Amendment to the
Atlantic and Cape May Counties, Lower Delaware and Tri-County Water Quality Management Plans

Six Total Maximum Daily Loads for Total Coliform to Address Shellfish-Impaired Waters in Watershed Management Area 15 Atlantic Coastal Water Region

Proposed: February 21, 2006
Established: September 7, 2006
Approved: September 27, 2006
Adopted:

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United States Environmental Protection Agency, Region 2

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EXECUTIVE SUMMARY

In accordance with Section 305(b) and 303(d) of the Federal Clean Water Act (CWA), the State of New Jersey, Department of Environmental Protection (NJDEP) developed the *2004 Integrated List of Waterbodies* addressing the overall water quality of the State's waters and, in Sublist 5, identifying impaired waterbodies for which Total Maximum Daily Loads (TMDLs) may be necessary. The *2004 Integrated List of Waterbodies was adopted* by the Department on October 4, 2004, (36 NJR 4543(a)) as an amendment to the Statewide Water Quality Management Plan, as part of the Department's continuing planning process pursuant to the Water Quality Planning Act at N.J.S.A. 58:11A-7 and the Statewide Water Quality Management Planning rules at N.J.A.C. 7:15-6.4(a). The *2004 Integrated List of Waterbodies* Sublist 5 identified thirteen waterbodies that are impaired with respect to total coliform in Watershed Management Area (WMA) 15. In that list, a waterbody was determined to be impaired if it does not fully support shellfish harvest in accordance with National Shellfish Sanitation Program (NSSP) criteria. Portions of some waterbodies that were initially listed as impaired on the *2004 Integrated List of Waterbodies* Sublist 5 were subsequently determined through this study to be ineligible for development of a TMDL for one of several reasons. For some, there was insufficient or no data to develop a TMDL for some waterbodies. Where data was insufficient to develop a TMDL, the waterbodies will remain on Sublist 5 until additional data is obtained to develop a TMDL. Where there was no data, the waterbody was incorrectly listed as impaired and it will be placed on Sublist 3 in the 2006 Integrated List. In addition, based on a spatial analysis of monitoring station locations and best available data, some of these waterbodies were found to be closed according to administrative requirements and not because of water quality data. Closures of waters as the result of administrative precautions will be removed from Sublist 5 and placed on the appropriate Sublist in the 2006 Integrated List of Waterbodies, as the impairment is due to pollution and not pollutants. TMDLs were developed for the shellfish impaired waterbodies that were impaired because of water quality, as listed in Table 1. During the TMDL assessment process, the sampling sites encompassed within each impaired waterbody spatial extent were reevaluated and data from all sites within the spatial extent were considered for TMDL development. The more inclusive sampling site information for the waterbodies is included under "Site IDs Addressed" in Table 1. Some of the waterbodies were divided into smaller sub-groups that reflect more consistent local water quality conditions, watershed characteristics, and local pollution sources for the purpose of establishing more localized load reduction targets.

Table 1. Waterbodies in WMA 15 identified on the *2004 Integrated List of Waterbodies* as impaired for shellfishing

Waterbody	2004 303(d) Listing	Action
Absecon Bay[(1)]	Absecon Bay-1 thru 15	TMDL Assessment - Reduction
Absecon Creek Estuary	2401	TMDL Assessment - No Reduction
Cordery Creek Estuary	2308	TMDL Assessment -

		No Reduction
Great Egg Harbor	Great Egg Harbor-1, 4 thru 11, and 13 thru 14	TMDL Assessment - No Reduction
Great Egg Harbor River Middle Estuary(2)	2807A, 2807B, 2810, 2810A, 2812, 2805, 2806, 2808, 2808A	TMDL Assessment – Reduction Grouped with Great Egg Harbor River Estuary
Great Egg Harbor River Upper Estuary(3)	2812B, 2814,2814A, 2816,2816A, 2816B, 2818, 2818A, 2819, 2821,2821A, 2821B, 2821C, 2821D, 2822A, 2823A, 2824A, 2824B, 2825, 2826, 2826A, 2827, 2827A	TMDL Assessment – Reduction Grouped with Great Egg Harbor River Estuary
Great Egg River Tidal(4)	*Not on Sublist 5* (2800, 2800A, 2800B, 2801, 2801A, 2804, 2804A, 2803)	TMDL Assessment – Reduction Grouped with Great Egg Harbor River Estuary
Lakes Bay(5)	Lakes Bay-1 thru 10 and 12 thru 14	TMDL Assessment - Reduction
Middle River Estuary	2900A, 2900B, 2900C, 2900D, 2900E	TMDL Assessment - No Reduction
Patcong River Estuary	2801A, 2862, 2863A, 2863B, 2863C, 2863D, 2863E, 2863G, 2863H, 2863L, 2863M	TMDL Assessment - No Reduction
Reeds Bay(6)	Unnamed Creek-1; Somers Cove-2; Somers Marsh-3; Reeds Bay-5, 6, 8	TMDL Assessment - Reduction
Skulls Bay	Skulls Bay-2,3	Unable to assess for TMDL
Tuckahoe River Estuary	2901A, 2901B, 2902, 2902A	TMDL Assessment - No Reduction

Footnote: (#) WMA 15 TMDL count.

Nonpoint and stormwater point sources are the primary sources of total coliform loads in these waterbodies. Source loads were estimated for land uses in each watershed and for local marinas that may be causing water quality impacts in these waterbodies. Traditional point sources, i.e., treatment facilities that have a sanitary waste component, were considered de minimus, due to the use of effective disinfection practices by these facilities. TMDLs were developed based on an analysis of the existing pathogen indicator data compared to National Shellfish Sanitation Program (NSSP) and NJDEP pathogen indicator criteria, and the loading capacity has been allocated among the point and nonpoint sources. This TMDL report includes implementation strategies that will bring the subject waterbodies into compliance with the NSSP criteria for unrestricted shellfish harvest.

This report establishes six TMDLs as amendments to the appropriate area-wide water quality management plan in accordance with N.J.A.C. 7:15-3.4(g). This TMDL report was developed consistent with the United States Environmental Protection Agency's (USEPA's) May 20, 2002 guidance document entitled: "Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992," (Sutfin, 2002) which describes the statutory and regulatory requirements for approvable TMDLs. Upon approval by EPA, these TMDLs will be adopted as amendments to the Atlantic and Cape May Counties, Tri-County and Lower Delaware Water Quality Management Plans in accordance with N.J.A.C. 7:15-3.4 (g).

1.0 INTRODUCTION

In accordance with Section 303(d) of the Federal Clean Water Act (CWA) (33 U.S.C. 1315(B)), the State of New Jersey is required biennially to prepare and submit to the USEPA a report that identifies waters that do not meet or are not expected to meet water quality standards after implementation of technology-based effluent limitations or other required controls. This report is commonly referred to as the 303(d) List. In accordance with Section 305(b) of the CWA, the State of New Jersey is also required biennially to prepare and submit to the USEPA a report addressing the overall water quality of the State's waters. This report is commonly referred to as the 305(b) Report or the Water Quality Inventory Report. The *Integrated List of Waterbodies* combines these two assessments and assigns waterbodies to one of five sublists. Sublists 1 through 4 include waterbodies that are generally unimpaired (Sublist 1 and 2), have limited assessment or data availability (Sublist 3), are impaired due to pollution rather than pollutants or have had a TMDL or other enforceable management measure approved by EPA (Sublist 4). Sublist 5 constitutes the traditional 303(d) list for waters impaired or threatened by one or more pollutants, for which a TMDL may be required. In WMA 15, the *2004 Integrated List of Waterbodies* currently identifies thirteen waterbodies as impaired because they do not fully support shellfish use. In the course of developing TMDLs for the listed impairments, it was determined that portions of the waterbodies that were initially listed as impaired on the *2004 Integrated List of Waterbodies* Sublist 5 were subsequently determined to be ineligible for development of a TMDL for one of several reasons. For some, there was insufficient or no data to develop a TMDL for some waterbodies. Where data was insufficient to develop a TMDL, the waterbodies will remain on Sublist 5. Where there was no data, the waterbody will be placed on Sublist 3 in the 2006 Integrated List until additional data is obtained to develop a TMDL. In addition, based on a spatial analysis of monitoring station locations and best available data, some of the site identifications were found to be closed as the result of considering administrative requirements and not because of water quality data. Proximity to potential sources such as marinas, development served by septic systems and concentrated stormwater outfall locations warrants precautionary closures of shellfish waters on a seasonal or full time basis. Closures of waters for shellfishing as the result of administrative precautions will be removed from Sublist 5 and placed on Sublist 4 in the 2006 Integrated List of Waterbodies because the impairment is due to pollution and not pollutants. TMDLs were developed for the shellfish impaired waterbodies that were impaired because of water quality.

A TMDL represents the assimilative or carrying capacity of a waterbody, taking into consideration point and nonpoint sources of pollutants of concern, natural background and surface water withdrawals. A TMDL quantifies the amount of a pollutant a waterbody can assimilate and still conform to applicable water quality standards and support designated uses. The TMDL or loading capacity is allocated to known point and nonpoint sources in the form of waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and a margin of safety (MOS).

Recent EPA guidance (Sutfin, 2002) describes the statutory and regulatory requirements for approvable TMDLs, as well as additional information generally needed for EPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations. These TMDLs address the following required items in the May 20, 2002 guideline document:

1. Identification of waterbody(ies), pollutant of concern, pollutant sources and priority ranking.
2. Description of applicable water quality standards and numeric water quality target(s).
3. Loading capacity – linking water quality and pollutant sources.
4. Load allocations.
5. Wasteload allocations.
6. Margin of safety.
7. Seasonal variation.
8. Reasonable assurances.
9. Monitoring plan to track TMDL effectiveness.
10. Implementation (USEPA is not required to and does not approve TMDL implementation plans).
11. Public Participation.

This report establishes six TMDLs for total coliform to address the impaired shellfish waters in WMA 15. All of the impaired waterbodies were assigned a High priority ranking in the *2004 Integrated List of Waterbodies* Sublist 5. These TMDLs include management approaches to reduce pathogen contributions from various sources in order to attain applicable surface water quality standards and fully support the designated shellfish use. These TMDLs cover more area then is actually listed as being impaired due to the fact that the implementation plans, as described in detail later in this document, cover entire watersheds, not just the impaired waterbodies. These waterbodies will be moved to Sublist 4 following approval of the TMDLs by USEPA. In addition to the shellfish impairments, Middle River Estuary and Patcong River Estuary were also listed as impaired for low dissolved oxygen on the 2004 *Integrated List*. These waterbodies will remain on Sublist 5 for the remaining pollutants, which will be addressed in future TMDL efforts.

2.0 POLLUTANT OF CONCERN AND AREA OF INTEREST

The pollutant of concern for the proposed TMDLs is total coliform, which is measured as an indicator for the presence of pathogens. The National Shellfish Sanitation Program (NSSP) has established criteria for indicator organisms that are used to determine support of the shellfishing use. The NSSP sets forth other requirements for restricting shellfish harvest based on shoreline surveys. Where potential sources, such as wastewater or stormwater outfalls, septic systems or marinas, are present, precautionary restrictions are applied. These shellfish restrictions are referred to as administrative closures and are not appropriate for TMDL development. As discussed, where portions of listed impaired waterbodies were found to be administratively closed, they will be properly placed on Sublists 1, 3 or 4 on the 2006 Integrated List. TMDLs were developed for the waterbodies listed in Table 2 and shown in Figure 1. As an aid to analysis and to help focus implementation efforts, some waterbodies were divided into smaller sub-groups to reflect local water quality conditions, watershed characteristics, and local pollution sources. Sub-groups were delineated based on several criteria including the location of monitoring stations and data availability, the size and spatial extent of each waterbody, the location of possible pathogen sources, and other waterbody/watershed characteristics. A TMDL calculation was made for each waterbody sub-group or the entire waterbody if there were no sub-groups delineated. Waterbody sub-groups are listed in Table 2 and shown in Figure 1. The 2004 New Jersey 303(d) impairment listing for each waterbody (Sublist 5) is also provided in Table 2 for reference.

Table 2. Waterbodies listed for shellfish use impairment in WMA 15

Waterbody	2004 303(d) Listing Site IDs	TMDL Site ID	Sub-group	Percent reduction
Absecon Bay	Absecon Bay-1 thru 15	Absecon Bay-2, 5, 13, 14, 15, northern portions of 1 and 12	A	0%
		Absecon Bay-6, 9, southern portion of 12	B	86%
		Absecon Bay-3, 8, northern portion of 1	C	0%
Absecon Creek Estuary	2401	2401	-	0%
Cordery Creek Estuary	2308	2308	-	0%
Great Egg Harbor	Great Egg Harbor-1, 4 thru 11, and 13 thru 14	Great Egg Harbor-1	A	0%
		Great Egg Harbor-6, 9	B	0%
		Great Egg Harbor-11	C	0%
		Great Egg Harbor-13	D	0%
		Great Egg Harbor-7, 10, 14	F	0%
Great Egg Harbor River Estuary	**Great Egg Harbor River Middle Estuary** 2807A, 2807B, 2810, 2810A, 2812, 2805, 2806, 2808, 2808A **Great Egg Harbor River Upper Estuary** 2812B, 2814,2814A, 2816,2816A, 2816B, 2818, 2818A, 2819, 2821,2821A, 2821B, 2821C, 2821D, 2822A, 2823A, 2824A, 2824B, 2825, 2826, 2826A, 2827, 2827A **Great Egg River Tidal** 2800, 2800A, 2800B, 2801, 2801A, 2803, 2804, 2804A	**Great Egg Harbor River Middle Estuary** 2807A, 2807B, 2810, 2810A, 2812, 2805, 2806, 2808, 2808A **Great Egg Harbor River Upper Estuary** 2812B, 2814,2814A, 2816,2816A, 2816B, 2818, 2818A, 2819, 2821,2821A, 2821B, 2821C, 2821D, 2822A, 2823A, 2824A, 2824B, 2825, 2826, 2826A, 2827, 2827A **Great Egg River Tidal** 2800, 2800A, 2800B, 2801, 2801A, 2803, 2804, 2804A	-	46%
Lakes Bay	Lakes Bay-1 thru 10 and 12 thru 14	Lakes Bay-2, 7, 10	A	94%
		Lakes Bay-3, 8, 9	B	
		Lakes Bay-4, 5, 6, 14	C	
Middle River	2900A, 2900B, 2900C, 2900D,	2900A, 2900B, 2900C, 2900D,	-	0%

Waterbody	2004 303(d) Listing Site IDs	TMDL Site ID	Sub-group	Percent reduction
Estuary	2900E	2900E		
Patcong River Estuary	2801A, 2862, 2863A, 2863B, 2863C, 2863D, 2863E, 2863G, 2863H, 2863L, 2863M	2863, 2863A, 2863B, 2863C, 2863D, 2863E, 2863G, 2863H, 2863L, 2863M, R35	-	0%
Reeds Bay	Unnamed Creek-1; Somers Cove-2; Somers Marsh-3; Reeds Bay-5, 6, 8	Reeds Bay-1, 2	A	0%
		Reeds Bay-3	B	52%
		Reeds Bay-6	C	0%
		Reeds Bay-8	D	0%
Tuckahoe River Estuary	2901A, 2901B, 2902, 2902A	2901A, 2901B, 2902, 2902A	-	0%

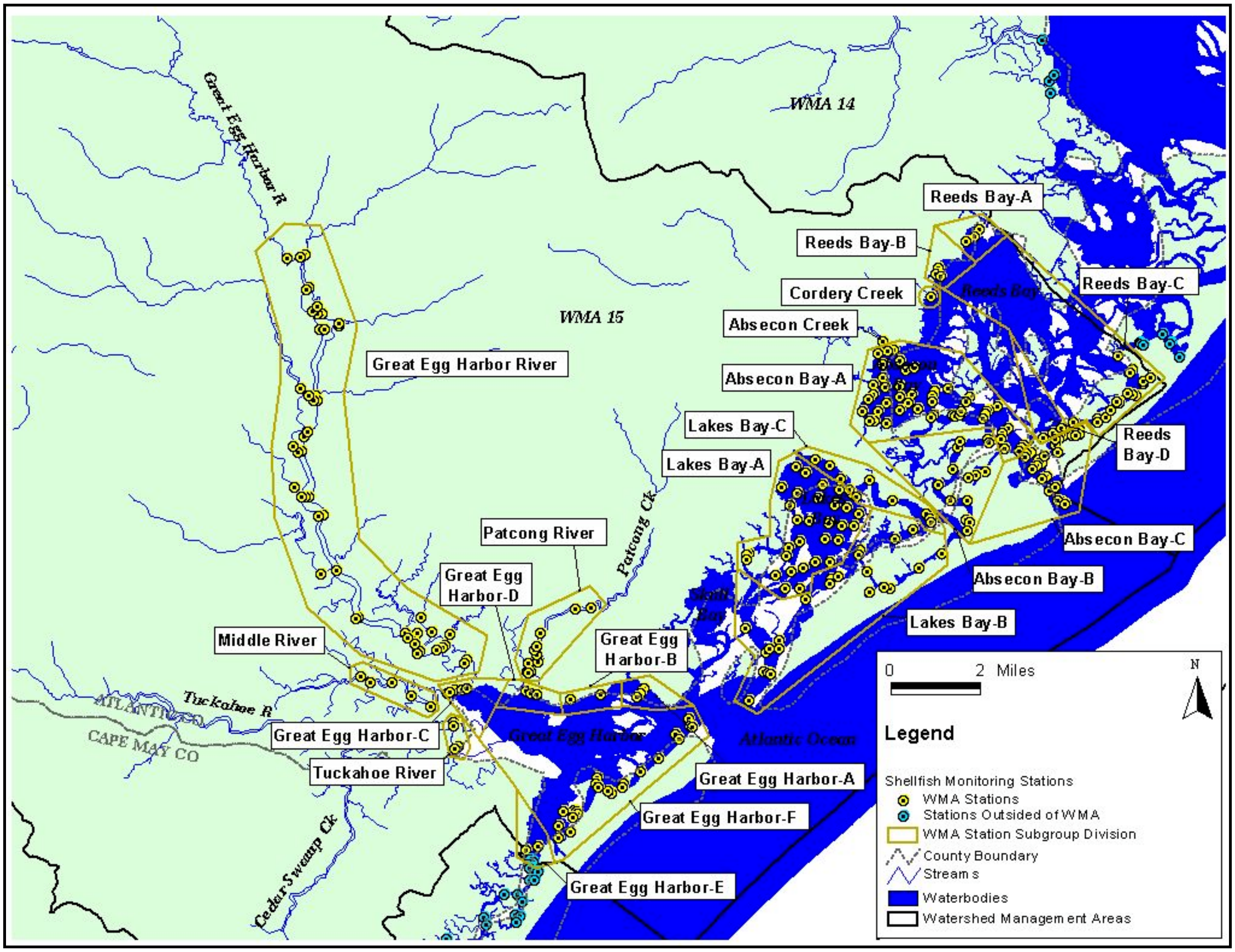


Figure 1. Shellfish impaired waterbodies in WMA 15

2.1 Applicable Water Quality Standards

New Jersey Surface Water Quality Standards (SWQS) include pathogen indicator criteria for the assessment of the recreational use (primary and secondary contact recreation) for all waterbodies (Table 3). New Jersey SWQS also specify that shellfish waters shall meet the guidelines of the National Shellfish Sanitation Program (NSSP). The NSSP guidelines include stringent criteria, expressed in terms of indicator organisms, to protect against the harvest of shellfish in waters where the sanitary quality could have health risks for consumers. Total coliform data are used to assess the shellfish designated use for the waterbodies in all waters according to the New Jersey 2004 Integrated Water Quality Monitoring and Assessment Report. With the exception of ocean waters, data were collected by NJDEP using Systematic Random Sampling (SRS) protocol. Ocean waters were collected using the Adverse Pollution Condition (APC) protocol. The analytical methods used were 3-tube dilution analysis for total coliform and 5-tube analysis for fecal coliform. These TMDLs were developed to meet the NSSP 90th percentile (330 cfu/100ml) and geometric mean (70 cfu/100ml) criteria for total coliform (in colony forming units, or cfu) because this is the basis for determining impairment in the subject waters.

Table 3. Water quality criteria expressed as cfu/100 ml

Bacterial Indicator	NJ Surface Water Quality Standards (SWQS)		National Shellfish Sanitation Program (NSSP)
	Within 1500 ft. of shoreline	1500 ft. to 3 mi. from shoreline	
Total Coliform	N/A	N/A	• Geometric Mean (Geomean) shall not exceed 70 • No more than 10% of samples shall exceed 330 for APC monitoring • Estimated 90th percentile shall not exceed 330 for SRS monitoring
Fecal Coliform	• Geomean shall not exceed 50	• Geomean shall not exceed 200 • No more than 10% in any 30-day period to exceed 400	• Median or geomean shall not exceed 14 • No more than 10% shall exceed 49 for APC monitoring • Estimated 90th percentile shall not exceed 49 for SRS monitoring
Enterococcus	• Geomean shall not exceed 35 • Single sample shall not exceed 104	N/A	N/A

Source: NJDEP SWQS, 2005 and USFDA NSSP Guide for the Control of Molluscan Fish, 2003.

Notes:

- Samples shall be obtained at sufficient frequencies and at locations during periods which will permit valid interpretation of laboratory analyses. A minimum of five samples as equally spaced over a 30-day period, as feasible, should be collected; however, the number of samples, frequencies and locations will be determined by NJDEP or other appropriate agency in any particular case.
- NSSP standards shown are based on a 3-tube decimal dilution test. Additional standards for 5- and 12-tube decimal dilution tests apply.
- For NSSP sampling, sample collection requirements vary based on attributes of the waters where samples are collected (e.g., whether the area is affected by point sources, etc.).
- Standards shown are those that apply to waters approved for shellfish growing. Additional requirements and exceptions may apply and can be found in NJDEP's SWQS and NSSP's guidelines documents.
- APC = Adverse Pollution Conditions. APC sampling occurs in areas with known point sources, including around some marinas.
- SRS = Systematic Random Sampling. SRS sampling methods are used in the majority of shellfish waters and is based on a random statistical sampling approach.

Each year, the Department updates the classification of New Jersey's coastal waters for shellfish harvesting based on analysis of extensive sampling (over 15,000 samples per year) and pollution source surveys. The classifications indicate sanitary coastal water quality. New Jersey has had a long history of improving the sanitary quality of its coastal waters.

In accordance with the NSSP, the Department must also perform a sanitary survey/Local Area Report (LAR) that collects and evaluates information concerning actual and potential pollution sources that may adversely affect the water quality in each growing area. Based on the sanitary survey information, the Department assigns the growing area to one of five classifications. These classifications are summarized below.

Classification	Description
Approved	No restrictions on licensed harvesters
Seasonal (November - April)	Water open for harvest seasonally from Nov - April
Seasonal (January - April)	Water open for harvest seasonally from January - April
Restricted	Harvest only by Special Permit. Shellfish harvested must be further purified by relay to Approved waters or processing in a depuration plant prior to being sold.
Prohibited	No harvest under any conditions.

The impaired waterbodies addressed in this document are classified as Saline Estuary 1 (SE1) except for the upper reaches of the tidal streams, which are classified as Fresh Water 2 (FW2).

In all SE1 waters the designated uses are:

1. Shellfish harvesting in accordance with N.J.A.C. 7:12;
2. Maintenance, migration and propagation of the natural and established biota;
3. Primary and secondary contact recreation; and
4. Any other reasonable uses.

In all FW2 waters, the designated uses are (see NJAC 7:9B-1.12):

1. Maintenance, migration and propagation of the natural and established aquatic biota;
2. Primary and secondary contact recreation;
3. Industrial and agricultural water supply;
4. Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation and sedimentation, resulting in substantial particulate removal but no consistent removal of chemical constituents) and disinfection; and
5. Any other reasonable uses.

2.2 Description of Land Use in the Watershed Management Area

The watershed management area includes watersheds draining to Great Egg Harbor Bay in Atlantic County. The watershed's dominant land use is forest, with the remainder being primarily agricultural and developed. The Great Egg Harbor River is the primary stream system in the watershed management area. Table 4 shows the land use distribution among the waterbody subgroup watersheds. Land use data for each watershed were derived from the 1995/1997 land use/land cover dataset developed for New Jersey.

Table 4. Land use area distribution in WMA 15 subgroup watersheds

Waterbody	Subgroup	Agriculture		Barren Land		Forest		Urban		Water		Wetlands		Total Area
		km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2
Absecon Bay	A	0.14	0.2%	1.51	1.7%	29.54	32.9%	31.05	34.6%	10.86	12.1%	16.55	18.5%	89.65
Absecon Bay	B	0.00	0.0%	0.08	0.6%	0.79	6.2%	3.86	30.3%	2.12	16.6%	5.91	46.3%	12.75
Absecon Bay	C	0.14	0.2%	1.67	1.7%	29.68	31.1%	34.02	35.6%	12.87	13.5%	17.05	17.9%	95.44
Absecon Creek Estuary	-	0.14	0.2%	1.49	2.2%	29.24	42.7%	29.60	43.2%	1.53	2.2%	6.45	9.4%	68.46
Cordery Creek Estuary	-	0.00	0.0%	0.05	1.2%	1.56	41.6%	1.55	41.3%	0.02	0.5%	0.58	15.4%	3.76
Great Egg Harbor	A	0.00	0.0%	0.01	0.1%	0.22	3.7%	3.03	50.2%	0.61	10.0%	2.17	36.0%	6.03
Great Egg Harbor	B	0.00	0.0%	0.01	0.1%	0.22	3.7%	3.03	50.2%	0.61	10.0%	2.17	36.0%	6.03
Great Egg Harbor	C	70.45	7.8%	10.05	1.1%	417.49	46.5%	118.75	13.2%	22.12	2.5%	259.31	28.9%	898.16
Great Egg Harbor	D	2.50	3.2%	2.24	2.9%	28.77	37.2%	26.36	34.1%	2.02	2.6%	15.36	19.9%	77.26
Great Egg Harbor	F	0.00	0.0%	0.08	1.2%	0.03	0.4%	4.95	76.1%	0.49	7.5%	0.95	14.6%	6.50
Great Egg Harbor River	-	69.96	8.1%	10.04	1.2%	414.56	47.8%	118.47	13.7%	18.72	2.2%	235.17	27.1%	866.91
Lakes Bay	A, B, C	0.00	0.0%	0.25	0.5%	1.60	3.2%	17.60	34.8%	15.88	31.4%	15.24	30.1%	50.57
Middle River Estuary	-	0.49	1.7%	0.00	0.0%	2.93	10.1%	0.28	1.0%	2.62	9.0%	22.59	78.1%	28.91
Patcong River Estuary	-	2.50	3.3%	2.24	3.0%	28.60	38.0%	26.24	34.9%	1.55	2.1%	14.14	18.8%	75.28
Reeds Bay	A	0.19	1.8%	0.24	2.4%	5.34	51.6%	1.92	18.5%	0.45	4.3%	2.22	21.4%	10.36
Reeds Bay	B	0.06	1.2%	0.01	0.2%	1.45	30.2%	2.02	42.1%	0.03	0.5%	1.24	25.8%	4.79
Reeds Bay	C	0.00	0.0%	0.00	0.0%	0.02	0.3%	2.00	25.5%	2.36	30.0%	3.48	44.2%	7.86
Reeds Bay	D	0.00	0.0%	0.00	0.0%	0.05	15.3%	0.07	24.3%	0.04	13.7%	0.14	46.7%	0.30
Tuckahoe River Estuary	-	11.92	4.5%	3.44	1.3%	124.60	47.0%	17.55	6.6%	8.20	3.1%	99.40	37.5%	265.10

Notes: - The land area values for Great Egg Harbor include contributions from Great Egg Harbor River and Middle River Estuary.

3.0 SOURCE ASSESSMENT

A source assessment was conducted to identify and characterize potential pathogen sources that may be impacting water quality and shellfish growing areas in the listed waters. Point and nonpoint sources of total coliform were considered in TMDL development. Source assessment also included the determination of the relative contribution of the primary bacteria sources to facilitate proper management responses through TMDL implementation. A variety of information was used to characterize possible pathogen sources including shoreline surveys conducted by the Department, land use information gathered for each watershed, point source information, literature sources, and other available data.

3.1 Shoreline Surveys

WMA 15 includes two shoreline survey areas: Little Bay to Beach Thorofare (SE-2) and Peck Bay to Beach Thorofare (SE-3). SE-2 is also located within the boundary for WMA 14. Local Area Reports (LARs) were completed for each shoreline survey area by the Department to characterize shellfish growing areas, surrounding land uses, and potential pollution sources in the watershed. These reports satisfy the requirements of the NSSP program by providing information on local shellfish growing areas. This information is also used by the Department in the assessment process and for determining impairment status. The data contained in these reports was used to help identify and characterize the pathogen sources that may be impacting the shellfish harvest areas located within each TMDL waterbody sub-group. Note that recent data collected by NJDEP regarding shellfish classifications (2004 GIS coverage) and pollution sources may not be reflected in these reports. Updated information on the point and nonpoint sources identified and the respective loading estimates are provided in the following source assessment sections.

The 2004 shellfish classification GIS coverage was provided by NJDEP and used to cross-reference with TMDL waterbody sub-groups. A summary of the information presented in the most recent LAR for each shoreline survey area is presented below.

- SE-2: Little Bay to Beach Thorofare
  A reappraisal report for SE-2 was published in March 2004 and represents the data collection period: 1998-1992. The primary water bodies of SE-2 include Absecon Bay and Channel, Reeds Bay, Grassy Bay, Little Bay, and Beach Thorofare. Enclosed in these water bodies are numerous thorofares, channels, and inlets. Some of the larger thorofares and channels are the Absecon Channel, Beach Thorofare, Bonita Tideway, and Brigantine Channel. There are several coves in the SE-2 area, which include the Hammock Cove, Perch Cove, Somers Cove, and Turtle Cove. SE-2 is surrounded by Absecon City, Atlantic City, Brigantine City, Galloway Township, and Pleasantville City. Within these five municipalities, Atlantic City has the largest residential population as well as the greatest density of people. The Absecon and Brigantine Inlets act as an entrance for salt water flow and tidal influence to the SE-2 area from the Atlantic Ocean. The only major source of fresh water to this area comes from the Atlantic City Reservoir, which is approximately 4 kilometers northwest of the Absecon Bay. Water from the reservoir flows directly to the Absecon Creek, which then discharges to the Absecon Bay. The Absecon Creek is estimated to be 3.12 miles in distance from the tip of the reservoir to the mouth of the Absecon Bay. The majority of the waters within SE-2 area are classified as Approved year-round. This includes waters in Reeds Bay and Little Bay. The Absecon Bay, Absecon Channel, St. George Thorofare, and Bonita Tideway are classified as Approved year-round, Seasonally Approved, Special Restricted, and Prohibited. Waters toward Atlantic City, including Beach Thorofare and Clam Creek, are classified as Special Restricted or Prohibited. Portions of SE-2 are impacted by nonpoint sources, such as storm drains,

boating activities, illegal dumping, and malfunctioning septic systems. Land uses within the SE-2 area are primarily wetland, forest, and urban development. There are no direct discharges to the SE-2 area. The greatest causes for concern are the storm water outfalls that are situated in close proximity to the shellfish growing waters, particularly in Absecon City and Brigantine City. There are 21 marinas in the SE-2 area.

- SE-3: Peck Bay to Beach Thorofare
  A reappraisal report for SE-3 was published in August 1999 and represents the data collection period: 1995-1999. There are six municipalities that border the waters in this area. Pleasantville, marginally contacts a very small area located by Lakes Bay. Ocean City, Ventnor, Margate and Longport have a large impact on the area from storm drains and nonpoint source runoff. Some of the major factors affecting water quality are tidal exchange through the Great Egg Harbor Inlet and nonpoint source pollution from the densely developed barrier islands. The population of these islands increases significantly during the summer. This is a reason for seasonal classifications in the area. The shellfish waters in this area are currently classified as Approved, Seasonally Approved, Special Restricted, or Prohibited (2004). This drainage area includes a large amount of wetlands as well as urban development. All of Ocean City is sewered and the majority of the other municipalities that surround this area (Somers Point, Ventnor, Margate, and Egg Harbor Township) are also sewered. There are 20 marinas in the Great Egg Harbor Estuary, with the largest concentration of marinas located in Ocean City.

3.2 Assessment of Point Sources

For TMDL development purposes, point sources include domestic and industrial wastewater treatment plants that discharge to surface waters, as well as surface water discharges of stormwater subject to regulation under the National Pollutant Discharge Elimination System (NPDES). This includes facilities with individual or general industrial stormwater permits, Tier A municipalities, and federal, interstate agency, state, and county facilities regulated under the New Jersey Pollutant Discharge Elimination System (NJPDES) municipal stormwater permitting program. Tier A municipalities are generally located within the more densely populated regions of the state or along the coast. These municipalities meet the population size requirements of EPA's Municipal Separate Storm Sewer System (MS4) program for regulating urban stormwater discharges. Stormwater point sources, like nonpoint sources, derive their pollutant loads from runoff from land surfaces and load reduction is accomplished through the use of best management practices (BMPs). The distinction is that stormwater point sources are regulated under the Clean Water Act (under the MS4 program). Stormwater point sources are or will be addressed through the management practices required through the discharge permits.

Wastewater treatment facilities and Tier A municipalities that directly discharge to the shellfish waters in WMA 15 or tributaries that eventually flow into these waters are identified in Appendices B and C. Per Department NJPDES Regulation, N.J.A.C. 7:14A-12.5(a), "All wastewater that could contain pathogenic organisms such as fecal coliform and/or enterococci organisms shall be subject to continuous year round disinfection prior to discharge into surface waters." Therefore, loads from wastewater treatment facilities were considered de minimus, consistent with previous pathogen TMDLs developed by the Department. The NJPDES permit limits for these point sources will not be changed as a result of these TMDLs and will remain a 200 cfu/100 ml monthly geometric mean and a 400 cfu/100 ml weekly geometric mean. Stormwater loads from Tier A MS4 systems are point sources that can be significant. These loads were estimated using the watershed loading methods described in the nonpoint source section, as they will be addressed through BMPs.

3.3 Assessment of Nonpoint Sources

Nonpoint sources that may affect shellfish waters include stormwater discharges that are not subject to regulation under the Clean Water Act, including Tier B municipalities, direct stormwater runoff from land surfaces, as well as malfunctioning sewage conveyance systems, failing or inappropriately located septic systems, and direct contributions from wildlife, livestock and pets. Tier B municipalities are generally located in more rural, non-coastal regions of the state. Tier B municipalities located in the affected drainage areas are identified in Appendix C.

Alternative methods were considered to determine the best approach for estimating land-based loads contributed by each watershed, including the Watershed Treatment Model (WTM) a study of nonpoint source loadings generated in a study of the Toms River watershed, and simpler bacteria load estimation equations. The WTM model was selected because it encompasses local rainfall data and stream length information to better tailor load estimates. In addition, it has been successfully applied in previous coastal TMDL studies (Oyster Bay-New York, U.S. Virgin Islands TMDLs). The goal of applying WTM is to characterize all the point and nonpoint sources, as available data allows, in the existing system and to determine their relative contributions to the waterbody of interest. The loading values thus derived, along with the loads contributed by marinas as discussed below, serve as the reference point from which reductions are made to meet TMDL targets.

The WTM model is a series of spreadsheets that quantifies the loading of pathogen indicators based on land use distribution, stream network length in the watershed, and annual rainfall. The model is designed as a planning level tool for watersheds that do not have sufficient data for complex modeling applications. Although the WTM model has several tiers of data specificity, loading estimates can be calculated with simple land use data, as they were for these shellfish TMDLs. Land use loads are calculated on an annual basis by using a series of coefficients for runoff volume and pathogen loading derived from scientific literature. General land use categories are assigned either a coefficient that is then multiplied by an annual runoff volume to calculate an annual load (e.g., urban land uses), or an annual unit area load that is applied as a function of land use (e.g., rural land uses). These coefficients, presented in Table 5, were chosen based upon the best available research and are summarized in WTM's user manual (Caraco, 2001).

Table 5. Default WTM land use categories and loading variables

WTM Land Use	Corresponding New Jersey Land Uses	Average % Impervious Cover	Fecal Coliform Conc. (MPN/100 ml) or Annual Load (billion/acre)
Low Density Residential	Low Density Residential, Rural Residential, Recreational Land, Athletic Fields	19	20,000
Medium Density Residential	Medium Density Residential, Mixed Residential, Mixed Urban or Built-Up, Other Urban or Built-Up, Military Reservations, No Longer Military	35	20,000
High Density Residential	High Density Residential	56	20,000
Commercial	Commercial Services	71	20,000
Roadway	Transportation/Communication/Utilities	39	20,000
Industrial	Industrial, Industrial/Commercial	78	20,000
Forest	Forest	0	Load: 12 billion/acre
Rural	Agriculture	0	Load: 39 billion/acre
Barren (replaced "Vacant Lots" category in WTM)	Barren	2	Load: 12 billion/acre (estimated)

The default fecal coliform loading rates in the WTM model were converted to total coliform values based on a regression equation developed to examine the relationship between fecal coliform and total coliform concentrations using New Jersey shellfish monitoring data collected from 1991 through 2004. Fecal coliform is a component of total coliform, therefore, the loading values were increased based on this equation.

The potential to accurately convert observed fecal coliform values to equivalent total coliform values is supported by a November 1996 study by Espy, Huston, and Associates, Inc. This study investigated public health issues related to recreational and commercial fisheries use of Corpus Christi Bay, Texas produced for the Corpus Christi Bay National Estuary Program (Jensen et al., 1996). A significant correlation (R^2=85.7%) was found between total and fecal coliform concentrations reported for water samples collected in shared sampling quadrants when plotted on a logarithmic scale. The regression equation derived from the Texas data, converted into an exponential expression ($TC=1.69*FC^{1.013}$) is very similar to the equation derived from water quality data analyzed as part of these TMDLs ($TC=1.22*FC^{1.061}$).

The watershed for each TMDL waterbody sub-group was delineated using the Hydrologic Unit Coverage (HUC-14 digit) developed by NJDEP, digital elevation model (DEM) data, and the National Hydrography Dataset (NHD) stream coverage for New Jersey. Land use data for each watershed was obtained from the 1995/1997 land use coverage developed for New Jersey's WMAs. Land use categories were consolidated into broader groups for use in estimating land-based loads using the WTM model and for presenting the loading results. The percent impervious information for each land use category was derived from the percent impervious information in the Department's GIS land use coverage, averaged across similar land uses. The bacterial loads for urban areas in each watershed were calculated based on the default fecal coliform concentration literature value for urban land uses, the average percent impervious cover, and the annual runoff volume calculated by the WTM model.

Agricultural, forest, and barren land use loads were calculated based on the specific loading rate for each category. Wetland areas and waterways were not included in loading calculations based on WTM model assumptions.

In addition to land-based sources, pathogens can also be associated with direct discharges from boats at marinas. This potential source can be a primary cause of high bacteria concentrations in and around marinas. The bacteria load from inappropriate and illicit wastewater discharges in marinas and mooring locations was estimated based on the the Department's marina GIS coverage. This dataset includes information on the number of boat slips and boat sizes typical of each marina. The marina formula presented in the Department's shoreline surveys (LARs) was used to calculate the bacteria load for each marina. Marina loads were calculated for the summer months (May – September). In addition, marina loads were multiplied by a factor of 0.25 to recognize a lower contribution during other months (October through April) based on best professional judgment. The marina formula was updated to calculate total coliform loads based on the total coliform-fecal coliform regression equation developed for this TMDL study, as described in the WTM model discussion above. Marinas associated with each waterbody (or sub-group) and the calculated total coliform/fecal coliform loads are presented in Appendix D.

The equation used to estimate fecal coliform loads from marina buffers is:

$$FC/day = 2x10^9(FC/person/day)x2(person/boat)x[(.25slips \geq 24') + (0.065 \times slips < 24')]$$

Explanation of terms in equation:

Fecal coliform per person per day: 2×10^9
Number of people per boat: 2
For slips able to accommodate boats > 24 feet (combination of factors yields multiplier of 0.25):
Number of slips occupied: 50%
Number of boats occupied: 50%
For boats < 24': 6.5% discharge waste

Direct contributions from illicit discharges, livestock, pets, and wildlife (e.g. seagulls, geese, and other waterfowl in particular) were not estimated based on the lack of site-specific information needed to represent these sources. Note that waterfowl direct deposition in some shellfish areas was mentioned as a likely source according to several published shoreline survey reports for New Jersey. Population estimates, bacteria production rates, and other information would be needed to estimate these sources. For these TMDLs, the loads contributed by wildlife, sediment, and the other sources were assumed to be included in the land use loading coefficients.

Pathogen indicator source data used in TMDL development are shown in Figures 2 through 5. Land uses, NJPDES-permitted wastewater treatment facilities, marinas, stormwater outfalls, and water quality stations are shown in these maps.

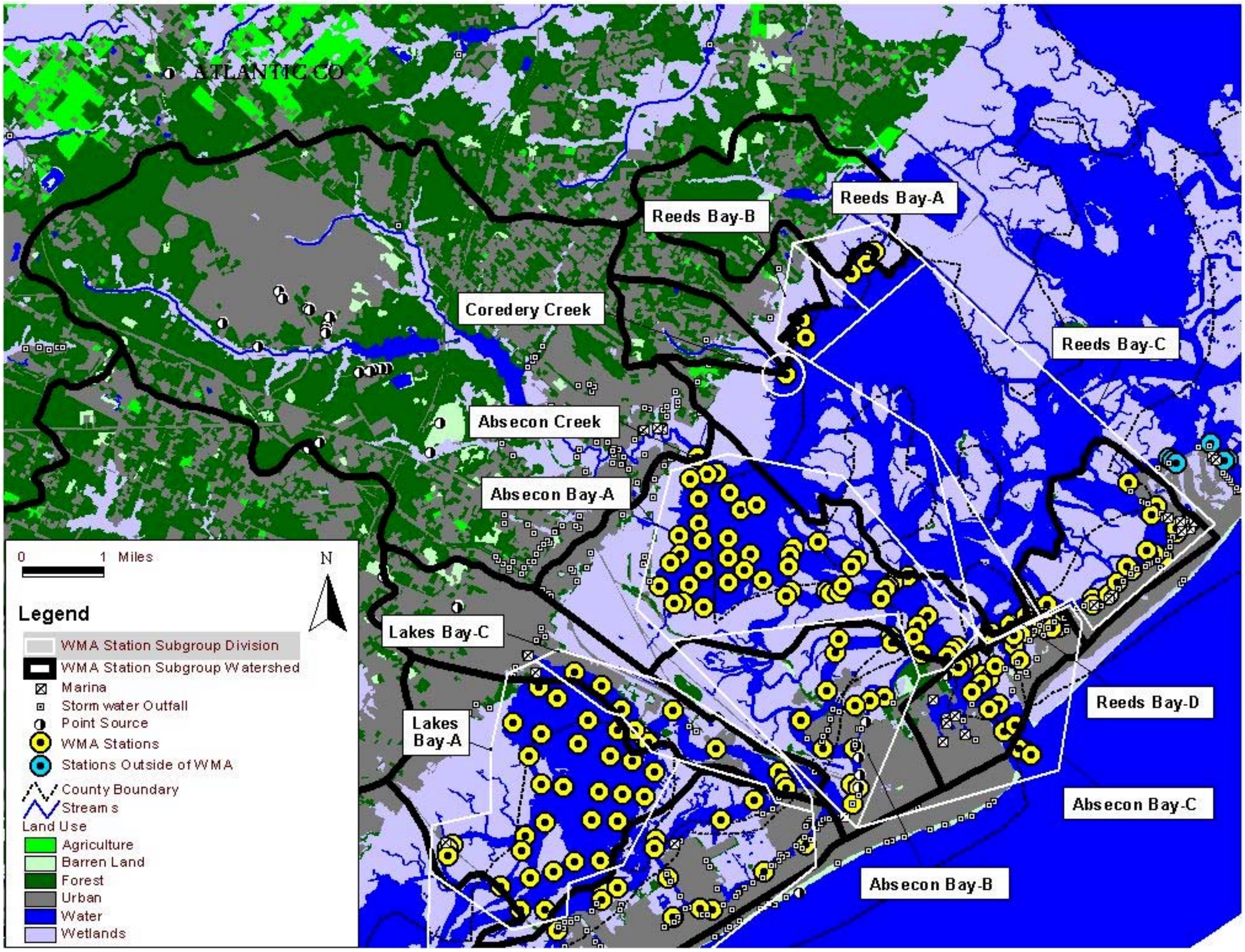


Figure 2. Primary pathogen indicator source data used in TMDL development for northern portions of WMA 15 (northern map 1)

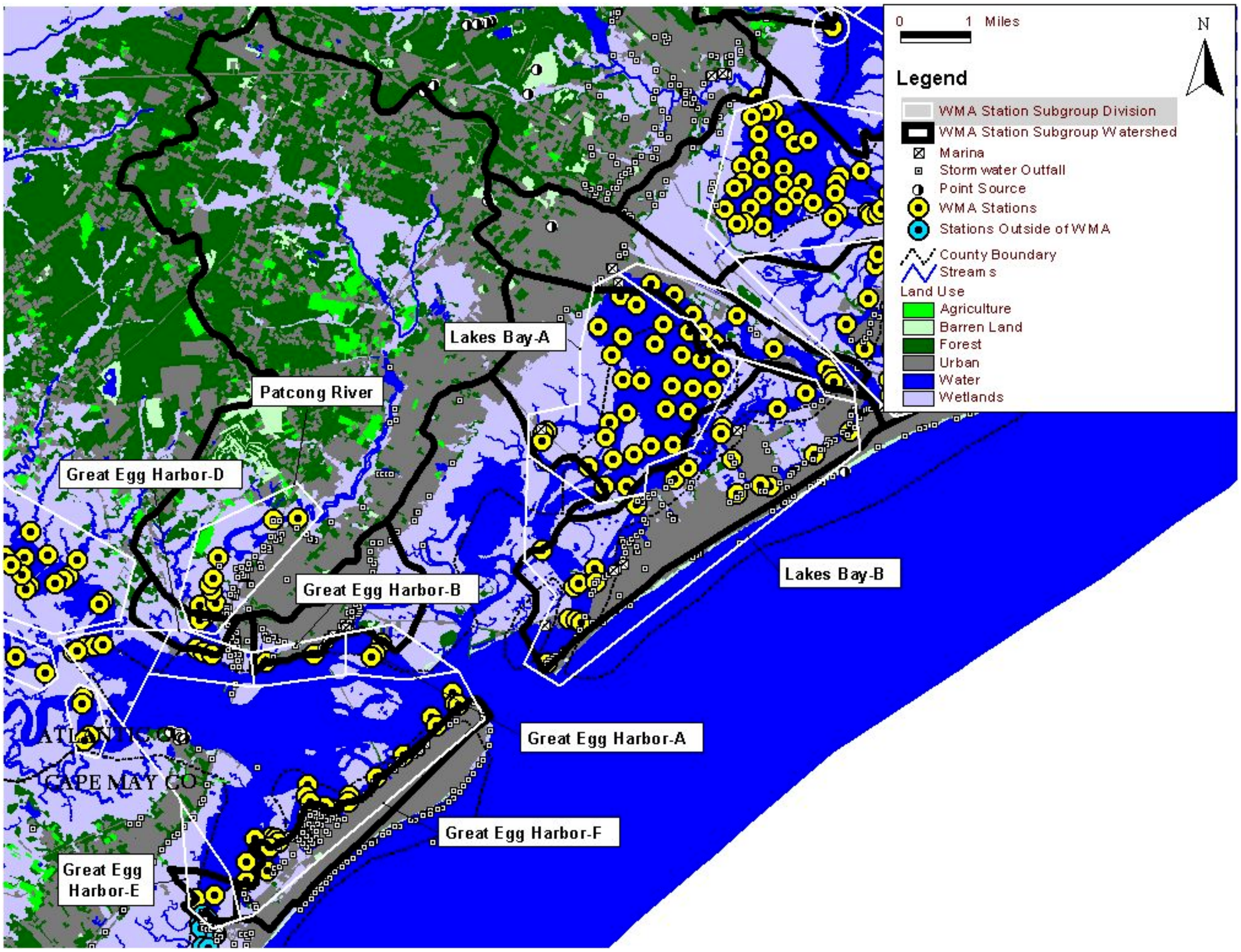


Figure 3. Primary pathogen indicator source data used in TMDL development for northern portions of WMA 15 (northern map 2)

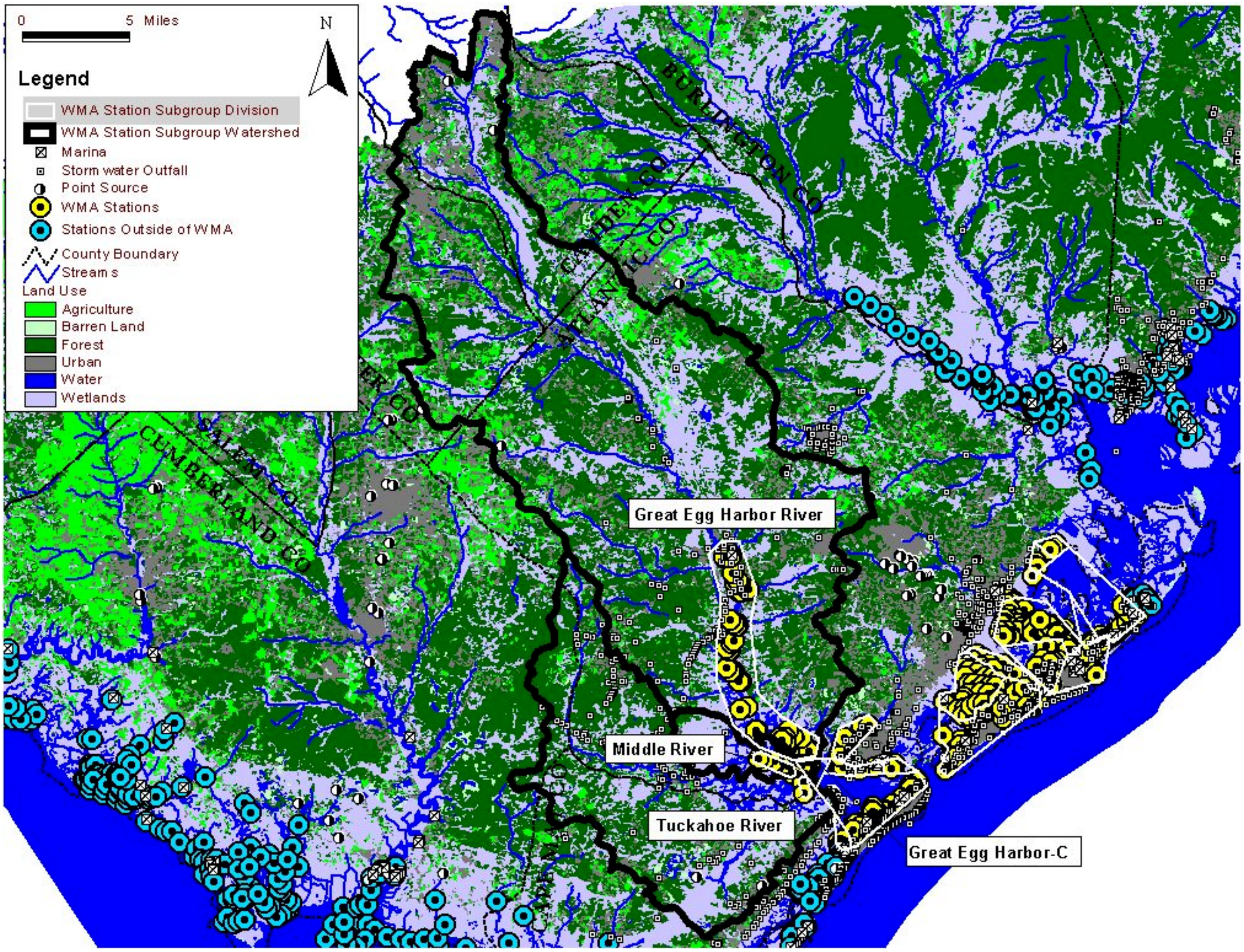


Figure 4. Primary pathogen indicator source data used in TMDL development for southern portions of WMA 15

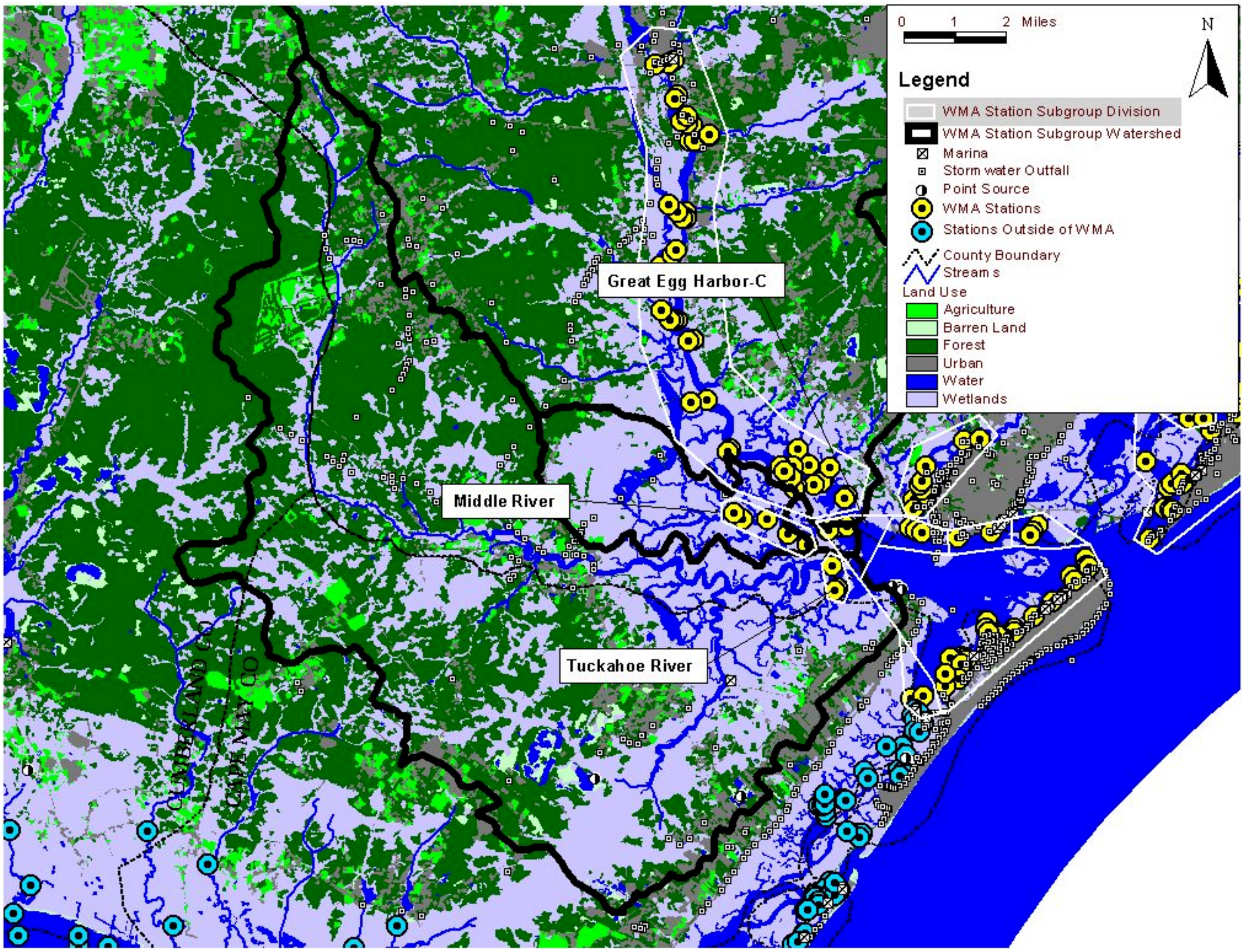


Figure 5. Primary pathogen indicator source data used in TMDL development for southern portions of WMA 15 (close-up)

4.0 WATER QUALITY ANALYSIS

Relating pathogen sources to concentrations of bacterial indicators in the impaired waters is distinguished from quantifying that relationship for other pollutants given the inherent variability in population size and dependence not only on physical factors such as temperature and soil characteristics, but also on less predictable factors such as re-growth media. Since bacteria loads and concentrations can vary many orders of magnitude over short distances and over time at a single location, dynamic water quality models can be very difficult to calibrate. Options available to control nonpoint sources of bacteria typically include measures such as sewage infrastructure improvements, goose management strategies, pet waste ordinances, agricultural conservation management plans, and septic system replacement and maintenance. The effectiveness of these control measures is not easily measured relative to observed ambient concentrations. Given these considerations, detailed water quality modeling was not selected for determining the load reductions needed to attain standards and support the designated shellfish use.

