5.30	0.30	12.842	0.727	0.0%	0.0%
B05	PA0011568-016	0.5045	12.00	0.30	22.919	0.573	12.00	0.30	22.919	0.573	0.0%	0.0%
B05	PA0026859	3.8500	30.00	1.48	437.264	21.572	30.00	1.48	437.264	21.572	0.0%	0.0%
B05	PA0036897	0.3900	30.00	2.00	44.294	2.953	30.00	2.00	44.294	2.953	0.0%	0.0%
B06	PA0053228	0.0005	20.00	10.00	0.038	0.019	20.00	10.00	0.038	0.019	0.0%	0.0%
B06	PA0053236	0.0005	20.00	10.00	0.038	0.019	20.00	10.00	0.038	0.019	0.0%	0.0%
B09	PA0054691	0.0005	20.00	10.00	0.038	0.019	20.00	10.00	0.038	0.019	0.0%	0.0%
B10	PA0050547	0.0375	7.26	1.00	1.031	0.142	7.26	1.00	1.031	0.142	0.0%	0.0%
B10	PA0055492	0.0005	20.00	10.00	0.038	0.019	20.00	10.00	0.038	0.019	0.0%	0.0%
B17	PA0053082	0.0206	7.26	2.00	0.566	0.156	7.26	2.00	0.566	0.156	0.0%	0.0%
B33	PA0012416	0.1400	0.24	0.10	0.127	0.053	0.24	0.10	0.127	0.053	0.0%	0.0%
B33	PA0052990	0.0005	20.00	10.00	0.038	0.019	20.00	10.00	0.038	0.019	0.0%	0.0%
B33	PA0056073	0.0005	20.00	10.00	0.038	0.019	20.00	10.00	0.038	0.019	0.0%	0.0%

Table 4-5. TMDL summary for Red Clay Creek Watershed

Subbasin	Baseline (kg/day)			Allocations (kg/day)				Percent Reduction
	PS	NPS	Baseline	WLA	MS4 WLA	MOS	TMDL	
Total Nitrogen								
R01	0.227	143.230	143.457	0.227	68.023	3.592	71.842	49.9%
R02	20.114	182.702	202.816	20.114	85.778	5.573	111.465	45.0%
R03	2.749	132.076	134.825	2.749	62.599	3.439	68.787	49.0%
R04	2.085	72.099	74.184	2.085	34.143	1.907	38.135	48.6%
R05	0.206	63.244	63.450	0.206	30.031	1.591	31.828	49.8%
R06	0.038	52.210	52.248	0.038	37.694	1.986	39.718	24.0%
R07	0.000	3.015	3.015	0.000	3.015	0.000	3.015	0.0%

Subbasin	Baseline (kg/day)			Allocations (kg/day)				Percent Reduction
	PS	NPS	Baseline	WLA	MS4 WLA	MOS	TMDL	
R08	0.318	43.799	44.117	0.318	43.799	0.000	44.117	0.0%
R09	0.000	13.423	13.423	0.000	13.423	0.000	13.423	0.0%
Total Phosphorus								
R01	0.095	1.025	1.120	0.095	0.482	0.030	0.608	45.8%
R02	5.330	46.122	51.452	5.330	8.497	0.728	14.554	71.7%
R03	1.136	1.093	2.229	1.136	0.462	0.084	1.683	24.5%
R04	32.918	6.665	39.583	32.918	0.317	1.749	34.984	11.6%
R05	0.114	4.484	4.598	0.114	4.484	0.000	4.598	0.0%
R06	0.019	1.270	1.289	0.019	1.270	0.000	1.289	0.0%
R07	0.000	0.424	0.424	0.000	0.424	0.000	0.424	0.0%
R08	0.133	1.594	1.727	0.133	1.594	0.000	1.727	0.0%
R09	0.000	0.430	0.430	0.000	0.430	0.000	0.430	0.0%

Table 4-6. WLA summary for Red Clay Creek Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads				WLA				Percent Reduction	
			TN mg/L	TP mg/L	TN kg/day	TP kg/day	TN mg/L	TP mg/L	TN kg/day	TP kg/day	TN	TP
R01	PA0050679	0.2500	0.24	0.10	0.227	0.095	0.24	0.10	0.227	0.095	0.0%	0.0%
R02	PA0024058	1.1000	4.83	1.28	20.114	5.330	4.83	1.28	20.114	5.330	0.0%	0.0%
R03	PA0055107	0.1500	4.84	2.00	2.749	1.136	4.84	2.00	2.749	1.136	0.0%	0.0%
R04	DE0000451	2.1700	0.24	0.30	1.972	2.465	0.24	0.30	1.972	2.465	0.0%	0.0%
R04	DE0050067	0.0015	20.00	10.00	0.114	0.057	20.00	10.00	0.114	0.057	0.0%	0.0%
R05	DE0021709	0.0150	3.63	2.00	0.206	0.114	3.63	2.00	0.206	0.114	0.0%	0.0%
R06	PA0055425	0.0005	20.00	10.00	0.038	0.019	20.00	10.00	0.038	0.019	0.0%	0.0%
R08	DE0000230	0.3500	0.24	0.10	0.318	0.133	0.24	0.10	0.318	0.133	0.0%	0.0%