Shellfish monitoring data collected by the Department, in accordance with NSSP guidelines, were used as the basis for TMDL development for the listed shellfish waters. Total coliform data were used to assess the shellfish designated use for the listed waterbodies in WMA 17 according to the New Jersey 2004 *Integrated Water Quality Monitoring and Assessment Report*; therefore, total coliform data were used in TMDL development. As described in Section 3.0, each waterbody was divided into smaller sub-groups (as necessary) in order to better represent local water quality conditions, watershed characteristics, and local pollution sources and, thereby inform implementation efforts. The data collected for each waterbody sub-group (or the entire waterbody if not sub-divided) were compared to the NSSP criteria for total coliform. In order to account for the spatial distribution in pathogen sources, critical conditions, and other TMDL considerations, the "worst case" station within each waterbody (or sub-group) was identified and used in TMDL development. Monitoring data collected at stations located within marina buffer areas were not included in the analysis because these areas will remain restricted for shellfish harvest as a precautionary measure. Seasonal trends and other factors were evaluated to determine the critical condition period for TMDL development, as described in the next section. Critical condition analyses indicated that bacteria concentrations were typically higher during summer months, therefore, summer data (collected during May-September) were exclusively used in the analysis.

"Worst case" stations were identified based on the calculated 90th percentile (arithmetic), median, data period (emphasis on recent data), and sample size (priority given to stations with sample sizes >20). The "worst case" station identified for each waterbody (or sub-group) is shown in Table 6, along with summary data statistics. The data collected at each "worst case" station were then used to develop TMDLs for each respective waterbody (or sub-group). The percent reduction required was based on the difference between the calculated 90th percentile (using the FDA method specified in NSSP guidelines) and the NSSP 90th percentile criteria or the calculated geometric mean and the NSSP geometric mean criteria whichever was greater. Source loads were then reduced for each waterbody (or sub-group) to meet the overall percent reduction required.

As a result of this analysis, several waterbodies (or sub-groups) were found to meet the NSSP criteria. The listing of these waterbodies reflects application of the shoreline survey information in making water classifications. Critical to the shoreline survey is the identification of potential pollution sources that may intermittently impact water quality and not be detected by water samples collected 5-12 times a year. According to the NSSP *Guide for the Control of Molluscan Shellfish*, if in the judgment of the state authority, pollution sources present an actual or potential public health hazard, those waters cannot be classified as "Approved". Shellfish harvest restrictions that are imposed because of the shoreline surveys will remain restricted, regardless of water quality. Therefore, development of a TMDL for these areas is not generally appropriate. These areas will be reassigned on the 2006 Integrated List. In areas subject to administrative closure where water quality conforms to criteria, the areas will be placed on Sublist 1; where there is insufficient data to determine conformance with the criteria, the areas will be placed on Sublist 3; where the water quality does not conform to the criteria, but the areas would not be open even if water quality improved, the areas will be placed on Sublist 4, as the impairment is due to pollution, not pollutants.

Table 6. Worst case stations in WMA 15

Waterbody	Subgroup	Worst Case Station	Parameter	Count*	Start Date	End Date	90th Percentile* (arithmetic)	Geometric Mean*	Median*
Absecon Bay	A	2418	Total Coliform	62	6/18/84	9/9/03	460	31	23
Absecon Bay	B	2500	Total Coliform	83	6/18/84	6/18/04	2400	234	460
Absecon Bay	C	2417C	Total Coliform	103	6/4/84	7/20/04	240	17	9
Absecon Creek Estuary	-	2401	Total Coliform	20	1/5/84	11/17/04	240	31	26
Cordery Creek Estuary	-	2308	Total Coliform	74	1/5/84	11/17/04	65	11	9
Great Egg Harbor	A	2710A	Total Coliform	84	5/30/85	12/13/04	93	9	7
Great Egg Harbor	B	2719	Total Coliform	56	5/22/85	12/13/04	93	14	13
Great Egg Harbor	C	2900	Total Coliform	54	1/4/84	11/12/04	213	18	15
Great Egg Harbor	D	2864	Total Coliform	54	1/4/84	12/14/04	133	20	15
Great Egg Harbor	F	3002C	Total Coliform	65	10/19/84	3/17/04	240	17	9
Great Egg Harbor River	-	2804	Total Coliform	34	1/4/84	7/2/04	460	59	43
Lakes Bay	A	2513B	Total Coliform	79	6/18/84	7/17/03	240	26	23
Lakes Bay	B	2534	Total Coliform	79	6/18/84	8/6/04	2400	785	1100
Lakes Bay	C	2502B	Total Coliform	79	6/18/84	9/30/03	2400	246	240
Middle River Estuary	-	2900E	Total Coliform	55	1/4/84	11/12/04	372	33	23
Patcong River Estuary	-	2863	Total Coliform	50	1/4/84	3/17/04	240	24	23
Reeds Bay	A	2301	Total Coliform	73	6/28/85	11/17/04	240	18	9
Reeds Bay	B	2307	Total Coliform	54	1/5/84	8/4/04	1100	58	43
Reeds Bay	C	2214	Total Coliform	50	10/11/84	11/16/04	93	12	9
Reeds Bay	D	2210F	Total Coliform	85	6/4/84	11/16/04	43	9	7

Waterbody	Subgroup	Worst Case Station	Parameter	Count*	Start Date	End Date	90th Percentile* (arithmetic)	Geometric Mean*	Median*
Tuckahoe River Estuary	-	2901B	Total Coliform	55	1/4/84	8/12/04	240	19	15

* Concentration expressed in cfu/100 ml
Green highlighted, worst case stations meet NSSP standards.

4.1 Seasonal Variation/Critical Conditions

The technical approach used to develop these TMDLs includes conservative assumptions that take into account seasonal variability and critical conditions. Tidal waterbodies are difficult to assess given the dynamic flow regime, flushing characteristics, spatial and temporal variability in pathogen sources and contributions, watershed characteristics, and other factors. Seasonal trends were evaluated to determine the critical condition period for TMDL development. The results of this analysis indicated that bacteria concentrations were typically higher during summer months. The influx of summer vacationers and the resulting increase in septic and potential leaking sewer volumes, increased marina and boat use, and other factors contribute to this seasonal trend. Rainfall and flow impacts were also evaluated, but correlation results did not show a clear relationship between bacteria concentrations and these factors. As a result, TMDLs were developed based on summer data collected at the "worst case" station identified for each waterbody (or sub-group). Figure 6 shows the seasonal trend in shellfish monitoring data for "worst case" stations located in WMA 15.

This conservative approach takes into account seasonal variation and critical conditions because only the data collected during summer months were used to identify "worst case" stations and for determining the TMDL percent reduction required and load allocations. These assumptions are consistent with previous freshwater TMDLs developed in New Jersey and recent shellfish TMDLs developed in New York.

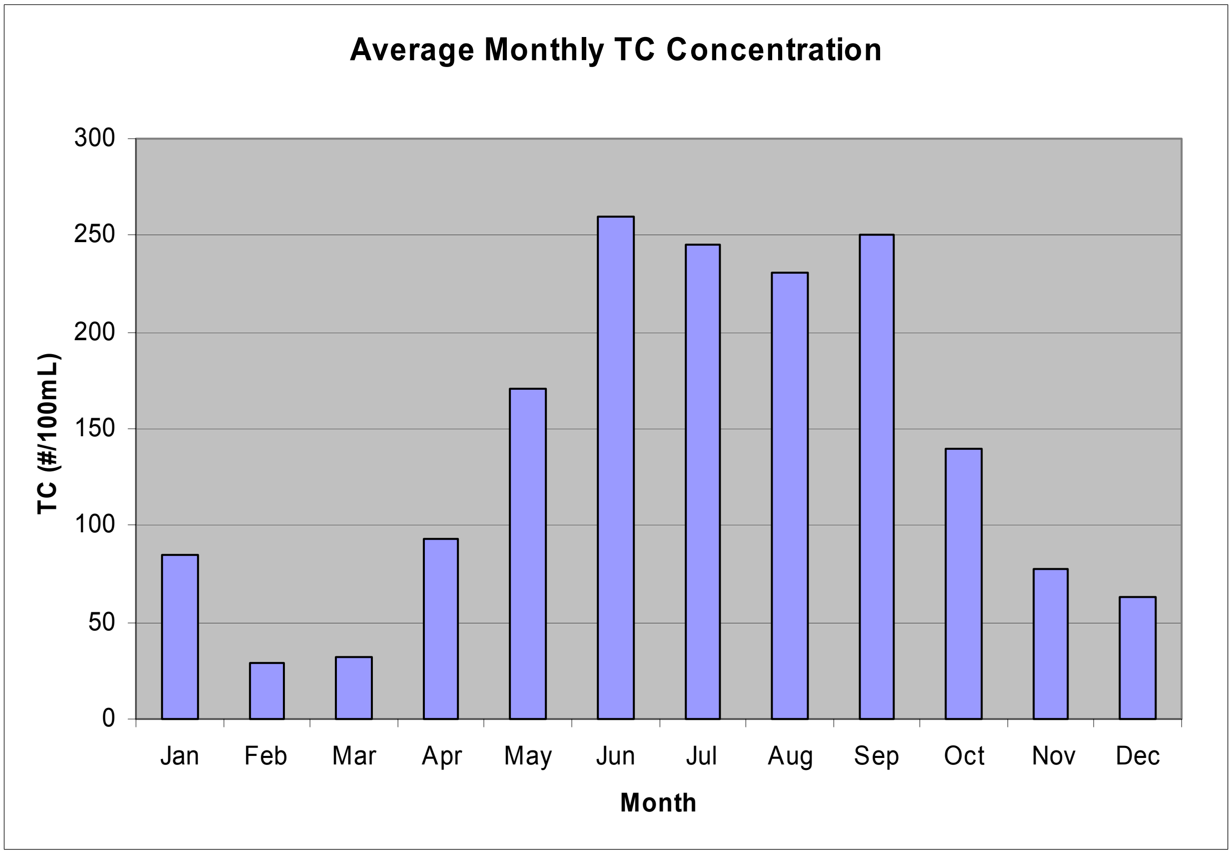


Figure 6. Seasonal trend in TC data for all worst case stations in WMA 15

4.2 Margin of Safety

A Margin of Safety (MOS) is provided to account for "lack of knowledge concerning the relationship between effluent limitations and water quality" (40 CFR 130.7(c)). For these TMDLs, both an implicit and explicit Margin of Safety (MOS) were incorporated. An implicit MOS was incorporated by using conservative assumptions, including the use of "worst case" stations to determine the percent reduction required, using data collected during the summer critical condition period to develop TMDLs, treating total coliform as a conservative substance (source loads were estimated without including die-off rates, soil incorporation, etc.), using conservative methods to estimate land-based loads, and other factors. In addition, a 5% explicit MOS was calculated for each TMDL eligible waterbody.

5.0 TMDL CALCULATIONS

TMDLs were developed based on the percent reduction calculated by comparing the data collected at each "worst case" station to the NSSP 90th percentile criteria for total coliform (with the exception of the Lakes Bay reduction, where the NSSP geometric mean criteria was used because it was more conservative). The overall percent reduction (including a minimum explicit 5% MOS) was calculated and load reductions for point and nonpoint sources were estimated. The percent reduction specified for each waterbody (or sub-group) was applied equally to all pathogen sources in each watershed for which source reductions measures can reasonably be applied. The loads contributed by forest lands and barren lands were not reduced in the TMDL allocation because these loads represent natural background levels (e.g. wildlife contributions) and/or sources that cannot be reasonably reduced. As a result, existing loads from these sources are equal to the future loads. Therefore, the load reduction from land uses and marinas for which reduction measures can reasonably be applied must be increased proportionally, as presented in Table 9.

The TMDL was allocated among point and nonpoint sources. Wastewater treatment plants typically have a negligible discharge due to required disinfection practices designed to reduce and/or eliminate the bacteria concentration in wastewater. These point source loads were, therefore, considered de minimus discharges and are not included in the overall WLA. Individual WLAs, presented in Appendix B, were calculated to reflect the load that could be generated if the treatment facility were to discharge the full permitted flow at the effluent limit. Stormwater from Tier A municipalities, as represented by urban land uses, was assigned a WLA, while Tier B municipalities, non-urban land uses and marinas were assigned LAs.

In the TMDL analysis, some of the waterbodies were divided into smaller subgroups. In several situations, one subgroup was determined to flow/contribute loads to another subgroup. This is referred to as a “nested” watershed situation. Because the load reductions were calculated on progressively larger, overlapping drainage areas, this led to some waterbodies initially receiving more than one load reduction percentage. To eliminate multiple reductions, the presentation has been revised to clarify that the more conservative downstream reduction applied to the whole drainage area. The revised values are presented in Table 1, Table 2, Table 8, and Table 9 for the affected watersheds. There were no changes in the number of 2004 303(d) Listings receiving TMDLs.

5.1 Wasteload Allocations and Load Allocations

WLAs were established for point source discharges within each watershed and for NJPDES-regulated municipal stormwater discharges subject to regulation under the CWA.. LAs were established for all stormwater sources that are not subject to regulation under the CWA, and for all other nonpoint sources. Stormwater point sources that received a WLA were distinguished from stormwater sources receiving a LA on the basis of land use type and municipal tier designation (Tier A/Tier B).

This distribution of loading capacity between WLAs and LAs is consistent with recent EPA guidance that clarifies existing regulatory requirements for establishing WLAs for stormwater discharges (Wayland, November 2002). Stormwater discharges are captured within the runoff sources quantified according to land use, as described previously. Distinguishing between regulated and unregulated stormwater is necessary in order to express WLAs and LAs numerically; however, “EPA recognizes that these allocations might be fairly rudimentary because of data limitations and variability within the system” (Wayland, November 2002, p.1). Therefore, allocations are established according to source categories as shown in Table 7. This demarcation between WLAs and LAs based on land use source categories is not perfect, but it represents the best estimate defined as narrowly as data allow. The Department acknowledges that there may be stormwater sources in the residential, commercial, industrial and mixed urban runoff source categories that are not NJPDES-regulated. Nothing in these TMDLs shall be construed to require the Department to regulate a stormwater source under NJPDES that would not already be regulated as such, nor shall anything in these TMDLs be construed to prevent the Department from regulating a stormwater source under NJPDES.

Table 7. Assignment of WLAs and LAs for stormwater point sources and nonpoint sources

Land Use Source Category	Municipal Tier	TMDL Allocation Type
High density residential	A	WLA
Medium density residential (incl. mixed residential, mixed urban, other urban, military reservations, and no longer military)	A	WLA
Low density residential (incl. rural residential, recreational land, and athletic fields)	A	WLA
Commercial	A	WLA
Industrial	A	WLA
Roadways	A	WLA
High density residential	B	LA
Medium density residential (incl. mixed residential, mixed urban, other urban, military reservations, and no longer military)	B	LA
Low density residential (incl. rural residential, recreational land, and athletic fields)	B	LA
Commercial	B	LA
Industrial	B	LA
Roadways	B	LA
Agricultural	N/A	LA
Forest	N/A	LA
Barren land	N/A	LA

Note: Wetland areas were not included in load estimates based on model assumptions.

A summary of the WLAs, LAs and MOS is provided for each subject waterbody (or sub-group) in Table 8 and source loads and allocations are presented in Table 9. The loads contributed by forest lands and barren lands were not reduced in the TMDL allocation table, as described above. The load reduction for controllable sources (i.e. urban lands, agricultural lands, and marinas) was increased proportionally to meet the overall percent reduction required for each waterbody (or subgroup).

Table 8. TMDL calculations for shellfishing impaired waters in WMA 15

Waterbody	Sub-group	WLA			LA			MOS		TMDL (cfu/yr)	TMDL (cfu/day)
		Load (cfu/yr)	Load (cfu/day)	% of TMDL	Load (cfu/yr)	Load (cfu/day)	% of TMDL	Load (cfu/yr)	Load (cfu/day)		
Absecon Bay	B	1.14E+14	3.12E+11	90%	5.70E+12	1.56E+10	5%	6.28E+12	1.72E+10	1.26E+14	3.45E+11
Great Egg Harbor River	-	7.45E+15	2.04E+13	62%	4.04E+15	1.11E+13	33%	6.05E+14	1.66E+12	1.21E+16	3.32E+13

Lakes Bay	A,B, C	2.01E+14	5.51E+11	78%	4.30E+13	1.18E+11	17%	1.28E+13	3.51E+10	2.57E+14	7.04E+11
Reeds Bay	B	9.92E+13	2.72E+11	86%	1.02E+13	2.79E+10	9%	5.76E+12	1.58E+10	1.15E+14	3.15E+11

Footnote: - Daily TMDLs were calculated by dividing the annual load values by 365 days/year. The daily loads are based on the TMDL not exceeding the calculated annual load. MOS is 5% of the TMDL.

Table 9. WMA 15 land-based load allocations

Waterbody	Subgroup	Overall % Reduction	Agriculture (LA)			Barren Land (LA)			Forest (LA)			Urban Total (WLA)			Urban Total (LA)			Marinas (LA)			MOS (cfu/yr)	TMDL (cfu/yr)
			Existing Load (cfu/yr)	Percent Reduction	Allocated Load (cfu/yr)	Existing Load (cfu/yr)	Percent Reduction	Allocated Load (cfu/yr)	Existing Load (cfu/yr)	Percent Reduction	Allocated Load (cfu/yr)	Existing Load (cfu/yr)	Percent Reduction	Allocated Load (cfu/yr)	Existing Load (cfu/yr)	Percent Reduction	Allocated Load (cfu/yr)	Existing Load (cfu/yr)	Percent Reduction	Allocated Load (cfu/yr)		
Absecon Bay	B	86%	0.00E+00	86%	0.00E+00	5.10E+11	0%	5.10E+11	5.19E+12	0%	5.19E+12	8.39E+14	86%	1.14E+14	0.00E+00	86%	0.00E+00	0.00E+00	86%	0.00E+00	6.28E+12	1.26E+14
Great Egg Harbor River	-	46%	1.50E+15	53%	7.13E+14	6.64E+13	0%	6.64E+13	2.74E+15	0%	2.74E+15	1.57E+16	53%	7.45E+15	1.08E+15	53%	5.10E+14	1.76E+13	53%	8.32E+12	6.05E+14	1.21E+16
Lakes Bay	A, B, C	94%	0.00E+00	94%	0.00E+00	1.67E+12	0%	1.67E+12	1.06E+13	0%	1.06E+13	3.49E+15	94%	2.01E+14	0.00E+00	94%	0.00E+00	5.34E+14	94%	3.08E+13	1.28E+13	2.57E+14
Reeds Bay	B	52%	1.19E+12	54%	5.45E+11	6.81E+10	0%	6.81E+10	9.57E+12	0%	9.57E+12	2.16E+14	54%	9.92E+13	0.00E+00	54%	0.00E+00	0.00E+00	54%	0.00E+00	5.76E+12	1.15E+14

Footnote: **- Daily TMDLs can be calculated by dividing the load values by 365 days/year.**

5.2 Reserve Capacity

Reserve capacity is an optional means of reserving a portion of the loading capacity to allow for future growth. Reserve capacities are not included for the subject waters. Wastewater treatment facilities will continue to be required to achieve disinfection. Nonpoint source reduction strategies applied to land uses will be equally effective with respect to existing and future use of the land.

6.0 FOLLOW - UP MONITORING

The Department maintains a large network of monitoring stations throughout the State's coastal region. The Department's Bureau of Marine Water Monitoring collects water quality data to determine compliance with the National Shellfish Sanitation Program, for the evaluation of the ecological health of coastal waters, and to monitor, identify and track pollution sources impacting the State's coastal waters. Shellfish monitoring data collected the Bureau and information on pollution sources within each watershed and waterbody were used to identify the shellfish-impaired waters that are the subject of these TMDLs. Pathogen indicator data will continue to be collected by the Bureau on a routine basis to assess changes in water quality over time and to determine compliance with the NSSP criteria for shellfish growing areas.

7.0 IMPLEMENTATION

Management measures are "economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint and stormwater sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint and stormwater source pollution control practices, technologies, processes, citing criteria, operating methods, or other alternatives" (USEPA, 1993).

Development of effective management measures depends on accurate source assessment. Coliform bacteria are contributed to the environment from a number of categories of sources including human, domestic or captive animals, agricultural practices, and wildlife. Coliform bacteria from these sources can reach waterbodies directly, through overland runoff, or through sewage or stormwater conveyance facilities. Each potential source will respond to one or more management strategies designed to eliminate or reduce that source of coliform bacteria. Each management strategy has one or more entities that can take lead responsibility to effect the strategy. Various funding sources are available to assist in accomplishing the management strategies. The Department will address the sources of impairment through systematic source trackdown, matching strategies with sources, selecting responsible entities and aligning available resources to effect implementation.

For example, the stormwater discharged to the impaired waterbodies through "municipal separate storm sewer systems" (MS4s) are regulated under the Department's Municipal Stormwater Regulation Program. Under these rules and associated general permits, many municipalities (and various county, State, and other agencies) will be required to implement various control measures that should substantially reduce bacteria loadings, including measures to eliminate "illicit connections" of domestic sewage and other waste to the MS4s, adopt and enforce a pet waste ordinance, prohibit feeding of unconfined wildlife on public property, clean catch basins, perform good housekeeping at maintenance yards, and provide related public education and employee training. These measures are to be phased in over a timeframe specified in the Department's Municipal Stormwater permitting program. The Department will use its Water Quality Management Planning program to expedite implementation of these measures where amendments to areawide Water Quality Management Plans are proposed. The Department has provided State funds as well as a portion of its Clean Water Act 319(h) pass through grant funds to assist municipalities in meeting these requirements.

Sewage conveyance facilities are potential sources of fecal coliform in that equipment failure or operational problems may result in the release of untreated sewage. These sources, once identified, can be eliminated through appropriate corrective measures that can be affected through the Department's enforcement authority. Inadequate on-site sewage disposal can also be a source of fecal coliform. Systems that were improperly designed, located or maintained may result in surfacing of effluent; illicit remedies such as connections to storm sewers or streams add human waste directly to waterbodies. Once these problems have been identified through local health departments, sanitary surveys or other means, alternatives to address the problems can be evaluated and the best solution implemented. The New Jersey Environmental Infrastructure Financing Program, which includes New Jersey's State Revolving Fund, provides low interest loans to assist in correction of water quality problems related to stormwater and wastewater management.

Geese are migratory birds that are protected by the Migratory Bird Treaty Act of 1918 and other Federal and State Laws. Resident Canada geese do not migrate, but are nevertheless protected by this and other legislation. The United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS)-Wildlife Services program reports that the 1999 estimated population of non-migratory geese in New Jersey was 83,000. Geese may produce up to 1½ pounds of fecal matter a day and when the congregate in large numbers they can represent a locally significant source of coliform bacteria. This may warrant taking steps to reduce populations in these areas.

Because geese are free to move about and commonly graze and rest on large grassy areas associated with schools, parks, golf courses, corporate lawns and cemeteries, measures to reduce populations, where necessary, are best developed and conducted at the community level through a community-based goose damage management program. USDA's Wildlife Services program recommends that a community prepare a written Canada Goose Damage Management Plan that may include the following actions:

- Initiate a fact-finding and communication plan
- Enact and enforce a "no feeding" ordinance
- Conduct goose damage control activities such as habitat modification
- Review and update land use policies
- Reduce or eliminate goose reproduction (permit required)
- Hunt geese to reinforce nonlethal actions (permit required)

Procedures such as handling nests and eggs, capturing and relocating birds, and the hunting of birds require a depredation permit from either the USDA APHIS Wildlife Services or U.S. Fish and Wildlife Services. Procedures requiring permits should be a last resort after a community has exhausted the other listed measures. The Department's draft guide *Management of Canada Geese in Suburban Areas, March 2001,* which may be found at www.state.nj.us/dep/watershedmgt under publications, provides extensive guidance on how to modify habitat to serve as a deterrent to geese as well as other prevention techniques such as education through signage and ordinances.

In coastal areas, other waterfowl are naturally present in significant numbers and vary seasonally with migratory patterns. Other wildlife contributions may include deer populations, which have been identified as a potential fecal coliform source in the impaired watersheds. The forested and low-density residential areas that provide deer habitat can be found in close proximity to the impaired stream segments. Deer have been evaluated in fecal coliform TMDLs by other States (e.g. Alabama and South Carolina) and could be a fecal coliform source in New Jersey. Management measures to reduce coliform bacteria contributed by wildlife are not generally practicable.

Agricultural activities are another example of potential sources of coliform bacteria. Possible contributors are direct contributions from livestock permitted to traverse streams and stream corridors, manure management from feeding operations, or use of manure as a soil fertilizer/amendment. Implementation of conservation management plans and best management practices are the best means of controlling agricultural sources of coliform bacteria. Several programs are available to assist farmers in the development and implementation of conservation management plans and best management practices. The Natural Resource Conservation Service is the primary source of assistance for landowners in the development of resource management pertaining to soil conservation, water quality improvement, wildlife habitat enhancement, and irrigation water management. The USDA Farm Services Agency performs most of the funding assistance. All agricultural technical assistance is coordinated through the locally led Soil Conservation Districts. The funding programs include:

- **The Environmental Quality Incentive Program (EQIP)** is designed to provide technical, financial, and educational assistance to farmers/producers for conservation practices that address natural resource concerns, such as water quality. Practices under this program include integrated crop management, grazing land management, well sealing, erosion control systems, agri-chemical handling facilities, vegetative filter strips/riparian buffers, animal waste management facilities and irrigation systems.

- **The Conservation Reserve Program (CRP)** is designed to provide technical and financial assistance to farmers/producers to address the agricultural impacts on water quality and to maintain and improve wildlife habitat. CRP practices include the establishment of filter strips, riparian buffers and permanent wildlife habitats. This program provides the basis for the Conservation Reserve Enhancement Program (CREP).

- **The Conservation Reserve Enhancement Program** The New Jersey Departments of Environmental Protection and Agriculture, in partnership with the Farm Service Agency and Natural Resources Conservation Service, have established a $100 million dollar CREP agreement. The program matches $23 million of State money with $77 million from the Comodity Credit Corporation within USDA. Through CREP, financial incentives are offered for agricultural landowners to voluntarily implement conservation practices on agricultural lands. NJ CREP will be part of the USDA's Conservation Reserve Program (CRP). There will be a ten-year enrollment period, with CREP leases ranging between 10-15 years. The State intends to augment this program thereby making these leases permanent easements. The enrollment of farmland into CREP in New Jersey is expected to improve stream health through the installation of water quality conservation practices on New Jersey farmland.

Uses of the marine environment as a recreational area and receiving water have the potential to contribute pathogen loads. As part of the Governor's Coast 2005 initiative, the Department has taken many steps toward stronger protection for water quality and habitat, including:

- The Department has worked to strengthen standards for ocean dischargers to avoid impacts to water quality. The Department requires implementation of measures that will prevent catastrophic sewage spills though the maintenance and upgrading of aging infrastructure.
- The Department targets $30 million in grants to accelerate projects that improve coastal water quality.
- The Department partners with other state agencies, non-profit groups, trade organizations, and marina owners to activate the "New Jersey Clean Marina" program.
- New Jersey will work with anglers, environmentalists, and the New Jersey congressional delegation to establish a "Clean Ocean Zone" to protect water quality in the NY/NJ Bight by eliminating and preventing pollution.

In March 2005, the New Jersey Clean Marina Program was established. It is a voluntary education program that provides information, guidance, and technical assistance to marina operators, local government, and recreational boaters regarding the most effective practices to protect water quality and coastal resources. Marina and boat operational and maintenance activities can contribute to nonpoint source pollution by discharging substances such as oil, grease, paint and cleaning chemicals, and fish waste. This Program gives marina managers the information they need to reduce these incidental effects of their activities. Facilities that meet the requirements of the Program are recognized as "Clean Marinas." By adopting pollution prevention measures, marina owners and managers can engage in environmentally responsible operations and management of their facility. The New Jersey Clean Marina Program is a partnership among state and federal government agencies, trade associations, marine businesses and other interested parties. The Department website (www.njcleanmarina.org) contains more information and a complete list of participating agencies and organizations.

Another program designed for coastal water quality improvement is New Jersey's Clean Vessel Act (CVA) Committee. Passed by the Congress in 1992, the CVA helps reduce pollution from vessel sewage discharges. Federal grants are available to states on a competitive basis for the construction and/or renovation, operation and maintenance of pumpout and portable toilet dump stations. Currently, states submit grant proposals, by May 1st of each year, to one of seven Fish and Wildlife Service regional offices for review. The service's Division of Federal Aid then convenes a panel including representatives from the Service's Washington Office of the Division of Federal Aid, the National Oceanic and Atmospheric Administration (NOAA), the USEPA, and the U.S. Coast Guard. The panel reviews, ranks and makes funding recommendations to the Director of the Fish and Wildlife Service. The Director gives priority consideration to grant proposals which provide installation and/or operation of pumpout and dump stations under federally approved state plans.

All recreational vessels must have access to pumpouts funded under the Clean Vessel Act. NOAA will mark pumpout and dump station locations on its nautical charts. Halfway through the program, grants have been awarded to install 1,200 pumpout stations and 630 dump stations. A maximum fee of $5.00 may be charged for the use of pumpout facilities constructed or maintained with grant funds.

As part of this program, four CVA funded pumpout boats are in service in New Jersey. They are operated by the Borough of Seaside Park, by Monmouth County, and by Ocean County. Pumpout boats can pull up along side a recreational boat and pump out its sewage holding device with a suction hose. Once a pumpout boat is full of waste, it discharges the waste into a sewage treatment facility for proper disposal.

Management strategies are summarized below in Table 10.

Table 10. Implementation management strategies

Source Category	Responses	Potential Responsible Entity	Funding options
Human Sources			
Inadequate (per design, operation, maintenance, location, density) on-site disposal systems	Sanitary surveys, septic management programs/ordinances	Municipality	CWA 604(b) for confirmation of inadequate condition; Environmental Infrastructure Financing Program for construction of selected option
Inadequate or improperly maintained stormwater facilities; illicit connections	Measures required under Municipal Stormwater permitting program including any additional measures determined in the future to be needed through TMDL process	Municipality, State and County regulated entities, stormwater utilities	CWA 319(h); Environmental Infrastructure Financing Program for construction of selected option
Malfunctioning sewage conveyance facilities	Identify through source trackdown and repair	Owner of malfunctioning facility--compliance issue	User fees
Marinas	Clean Marina Program; No Discharge Zones; Marina BMPs including: Marine pump-out facilities; Marina flushing design; Fish waste management including fish-	Marina property owner; Municipalities for ordinance adoption and compliance	State source and CWA319(h) assistance for BMPs

Source Category	Responses	Potential Responsible Entity	Funding options
	cleaning restrictions, public education, and fish waste disposal; Proper sewage handling including: installing a sanitary pump-out system, providing on-shore restrooms, provide accommodations for emptying potable Marine Sanitation Devices (MSDs), safeguarding and maintaining septic systems, providing live aboard facilities, offering MSD inspections, encouraging compliance, and educating boaters.		
Domestic/captive animal sources			
Pets	Pet waste ordinances	Municipalities for ordinance adoption and compliance	State source and CWA 319(h) assistance to municipalities to implement municipal stormwater regulations
Horses, livestock, zoos	Confirm through source trackdown: SCD/NRCS develop conservation management plans	Property owner	EQIP, CRP, CREP
Agricultural practices	Confirm through source trackdown; SCD/NRCS develop conservation management plans, exercise CAFO/AFO authority if applicable	Property owner	EQIP, CRP, CREP
Wildlife			
Locally excessive populations of resident Canada geese or other waterfowl	Feeding ordinances; Goose Management BMPs	Municipality for ordinance; local community groups for BMPs	State source; CWA 319(h)
Indigenous wildlife	Confirm through trackdown; riparian buffer restoration; consider revising designated uses	State	State source

7.1 Source Trackdown

Sewage Infrastructure Improvement Act (SIIA)

N.J.A.C. 7:22A was originally adopted by the Department on December 29, 1989 (see 22 N.J.R. 368(a)) to implement the Sewage Infrastructure Improvement Act (SIIA), N.J.S.A. 58:25-23 et seq. The SIIA has two main components: (1) to address discharges from combined sanitary and stormwater sewer systems (CSO) throughout the State (planning and design grants for CSOs) and (2) to map and investigate stormwater sewer systems in Atlantic, Cape May, Monmouth and Ocean counties (stormwater mapping grants). The SIIA, which became effective on August 3, 1988, was designed to address nonpoint and point sources of pollution from stormwater sewer systems and combined sewer overflow points. The New Jersey Legislature has declared that these sources of pollution contribute greatly to the biological and chemical degradation of coastal and surface waters of the state. The SIIA recognized that nonpoint sources of pollution create public health dangers and mandate beach and shellfish bed closings by contributing high levels of bacteria to surface waters through stormwater sewer systems. The SIIA also recognized that overflows of raw sewage from combined sewer systems are another major source of water pollution and established various requirements for municipalities and public entities to address these pollution problems.

The SIIA required all municipalities with stormwater sewer systems discharging into the salt waters of Monmouth, Ocean, Atlantic or Cape May counties to prepare and submit a map of their sanitary and stormwater sewer systems and to conduct periodic stormwater monitoring of outfalls discharging to saltwater. Grant funding was provided for mapping, sampling and identification of cross connections and interconnections between the stormwater and sanitary sewers. This work is essentially complete and will inform implementation efforts.

While there are no CSOs in the waterbodies addressed in this TMDL report, it should be noted that significant source reduction strategies have been and continue to be put in place to address this source of pathogens in other waterbodies, such as the New York/New Jersey Harbor, which will be addressed in future TMDL efforts.

Pathogen Indicators and Microbial Source Tracking:

Advances in microbiology and molecular biology have produced several methodologies that discriminate among sources of fecal coliform and thus more accurately identify pathogen sources. The numbers of pathogenic microbes present in polluted waters are few and not readily isolated nor enumerated. Therefore, analyses related to the control of these pathogens must rely upon indicator microorganisms. The commonly used pathogen indicator organisms are the coliform groups of bacteria, which are characterized as gram-negative, rod-shaped bacteria. Coliform bacteria are suitable indicator organism because they are generally not found in unpolluted water, are easily identified and quantified, and are generally more numerous and more resistant than pathogenic bacteria (Thomann and Mueller, 1987).

Tests for fecal organisms are conducted at an elevated temperature (44.5°C), where the growth of bacteria of non-fecal origin is suppressed. While correlation between indicator organisms and diseases can vary greatly, as seen in several studies performed by the EPA and others, two indicator organisms *Esherichia coli* (*E. coli*) and enterococci species showed stronger correlation with incidence of disease in bathers than fecal coliform (USEPA, 2001). Similar epidemiological studies for shellfish consumption have not been performed for *E. coli* or enterococci. Recent advances have allowed for more accurate identification of pathogen sources. A few of these methods, including, molecular, biochemical, and chemical are briefly described in the following paragraph.

Molecular (genotype) methods are based on the unique genetic makeup of different strains, or subspecies, of fecal bacteria (Bowman et al, 2000). An example of this method includes "DNA fingerprinting" (i.e., a ribotype analysis which involves analyzing genomic DNA from fecal *E. coli* to distinguish human and non-human specific strains of *E. coli*.). Biochemical (phenotype) methods include those based on the effect of an organism's genes actively producing a biochemical substance (Graves et al., 2002; Goya et al 1987). An example of this method is multiple antibiotic resistance (MAR) testing of fecal *E. coli*. In MAR testing, *E. coli* are isolated from fecal samples and exposed to 10-23 different antibiotics. In theory, *E. coli* originating from wild animals should show resistance to a smaller number of antibiotics than *E. coli* originating from humans or pets. Given this general trend, MAR patterns or '"signatures" can be defined for each class of *E. coli* species. Chemical methods are based on finding chemical compounds associated with human wastewater, and useful in determining if the sources are human or non-human. Such methods measure the presence of optical brighteners, which are contained in all laundry detergents, and soap surfactants in the water column. Unlike the optical brightener method, the measurement of surfactants may allow for some quantification of the source.

MST methods have already been successfully employed at the Department in the past decade. Since 1988, the Department has worked cooperatively with the University of North Carolina in developing and determining the application of RNA coliphage as a pathogen indicator. This research was funded through USEPA and Hudson River Foundation grants. These studies showed that the RNA coliphages are useful as an indicator of fecal contamination; particularly in chlorinated effluents and that they can be serotyped to distinguish human and animal fecal contamination. Through these studies, the Department has developed an extensive database of the presence of coliphages in defined contaminated areas (point human, non-point human, point animal, and non-point animal).

More recently, the Department has established a MST methodology that utilizes both genotype (genotyping of F+RNA coliphages) and phenotype (MAR testing) tests. The results of these tests are collectively evaluated to best determine sources of fecal contamination. The Bureau's methodology includes evaluation of long-term microbial results as well as data (GIS Land use coverage, aerial photographs, visual assessments) of actual and potential sources, stormwater monitoring to delineate the location of major sources and the use of MAR and F+ coliphage in conjunction with conventional microbial indicators. This methodology has been successfully applied in several areas including Seaside Park, Long Swamp, Atlantic City, and Parvin State Park. This methodology may be utilized for select TMDL waterbodies.

7.2 Segment Specific Strategies

In addition to generic strategies described previously, a number of projects have been undertaken which are expected to aid in achieving the load reductions assigned to the impaired waterbodies.

Ongoing activities to develop and implement watershed restoration plans are expected to result in additional specific projects to reduce pollutant loads.

Table 11. WMA 15 Outreach and Restoration Projects

WMA	FY	Funding Source	Recipient	Project Title	Grant Amount
15	2001	319	City of Linwood	To restore Mary Jane Pond and retrofit the stormwater drainage system that feeds into it. There is also an education & outreach component for local schools.	$100,000.00
15	2002	319	Folsom Boro	Clean out of existing stormwater collection system in Folsom Boro	$52,440.00
	1998	319	Rutgers Department of Environmental Services	BMPs for the use of Non-traditional Organic Wastes in Agriculture	$79,000.00

8.0 REASONABLE ASSURANCE

With the implementation of follow-up monitoring, source identification and source reduction as described in general and for each segment, the Department has reasonable assurance that a significant increase in the shellfish designated use will be attained. The results of trackdown and follow up ambient monitoring will be evaluated to determine effectiveness of the identified measures and if additional measures are needed.

9.0 PUBLIC PARTICIPATION

The Water Quality Management Planning Rules N.J.A.C. 7:15-7.2 requires the Department to initiate a public process prior to the development of each TMDL and to allow public input to the Department on policy issues affecting the development of the TMDL. Further, the Department shall propose each TMDL as an amendment to the appropriate areawide water quality management plan in accordance with procedures at N.J.A.C. 7:15-3.4(g). As part of the public participation process for the development and implementation of the subject TMDLs, the Department worked collaboratively with a series of stakeholder groups as part of the Department's ongoing watershed management efforts.

The Department conducted three outreach sessions: November 17, 2005 for WMAs 12 and 13 with the Barnegat Bay Advisory Committee at Ocean County College; December 15, 2005 for WMAs 14, 15, and 16 at the Galloway Township Library in Galloway, New Jersey; and January 3, 2006 for WMAs 16 and 17 at the Commercial Township Municipal Building in Port Norris. During the sessions, presentations of the Department TMDL process, the locations of impaired shellfish waterbodies, and potential methods to achieve bacteria source reductions were shared. GIS maps aided in soliciting information regarding potential sources within each watershed.

10.0 AMENDMENT PROCESS

Notice proposing these TMDLs was published February 21, 2006 in the New Jersey Register and in newspapers of general circulation in order to provide the public an opportunity to review the TMDL document and submit formal comments. In addition, a public hearing was held on March 23, 2006 at the Ocean County Community College – Toms River Campus in the Technology Building Lecture Hall. There was an informal presentation from 7:00 p.m. to 7:30 p.m., which was followed by the public hearing from 7:30 p.m. until the end of testimony. Notice of the proposal and hearing was provided to affected municipalities in the watershed.

All comments received during the public notice period and at the public hearing has become part of the record for this TMDL and is considered in the Department's decision to establish this TMDL through submittal to EPA Region 2. Once approved by EPA, this TMDL will be adopted as an amendment to the Atlantic and Cape May Counties, Lower Delaware and Tri-County Water Quality Management Plans in accordance with New Jersey's Water Quality Management Planning Rules at N.J.A.C. 7:15-3.4 (g). The outcome of the public participation process is described in Appendix F.

APPENDIX A: REFERENCES

Bacteria Load Estimation methods used to estimate land-based bacteria load contributions: (1) Toms River studies – USGS (May 2005); (2) Loading Coefficient Analysis and Selection Tool (LCAST). Developed by NJDEP and Tetra Tech, December 2001.; (3) Watershed Treatment Model (WTM). Developed by the Center for Watershed Protection in July 2001; (4) Simple Method for calculating bacteria loads (Schueler, T. 1987).

Caraco, D. 2001. The Watershed Treatment Model, Version 3.0. Center for Watershed Protection, Ellicott City, MD.

Cooperative Coastal Monitoring Program (CCMP) station locations, provided by NJDEP on 5/25/2005.

Cooperative Coastal Monitoring Program (CCMP) bacteria data, county-year spreadsheets provided by NJDEP on 6/8/2005 and 10/25/2005.

Fecal Coliform Bacteria Total Maximum Daily Load, Limetree Bay, St. Thomas, U.S. Virgin Islands. Final Draft. Tetra Tech. May 2005.

Jensen, Paul, Su, Yu-Chun. Investigation of Selected Public Health Issues in the Corpus Christi Bay National Estuary Program Study Area. Publication CCBNEP-11. Texas Natural Resource Conservation Commission, Austin, TX. Nov. 1996.

Monitoring station locations (Shellfish Monitoring, CCMP, etc.), provided by EPA Region 2 on 5/9/2005 (everystation.shp)

New Jersey Department of Environmental Protection, Integrated Water Quality Monitoring and Assessments Methods, November 2003

New Jersey Department of Environmental Protection, New Jersey 2004 Integrated Water Quality Monitoring and Assessment Report (305(b) and 303(d)

New Jersey Department of Environmental Protection, Surface Water Quality Standards, N.J.A.C. 7:9B, June 2005

NJDEP, Water Monitoring & Standards - Local Area Reports (LARs) and Shoreline Surveys. Reports provide information on pathogen sources and other information on shellfish areas in New Jersey. Obtain at http://www.state.nj.us/dep/wmm/bmw/reports.htm

"NJDEP 2004 Integrated Water Quality Monitoring and Assessment Report", published 6/2004 by NJDEP, Watershed Assessment Group (WAT). Online at: http://www.nj.gov/dep/gis/irshp2004.html. Key shapefile coverages include ir_coastal2004.shp (coastal waterbody assessments), ir_river_conventionals2004.shp (stream/river assessments). Updated coverages provided by EPA on 5/9/2005.

"NJDEP 1995/97 Land use/Land cover Update for New Jersey (by WMA)", published 12/01/2000 by the NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), and delineated by watershed management area. Online at: http://www.nj.gov/dep/gis/lulc95shp.html

"NJDEP Streams of New Jersey (1:24000)", published 11/01/1998 by NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA). Online at: http://www.state.nj.us/dep/gis/strmshp.html

"NJDEP 14 Digit Hydrologic Unit Code delineations for New Jersey (DEPHUC14)", published 4/5/2000 by NJDEP, New Jersey Geological Survey (NJGS). Online at: http://www.nj.gov/dep/gis/stateshp.html#HUC14

"NJDEP Head of Tide Points for Watercourses of New Jersey", published 1986 by NJDEP, Office of Environmental Analysis (OEA), Coast Survey Ltd. (CTD). Online at: http://www.nj.gov/dep/gis/stateshp.html#HOT

"NJDEP County Boundaries for the State of New Jersey", published 01/23/2003 by NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), Online at: http://www.nj.gov/dep/gis/stateshp.html#NJCO

"NJDEP Municipality Boundaries for the State of New Jersey", published 01/23/2003 by NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information Systems (BGIS). Online at: http://www.nj.gov/dep/gis/stateshp.html#NJMUN

NJDEP "Shellfish Classification 2005", published 8/18/2005 by NJDEP, Water Monitoring & Standards, Bureau of Marine Water Monitoring (BMW). Online at: http://www.nj.gov/dep/gis/stateshp.html#SHELLFISH

NJDEP "Sewer Service Area (Proposed Revision)", published 10/2005 by NJDEP, Division of Watershed Management (DWM), Bureau of Watershed Regulation (BWR). Online at: http://www.state.nj.us/dep/gis/stateshp.html#SSAP

"NJPDES Surface Water Discharges", published 9/12/2002 and updated in 2005 by NJDEP. Online at http://www.nj.gov/dep/gis/stateshp.html#NJPDESSWD

NJPDES point source discharge limits, provided by NJDEP on 11/1/2005. New Jersey Environmental Management System (NJEMS) Discharge Monitoring Report (DMR) data submitted on 5/26/2005

NJDEP Marina locations, shellfish growing areas, and stormwater outfall locations provided by NJDEP, Water Monitoring & Standards on 6/16/2005.

Noble, T., Leecaster, M., Moore, D., Schiff, K., and S. Weisberg. 1998. Relationships among bacterial indicators during a regional survey of microbiological water quality along the shoreline of the Southern California Bight. Southern California Coastal Water Research Project Authority (SCCWRP).

Pathogen Total Maximum Daily Loads for Shellfish Waters in Oyster Bay and Mill Neck Creek. New York State Department of Environmental Conservation. September 2003.

Shellfish monitoring data, CD provided by NJDEP, Water Monitoring & Standards on 5/19/2005

Sutfin, C.H. May 2002. Memo: EPA Review of 2002 Section 303(d) Lists and Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992. Office of Wetlands, Oceans and Watersheds, U.S. EPA.

Toms River studies (USGS): (1) Relation of Water Quality to Streamflow, Season, and Land Use in four tributaries to the Toms River, Ocean County, NJ, 1994-1999 (draft provided by NJDEP on 10/28/2005); (2) Relation of Water Quality to Land Use in the Drainage Basins of Four Tributaries to the Toms River, NJ, 1994-1995 (provided by EPA on 5/27/2005).

U.S. Environmental Protection Agency (EPA). 1993. Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters. EPA-840-B-92-002. Washington, DC.

U.S. Environmental Protection Agency (EPA). January 2001. Protocol for Developing Pathogen TMDLs, First Edition, EPA 841-R-00-002, ("Pathogen Protocol"), Washington, DC.

U.S. Food and Drug Administration (FDA). 2003. National Shellfish Sanitation Program Guide for the Control of Molluscan Fish. FDA, Washington, D.C.

Wayland, R.H. III. November 22, 2002. Memo: Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs. Office of Wetlands, Oceans and Watersheds, U.S.E.P.A.

APPENDIX B: NJPDES WASTEWATER TREATMENT FACILITIES

WMA 15 Wastewater Treatment Facilities

Waterbody	Subgroup	NJPDES ID	Facility Name	Pipe	Design Flow** (MGD)	FC Limit (cfu/100ml)	WLA*** (cfu/day)	Permit Category*	Receiving Waters
Great Egg Harbor River Estuary	-	NJ0021717	Buena Borough MUA	001A	0.4	200 MoGeoAvg	3.03E+09	A	Deep Run
		NJ0031615	Camden County BOE-Vo Tech School	001A	0.058	200 MoGeoAvg	4.39E+08	A	Sharps Branch (GEHR) via storm sewer

*Permit Categories: A = Sanitary Surface Water Discharge; A8 = Discharge to Reg. Outfall Auth.; B = Industrial/Commercial Surface Water; RF = Stormwater; 05 = Stormwater Runoff

** Design Flow reflects the design capacity of the entire treatment facility, and does not indicate individual pipe/outfall capacity.

*** Because sanitary discharges require disinfection that achieves nearly complete removal, they are considered a de minimus contribution. The “WLA” was calculated using:

“WLA” (cfu/day) = Design Flow (MGD) x 3785411.78 liters/1 million gallons x FC Limit (cfu/100ml) x 100ml/0.1 liters

APPENDIX C: MUNICIPALITIES

WMA15 Tier A and Tier B Municipalities

Tier	Waterbody	Subgroup	Municipality	NJPDES Number
A	Absecon Bay	A	ABSECON CITY	NJG0149926
			ATLANTIC CITY	NJG0153168
			PLEASANTVILLE CITY	NJG0154598
		B	ABSECON CITY	NJG0149926
			ATLANTIC CITY	NJG0153168
			PLEASANTVILLE CITY	NJG0154598
		C	ATLANTIC CITY	NJG0150509
			BRIGANTINE CITY	NJG0153168
	Absecon Creek Estuary	-	ABSECON CITY	NJG0149926
			EGG HARBOR TWP	NJG0154342
			GALLOWAY TWP	NJG0152447
			HAMILTON TWP	NJG0149225
			PLEASANTVILLE CITY	NJG0154598
	Cordery Creek Estuary	-	ABSECON CITY	NJG0149926
			GALLOWAY TWP	NJG0152447
	Great Egg Harbor	A	EGG HARBOR TWP	NJG0154342
			SOMERS POINT CITY	NJG0148199
		B	EGG HARBOR TWP	NJG0154342
			LINWOOD CITY	NJG0152439
			SOMERS POINT CITY	NJG0148199
		C	CORBIN CITY	NJG0149055
			EGG HARBOR TWP	NJG0154342
			ESTELL MANOR CITY	NJG0155179
		D	EGG HARBOR TWP	NJG0154342
			HAMILTON TWP	NJG0149225
			LINWOOD CITY	NJG0152439
			NORTHFIELD CITY	NJG0150487
			PLEASANTVILLE CITY	NJG0154598
			SOMERS POINT CITY	NJG0148199
		E	OCEAN CITY	NJG0151289
			UPPER TWP	NJG0153702
		F	OCEAN CITY	NJG0151289
	Great Egg Harbor River Estuary	-	BERLIN BORO	NJG0153222
			BERLIN TWP	NJG0150339
			BUENA BORO	NJG0149314
			BUENA VISTA TWP	NJG0154989
			EGG HARBOR TWP	NJG0154342
			ESTELL MANOR CITY	NJG0155179
			FOLSOM BORO	NJG0151343
			FRANKLIN TWP	NJG0151025
			GALLOWAY TWP	NJG0152447
			GLOUCESTER TWP	NJG0148695
			HAMILTON TWP	NJG0149225
			MONROE TWP	NJG0148946
			PINE HILL BORO	NJG0152838
			WASHINGTON TWP	NJG0153664
			WEYMOUTH TWP	NJG0148784

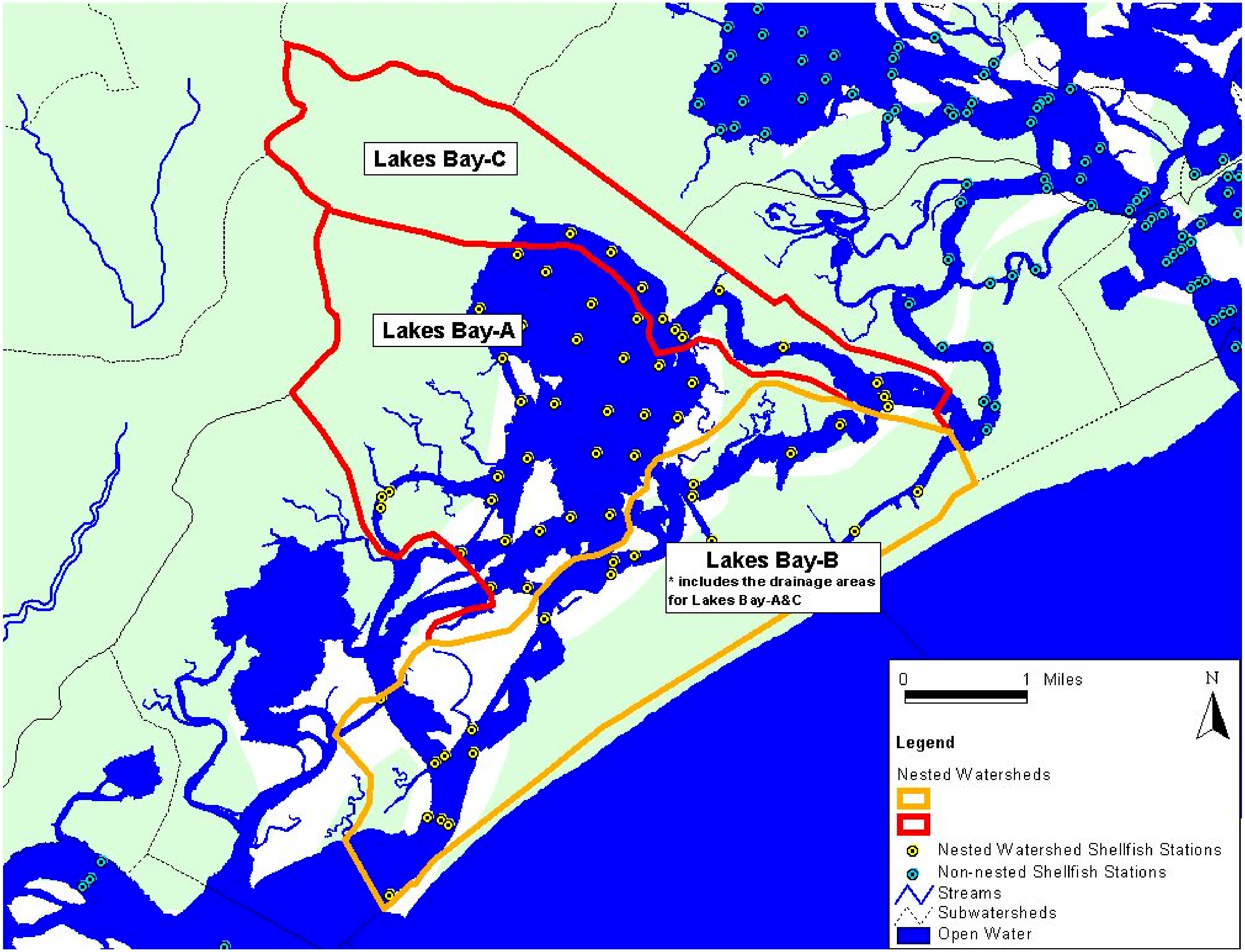
			WINSLOW TWP	NJG0154601
	Lakes Bay	A	ATLANTIC CITY	NJG0153168
			EGG HARBOR TWP	NJG0154342
			NORTHFIELD CITY	NJG0150487
			PLEASANTVILLE CITY	NJG0154598
			VENTNOR CITY	NJG0151114
		B	ATLANTIC CITY	NJG0153168
			EGG HARBOR TWP	NJG0154342
			LONGPORT BORO	NJG0152081
			MARGATE CITY	NJG0153150
			NORTHFIELD CITY	NJG0150487
			VENTNOR CITY	NJG0151114
		C	ATLANTIC CITY	NJG0153168
			EGG HARBOR TWP	NJG0154342
			PLEASANTVILLE CITY	NJG0154598
	Middle River Estuary	-	CORBIN CITY	NJG0149055
			ESTELL MANOR CITY	NJG0155179
	Patcong River Estuary	-	EGG HARBOR TWP	NJG0154342
			HAMILTON TWP	NJG0149225
			LINWOOD CITY	NJG0152439
			NORTHFIELD CITY	NJG0150487
			PLEASANTVILLE CITY	NJG0154598
			SOMERS POINT CITY	NJG0148199
	Reeds Bay	A	GALLOWAY TWP	NJG0152447
		B	GALLOWAY TWP	NJG0152447
		C	BRIGANTINE CITY	NJG0150509
		D	ATLANTIC CITY	NJG0153168
			BRIGANTINE CITY	NJG0150509
	Tuckahoe River Estuary	-	BUENA VISTA TWP	NJG0154989
			CORBIN CITY	NJG0149055
			DENNIS TWP	NJG0150291
			ESTELL MANOR CITY	NJG0155179
			HAMILTON TWP	NJG0149225
			UPPER TWP	NJG0153702
			WEYMOUTH TWP	NJG0148784
B	Great Egg Harbor River Estuary	-	HAMMONTON TOWN	NJG0149870
			MULLICA TWP	NJG0150363
			PINE VALLEY BORO	NJG0154920
	Tuckahoe River Estuary	-	MAURICE RIVER TWP	NJG0151181
			WOODBINE BORO	NJG0149721

APPENDIX D: MARINA LOADING ESTIMATES

WMA 15 Marina Loading Estimates

Waterbody	Subgroup	Marina Name	Load (cfu/year)
Absecon Bay	B	ISLAND MARINA	0.000E+00
	C	A.C. WESCOAT CO	0.000E+00
		AC FISHING CENTER	1.117E+13
		FARLEY STATE MARINA	5.957E+14
		HARRAH'S MARINA	9.960E+13
		KAMMERMAN'S MARINA	7.447E+12
		M&W BOAT WORKS	1.024E+13
		SNUG HARBOR MARINA	6.516E+12
Absecon Creek Estuary	-	ABSECON BAY & SPORTS	1.862E+13
		UP THE CREEK MARINA	3.258E+13
		WAYNES WORLD BAIT &	1.955E+13
Great Egg Harbor	B	Bayshore Restaurant	2.793E+13
		Corletto Marina	6.981E+13
		Harbor Cove Marina	2.793E+14
		Somers Point Marina	6.952E+13
		Waterfront Power Sup	5.585E+12
	F	Bayview Marina	7.447E+13
		HARBOR HOUSE MARINA	1.024E+14
		LEMONT'S	3.723E+13
		Noreaster Condominiu	6.051E+13
		OCEAN CITY MARINA	2.234E+13
Great Egg Harbor River	-	Mays Landing Marina	1.756E+13
Lakes Bay	A	Campbell's Marina	6.144E+13
	B	Blue Water Marina	4.654E+13
		Crown Key Yacht Club	4.189E+13
		Name unknown	2.793E+13
		Seaview Harbor Marin	2.793E+14
		Sunset Bay Marina	2.979E+13
	C	Abandoned	3.723E+13
		Randalls Seafood	1.024E+13
Reeds Bay	C	BOBS OUTBOARD	2.234E+13
		CONDOMINIUM MARINA	3.537E+13
		CONWAY MARINE	2.327E+13
		DEEBOLD BOAT YARD	1.955E+13
		ELKS LODGE MARINA	4.654E+13
		FISH & FUN MARINA	2.048E+13
		JERSEY STATE MARINE	3.537E+13
		JOLLY ROGER MARINA	1.676E+13
	D	BAYSHORE MARINA	8.750E+13
Tuckahoe River Estuary	-	HOLTZ'S BOATWORKS	0.000E+00

APPENDIX E: MAPS OF NESTED WATERSHEDS



E-1. Lakes Bay-A, B, and C Nested Watersheds (WMA 15)

APPENDIX F: RESPONSE TO PUBLIC COMMENTS

This constitutes the New Jersey Department of Environmental Protection's (Department) response to comments raised during the comment period for the document entitled "Six Total Maximum Daily Loads for Total Coliform to Address Shellfish-Impaired Waters in Watershed Management Area 15, Atlantic Coastal Water Region", which was proposed on February 21, 2006. These TMDLs were proposed as an amendment to the Atlantic and Cape May Counties, Lower Delaware and Tri-County Water Quality Management Plans and include management approaches to reduce loadings of total coliform from various sources in order to support the shellfish harvesting use.

The notice proposing the TMDLs was published on February 21, 2006 in the New Jersey Register and in newspapers of general circulation in order to provide the public an opportunity to review the TMDL document and submit formal comments. The TMDL documents were made available at the Department, upon request by mail, and on the Department's website. The Department conducted a non-adversarial public hearing on March 23, 2006 at the Ocean County Community College - Toms River Campus in the Technology Building Lecture Hall. The public comment period ended on April 7, 2006.

No comments were received during the public hearing. However, three comment letters were received on the proposed TMDLs during the open public comment period. The letters were received from:

1. Mid-Atlantic Environmental Law Center, c/o Widener University School of Law, 4601Concord Pike, PO Box 7474, Wilmington, Delaware 19803

2. Clean Ocean Action, 18 Hartshorne Drive, PO Box 505, Sandy Hook, Highlands, NJ 07732-0505

3. American Littoral Society, Building 18, Sandy Hook, Highlands, NJ 07732

Department initiated changes to the document include the following:
1. In several TMDLs, situations arose where one impaired subgroup flows into another impaired subgroup. This was referred to as a "nested" watershed situation. To compensate for the overlapping subgroups' drainage contribution areas, the document was revised. Load reductions from impaired down-stream drainages, which were more conservative, were applied to up-stream subgroups to clarify the proper reduction to apply. The result in WMA 15 was that Lakes Bay A and Lakes Bay C received the same reduction as Lakes Bay B. Values were revised in Table 1, Table 2, Table 8, and Table 9 for the affected nested watershed.
2. Table 8 was revised to present Daily TMDLs. The daily loads were calculated by dividing the annual load values by 365 days/year, and are based on the TMDL not exceeding the calculated annual load.
3. "Appendix E: Maps of Nested Watersheds" has been added to show more detail in these drainages.
4. Several references in Appendix A have been added or revised.
5. Appendix B, C, and D were revised to eliminate duplicate facility, municipality, and/or marina listings. Appendix B was revised to include a column with potential WLAs for wastewater treatment facilities.

A summary of comments to the proposal and the Department's responses to those comments follow. The number(s) in brackets at the end of each comment corresponds to the commenter(s) listed above.

Comment 1.

The Department has a duty to develop TMDLs for impaired waters in all shellfish harvest restriction areas, including those restricted based on shoreline surveys or where insufficient data or no data for a waterbody exists. The Department cannot move a waterbody from one Sublist to another without the approval of the USEPA.

Response 1.

The Department acknowledges that EPA must approve any change in status of a waterbody with respect to Sublist 5 of the Integrated List. The EPA has been involved in the development of these TMDLs and concurs with the approach for each segment. In the course of developing the TMDLs, all available data was gathered and analyzed and the spatial extent of each listing was assessed. For some segments it was determined that, while there was sufficient data to declare the waterbody as impaired, there was insufficient data to calculate a TMDL. These waterbodies will remain on Sublist 5 until enough data is gathered to permit calculation of a TMDL. In some cases it was determined that a waterbody was listed as impaired in the absence of water quality data applicable to the waterbody. For example, the spatial extent used for initial assessment may have been revised as the result of more detailed assessment during TMDL development. In these cases, the resultant waterbody with no water quality data will be moved to Sublist 3 until a determination as to impairment status based on data can be made. Where there was sufficient data, TMDLs were calculated for each waterbody that was impaired based on the water quality data, provided an improvement in water quality would result in lifting the harvesting restriction. However, beyond requiring compliance with the numeric water quality standards, the NSSP requires the State authority to impose precautionary restrictions based on the presence of sources that could deliver loads of pathogens unexpectedly, for example as the result of a malfunction of a sewer or septic system, or behaviors that are difficult to regulate, such as the handling of waste generated on watercraft. In order to protect human health, precautionary harvesting restrictions are required, even if ambient monitoring data conform to the standards, because ambient monitoring may not capture random, unpredictable excursions due to such sources. Waterbodies that are restricted based on such administrative precautions were not considered for TMDLs because no improvement in water quality would result in full support of the designated use. As these waterbodies are closed due to the potential for contamination, regardless of actual water quality data, closures of waters for shellfishing as the result of administrative precautions will be removed from Sublist 5 and placed on Sublist 4 in the 2006 Integrated List of Waterbodies because the impairment is due to pollution, not pollutants.

Comment 2.

The Department does not indicate that it developed the TMDLs with the USEPA's guidance document, "Protocol for Developing Pathogen TMDLs", First Edition, January 2001, USEPA Document Number EPA 841-R-00-002, ("Pathogen Protocol"). The Pathogen Protocol is the more specific guidance document, and should have been utilized in the development of the TMDL. (1)

Response 2.
The USEPA guidance document "Protocol for Developing Pathogen TMDLs" establishes an organizational framework for states to utilize in the development of pathogen TMDLs. These TMDLs have been developed consistent with the protocol, even though this was not specifically stated in the document.

Comment 3.
There is a blank page in the document, yet there is no explanation for whether this was intentional. (1)

Response 3.
The Department has removed the unintentional, blank page from the document.

Comment 4.
MAELC appreciates the effort put into the source assessment. (1)

Response 4.
The Department appreciates MAELC support.

Comment 5.
The Department does not state when the waterbodies included in the LAR were first listed as impaired yet in some cases it relies on data from 1992. If the water bodies were not impaired when this data was gathered then it would not reflect the impairment for which this TMDL is to address. To ensure that accurate data is being used to develop this TMDL, the Department must use recent data. (1)

Response 5.
Local Area Report summaries were included to provide background information on water quality conditions, pollution sources, and watershed characteristics. Recent shellfish monitoring data collected by the Department (data period: 1980-2004) and updated source information (marina locations, land use data, and other geographic information) were used to develop these TMDLs. These TMDLs, therefore, reflect the most current data available.

Comment 6.
Although the Department, in Table 8, provides the sum of the WLAs for each waterbody, it has failed to list the WLA for each individual point source, including NJPDES permit holders and Tier A municipality point sources, as required by the Regulations. (1)

Response 6.
As stated in the document, wastewater discharges in the affected waterbodies (listed individually in Appendix B) are considered de minimus sources and have each been assigned a WLA of zero, with no change in the effluent limit of 200 cfu/ml. Tier A municipalities (identified individually in Appendix C) have each been assigned the percent reduction assigned to all reduceable sources. This method of assigning WLAs to MS4 sources is accepted by EPA, as described in the document.

The distinction is that the point sources receive the reduction as a WLA, while nonpoint sources receive the reduction as a LA.

Comment 7.

Although each individual permit holder may meet the SWQS, the cumulative effect may be causing the impairment of the water. The permit holders are consistently below the permit limits. MAELC suggests that the permit limitations be reduced so that the permit holders are held to a lower standard on a regular basis. (1)

Response 7.

In TMDL development, the worst case condition was considered for wastewater discharges, that is the load is assumed to equal the effluent limit at the permitted flow. The calculated contribution from these sources was compared to the TMDL load calculated for each waterbody. Wastewater facilities were found to have negligible fecal coliform contributions even at their maximum potential discharge.

Comment 8.

The Department must provide assurances that NJPDES permitted facilities will comply with their permits in the future. (1)

Response 8.

The Department maintains an effective compliance and enforcement program. Both the Department and the entities maintaining the wastewater treatment and collection systems routinely respond to unauthorized discharges as they are identified, including remedial measures and fines.

Comment 9.

The NJPDES permits provide limitations for fecal coliform; however, they do not specify limitations for total coliform. While fecal coliform is addressed in a total coliform limit, total coliform is not addressed in a fecal coliform limit. Because the impairment is for total coliform, NJPDES limitations on total coliform should be established. (1)

Response 9.

Commenter is correct in that fecal coliform is a subset of total coliform. Fecal coliform are bacteria that live in the digestive tract of warm-blooded animals (humans, pets, farm animals, and wildlife) and are excreted in the feces. Total coliform include bacteria that live in the soil and are not necessarily associated with fecal material. Both total and fecal coliform bacteria are used as indicators of the potential presence of disease-causing organisms, which are generally present in such minute amounts they are not easily monitored for directly. Because the source in question (wastewater treatment facilities) derives from human waste, fecal coliform is the more appropriate indicator when establishing effluent limits.

Comment 10.

MAELC assumes that by "malfunctioning sewage conveyance systems the Department is referring to combined sewer overflows, which should be a point source, not a nonpoint source. (1)

Response 10.
The term refers to broken pipes and pumping facilities, which are episodic, unplanned events that are immediately corrected and do not figure into either load or wasteload allocations.

Comment 11.
The Department fails to state where the runoff volume figures were derived. (1)

Response 11.
The WTM model calculates the annual runoff volume for each watershed based on annual average (or median) rainfall data (inches/year). Annual median rainfall estimates were derived from the rainfall data collected at NOAA weather stations (for the period of record) within or proximate to these watersheds.

Comment 12.
After examination of the WTM's User Manual, MAELC was unable to reconcile the figures and land uses listed in Table 5. (1)

Response 12.
The bacteria loading coefficients presented in Table 5 are the default values used in the WTM model. The online WTM user's manual references the WTM model spreadsheet in the introductory statement and also provides a download link to the spreadsheet. A loading coefficient for barren lands was not included in the WTM model; therefore, an estimated value was used for this land use category.

Comment 13.
The Department does not state what the load capacity is or how such a figure was calculated. There is no way to verify the accuracy of the TMDLs. (1)

Response 13.
The TMDL that was calculated for each waterbody defines the loading capacity, which is the amount of pollutant loading that a waterbody can receive without violating water quality standards. TMDLs were developed based on comparing current bacteria levels to National Shellfish Sanitation Program (NSSP) criteria for total coliform. Source load reductions necessary to meet these TMDLs (i.e. loading capacity) were calculated and are presented in Table 8 and Table 9 of these reports.

Comment 14.
The Department does not offer a timeframe for implementing the proposed implementation management strategies, including a timeframe for when the control measures are to be phased in under the Municipal Stormwater permitting program. The Department should fast-track the MS4 program for these waterbodies to implement the reductions through MS4 permits. (1)

Comment 15.
Clean Ocean Action commends NJDEP for setting over 48 TMDLs in 6 watershed management areas, but achievement of the needed reductions is not ensured because of the lack of detailed information on monitoring, implementation, and enforcement strategies. Because several different

“potentially responsible entities” will need to implement management strategies to meet the TMDL for each waterbody, it is imperative that NJDEP elaborate as to the specific actions in TMDL implementation to be taken for success, including the Division of the NJDEP that will be taking on these responsibilities. It is also essential that this program be adequately funded with a dedicated staff person. (2)

Comment 16.

It appears that the TMDLs will be implemented primarily through the Municipal Stormwater Regulation Program. The rules for this program provide for “additional measures” which can be required by, among other things, a TMDL approved or established by EPA. The TMDLs must be included in each municipal permit as an additional measure and must, therefore, include BMPs that are required to be implemented with measurable goals for each BMP, and a specific timeframe in which to complete the implementation of the BMPs. (2)

Comment 17.

There are neither timelines on when required reductions must be achieved, nor any enforcement provisions when a waterbody fails to achieve the required reduction. These deficiencies make it impossible to for the NJDEP to effectively manage the responsible entities and enforce these mandated fecal coliform concentration reductions. If the NJDEP finds that enforcement is not appropriate, they must identify specific follow-up action that will be required to successfully achieve the imposed TMDLs. (2)

Response to Comments 14 through 17.

New Jersey has a long history of improvement for coastal waters. Between 1978 and 2003, the area of New Jersey’s harvestable shellfish waters have increased 16%, or from 74% to 90%. The rate of improvement over the past 10 years has been, roughly, a 0.4%per year increase in “Approved” waters. The commenter is correct that, going forward, the primary means to implement the TMDLs is through the municipal stormwater regulation program. As described in 7.0 Implementation section of the TMDL, the Statewide Basic Requirements implement various control measures that should substantially reduce bacteria loadings, including measures to eliminate “illicit connections” of domestic sewage and other waste to the MS4s, adopt and enforce a pet waste ordinance, prohibit feeding of unconfined wildlife on public property, clean catch basins, perform good housekeeping at maintenance yards, and provide related public education and employee training. Upon implementation, these requirements are expected to be highly effective in controlling inputs of total coliform load into the waterbodies. The implementation schedule for the municipal stormwater regulation program has already been set forth in rules and can be found at www.njstormwater.org. The Department believes that this schedule is sufficiently aggressive and would note that the Statewide basic requirements are currently operative. “Additional measures” as provided for in the rules are those that are identified to be needed, beyond the basic requirements, to address water quality problems. No “additional measures” have been identified at this time, therefore, the statement that BMPs with associated goals and timeframes must be identified is incorrect. Through the effectiveness monitoring, it may be determined that the objective of the TMDLs has not been met. Adaptive management would then call for consideration of additional measures at that time.

The remaining elements of the plan for attaining the designated use will proceed over time and may be adjusted, as needed, through adaptive management, to respond to results of the shellfish waters classification monitoring program. Data is collected and assessed continually throughout the year, and will inform further development and/or refinement of management measures to implement the TMDLs. The Department is continually working through its watershed management initiative to implement nonpoint source reduction strategies within the 20 watershed management areas, consistent with established TMDLs, using available resources. The TMDL documents provide the basis upon which regulatory action can be taken to implement management strategies and to prioritize funding for water quality improvement. The Department has been and continues to target available resources, like the 319(h) grant program, Corporate Business Tax (CBT) revenues, and allied grant programs for agricultural areas (EQIP, CRP and CREP) to address sources in the impaired areas for which TMDLs were completed. Follow up monitoring will determine where efforts need to be stepped up or redirected to attain the designated use. Finally, the TMDL process and adoption of the TMDLs as amendments to the applicable areawide Water Quality Management Plans (WQMPs) is significant because it assures that plan amendments and permitting throughout the Department are consistent with the TMDLs. For example, implementation of septic management districts may be required through wastewater management plan updates where septic system sources are identified.

The overall implementation plan, while relying on monitoring, permitting and enforcement programs as well as funding sources available within and outside of the Department, is coordinated through the Division of Watershed Management, which has dedicated resources to this purpose.

Comment 18.

The proposed amendments fail to incorporate management strategies to systematically monitor and improve TMDL compliance. Adequate and continual assessment of the implemented TMDLs must happen to ensure that loadings are reduced. Sections 6.0 and 7.0, addressing follow-up monitoring and implementation, do not explicitly require regular monitoring in all listed waterbodies or a schedule to assess the effectiveness of the TMDLs through monitoring. It is strongly urged that DEP include in the proposed amendments the requirement to perform regular monitoring on all listed waterbodies and a timeline for using these data in trend analyses to assess the effectiveness of the TMDL implementation. (2)

Response 18.

The Department's Bureau of Marine Water Monitoring conducts extensive sampling in the shellfishing waterbodies addressed in this TMDL report. Trend analysis of water quality for shellfish classification is performed throughout the year and will also be used to assess effectiveness of TMDL implementation.

Comment 19.

In general we strongly support the Department's efforts to document declining water quality throughout the coastal zone, estuaries, and shellfish areas. Providing scientific evidence of water quality degradation and developing management and implementation strategies to improve the situation are needed for estuarine recovery. The data show that over time, resources like harvestable shellfish waters can recover and we applaud the Department for this proposal which could, if forcefully implemented, lead to continued estuarine recovery. We support numerical thresholds for resolving impairments and believe integration of these standards into the WQM plan and Stormwater Management programs is the right step toward implementation. However, the TMDLs lack specific requirements for coordinated regulatory, regional and municipal implementation, without which land use decisions will continue to undermine plans for water quality improvement.

Studies show development and increasing impervious cover is directly linked to diminishing water quality in our bays and estuaries. Natural resource capacity is currently not reflected in permitting and planning in the coastal zone, including in establishing Coastal Centers and in the cross-acceptance/endorsed plan process. The Department must require that these TMDLs are integrated into the policies and permitting decisions made by other agencies and by all sections of the Department as scientifically verified and appropriate limits on how much growth is sustainable and where growth should go. In particular, the Land Use Regulation Program (LURP), the Division of Watershed Management, the Office of Policy and Planning and the Coastal Management Program must work collaboratively to ensure that decisions affecting coastal watersheds are consistent with capacity limits that will achieve water quality objectives. No permits should be issued for land uses that threaten shellfish waters and there should be no further extension of sewer service area to support center-based development in sensitive coastal watersheds.

Also needed is a fully funded watershed area management plan in which State-sponsored stakeholders in every coastal county are charged with integrating TMDLs into regional and local stormwater management plans and local ordinances. Additional funding for stormwater plans is needed as well. Monitoring and implementation of TMDLs at the local level could assist the Department to increase the frequency of monitoring for those waterbodies. In this way, problems could be more quickly identified, and Sublist 5 could be more quickly updated and the risks to the public health could be reduced. Regulatory requirements in both the Stormwater Management and Surface Water Quality Protection programs must also be strengthened so that counties and municipalities can be held accountable for land use decisions that undermine the specific TMDL standards and/or the intent and purpose of this proposed shellfish water quality recovery program. Recognizing 2006 budget constraints, alternatively, funding benefits in other programs should be linked to completion of updated Plans and in so doing direct that municipalities take steps in both land use planning and stormwater management to implement these proposed TMDLs. (3)

Response 19.

In general, TMDLs have certain regulatory authority that is applied to advance implementation strategies. For example, NJPDES permits may have requirements added as specified in a TMDL to achieve load reductions. In addition, once adopted as an amendment to the applicable Water Quality Management Plan, State permits must be consistent with the findings of a TMDL. These TMDLs do not establish any capacity limitations, as it is expected that the measures identified will control new sources as well as existing sources. The suggestion that there be no further sewer service provided in coastal areas may be counter productive, as some closure areas are so designated because of high density development served by septic systems. If these systems are failing, sewer installation may be an appropriate solution to address the problem and should not be discounted out of hand. Other implementation measures require voluntary participation, encouraged and assisted by the Department's watershed management program and funding programs managed by the Department (CBT, 319(h), 604(b) and the Environmental Infrastructure Financing Program) and other agencies (Farm Bill programs). As stated by the commenter, the 2006 budget does not allow for funding beyond that which has already been provided to assist municipalities to implement the stormwater regulation requirements. The watershed management program has resources dedicated to coordinating the Department's and other agencies activities aimed at implementing the TMDLs. The Department welcomes assistance provided by watershed partners, such as monitoring, and uses quality data provided by partners in assessing water quality throughout the State. As previously stated, if the implementation of identified measures is found to be inadequate to achieve support of designated uses, additional measures, which would become enforceable requirements of stormwater permits, will be considered.

Comment 20.
To enhance implementation, TMDL segments should be designated as C1 waters, thereby receiving larger buffer protection and more aggressive anti-degradation thresholds. C1 thresholds should be revised to include Cedar Creek (portions of which are already FW1 and SE1), the Mullica River (portions of which are already C1 and SE1), and the Cohansey River (portions of which are already SE1). C1 designation would allow greater control over uplands and feeder streams, development of which harms downstream and estuarine water quality. (3)

Response 20.
The Department concurs that riparian buffers are important for water quality protection/restoration and riparian restoration is identified as one of the measures needed to implement the TMDLs. None of the above listed waters were officially petitioned for upgrade to C1. The Department periodically evaluates waters and designates C1antidegradation designation for those that qualify through a rulemaking process. Waters designated as C1 and the mapped tributaries within the CI subwatershed have 300-foot Special Water Resource Protection Areas within which future development is regulated. However, designation as C1 will not effect restoration of currently developed/disturbed buffers. This will be accomplished through voluntary projects undertaken with State and other resources. Furthermore, antidegradation policies apply to C2 waters as well. A lowering of water quality is only allowed if alternatives that avoid a lowering are infeasible and a socio-economic justification warrants a lowering, but not below the Surface Water Quality Criteria. In any case, the Surface Water Quality Standards rules provide for changing a stream designation at N.J.A.C. 7:9B, which includes a petition option that the commenter may choose to exercise.

Comment 21.
Regarding marina sources, we urge the Department to not just encourage but require more marinas to engage in the Clean Marina Program. This strategy requires no additional funding by using more aggressive, perhaps mandatory, participation or compliance requirements. (3)

Response 21.
The Department will explore options to increase funding to further encourage participation in the Clean Marina Program. Requiring individual marina enrollment could be used, on a case by case

basis, when impairment is directly linked to marina operation. The cost of comprehensive statewide marina enrollment is likely to be prohibitively high for marina owners.

Comment 22.

Because public participation plays a key role in TMDL development, MAELC suggests TMDLs be geared towards laypeople by providing a more user friendly approach in regard to data analysis and explanations. (1)

Response 22.

The Department endeavors to make each TMDL report understandable and also provides multiple opportunities through presentations of methodology and results to aid public understanding and to obtain feedback. The Department would welcome any specific recommendations that would enhance understanding of the TMDL information.

Comment 23.

MAELC is disappointed that multiple water body segments are addressed in a single TMDL and that the language within all of February's proposed TMDLs is verbatim. (1)

Response 23.

The Department aims to maximize efficiency in conveying the outcomes of TMDL studies. Where information and methodologies are the same it is logical to consolidate those aspects, rather than generate a large number of repetitious written materials. Wherever information is unique, it is conveyed, such as by providing separate maps, calculations, local area report information, ongoing projects tailored to the applicable area. The documents proposed are clearly not "verbatim" except where the information to be conveyed is the same, such as the introductory remarks and the process description.

Amendment to the
Tri-County Water Quality Management Plan

Total Maximum Daily Loads for Total Phosphorus
To Address Four Streams Segments and Two Lakes in
Cooper River Watershed, Camden County
Lower Delaware Water Region

Watershed Management Area 18
COOPER RIVER AT LINDENWOLD
COOPER RIVER AT LAWNSIDE
COOPER RIVER AT HADDONFIELD
NORTH BRANCH COOPER RIVER AT KRESSON
COOPER RIVER LAKE
EVANS POND and WALLWORTH LAKE

Proposed: **April 19, 2004**
Established: **August 25, 2004**
Approved (by EPA Region 2): **September 30, 2004**
Adopted:

New Jersey Department of Environmental Protection
Division of Watershed Management
P.O. Box 418
Trenton, New Jersey 08625-0418

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1.0 Executive Summary

In accordance with Section 305(b) of the Federal Clean Water Act (CWA), the State of New Jersey developed *2002 Integrated List of Waterbodies* (35 N.J.R. 470(a), January 21, 2003. Three (3) stream segments in the Cooper River Watershed were listed as being phosphorous impaired, as indicated by elevated total phosphorus (TP). The *Proposed* 2004 *Integrated List of Waterbodies* (36 N.J.R. 1238(b) March 1, 2004) identified one (1) additional impaired segment for phosphorus in this watershed. The proposed amendment to the Tri-County Water Quality Management Plan will establish four total maximum daily loads (TMDLs) for TP that address phosphorus impairment of the stream segments as listed in Table 1. In addition, two TMDLs for TP will be established that address phosphorus impairment of the three lakes in the Cooper River watershed as listed in Table 2. A TMDL for Kirkwood Lake was previously established and will be integrated with these six TMDLs.

Table 1 Phosphorus-impaired stream segments of the Cooper River for which phosphorus TMDLs are being established.

TMDL Number	WMA	Station Name/Waterbody	Site ID	County(s)	River Miles
1	18	Cooper River at Lindenwold	01467120	Camden	1.6
2	18	Cooper River at Lawnside	01467140	Camden	13.6
3	18	Cooper River at Haddonfield	01467150	Camden	1.0
4	18	Cooper River N Br at Kresson	01467155	Camden, Burlington	9.0
Total River Miles					25.2

Table 2 Phosphorus-impaired lakes in the Cooper River Watershed for which phosphorus TMDLs are being established.

TMDL Number	WMA	Lake Name	Municipality (ies); Camden County	Acres
5	18	Cooper River Lake	Camden City, Pennsauken Township, Collingswood Borough, Haddonfield Borough, Cherry Hill Township	192.1
6	18	Evans Pond and Wallworth Lake*	Haddonfield Borough, Cherry Hill Township	17.9
	18	Kirkwood Lake **	Voorhees Township, Lindenwold Borough	24.9

* Added to the report based on monitoring data from stations upstream an downstream
** Moved to Sublist 4a in the draft 2004 Integrated List of Waterbodies

These six TMDLs identify sources of phosphorus and establish load reductions required in order to attain applicable surface water quality standards (SWQSs).

In order to prevent excessive primary productivity[1] and consequent impairment of recreational, water supply and aquatic life designated uses, the SWQS define both numerical and narrative criteria that address eutrophication in lakes due to overfertilization. Phosphorus sources were characterized on an annual scale (kg TP/yr) for both point and nonpoint sources. Runoff from land surfaces comprises a substantial source of phosphorus into streams and lakes.

The lakes were selected as the critical locations for all six TMDLs. It was determined that this approach would also ensure attainment of the SWQS for the impaired stream segments. An empirical model was used to relate annual phosphorus load and steady-state in-lake concentration of total phosphorus. To achieve the TMDLs, overall load reductions were calculated for six source categories. In order to track effectiveness of remediation measures (including TMDLs) and to develop baseline and trend information on lakes and streams, the Department will augment its ambient monitoring program to include lakes on a rotating schedule. The implementation plan also calls for the collection of additional monitoring data and the development of a Lake Restoration Plan for each lake for which a TMDLis being established. These plans will consider what specific measures are necessary to achieve the nutrient reductions required by the TMDL as well as what in-lake measures need to be taken to supplement the nutrient reductions required by the TMDL.

Each TMDL shall be proposed and adopted by the Department as an amendment to the Tri-County Water Quality Management Plan in accordance with N.J.A.C. 7:15-3.4(g).

This TMDL Report is consistent with EPA's May 20, 2002 guidance document entitled: "Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992," (Sutfin, 2002), which describes the statutory and regulatory requirements for approvable TMDLs.

2.0 Introduction

Sublist 5 (also known as the 303(d) List) of the State of New Jersey's *Proposed 2004 Integrated List of Waterbodies* identified several waterbodies in the Cooper River watershed, Lower Delaware Water Region, as being impaired by phosphorus, as evidenced by the presence of total phosphorus at concentrations in excess of the standards. This report establishes six TMDLs, which address phosphorus loads to the identified waterbodies. This TMDL document includes management approaches or restoration plans to reduce loadings of total phosphorus from various sources in order to attain applicable surface water quality standards for total phosphorus. The segments addressed in this document are listed on Sublist 5 for impairment caused by other pollutants; these TMDLs address only total phosphorus impairments. Separate TMDL evaluations will be developed to address the other pollutants of concern. The waterbodies will remain on Sublist 5 with respect to other impairments until such time as TMDL evaluations for all pollutants have been completed and approved by EPA. With respect to the total phosphorus impairments, the waterbodies will be moved to Sublist 4 following approval of the TMDLs by USEPA.

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[1] Primary productivity refers to the growth rate of primary producers, namely algae and aquatic plants, which form the base of the food web.

A TMDL is considered "proposed" when The Department publishes the TMDL Report as a proposed Water Quality Management Plan Amendment in the New Jersey Register (NJR) for public review and comment. A TMDL is considered to be "established" when the Department finalizes the TMDL Report after considering comments received during the public comment period for the proposed plan amendment and formally submits it to EPA Region 2 for a thirty (30)-day review period. The TMDL is considered "approved" when the TMDL is approved by EPA Region 2. The TMDL is considered to be "adopted" when the approved TMDL is adopted by the Department as a water quality management plan amendment.

3.0 Background

A TMDL represents the assimilative or carrying capacity of a waterbody, taking into consideration point and nonpoint sources of pollutants of concern, natural background and surface water withdrawals. A TMDL quantifies the amount of a pollutant a waterbody can assimilate without violating a state's water quality standards and allocates that load capacity to known point sources in the form of wasteload allocations (WLAs), nonpoint sources in the form of load allocations (LAs), and a margin of safety. A TMDL is developed to identify all the contributors to surface water quality impacts and set load reductions for pollutants of concern as necessary to meet SWQS.

The Federal Clean Water Act under Section 303(d) requires states to identify "Impaired Waters" where specific designated uses are not fully supported. For these waters, the state is required to establish total maximum daily loads (TMDLs) in accordance with a priority ranking. To carry out this mandate, the Department prepares a list of impaired waters. Section 305(b) of the Act also requires states to periodically assess and report on the overall quality of their waters. Historically, the Department has summarized the water quality of the state in a biennial report entitled New Jersey's Water Quality Inventory Report (also known as the 305b Report). EPA issued guidance that encouraged states to integrate the two reports into a single report. Beginning with the *2002 Integrated List of Waterbodies*, the Department opted to use the single report approach.

In July 2003, EPA again issued guidance for the 2004 reports that encouraged states to integrate the 305(b) Report and the 303(d) List into one report. The Department has updated the *2002 Integrated Water Quality Monitoring and Assessment Methods Document*. This document includes a description of the quality assurance requirements as well as the rationale for the placement of waterbodies in Sublists 1 through 5. The *2004 Integrated List of Waterbodies* will be submitted to the EPA for approval as part of the *2004 Integrated Water Quality Monitoring and Assessment Report*.

EPA guidance dated July 21, 2003 describes the statutory and regulatory requirements for approvable TMDLs, as well as additional information generally needed for EPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations. The Department believes that this TMDL report, which includes six TMDLs, addresses the following components:

1. Identification of waterbody(ies), pollutant of concern, pollutant sources and priority ranking.

2. Description of applicable water quality standards and numeric water quality target(s).
3. Loading capacity – linking water quality and pollutant sources.
4. Load allocations.
5. Wasteload allocations.
6. Margin of safety.
7. Seasonal variation.
8. Reasonable assurances.
9. Monitoring plan to track TMDL effectiveness.
10. Implementation (EPA does not require and does not approve TMDL implementation plans).
11. Public Participation.

4.0 Pollutant of Concern and Area of Interest

The pollutant of concern for these TMDLs is phosphorus. The mechanism by which phosphorus can cause use impairment is via excessive primary productivity. Phosphorus is an essential nutrient for plants and algae, but can be considered a pollutant because it can stimulate excessive growth (primary production). Phosphorus is most often the major nutrient in shortest supply relative to the nutritional requirements of primary producers in freshwater systems. Consequently, phosphorus is frequently a prime determinant of algal activity in a stream or lake. Eutrophication has been described as the acceleration of the natural aging process of surface waters. It is characterized by excessive loading of silt, organic matter, and nutrients, causing high biological production and decreased basin volume (Cooke et al, 1993). Symptoms of eutrophication (primary impacts) include oxygen super-saturation during the day, oxygen depletion during the night, and high sedimentation (filling in) rate. Algae and aquatic plants are the catalysts for these processes. Secondary biological impacts can include loss of biodiversity and structural changes to communities.

As a result of monitoring conducted by the Department, TP concentrations were found to exceed New Jersey's SWQS, published at N.J.A.C. 7-9B et seq., for the stream segments and lakes in the Cooper River Watershed as identified in Table 2. The State of New Jersey's 2002 *Integrated List of Waterbodies* (35 N.J.R. 470 (a), January 21, 2003), identifed three stream segments in the Cooper River Watershed as being phosphorus impaired. These impairments were carried over to the Proposed 2004 *Integrated List of Waterbodies* (36 N.J.R. 1238(b), March 1, 2004), which also identifed one additional impaired segment for phosphorus. These TMDLs address four phosphorus impaired stream segments from Sublist 5 and one phosphorus impaired lake from Sublist 3 (Cooper River Lake). In addition, based on monitoring data from stations upstream and downstream, the Department has determined that the Evans Pond and Wallworth Lake system are impaired and will prepare a TMDL for these waterbodies as well. These two artificial lakes were formed in 1913 by building two consecutive dams on the Cooper River (see Appendix G). A TMDL was proposed for Kirkwood Lake (35 N.J.R. 1727(a), April 21, 2003) and subsequently approved by EPA Region 2 on September 30, 2003 (written communication); the Department has integrated this lake TMDL with the current proposed TMDLs for continuity in addressing the phosphorus impairments in the Cooper River watershed.

Table 3 Phosphorus-impaired sites in the Cooper River Watershed for which phosphorus TMDLs are being established.

TMDL No	Station Name/Waterbody	Site ID	Lake Area	River Miles	Management Response
1	Cooper River at Lindenwold	1467120	--	1.6	establish TMDL
2	Cooper River at Lawnside	1467140	--	13.6	establish TMDL
3	Cooper River at Haddonfield	1467150	--	1.0	establish TMDL
4	Cooper River N Br at Kresson	1467155	--	9.0	establish TMDL
5	Evans Pond and Wallworth Lake	--	17.89	--	establish TMDL
6	Cooper River Lake	--	192.1	--	establish TMDL
	Kirkwood Lake	--	24.91	--	TMDL established in 2003, in 2004 proposed to move to Sublist 4

These six TMDLs will address 25.2 river miles and 235 acres of lake surface area with a corresponding total of 22,500 acres of land within the affected watershed. Together with the established TMDLs for Kirkwood Lake, these TMDLs will cover the entire non-tidal part of the Cooper River watershed. The implementation plans also will be developed to address phosphorus reduction for the whole non-tidal Cooper River watershed. Segments that appear on the 2002 Integrated List were identified as Medium Priority (1, 2 and 3); segments that appear on the 2004 Integrated List were identified as High Priority (1, 3 and 4). The lakes for which TMDLs have been developed (5 and 6) were on Sublist 3 or not listed and were not ranked.

Data Sources

The Department's Geographic Information System (GIS) was used extensively to describe the Cooper River Watershed characteristics. In concert with the USEPA's November 2001 listing guidance, the Department is using Reach File 3 (RF3) from the 2002 Integrated Report to represent rivers, stream, lakes and lakesheds (watersheds of the lakes). The following is general information regarding the data used to describe the watershed management area:

- 1995/97 Land use/Land cover Update, published 12/01/2000 by NJDEP Bureau of Geographic Information and Analysis, delineated by watershed management area.
- Lakes 2003, Lakes Coverage, NJDEP - Bureau of Freshwater and Biological Monitoring, upublished coverage, created March 2003.
- 2004 Assessed Rivers coverage, NJDEP, Watershed Assessment Group, unpublished coverage.

- NJPDES Surface Water Discharges in New Jersey, (1:12,000), published 02/02/2002 by Division of Water Quality (DWQ), Bureau of Point Source Permitting - Region 1 (PSP-R1).
- County Boundaries: Published 11/01/1998 by the NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), "NJDEP County Boundaries for the State of New Jersey." Online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/stco.zip
- Detailed stream coverage (RF3) by County: Published 11/01/1998 by the NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA). "Hydrography of Camden County, New Jersey (1:24000)." Online at: http://www.state.nj.us/dep/gis/digidownload/zips/strm/
- NJDEP Existing Water Quality Stations in New Jersey, published 5/12/2003, NJDEP, Division of Land Use Management (LUM), Water Monitoring & Standards, Bureau of Freshwater Biological Monitoring (BFBM)
- http://www.state.nj.us/dep/gis/digidownload/zips/statewide/ewqpoi.zip
- NJDEP Ambient Stream Quality Monitoring Sites, published 5/30/2001, NJDEP , Bureau of Freshwater Biological Monitoring (BFBM), http://www.state.nj.us/dep/gis/digidownload/zips/statewide/swpts01.zip

Lakesheds were delineated based on 14-digit hydrologic unit code coverage (HUC-14) and elevation contours.

- NJDEP 14 Digit Hydrologic Unit Code delineations (DEPHUC14), published 4/5/2000 by New Jersey Geological Survey,
- http://www.state.nj.us/dep/gis/digidownload/zips/statewide/dephuc14.zip.
- NJDEP Hillshade Grid for New Jersey (100 meter), published 05/01/2002, Department of Environmental Protection (NJDEP), Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/nj100mhill.zip
- Statewide Elevation Contours (10 Foot Intervals), unpublished, auto-generated from: 7.5 minute Digital Elevation Models, published 7/1/1979 by U.S. Geological Survey.
- NJDEP Statewide Elevation Contours (20 Foot Intervals), published 1987 by Bureau of Geographic Information and Analysis (BGIA), http://www.state.nj.us/dep/gis/digidownload/zips/statewide/stcon.zip.

4.1 Description of the Cooper River Watershed and Impaired Waterbodies

The Cooper River watershed is a part of the Water Management Area 18 (WMA 18) in the Lower Delaware Water Region. The Cooper River watershed encompasses approximately 37 square miles within the WMA 18. The non-tidal mainstem Cooper River extends 16 miles from the Cooper River Parkway Dam, which marks the head of tide, located at Kaighn Avenue in Camden, to Gibbsboro. The river flow direction is generally from southeast to northwest as it empties to the Delaware River at Camden City. The significant tributaries include: North Branch Cooper River, Millard Creek, Woodcrest Creek, and Tindale Run. Land use is primarily urban and suburban as the Cooper River watershed drains the densest populated part of southwestern New Jersey in Camden County. The main urban centers include Camden, Pennsauken, Collingswood, Cherry Hill, Haddonfield, and Haddon Township, which are situated mainly along the Cooper River's main stem and areas adjacent to North Branch Cooper River. Major impoundments include, going upstream from the Cooper River Parkway Dam, Cooper River Lake, Hopkins Pond (on the Cooper River's west tributary), Wallworth Lake, Evans Pond, Kirkwood Lake, Bridgewood Lake, Woodland Lake, Linden Lake, and Edgewood Lake. Figure 1 is provided as a Cooper River watershed overview map. All of the streams in the Cooper River watershed have been classified as FW2 Non-trout.

Figure 1 Spatial extent of the impaired segments in the Cooper River Watershed, WMA 18, for which TMDLs are being developed

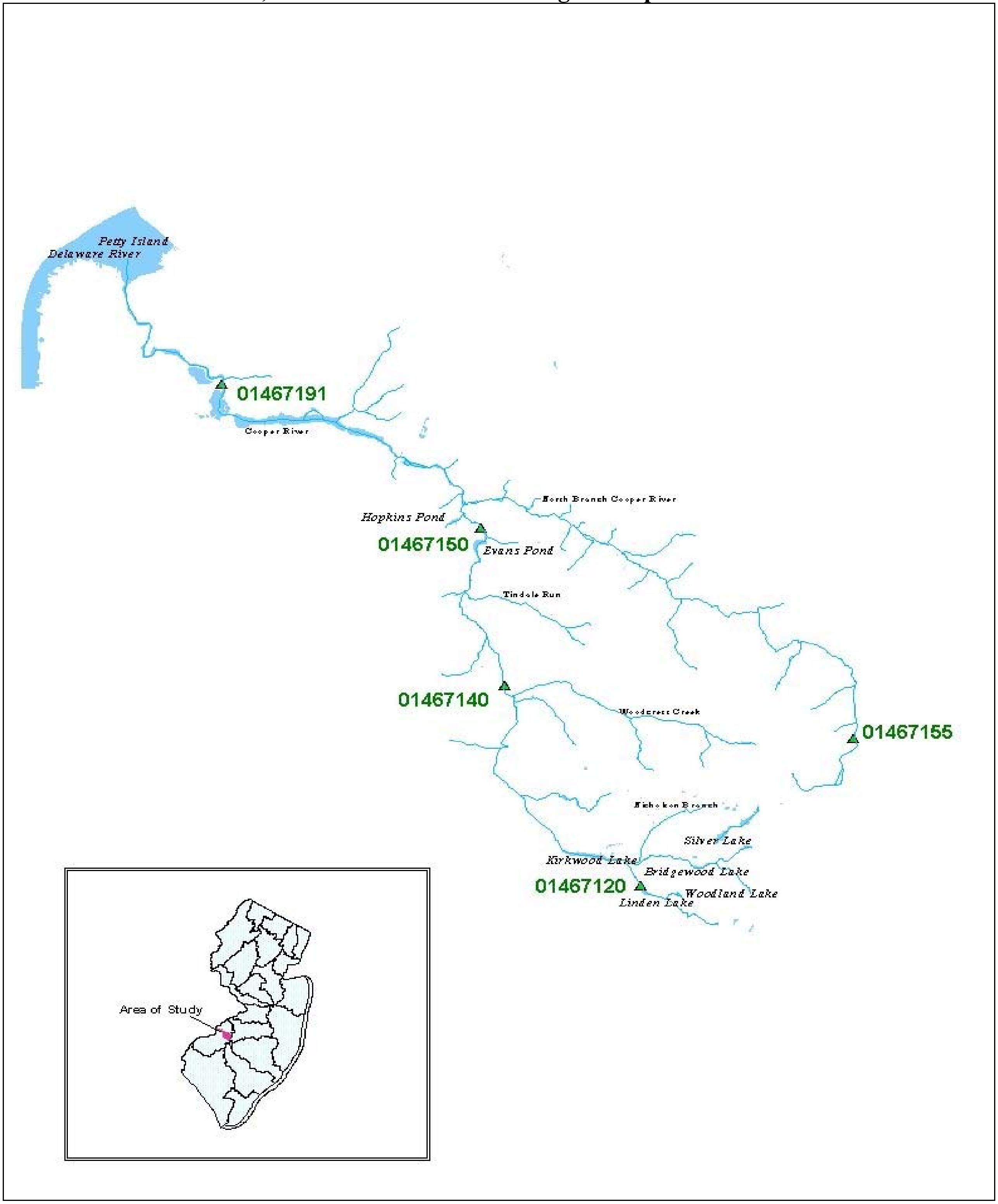


Figure 2 Map of Four Segments in the Cooper River Watershed

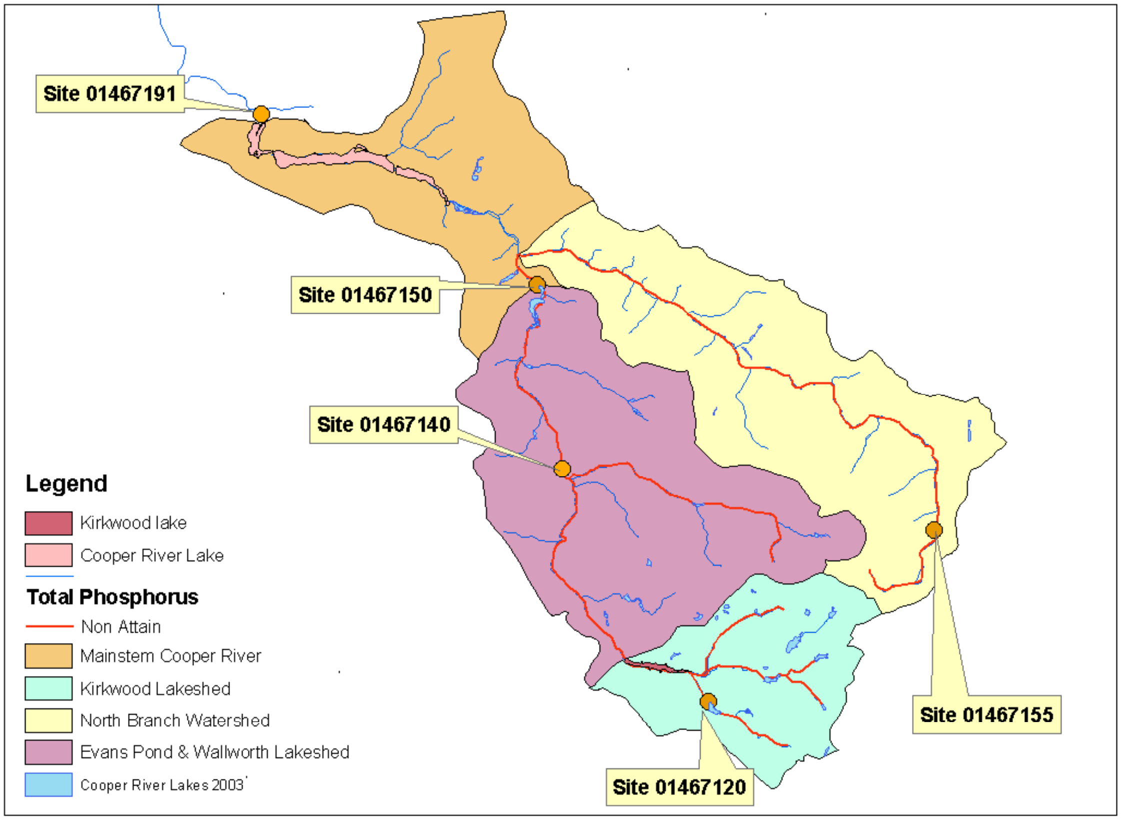


Table 4 Description of the spatial extent of each phosphorus impairment in the Cooper River Watershed, WMA 18

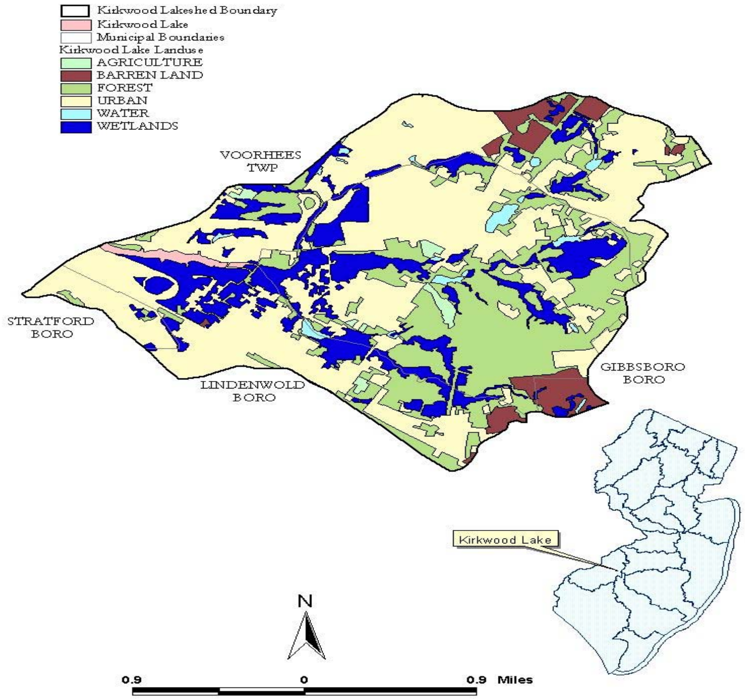
Site Name	USGS Station ID #	River Miles / Lake Area	Description of the impaired segments
Cooper River at Lindenwold	**01467120**	1.6	Cooper River watershed upstream of the Lindenwold monitoring station and downstream portion to the confluence with the Northern parts of the South Branch Cooper River. This stream stretch was covered by 2003 TMDL for Kirkwood Lake.
Cooper River at Lawnside	**01467140**	13.6	South Branch Cooper River segments from Evans Pond to the headwaters excluding most southern segment with Station 01467120 (see above).
Cooper River at Haddonfield	**01467150**	1.0	South Branch Cooper River segment from confluence with the North Branch Cooper River including Evans Pond and Wallworth Lake.
North Branch Cooper River at Kresson	**01467155**	9.0	North Branch Cooper River watershed upstream of the confluence with the Cooper River main stem at Cherry Hill
Cooper River Lake	**01467191**		Cooper River watershed upstream of the Cooper River Parkway Dam located at Kaighn Avenue in Camden. The Station #01467191 is located on the tidal side of the dam and is under tidal influence. This segment covers entire watershed, with the exception of Kirkwood Lake watershed.

Site Name	USGS Station ID #	River Miles / Lake Area	Description of the impaired segments
Wallworth Lake and Evans Pond	**01467150**		Cooper River watershed upstream from the Wallworth Lake dam. This lakeshed includes Evans Pond and excludes Kirkwood Lake watershed. Monitoring station #01467150 is located on the Wallworth Lake
Kirkwood Lake	**01467120**		Cooper River watershed upstream from the outlet of the lake. This lakeshed includes Kirkwood Lake, Linden Lake, Bridgewood Lake, Silver Lake, and Woodland Lake watersheds. It includes segment with the monitoring station #01467120.

4.1.1 Kirkwood Lake

Kirkwood Lake is a small, narrow lake approximately 0.75 miles in length and is located on the boundary of Voorhees and Lindenwold, Camden County. Historically, the lake has been used for fishing, boating and swimming purposes. More recently, these uses have lessened with the associated decrease in water quality. It has a total surface area of 25 acres, a volume of 215,000 m^3, a mean depth of 2.1 m, and a hydraulic detention time of around 8 days (depth and discharge taken from NJDEP 1983). The 3250-acre lakeshed is about 130 times the size of the lake and has a high percentage of urban land use. The primary tributaries to Kirkwood Lake include the Cooper River, Millard Creek, and Nicholson Branch. The USGS station #01467120 phosphorus impaired segment is located in the Kirkwood Lake watershed. A TMDL, already approved by EPA in 2003 for Kirkwood Lake, will address the phosphorus impaired segment at Norcross Road at Lindenwold.

Figure 3 Lakeshed of Kirkwood Lake with Land Use Coverage



4.1.2 Evans Pond and Wallworth Lake

Evans Pond and Wallworth Lake are artificial lakes formed in 1913 by two dams across the Cooper River. Both lakes are located on the boundary of Cherry Hill Township and Haddonfield Borough and bounded by Kings Highway and Brace Road. Evans Pond dam forms a 14-acre lake. The Wallworth Lake dam is located about 0.5 mile downstream from the Evans Pond dam and forms a 3.3-acre lake. A 55.65 acre park known as Wallworth Park surrounds these lakes.

The USGS station #01467150 is located on the northeast side of the Wallworth Lake, close to the dam. Continuous flow data have been collected from 1964 up to the present. Over the years sediment has substantially filled both lakes, decreasing their water capacities. Accumulated bottom sediments may be rich in phosphorus which, under high flow condition, is released to the water column.

4.1.3 Cooper River Lake

The Cooper River Lake was formed in 1940, when the Cooper River Parkway dam was built at Kaighn Avenue in Camden City. The dam prevents tidal flow upstream into Cooper River Lake at high tide, even though the elevation of the Cooper River Lake is lower than the high tide levels. Cooper River Lake is a narrow lake, about two miles long with the surface area approximately 192 acres. It drains a watershed of 37 square miles. The maximum depth is 2.1 m and the average depth is 1.2 m. It is expected that a considerable layer of bottom sediments has accumulated in the lake, decreasing its capacity. Cooper River Park (347 acres) runs along the lake through Pennsauken, Collingswood and Haddon Township. The lake is used for rowing events. A fish ladder has been constructed at the Cooper River dam and in May 1998 the river was stocked with fish.