Table 4-7. TMDL summary for White Clay Creek Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)				Percent Reduction
	PS	NPS	Baseline	WLA	MS4 WLA	MOS	TMDL	
Total Nitrogen								
W01	0.550	157.120	157.670	0.550	74.605	3.956	79.110	49.8%
W02	10.998	133.823	144.821	10.998	56.659	3.561	71.218	50.8%
W03	0.000	154.723	154.723	0.000	73.493	3.868	77.362	50.0%
W04	0.000	83.403	83.403	0.000	39.616	2.085	41.702	50.0%
W06	58.211	168.697	226.908	58.211	77.221	7.128	142.560	37.2%
W07	8.010	29.485	37.495	8.010	13.605	1.138	22.753	39.3%
W08	0.000	216.797	216.797	0.000	102.979	5.420	108.399	50.0%
W09	0.091	141.336	141.427	0.091	67.130	3.538	70.759	50.0%
W10	0.000	59.065	59.065	0.000	28.056	1.477	29.533	50.0%
W11	0.000	71.329	71.329	0.000	71.329	0.000	71.329	0.0%
W12	0.027	96.990	97.017	0.027	96.990	0.000	97.017	0.0%
W13	0.000	23.795	23.795	0.000	23.795	0.000	23.795	0.0%
W14	0.000	25.388	25.388	0.000	25.388	0.000	25.388	0.0%
W15	0.000	34.814	34.814	0.000	34.814	0.000	34.814	0.0%
W16	0.000	39.049	39.049	0.000	39.049	0.000	39.049	0.0%
W17	0.000	84.315	84.315	0.000	84.315	0.000	84.315	0.0%
Total Phosphorus								

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)				Percent Reduction
	PS	NPS	Baseline	WLA	MS4 WLA	MOS	TMDL	
W01	0.151	1.924	2.075	0.151	0.815	0.051	1.017	51.0%
W02	1.893	1.420	3.313	1.893	0.512	0.127	2.532	23.6%
W03	0.000	17.214	17.214	0.000	7.359	0.387	7.746	55.0%
W04	0.000	1.173	1.173	0.000	0.501	0.026	0.528	55.0%
W06	4.816	2.208	7.024	4.816	0.284	0.268	5.368	23.6%
W07	0.074	1.892	1.966	0.074	0.805	0.046	0.925	52.9%
W08	0.000	60.821	60.821	0.000	16.178	0.851	17.030	72.0%
W09	0.045	15.989	16.034	0.045	6.833	0.362	7.240	54.8%
W10	0.000	5.098	5.098	0.000	2.179	0.115	2.294	55.0%
W11	0.000	5.736	5.736	0.000	5.736	0.000	5.736	0.0%
W12	0.011	4.576	4.587	0.011	4.576	0.000	4.587	0.0%
W13	0.000	1.174	1.174	0.000	1.174	0.000	1.174	0.0%
W14	0.000	0.755	0.755	0.000	0.755	0.000	0.755	0.0%
W15	0.000	0.495	0.495	0.000	0.495	0.000	0.495	0.0%
W16	0.000	0.833	0.833	0.000	0.833	0.000	0.833	0.0%
W17	0.000	2.158	2.158	0.000	2.158	0.000	2.158	0.0%

Table 4-8. WLA summary for White Clay Creek Watershed

Subbasin	NPDES		Baseline Point Source Loads				WLA				Percent Reduction	
		Flow mgd	TN mg/L	TP mg/L	TN kg/day	TP kg/day	TN mg/L	TP mg/L	TN kg/day	TP kg/day	TN	TP
W01	PA0053783	0.0200	7.26	2.00	0.550	0.151	7.26	2.00	0.550	0.151	0.0%	0.0%
W02	PA0024066	0.2500	11.62	2.00	10.998	1.893	11.62	2.00	10.998	1.893	0.0%	0.0%
W06	PA0029343	0.0270	7.26	2.00	0.742	0.204	7.26	2.00	0.742	0.204	0.0%	0.0%
W06	PA0040436	0.0090	20.00	2.00	0.681	0.068	20.00	2.00	0.681	0.068	0.0%	0.0%
W06	PA0025488	0.3000	50.00	4.00	56.788	4.543	50.00	4.00	56.788	4.543	0.0%	0.0%
W07	PA0056898	0.0650	32.55	0.30	8.010	0.074	32.55	0.30	8.010	0.074	0.0%	0.0%
W09	PA0052451	0.0012	20.00	10.00	0.091	0.045	20.00	10.00	0.091	0.045	0.0%	0.0%
W12	DE0000191	0.0300	0.24	0.10	0.027	0.011	0.24	0.10	0.027	0.011	0.0%	0.0%

Table 4-9. Baseline and WLA nitrogen and phosphorus loads for CSO discharges

Location	**CSO ID numbers**	**Baseline (kg/day)**	**WLA (kg/day)**	**Reduction**
Total Nitrogen				
Little Mill Creek (C05)	27, 28, 29	4.14	0.62	85.0%
Christina River (C09)	5, 6, 7, 9a, 9c, 10, 11, 12, 13, 14, 15, 16, 17, 30	9.40	1.41	85.0%
Brandywine Cr. (B34)	3, 4a, 4b, 4c, 4d, 4e, 4f, 18, 19, 20, 21a, 21b, 21c, 22b, 22c, 23, 24, 25, 26, RR	17.10	2.56	85.0%
Total CSO load	-	30.64	4.60	85.0%
Total Phosphorus				
Little Mill Creek (C05)	27, 28, 29	0.64	0.10	85.0%

Location	CSO ID numbers	Baseline (kg/day)	WLA (kg/day)	Reduction
Christina River (C09)	5, 6, 7, 9a, 9c, 10, 11, 12, 13, 14, 15, 16, 17, 30	1.46	0.22	85.0%
Brandywine Cr. (B34)	3, 4a, 4b, 4c, 4d, 4e, 4f, 18, 19, 20, 21a, 21b, 21c, 22b, 22c, 23, 24, 25, 26, RR	2.54	0.38	85.0%
Total CSO load	-	4.64	0.70	85.0%