Figure 4 Evans Pond/Wallworth Lake Watershed

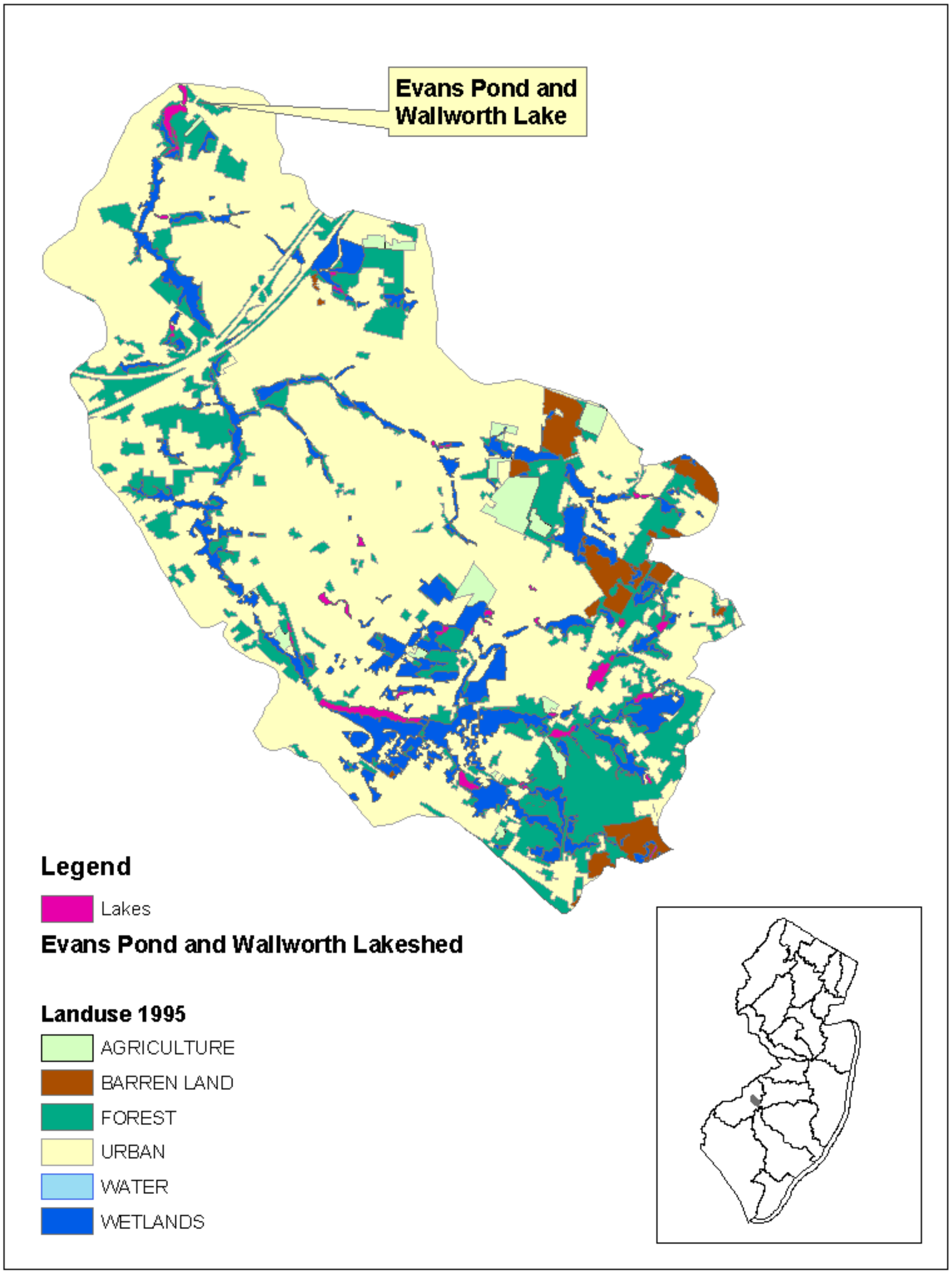
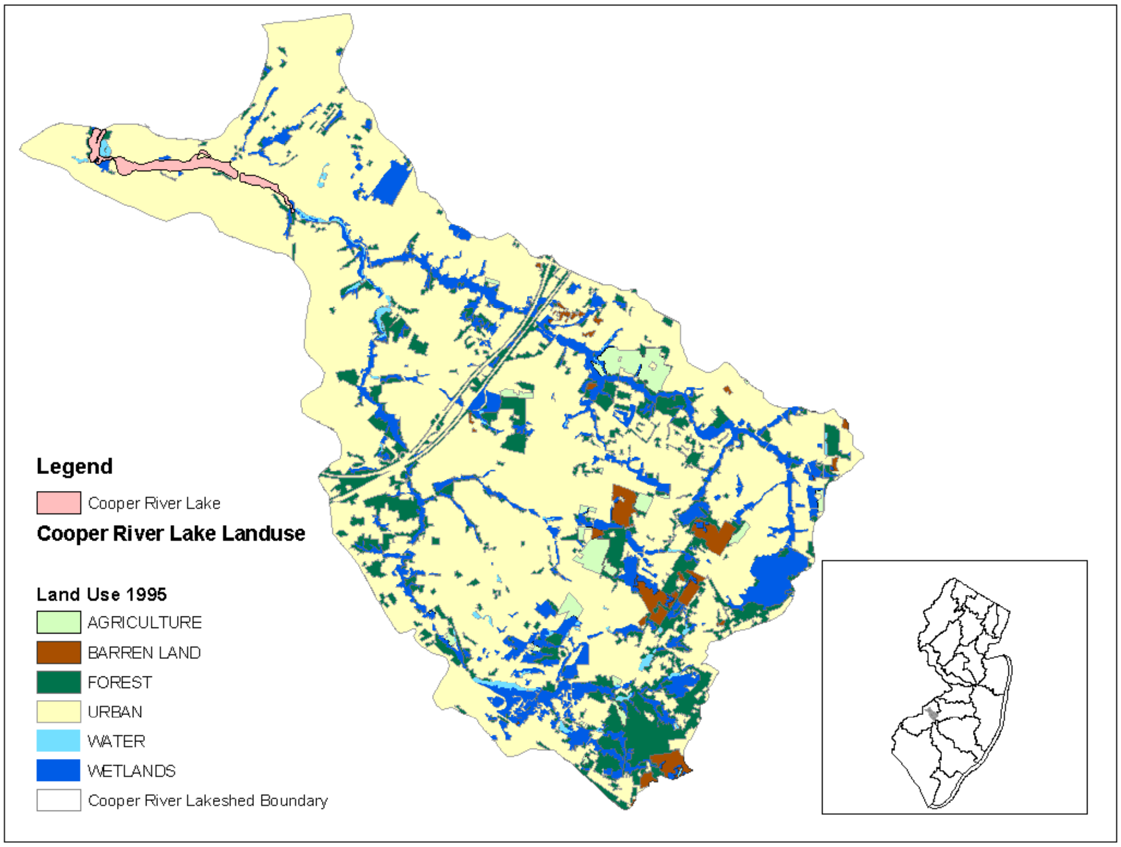


Figure 5 Lakeshed of Cooper River Lake with Land Use Coverage



5.0 Pollutant of Concern and Applicable Surface Water Quality Standards

The pollutant of concern is phosphorus. The standards for phosphorus, as stated in N.J.A.C. 7:9B-1.14(c) of the New Jersey Surface Water Quality Standards (SWQS) for Fresh Water 2 (FW2) waters are:

Phosphorus, Total (mg/l):

i. Lakes: Phosphorus as total P shall not exceed 0.05 in any lake, pond, reservoir, or in a tributary at the point where it enters such bodies of water, except where site-specific criteria are developed pursuant to N.J.A.C. 7:9B-1.5(g)3.

ii. Streams: Except as necessary to satisfy the more stringent criteria in paragraph i. above or where site-specific criteria are developed pursuant to N.J.A.C. 7:9B1.5(g)3, phosphorus as total P shall not exceed 0.1 in any stream, unless it can be demonstrated that total P is not a limiting nutrient and will not otherwise render the waters unsuitable for the designated uses.

Also as stated in N.J.A.C. 7:9B-1.5(g)2:

Nutrient policies are as follows:

> Except as due to natural conditions, nutrients shall not be allowed in concentrations that cause objectionable algal densities, nuisance aquatic vegetation, or otherwise render the waters unsuitable for the designated uses.

The impaired waterbodies covered under these TMDLs have a FW2 classification. The designated uses, both existing and potential, that have been established by the Department for waters of the State classified as such are as stated below:

> In all FW2 waters, the designated uses are (NJAC 7:9B-1.12):
> 1. Maintenance, migration and propagation of the natural and established aquatic biota;
> 2. Primary and secondary contact recreation;
> 3 Industrial and agricultural water supply;
> 4. Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation and sedimentation, resulting in substantial particulate removal but no consistent removal of chemical constituents) and disinfection; and
> 5. Any other reasonable uses.

6.0 Source Assessment

In order to evaluate and characterize total phosphorus loadings in the waterbodies of interest in these TMDLs, and thus propose proper management responses, source assessments are warranted. Source assessments include identifying the types of sources and their relative contributions to total phosphorus loadings, in both time and space variables. Phosphorus sources were characterized on an annual scale (kg TP/yr). Long-term pollutant loads are typically more critical to overall lake water quality than the load at any particular short-term time period (e.g. day). Storage and recycling mechanisms in the lake, such as luxury uptake and sediments dynamics, allow phosphorus to be used as needed regardless of the rate of delivery to the system. Also, empirical lake models use annual loads rather than daily or monthly loads to estimate in-lake concentrations.

6.1 Assessment of Point Sources other than Stormwater

By 1996, all municipal and industrial discharges to the Cooper River watershed were eliminated. A total of thirty-nine individual sewage treatment plants, previously discharging inadequately treated effluent into the Cooper River and its tributaries, were connected to the upgraded and expanded Camden County Municipal Utility Authority (CCMUA) facility located in Camden City, which discharges to the Delaware River. As a result of these changes, overall surface water quality has improved in the Cooper River watershed; however, the monitoring data still indicate phosphorus impairment in the Cooper River watershed.

6.2 Assessment of Nonpoint and Stormwater Point Sources

Nonpoint and stormwater point sources include storm-driven loads such as runoff from various land uses that transport phosphorus from sources such as geese, farms, and domestic pets to the receiving water. The phosphorus deposited in the lakes and streams sediments could be an additional source of phosphorus released to the water column under certain conditions. Domestic pet waste, geese waste, as well as loading from storm water detention basins and sediments will be addressed by the Phase II MS4 program. Nonpoint sources also include steady-inputs from “illicit” sources such as failing sewage conveyance systems, sanitary sewer overflows (SSOs), and failing or inappropriately located septic systems. When “illicit” sources are identified, either through the Phase II MS4 requirements or trackdown studies conducted by the Department, appropriate enforcement measures will be taken to eliminate them.

Runoff from land surfaces comprises most of the nonpoint and stormwater point sources of phosphorus into lakes. Watershed loads were estimated using the Unit Areal Load (UAL) methodology, which applies pollutant export coefficients obtained from literature sources to the land use patterns within the watershed, as described in EPA's Clean Lakes Program guidance manual (Reckhow, 1979b). Land use was determined using the Department's GIS system using the 1995/1997 land use coverage. The Department reviewed phosphorus export coefficients from an extensive database (Appendix B) and selected the land use categories and values shown in Table 5.

Table 5 Phosphorus export coefficients (Unit Areal Loads)

land use / land cover	**LU/LC codes**[2]	**UAL (kg TP/ha/yr)**
medium / high density residential	1110, 1120, 1150	1.6
low density / rural residential	1130, 1140	0.7
Commercial	1200	2.0
Industrial	1300, 1500	1.7
mixed urban / other urban	other urban codes	1.0
Agricultural	2000	1.5
forest, wetland, water	4000, 6000, 5000	0.1
barren land	7000	0.5

Units: 1 hectare (ha) = 2.47 acres
1 kilogram (kg) = 2.2 pounds (lbs)
1 kg/ha/yr = 0.89 lbs/acre/yr

For all lakes in this TMDL document, a UAL of 0.07 kg/ha/yr was used to estimate air deposition of phosphorus directly onto the lake surface. This value was developed from statewide mean concentrations of total phosphorus from the New Jersey Air Deposition Network (Eisenreich and Reinfelder, 2001). Land uses and calculated runoff loading rates for each of the watersheds are shown in Table 6.

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[2] LU/LC code is an attribute of the land use coverage that provides the Anderson classification code for the land use. The Anderson classification system is a hierarchical system based on four digits. The four digits represent one to four levels of classification, the first digit being the most general and the fourth digit being the most specific description.

Table 6 Nonpoint and Stormwater Sources of Phosphorous Loads

Nonpoint Source	**Cooper River Main Stem**		**Evans Pond & Wallworth Lake Lakeshed**		**Kirkwood Lake Lakeshed**		**North Branch Cooper River Lakeshed**		**Cooper River Lake Watershed**	
	acres	kg/yr	acres	kg/yr	acres	kg/yr	acres	kg/yr	acres	kg/yr
land use loads										
medium / high density residential	2219	1437	3998	2589	742	481	2854	1848	9072	5874
low density / rural residential	68.9	19.5	662	188	212	60.1	789	223	1520	431
commercial	651	527	1002	811	260	211	460	372	2152	1742
industrial	226	155.6	214	147	38.6	26.6	87.1	59.9	527	363
mixed urban / other urban	1063	430	1361	551	342	139	733	297	3158	1278
agricultural	0	0	256	155	39.3	23.9	231	140	487	296
forest, wetland, water	454	18.4	3068	124	1410	57.0	1773	71.7	5313	215
barren land	2.23	0.45	360	72.7	184	37.3	160	32.3	521	105
other loads										
septic systems	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
waterfowl	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
internal load	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
tributary load	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
natural loads										
air deposition	192	5.44	17.89	0.5	24.9	0.7			192	5.44
groundwater	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTAL	**4916**	**2594**	**10939**	**4638**	**3250**	**1040**	**7087**	**3045**	**22749**	**10309**

7.0 Water Quality Analysis

As described in EPA guidance, a TMDL identifies the loading capacity of a waterbody for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a waterbody can receive without violating water quality standards (40 C.F.R. 130.2). The loadings are required to be expressed as either mass-per-time, toxicity, or other appropriate measures (40 C.F.R. 130.2(i)). For lake nutrient TMDLs, it is appropriate to express the TMDL on a yearly basis. Long-term average pollutant loadings are typically more critical to overall lake water quality due to the storage and recycling mechanisms in the lake. Also, most available empirical lake models, such as the Reckhow model used in this analysis, use annual loads rather than daily loads to estimate in-lake concentrations.

7.1 Historical Surface Water Quality Data Overview

The United States Geological Survey (USGS) has collected monitoring data on the Cooper River since 1908. Although the monitored stations and monitoring schedule have changed over the years, the historical data is useful to understand trends in water quality over time. Table 7 shows all of the historical and current monitoring stations in the Cooper River watershed.

Table 7 Historical Monitoring in the Cooper River Watershed

USGS Station #	Data for period	Station Location
01467120	105 samples: 1975-1991 (USGS) 1998 (NJDEP-metal recon.), 2002 (NJDEP-TMDL)	Cooper River at Norcross Road at Lindenwold, NJ
01467130	51 samplings: 1964-1982 (USGS)	Cooper River at Kirkwood, NJ
01467140	93 samples: 1975- 1991 (USGS), 1998 (NJDEP-metal recon.), 2001 (NJDEP-diurnal Oxygen), 2002 (NJDEP-TMDL)	Cooper River at Lawnside, NJ
01467150	311 samples: 1925-8/7/02 (USGS) 2001 (NJDEP) diurnal Oxygen	Cooper River at Haddonfield, NJ
01467155	27 samples: 1997-9/4/2002 (USGS), 1998(NJDEP-metal recon.), 2001 (NJDEP-diurnal Oxygen), 2002 (NJDEP-TMDL)	North Branch Cooper River at Kresson, NJ
01467180	3 samples: 1964, 1967, 1977 (USGS)	North Branch Cooper River at Ellisburg, NJ
01467181	34 samplings: 1975- 1978 (USGS), 2002 (NJDEP-TMDL)	North Branch Cooper River at Erlton, NJ
01467190	56 samplings: 1969-1983 (USGS)	Cooper River at Camden, NJ
01467191	2000-2002 (NJDEP-EWQ sampling)	Cooper River at Camden (Kaighn Ave – tidal influenced)
01467193	3 samples: 1980 (USGS)	Cooper River at Camden (below Federal Street-tidal influenced)

The water samples collected in the very early monitoring period were tested mainly to assess the fecal coliform count and biological oxygen demand (BOD5). Other parameters were added as water quality assessment matured.

Based on the pre-1998 Ambient Stream Quality Monitoring data, the Cooper River exceeded the SWQS for phosphorus at three stations. The Department determined in its *Surface Water Quality Inventory Report of 1998*, that the surface water quality standard for total phosphorus was not met at Lindenwold (#01467120), Lawnside (#01467140) and Haddonfield (#01467150). The Kresson station on the North Branch Cooper River (#01467155), included in the USGS monitoring program in 1997, exceeded TP concentration criterion and, in 2002, was added to the Sublist 5 of the *Integrated List of Waterbodies.*

In 2000, the Department collected additional surface water quality data to enhance the established ambient network. Under this program, station #01467191, located in Camden at Kaighn Avenue, was monitored eight times from December 2000 to September 2002.

Currently, the Cooper River watershed is monitored at Haddonfield (#01467150) and Kresson (#01467155).

7.1.1 Lindenwold (Station #01467120)

The Lindenwold station (#01467120) is located at the head of the Cooper River, at the outlet of Linden Lake and upstream of Kirkwood Lake. The watershed discharging to this location covers about one square mile. The water samples were collected for chemical analysis from November 1975 to May 1991 on a 6 to 7 times per year schedule. In August 1998, the Department monitored this station for three consecutive days with the focus on metal contamination. Flow data were not collected during the sampling events. In 2002, the Department collected six samples from June 18th to October 1st to obtain data for TMDL development.

A total of seventy eight TP results were obtained from 1975 through October 2002. From the TP concentration data set, seven samples (9 percent) exceeded the 0.1 mg/L TP criterion for streams, but 30 percent of samples exceeded the 0.05 mg/L TP criterion for lakes and lake inflow. TP concentration ranged between 0.01 mg/L and 0.21 mg/l with an average of 0.053 mg/L.

Figure 6 Changes in Phosphorus Concentration with Flow

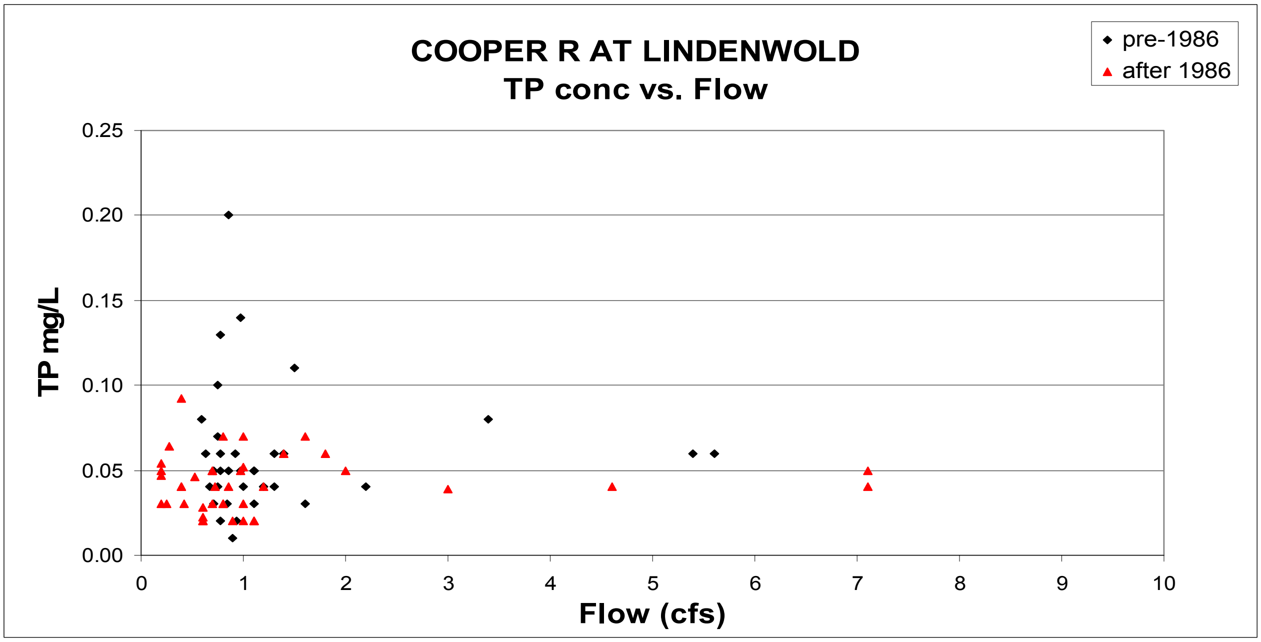
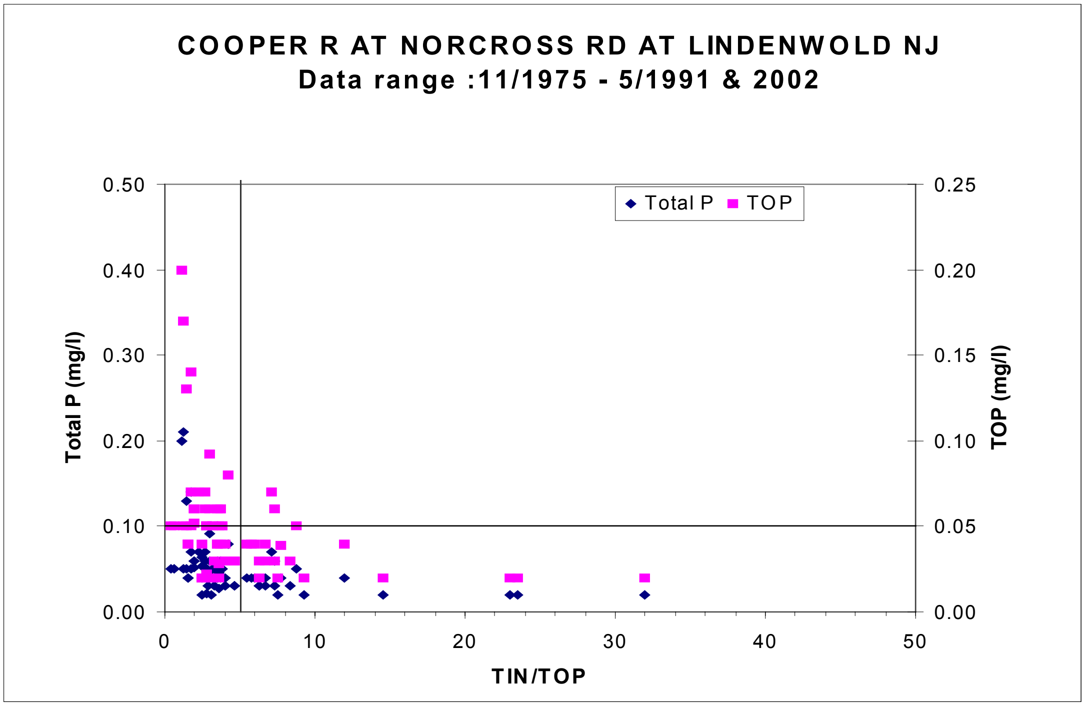


Figure 6 illustrates changes in TP concentration compared to flow rate. The monitoring results are presented in two different time periods: before 1986 and from 1986 to 2002. This distinction was made because point source discharges began to be eliminated and phosphorus concentrations tended to decline. The flow rate ranged from 0.1 to 12.0 cubic feet per second (cfs) with 1.4 cfs average flow. Under low flow conditions the changes in the phosphorus concentration were more differentiated.

The Department's Division of Water Quality's March 2003 guidance document entitled, *"Technical Manual for Phosphorus Evaluations (N.J.A.C. 7:9B-1.14(c)) for NJPDES Discharge to Surface Water Permits"*, recommends considering ratios of nitrogen and phosphorus as an indicator of a nutrient rich environment suitable for algal overgrowth. When the ratio of total inorganic nitrogen (TIN) to total orthophosphate (TOP) is smaller than or equal to 5, then phosphorus is not limiting the system. Figure 7 depicts the relationship of the two key nutrients at the Lindenwold station. At the Lindenwold station, when total phosphorus TP > 0.1 mg/L when a total organic phosphorus TOP < 0.05 mg/L, the ratio TIN/TOP did not exceed 5. This suggests that phosphorus is not the limiting nutrient. For a more detailed explanation, please refer to Appendix C.

Figure 7 Limiting Nutrients



TIN = dissolved nitrite, nitrate and ammonia. TIN calculated as: a sum of dissolved ammonia (P00608) & dissolved nitrite and nitrate (P00631) or a sum of total ammonia (P00610) and total nitrite & nitrate (P00630)

TOP = dissolved reactive phosphorus: orthophosphorus (P00671) if available, or dissolved phosphorus (P00666) if available, or total phosphorus (P00665)

7.1.2 Lawnside (Station #01467140)

The Lawnside monitoring station is located on the Cooper River, downstream from Kirkwood Lake and downstream from the location where the Woodcrest Creek merges with the Cooper River. The watershed draining to this station is about 13 square miles with 63% characterized as an urban/suburban land use, 18% forest, 10% wetland, 3% agriculture, and the remaining 6% is covered by barren land and water. This station was continuously monitored by USGS from 1975 to 1991 on a 6 to 7 times per year schedule. In August 1998, the Department monitored this station for three consecutive days with the focus on metal contamination. Flow data were not collected during this sampling event. In 2001, the Department performed a three-day sampling event designed to determine algal growth. The results were inconclusive. The next sampling event occurred during the summer of 2002; the Department performed six sampling rounds designed to augment nutrient data for the TMDLs.

The phosphorus results (see Figure 8) ranged from 6.7 mg/L in 1976 to 0.03 mg/L in 1991 and include the highest concentrations recorded in the Cooper River watershed. The average TP concentration for the period 1975-1991 was 1.42 mg/L. This station was discontinued as an ambient station in 1991. The post-1991 data is limited in value. For example, the 2002 monitoring data were taken during a very low flow period (drought emergency) and phosphorus results may not be characteristic. The phosphorus concentration for June-October 2002 varied from a minimum value of 0.20 mg/L to the maximum value of 2.29 mg/L with an average from six samplings equal to 0.83 mg/L.

Figure 8 Changes in Phosphorus Concentration with Flow Rate

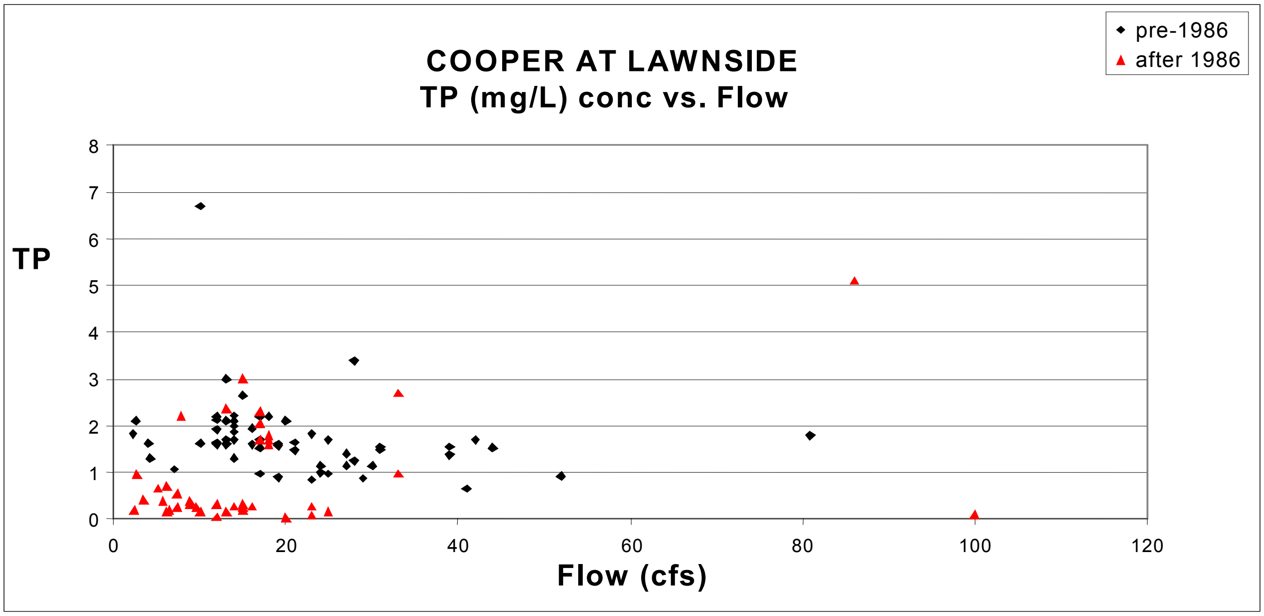
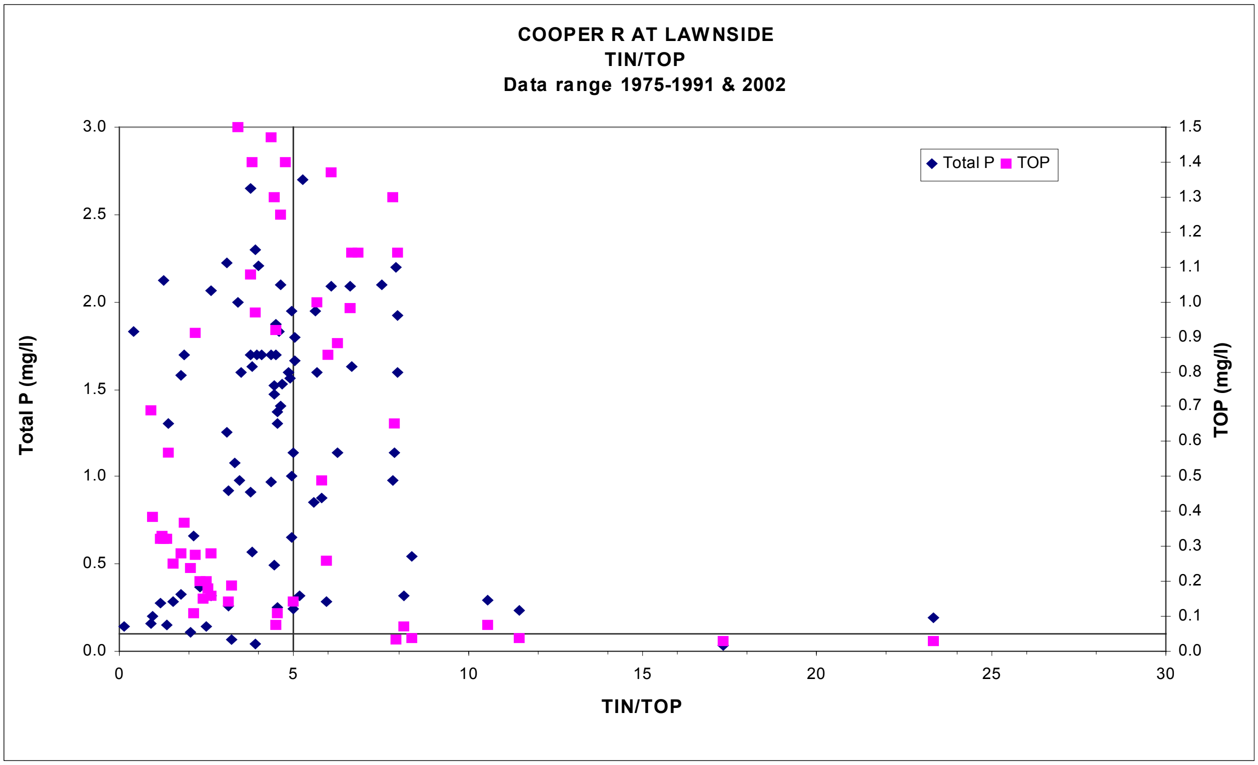


Figure 8 illustrates changes in the TP concentration relative to flow changes. The TP results are presented in two time periods: before 1986 and after 1986, when most of point-source discharges were connected to CCMUA. The TP concentration significantly decreased from an average TP concentration of 1.676 mg/L to an average TP concentration of 0.861 mg/L. While data is inconclusive, the pre-1986 data show concentrations relatively steady with flow and the post 1986 data suggest nonpoint sources are more significant.

Figure 9 Limiting Nutrients



TIN = dissolved nitrite, nitrate and ammonia. TIN calculated as: a sum of dissolved ammonia (P00608) & dissolved nitrite and nitrate (P00631) or a sum of total ammonia (P00610) and total nitrite & nitrate (P00630)
TOP = dissolved reactive phosphorus: orthophosphorus (P00671) if available, or dissolved phosphorus (P00666) if available, or total phosphorus (P00665)

Figure 9 shows the relationship of the two key nutrients at the Lawnside station. The majority (69%) of the TIN/TOP nutrient ratios are below or equal to 5. This suggests that phosphorus is not the limiting nutrient most of the time.

7.1.3 Haddonfield (Station 01467150)

The Haddonfield monitoring station is located close to the Wallworth Lake dam. The drainage area covers about 18 square miles. The land use in the watershed is 68% urban. (The other uses include: forest 17%, wetland 9%, barren land 3%, agriculture 2%, and water about 1%. The station was monitored by USGS from 1972 to 1978. The monitoring schedule was resumed in August 1991 and is continued to the present time.

Figure 10 demonstrates changes in phosphorus concentration over the monitoring period. The total phosphorus concentration varies from 0.036 mg/L to 1.43 mg/L with the average value for TP of 0.25 mg/L. The flow rate is steady most of the time as a result of controlled flows on Evans Pond and Wallworth Lake. Because the Haddonfield station is at the outlet of the Wallworth Lake, the data may be more representative of water quality in the lake than ambient stream conditions. When the runoff water flashes the lakes during a flooding condition, the phosphorus concentration slightly increases.

Figure 10 Changes in Phosphorus Concentration with Flow Rate

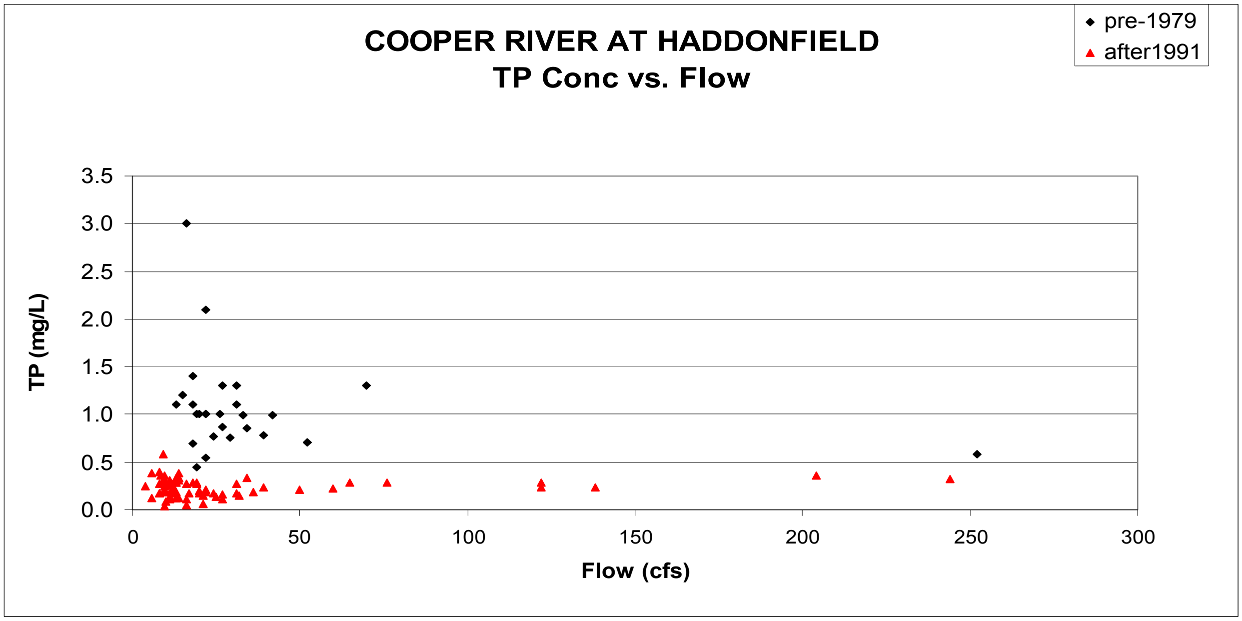
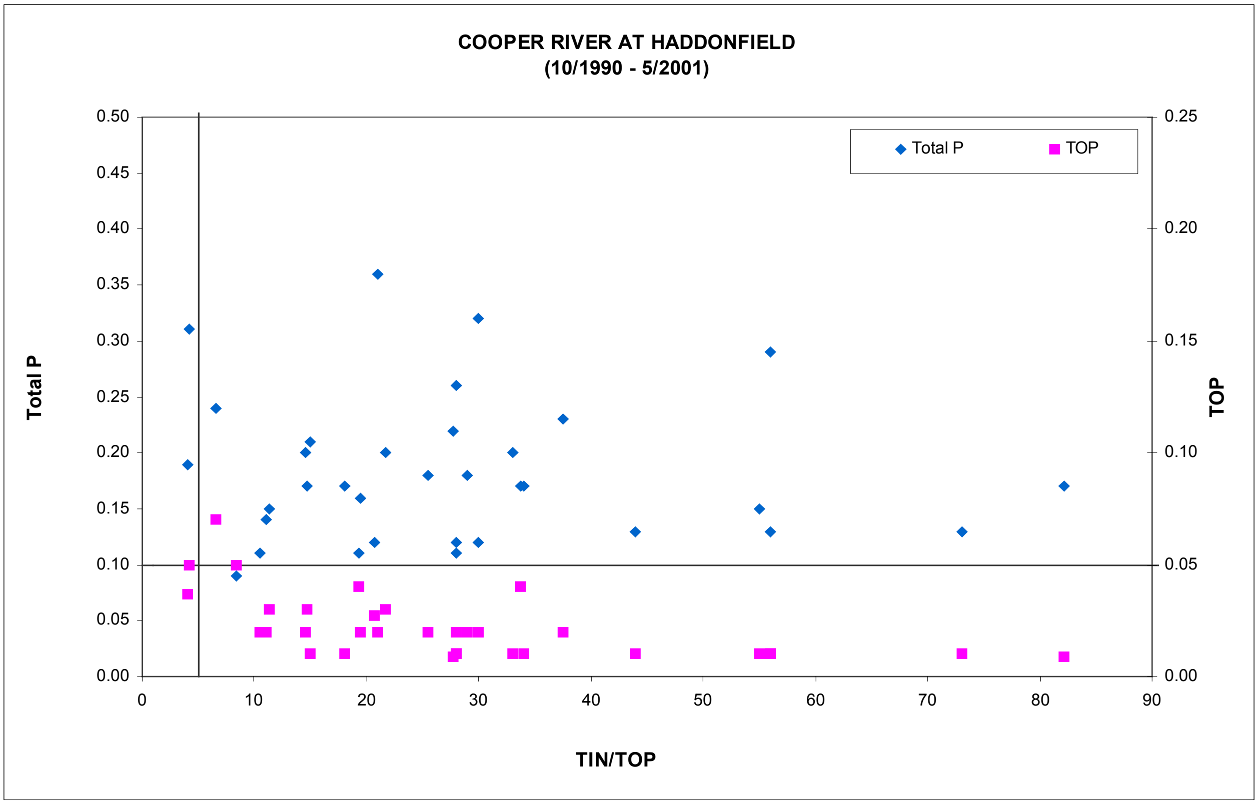


Figure 11 Nutrients Limitations



TIN = dissolved nitrite, nitrate and ammonia. TIN calculated as: a sum of dissolved ammonia (P00608) & dissolved nitrite and nitrate (P00631) or a sum of total ammonia (P00610) and total nitrite & nitrate (P00630)
TOP = dissolved reactive phosphorus: orthophosphorus (P00671) if available, or dissolved phosphorus (P00666) if available, or total phosphorus (P00665)

Analyzing Figure 11, the phosphorus concentration exceeds the lake criterion of 0.05 mg/L in 99% of samples (1991-2002 data set) and, for the same data set, 95.5% of TP results exceeded the 0.1 mg/L stream criterion. Most of the data (93 percent) suggest that phosphorus is a limiting nutrient (TP>0.1 mg/l, TOP≤0.05 mg/L, and TIN/TOP>5). However, because the station characterizes the lake more than the stream, this may not be relevant ot applicability of the in-stream criterion.

7.1.4 Kresson, Station 01467155

This station was added to the USGS monitoring program in 1997. The station is located at the head of the North Branch Cooper River. The watershed area discharging to this station is about one square mile with the 48% of watershed covered by urban/suburban areas, 34% wetland, 18% forest, and about 0.5% is covered by barren land.

The total phosphorus concentrations are presented at Figure 12. In two samples of 11 (18%), the total phosphorus concentration exceeded 0.1mg/L value. The flow rate was not recorded at the Kresson station. Based on this data, the stream segment was listed as an impaired body of water. Figure 12 illustrates changes in the phosphorus concentration over the sampling period.

Figure 12 Changes in Phosphorus Concentration

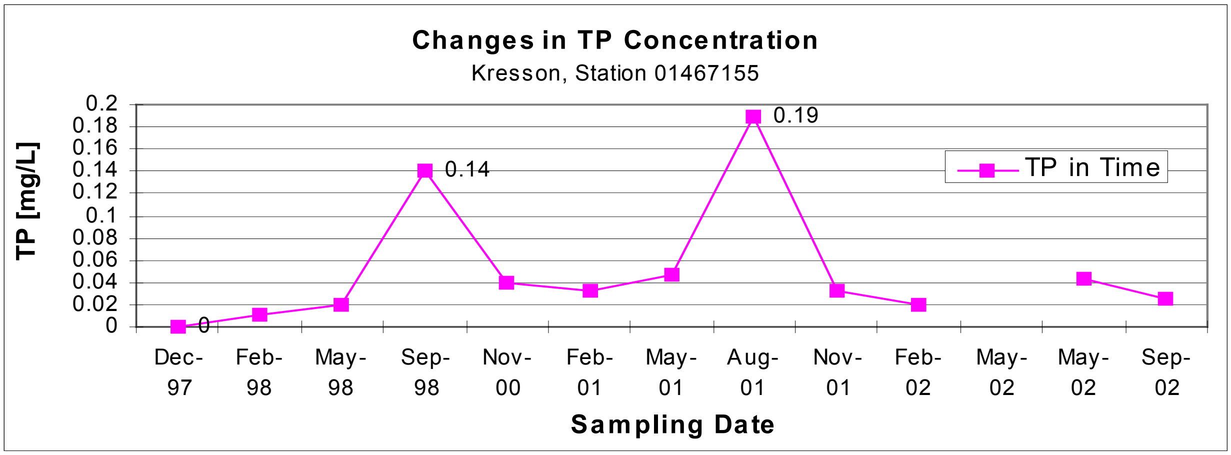
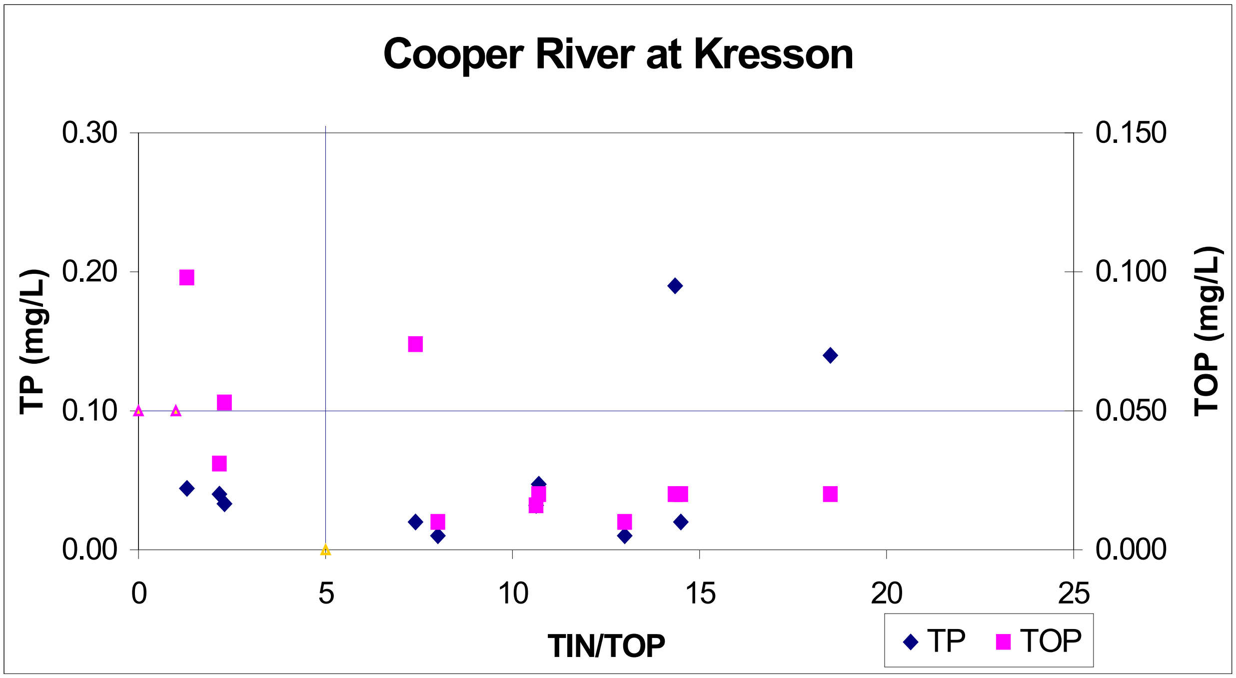


Figure 13 Nutrient Limitations



TIN = dissolved nitrite, nitrate and ammonia. TIN calculated as: a sum of dissolved ammonia (P00608) & dissolved nitrite and nitrate (P00631) or a sum of total ammonia (P00610) and total nitrite & nitrate (P00630)
TOP = dissolved reactive phosphorus: orthophosphorus (P00671) if available, or dissolved phosphorus (P00666) if available, or total phosphorus (P00665)

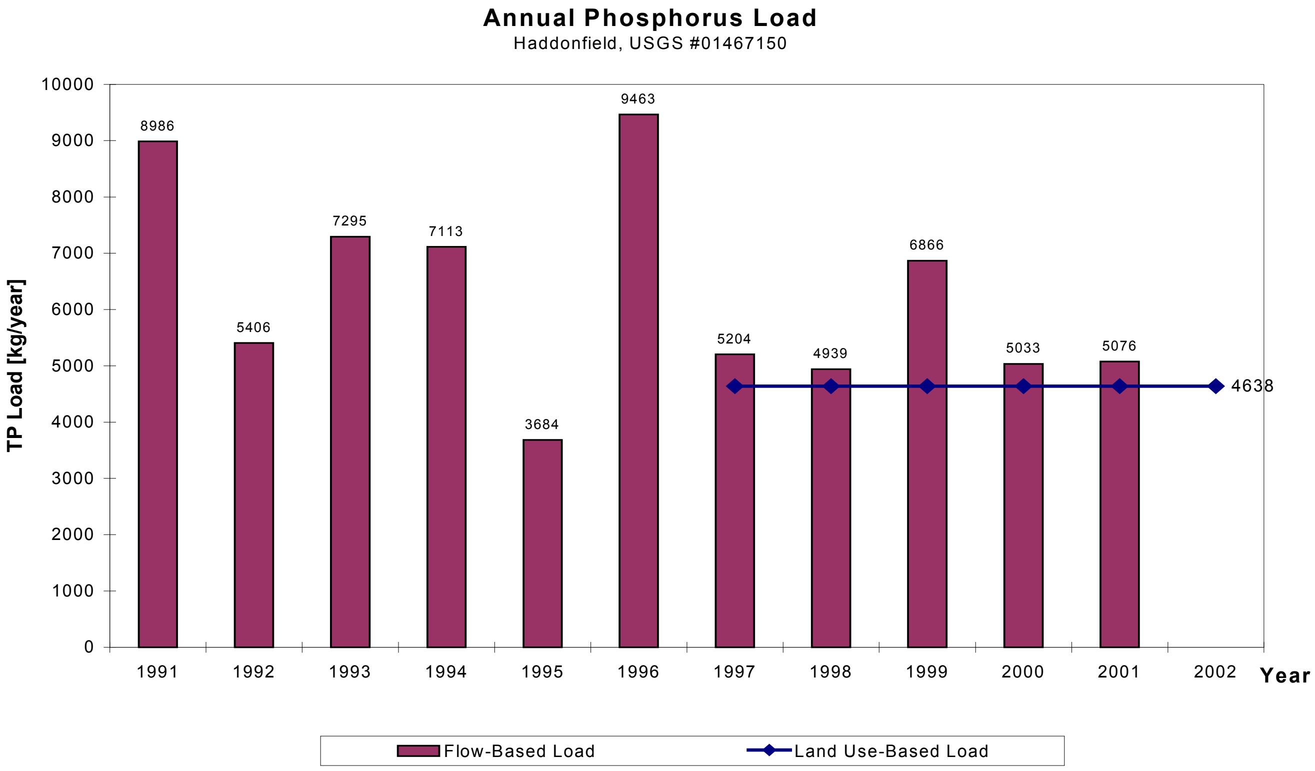
Total phosphorus concentration of TP > 0.1 mg/L was violated two times of eleven sampling events during the monitoring period (18% of samples). The graph suggests that phosphorus is the limiting nutrient for both results where $TP>0.1$mg/L, $TOP\leq 0.05$ mg/L, and $TIN/TOP>5$. These exceedances occurred after very high rainfall events.

7.2 Analysis of Phosphorus Loadings

Based on the history of effluent discharges from point sources, the water quality in the Cooper River deteriorated. In 1970’s and 1980’s the contamination of the Cooper River became an issue affecting biological life and human health. To improve water quality, all point sources of surface water contamination were eliminated by diverting point source effluents to the water treatment plant at CCMUA. As demonstrated in Figures 6, 8, 10, and 12, water quality in the Cooper River has improved, but the TP concentration is still above SWQS criteria for phosphorus in stream (0.1 mg/L) and/or for phosphorus in streams emptying into lakes (0.05 mg/L), thus warranting TMDLs.

The monitoring data from USGS Station #01467150 in Haddonfield were used to calculate phosphorus load to the Evans Pond and Wallworth Lake. For the monitoring period 1991-2001, based on the annual average flow and average annual phosphorus concentration, the phosphorus load was calculated. Figure 14 presents annual phosphorus loadings to the Evans Pond and Wallworth Lake. After eliminating point sources of phosphorus in 1996, the phosphorus load from 1997 to 2001 is stable. The highest load was calculated for the year 1999, what is most likely an effect of an intensive washout from excessive rainfall (Hurricane Floyd). Sources of phosphorus could include phosphorus from sediments as well as nonpoint sources from the entire watershed.

Figure 14 Phosphorus Load Calculations for the Haddonfield Monitoring Station



On Figure 14 is also shown the phosphorus loading calculated for the same watershed but based on the unified land use as presented in Table 5 (section 6). The loads based on an annual average flow and annual average TP are 6 to 11 percent higher except the 1999 load, an exception attributed to Hurricane Floyd.

Based on this fit and because the Haddonfield station is the only station in the Cooper River watershed monitored continuously from 1991 to the present time, the Department made a decision to use land use to calculate annual phosphorus loading for all impaired segments.

The geographic configuration of the watershed includes multiple run-of-the-river lakes, including Cooper River Lake and the downstream terminus of the drainage area. The numeric criterion for TP in lakes is more stringent than the criterion for streams, 0.05 mg/l compared to 0.01 mg/l. Therefore, the lakes were selected as the critical locations and the load reductions needed to achieve the in-lake criterion will also address the stream TP impairments in the watershed. While this approach is intuitively valid, the relationship was tested and verified as detailed in Appendix H.

7.3 Model Selection

Empirical lake models consist of equations derived from simplified mass balances that have been fitted to large datasets of actual lake measurements. The resulting regressions can be applied to lakes that fit within the range of hydrology, morphology and loading of the lakes in the model database. The Department surveyed the commonly used models in Table 8.

Table 8 Empirical models considered by the Department

reference	steady-state TP concentration in lake (mg/l)	Secondary term	Application
Rast, Jones and Lee, 1983	$1.81 \times NPL^{0.81}$	$NPL = \left(\dfrac{P_a \times DT/D_m}{1+\sqrt{DT}} \right)$	Expanded database of mostly large lakes
Vollenweider and Kerekes, 1982	$1.22 \times NPL^{0.87}$	$NPL = \left(\dfrac{P_a \times DT/D_m}{1+\sqrt{DT}} \right)$	mostly large natural lakes
Reckhow, 1980	$\dfrac{P_a}{13.2}$	none	Upper bound for closed lake
Reckhow, 1979a	$\dfrac{P_a}{(11.6+1.2 \times Q_a)}$	$Q_a = \dfrac{Q_i}{A_l}$	**General north temperate lakes, wide range of loading concentration, areal loading, and water load**
Walker, 1977	$\dfrac{P_a \times DT/D_m}{(1+0.824 \times DT^{0.454})}$	none	oxic lakes with $D_m/DT < 50$ m/yr
Jones and Bachmann, 1976	$\dfrac{0.84 \times P_a}{(D_m \times (0.65+DT^{-1}))}$	none	may overestimate P in shallow lakes with high D_m/DT

reference	steady-state TP concentration in lake (mg/l)	Secondary term	Application
Vollenweider, 1975	$\frac{P_a}{\left(D_m \times \left(DT^{-1} + S\right)\right)}$	$S = {}^{10}\!/_{D_m}$	Overestimate P lakes with high ${}^{D_m}\!/_{DT}$
Dillon-Kirchner, 1975	$\frac{P_a}{\left(13.2 + {}^{D_m}\!/_{DT}\right)}$	none	low loading concentration range
Dillon-Rigler, 1974	$P_a \times {}^{DT}\!/_{D_m} \times (1 - R)$	R = phosphorus retention coefficient	General form
Ostrofksy, 1978	Dillon-Rigler, 1974	$R = 0.201 \times e^{(-0.0425 \times Q_a)}$ $+ 0.5743 \times e^{-0.00949 * Q_a}$	lakes that flush infrequently
Kirchner-Dillon, 1975	Dillon-Rigler, 1974	$R = 0.426 \times e^{\left(-0.271 \times {}^{D_m}\!/_{DT}\right)}$ $+ 0.5743 \times e^{-0.00949 * {}^{D_m}\!/_{DT}}$	General application
Larsen-Mercier, 1975	Dillon-Rigler, 1974	$R = \frac{1}{1 + \sqrt{{}^{1}\!/_{DT}}}$	Unparameterized form

where:
NPL = normalized phosphorus loading
P_a = areal phosphorus loading (g/m²/yr)
DT = detention time (yr)
D_m = mean depth (m)
Qa = areal water load (m/yr)[3]
Q_i = total inflow (m³/yr)
A_l = area of lake (m²)
S = settling rate (per year)

Reckhow (1979a) model was selected because it has the broadest range of hydrologic, morphological and loading characteristics in its database. Also the model includes an uncertainty estimate that was used to calculate a Margin of Safety. The Reckhow (1979a) model is described in USEPA Clean Lakes guidance documents: Quantitative Techniques for the Assessment of Lake Quality (Reckhow, 1979b) and Modeling Phosphorus Loading and Lake Response Under Uncertainty (Reckhow *et al*, 1980). The derivation of the model is summarized in Appendix D. The model relates TP load to steady state TP concentration, and is generally applicable to north temperate lakes, which exhibit the following ranges of characteristics (see Symbol definitions after Table 8):

phosphorus concentration: $0.004 < P < 0.135$ mg/l
average influent phosphorus concentration: $P_a * DT / D_m < 0.298$ mg/l
areal water load: $0.75 < Q_a < 187$ m/yr

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[3] Areal water load is defined as the annual water load entering a lake divided by the area of the lake. Since, under steady-state conditions, the water coming in to the lake is equal to the water leaving the lake, either total inflow or total outflow can be used to calculate areal water load. If different values were reported for total inflow and total outflow, the Department used the higher of the two to calculate areal water load.

areal phosphorus load: $0.07 < P_a < 31.4$ g/m²/yr

For comparison, Table 9 below summarizes the characteristics for each lake based on their current and target conditions as described below. The above ranges of characteristics apply to most of the lakes covered under these TMDLs; however, the areal water load for Evans Pond and Wallworth Lake is outside the calibration range (340.4 m/year). Nevertheless, the model still remains the best choice since it has the broadest range of lake characteristics in its database. While the target concentration for each lake (Section 7) is well within the range, the areal phosphorus load provides a better representation of a lake's intrinsic loading characteristics. Also it is the model's prediction of target condition that is being used to calculate the TMDL; if current loads are higher than the range that can produce reliable model results; this has no affect on the model's reliability to predict target condition under reduced loads. It should also be noted that no attempt was made to recalibrate the Reckhow (1979a) model for lakes in New Jersey or in this Water Region, since sufficient lake data were not available to make comparisons with model predictions of steady-state in-lake concentration of total phosphorus. The model was already calibrated to the data set on which it is based, and is generally applicable to north temperate lakes that exhibit the range of characteristics listed previously.

Table 9 Hydrologic and loading characteristics of lakes

Lake	Current Avg Influent [TP] (mg/l)	Target Avg Influent [TP] (mg/l)	Current Areal TP load (g/m²/yr)	Target Areal TP load (g/m²/yr)	Areal Water Load (m/year)
Kirkwood Lake	0.109	0.026	10.27	2.47	94.0
Evans Pond and Wallworth Lake	0.188	0.037	64.06	6.10	340
Cooper River Lake	0.201	0.041	13.25	1.19	66.0

7.4 Current Condition

Using these estimated physical parameters and current loads, the predicted steady-state phosphorus concentration of each lake was calculated using the Reckhow (1979a) formulation as listed in Table 7. The current phosphorus load distribution for each lake is shown in Figures 15 to 17 below.

Figure 15 **Current distribution of phosphorus load for Kirkwood Lake**

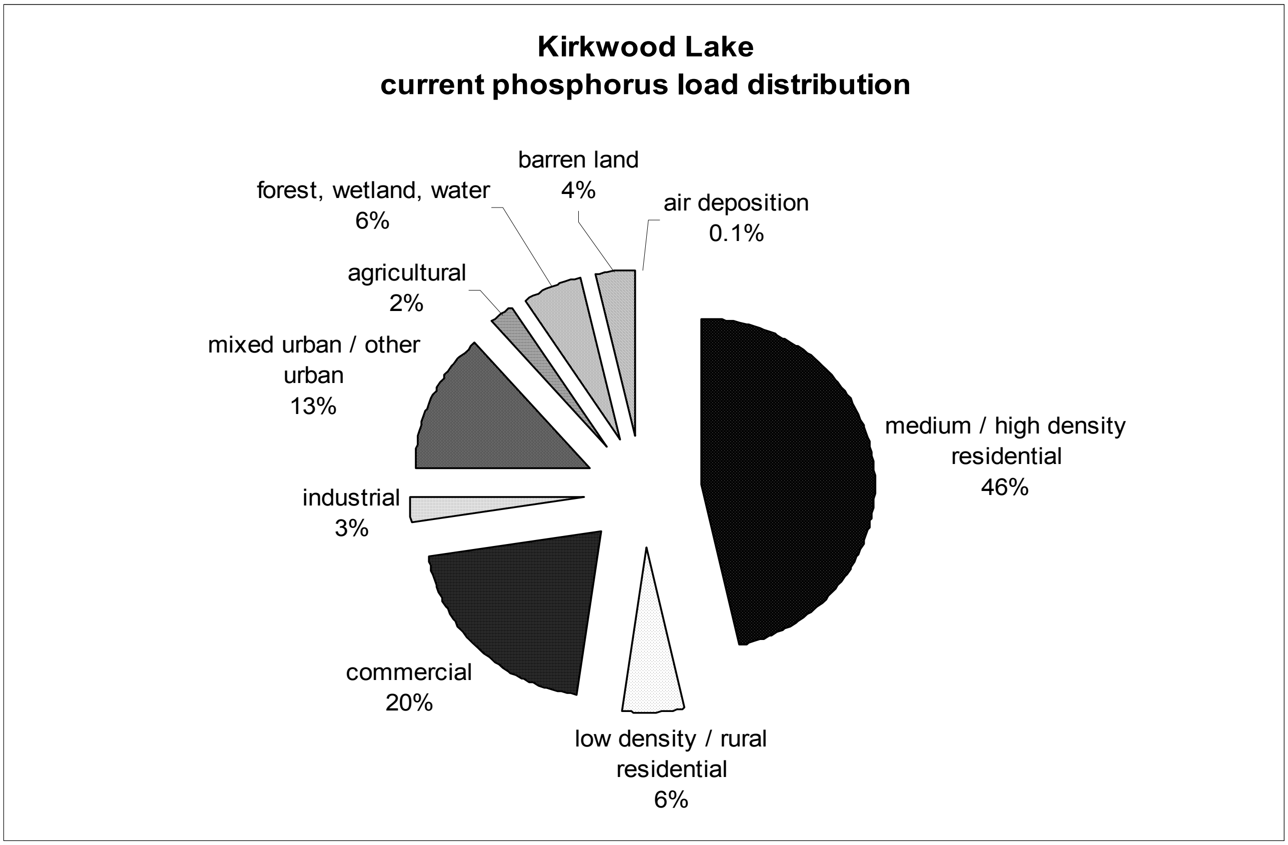


Figure 16 **Current distribution of phosphorus for Evans Pond and Wallworth Lake**

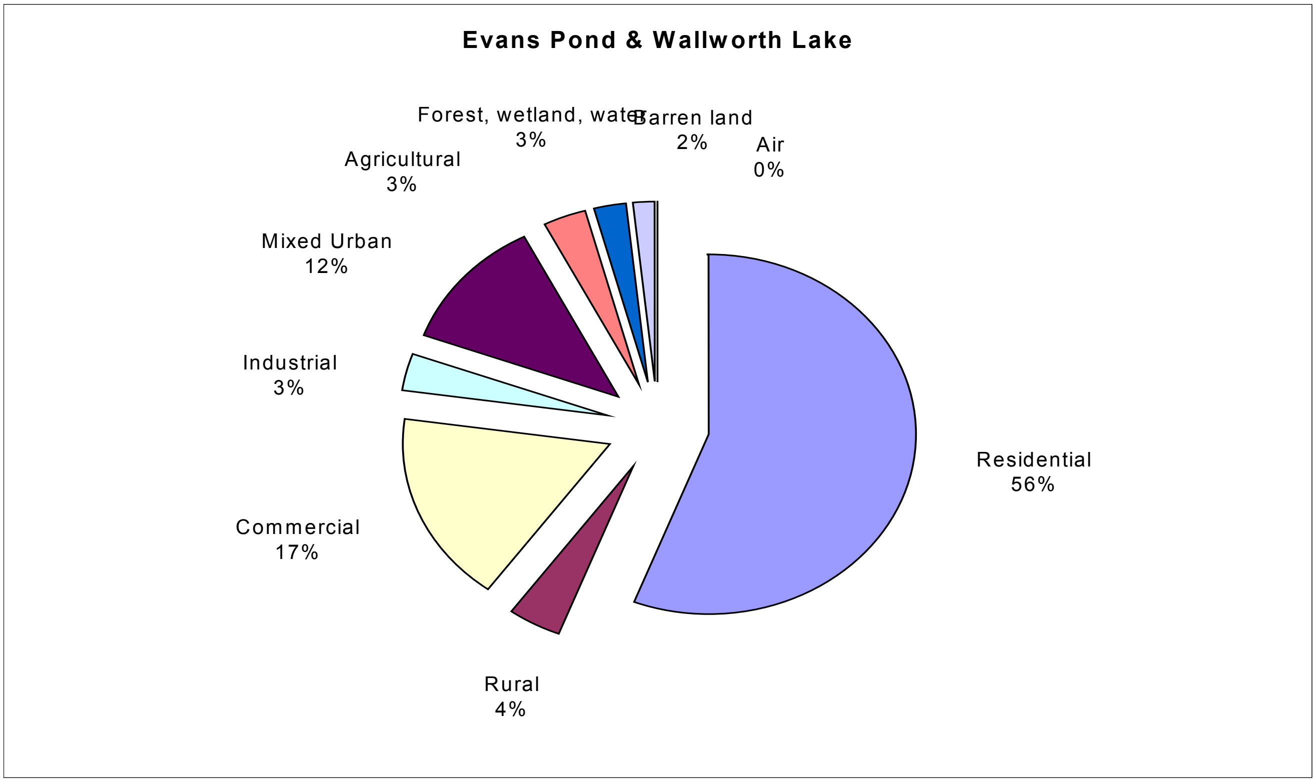
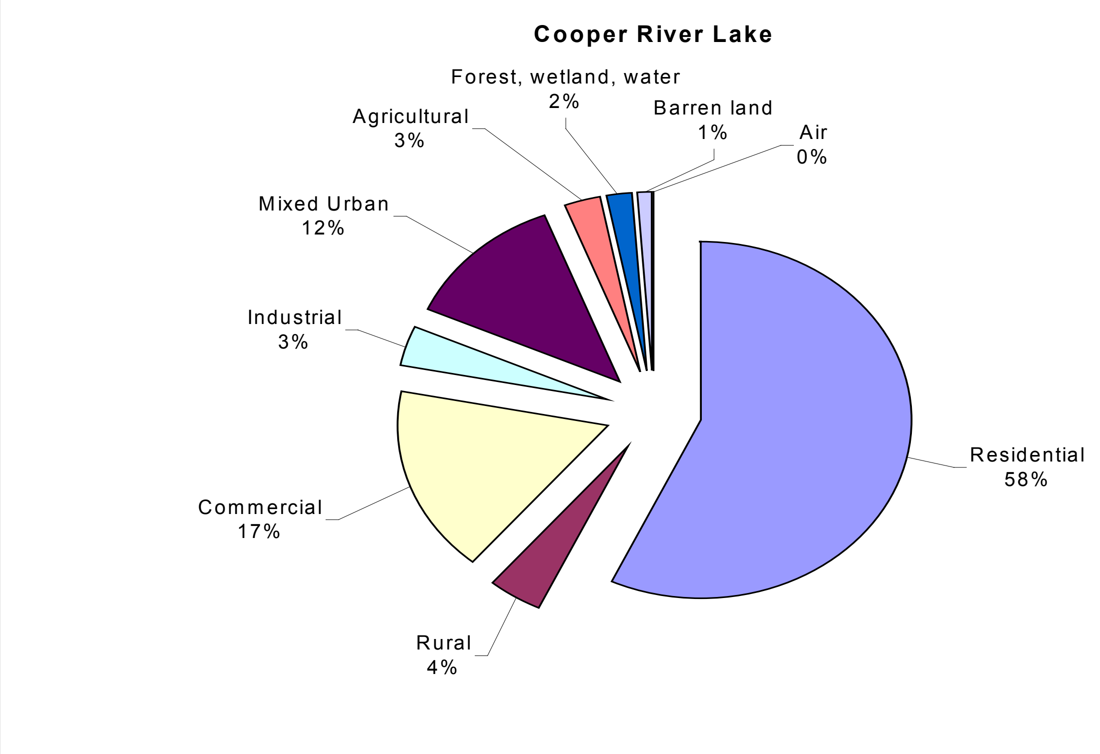


Figure 17 **Current distribution of phosphorus for Cooper River Lake**



7.5 Reference Condition

A reference condition for each lake was estimated by calculating external loads as if the land use throughout the lakeshed were completely forest and wetlands. Estimates of air deposition loads were included to calculate the reference condition. Using the same physical parameters and external loads from forest and wetlands, a reference steady-state phosphorus concentration was calculated for each lake using the Reckhow (1979a) formulation and listed in Table 10.

7.6 Seasonal Variation/Critical Conditions

These TMDLs will attain applicable surface water quality standards year round. The Reckhow model predicts steady-state phosphorus concentration. To account for data variability, the Department generally interprets threshold criteria as greater than 10% exceedance for the purpose of defining impaired waterbodies. Data from two lakes in New Jersey for which the Department had ready access to data (Strawbridge Lake, NJDEP 2000a; Sylvan Lake, NJDEP 2000b) exhibit peak (based on the 90th percentile) to mean ratios of 1.56 and 1.48, resulting in target phosphorus concentrations of 0.032 and 0.034 mg TP/l, respectively. Since the peak to mean ratios were close and the target concentration not very sensitive to differences in peak to mean ratios, the Department determined that a target phosphorus concentration of 0.03 mg TP/l is reasonably conservative. The seasonal variation was therefore assumed to be 67%, resulting in a target phosphorus concentration of 0.03 mg TP/l. Since it is the annual pollutant load rather than the load at any particular time that determines overall lake water quality (Section 6), the target phosphorus concentration of 0.03 mg TP/l accounts for critical conditions.

7.7 Margin of Safety

A Margin of Safety (MOS) is provided to account for "lack of knowledge concerning the relationship between effluent limitations and water quality." (40 CFR 130.7(c). A MOS is required in order to account for uncertainty in the loading estimates, physical parameters and the model itself. The margin of safety, as described in USEPA guidance (Sutfin, 2002), can be either explicit or implicit (i.e., addressed through conservative assumptions used in establishing the TMDL). For these TMDL calculations, an implicit as well as explicit Margin of Safety (MOS) is provided.

These TMDLs contain an implicit margin of safety by using conservative critical conditions, over-estimated loads, and total phosphorus. Each conservative assumption is further explained below.

Critical conditions are accounted by comparing peak concentrations to mean concentrations and adjusting the target concentration accordingly (0.03 mg TP/l instead of 0.05 mg TP/l). In addition to the conservative approach used for critical conditions, the land use export methodology does not account for the distance between the land use and the lake, which will result in phosphorus reduction due to adsorption onto land surfaces and in-stream kinetic processes**.** Furthermore, the lakesheds are based on topography without accounting for the diversion of stormwater from lakes, which is common in urban areas. Neither is any reductions assumed due to the addition of lakeside vegetative buffer construction or other management practices aimed at minimizing phosphorus loads. Finally, the use of total phosphorus, as both the endpoint for the standard and in the loading estimates, is a conservative assumption. Use of total phosphorous does not distinguish readily between dissolved orthophosphorus, which is available for algal growth, and unavailable forms of phosphorus (e.g. particulate). While many forms of phosphorus are converted into orthophosphorus in the lake, many are captured in the sediment, for instance, and never made available for algal uptake.

In addition to the multiple conservative assumptions built in to the calculation, an additional explicit margin of safety was included to account for the uncertainty in the model itself. As described in Reckhow *et al* (1980), the Reckhow (1979a) model has an associated standard error of 0.128, calculated on log-transformed predictions of phosphorus concentrations. Transforming the terms in the model error analysis from Reckhow *et al* (1980) yields the following (Appendix E):

$$MoS_p = \sqrt{1 \big/ \left((1-\rho)*4.5\right)} \times \left(10^{0.128} - 1\right),$$

where: MoS_p = margin of safety as a percentage over the predicted phosphorus concentration;

ρ = the probability that the real phosphorus concentration is less than or equal to the predicted phosphorus concentration plus the margin of safety as a concentration.

Setting the probability to 90% yields a margin of safety of 51% when expressed as a percentage over predicted phosphorus concentration or estimated external load. The external load for each lake was therefore multiplied by 1.51 to calculate an "upper bound" estimate of steady-state phosphorus concentration. An additional explicit margin of safety was included in the analyses by setting the upper bound calculations equal to the target phosphorus concentration of 0.3 mg TP/l, as described in the next section and shown in Table 10. Note that the explicit Margin of Safety is equal to 51% when expressed as a percentage over the predicted phosphorus concentration; when expressed as a percentage of total loading capacity, the Margin of Safety is equal to 34%:

$$\left(MoS_{lc} = \frac{MoS_p \times P}{P + (MoS_p \times P)} = \frac{MoS_p}{1 + MoS_p} = \frac{0.51}{1.51} = 0.34 \right),$$

where:
MoS_p = margin of safety expressed as a percentage over the predicted phosphorus concentration or external load;
MoS_{lc} = margin of safety as a percentage of total loading capacity;
P = predicted phosphorus concentration (or external load).

7.8 Target Condition

As discussed above, when considering the seasonal variation, the steady state concentration of phosphorus in the lake must be equal to or less than 0.03 mg/L to avoid exceeding the 0.05mg/L phosphorus criterion. Using Reckhow (1979a), any predicted concentration has a margin of safety of 51% when expressed as a percentage over predicted phosphorus concentration. To assure the compliance of 0.03 mg/L, the predicted concentration can not be higher than 0.02 mg/L (0.02 + 0.02 * 51% = 0.03 mg/L) considering the effect of MOS. Therefore, 0.02 mg/L is chosen as the target concentration to attain the standard while 0.03 mg/L is defined as the upper bound target condition. Portion of the load corresponding to 0.03 mg/L will be addressed as MOS. In this case, the percentage of MOS is 34% (0.51/1.51 = 34%). The overall reduction necessary to attain the standard level in each lake was calculated by comparing the current concentration (calculated using the Reckhow model) to 0.02 mg/L, the target concentration (Table 10). Because most of these lakes drain very large watersheds, the reference condition is very close to the target concentration; thus the overall load reductions necessary to achieve the target conditions are quite substantial.

Table 10 Current condition, reference condition, target condition and overall percent reduction for each lake

Lake	current condition [TP] (mg/l)	reference condition [TP] (mg/l)	upper bound target condition [TP] (mg/l)	Target condition [TP] (mg/l)	% overall TP load reduction
Kirkwood Lake	0.083	0.011	0.030	0.020	76%
Evans Pond and Wallworth Lake	0.152	0.0145	0.030	0.020	87%
Cooper River Lake	0.146	0.0131	0.030	0.020	86%

8.0 TMDL Calculations

8.1 Loading Capacity

Given the upper bound target concentration of 0.03 mg/l (which incorporates the margin of Safety), the Reckhow (1979a) model was used to solve the loading capacity for Evans Pond and Wallworth Lake watershed and Copper River Lake watershed, which is 912 kg/yr and 2110 kg/yr, respectively. As shown in Figure 2, the entire Cooper River Lake watershed was geographically divided into four segments, Kirkwood Lake watershed, Evans Pond and Wallworth Lake watershed excluding Kirkwood Lake watershed, northern branch of Cooper River Lake Watershed, and the watershed of main stem Cooper River. The loading capacity of Kirkwood Lake, 380 kg/yr, was determined previously in the approved Kirkwood Lake TMDL. Therefore, the loading capacity for the rest of the Kirkwood Ponds and Wallworth Lake watershed is allowed to be 532 kg/yr. Subtracting the loading capacity for Evans Pond and Wallworth Lake watershed (including Kirkwood Lake watershed) from the entire Cooper River Lake watershed, the remaining 1198 kg/yr is determined to be the loading capacity for northern branch and main stem watershed. As explained in the Allocation section, 1198 kg/yr is further divided into 693 kg/yr for the northern branch and 505 for the main stem watershed based on the land use coverage. The acceptable loading capacity for each segment and for the entire Cooper River Lake watershed is provided in Tables 11-15.

8.2 Reserve Capacity

Reserve capacity is an optional means of reserving a portion of the loading capacity to allow for future growth. Because the watershed is almost entirely developed, management strategies designed to reduce phosphorus loads from existing development will be equally effective with respect to future development. Therefore, the loading capacities and accompanying WLAs and LAs must be attained in consideration of any new sources that may accompany future development.

8.3 Allocations

USEPA regulations at 40 CFR § 130.2(i), state that "pollutant loadings may be expressed in terms of either mass per time, toxicity, or other appropriate measure." For lake nutrient TMDLs, it is appropriate to express the TMDL on a yearly basis. Long-term average pollutant loadings are typically more critical to overall lake water quality due to the storage and recycling mechanisms in the lake. Also, most available empirical lake models, such as the Reckhow model used in this analysis, use annual loads rather than daily loads to estimate in-lake concentrations.

The TMDLs for total phosphorus are therefore calculated as follows (Tables 10-15):

TMDL = loading capacity
= Sum of the wasteload allocations (WLAs) + load allocations (LAs) + margin of safety.

WLAs are hereby established for all NJPDES-regulated point sources within each source category, while LAs are established for stormwater sources that are not subject to NJPDES regulation and for all nonpoint sources. This distribution of loading capacity between WLAs and LAs is consistent with recent EPA guidance that clarifies existing regulatory requirements for establishing WLAs for stormwater discharges (Wayland, November 2002). Stormwater discharges are captured within the runoff sources quantified according to land use, as described previously. Distinguishing between regulated and unregulated stormwater is necessary in order to express WLAs and LAs numerically; however, "EPA recognizes that these allocations might be fairly rudimentary because of data limitations and variability within the system" (Wayland, November 2002, p.1). While the Department does not have the data to actually delineate lakesheds according to stormwater drainage areas subject to NJPDES regulation, the land use runoff categories previously defined can be used to estimate between them. Therefore allocations are established according to source categories as shown in Table 11. This demarcation between WLAs and LAs based on land use source categories is not perfect, but it represents the best estimate defined as narrowly as data allow. A list of NJPDES permitted stormwater dischargers may be found in Appendix F. The permits for these facilities were evaluated and it was determined that they are general permits and do not require phosphorus monitoring. The

Department acknowledges that there may be stormwater sources in the residential, commercial, industrial and mixed urban runoff source categories that are not NJPDES-regulated. Nothing in these TMDLs, including Table 11, shall be construed to require the Department to regulate a stormwater source under NJPDES that would not already be regulated as such, nor shall anything in these TMDLs be construed to prevent the Department from regulating a stormwater source under NJPDES. WLAs are hereby established for all NJPDES-regulated point sources, including stormwater, according to their source category. Quantifying WLAs and LAs according to source categories provides the best estimation defined as narrowly as data allow. However, it is clearly noted that WLAs are hereby established for all NJPDES-regulated point sources within each source category, while LAs are established for stormwater sources that are not subject to NJPDES regulation and for all nonpoint sources. The WLAs and LAs in Tables 12-16 are not themselves "Additional Measures" under proposed N.J.A.C. 7:14A-25.6 or 25.8.

Table 11 Distribution of WLAs and LAs among source categories

Source category	TMDL allocation
Nonpoint and Stormwater Sources	
medium / high density residential	WLA
low density / rural residential	WLA
commercial	WLA
industrial	WLA
Mixed urban / other urban	WLA
agricultural	LA
forest, wetland, water	LA
barren land	LA
air deposition onto lake surface	LA
septic systems	LA
internal load	LA
tributary load	LA

In order to attain the TMDLs, the overall load reductions shown in Table 10, or those determined through additional monitoring, must be achieved. Since loading rates have been defined for at least eight source categories, countless combinations of source reductions could be used to achieve the overall reduction target. Among the total allowable loading capacity, 34% of it is reserved for the Margin of Safety given by the uncertainty in the Reckhow model. In addition, the current loading is assumed to be unchangeable for air deposition and certain types of land use, such as forest/wetland/water and barren land. Therefore, the reduction from other loading sources need be sufficient to achieve the necessary overall load reductions. Equal percent reduction is applied to all the loading sources that can be affected by BMP implementation. The reduction rate for Kirkwood Lake watershed is obtained from the previously approved TMDL for Kirkwood Lake. The reduction rate is calculated to be 92.9% for the Evans Pond and Wallworth Lake watershed excluding Kirkwood Lake watershed and 88% for non-Evans Pond and Wallworth Lake portion of the Cooper River Lake watershed. The current loading from each type of land use is used to calculate the allocation based on the reduction rate. For the Northern Branch Cooper River and the Main Stem Cooper River segments, the sum of the allocation is divided by 66% to compute the individual loading capacity.

The Lake Restoration Plans developed for each lake as part of the TMDL implementation (Section 10) may revisit the distribution of reductions among the various sources in order to better reflect actual implementation projects. The resulting TMDLs, rounded to two significant digits, are shown in Tables 12-16 and illustrated in Figures 18 to 22. The reductions for Kirkwood Lake are taken from the previously established TMDL and are not intended to be considered new or amended for that impaired waterbody.

Table 12 TMDL calculations for Kirkwood Lake (annual loads and percent reductions[a]

lake	Kirkwood Lake		% reduction
	kg TP/yr	% of LC	
loading capacity (LC)	380	100%	n/a
Point Sources other than Stormwater			
minor municipal	n/a		
Nonpoint and Stormwater Sources			
medium / high density residential	79	21%	84%
low density / rural residential	9.8	2.6%	84%
commercial	34	9.2%	84%
industrial	4.4	1.2%	84%
Mixed urban / other urban	23	6.0%	84%
agricultural	3.9	1.0%	84%
forest, wetland, water	57	15%	0%
barren land	37	9.9%	0%
septic systems	n/a		
waterfowl	n/a		
internal load	n/a		
tributary load	n/a		
Natural Sources / Background			
air deposition onto lake surface	0.7	0.2%	0%
groundwater	n/a		
Other Allocations			
explicit Margin of Safety	130	34%	n/a

Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 10.

Figure 18 Phosphorus allocations for Kirkwood Lake

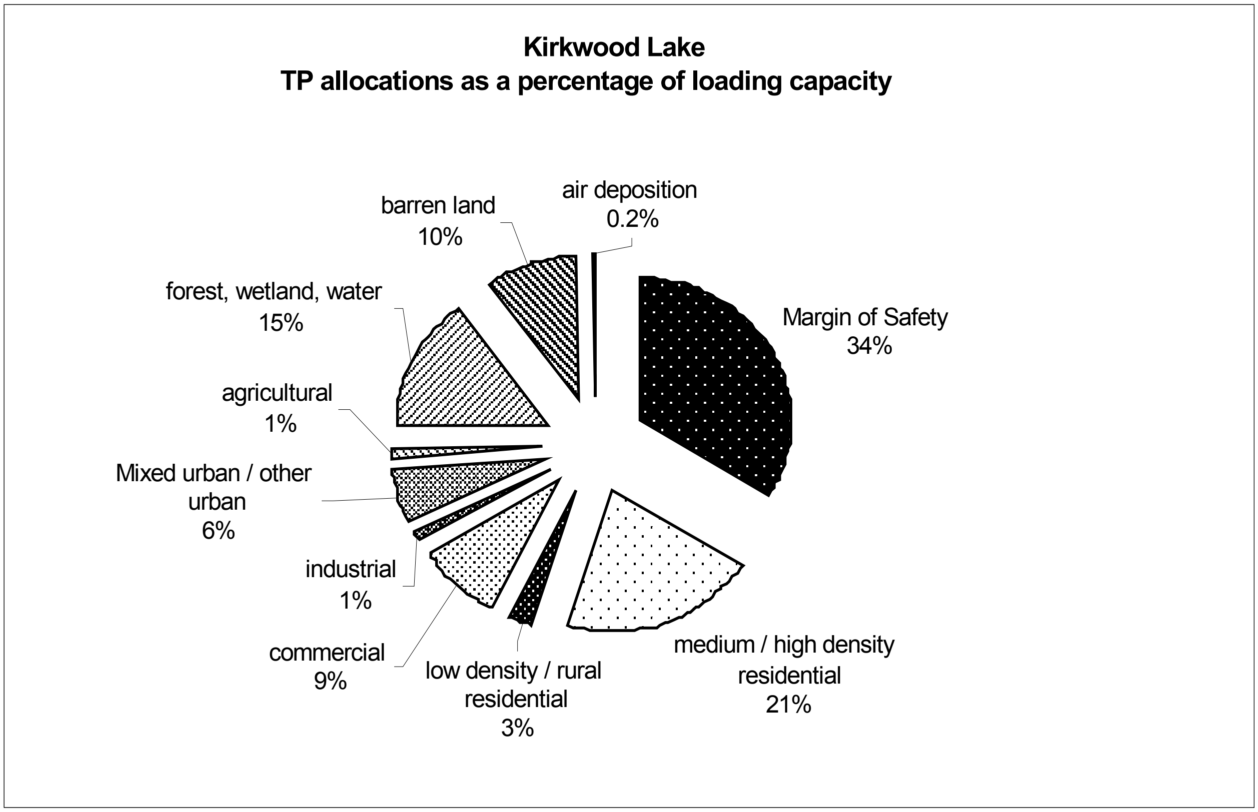


Table 13 TMDL calculations for Evans Pond & Wallworth Lake (w/o Kirkwood Lake) (annual loads and percent reductions*)

lake	Evans Pond & Wallworth Lake		% reduction
	kg TP/yr	% of LC	
loading capacity (LC)	532	100%	n/a
Point Sources other than Stormwater			
minor municipal	n/a		
Nonpoint and Stormwater Sources			
medium / high density residential	150	28.2%	92.9%
low density / rural residential	9	1.7%	92.9%
commercial	43	8%	92.9%
industrial	8.6	1.6%	92.9%
Mixed urban / other urban	29	5.5%	92.9%
agricultural	9.3	1.8%	92.9%
forest, wetland, water	66	12%	0%
barren land	35	7%	0%
septic systems	n/a		
waterfowl	n/a		
internal load	n/a		
tributary load	n/a		
Natural Sources / Background			
air deposition onto lake surface	1	0.1%	0%
groundwater	n/a		
Other Allocations			
explicit Margin of Safety	181	34%	n/a

***Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 10.**

Figure 19 Phosphorus allocations for Evans Pond and Wallworth Lake (without Kirkwood Lake)

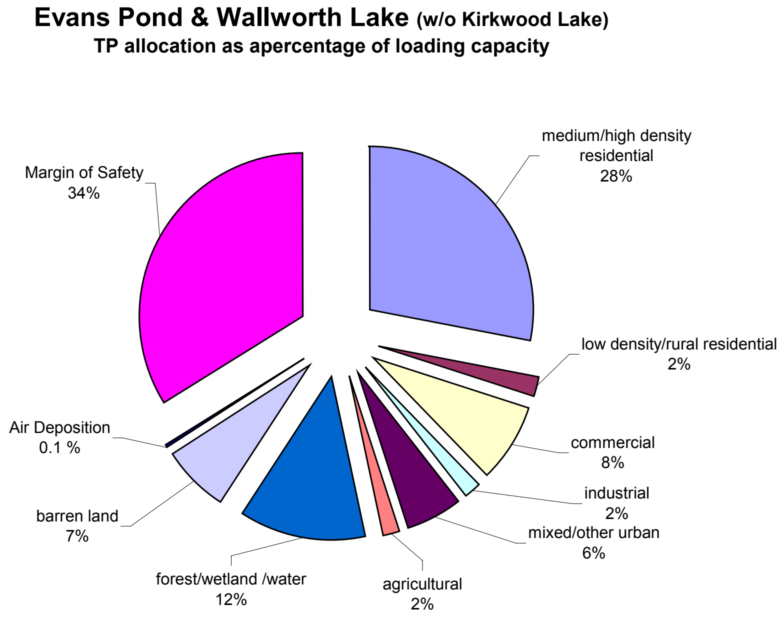


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Table 14 TMDL calculations for North Branch Cooper River (annual loads and percent reductions*)

lake	North Branch Cooper River		% reduction
	kg TP/yr	% of LC	
loading capacity (LC)	693	100%	n/a
Point Sources other than Stormwater			
minor municipal	n/a		
Nonpoint and Stormwater Sources			
medium / high density residential	222	32%	88%
low density / rural residential	27	4%	88%
commercial	45	6%	88%
industrial	7	1%	88%
Mixed urban / other urban	36	5%	88%
agricultural	17	2%	88%
forest, wetland, water	72	10%	0%
barren land	32	5%	0%
septic systems	n/a		
waterfowl	n/a		
internal load	n/a		
tributary load	n/a		
Natural Sources / Background			
air deposition onto lake surface	-	-	0%
groundwater	n/a		
Other Allocations			
explicit Margin of Safety	236	34%	n/a

***Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 10.**

Figure 20 Phosphorus allocations for North Branch Cooper River

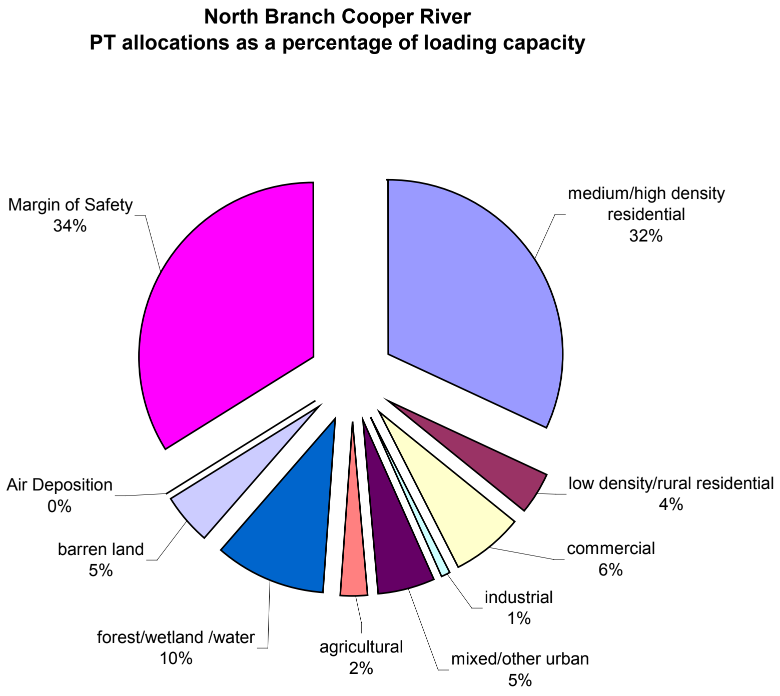


Table 15 TMDL calculations for Main Stem (annual loads and percent reductions*)

lake	Cooper River Main Stem		% reduction
	kg TP/yr	% of LC	
loading capacity (LC)	505	100%	n/a
Point Sources other than Stormwater			
minor municipal	n/a		
Nonpoint and Stormwater Sources			
medium / high density residential	173	34%	88%
low density / rural residential	2	0.5%	88%
commercial	63	13%	88%
industrial	19	4%	88%
Mixed urban / other urban	52	10%	88%
agricultural	-	-	0%
forest, wetland, water	18	4%	0%
barren land	0.5	0.1%	0%
septic systems	n/a		
waterfowl	n/a		
internal load	n/a		
tributary load	n/a		
Natural Sources / Background			
air deposition onto lake surface	5.4	1%	0%
groundwater	n/a		
Other Allocations			
explicit Margin of Safety	172	34%	n/a

***Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 10.**

Figure 21 Phosphorus allocations for Cooper River Main Stem

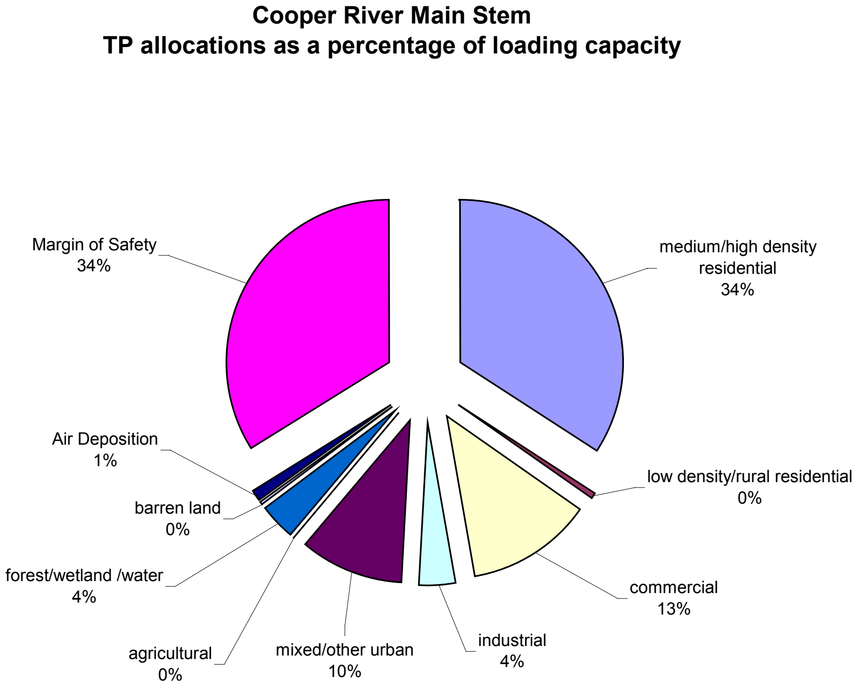
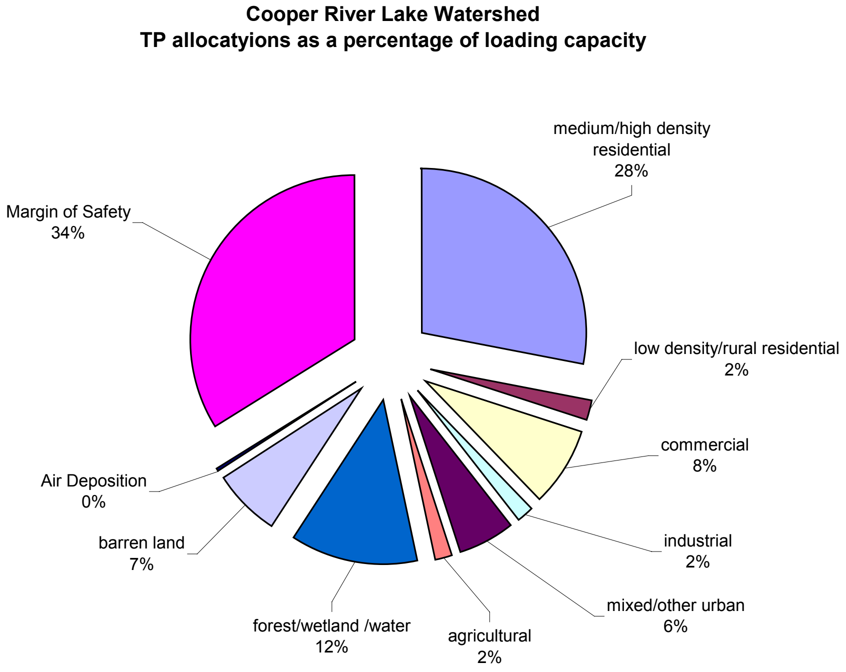


Table 16 TMDL calculations for the entire Cooper River Lake Watershed (annual loads and percent reductions*)

lake	Cooper River		% reduction
	kg TP/yr	% of LC	
loading capacity (LC)	2110	100%	n/a
Point Sources other than Stormwater			
minor municipal	n/a		
Nonpoint and Stormwater Sources			
medium / high density residential	624	30%	89.4%
low density / rural residential	48	2.3%	88.8%
commercial	185	9%	89.4%
industrial	39	1.8%	89.3%
Mixed urban / other urban	140	6.6%	89.1%
agricultural	30	1.4%	89.8%
forest, wetland, water	213	10%	0%
barren land	105	5%	0%
septic systems	n/a		
waterfowl	n/a		
internal load	n/a		
tributary load	n/a		
Natural Sources / Background			
air deposition onto lake surface	7	0.3%	0%
groundwater	n/a		
Other Allocations			
explicit Margin of Safety	718	34%	n/a

***Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 10.**

Figure 22 Phosphorus allocations for Cooper River Lake



9.0 Follow-up Monitoring

In the Cooper River watershed almost all monitored stations exceeded SWQSs for phosphorus concentration. Moreover, the exceedances decreased after eliminating all point-source dischargers in 1996, but still test results show elevated phosphorus concentration. The elevated phosphorus concentration at the Cooper River watershed could be caused by:

- releases of phosphorus accumulated in the bottom sediments during the period of time in which there were point sources dischargers and which are still released to the water column,
- phosphorus released by biological activity from decomposition of the organic matter,
- phosphorus in runoff from the entire watershed.

In evaluating the remaining impairments in the Cooper River watershed, particularly dissolved oxygen, a targeted sampling study will be performed of the sediments to determine the significance of the sediments in phosphorus concentrations and in exerting an oxygen demand.

The Water Resources Division of the U.S. Geological Survey and the Department have cooperatively operated the Ambient Stream Monitoring Network (ASMN) in New Jersey since the 1970s. The ASMN currently includes approximately 115 stations that are routinely monitored on a quarterly basis. The data from this network has been used to assess the quality of freshwater streams and percent load reductions. The Department is also initiating an ambient lake monitoring network. The ambient networks, as well as the targeted studies, will be the means to determine the effectiveness of TMDL implementation.

10.0 Implementation

The next steps toward implementation are preparation of lake characterization and lake restoration plans, where they have not already been developed. In the development of these plans, the loads by source will be revised, as necessary, to reflect refinements in source contributions. It will be on the basis of refined source estimates that specific strategies for reduction will be developed. These will consider issues such as cost and feasibility when specifying the reduction target for any source or source type. As appropriate, WLAs or other measures to be applied to traditional or stormwater point sources through NJPDES permits will be adopted by the Department as amendments to the applicable areawide Water Quality Management Plan.

The Department recognizes that TMDLs alone are not sufficient to restore eutrophic lakes. The TMDL establishes the required nutrient reduction targets and provides the regulatory framework to effect those reductions. However, the nutrient load only affects the eutrophication potential of a lake. The implementation plan therefore calls for the collection of additional monitoring data and the development of a Lake Restoration Plan for each lake. The plans will consider in-lake measures that need to be taken to supplement the nutrient reduction measures required by the TMDL. In addition, the plans will consider the ecology of the lake and adjust the eutrophication indicator target as necessary to protect the designated uses.

For instance, all of these lakes are shallow lakes, as defined by having a mean depth less than 3 meters. For a lake to be shallow means that most of the lake volume is within the photic zone and therefore more able to support aquatic plant growth (Holdren *et al*, 2001). Shallow lakes are generally characterized by either abundant submerged macrophytes and clear water or by abundant phytoplankton and turbid water. From an aquatic life and biodiversity perspective, it is desirable for shallow lakes to be dominated by aquatic plants rather than algae, especially phytoplankton. While lower nutrient concentrations favor the clear/plant state, either state can persist over a wide range of nutrient concentrations. Shallow lakes have ecological stabilizing mechanisms that tend to resist switches from clear/plant state to turbid/algae state, and vice-versa. The clear/plant state is more stable at lower nutrient concentrations and irreversible at very low nutrient concentrations; the turbid/algae state is more stable at higher nutrient concentrations. The Lake Restoration Plans for each lake will need to consider the ecological nuances of shallow and deep lakes.

The State of New Jersey has adopted a watershed approach to water quality management. That plan divides the state into five watershed management regions, one of which is the Lower Delaware Water Region. The Department recognizes that lake restoration requires a watershed approach. Lake Restoration Plans will be used as a basis to address overfertilization and sedimentation issues in watersheds that drain to these sensitive lakes. In addition, the Department will direct research funds to understand and demonstrate biomanipulation and other techniques that can be applied in New Jersey lakes to promote the establishment of healthy and diverse aquatic plant communities in shallow lakes. Finally, public education efforts will focus on the benefits of aquatic plants in shallow lakes and the balance of aquatic life uses with recreational uses of these lakes. With the combination of New Jersey's strong commitment to the collection and use of high quality data to support environmental decisions and regulatory programs, including TMDLs, the Department is reasonably assured compliance with the total phosphorus criteria applicable to these eutrophic lakes.

10.1 Watershed Characterization and Restoration Plans

In order to develop the Lake Restoration Plans to implement these TMDLs, additional monitoring may be performed. The level of characterization necessary to plan restoration will be specific to individual lakes depending on the remedial options being considered. During at least one or two summer trips, the following information may be collected as necessary.

- for shallow lakes, vegetation mapping using shore to center transects, measuring density and composition (emergents, rooted floaters, submergents, free-floating plants, submerged macro-algae)
- 1-5 mid-lake sampling stations as needed to characterize the lake
    - at least 2 samples per station per day; min 4 samples per trip
    - secchi depths
- chemistry (nutrients, chlorophyll-*a*, etc.)
    - surface, metalimnion, hypolimnion, and bottom if stratified
    - otherwise surface and bottom
- biology (integrated sample from mixed surface layer)
    - algal abundance and composition (greens, diatoms, blue-greens)
    - zooplankton abundance, composition and size ranges
- DO, temperature and pH profiles (hourly throughout day).

Where necessary, flow and water quality measurements of influent and effluent streams will be taken periodically from Spring to Fall, and fish abundance and composition will be assessed in early autumn.

The schedules for lake characterization and development of Lake Restoration Plans to implement these TMDLs are provided in Table 17.

Table 17 Implementation Schedule

Lake	Lake Characterization	Lake Restoration Plan
Kirkwood Lake	Summer 2006	Spring 2007
Evans Pond & Wallworth Lake	Summer 2006	Spring 2007
North Branch Cooper River	Summer 2006	Spring 2007
Cooper River Main Stem	Summer 2006	Spring 2007

Management measures are "economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint and stormwater sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint and stormwater source pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives" (USEPA, 1993).

Development of effective management measures depends on accurate source assessment. Phosphorus is contributed to the environment from a number of sources including fertilizer application on agricultural lands, fertilizer application on lawns, discharge from treatment plants and the natural process of decomposition. Phosphorus from these sources can reach waterbodies directly, through overland runoff, or through sewage or stormwater conveyance facilities. Each potential source will respond to one or more management strategies designed to eliminate or reduce that source of phosphorus. Each management strategy has one or more entities that can take lead responsibility to effect the strategy. Various funding sources are available to assist in accomplishing the management strategies. The Department will address the sources of impairment through systematic source trackdown, matching strategies with sources, selecting responsible entities and aligning available resources to effect implementation.

On February 2, 2004 the Department promulgated two sets of stormwater rules. The first set, N.J.A.C. 7: 8 update the state's Stormwater Management Rules for the first time since their original adoption in 1983. The rules establish new statewide minimum standards for stormwater management. These standards will also become requirements of several state-issued permits such as freshwater wetlands and stream encroachment permits. The second set of adopted stormwater rules are the Phase II New Jersey Pollutant Discharge Elimination System Stormwater Regulation Program Rules N.J.A.C. 7:14A, which require municipalities, large public complexes such as hospitals, and highway systems to develop stormwater management programs consistent with Tier A or B or other requirements through the New Jersey Pollutant Discharge Elimination System (NJPDES) permit program.

A 300-foot buffer to protect Category One (C1) waterbodies will be required. C1 protection is the highest form of water quality protection in the state, preventing any measurable deterioration in the existing water quality. The rules also apply the buffer to tributaries of C1 waterbodies within the immediate watershed of C1 waterbodies. In total, the buffers will impact 6,093 stream miles – including the 3,307 miles of currently designated C1 rivers and streams and an additional 2,786 miles of non-C1 tributaries to C1 streams.

The Stormwater Management Rules include performance standards for ground water recharge to protect the integrity of the state's aquifers. They establish a standard of maintaining 100 percent of the average annual ground water recharge for new development projects, a major initiative toward mitigating future droughts and flooding.

In addition to recharge standards, the regulations also stress water quality controls, such as best management practices to reduce runoff of total suspended solids (TSS) by 80 percent and other pollutants including nutrients to the maximum extent feasible. The rules require low impact designs for stormwater management systems that maintain natural vegetation and drainage and reduce clear-cutting and the unnecessary loss of trees and minimize impervious surface.

The stormwater discharged to the impaired segments through "small municipal separate storm sewer systems" (small MS4s) will be regulated under the Department's Phase II NJPDES stormwater rules for the Municipal Stormwater Regulation Program. Under these rules and associated general permits, many municipalities (and various county, State, and other agencies) in the Cooper River Watershed will be required to implement various control measures that should substantially reduce phosphorus loadings, including adoption and enforcement of low phosphorus fertilizer and pet waste disposal ordinances, prohibiting the feeding of unconfined wildlife on public property, cleaning catch basins, performing good housekeeping at maintenance yards, and providing related public education and employee training.

Sewage conveyance facilities are potential sources phosphorus in that equipment failure or operational problems may result in the release of untreated sewage. These sources, once identifed, can be eliminated through appropriate corrective measures that can be affected through the Department's enforcement authority. Inadequate on-site sewage disposal can also be a source of phosphorus. The Department has committed a portion of its FY 03 CWA Section 319(h) pass through grant funds to assist municipalities in meeting Phase II requirements. Inn addition, The New Jersey Environmental Infrastructure Financing Program, which includes New Jersey's State Revolving fund, provides low interest loans to assist in correction of water quality problems related to stormwater and wastewater management.

Agricultural activities are another example of potential sources of phosphorus. Implementation of conservation management plans and best management practices are the best means of controlling agricultural sources of phosphorus. Several programs are available to assist farmers in the development and implementation of conservation management plans and best management practices. The Natural Resource Conservation Service is the primary source of assistance for landowners in the development of resource management pertaining to soil conservation, water quality improvement, wildlife habitat enhancement, and irrigation water management. The USDA Farm Services Agency performs most of the funding assistance. All agricultural technical assistance is coordinated through the locally led Soil Conservation Districts. The funding programs include:

- **The Environmental Quality Incentive Program (EQIP)** is designed to provide technical, financial, and educational assistance to farmers/producers for conservation practices that address natural resource concerns, such as water quality. Practices under this program include integrated crop management, grazing land management, well sealing, erosion control systems, agri-chemical handling facilities, vegetative filter strips/riparian buffers, animal waste management facilities and irrigation systems.

- **The Conservation Reserve Program (CRP)** is designed to provide technical and financial assistance to farmers/producers to address the agricultural impacts on water quality and to maintain and improve wildlife habitat. CRP practices include the establishment of filter strips, riparian buffers and permanent wildlife habitats. This program provides the basis for the Conservation Reserve Enhancement Program (CREP).

- **The Conservation Reserve Enhancement Program (CREP)** The New Jersey Departments of Environmental Protection and Agriculture, in partnership with the Farm Service Agency and Natural Resources Conservation Service, has recently submitted a proposal to the USDA to offer financial incentives for agricultural landowners to voluntarily implement conservation practices on agricultural lands through CREP. NJ CREP will be part of the USDA's Conservation Reserve Program (CRP). The enrollment of farmland into CREP in New Jersey is expected to improve stream health through the installation of water quality conservation practices on New Jersey farmland.

Short Term Management Strategies

Short-term management measures include projects recently completed; underway or planned that will address sources of phosphorus load. Pertinent projects in the Cooper River Watershed are as follows:

Riparian Buffer Fencing Project for Cooper River Lake

In SFY 01, the Delaware Riverkeeper Network received a $8,450.00 Section 319(h) NPS grant to continue efforts of previous riparian buffer restoration work started by the Riverkeeper in 1994. To address the severe sedimentation from excessive urban stormwater runoff (from both upstream and in-lake sources) the Riverkeeper had previously restored 2 miles of riverbank using bio-engineering methods of erosion control, including coconut fiber logs and blankets in addition to planting shrubs grasses and trees. As a result, a 35-50 buffer of vegetation was created along much of the 1-mile project site. Because the buffer was in jeopardy of mowing to the waters edge, which would have greatly reduced the effectives of the BMP, this project supplemented sections of existing riparian buffer with larger plant stock and installed split rail fencing along selected sections to delineate the restoration site. No mow signs were also placed strategically to advise maintenance personnel not to mow the buffer area. This project resulted in the reduction of shoreline erosion and NPS from degrading Cooper River Lake and the Cooper River Watershed.

Biofilter Wetland Cooper River Lake

Camden County received a $159,450 section 319(h) NPS grant in SFY 01 to construct a biofilter wetland on the north side of Cooper River Lake in Collingswood. The creation of biofilter wetlands improves water quality by extending the detention time within the wetland. This enables sediments with adsorbed pollutants to settle out, and allows the plants and micro-organisms within the wetland to take up the nutrients and biodegrade various pollutants, in addition to enabling certain chemical transformations.

10.2 Reasonable Assurance

Reasonable assurance for the implementation of these TMDLs has been considered for point and nonpoint sources for which phosphorus load reductions are necessary. The Department has initiated an ambient lake monitoring network and proposes to characterize and develop specific restoration plans for these particular lakes according to the schedule in Table 17. Moreover, stormwater sources for which WLAs have been established will be regulated as NJPDES point sources.

With the implementation of follow-up monitoring and development of Lake Restoration Plans through watershed management process, the Department is reasonably assured that New Jersey's Surface Water Quality Standards will be attained for these lakes. Activities directed in the watersheds to reduce nutrient loadings shall include a whole host of options, included but not limited to education projects that teach best management practices, approval of projects funded by CWA Section 319 Nonpoint Source Grants, recommendations for municipal ordinances regarding feeding of wildlife, and pooper-scooper laws, and stormwater control measures.

11.0 Public Participation

The Water Quality Management Planning Rules NJAC 7:15-7.2 require the Department to initiate a public process prior to the development of each TMDL and to allow public input to the development of the TMDL. Further, the Department shall propose each TMDL as an amendment to the appropriate areawide water quality management plan in accordance with procedures at N.J.A.C. 7:15-3.4(g). As part of the public participation process for the development and implementation of the TMDLs for phosphorus to address eutrophic lakes in the Lower Delaware Water Region, the Department worked collaboratively with stakeholders in WMA 18. Stakeholder meetings were held in December 2002 to explain the Kirkwood Lake phosphorus TMDL and more recently on March 31, 2004 to explain the TMDL document. The purpose of the informal meetings was for stakeholders to identify areas of concern based on their local knowledge. The stakeholders were encouraged to provide any additional source information through the formal comment period after advertisement of the TMDL proposal in the New Jersey Register.

Additional input was received through the Rutgers New Jersey EcoComplex (NJEC). The Department contracted with NJEC in August 2001. The NJEC consists of a review panel of New Jersey University professors whose role is to provide comments on the Department's technical approaches for development of TMDLs and management strategies. The Rechow method for lake TMDLs was presented previously to the NJEC, while the Technical Approach for the Cooper River Watershed was presented to the NJEC on December 12, 2003.

Amendment Process

In accordance with N.J.A.C. 7:15-7.2(g), these TMDLs are hereby proposed by the Department as an amendment to the Tri-County WQMP.

Notice proposing these TMDLs was published April 19, 2004 in the New Jersey Register and in newspapers of general circulation in the affected area in order to provide the public an opportunity to review the TMDLs and submit comments. In addition, a public hearing was held on May 25, 2004. Notice of the proposal and the hearing was provided to applicable designated planning agencies and to affected municipalities.

Appendix A :References

Annadotter, H., G. Cronberg, R. Aagren, B. Lundstedt, P.-A. Nilsson and S. Ströbeck, 1999. Multiple techniques for lake restoration. Hydrobiologia 395/396:77-85.

Birch, S. and J. McCaskie, 1999. Shallow urban lakes: a challenge for lake management. Hydrobiologia 395/396:365-377.

Center for Watershed Protection, 2001. *Watershed Protection Techniques: Urban Lake Management*. T.R. Schueler, Ed.in Chief. Ellicott City, MD. www.cwp.org.

Cooke, G.D., P. Lombardo and C. Brant, 2001. Shallow and deep lakes: determining successful maangement options. Lakeline, Spring 2001, 42-46.

Cooke, G.D., E.B. Welch, S.A. Peterson, P.R. Newroth. 1993. Restoration and Management of Lakes and Reservoirs. Lewis Publishers.

Dillon, P.J. and F.H. Rigler, 1974. A test of a simple nutrient budget model predicting the phosphorus concentration in lake water. J. Fish. Res. Board Can. 31:1771-1778.

Donabaum, K., M. Schagerl and M.T. Dokulil, 1999. Integrated management to restore macrophyte domination. Hydrobiologia 395/396:87-97.

Draft TMDL Technical Approach To Address a Phosphorus Impairment in Cooper River, January 2004, NDEP Division of Watershed Management, Bureau of Environmental Analysis and Restoration.

Eisenreich, S.J. and J. Reinfelder. 2001. The New Jersey Air Deposition Network: Interim Report. Department Environmental Sciences, Rutgers University.

F. X. Brown Associates, Inc. 1993. Diagnostic/Feasibility Study of Burnt Mill Pond. Prepared for the City of Vineland. Vineland, New Jersey. December 1993.

F. X. Brown Associates, Inc. 1992. Diagnostic/Feasibility Study for Blackwood Lake. Gloucester Township, Camden County, New Jersey. FXB Project Number 1217-01.

F. X. Brown Associates, Inc. 1989. Diagnostic-Feasibility Study of Bell Lake. Prepared for the City of Woodbury, New Jersey. June 1989.

F. X. Brown Associates, Inc. 1989. Diagnostic/Feasibility Study of Giampietro Park Lake. Prepared for the City of Vineland. Vineland, New Jersey. May 1989.

Holdren, C., W. Jones, and J. Taggart, 2001. Managing Lakes and Reservoirs. North American Lake Management Society and Terrene Institute, in cooperation with U.S. Environmental Protection Agency. Madison, WI.

Hosper, S.H., 1998. Stable states, buffer and switches: an ecosystem approach to the restoration and management of shallow lakes in The Netherlands. Water Science Technology 37(3):151-164.

Madgwick, F.J., 1999. Strategies for conservation management of lakes. Hydrobiologia 395/396:309-323.

Melzer, A., 1999. Aquatic macrophytes as tools for lake management. Hydrobiologia 395/396:181-190.

Moss, B., J. Madgwick, G. Phillips, 1996. A Guide to the restoration of nutrient-enriched shallow lakes. Norfolk Broads Authority, 18 Colegate, Norwich, Norfolk NR133 1BQ, Great Britain.

Moss, B., M. Beklioglu, L. Carvalho, S. Kilinc, S. McGowan and D. Stephen. Vertically-challenged limnology; contrasts between deep and shallow lakes. Hydrobiologia 342/343:257-267.

National Research Council, Assessing the TMDL Approach to water quality management. National Academy Press, Washington, D.C. 2001

New Jersey Department of Environmental Protection. 1983a. New Jersey Lakes Management Program Lakes Classification Study: Bethel Lake, Mantua, Gloucester County. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

New Jersey Department of Environmental Protection. 1983b. New Jersey Lakes Management Program Lakes Classification Study: Imlaystown Lake, Imlaystown, Monmouth County. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

New Jersey Department of Environmental Protection. 1983c. New Jersey Lakes Management Program Lakes Classification Study: Kirkwood Lake, Lindenwold, Camden County. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

New Jersey Department of Environmental Protection. 1983d. New Jersey Lakes Management Program Lakes Classification Study: Mary Elmer Lake, Hopewell, Cumberland County. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

New Jersey Department of Environmental Protection. 1983e. New Jersey Lakes Management Program Lakes Classification Study: Memorial Lake, Woodstown, Salem County. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

New Jersey Department of Environmental Protection. 1983f. New Jersey Lakes Management Program Lakes Classification Study: Spring Lake, Hamilton, Mercer County. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

New Jersey Department of Environmental Protection. 1983g. New Jersey Lakes Management Program Lakes Classification Study: Sunset Lake, Upper Deerfield, Cumberland County. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

New Jersey Department of Environmental Protection. 1983h. New Jersey Lakes Management Program Lakes Classification Study: Woodbury Lake, Woodbury, Gloucester County. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

New Jersey Department of Environmental Protection. 1998. Identification and Setting of Priorities for Section 303(d) Water Quality Limited Waters in New Jersey, Office of Environmental Planning.

New Jersey Department of Environmental Protection. 2000a. Report on the Establishment of TMDL for Phosphorus in Strawbridge Lake. Amendment to Tri-County WQMP.

New Jersey Department of Environmental Protection. 2000b. Report on the Establishment of TMDL for Phosphorus in Lower Sylvan Lake. Amendment to Tri-County WQMP.

New Jersey Department of Environmental Protection. 2001. Status of Use Impairment of Public Lakes. Bureau of Freshwater and Biological Monitoring, Lakes Management Program.

New Jersey Department of Environmental Protection. 2002. New Jersey 2002 Integrated Water Quality Monitoring and Assessment Report. Water Monitoring and Management, Bureau of Water Quality Standards and Assessment.

New Jersey Department of Environmental Protection. 2003a. Technical Manual for Phosphorus Evaluation for NJPDES Discharge to Surface Water Permits", Division of Water Quality, N.J.A.C. 7:9b-1.14(c).

New Jersey Department of Environmental Protection. 2003b. Report on the Establishment of TMDL for Phosphorus to Address 13 Eutrophic Lakes in the Lower Delaware Water Region. Amendment to Atlantic County WQMP, Lower Delaware WQMP, Mercer County WQMP, Monmouth County WQMP, Tri-County WQMP. Division of Watershed Management.

New Jersey Department of Environmental Protection. 2003c. Surface Water Quality Standards. N.J.A.C. 7:9B.

New Jersey Department of Environmental Protection. 2004a. Draft TMDL Technical Approach to Address a Phosphorus Impairment in Cooper River. Prepared by Division of Watershed Management, Bureau of Environmental Analysis and Restoration.

New Jersey Department of Environmental Protection. 2004b. Proposed New Jersey 2004 Integrated Water Quality Monitoring and Assessment Report. Water Monitoring and Management, Bureau of Water Quality Standards and Assessment.

Ostrofsky, M.L., 1978. Modification of phosphorus retention models for use with lakes with low areal water loading. J. Fish. Res. Bd. Can. 35(12):1532-1536.

Perrow, M.R., A.J.D. Jowitt, J.H. Stansfield, G.L. Phillips, 1999. The practical importance of the interaction between fish, zooplankton and macrophytes in shallow lake restoration. Hydrobiologia 395/396:199-210.

Phillips, G., A. Bramwell, J. Pitt, J. Stansfield and M. Perrow, 1999. Practical application of 25 years' research into the management of shallow lakes. Hydrobiologia 395/395:61-76.

Princeton Hydro, LLC. 2003. Phase I Diagnostic / Feasibility Study of Harrisonville Lake, Gloucester and Salem Counties, New Jersey. Prepared for New Jersey Department of Fish & Game, Bureau of Freshwater Fisheries. Project No. 208.01.

Rast, W., A. Jones and G.F. Lee, 1983. Predictive capability of U.S. OECD phosphorus loading-eutrophication response models. Journal WPCF 55(7):990-1002.

Reckhow, K.H., 1979a. Uncertainty analysis applied to Vollenweider's phosphorus loading criterion. J. Water Pollution Control Federation 51(8):2123-2128.

Reckhow, K.H., 1979b. Quantitative Techniques for the Assessment of Lake Quality. EPA-440/5-79-015.

Reckhow, K.H., 1977. <u>Phosphorus Models for Lake Management</u>. Ph.D. dissertation, Harvard University.

Reckhow, K.H., M.N. Beaulac and J.T. Simpson, 1980. Modeling phosphorus loading and lake response under uncertainty: a manual and compilation of export coefficients. EPA 440/5-80-011.

Remington & Vernick Engineers. 1998. An Application for a New Jersey Department of Environmental Protection Lake Management Program. Phase II – Implementation Projects for the Restoration of Blackwood Lake. February.

Rodiek, R.K., 1979. Some watershed analysis tools for lake management. In <u>Lake Restoration</u>, EPA 400/5-79-001.

Scheffer, M., 1990. Multiplicity of stable states in freshwater systems. Hydrobiologia 200/201:475-486.

Soil Conservation Service. 1959. Soil Survey of Gloucester County, New Jersey. In cooperation with: New Jersey Agricultural Experiment Station and Cook College, Rutgers University.

Sutfin, C.H. May, 2002. Memo: EPA Review of 2002 Section 303(d) Lists and Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992. Office of Wetlands, Oceans and Watersheds, U.S.E.P.A.

Total Maximum Daily Loads for Phosphorus to Address 13 Eutrophic Lakes in the Lower Delaware Water Region, April 2003, NJDEP Division of Watershed Management.

U.S.E.P.A., 1999. Protocol for Developing Nutrient TMDLs. Watershed Branch, Assessment and Watershed Protection Division, Washington, DC.

Vollenweider, R.A., and J. Kerekes, 1982. Eutrophication of Waters: Monitoring, Assessment and Control. Organization for Economic Cooperation and Development (OECD), Paris. 156 p.

Wayland, R.H. III. November 22, 2002. Memo: Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs. Office of Wetlands, Oceans and Watersheds, U.S.E.P.A.

Appendix B: Database of Phosphorus Export Coefficients

In December 2001, the Department concluded a contract with the USEPA, Region 2, and a contracting entity, TetraTech, Inc., the purpose of which was to identify export coefficients applicable to New Jersey. As part of that contract, a database of literature values was assembled that includes approximately four-thousand values accompanied by site-specific characteristics such as location, soil type, mean annual rainfall, and site percent-impervious. In conjunction with the database, the contractor reported on recommendations for selecting values for use in New Jersey. Analysis of mean annual rainfall data revealed noticeable trends, and, of the categories analyzed, was shown to have the most influence on the reported export coefficients. Incorporating this and other contractor recommendations, the Department took steps to identify appropriate export values for these TMDLs by first filtering the database to include only those studies whose reported mean annual rainfall was between 40 and 51 inches per year. From the remaining studies, total phosphorus values were selected based on best professional judgement for eight land uses categories.

The sources incorporated in the database include a variety of governmental and non-governmental documents. All values used to develop the database and the total phosphorus values in this document are included in the below reference list.

Export Coefficient Database Reference List:

Allison, F.E., E.M. Roller, and J.E. Adams, 1959. Soil Fertility Studies in Lysimeters Containing Lakeland Sand. Tech. Bull. 1199, U.S. Dept. of Agriculture, Washington, D.C. p. 1-62.

Apicella, G., 2001. Urban Runoff, Wetlands and Waterfowl Effects on Water Quality in Alley Creek and Little Neck Bay. TMDL Science Issues Conference, WEF Specialty Conference.

Athayde, D. N, P. E. Shelly, E. D. Driscoll, D. Gaboury and G.B. Boyd, 1983. Results of the Nationwide Urban Runoff Program: Final Report. USEPA Water Planning Division. Washington, DC.

Avco Economic Systems Corporation, 1970. Storm Water Pollution from Urban Land Activity. Rep.11034 FKL 07/70, Federal Water Qual. Adm., U.S. Dept. of Interior, Washington, D.C. p. 325.

Bannerman, R., K. Baun, M. Bohm, P. E. Hughes, and D. A. Graczyk, 1984. Evaluation of Urban Nonpoint Source Pollution Management in Milwaukee, County, Eisconsin, Report No. PB84-114164, U.S. Environmental Protection Agency, Region V, Chicago, IL.

Bengtson, R.L. and C.E. Carter, 1989. Simulating Soil Erosion in the Lower Mississippi Valley with the CREAMS Model. From: Application of Water Quality Models for Agricultural and Forested Watersheds, edited by D.B. Beasley and D.L Thomas. Southern Cooperative Series Bulletin No. 338.

Broadbent, F.E., and H.D. Chapman, 1950. A Lysimeter Investigation of Gains, Losses and Balance of Salts and Plant Nutrients in an Irrigated Soil. Soil Sci. Soc. Amer. Proc. 14:261-269.

Carter, Gail P., 1998. Estimation of Nonpoint Source Phosphorus and Nitrogen Loads in Five Watersheds in New Jersey's Atlantic Coastal Drainage Basin. Surveying and Land Information Systems, Vol. 58, no 3. pp167-177.

CH2M Hill, 2000. Technical Memorandum 1, Urban Stormwater Pollution Assessment, prepared for North Carolina Department of Environment and Natural Resources, Division of Water Quality.

Claytor, R.A. and T.R. Schueler, 1996. "Design of Stormwater Filtering Systems," The Center for Watershed Protection, Prepared for Chesapeake Research Consortium, Inc.

Corsi, S.R., D.J. Graczyk, D.W. Owens, R.T. Bannerman, 1997. Unit-Area Loads of Suspended Sediment, Suspended Solids, and Total Phosphorus From Small Watersheds of Wisconsin. USGS FS-195-97.

Delaware Valley Regional Planning Commission, 1977. Average Pollutant Concentrations Associated with Urban Agriculture and Forest Land Use. Working Paper 5.01-1, Extent of NPS Problems.

Eck, P., 1957. Fertility Erosion Selectiveness on Three Wisconsin Soils. Ph. D. Thesis, Univ. of Wisconsin, Madison, WI.

F.X. Brown, Inc., 1993. Diagnostic-Feasibility Study of Strawbridge Lake. FXB Project Number NJ1246-01.

Frink, C.R., 1991. Estimating Nutrient Exports to Estuaries. Journal of Environmental Quality. 20:717-724.

Horner, R., B. W. Mar, L. E. Reinelt, J. S. Richey, and J. M. Lee, 1986. Design of monitoring programs for determination of ecological change resulting from nonpoint source water pollution in Washington State. University of Washington, Department of Civil Engineering, Seattle, Washington.

Horner, R.R., 1992. Water Quality Criteria/Pollutant Loading Estimation/Treatment Effectiveness Estimation. In R.W. Beck and Associates. Covington Master Drainage Plan. King County Surface Water Management Division., Seattle, WA.

Horner, Richard R., Joseph J. Skupien, Eric H. Livingston, and H. Earl Shaver, 1994. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. Prepared by the Terrene Institute, Washington, DC, in cooperation with the U.S. Environmental Protection Agency. EPA/840/B-92/002.

Johnston, W.R., F. Ittihadieh, R.M. Daum, and A.F. Pillsbury, 1965. Nitrogen and Phosphorus in Tile Drainage Effluent. Soil Sci. Soc. Amer. Proc. 29:287-289.

Knoblauch, H.C., L. Kolodny, and G.D. Brill, 1942. Erosion Losses of Major Plant Nutrients and Organic Matter from Collington Sandy Loam. Soil Sci. 53:369-378.

Loehr, R.C., 1974. Characteristics and comparative magnitude of non-point sources. Journal of WPCF 46(11):1849-1872.

Lopes, T.J., S.G. Dionne, 1998. A Review of Semivolatile and Volatile Organic Compounds in Highway Runoff and Urban Stormwater. U.S. Geological Survey, U.S. Department of Interior.

Marsalek, J., 1978. Pollution Due to Urban Runoff: Unit Loads and Abatement Measure, Pollution from Land Use Activities Reference Group. International Joint Commission, Windsor, Ontario.

McFarland, Anne M.S and L. M. Hauck, 2001. Determining Nutrient Export Coefficients and Source Loading Uncertainty Using In-stream Monitoring Data. Journal of the American Water Resources Association, pp. 223, 37. No. 1, February.

Menzel, R. G., E. D. Rhoades, A. E. Olness, and S. J. Smith, 1978. Variability of Annual Nutrient and Sediment Discharges in Runoff from Oklahoma Cropland and Rangeland. Journal of Environmental Quality, 7:401-406.

Mills, W.B., D.B. Porcella, M.J. Ungs, S.A. Gherini, K.V. Summers, L. Mok, G.L. Rupp, G.L. Bowie, 1985. Water Quality Assessment – A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water – Part I and II. EPA-600/6-85-002A&B.

Minshall, N.E., M.S. Nichols, and S.A. Witzel, 1969. Plant Nutrients in Base Flow of Streams in Southwestern Wisconsin. Water Resources. 5(3):706-713.

Mundy, C., M. Bergman, 1998. Technical Memorandum No. 29, The Pollution Load Screening Model: A tool for the 1995 District Water Management Plan and the 1996 Local Government Water Resource Atlases, Department of Water Resources, St. Johns River Water Management District.

NCDWQ, 1998. Neuse River Basinwide Water Quality Plan, Chapter 5, Section A.

Nelson, M.E., 1989. Predicting Nitrogen Concentrations in Ground Water An Analytical Model. IEP, Inc.

Northeast Florida Water Management District, 1994. St. Marks and Wakulla Rivers Resource Assessment and Greenway Protection Plan. Appendix 4.

Northern Virginia Planning District Commision, 1979. Guidebook for Screening Urban Nonpoint Pollution Management Strategies. Prepared for the Metropolitan Washington Council of Governments.

Novotny, V., H. Olem, 1994. Water Quality: Prevention, Identification, and Management of Diffuse Pollution. Van Nostrand Reinhold, NY

Omernik, J. M., 1976. The influence of land use on stream nutrient levels, US EPA January. EPA-60/3-76-014

Omni Environmental Corporation, 1991. Literature Search on Stormwater Pollutant Loading Rates. Literature cited from DVRPC 1977; Wanielista et al. 1977; Whipple and Hunter 1977; NVPDC 1980; USEPA 1983; Mills et al. 1985; Nelson 1989; Walker et al. 1989.

Omni Environmental Corporation, 1999. Whippany River Watershed Program Stormwater Model Calibration and Verification Report.

Overcash, M. R., F. J. Humenik, and J. R. Miner, 1983. Livestock Waste Management, Vol. II, CRC Press, Inc., Boca Raton, Florida.

Pacific Northwest Environmental Research Laboratory, 1974. Relationships Between Drainage Area Characteristics and Non-Point Source Nutrients in Streams. Prepared for the National Environmental Research Center, August 1974.

Panuska, J.C. and R.A. Lillie, 1995. Phosphorus Loadings from Wisconsin Watersheds: Recommended Phosphorus Export Coefficients for Agricultural and Forested Watersheds. Research Management Findings, Bureau of Research, Wisconsin Department of Natural Resources, Number 38.

Pitt, R.E., 1991. Nonpoint Source Water Pollution Management. Dep. Civil Eng., Univ. Alabama, Birmingham, AL.

Polls, Irwin and Richard Lanyon, 1980. Pollutant Concentrations from Homogeneous Land Uses. Journal of the Environmental Engineering Division.

Prey, J., D. Hart, A. Holy, J. Steuer, J. Thomas, 1996. A Stormwater Demonstration Project in Support of the Lake Superior Binational Program: Summary. Wisconsin Dept. of Natural Resources. (http://www.dnr.state.wi.us/org/water/wm/nps/tpubs/summary/lakesup.htm)

Rast, W. and G.F. Lee, 1978. Summary Analysis of the North American (U.S. Portion) OECD Eutrophication Project: Nutrient Loading—Lake Response Relationships and Trophic State Indices., EPA-600/3-78-008.

Reckhow, K.H., M.N. Beaulac and J.T. Simpson, 1980. Modeling of Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients. Report No. EPA 440/5-80-011. U.S. EPA, Washington, D.C.

Ryding, S. and W. Rast, 1989. The Control of Eutrophication of Lakes and Reservoirs. Man and the Biosphere Series, United Nations Educational Scientific and Cultural Organization, Paris, France.

Schueler, T.R., 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Prepared for the Metropolitan Washington Council of Governments.

Sonzogni, W.C. and G.F. Lee, 1974. Nutrient Sources for Lake Mendota - 1972. Trans. Wisc. Acad. Sci. Arts Lett. 62:133-164.

Uchrin, C.G. and T.J. Maldanato, 1991. Evaluation of Hydrocarbons in Urban Runoff and in Detention Basins. Water Writes. Water Research Institute, Division of Coastal and Environmental Studies, Rutgers University.

United States Geological Survey, U.S. Department of the Interior, 1998. Comparison of NPDES Program Findings for Selected Cities in the United States, USGS Fact Sheet, January

USEPA, 1987. Guide to Nonpoint Source Pollution Control. U.S. EPA, Criteria and Standards Division, Washington D.C.

USEPA, 1993. Urban Runoff Pollution Prevention and Control Planning (handbook). EPA/625/R-93/004.

USEPA, 2000. Watershed Analysis and Management (WAM) Guide for Tribes. (http://www.epa.gov/owow/watershed/wacademy/wam/)

Uttormark, P.D., J.D. Chapin, and K.M. Green, 1974. Estimating nutrient loadings of lakes from non-point sources. U.S. Environmental Protection Agency, Washington, D.C. 112 p. (WRIL 160609). EPA-660/3-74-020.

Walker, J.F., 1989. Spreadsheet Watershed Modeling for Nonpoint Source Pollution Management in a Wisconsin Basin, Water Resources Bulletin, Vol. 25, no. 1, pp. 139-147.

Wanielista, M.P., Y.A. Yousef, and W.M. McLellon, 1977. Nonpoint Source Effects on Water Quality, Journal Water Pollution Control Federation, Part 3, pp. 441-451.

Washington State Department of Ecology, 2000. Stormwater Management Manual for Western Washington: Volume I Minimum Technical Requirements. Publication No. 99-11.

Weidner, R.B., A.G. Christianson, S.R. Weibel, and G.G. Robeck, 1969. Rural Runoff as a Factor in Stream Pollution. J. Water Pollution. Con. Fed. 36(7):914-924.

Whipple, W. and J.V. Hunter, 1977. Nonpoint Sources and Planning for Water Pollution Control. Journal Water Pollution Control Federation. pp. 15-23.

Whipple, W., et al., 1978. Effect of Storm Frequency on Pollution from Urban Runoff, J. Water Pollution Control Federation. 50:974-980.

Winter, J.G. and H.C. Duthie, 2000. Export Coefficient Modeling to assess phosporus loading in an urban watershed. Journal of American Water Resources Association. Vol. 36 No. 5.

Zanoni, A.E., 1970. Eutrophic Evaluation of a Small Multi-Land Use Watershed. Tech. Completion Rep. OWRR A-014-Wis., Water Resources Center, Univ. of Wisconsin, Madison, WI.

Appendix C: Phosphorus Criterion Applicability Determination

This discussion is taken from the New Jersey Department of Environmental Protection's 2003 report, *Technical Manual for Phosphorus Evaluation for NJPDES Discharge to Surface Water Permits,* Division of Water Quality, N.J.A.C. 7:9b-1.14(c).

Is Phosphorus Limiting?

The limiting nutrient can be evaluated using available nutrient concentrations by using the following thresholds to exclude phosphorus as the limiting nutrient (The acronyms TIN and DRP refer to biologically-available forms of nitrogen and phosphorus, respectively: TIN = dissolved nitrite, nitrate and ammonia; DRP = dissolved reactive phosphorus):

IF [DRP] $\geq$ 0.05 mg/l
OR TIN/DRP $\leq$ 5
THEN phosphorus can be excluded as the limiting nutrient

Figures 2 and 3 show examples of how to plot pairs of TP and DRP data along a TIN/DRP axis to visually evaluate the phosphorus limitation thresholds at a particular location. By making the TP range twice the DRP range, the thresholds of 0.1 mg/l TP and 0.05 mg/l DRP coincide, simplifying the interpretation. Episodes when TP > 0.1 mg/l AND DRP $\leq$ 0.05 mg/l and TIN/DRP $\geq$ 5 can be identified by seeing TP in the upper right quadrant while DRP is in the lower right quadrant. If phosphorus cannot be excluded as the limiting nutrient for more than 10% of the samples that exceed the 0.1 mg/l threshold (a minimum of 2 samples), then the 0.1 mg/l criterion is applicable.

Figure 1: Example of site where 0.1 mg/l criterion is applicable and exceeded

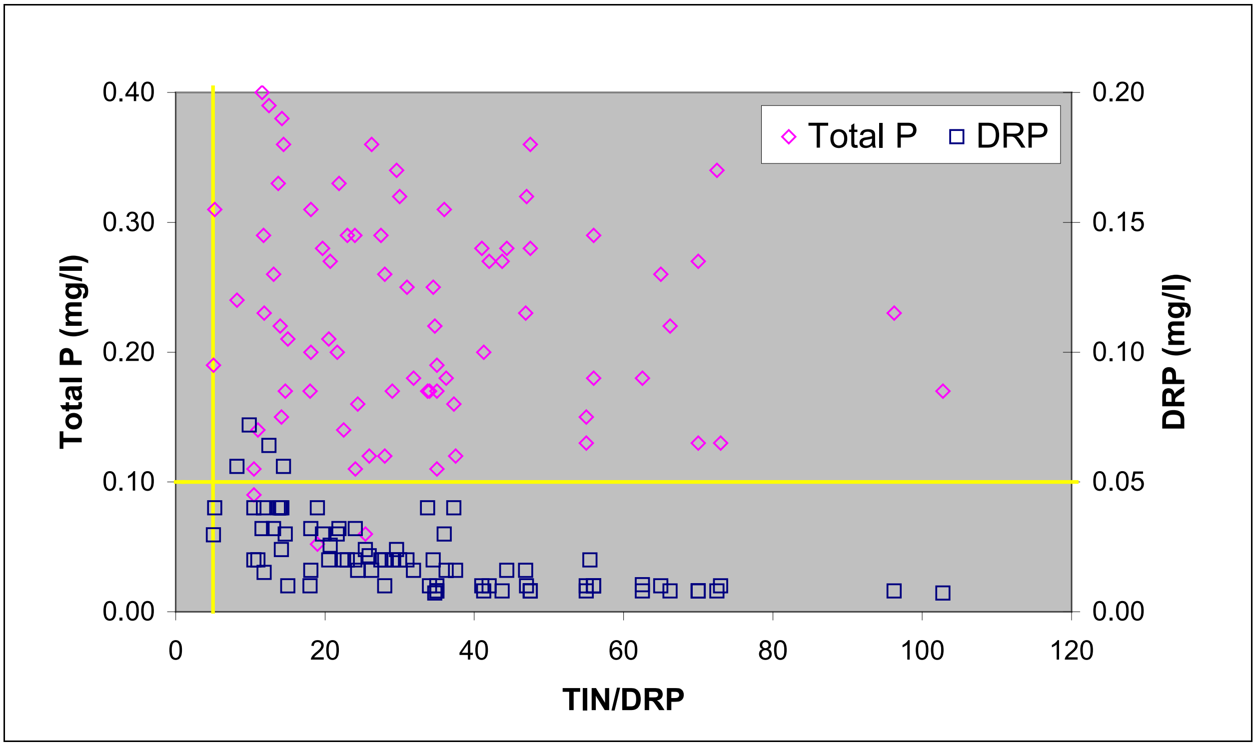
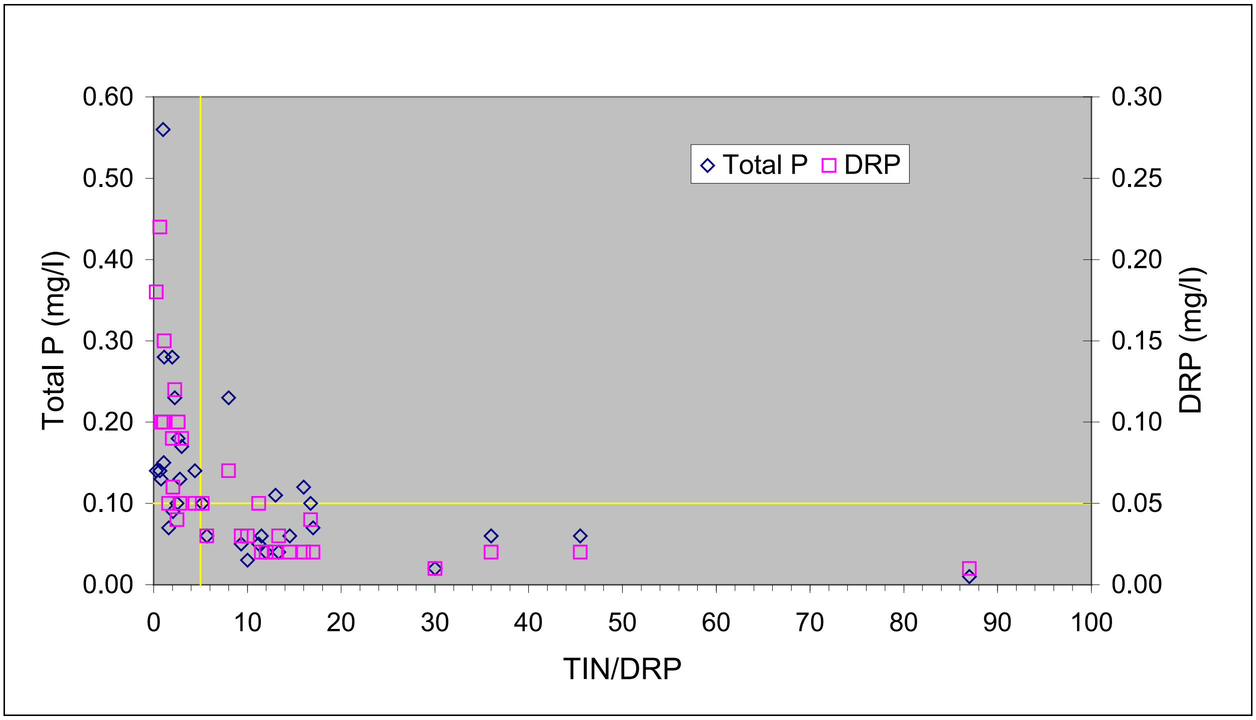


Figure 2: Example of site where phosphorus is not limiting algal growth when 0.1 mg/l threshold is exceeded



Please note that the use of the acronym DRP has been replaced with the acronym TOP for Figures 7, 9, 11, and 13. TOP stands for total organic phosphorus.

Appendix D: Summary of Reckhow (1979a) model derivation

The following general expression for phosphorus mass balance in lake assumes the removal of phosphorus from a lake occurs through two pathways, the outlet (M_o) and the sediments (ϕ):

$$V \cdot \frac{dP}{dt} = M_i - M_o - \phi$$ **Equation 1**

where:
V = lake volume (10^3 m³)
P = lake phosphorus concentration (mg/l)
M_i = annual mass influx of phosphorus (kg/yr)
M_o = annual mass efflux of phosphorus (kg/yr)
ϕ = annual net flux of phosphorus to the sediments (kg/yr).

The sediment removal term is a multidimensional variable (dependent on a number of variables) that has been expressed as a phosphorus retention coefficient, a sedimentation coefficient, or an effective settling velocity. All three have been shown to yield similar results; Reckhow's formulation assumes a constant effective settling velocity, which treats sedimentation as an areal sink.

Assuming the lake is completely mixed such that the outflow concentration is the same as the lake concentration, the phosphorus mass balance can be expressed as:

$$V \cdot \frac{dP}{dt} = M_i - v_s \cdot P \cdot A - P \cdot Q$$ **Equation 2**

where:
v_s = effective settling velocity (m/yr)
A = area of lake (10^3 m²)
Q = annual outflow (10^3 m³/yr).

The steady-state solution of Equation 2 can be expressed as:

$$P = \frac{P_a}{v_s + z/T} = \frac{P_a}{v_s + Q_a}$$ **Equation 3**

where:
P_a = areal phosphorus loading rate (g/m²/yr)
z = mean depth (m)
T = hydraulic detention time (yr)
Q_a = Q/A = areal water load (m/yr).

Using least squares regression on a database of 47 north temperate lakes, Reckhow fit the effective settling velocity using a function of areal water load:

$$P = \frac{P_a}{11.6 + 1.2 \cdot Q_a}$$ **Equation 4**

Appendix E: Derivation of Margin of Safety from Reckhow *et al* (1980)

As described in Reckhow *et al* (1980), the Reckhow (1979a) model has an associated standard error of 0.128, calculated on log-transformed predictions of phosphorus concentrations. The model error analysis from Reckhow *et al* (1980) defined the following confidence limits:

$$P_L = P - h \cdot \left(10^{(\log P - 0.128)} - P\right)$$
$$P_U = P + h \cdot \left(10^{(\log P + 0.128)} - P\right)$$
$$\rho \geq 1 - \frac{1}{2.25 \cdot h^2}$$

where:
P_L = lower bound phosphorus concentration (mg/l);
P_U = upper bound phosphorus concentration (mg/l);
P = predicted phosphorus concentration (mg/l);
h = prediction error multiple
ρ = the probability that the real phosphorus concentration lies within the lower and upper bound phosphorus concentrations, inclusively.

Assuming an even-tailed probability distribution, the probability (ρ_u) that the real phosphorus concentration is less than or equal to the upper bound phosphorus concentration is:

$$\rho_u = \rho + \frac{1-\rho}{2} = \rho + \frac{1}{2} - \frac{\rho}{2} = \rho \cdot \left(1 - \frac{1}{2}\right) + \frac{1}{2} = \frac{1}{2} \cdot \rho + \frac{1}{2}$$

Substituting for ρ as a function of h:

$$\rho_u = \frac{1}{2} \cdot \left(1 - \frac{1}{2.25 \cdot h^2}\right) + \frac{1}{2} = \frac{1}{2} - \frac{1}{4.5 \cdot h^2} + \frac{1}{2} = 1 - \frac{1}{4.5 \cdot h^2}$$

Solving for h as a function of the probability that the real phosphorus concentration is less than or equal to the upper bound phosphorus concentration:

$$\frac{1}{4.5 \cdot h^2} = 1 - \rho_u$$
$$h^2 = \frac{1}{4.5(1-\rho_u)}$$
$$h = \sqrt{\frac{1}{4.5(1-\rho_u)}}$$

Expressing Margin of Safety (MoS_p) as a percentage over the predicted phosphorus concentration yields:

$$MoS_p = \frac{P_U}{P} - 1 = \frac{P_U - P}{P}$$

Substituting the equation for P_U:

$$MoS_p = \frac{P + h\cdot\left(10^{(\log P + 0.128)} - P\right) - P}{P} = \frac{h\cdot\left(10^{(\log P+0.128)} - P\right)}{P}$$
$$P\cdot MoS_p = h\cdot\left(10^{(\log P+0.128)} - P\right)$$
$$\frac{P\cdot MoS_p}{h} = 10^{(\log P+0.128)} - P$$
$$\frac{P\cdot MoS_p}{h} + P = 10^{(\log P+0.128)}$$

Taking the log of both sides and solving for margin of safety:

$$\log\left(\frac{P\cdot MoS_p}{h} + P\right) = \log P + 0.128$$
$$\log\left(\frac{P\cdot MoS_p}{h} + P\right) - \log P = 0.128$$
$$\log\left(P\left(\frac{MoS_p}{h} + 1\right)\right) - \log P = 0.128$$
$$\log P + \log\left(\frac{MoS_p}{h} + 1\right) - \log P = 0.128$$
$$\log\left(\frac{MoS_p}{h} + 1\right) = 0.128$$
$$\frac{MoS_p}{h} + 1 = 10^{0.128}$$
$$\frac{MoS_p}{h} = 10^{0.128} - 1$$
$$MoS_p = h\left(10^{0.128} - 1\right)$$

Finally, substituting for *h* yields Margin of Safety (*MoS*$_p$*)* as a percentage over the predicted phosphorus concentration, expressed as a function of the probability (ρ_u) that the real phosphorus concentration is less than or equal to the upper bound phosphorus concentration:

$$MoS_p = \sqrt{1\Big/\left((1-\rho_u)*4.5\right)} \times \left(10^{0.128} - 1\right)$$

Appendix F: Stormwater Dischargers into Cooper River Watershed

NJPDES Permit Number	PI Number	Facility Name	Municipality	Effective Start Date	Expiration Date	Discharge Category Code	Discharge Category Description
NJG0144533	196552	WILLIAM R HALL CO	Lindenwold Boro	7/30/03	5/31/07	5G2	Basic Industrial Stormwater GP - NJ0088315 (5G2)
NJG0119768	48595	UNITED PARCEL SERVICE	Lawnside Boro	6/1/02	5/31/07	5G2	Basic Industrial Stormwater GP - NJ0088315 (5G2)
NJG0120553	48656	CATELLI BROTHERS INC	Collingswood Boro	6/1/02	5/31/07	5G2	Basic Industrial Stormwater GP - NJ0088315 (5G2)
NJG0120537	48654	NATIONAL KEYSTONE PRODUCTS CO	Cherry Hill Twp	6/1/02	5/31/07	5G2	Basic Industrial Stormwater GP - NJ0088315 (5G2)
NJG0003999	46605	VICTORY REFRIGERATION LLC	Cherry Hill Twp	6/1/02	5/31/07	5G2	Basic Industrial Stormwater GP - NJ0088315 (5G2)
NJG0117196	48386	INCOLN GRAPHICS INC	Cherry Hill Twp	6/1/02	5/31/07	5G2	Basic Industrial Stormwater GP - NJ0088315 (5G2)
NJG0104612	47526	RCA-BUZBY LANDFILL	Voorhees Twp	6/1/02	5/31/07	5G2	Basic Industrial Stormwater GP - NJ0088315 (5G2)
NJG0121011	48702	L & L REDI-MIX INC/PLANT 2	Voorhees Twp	10/1/03	9/30/08	CPM	Concrete Products Management (GP)
NJG0121096	48707	L & L REDI-MIX INC/GIBBSBORO B	Voorhees Twp	10/1/03	9/30/08	CPM	Concrete Products Management (GP)
NJG0146471	215808	LINK BURNS MFG CO INC	Voorhees Twp	1/28/04	5/31/07	5G2	Basic Industrial Stormwater GP - NJ0088315 (5G2)

Appendix G: Cooper River Watershed's Photo-documentation

Cooper River Parkway Dam at Kaighn Avenue in Camden City: the tide gates prevent flow upstream during a high tide.

Cooper River Parkway Dam at Kaighn Avenue (from the lake side)

View on the Cooper River Lake from the Cooper River Parkway Dam

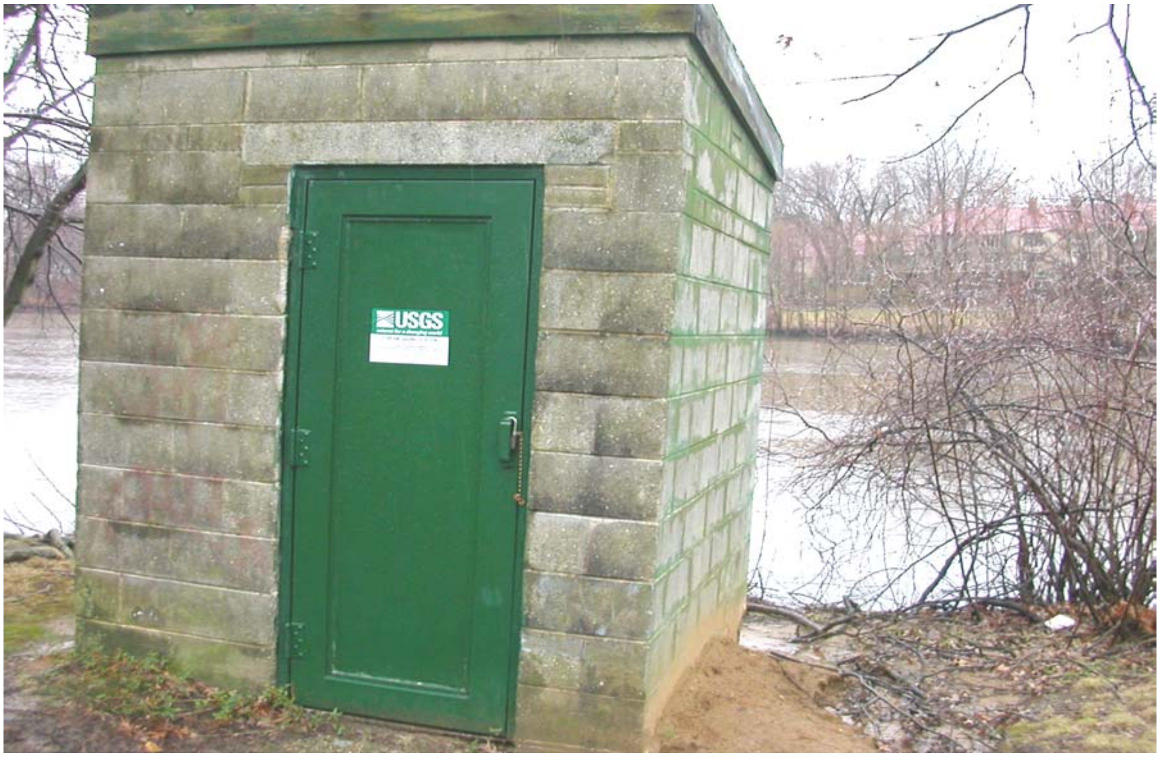
Cooper River Lake between Kaighn Avenue and Rt 130

Cooper River Lake at Route 130 bridge, Collingswood. View on the Cooper River Lake from the east side toward west

Cooper River Lake between Rt 130 and Wallworth Dam

Wallworth Lake Dam, View from the bridge - Wallworth Park in Haddonfied

Wallworth Lake: Fishway from Wallworth Lake to Evans Pond, at the bottom of the picture, stormwater discharge. North side of the lake



USGS Station #01467150 at north side of the Wallworth Lake

Wallworth Lake, USGS station 01467150

Spill through the Evans Pond Dam to Wallworth Lake

As above

Appendix H: Validation of Lakes as Endpoints for Stream Segment Impairments

The stream segments were assessed to determine whether or not the 0.1 mg/l TP stream standard should apply. Because applicability of the standard could not be ruled out, an approach was developed to verify that achieving the lake criterion would also serve to attain SWQS in the stream segments.

Summary of Impairment Measures for Stream Segments: Evaluation of 1998 and 2002 sampling results

1. LINDENWOLD
Station 01467120, outlet of Linden Lake

Nutrient Parameters	**Impairment Triggers**
Diurnal Dissolved Oxygen **NOT TESTED: no conclusion**	1. Daytime average is 3 mg/L or more higher than nighttime average 2. Minimum DO threshold is violated in greater than 10% of the samples taken during the night 3. DO daily average violates the applicable 24-hour average criteria Phosphorus is rendering the water unsuitable for aquatic life use if both 1 and 2 **<u>or</u>** 1 and 3 occur in any single 3-day sampling event
AND Periphyton Concentration (Chl a) **NOT TESTED: no conclusion**	>150 mg/m^2 Seasonal Mean > 200 mg/m^2 Individual Sample
AND Phytoplankton Concentration (Chl a) **<u>Results</u>** **from 3.7 μg/L to 47.9 μg/L (six results)** **2002: seasonal mean 21.5 μg/L: not impaired**	>24 μg/L Seasonal Mean > 32 μg/L 2 week mean

Phosphorus limiting IF [DRP] ≥ 0.05 mg/L	**NO** **DRP** = 0.02 mg/L for the 2002's season
OR **TIN/DRP ≤ 5**	**78% of TIN/DRP ≤ 5;** **22% of TIN/DRP ≥ 5**
PHOSPHORUS CAN NOT BE EXCLUDED AS THE LIMITING NUTRIENT	

2. LAWNSIDE
Station 01467140

Nutrient Parameters	**Impairment Triggers**
Diurnal Dissolved Oxygen <u>**Results:**</u> **1. 0.7 mg/L** **2. 100% samples do not violate DO threshold** **3. DO daily average does not violate 5.0 mg/L standard for FW-2NT** **Phosphorus <u>is not rendering</u> the water unsuitable for aquatic life use**	1. Daytime average is 3 mg/L or more higher than nighttime average 2. Minimum DO threshold is violated in greater than 10% of the samples taken during the night 3. DO daily average violates the applicable 24-hour average criteria Phosphorus is rendering the water unsuitable for aquatic life use if both 1 and 2 **<u>or</u>** 1 and 3 occur in any single 3-day sampling event
AND Periphyton Concentration (Chl a) **NOT TESTED: no conclusion**	>150 mg/m^2 Seasonal Mean > 200 mg/m^2 Individual Sample
AND Phytoplankton Concentration (Chl a) <u>**Results**</u> **from 1.5 μg/L to 11.2 μg/L (six results)** **Seasonal mean 2002: 5.98 μg/L: not impaired**	>24 μg/L Seasonal Mean > 32 μg/L 2 week mean

Phosphorus limiting IF [DRP] ≥ 0.05 mg/L	**NO** **DRP ≥ 0.05 mg/L in 56% samples**
OR **TIN/DRP ≤ 5**	**TIN/DRP ≤ 5 in 33% (3 of 9)**
PHOSPHORUS CAN NOT BE EXCLUDED AS THE LIMITING NUTRIENT	

3. KRESSON
Station 01467155

Nutrient Parameters	**Impairment Triggers**
Diurnal Dissolved Oxygen **<u>Results:</u>** **1. 2.45 mg/L** **2. 100% samples do not violate DO threshold** 3. **DO daily average does not violate 5.0 mg/L standard for FW-2NT** **Phosphorus <u>is not rendering</u> the water unsuitable for aquatic life use**	1. Daytime average is 3 mg/L or more higher than nighttime average 2. Minimum DO threshold is violated in greater than 10% of the samples taken during the night 3. DO daily average violates the applicable 24-hour average criteria Phosphorus is rendering the water unsuitable for aquatic life use if both 1 and 2 **<u>or</u>** 1 and 3 occur in any single 3-day sampling event
AND Periphyton Concentration (Chl a) **NOT TESTED: no conclusion**	>150 mg/m^2 Seasonal Mean > 200 mg/m^2 Individual Sample
AND Phytoplankton Concentration (Chl a) **Results: from 0.0 to 1.9 μg/L** **Seasonal mean 2002: 0.68 μg/L: not impaired**	>24 μg/L Seasonal Mean > 32 μg/L 2 week mean

Phosphorus limiting IF [DRP] ≥ 0.05 mg/L	**YES** **DRP ≥ 0.05 mg/L in 100% samples**
OR **TIN/DRP ≤ 5**	**TIN/DRP ≤ 5 in 12.5% (1 of 8)**
PHOSPHORUS CAN NOT BE EXCLUDED AS THE LIMITING NUTRIENT	

Data assessment for TMDL development

The following analysis was completed to ensure that using the lakes as the critical locations for TP and concluding that load reductions calculated to attain the lake SWQS of 0.05 mg/l will result in attainment of the stream standard of 0.1 mg/l is valid. Where sufficient concentration and flow data were available, a method that determines the percent reduction based on the linear regression of daily total phosphorus loading (pound per day, lb/day) versus flow (cubic feet per second, cfs) was used. The method was adapted from "TMDL Development Using Load Duration Curves" as presented at an ASIWPCA TMDL "Brown Bag" by Tom Stiles (Kansas Department of Health and Environment), Andrew Sullivan (Texas Natural Resource Conservation Commission), Charles Martin (Virginia Department of Environmental Quality), and Bruce Cleland (America's Clean Water Foundation), May 16, 2002.

To get the percent reduction, the technique in “TMDL Development Using Load Duration Curves” (Stiles et al., 2002) was modified to 1) use instantaneous flow measurements in place of a flow-duration (cumulative frequency of average daily flows), 2) use a load versus flow in place of a load versus flow probability relationship, and 3) provide more certainty in the location of the y-intercept. In many cases, long-term continuous flow monitoring data are not available along streams requiring TMDLs. When continuous flow data are not available, flows must be estimated using either continuous flow records from a flow measurement station in a nearby watershed, or by using a constant flow per unit drainage area. Both of these flow estimating techniques introduce variability that is inherent to the use of data from other locations or from approximations of watershed characteristics. Therefore, the modifications to the regression technique permit the use of fewer flow data while providing a site-specific analysis of loading exceedances over a range of measured flows.

Percent loading reduction is the difference between the upper 95 percent confidence limit of the slope of the regression for the loadings exceeding the target loading line and the slope of the target loading. The resultant percent reduction is the same whether the y-axis is expressed as pounds per day, pounds per year, or as metric units of kilograms per day or per year.

The referenced approach requires enough historical flow and concentration data to define a representative flow duration curve and associated loading duration curve. The concept of this approach is to determine the average of the loading exceedances derived from the measured data loadings that exist between the probability curve of the associated regulatory loading target and a selected upper confidence limit of a regression through the exceedances. The regulatory loading target and measured pollutant loadings are plotted against flow duration.

For the Haddonfield (Station 01467150), the actual phosphorus loadings are compared to the 0.1 mg/L total phosphorus target (presented as daily loadings) (Figure 1) . Exceedances are analyzed and load reductions are calculated. Also the upper 95 percent confidence limit for the regression of the exceedances are calculated and plotted. Finally, the percent reduction in total phosphorus loads (difference between the upper 95 percent confidence limit of the exceedance regression and the target load regression) are calculated to maintain compliance with the both standards (0.05 mg/L and 0.1 mg/L TP SWQSs.)

The same method was used for the Lawnside segment (Station 01467140). The data set consisted of 38 TP concentration data with the corresponding flows. These data were collected from 1986 through 1991, 1998, and 2002. For the statistical analysis, a set of 34 pairs of TP concentration-flow data were used. Figure 2 presents actual phosphorus loadings (points), linear exceedence regression line, and an upper 95% confidence line and shows how they relate to the target load at 0.1 mg/L TP for Lawnside. Exceedances are analyzed and load reductions calculated as well as the upper 95 percent confidence limit for the regression of the exceedances. The percent reduction in total phosphorus loads (difference between the upper 95 percent confidence limit of the exceedance regression and the target load) is calculated to maintain compliance with a 0.1 mg/L TP standard for the stream.

For remaining stream segments, Lindenwold (01467120) and Kresson (01467155), this method could not be applied because of the lack of flow data. Instead, a linear relationship, between load reduction and in-stream concentration was assumed to exist. The load reduction needed to attain the SWQS for streams was calculated, based on the highest recorded data point. Data for these stations is presented in Figures 3 and 4. Table 1 summarizes the load reductions required using the TMDL methodology and the two alternate methods for assessing attainment of SWQS in stream segments.

Figure 1

TMDL of Total Phosphorus Loading for 0.1 mg/L TP Target Condition

Haddonfield, Station 01467150

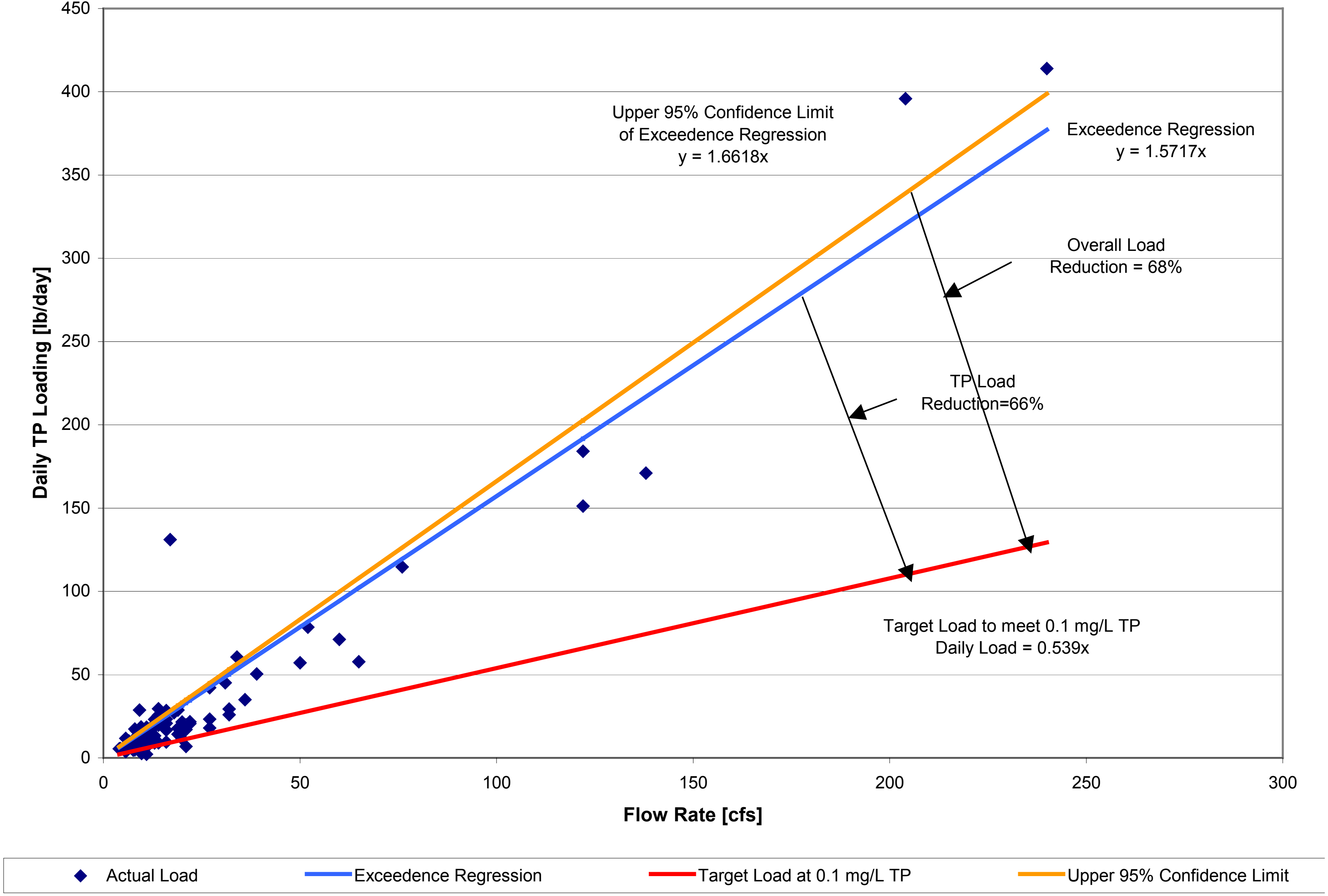
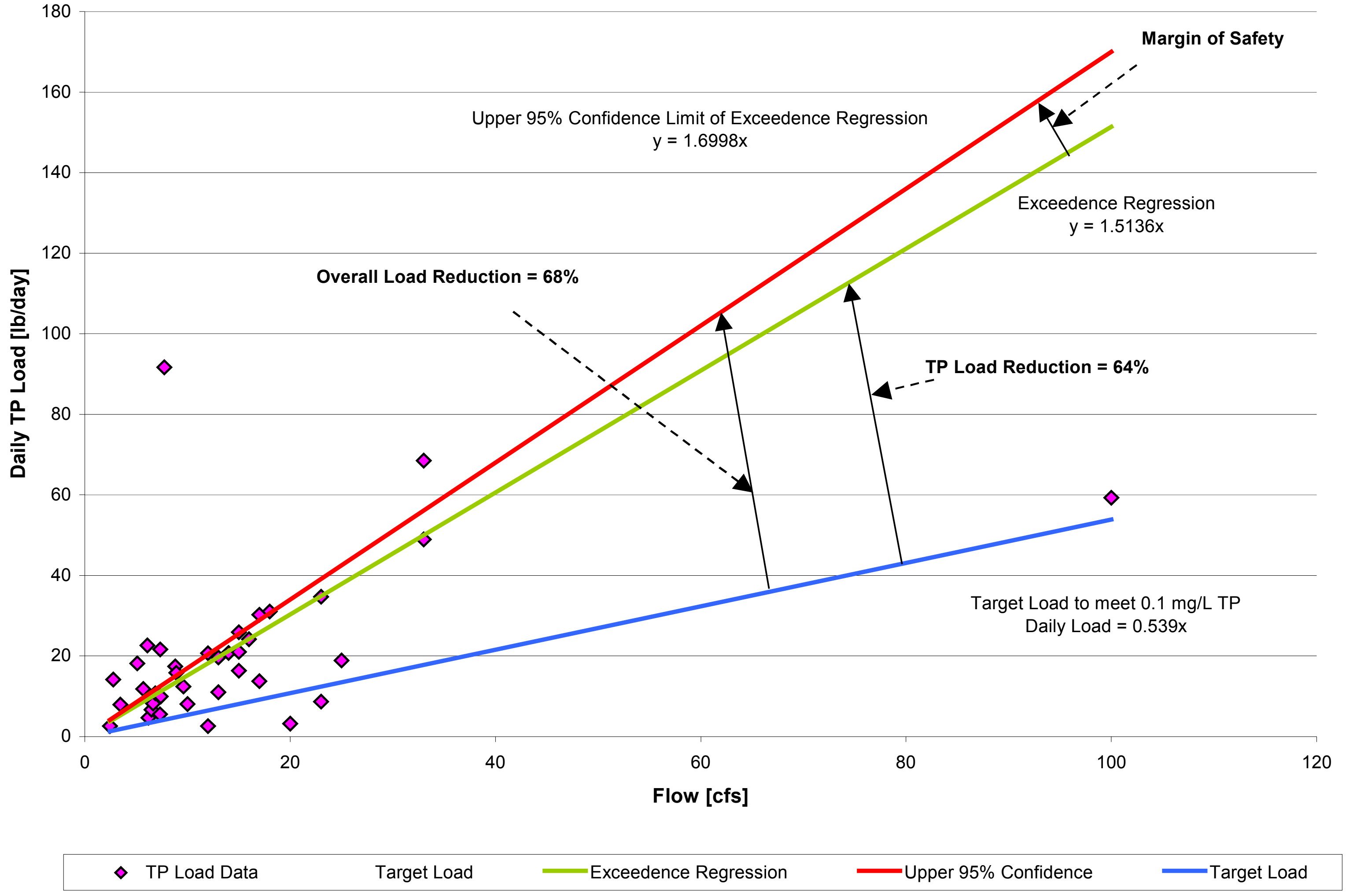


Figure 2
TMDL of Total Phosphorus Loading for 0.1 mg/L TP Target Condition
Lawnside, Station 01467140



Haddonfield 01467150

SUMMARY OUTPUT (Load exceedences for TP>0.1mg/L)

Regression Statistics	
Multiple R	0.957857671
R Square	0.917491318
Adjusted R Square	0.905145639
Standard Error	19.56525199
Observations	82

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	344792.83	344792.83	900.7148738	2.68495E-45
Residual	81	31006.72593	382.7990855		
Total	82	375799.5559			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	1.571744434	0.045236558	34.74500535	1.99167E-50	1.481737802	1.661751066

Note: 1. The highest monitoring result was rejected (outlier)
2. Only four TP concentrations were below SWQS of 0.1 mg/L

To achieve water quality standard at the Haddonfield station at the TP concentration of 0.1 mg/L (SWQS for streams), the required reductions are as follows:

Target Load (lb/day) for the given TP SWQS of 0.1 mg/L = 0.0.539 x flow (cfs)

Required TP Load Reduction based on the regression line: (from Figure 1)

Required TP Load Reduction = $(1-\frac{0.539}{1.5717}) = 0.6571x100\% = 66\%$

TP Load reduction required, based on the Upper 95% Confidence Limit of the regression line:

Load Reduction = $1-\frac{0.539}{1.6618}=0.6757x100\%=68\%$

The loading capacity is determined by 68% reduction on the existing loading, of which 5% will be a margin of safety (MOS):

MOS = $\frac{0.6757-0.6571}{1-0.6571}x100\%=5\%$

Lawnside, station 01467140

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.833613479
R Square	0.694911433
Adjusted R Square	0.662653369
Standard Error	7.363080178
Observations	32

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3828.108843	3828.108843	70.60983848	2.22978E-09
Residual	31	1680.663441	54.21494971		
Total	32	5508.772284			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	1.513610114	0.090307071	16.76070434	4.28999E-17	1.329427526	1.697792702

Note:

1. One highest monitoring result was rejected, did not fit to data population (outlier);
2. Three TP concentration results were below 0.1 mg/L (SWQS of 0.1 mg/L for the stream)

To achieve SWQS for streams, total phosphorus concentration of 0.1 mg/L TP, the required reductions are as follows:

Target Load (lb/day) for the given TP concentration of 0.1 mg/L = 0.539 x flow (cfs)

Required TP Load Reduction based on the regression line: (from Figure 2)

Required TP Load Reduction = $(1-\frac{0.539}{1.5136})x100\% = 64\%$

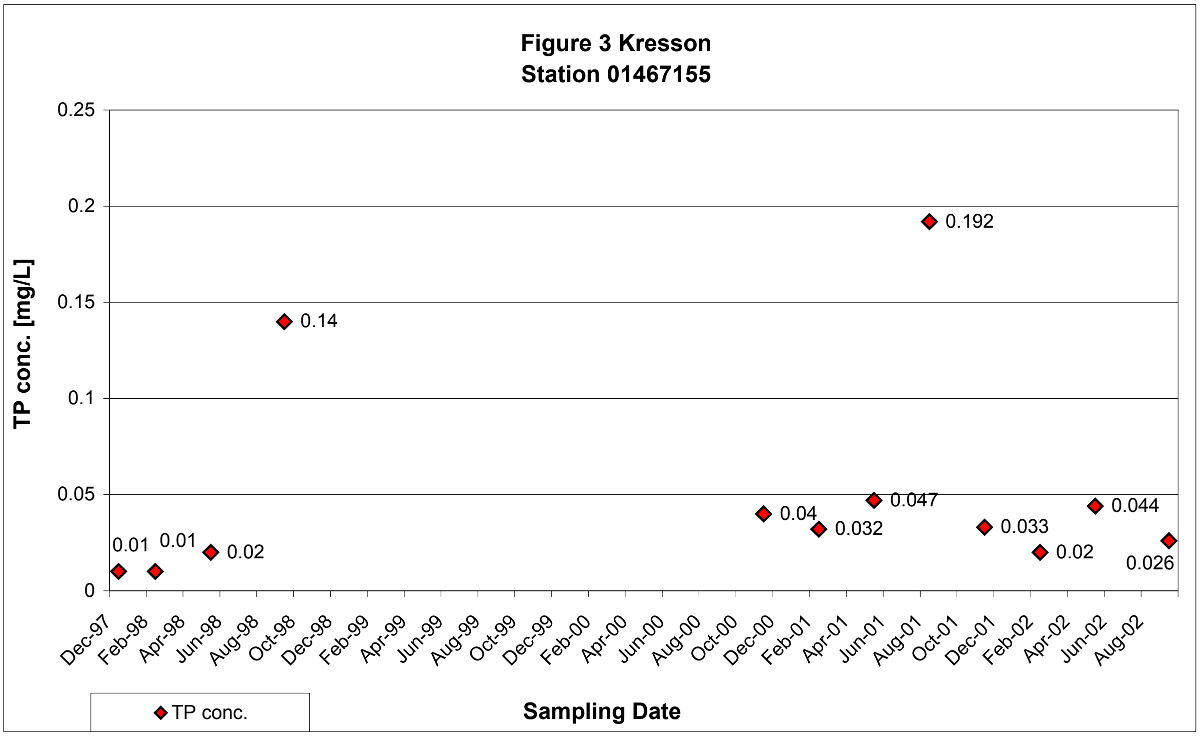
TP Load reduction required, based on the Upper 95% Confidence Limit of the regression line:

Load Reduction = $(1-\frac{0.539}{1.6978})x100\% = 68\%$

The loading capacity is determined by 64% reduction on the existing loading, of which 24% will be margin of safety (MOS):

MOS = $\frac{68\%-64\%}{100\%-64\%} = 11\%$

Kresson, station 01467155



The reduction required to achieve a SWQS of 0.1 mg/L for the highest TP concentration result (0.192 mg/L) is 47%. The total phosphorus reduction required for the Cooper River North Branch, as calculated from the Reckhow model for the Cooper

River Lakeshed, is 86%. It is concluded that, if the required reduction of 86% is reached for the Cooper River Lakeshed, it will satisfy the 47% reduction required to reduce the highest ever recorded TP concentration, and the SWQS of 0.1 mg/L TP will be attained in stream.

Lindenwold, station 01467120

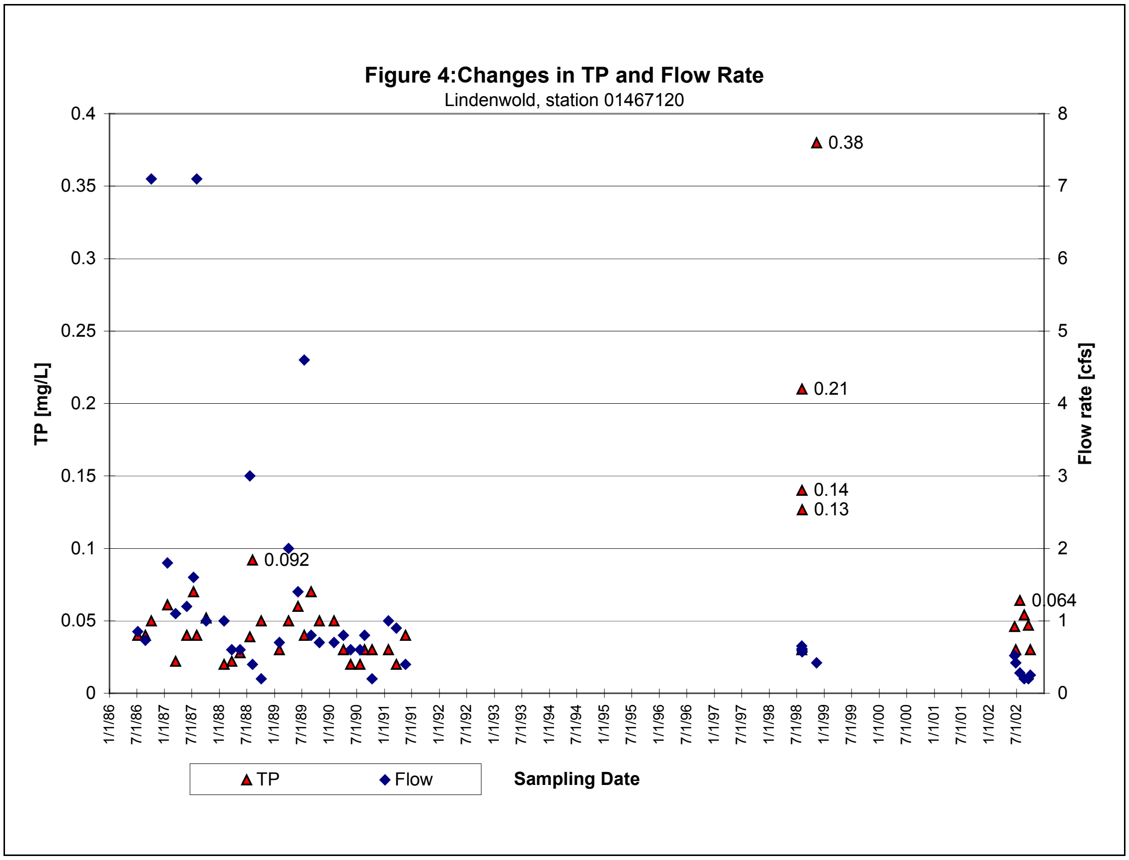


Figure 4:Changes in TP and Flow Rate

Lindenwold, station 01467120

The reduction required to achieve a SWQS of 0.1 mg/L, compared to the highest TP concentration of 0.38 mg/L TP, is 74%. The required reduction of 76% for the Kirkwood Lake watershed, as calculated from the Reckhow empirical model (April 2003 TMDLs), will also satisfy a 74% percent reduction required for the highest ever recorded TP concentration to meet a SWQS of 0.1 mg/L TP.

Table1: Comparison of Reductions Required

Lake Endpoints and Alternate Method for Stream Segments

TMDL	**Watershed** **Impaired Site**	**Target TP Conc. (mg/L)**	**Reduction Required in Proposed TMDL**	**Reduction Required from alternative method**
	Kirkwood Lake	0.05	76%	--
1	Lindenwold 01467120	0.1	--	74%
2	**Evans Pond & Wallworth Lake**	0.05	87%	--
3	Haddonfield - 01467150	0.1	--	68%
4	Lawnside - 01467140	0.1	--	68%
5	**Cooper River Lake**	0.05	86%	--
6	Kresson - 01467155	0.1	--	47%

TOTAL MAXIMUM DAILY LOADS FOR POLYCHLORINATED BIPHENYLS (PCBs) FOR ZONES 2 - 5 OF THE TIDAL DELAWARE RIVER

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

DELAWARE RIVER BASIN COMMISSION
WEST TRENTON, NEW JERSEY

December 2003

Acknowledgements

This report was prepared by the Delaware River Basin Commission staff: Carol R. Collier, Executive Director. Dr. Thomas J. Fikslin and Dr. Namsoo Suk were the principal authors of the report. Dr. Fikslin is the Head of the Commission's Modeling & Monitoring Branch. Dr. Suk is a Water Resources Engineer/Modeler in the Modeling & Monitoring Branch. Significant technical contributions were made by Gregory J. Cavallo, Dr. Daniel S. L. Liao, Dr. Ronald A. MacGillivray, and John R. Yagecic. Richard W. Greene is gratefully acknowledged for his efforts in summarizing fish tissue data for PCBs, and for providing Figures 2 and 3 of the report. Technical recommendations were provided by the Commission's Toxic Advisory Committee and its TMDL Policies and Procedures Subcommittee.

Special acknowledgment is made to the following organizations for their support in development of the report and the studies leading up to it:

Delaware Department of Natural Resources & Environmental Control
New Jersey Department of Environmental Protection
Pennsylvania Department of Environmental Protection
U.S. Environmental Protection Agency, Region II
U.S. Environmental Protection Agency, Region III
Rutgers University
Limno-Tech, Inc.

Suggested Citation

Fikslin, T.J. and N.S. Suk. 2003. Total Maximum Daily Loads for Polychlorinated Biphenyls (PCBs) for Zones 2 - 5 of the Tidal Delaware River. Delaware River Basin Commission. West Trenton, NJ. December 2003.

EXECUTIVE SUMMARY

Introduction

On behalf of the states of Delaware, New Jersey and Pennsylvania, and in cooperation with the Delaware River Basin Commission, the United States Environmental Protection Agency Regions II and III (EPA) establish these total maximum daily loads (TMDLs) for polychlorinated biphenyls (PCBs) in the Delaware River Estuary. EPA establishes these TMDLs in order to achieve and maintain the applicable water quality criteria for PCBs designed to protect human health from the carcinogenic effects of eating the contaminated fish now found in the Delaware Estuary. In accordance with Section 303(d) of the Clean Water Act (CWA) and its implementing regulations, these TMDLs provide allocations to point sources (WLAs) discharging PCBs as well as allocations to nonpoint sources (LAs) of PCBs, and an explicit margin of safety to account for uncertainties. This TMDL report and its appendices set forth the basis for these TMDLs and allocations and discusses follow up strategies that will be necessary to achieve these substantial reductions of PCBs. EPA will continue to work with the Commission and the States to develop enhanced Stage 2 PCB TMDLs based on information to be collected and analyzed over the next several years. While EPA acknowledges that implementation of these TMDLs will be difficult and may take decades to fully achieve, the establishment of these TMDLs sets forth a framework and specific goals to protect human health and restore the Delaware River from the effects of PCB pollution.

Background

The states of Delaware, New Jersey and Pennsylvania have identified the Delaware Estuary as impaired on their respective lists pursuant to Section 303(d) of the CWA. The States identified the impairments based on their findings of elevated levels of polychlorinated biphenyls (PCBs) in the tissue of fish caught in this portion of the Delaware River. The listing was based upon failure to attain one of the estuary's primary designated uses – fishable waters and the inherent protection of human health from consumption of unsafe fish. When water quality standards, including a numeric criterion and a designated use, are not attained despite the technology-based control of industrial and municipal wastewater (point sources), the Clean Water Act requires that the impaired water be identified on the state's Section 303(d) list of impaired waters and that a total maximum daily load (TMDL) be developed. A TMDL expresses the maximum amount of a pollutant that a water body can receive and still attain standards. Once the load is calculated, it is allocated to all sources in the watershed – point and nonpoint – which then must reduce loads to the allocated levels in order to achieve and maintain the applicable water quality standards.

For management purposes, the Delaware River Estuary has been designated by the Delaware River Basin Commission (also referred to in this report as the Commission) as that section of the main stem of the Delaware River and the tidal portions of the tributaries thereto, between the head of Delaware Bay (River Mile 48.2) and the head of the tide at Trenton, New Jersey (River Mile 133.4). The portion of the Delaware where the river meets the sea, the estuary is characterized by varying degrees of salinity and complex water movements affected by river flows, wind and ocean tides. A map of the estuary showing the water quality management zones 2 through 5 that comprise the tidal Delaware River appears on the following page.

In the late 1980s, the states of Delaware, New Jersey and Pennsylvania began issuing fish consumption advisories for portions of the Delaware Estuary due to elevated concentrations of PCBs measured in fish tissue. Today, the states' advisories cover the entire estuary and bay. The advisories range from a no-consumption recommendation for all species taken between the C&D Canal and the Delaware-Pennsylvania border to consumption of no more than one meal per month of striped bass or white perch in Zones 2 through 4. Why the need for such advisories? PCBs are classified as a probable human carcinogen by the U.S. Environmental Protection Agency (EPA). They also have been shown to have an adverse impact on human reproductive and immune systems and may act as an endocrine disruptor.

PCBs are a class of synthetic compounds that were typically manufactured through the progressive chlorination of batches of biphenyl to achieve a target percentage of chlorine by weight. Individual PCB compounds called congeners can have up to 10 chlorine atoms attached to a basic biphenyl structure consisting of two connected rings of six carbon atoms each. There are 209 patterns in which chlorine atoms may be attached, resulting in 209 possible PCB compounds. These compounds can be grouped into "homologs" defined by the number of chlorine atoms attached to the carbon rings. Thus, for example, PCB compounds that contain five chlorine atoms comprise a homolog referred to as pentachlorobiphenyls or penta-PCBs.


Blue Marsh Reservoir
Reading
Manatawny Cr.
Pottstown
Green Lane
Perkiomen Creek
Lake Galena
Neshaminy Creek
Delaware River
Assunpink Cr.
RM 133.4
Trenton
Crosswicks Creek
Blacks Creek
Wissahickon Cr.
Schuylkill River
RM 108.4
Zone 2
Marsh Creek Reservoir
Pennsylvania
Philadelphia
Rancocas Creek
West Br. Brandywine Cr.
Brandywine Creek
Geist
Crum Cr.
Pennsauken Cr.
Camden
Zone 4
RM 95
Zone 3
RM 78.83
Cooper River
White Clay Cr.
Big Timber Cr.
Mantua Cr.
Wilmington
Hoopes Res.
Raccoon Cr.
New Jersey
Oldmans Cr.
Christina River
Maryland
Salem River
Zone 5
Maurice River
C & D Canal
Salem
Cohansey River
Alloway Cr.
Stowe Cr.
RM 48.23
Union Lake
Zone 6
Smyrna River
Delaware
Leipsic River
Dover
Dennis Cr.
N
St. Jones River
Delaware Bay
Murderkill River
0
5
10
Miles
Mispillion River
Cedar Cr.
Milford
RM 0
Atlantic Ocean
Broadkill River
Lewes

Due to their stable properties, PCBs were used in hundreds of industrial and commercial applications, including electrical, heat transfer, and hydraulic equipment; as plasticizers in paints, plastics and rubber products; and in pigments, dyes and carbonless copy paper, among other applications. PCB laden oil is often associated with electrical transformers. More than 1.5 billion pounds of PCBs were manufactured in the United States before their manufacture and general use, with a few small exceptions, was banned by the EPA in the late 1970s. Existing uses in some electrical equipment continue to be allowed. PCBs are hydrophobic and thus tend to bind to organic particles in sediment and soils. Their chemical stability allows them to persist in the environment for years. PCBs accumulate in the tissue of fish and other wildlife, entering the organism through absorption or ingestion. As a result, they may be present in fish and marine mammals at levels many times higher than in the surrounding water and at levels unsuitable for human consumption.

The water quality standards that form the basis for the TMDLs are the current Delaware River Basin Commission water quality criteria for total PCBs for the protection of human health from carcinogenic effects. These criteria were identified as the TMDL targets by a letter dated April 16, 2003 from the Regional Administrators of EPA Regions II and III to the Executive Director of the Delaware River Basin Commission. The criteria are 44.4 picograms per liter in Zones 2 and 3, 44.8 picograms per liter in Zone 4 and the upper portion of Zone 5, and 7.9 picograms per liter in lower Zone 5. The more stringent criterion in the lower estuary reflects a higher fish consumption rate utilized by the Commission and the State of Delaware, based upon an evaluation of fish consumption there. A consequence of the inconsistency in criteria is that a critical location occurs at the point between upper and lower Zone 5 where the criteria drop sharply from 44.8 picograms per liter to 7.9 picograms per liter. Achieving the lower standard in a portion of Zone 5 will require much larger reductions in the upper zones than would otherwise be necessary. Significant reductions are required throughout the estuary in any case, as ambient concentrations of PCBs in the water body currently exceed the criteria by two to three orders of magnitude.

PCBs have been dispersed throughout the environment by human activity. They enter the atmosphere as a gas, spill into soils and waterways, and lodge in sediments. They continue to be generated as a byproduct by some industrial processes. Thus, the sources of PCBs to the Delaware Estuary are multiple. They include loadings from the air, the main stem Delaware River above Trenton, tributaries to the Delaware both above and below Trenton, industrial and municipal point source discharges, combined sewer overflows, and storm water runoff, including runoff from seriously contaminated sites. For purposes of these TMDLs, point sources include all municipal and industrial discharges subject to regulation by the NPDES permit program, including combined sewer overflows and stormwater discharges. All other discharges are considered nonpoint sources.

Interagency and Interstate Cooperation

In the latter half of the 1990s, the three estuary states included the portions of Zones 2 through 5 of the Delaware River within their borders on their lists of impaired waters under Section 303(d) of the Clean Water Act, due to elevated levels of PCBs in estuary fish. This action required the states and EPA to agree upon a schedule for establishing TMDLs for PCBs. In order to provide for a single TMDL adoption process for the shared water body, one date for completion of the TMDLs – December 15, 2003 – was established. This is the date set for completion of the PCB TMDLs by a 1997 Consent Decree and Settlement Agreement in an action entitled *American Littoral Society and Sierra Club v. the United States Environmental Protection Agency et al.*, which established dates for adoption of TMDLs in the Delaware

Estuary. Because a unified legal process for issuance of the TMDLs could not be accomplished easily through independent state actions, at the request of the states, EPA agreed to issue the TMDLs for PCBs in the estuary on the states' behalf.

In the spring of 2000, the states and EPA asked the Delaware River Basin Commission to take the lead in developing the technical basis for the estuary PCB TMDLs. In consultation with its Toxics Advisory Committee (TAC), comprised of representatives from the states, EPA Regions II and III, municipal and industrial dischargers, academia, agriculture, public health, environmental organizations and fish and wildlife interests, the Commission undertook to do so. In September of 2000, the Commission established a panel of scientists expert in the modeling of hydrophobic contaminants such as PCBs to advise it and the TAC on the development of the complex hydrodynamic and water quality model required to develop the TMDLs. The Commission also initiated an extensive program of scientific investigations and data collection efforts. In response to a recommendation of the expert panel, in May of 2002 the Commission engaged a consultant experienced in water quality modeling to work closely with Commission staff to develop the model.

In consultation with the TAC, the Commission staff and the Delaware Estuary Program developed a strategy to address contamination of the Delaware Estuary by PCBs (the PCB Strategy). The PCB Strategy includes the following nine components: (1) determination of the water quality targets for PCBs; (2) characterization of PCB concentrations in the estuary ecosystem; (3) identification and quantification of all point and nonpoint sources and pathways of PCBs; (4) determination of the transport and fate of PCB loads to the estuary; (5) calculation of the TMDLs, including the wasteload and load allocations required for a TMDL;(6) development of an implementation plan to reduce PCBs entering the estuary; (7) initiation of an effort to increase public awareness of toxicity issues in the estuary; (8) long-term monitoring of PCB concentrations in air, water and sediments of the estuary; and (9) long-term monitoring of PCB concentrations in living resources of the estuary and impacts upon living resources of the estuary. The PCB Strategy is one component of EPA's reasonable assurance that the allocations of these TMDLs will ultimately be achieved.

In a cooperative effort, EPA, the Commission, the states, municipal and industrial dischargers and other stakeholders, have now completed the PCB Strategy components necessary for issuance of the TMDLs. This TMDL report discusses the identification of water quality targets for the TMDLs and calculation of the TMDLs in more detail below (components 1 and 5). An extensive program of scientific investigations and data collection efforts to further characterize PCB sources, concentrations and pathways in the estuary ecosystem is ongoing (components 2, 3 and 8). To date, studies have been assembled or undertaken on fish tissue, ambient water quality, sediment, air deposition, air-water exchange, bioaccumulation pathways, tributary loading, point source discharges, and stormwater loadings. The transport and fate of PCBs in the estuary ecosystem (component 4) has been established through the development of a complex mathematical model, also discussed below. The Commission has established a TMDL Implementation Advisory Committee (IAC) to develop strategies over the next two years for reducing PCB loads to the estuary and achieving the TMDLs (component 6). An effort to educate the public about toxicity issues in the estuary (component 7) began with a series of public information sessions in February and March of 2001. In October of 2002, a coalition of municipal and industrial dischargers sponsored a science symposium, at which the various scientific investigators presented their findings to date. A meeting among regulators and stakeholders on the TMDLs and their regulatory implications was held in April, 2003 (see Appendix 1).

EPA with assistance from the Commission and the States held three informational meetings about the proposed TMDLs on September 22, 24 and 25, 2003, and conducted a public hearing on the proposed

TMDLs on October 16, 2003. During the public comment period EPA received numerous written comments in addition to the testimony provided at the public hearing. EPA considered those comments in finalizing these TMDLs and prepared a Response to Comments document that is part of the record of this decision. Ongoing education initiatives regarding these issues continue to be carried out through the Delaware Estuary Program and the Partnership for the Delaware Estuary.

Development of the TMDLs

The three-year schedule for development of the estuary TMDLs by December 15, 2003 resulted in a decision to develop the TMDLs using a staged approach. The Stage 1 and Stage 2 TMDLs will each comply fully with EPA requirements and guidance. The staged approach will provide for adaptive implementation through execution of load reduction strategies while additional monitoring and modeling efforts proceed. As discussed below, these Stage 1 TMDLs are based on the best water quality-related monitoring data, modeling and scientific analysis available at this time. EPA expects that additional monitoring data and modeling results will be collected and developed following issuance of the Stage 1 TMDLs. This additional information will enable a more refined analysis to form the basis of the Stage 2 TMDLs. EPA will continue to work with the Commission and the States to develop and complete the Stage 2 TMDLs. Until the Stage 1 TMDLs are amended or replaced, the Stage 1 TMDLs are the final and effective TMDLs for purposes of the CWA.

EPA's regulations implementing Section 303(d) of the Clean Water Act provide that a TMDL must be expressed as the sum of the individual wasteload allocations (WLA) for point sources plus the load allocation (LA) for nonpoint sources plus a margin of safety (MOS). This definition may be expressed as the equation: TMDL = WLA + LA + MOS. A separate TMDL has been developed for each water quality management zone of the estuary. Each of the TMDLs must provide for achievement of the applicable water quality standards within the zone and also must ensure that water quality in downstream zones is adequately protected.

In June of 2002, the expert panel recommended that for the TMDLs to be completed by December 15, 2003, the Commission should develop and calibrate a water quality model for only one of the PCB homologs and use it to develop a set of TMDLs from which TMDLs for total PCBs could be extrapolated. This process became known as Stage 1 of an iterative approach to establishing the TMDLs for PCBs in the estuary. Since pentachlorobiphenyls were the dominant homolog in fish tissue monitored in the estuary, and since ambient data indicated that throughout the estuary this homolog represents approximately 25 percent of the total PCBs present, the pentachlorobiphenyls (penta-PCBs) were selected. Based on these recommendations and a review of the available data, EPA adopted this approach. Thus, based on the best scientific estimates and analysis as discussed further below, the Stage 1 TMDLs, WLAs and LAs for total PCBs were extrapolated, using a factor of 4 to 1, from TMDLs and allocations developed for penta-PCBs. EPA, the Commission and the States expect that the Stage 2 TMDLs, WLAs and LAs will be based on the summation of the PCB homolog groups, without the use of extrapolation. The partners intend that the Stage 2 TMDLs will be developed using all additional data collected and modeling performed after the establishment of these TMDLs. It is anticipated that the Stage 2 WLAs will be based upon an enhanced allocation methodology. When they are developed and established, the partners expect that the Stage 2 TMDLs will replace the Stage 1 TMDLs.

The TMDLs were calculated using both a conservative chemical model and a penta-PCB water quality model run until equilibrium was observed. This procedure was used because hydrophobic contaminants like PCBs sorb to particulates and interact significantly with the sediments of the estuary. Sediments respond more slowly than the water column to changes in PCB concentrations in either medium, and allowing the water column and sediments to come into equilibrium is necessary to ensure that water quality criteria are met. A modified version of the TOXI5 water quality model was used (DRBC 2003a and 2003b). Both models utilized outputs from a DYNHYD5 hydrodynamic model that was extended from the head of the Delaware Bay to the mouth of the bay (DRBC 2003a). The models cycled inputs from the period February 1, 2002 until January 31, 2003. This one-year period was considered to be representative of long-term hydrological conditions for two important reasons. First, during this period flows of the two main tributaries to the estuary – the main stem Delaware River and the Schuylkill River – reasonably represent the flows during the approximately 90- and 70-year periods of record, respectively, for the two tributaries (see Figures 5 and 6). Precipitation data during the one-year period also is in good agreement with the long-term precipitation record with respect to the number and percentage of days with and without precipitation. Upon the recommendation of the expert panel, in order to maintain hydrological and meteorological relationships between the various inputs to the model, effluent flows were based upon data for the same one-year period, rather than on design flows. The same approach was used for inputs such as air temperature, water temperature and wind speed.

Penta-PCB TMDLs were calculated in a four step procedure. The procedure initially utilized the conservative chemical model to establish contribution factors for two of the major tributaries to the estuary – the Delaware River at Trenton and the Schuylkill River – and each of the four estuary zones. The contribution factor reflects the influence of the loading attributable to each tributary or zone on the PCB concentration at the critical location in Zone 5 where the water quality criterion for PCBs drops from 44.4 picograms per liter to 7.9 picograms per liter. If the criterion at this location is met, then the water quality criteria are met throughout the estuary. Once the contribution factors were established, the TMDLs were calculated over a one-year period to determine an annual median loading. The annual median was used in order to be consistent with the model simulations and the 70-year exposure for human health criteria. A description of the four steps follows:

1. Calculate the contribution factor (CF) for each of the estuary zones and two of the tributary model boundaries to that critical location in Zone 5 where the criterion of 7.9 picograms per liter (approximately 2.0 picograms per liter of penta-PCBs) is controlling.

2. Calculate the allowable loadings from each of these sources that will still ensure that the water quality target is met at the critical location utilizing the CF and the proportion of the assimilative capacity at the critical location allocated to each source. Iteratively determine the amount of assimilative capacity (in picograms per liter) provided by the sediments, and add this concentration to the penta-PCB water quality target. Recalculate the allowable loadings from each of the six sources using this revised water quality target.

3. Utilize the water quality model for penta-PCBs with these allowable loadings to confirm that the sediment concentrations have reached pseudo-steady state, and confirm that the penta-PCB water quality target is met in Zones 2 through 5.

4. Estimate the gas phase concentrations that would be in equilibrium with the penta-PCB water concentrations when the water quality targets are met, include these in the water quality model, and then iteratively adjust the gas phase concentration of penta-PCBs in the air until the water quality target is reached.

For purposes of calculating the TMDLs, EPA notes that the model assumes that PCB loads from the ocean, the C&D Canal, the major tributaries and the air are at levels that ensure that the water quality standards are achieved, rather than at the actual levels, which in every case are higher. Thus, in developing the TMDLs, both the ocean boundary and the C&D Canal boundary were set to an equivalent penta-PCB criterion of 2.0 picograms per liter, corresponding to a total PCB water quality criterion of 7.9 picograms per liter, the criterion in lower Zone 5 where each of these water bodies meets the estuary. Other programs and factors beyond the scope of these TMDLs will be necessary to reduce PCB loads from these sources. The actual concentration at the mouth of the Bay exceeds the water quality criterion by one to two orders of magnitude, while the current concentration at the C&D Canal boundary exceeds this value by almost three orders of magnitude. Similarly, the Schuylkill and Delaware River boundary conditions were set to 9.68 picograms per liter and 10.72 picograms per liter respectively, although the actual concentrations in the two water bodies at the point where they enter the estuary are 1800 and 1600 picograms per liter respectively. The air concentration of PCBs also is considered by the model. When water quality standards are achieved, however, there will be no significant net exchange between dissolved PCBs in water and gas phase PCBs in the air. Because gas phase PCBs do not provide a load to the estuary when the water quality standards are met, they are not allocated any portion of the TMDLs. Actual air concentrations in the estuary region, however, currently exceed the levels required for equilibrium by two orders of magnitude.

The TMDLs for penta-PCBs calculated with the four-step procedure were 64.34 milligrams per day for Zone 2, 4.46 milligrams per day for Zone 3, 14.18 milligrams per day for Zone 4, and 12.02 milligrams per day for Zone 5. The higher TMDLs in Zones 2 and 4 are the result of the assimilative capacity provided by the flows from the main stem Delaware River in Zone 2 and the Schuylkill River in Zone 4.

Each of the zone TMDLs was then apportioned into three components: the WLA, LA and MOS. EPA has based these allocations upon recommendations of the Commission's TAC. The committee recommended that an explicit MOS of 5% be allocated in each estuary zone, and further recommended that for the Stage 1 TMDLs, the proportion of the TMDLs allocated to WLAs and LAs should be based upon the current proportion of loadings from the various PCB source categories to each of the zones during the one-year cycling period of February 1, 2002 to January 31, 2003.

Stage 1 TMDLs were then calculated using the ratio of penta-PCBs to total PCBs observed in ambient water samples collected during five surveys that encompass the range of hydrological conditions typically observed in the estuary. Median penta- to total PCB ratios of 0.23, 0.25, 0.25 and 0.23 were observed in Zones 2 to 5, respectively. For these TMDLs, a fixed value of 0.25 was used for all zones to scale up the zone-specific TMDLs, WLAs, LAs and MOSs. The following table summarizes the TMDLs for each estuary zone for total PCBs as well as the allocations to WLAs, LAs and the MOSs.

Stage 1 TMDLs for Total PCBs

Estuary Zone	TMDL	WLA	LA	MOS
	mg/day	mg/day	mg/day	mg/day
Zone 2	257.36	11.03	233.46	12.87
Zone 3	17.82	5.67	11.26	0.89
Zone 4	56.71	6.54	47.34	2.84
Zone 5	48.06	15.62	30.04	2.40
Sum	379.96	38.86	322.10	19.00

In the proposed PCB TMDLs, the LAs contained the loadings from municipal separate storm sewer systems (MS4s), which are regulated as NPDES point sources. Loadings from MS4s are now identified and included as part of the WLAs with the LAs adjusted accordingly.

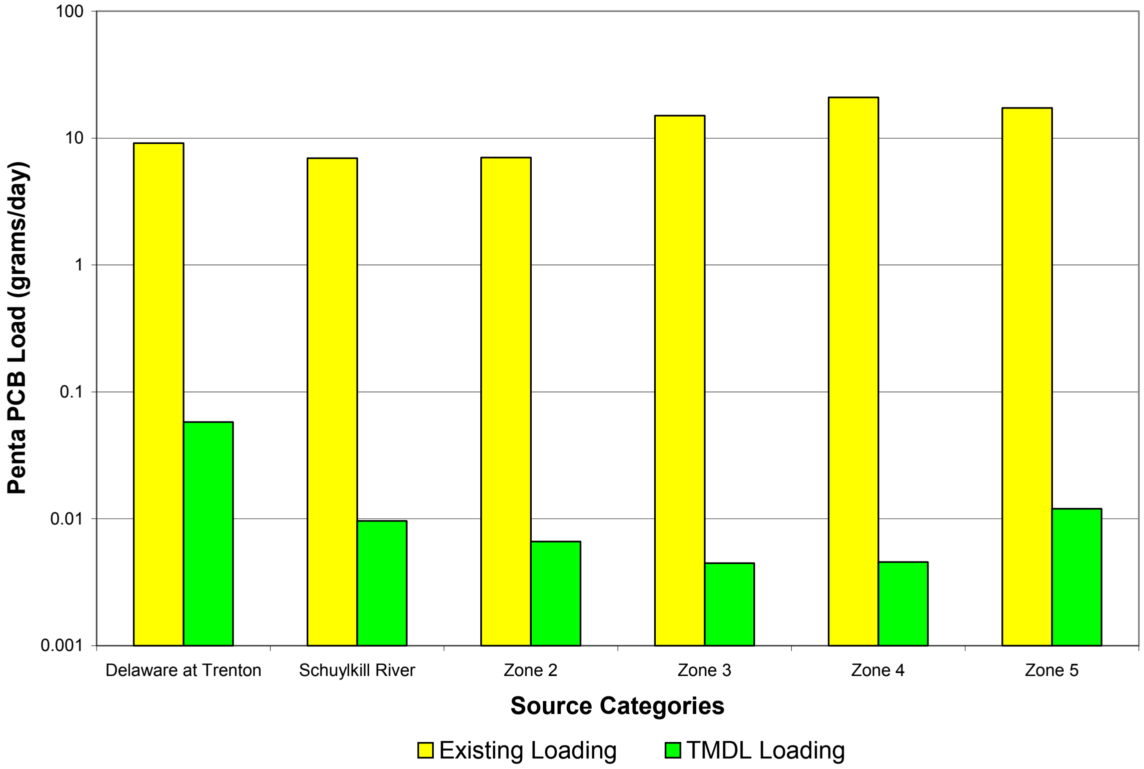
The portion of the TMDLs allocated to non-point sources is higher than the portion of the TMDLs allocated to point sources in all four estuary zones when the current loading proportions are used as the basis for allocating the zone TMDLs. This result is not unexpected. Nonpoint sources include, among other sources, contaminated sites, non-point source runoff, and the two main tributaries, which contribute greater loadings to the zones than the NPDES discharges (including stormwater discharges and combined sewer overflows) that comprise the point source contributions. The proportions vary between zones, with Zones 3 and 5 having the highest allocations to point sources (approximately 30%).

Implementing Load Reductions to Achieve the TMDLs

The following figure compares the current penta-PCB loadings for water quality management Zones 2 through 5 and the Delaware and Schuylkill Rivers to the Stage 1 TMDL penta-PCB loadings:

The chart illustrates that existing loadings are roughly two to three orders of magnitude higher than the TMDLs. Achieving the water quality standards for PCBs in the Delaware Estuary will require significant reductions from current loadings from both point and nonpoint sources. In addition to reducing PCB loads from sources discharging directly to the estuary, reductions from sources in the non-tidal portion of the river, local and regional air emissions, and sources contributing to elevated PCB concentrations in the Atlantic Ocean will be necessary to achieve and maintain the applicable PCB standards and adequately protect human health.

These TMDLs focus on the instream conditions which need to be met to protect human health and establish individual wasteload allocations (WLAs) for 142 point sources that are deemed to be potential sources of penta-PCBs (see Appendix 2). In order to begin to implement these TMDLs, the NPDES permitting authorities believe that it is appropriate for these discharges to receive non-numeric water quality-based effluent limits (WQBELs) consistent with their



respective individual WLAs when their NPDES permits are reissued or otherwise modified.[1] The Delaware River Basin Commission may also separately require actions to implement these TMDLs. On December 3, 2003, the DRBC passed Resolution 2003-27 authorizing and directing the Executive Director to require dischargers and other responsible parties to conduct monitoring and/or other data collection and analyses to further characterize point and non-point loadings of toxic contaminants, including PCBs, to the Delaware Estuary for purposes of developing and implementing TMDLs or actions under the DRBC Water Quality Regulations. Requirements in NPDES permits or through DRBC regulations may include: (1) the use of Method 1668A, a highly sensitive analytical method capable of detecting very small amounts of PCBs, for any monitoring of influent and effluent to better quantify individual PCB congeners; (2) the development of a PCB minimization plan; and (3) implementation of appropriate PCB minimization measures identified through PCB minimization planning. The respective NPDES permitting authorities will determine the discharge-specific effluent controls consistent with the WLAs, and may consider the following factors: the relative loading of penta-PCBs, the type of discharge, the type of analytical method used to measure the 19 penta-PCB congeners, the number of the penta-PCB congeners that were detected, and the proportion of the zone WLA that is represented by the discharge loading. When Stage 2 TMDLs are issued, it is expected that all NPDES permits issued, reissued or modified will include numeric or non-numeric requirements consistent with the Stage 2 WLAs for each zone. The implementation strategy for the development of NPDES permit effluent limits consistent with the WLAs is discussed at greater length in Appendix 3 of this report.

Reducing point source discharges alone will not be sufficient to achieve the estuary water quality standards. Runoff from contaminated sites is a significant source of PCBs. For these TMDLs, EPA and the states evaluated forty-nine contaminated sites within the estuary watershed (see Appendix 4). The combined loads from these sites are estimated to comprise 57.09% of the loading to Zone 3; 38.04% of the loading to Zone 4 and 46% of the loading to Zone 5 (see Table 7). Contaminated sites make up a much smaller proportion of the loading in Zone 2 – only 0.42% – because of the lack of contaminated sites and the significant influence in this zone of the main stem Delaware River. In order to achieve the reductions required by the TMDLs, EPA and the States would need to undertake a concerted effort using the authorities under CERCLA, RCRA and the related state statutes.

Significant reductions will be required in point and nonpoint sources to the major tributaries. Currently, concentrations of PCBs in the Schuylkill and Delaware Rivers where they discharge to the estuary are approximately 1800 and 1600 picograms per liter, respectively. Even if all the TMDLs are achieved, the water quality criteria in the estuary will not be attained until the

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[1] The States have indicated that a typical permit will include, among other requirements, the requirement to monitor the discharge using Method 1668A and to implement a PCB pollutant minimization program. The regulation at 40 CFR 122.44(k) allows the use of non-numeric, BMP-based WQBELs where a BMP is determined to be an appropriate means to control pollutants under specified circumstances. Where a permit uses such BMP WQBELs, compliance may be achieved by implementing such requirements.

concentration in the Schuylkill is reduced to 9.68 picograms per liter and the concentration in the main stem Delaware River falls to 10.72 picograms per liter.

Although the ocean boundary has a less significant influence on Zone 5 than does the main stem Delaware River, sources contributing to elevated PCB concentrations in the Atlantic Ocean also must be reduced. The concentration of PCBs in ocean water at the estuary boundary currently exceeds the water quality criterion for Delaware Bay by one to two orders of magnitude.

Finally, air concentrations of PCBs in the region currently are two orders of magnitude above the concentration required to achieve equilibrium and halt contributions of PCBs from the air to the water. Air monitoring data collected at several sites in New Jersey, Delaware and Pennsylvania suggest that PCB air concentrations primarily result from local sources. Thus, source reductions must focus on PCBs in the local and regional airshed.

These reductions cannot be achieved overnight. The Commission has created a TMDL Implementation Advisory Committee (IAC), with members from each of the estuary states, the major municipal dischargers and two of the smaller ones, industrial dischargers, and fishery, wildlife and environmental organizations. EPA Regions II and III also will participate, in an advisory role. The IAC will meet over a two-year period to develop creative and cost-effective strategies for achieving load reductions in the short term and attaining water quality standards in the longer term. Notably, some large dischargers already have undertaken studies to track down PCBs on a voluntary basis. However, due to the scope and complexity of the problem that has been defined through development of these TMDLs, achieving the estuary water quality standards for PCBs will take decades.

Additional Information

A notice about the proposed TMDLs for PCBs in the Delaware Estuary was published in the *Federal Register* and in each of the estuary states' registers on September 2, 2003. Additional notices were published in regional newspapers. The notices contained details about the comment period which closed on October 21, 2003, informational meetings and the public hearing for these TMDLs. Details about these events were also provided on the Commission's web site, at http://www.drbc.net. EPA received oral testimony from 8 groups or individuals and written comments from 30 groups or individuals from various sectors. After consideration of all data and information contained in the public comments, a document providing responses to these public comments has been prepared and appropriate revisions made to these final TMDLs.

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Appendix 1 - Reducing PCB Loadings to the Delaware Estuary: A Staged Approach to Establishing TMDLs

1. INTRODUCTION

1.1 Regulatory Background

Total Maximum Daily Loads or TMDLs are one of the approaches defined in the Clean Water Act (CWA) for addressing water pollution. The first approach of the CWA that was implemented by the U.S. EPA was the technology-based approach to controlling pollutants (Section 301). This approach was implemented in the mid-1970s through the issuance of permits authorized under Section 402 of the Act. The approach specified minimum levels of treatment for sanitary sewage and for various categories of industries. The other water quality-based approach was implemented in the 1980s. This approach includes water quality-based permitting and planning to ensure that standards of water quality established by States are achieved and maintained.

Section 303(d) of the Act establishes TMDLs as one of the tools to address those situations where the technology-based controls are not sufficient to meet applicable water quality standards for a water body (U.S. EPA, 1991). They are defined as the maximum amount of a pollutant that can be assimilated by a water body without causing the applicable water quality standard to be exceeded. The basis of a TMDLs is thus the water quality standard. This standard may be established for the protection of aquatic life, human health through ingestion of drinking water or resident fish, or wildlife. Under Section 303(d), States are required to identify, establish a priority ranking, and to develop TMDLs for those waters that do not achieve or are not expected to achieve water quality standards approved by the U.S. EPA. Federal regulations implementing Section 303(d) of the Clean Water Act provide that a TMDL must be expressed as the sum of the individual wasteload allocations for point sources (WLA) plus the load allocation for nonpoint sources (LA) plus a margin of safety (MOS). This definition may be expressed as the equation:

$$TMDL = WLA + LA + MOS$$

1.2 Study Area

Zones 2 through 5 of the Delaware River (Figure 1) have been designated by the Delaware River Basin Commission as that section of the mainstem of the Delaware River and the tidal portions of the tributaries thereto, between the head of Delaware Bay (River Mile 48.2) and the head of the tide at Trenton, New Jersey (River Mile 133.4). Zones 2 to 4 are bordered by the State of New Jersey and the Commonwealth of Pennsylvania. Zone 5 is bordered by the States of Delaware and New Jersey. Zone 2 encompasses the area from the head of the tide at Trenton to River Mile 108.4. Zone 3 encompasses the area from River Mile 108.4 to River Mile 95.0. Zone 4 encompasses the area from River Mile 95.0 to River Mile78.8, and Zone 5 encompasses the area from River Mile 78.8 to the head of Delaware Bay.

In 1989, the Delaware River Basin Commission created the Estuary Toxics Management Program to address the impact of toxic pollutants in the tidal Delaware River (also called the Delaware Estuary. The mission of this program was to develop policies and procedures to control the discharge of substances toxic to humans and aquatic biota from point sources discharging to this water body. In 1993, Commission staff identified several classes of pollutants and specific chemicals that were likely to exceed water quality criteria currently being developed under the program. These included polychlorinated biphenyls (PCBs), volatile organics, metals, chlorinated pesticides, chronic toxicity and acute toxicity. This list was subsequently included in the Delaware Estuary Programs's Comprehensive Conservation and Management Plan in 1996.

Beginning in the late 1980's, concern regarding the possible contamination of fish populations that were rebounding as dissolved oxygen levels improved resulted in a number of investigations of contaminant levels in resident and anadromous fish species. These species included the white perch, channel catfish and striped bass. The studies subsequently identified PCBs and several chlorinated organics at elevated levels (DRBC, 1988; Greene and Miller, 1994; Hauge et al, 1990; U.S. F&WS, 1991 and 1992). These studies and other data collected by DRBC and the states resulted in fish consumption advisories being issued by all three states bordering the Estuary beginning in 1989. These advisories were principally based upon PCB contamination; and to a lesser degree, chlorinated pesticides such as DDT and its metabolites DDE and DDD, and chlordane.

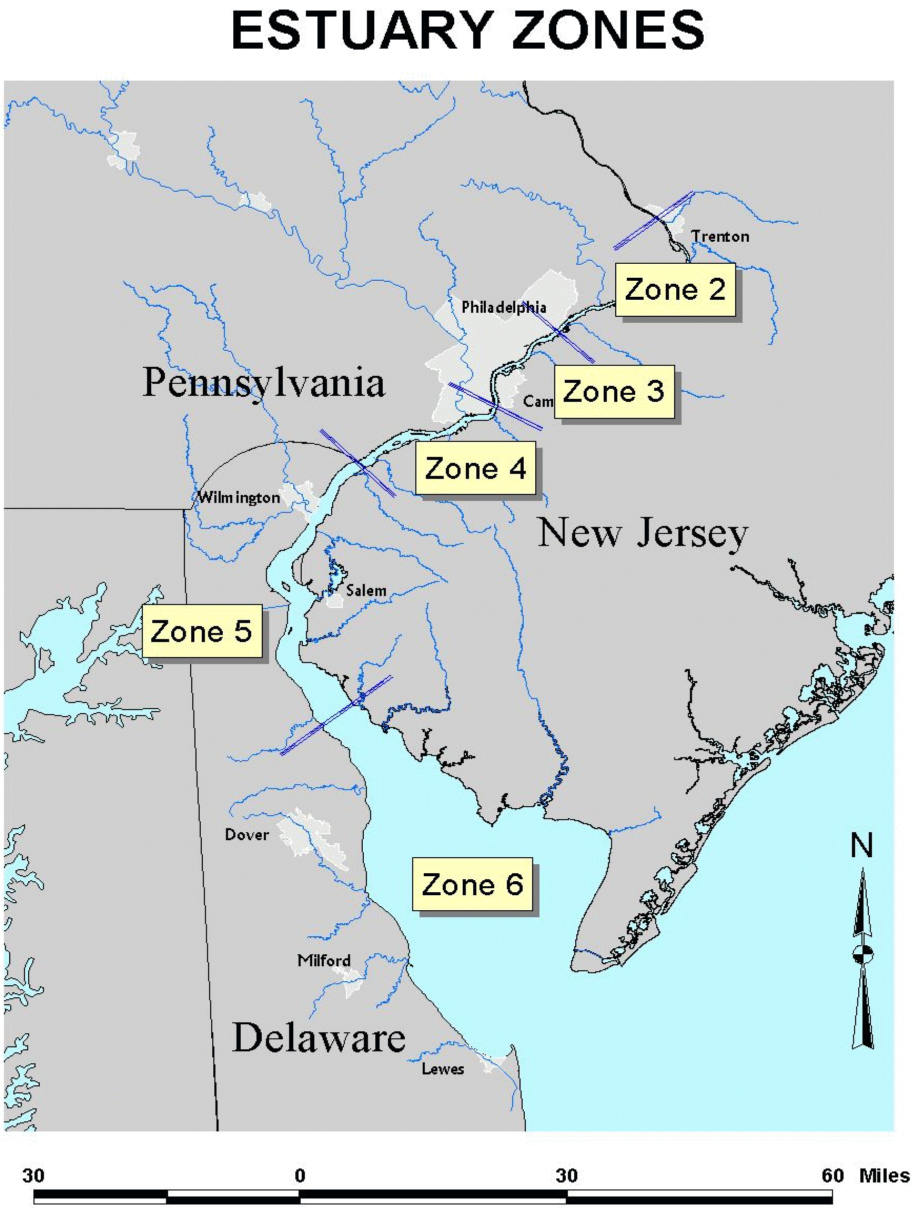
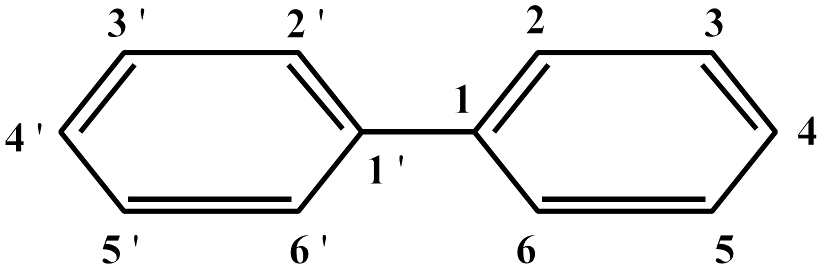


Figure1: Water Quality Zones of the Delaware River.

1.3 Polychlorinated biphenyls (PCBs)

Polychlorinated biphenyls (PCBs) are a class of man-made compounds that were manufactured and used extensively in electrical equipment such as transformers and capacitors, paints, printing inks, pesticides, hydraulic fluids and lubricants. Individual PCB compounds called congeners can have up to 10 chlorine atoms on a basic structure consisting of two connected rings of carbon atoms. There are 209 possible patterns where chlorine atoms can occur resulting in 209 possible PCB compounds. PCB compounds can be grouped by the number of chlorine atoms attached to the carbon rings. These groups are called homologs. PCB compounds containing five chlorine atoms, for example, are referred to as the pentachlorobiphenyls or penta-PCBs.



Although their manufacture and use were generally banned by federal regulations in the late 1970s, existing uses in electrical equipment and certain exceptions to the ban were allowed. In addition, PCBs may also be created as a by-product in certain manufacturing processes such as dye and pigment production. PCBs are hydrophobic, sorbing to organic particles such as soils and sediments and concentrating in the tissues of aquatic biota either directly or indirectly through the food chain.

1.4 Applicable Water Quality Standards and Numerical Target for TMDLs

Water quality criteria for toxic pollutants including Total PCBs were adopted on October 23, 1996 by the Commission and are included in Section 3.30 of Article 3 of the Commission's water quality regulations. The criteria do, however, differ between the zones of the estuary depending on the designated uses of the zone. In Zones 2 and 3, use of the water for public water supply after reasonable treatment is a designated use. In these two zones, human health criteria are based upon exposure to PCBs through ingestion of water and fish taken from these estuary zones. In Zone 4 and upper Zone 5 (above River Mile 68.75), use of the water for public water supply is not a designated use. In these two zones, human health criteria are based solely upon exposure to PCBs through ingestion of fish taken from these estuary zones. Current DRBC criteria assume a consumption rate of 6.5 grams per day (~½ pound meal every 35 days) is used in Zones 2, 3, 4, and the upper portion of Zone 5. This rate was the default national rate for freshwater fish consumption utilized in EPA's 1980 methodology for deriving human health criteria, and was used by the States in developing their freshwater water quality criteria. A consumption rate of 37.0 grams per day (~½ pound meal every 6 days) is used in the lower portion of Zone 5. This consumption rate is consistent with the rate utilized by the State of Delaware following a recent evaluation of available information on consumption rates.

Although criteria to protect aquatic life from acute and chronic effects of PCBs and criteria to protect human health from the carcinogenic and non-carcinogenic of PCBs were adopted, the most stringent standards adopted were based upon protecting human health from the carcinogenic effect of PCBs through ingestion of water and fish taken from these estuary zones (Table 1). The applicable DRBC water quality criteria are therefore:

Table 1: DRBC Water Qaulity Criteria for Zones 2 to 5 of the Delaware Estuary

Estuary Zone	**Exposure Route**	
	Water & Fish Consumption	Fish Consumption Only
Zone 2 & 3	44.4 picograms per liter	
Zone 4 and upper Zone 5		44.8 picograms per liter
Lower Zone 5		7.9 picograms per liter

These criteria are currently the same as criteria adopted by State of New Jersey and the Commonwealth of Pennsylvania. The DRBC criteria for the lower portion of Zone 5 is also the same as the water quality criteria adopted by the State of Delaware; however, a slightly higher and therefore less stringent criteria was adopted for the upper portion of Zone 5.

As part of the effort to establish TMDLs for total PCBs and to update adopted water quality standards based upon new information, the Commission's Toxic Advisory Committee did consider adopting wildlife criteria for total PCBs and revising the human health criteria for carcinogens. The latter was necessitated by two actions by the U.S. Environmental Protection Agency: the updating of the cancer potency factor (i.e., slope factor), one of the key elements used to calculate the criterion, in December 1998 (U.S. EPA, 1998); and the issuance of revised guidance on developing human health water quality criteria in October 2000 (U.S. EPA, 2000). In February 2003, the Toxics Advisory Committee recommended adoption of a revised human health criterion for carcinogens Zones 2 through 5, and that the NJ state-wide water quality criterion for total PCBs for the Delaware Estuary (Zones 2 though 6) for the protection of wildlife be adopted following the impending adoption by the New Jersey Department of Environmental Protection. Refinement of the wildlife criterion based upon site-specific data could then proceed. The Committee also recommended that the Commission consider alternatives to the current risk level of 10^{-6} (another element in the calculation of the human health criterion for carcinogens). On March 19, 2003, the Commission passed a resolution authorizing public participation of the revised human health criteria for carcinogens and directing the Toxics Advisory Committee to initiate development of site-specific wildlife criteria for Zones 2 through 6 of the Delaware River. Since the basis for the TMDLs could be affected by criteria adoption by either the NJDEP or the DRBC, and the TMDLs must be based on the water quality criteria in force when the TMDL is approved, the Commission further directed that the Commission's Executive Director request U.S. Environmental Protection Agency Regions II and II to identify which criteria should be the basis for the TMDLs at this time. In a letter dated April 16, 2003, both U.S. EPA regional offices indicated that the current and applicable DRBC water quality criteria should be the basis for the TMDLs being developed by Commission staff for December 2003.

1.5 Listing under Section 303(d)

Until recently, the attainment of water quality standards for total PCBs could not be measured directly in samples of ambient water so States relied on measurements of contaminants in fish fillet samples collected from the estuary. This is possible since the amount in fish tissue is related to the water concentration by a factor known as the bioaccumulation factor or BAF. This factor accounts for the uptake and concentration of a contaminant in the tissue either directly from the water or through the target species' food chain. Current and historical concentrations of total PCBs in filet samples collected from channel catfish in Zones 2 through 5 and white perch collected in Zones 2 through 6 are shown in Figures 2 and 3. While tissue concentrations have declined since the banning in the late 1970s, current levels in both species are approximately 800 to 1000 parts per billion (ppb), two to three orders of magnitude above the level expected to occur when estuary waters are at the water quality standards for total PCBs.

New Jersey was the first state to issue an advisory recommending no consumption of channel catfish in 1989. This was followed in 1990 by Pennsylvania who recommended no consumption of white perch, channel catfish and American eel caught between Yardley, PA above Trenton to the Pennsylvania/Delaware border.

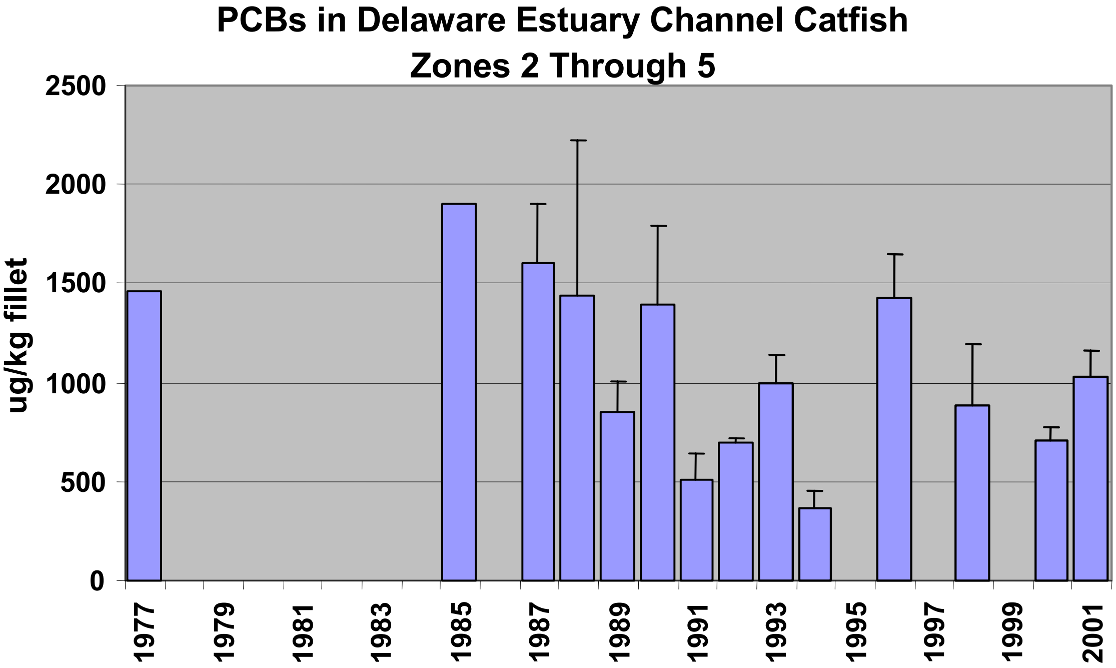


Figure 2: PCB concentrations in fillet samples of channel catfish collected from Zones 2 through 5 of the Delaware Estuary from 1977 to 2001. Units are in micrograms per kilogram or parts per billion (ppb). Graphs provided by Richard Greene, Delaware DNREC.

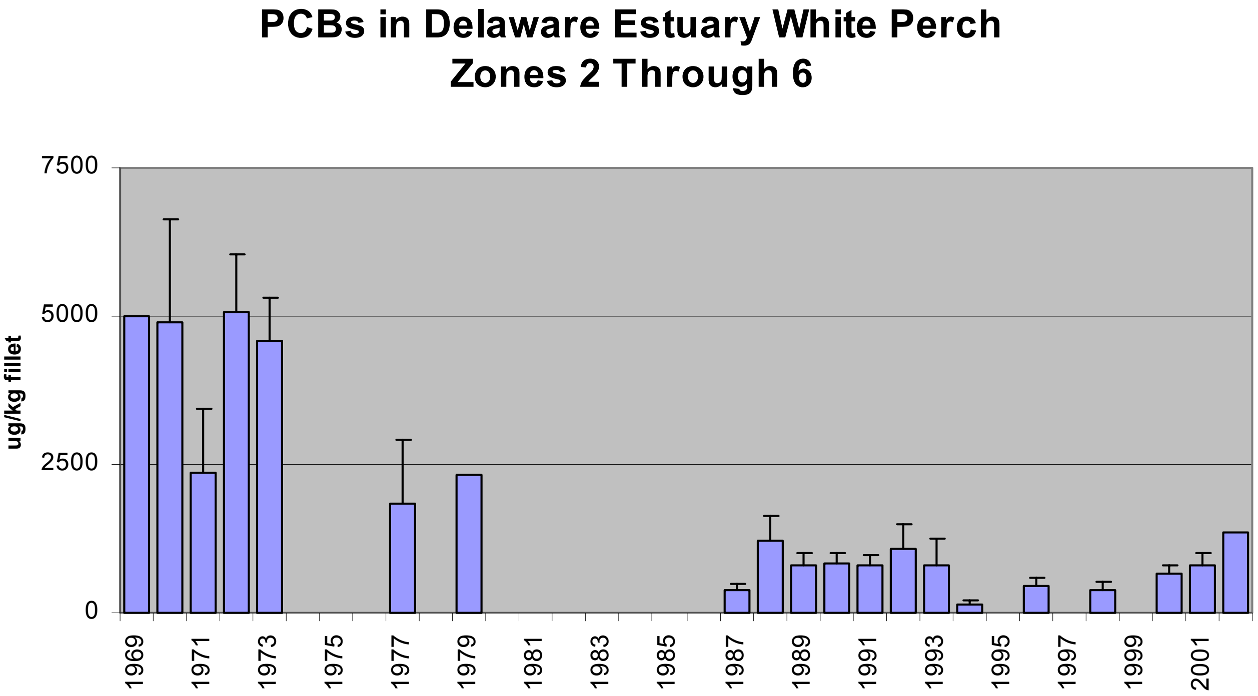


Figure 3: PCB concentrations in fillet samples of white perch collected from Zones 2 through 6 of the Delaware Estuary from 1977 to 2001. Units are in micrograms per kilogram or parts per billion (ppb). Graphs provided by Richard Greene, Delaware DNREC.

After conducting additional sampling in the lower tidal river, Delaware issued an advisory in 1994 recommending no consumption of striped bass, white perch, channel catfish and white catfish caught between the Pennsylvania/Delaware border and the Chesapeake and Delaware Canal (C&D Canal). These advisories remained essentially unchanged until 1999, when Pennsylvania recommended limited consumption (one meal per month) of white perch and striped bass, and one meal every two months for channel catfish in the same advisory area. Delaware meanwhile, increased the restrictions on consuming fish caught between the Pennsylvania/Delaware border and the C&D Canal to all fish species, and reduced the recommended consumption of striped bass, white perch, white catfish, channel catfish and American eel to one meal per year. In January 2003, New Jersey issued updated state-wide and water body-specific advisories due to PCB contamination that included Zones 2 through 5. These advisories contained recommended meal frequencies for two levels of lifetime cancer risk (10^{-5} and 10^{-6}), and for high risk individuals (children, infants, pregnant or nursing women, and women of child-bearing age). Recommended consumption (at a risk level of 10^{-6}) of channel catfish in Zones 2 to 4 is 6 meals per year while no consumption of striped bass in Zone 4 and all finfish in Zone 5 is recommended.

The New Jersey Department of Environmental Protection subsequently included Zones 2 through 5 of the Delaware River for PCBs in a report entitled "1998 Identification and Setting of Priorities for Section 303(d) Water Quality Limited Waters in New Jersey", September 15, 1998. By Memorandum of Agreement between U.S. Environmental Protection Agency, Region II and the New Jersey Department of Environmental Protection dated May 12, 1999, the NJDEP agreed to develop, public notice, respond to comments and submit to EPA, Total Maximum Daily Loads (TMDLs) for PCBs in the Delaware Estuary by September 15, 2003. This date was subsequently extended to December 31, 2003 in a revised Memorandum of Agreement dated September 16, 2002.

The Delaware Department of Natural Resources & Environmental Control (DNREC) first listed Zone 5 of the Delaware River for toxics in 1996. In 1998, DNREC again listed Zone 5 of the Delaware River, but specifically listed PCBs as a pollutant contributing to the impairment. In Attachment B to a Memorandum of Agreement between the Delaware Department of Natural Resources & Environmental Control and the U.S. Environmental Protection Agency, Region III dated July 25, 1997, DNREC agreed to complete the TMDLs for Zone 5 by December 31, 2002 provided that funding and certain other conditions were met. The MOA also provided that EPA Region III establish the TMDLs if DNREC was unable to complete the TMDLs by the date set forth in Attachment B. In a Consent Decree between the American Littoral Society, the Sierra Club, and the U.S. Environmental Protection Agency dated July 31, 1997, the U.S. EPA agreed to establish TMDLs by December 15, 2003 of the year following the state's deadline.

In a Consent Decree between the American Littoral Society and Public Interest Group of Pennsylvania, dated April 9, 1997, EPA agreed to approve or establish TMDLs for all water quality-limited segments listed on the 1996 303(d) list as impaired by sources other than acid mine drainage by April 9, 2007. PADEP listed Zones 2 to 5 of the Delaware River (included in areas E and G of the Pennsylvania State Water Plan) for priority organics including PCBs in both 1996 and 1998. No date has been set by PADEP for completion of the TMDLs for these water quality segments. The TMDLs currently being proposed will satisfy the commitments that resulted from these listings for each respective state.

1.6 Pollutant sources, loadings and ambient data

The basis for the inclusion of Zones 2 through 5 on the Section 303(d) lists of the estuary states was the levels of PCBs observed in fish tissue collected from the estuary. This was necessary since the common analytical method used for ambient water and wastewater had detection limits for total PCBs in the 500 nanogram per liter range. New Jersey was the first state to issue an advisory recommending no consumption of channel catfish in 1989. This was followed in 1990 by Pennsylvania who recommended no consumption of white perch, channel catfish and American eel caught between Yardley, PA above Trenton to the Pennsylvania/Delaware border. After conducting additional sampling in the lower tidal river, Delaware issued an advisory in 1994 recommending no consumption of striped bass, white perch, channel catfish and white catfish caught between the Pennsylvania/Delaware border and the Chesapeake and Delaware Canal C&D Canal.

Loadings of PCBs to the estuary from point sources were first investigated by the Delaware River Basin Commission in 1996 and 1997 (DRBC, 1998a). This study utilized a new analytical methodology (high resolution gas chromatography/high resolution mass spectrometry or HRGC/HRMS) and focused on discharges from five large sewage treatment plants and one industrial facility. The results of the study found effluent concentrations ranging from 1,430 to 45,140 picograms/L during dry weather, and 2,020 to 20,240 pg/L during wet weather. The dry weather sample from the effluent of the industrial facility had a concentration of 10,270 pg/L. In the spring of 2000, the Commission required 94 NPDES permittees to conduct monitoring of their continuous and stormwater discharges for 81 PCB congeners utilizing analytical methods that could achieve picogram per liter detection limits. The results of this monitoring were submitted to the Commission over the next two years, and indicated that loadings to the estuary zones from point sources were significant and of such magnitude to cause the water quality standards to be exceeded. Figures 4 and 5 present the cumulative loadings of total PCBs from continuous point source discharges during dry weather and wet weather, respectively.

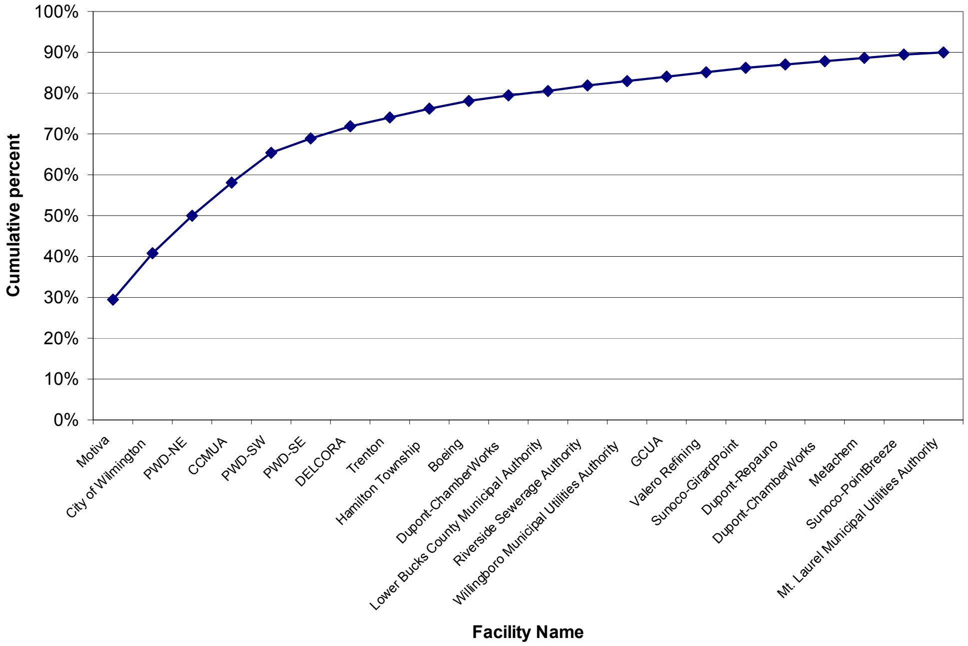


Figure 4: Cumulative loadings from continuous point source dischargers when the discharge was not influenced by precipitation (dry weather loadings).

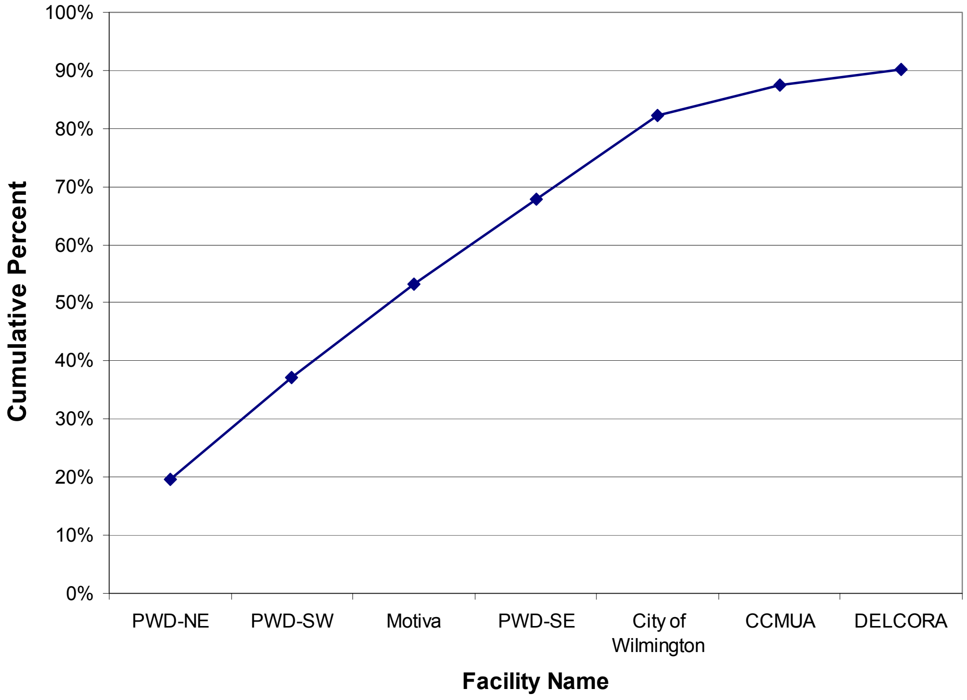


Figure 5: Loadings from continuous point source dischargers when the discharge was influenced by precipitation (wet weather loadings).

Beginning in September 2001, the Commission initiated surveys of the ambient waters of Zones 2 through 5 using the more sensitive HRGC/HRMS method (Method 1668A) and larger sample volumes to obtain data on PCBs adsorbed to particulate matter, PCBs adsorbed to dissolved organic matter and truly dissolved PCBs. Each survey involves sampling on a transect across the river at 15 locations between the C&D Canal and Trenton. A total of nine surveys have been completed to date with a focus on periods of intermediate and high inflows to the estuary. Figure 6 presents the results from surveys conducted in September 2001, May 2002, October 2002 and March 2003. Low flow conditions occurred during the September and October surveys (~3,300 cfs). Intermediate flow conditions (~16,000 cfs) occurred during the May survey, and high flow conditions (36,100 cfs) occurred during the March survey. As indicated in this graph, ambient concentrations of total PCBs based upon the sum of 124 congeners analyzed ranges between 443 and 10,136 pg/L with the highest values generally occurring during lower river inflows.

1.7 Other Required Elements for Establishing TMDLs

1.7.1 Seasonal variation

TMDL regulations at Section 130.32(b)(9) require the consideration of seasonal variation in environmental factors that affect the relationship between pollutant loadings and water quality impacts. Although seasonal variation is usually not as important for TMDLs based upon human health criteria for carcinogens since the duration for this type of criteria is a 70 year exposure, the Stage 1 TMDLs for total PCBs do include seasonal variation in several ways. Due to the interaction of PCBs with the sediments of the estuary, long-term model

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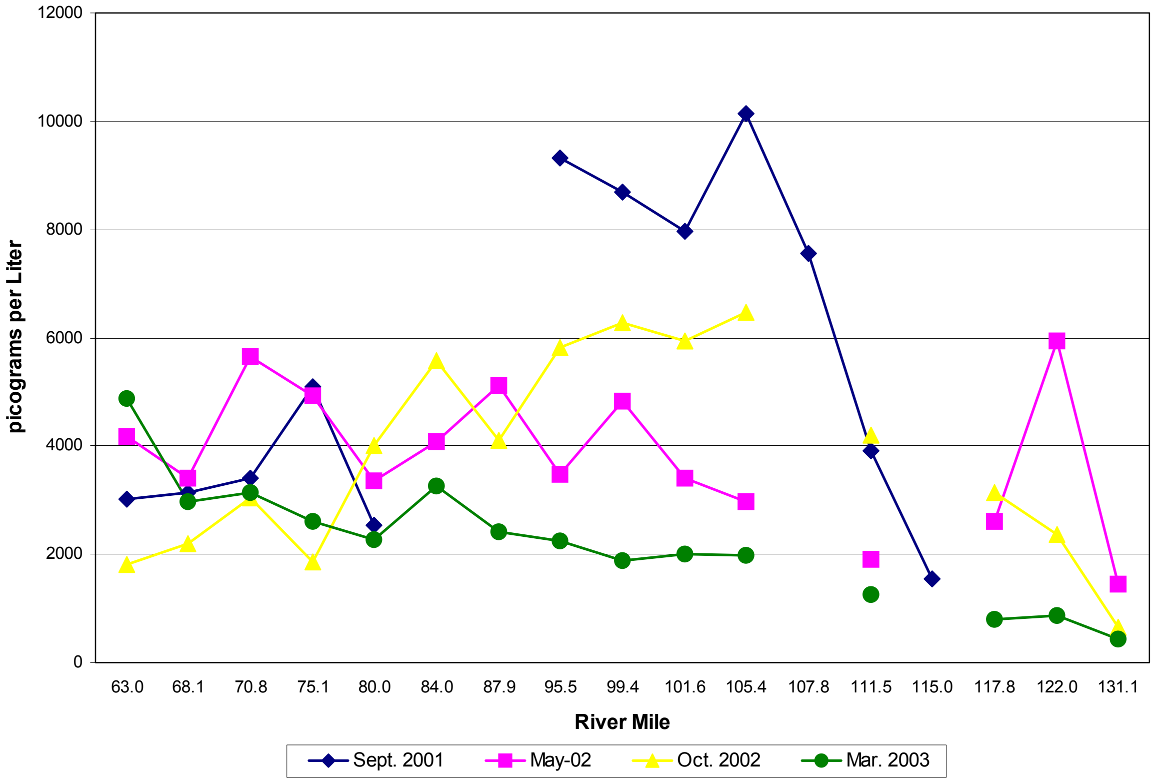


Figure 6: Concentrations of 124 PCB congeners at 15 locations in Zones 2 to 5 of the Delaware Estuary during varying flow conditions.

simulations were necessary to both confirm the model parameters established during the short-term calibration, and evaluate the time required for the sediments to reach pseudo steady-state with the overlying water column as loadings of PCBs were reduced.

The model will cycle model inputs from the period February 1, 2002 until January 31, 2003. This one year period is considered to be representative of long-term conditions (see Section 3.2.3.1), and is the same period utilized for long-term, decadal scale model simulations. Use of this one year cycling period, allowed consideration of seasonal variation in model input parameters such as tributary flows, tidal forcing functions, air and water temperature, wind velocity and loadings of penta-PCBs.

1.7.2 Monitoring Plan

The Delaware River Basin Commission has conducted nine surveys of the ambient waters of the Delaware Estuary between September 2001 and April 2003 to provide data for calibrating the water quality model for penta-PCBs that was used to establish the Stage 1 TMDLs. Samples collected during these surveys were analyzed using a more sensitive HRGC/HRMS method (Method 1668A) and larger sample volumes to obtain data at picogram per liter levels. The Commission plans to conduct additional surveys in both Zones 2 to 5 and in Delaware Bay (Zone 6) as part of the effort to calibrate water quality models for the other PCB homologs, and to establish and refine the TMDLs and associated WLAs and LAs for Stage 2. Contingent on available funding, the Commission plans to continue the ambient water surveys on a yearly basis to track the progress in achieving the load reductions and applicable water quality standards for PCBs.

In the spring of 2000, the Commission required 94 NPDES permittees to conduct monitoring of their continuous and stormwater discharges for 81 PCB congeners utilizing analytical methods that could achieve picogram per liter detection limits. The results of this monitoring indicated that loadings to the estuary zones from point sources were significant and of such magnitude to cause the water quality standards to be exceeded. These results have also be used to determine the need for and the frequency of additional monitoring in NPDES permits have been reissued in the last few years. Following approval of the Stage 1 TMDLs, most of the NPDES permittees included in the 2000 monitoring requirements will be required to conduct some additional monitoring using Method 1668A. These monitoring requirements will provided data in future years to assess the progress in achieving the TMDLs.

The Commission is also planning, contingent on available funding, to work cooperatively with the NJDEP and Rutgers University to continue air monitoring at Lums Pond near the western end of the C&D Canal and at a site in the NJ Pinelands which are located east of the estuary. Monitoring data at these sites and at a long-term site at Rutgers University will provided data to assess the long-term trends in regional background concentrations of PCBs (Lums Pond) and in regional concentrations in the estuary airshed.

1.7.3 Implementation Plan

Current EPA regulations do not require an implementation plan to be included with TMDLs. EPA NPDES regulations do require that effluent limitations must be consistent with approved WLAs [40 CFR Part 122.44(d)(1)(vii)(B)]. EPA regulations allow the use of non-numeric effluent limits in certain circumstances [40 CFR Part 122.44(K)]. In addition to EPA regulations, the Commission and its signatory parties currently have in place an implementation procedure for utilizing wasteload allocations and other effluent requirements formally issued by the Commission's Executive Director. This procedure has been in use for over 25 years with wasteload allocations for carbonaceous oxygen demand and other pollutants that were developed for discharges to the estuary. Section 4.30.7B.2.c.6). of the Commission regulations requires that WLAs developed by the Commission shall be referred to the appropriate state agency for use, as appropriate, in developing effluent limitations, schedules of compliance and other effluent requirements in NPDES permits.

As part of the implementation strategy, the NPDES permitting authorities believe that it is appropriate for 142 NPDES point source discharges to receive non-numeric WQBELs consistent with the WLAs. It is expected that the non-numeric WQBELs resulting from the Stage 1 WLAs require PCB minimization and reduction programs and additional monitoring using Method 1668A consistent with state and federal NPDES regulations. See Appendix 3 for details on the permit implications of this TMDL. These permit requirements are intended to expedite the reduction in PCB loadings to the estuary while Stage 2 TMDLs and WLAs are being completed.

A unique aspect of the implementation of these TMDLs is the establishment of a TMDL Implementation Advisory Committee (IAC)by the DRBC, which shall be asked to develop creative and cost-effective strategies for reducing PCB loadings and achieving the TMDLs for PCBs in the Delaware Estuary. The IAC will be encouraged to engage in creative, collaborative problem-solving. Its recommendations will be submitted to the Commission, which will consider them in consultation with all regulatory agencies whose approval is required to implement them. Each regulatory agency also will be represented on the IAC. The committee is expected to convene six times a year for two years.

1.7.4 Reasonable Assurance that the TMDLs will be Achieved

Data available to assess whether the TMDLs will be achieved include ambient water quality data collected by the Commission during routine surveys of Zones 2 through 6 of the Delaware River. Effluent quality data and source minimization plans required through NPDES permits issued by state permitting authorities will provide the basis for assessments regarding consistency with the WLAs developed or issued in Stage 1 and Stage 2. Commission regulations also require that the WLAs be reviewed and, if required, revised every five years, or as directed by the Commission. This will ensure that additional discharges of the pollutant or increased non-point source loadings in the future will be considered.

Achieving the reductions in the load allocations for tributaries will require the listing of the tributary on future Section 303(d) lists submitted by the estuary states for those tributaries that are not currently listed for impairment by PCBs, and completion and implementation of TMDLs for PCBs for those tributaries that are already listed as impaired by PCBs. Achieving the load reductions required for contaminated sites will require close coordination with the federal CERCLA programs and state programs overseeing the assessment and cleanup of these sites. In addition, the Commission has broad powers under Article 5 of the Delaware River Basin Compact (Public Law 87-328) to control future pollution and abate existing pollution in the waters of the basin including Section 2.3.5B of the Commission's Rules of Practice and Procedure (DRBC, 2002).

2. TWO STAGE APPROACH TO ESTABLISHING AND ALLOCATING TMDLs FOR PCBs

2.1 Background

Developing TMDLs for a complex pollutant in a complex estuarine ecosystem with numerous point and non-point sources is an enormous task requiring substantial levels of effort, funding and time. As discussed above, the deadlines contained in the Section 303(d) lists prepared by the States and approved by the U.S. EPA, Memoranda of Understanding, and Consent Decrees discussed above allocated five years for developing the TMDLs. A coordinated effort to develop the TMDLs was initiated in 2000 when Carol R. Collier, Executive Director of the Delaware River Basin Commission in a letter dated May 25, 2000 requested that U.S. EPA Regions II and III endorse the Commission as the lead agency in developing the TMDLs for PCBs in the Delaware Estuary. In a letter dated August 7, 2000, Region II endorsed the Commission's role as the lead agency to develop the TMDLs. An August 11, 2000 letter from Region III also acknowledge the important role of the Commission while identifying the legal constraints on the date for establishing the TMDLs. On July 26, 2000, the Commission passed Resolution 2000-13 stating that the Commission would continue its ongoing program to control the discharge of toxic substances, including PCBs, to the Delaware Estuary, and would work cooperatively with the signatory parties to the Delaware River Basin Compact and their agencies and affected parties in this effort.

2.2 Staged Approach

The complexity of a TMDL for a class of compounds such as PCBs, the limited time and data available, and the benefits of refining it through time with more data led to a decision to develop the TMDLs for PCBs in two stages consistent with EPA TMDL guidance. A staged approach provides for adaptive implementation through execution of load reduction strategies while additional monitoring and modeling efforts proceed. The approach recognizes that additional monitoring data and modeling results will be available following issuance of the Stage 1 TMDLs to enable a more refined analysis to form the basis of the Stage 2 TMDLs.

In the first stage, TMDLs and individual wasteload allocations were developed for each zone. Stage 1 WLAs were based upon a simplified methodology, while still meeting all of the regulatory requirements for establishing a TMDL. Consistent with the recommendations of an expert panel of scientists experienced with PCB modeling, these TMDLs were extrapolated from penta homolog data using the observed ratio in the Delaware Estuary of the penta homolog to total PCBs (see Section 3.4).

Stage 2 TMDLs, individual WLAs and LAs are targeted for development by December 31, 2005. Once the Stage 2 TMDLs are finalized, EPA expects the WLAs developed in Stage 2 to replace the Stage 1 WLAs. EPA expects the Stage 2 WLAs and LAs to be based on all of the monitoring data obtained through the development of the Stage 2 TMDLs, and the additional modeling that will be performed following the establishment of the Stage 1 TMDLs. Stage 2 TMDLs will also be based on the summation of the PCB homolog groups, without the use of extrapolation. It is anticipated that the Stage 2 WLAs will be based upon a more sophisticated allocation methodology than the Stage 1 WLAs, and will likely reflect application of the procedures set forth in the DRBC Water Quality Regulations.

As described in the documents released in April 2003 (Appendix 1) and following establishment of these TMDLs, the water quality-based effluent limitations (WQBELs) in NPDES permits that are issued, reissued or modified after the approval date must be consistent with the WLAs. The NPDES permitting authorities believe that these WQBELs will include non-numeric controls in the form of a best management practices (BMP) approach as the most appropriate way to identify and control discharges of PCBs consistent with the Stage 1 WLAs. Federal regulations (40 CFR Part 122.44(k)(4)) allow the use of non-numeric, BMP-based WQBELs in permits.

Guidelines describing appropriate NPDES permitting actions resulting from individual WLAs that may result following the establishment of the Stage 1 TMDLs by the U.S. Environmental Protection Agency are presented in Appendix 3. The guidelines include 1) the use of Method 1668A for any monitoring of the wastewater influent and effluent at a facility, 2) development of a PCB minimization plan, and 3) implementation of appropriate, cost-effective PCB minimization measures identified through the plan.

The identification of point source dischargers that are potentially significant sources of total PCBs is a dynamic process that depends on several factors including the availability and extent of PCB congener data for each discharge, the detection limit of the method used to analyze for PCB congeners, the flows used for each discharge, the procedure used to calculate the loadings, the location of the discharge in the estuary, and the proximity and loading of other sources of PCBs. EPA specifically requested comment on the list of significant point source dischargers, and has incorporated those comments, where appropriate, into this document (see Section 3.5). Expectations as to how the NPDES permits may appropriately address these specific WLAs can be found in Appendix 3.

An important component of the staged approach is the assessment and evaluation of options to control non-point sources of PCBs. These sources include contaminated sites (sites covered under CERCLA or RCRA), non-NPDES regulated stormwater discharges, tributaries to the estuary, air deposition, and contaminated sediments (see Section 1.4 and Appendix Tables 4-1). Addressing these sources is particularly important since contaminated sites and non-point stormwater discharges have been identified as the two largest categories of PCB loadings in this TMDL based upon current data and assessment procedures.

3. STAGE 1 APPROACH TO ESTABLISHING TMDLs

3.1 Background

TMDLs for total PCBs are estimates of the loading of the sum of all the PCB homologs that can enter the estuary and still meet the current water quality criteria. TMDLs are, by nature, abstract. They are the *projected*, not the current, loadings from all sources that should result in the achievement of water quality standards at all points in the estuary. Since current concentrations of PCB homologs are 500 times higher than the water quality criteria, the TMDLs and associated individual WLAs and LAs will be proportionately less.

In order to meet standards at all points in the estuary, some parts of the estuary will have to be less than the standard for that portion of the estuary. This is particularly true for these TMDLs in the Delaware Estuary since the water quality standards vary between the zones, and the standard in lower Zone 5 below the Delaware Memorial Bridges is approximately 5 times lower than the standards in Zones 2 to upper Zone 5 (see Section 1.4).

While simplistic approaches can be used to estimate TMDLs, significant effort has been devoted to developing and calibrating a hydrodynamic and water quality model for the Delaware Estuary to be used in establishing PCB TMDLs for this water body (DRBC, 2003a; DRBC, 2003b; DRBC, 2003c). There are several reasons why a more sophisticated approach is appropriate. These reasons include:

1. Zones 2 – 5 of the Delaware River are significantly influenced by tidal forces producing a 6 foot tidal range at Trenton, NJ and tidal excursions of up to 12 miles. The model incorporates this tidal movement in the hydrodynamic model (DRBC, 2003a).
2. PCBs are hydrophobic, sorb to dissolved, colloidal and particulate carbon, and are transported with carbon molecules and particulates associated with carbon. The model incorporates these

characteristics, partitions PCBs to each of these phases, and simulates the concentrations of the 3 phases in the estuary (DRBC, 2003b).

3. PCBs are a class of chemicals; each having different physical-chemical properties such as volatilization rate and partitioning rate. The model can incorporate these properties for each of the ten homolog groups (DRBC, 2003b).
4. There are many sources of PCBs enter the estuary at different locations in different amounts and at different times. The model can simulate the spatial and temporal nature of these sources (DRBC, 2003c).
5. A model can simulate the additional assimilative capacity provided by the burial of PCBs into the deeper layers of the estuary sediments, and the exchange of PCBs in the gas phase in the estuary airshed with the dissolved phase of PCBs in the ambient waters of the estuary (DRBC, 2003b).

3.2 Conceptual Approach

3.2.1 Guiding Principles

The TMDLs require that each source of PCBs including the sediment, air deposition meets water quality criteria by itself and in conjunction with all other sources. The procedure used to establish the TMDLs incorporates these principles by initially determining the concentration or loading from each source category followed by an assessment of the attainment of the water quality standards when loadings from all source categories are considered.

Another principle is that, when the water quality standards are met, additional loading of PCBs to the estuary is dependent on dilution by flows from other sources into the estuary, and the loss of PCBs through fate processes occurring in the estuary. Two of the source categories do not explicitly provide additional flows to the estuary and therefore do not provide assimilation capacity. The two sources are atmospheric dry deposition and gas phase transfer of PCBs, and contaminated sites. Ground and surface water flow from contaminated sites do occur, but these flows have not been adequately characterized and are not included in the current version of the penta-PCB model. As a result, the assimilative capacity for these sources must be obtained from other source categories.

All source categories and sources within categories are not created equally. Reductions in PCB loads in any source category will provide different amounts of assimilative capacity in different areas of the estuary. Figure7 illustrates this principle for the four boundaries of the penta-PCB model. In this example, each of the boundaries is set at a concentration of 100 milligrams per liter with the resulting model predicting ambient conservative chemical concentrations throughout the estuary. Of the four boundaries, the C&D Canal and the Schuylkill River have the smallest influence on conservative chemical concentrations in the estuary. This influence is also localized to the area where the source enters the estuary. The influence of the ocean boundary at the mouth of Delaware Bay appears to be limited to the Bay and the lower portions of Zone 5 (up to approximately River Mile 65). The Delaware River at Trenton, however, has a significant influence on the estuary conservative chemical concentrations from Zone 2 through Zone 5. Reductions in PCB loadings from the Delaware River at Trenton will therefore provide substantially more assimilative capacity in a larger area of the estuary.

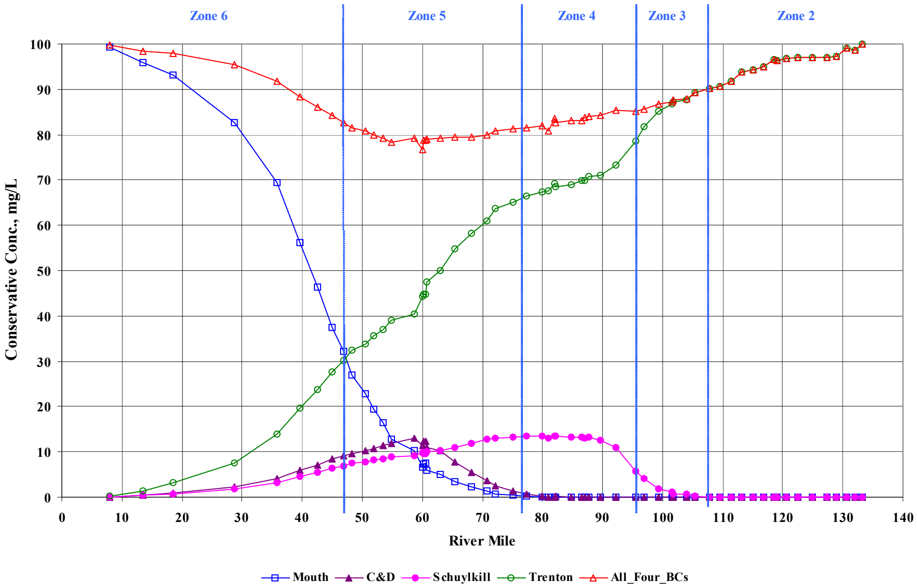


Figure 7: Relative impact of the four boundaries when the conservative chemical concentrations are set at 100 milligrams per liter.

Estuary sediments function as a sink or loss mechanism for PCBs through burial of PCBs that settle to the bottom of the estuary. This small (<1 cm/year) net deposition of particulates provides additional assimilation capacity in the estuary, and is incorporated in the calculation of the TMDLs for each of the zones.

Recent monitoring of air concentrations in the regional airshed surrounding the Delaware Estuary indicate that PCB concentrations are particularly high in the Philadelphia-Camden area, and contribute PCBs to the estuary through dry and wet deposition, and exchange of PCBs in the gas phase (Van Ry et al, 2002 and Figure 8). While the proportional loading of PCBs from dry and wet deposition is explicitly included in the load allocation portion of the TMDLs, the transfer of PCBs in the gas phase with dissolved PCBs in the estuarine waters is not since there will be no significant net exchange between dissolved PCBs in water and gas phase PCBs in the air (i.e., they will reach equilibrium) when water quality standards are achieved. The modeling approach used to develop the TMDLs takes this into account by setting the gas phase air concentrations at the equilibrium concentrations (see Section 3.3.1 and 3.3.5).

The difference between the current gas phase concentrations and the gas phase concentrations when the estuary meets standards, is a significant TMDL implementation issue since water quality standards will not be achieved without reducing the gas phase concentrations to a level where they are in equilibrium with the dissolved PCB concentrations at the water quality standard. Figure 8 illustrates the relative difference between the current gas phase air concentration of penta-PCBs in Zone 3 and the gas phase concentration at equilibrium with the dissolved penta-PCB concentrations when the TMDL is achieved.

Finally, the boundaries of the model which include the head of tide of the tributaries, the C&D Canal, and the mouth of Delaware Bay were assigned concentrations of penta-PCBs in determining the TMDLs and establishing WLAs. Section 4.20.4B.1 of the Commission's Water Quality Regulations specify that in establishing WLAs, the concentrations at the boundaries of the area of interest shall be set at the lower of actual data or the applicable water quality criteria (DRBC, 1996). Thus for modeling purposes, tributaries or other boundaries cannot exceed the water quality criteria for the zone of the estuary that they enter or border. In developing these TMDLs, both the C&D Canal boundary and the mouth of Delaware Bay boundary were set to 7.9 pg/L. This is the criterion for Zone 5 where the canal enters the mainstem of the Delaware River, and is the current criterion for Zone 6 (Delaware Bay). The current concentrations of PCBs at the mouth of the Bay exceed this value by 2 orders of magnitude, while current concentrations at the C&D Canal boundary exceed this value by almost 3 orders of magnitude. Thus like the gas phase concentrations of PCBs in the air, PCB concentrations at both the C&D Canal and the ocean boundary must also be reduced in order to achieve the water quality standards. The relative influence of these boundaries at the critical compliance location must also be considered in determining the relative importance of the required reductions (see Figure 7).

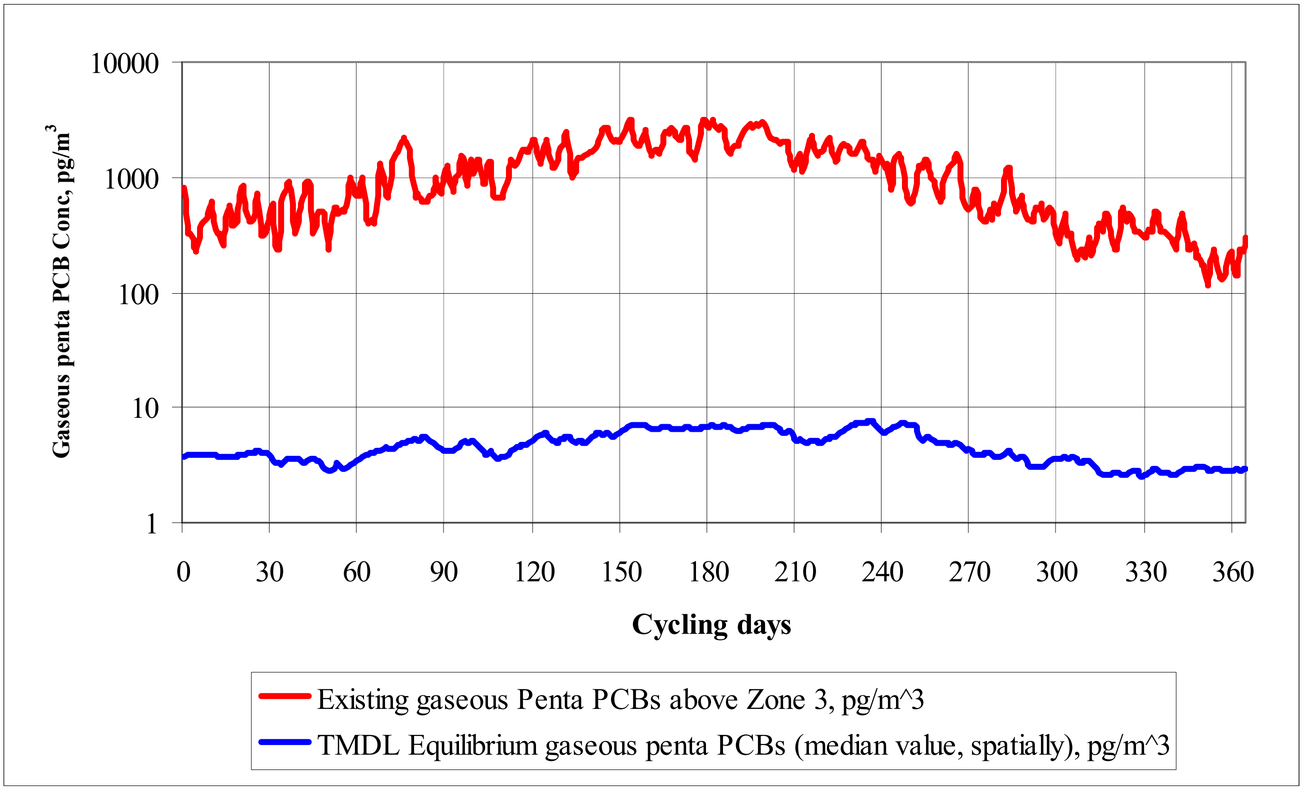


Figure 8: Atmospheric gas phase penta-PCB concentrations during the one year model cycling period based upon current data and the expected penta-PCB concentrations when the TMDLs are achieved.

3.2.2 Modeling Approach

Several mathematical models are used to develop the TMDLs for PCBs. The first is a hydrodynamic model that was extended to included Delaware Bay (Zone 6). The hydrodynamic model is discussed in Section 3.2.4.1 and fully described in the report entitled “DYNHYD5 Hydrodynamic Model (Version 2.0) and Chloride Water Quality Model for the Delaware River Estuary” (DRBC, 2003a). The water quality models used in this effort included an updated TOXI5 model for chlorides, and a new model for pentachlorobiphenyls (penta-PCBs)(DRBC, 2003b). The hydrodynamic and chloride models are discussed in Section 3.2.4.1 and

3.2.4.1, respectively and described in detail in the report on the hydrodynamic model (DRBC, 2003a). The organic carbon and penta-PCB models are discussed in Section 3.2.4.3 and fully described in the report entitled “PCB Water Quality Model for the Delaware Estuary (DELPCB)” (DRBC, 2003b).

TMDLs are calculated using both the conservative chemical model, and the penta-PCB water quality model run until equilibrium is observed. The model cycles model inputs from the period February 1, 2002 until January 31, 2003. This one year period is considered to be representative of long-term conditions (see Section 3.2.3.1), and is the same period utilized for the decadal scale (74 year) model simulations by HydroQual, Inc.

3.2.3 TMDL Approach

Although the water quality standards are expressed as total PCBs and the TMDLs must be expressed as Total PCBs, the current water quality model only addresses penta-PCBs. As discussed in Section 2.2, the TMDLs for total PCBs are extrapolated from TMDLs for penta-PCBs using the observed ratio in the Delaware River/Estuary of the penta homolog to total PCBs. Therefore, a water quality target for penta-PCBs must be established for use in the TMDL procedures. This target is determined by assuming that the ratio of penta-PCBs to total PCBs is approximately 0.25.

TMDLs for total PCBs for Zones 2 through 5 of the Delaware Estuary are established using a four step procedure. TMDLs are calculated over a one year period (annual median) to be consistent with both the model simulations and the 70 year exposure used for human health criteria. The procedure initially utilizes the conservative chemical model to establish contribution factors (Cfs) for two of the major tributaries to the estuary (the Delaware River at Trenton and the Schuylkill River), and each of the estuary zones. Allowable loadings are then calculated for each of these sources utilizing the CF and the proportion of the water quality target at the critical location allocated to each source. These loadings are used in the conservative chemical and penta-PCB models to establish the assimilative capacity provided by burial of PCBs into the estuary sediments. The gas phase concentrations that would be in equilibrium with the penta-PCB water concentrations when the water quality targets are met are then included in the water quality model. The model is then run to confirm that the water quality targets are still being met.

Following establishment of the TMDLs for each zone, each of the zone TMDLs are apportioned using the current percentage contribution for each of the source categories excluding loads from the Delaware River, Schuylkill River and contaminated sites based upon the respective loadings during the period Feb. 1, 2002 to Jan. 31, 2003 (Table 2, Figure 9)

Table 2: Apportionment of Zone TMDLs to Wasteload and Load Allocations excluding loads from the Delaware River, Schuylkill River and contaminated sites.

ZONE	WASTELOAD ALLOCATION	LOAD ALLOCATION
2	44.1%	55.9 %
3	78.1%	21.9 %
4	60.8%	39.2 %
5	63.4 %	36.6 %

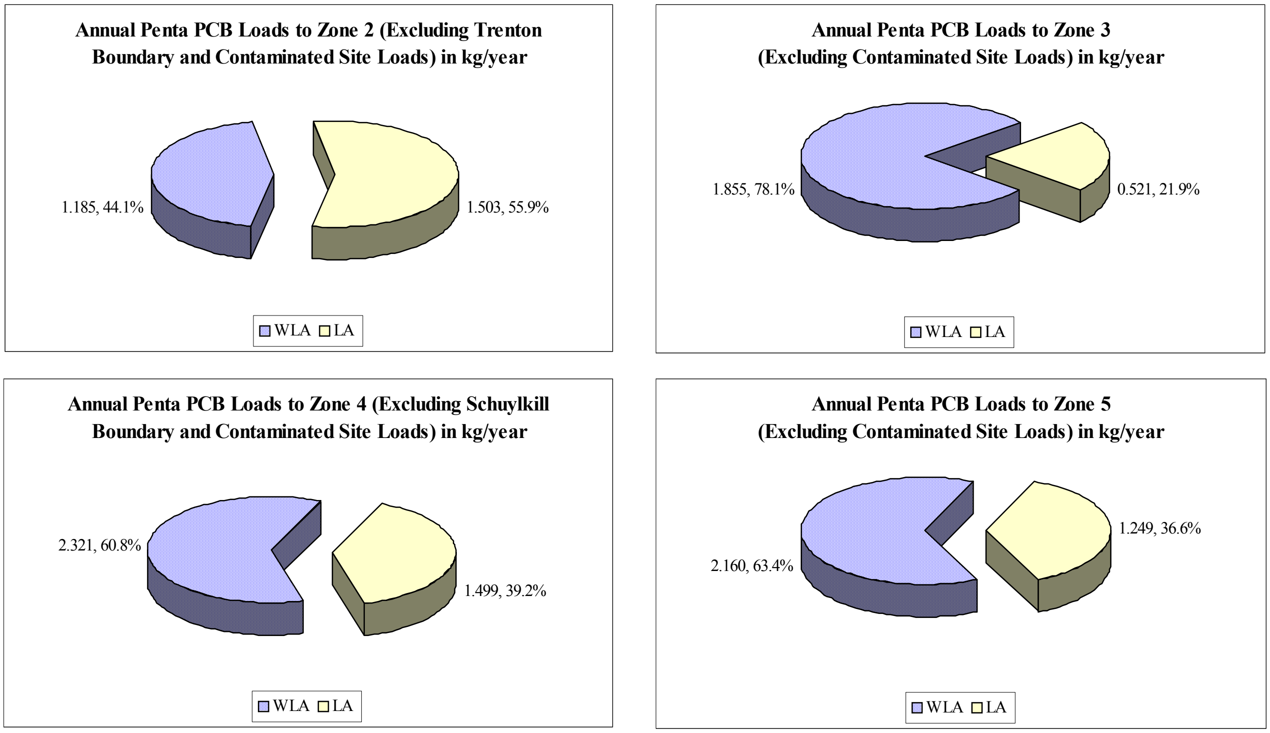


Figure 9: Apportionment of Zone TMDLs in kilograms per year (kg/year) to Wasteload and Load Allocations excluding loads from the Delaware River, Schuylkill River and contaminated sites.

The wasteload allocation portion of the TMDL represents those source categories that are regulated under the NPDES program (point sources, combined sewer overflows or CSOs, and municipal separate storm sewer systems or MS4s). The load allocation portion of the TMDL represents the remaining categories including contaminated sites, non-NPDES regulated stormwater discharges, tributaries and air deposition).

In accordance with the TMDL regulations, a portion of each zone TMDL must be allocated to a margin of safety. The margin of safety (MOS) is intended to account for any lack of knowledge concerning the relationships between pollutant loadings and receiving water quality. Commission regulations also require that a portion of the TMDL be set aside as a margin of safety, with the proportion reflecting the degree of uncertainty in the data and resulting water quality-based controls. The MOS can be incorporated into the TMDL either implicitly in the design conditions under which the TMDL is calculated or explicitly by assigning a fixed proportion of the TMDL. Since the conditions under which the TMDL is determined like tributary flows are related to the long-term conditions and not to design conditions associated with human health water quality standard for carcinogens (such as the harmonic mean flow of tributaries), expression of the MOS as an explicit percentage of each zone TMDL was considered the more appropriate approach. An explicit percentage of 5% was then utilized in the apportionment of the zone TMDLs. Both the apportionment of the zone TMDLs using the current percentage contribution and use of a margin of safety of 5% were recommended by the Commission's Toxic Advisory Committee.

3.2.4 Model Descriptions and Inputs

3.2.4.1 Hydrodynamic Model

Inputs to the hydrodynamic, conservative chemical and PCB models included daily tributary flows at the two major tributary boundary conditions, the Delaware River at Trenton and the Schuylkill River, and at 20 minor tributaries for the period February 1, 2002 to January 31, 2003. A comparison of the cumulative distribution curve for this one year period to the curve for the period of record for the Delaware River at Trenton (1912 to March 2003) and the Schuylkill River (1934 to March 2003) is presented in Figures 10 and 11, respectively. The figures indicate that the flows occurring during the one year cycling period are a reasonable representation of the flows during the period of record for these two tributaries.

The hydrodynamic model also includes precipitation induced flows for both point and non-point sources. The precipitation pattern occurring during the one year cycling period was compared to historical precipitation records (1872 to March 2003) maintained by the Franklin Institute (2003) to determine the degree to which the precipitation pattern for the one year cycling period was representative of the long term record. This comparison indicated good agreement for both the number and percentage of days when precipitation exceeded 0.01 inches, and the number and percentage of days when precipitation was less than 0.01 inches (Figures 12 and 13). This precipitation data was used to both calculate the flow of each discharge during precipitation events and determine when data collected during precipitation events would be used in loading calculations.

The tidal forcing function in the hydrodynamic model was based upon actual tide data for the one year cycling period. Since the major component of the tidal function has a periodicity of 12.42 hours and minor components with lunar and annual periodicity, this data set was considered representative of long-term tidal conditions. In addition, the expert panel recommended that alternative model inputs based upon design conditions not be used in TMDL simulations in order to maintain any hydrological relationships between the various inputs. For this reason, actual discharge flows for the point sources included in this TMDL determination during the one year cycling period were used rather than design effluent flows such as those specified in Section 4.30.7A.8. of the Commission's Water Quality Regulations or federal NPDES regulations. This is particularly important in the establishment of PCB TMDLs for the Delaware Estuary since the flow from a number of the point sources is significantly influenced by precipitation. For example, design effluent flows for the City of Philadelphia's wastewater treatment plants are approximately 200 million gallons per day, but can double during precipitation events. In addition, procedures have not been developed nor does the Commission's regulations specify procedures to establish design effluent flows for those discharges that are solely driven by precipitation (i.e., stormwater discharges). Such procedures and regulations will be developed for application in the Stage 2 TMDLs for PCBs, if necessary. The similarity of the precipitation pattern observed during the one year cycling period to the long term precipitation record suggests that the precipitation induced flows for both continuous and stormwater discharges used to develop the Stage 1 TMDLs may ultimately serve as design flows for these discharges.

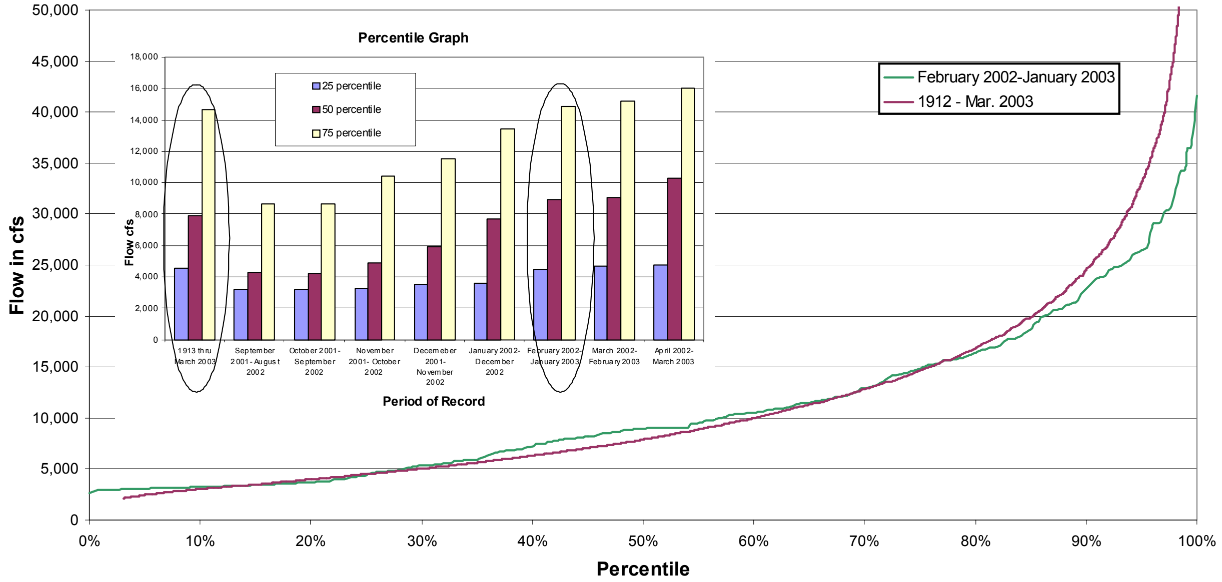


Figure 10: Cumulative distribution curve for the period of record for the Delaware River at Trenton (1912 to March 2003) compared to the period February 1, 2002 to January 31, 2003.

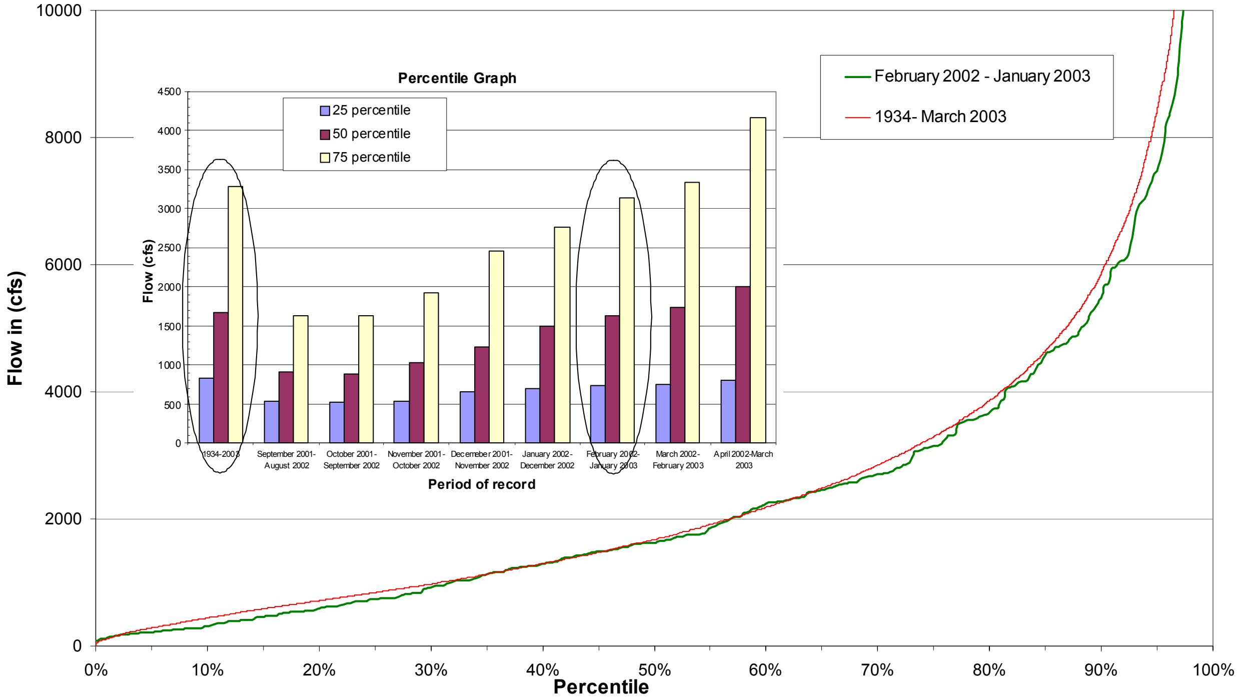


Figure 11: Cumulative distribution curve for the period of record for the Schuylkill River (1934 to March 2003) compared to the period February 1, 2002 to January 31, 2003.

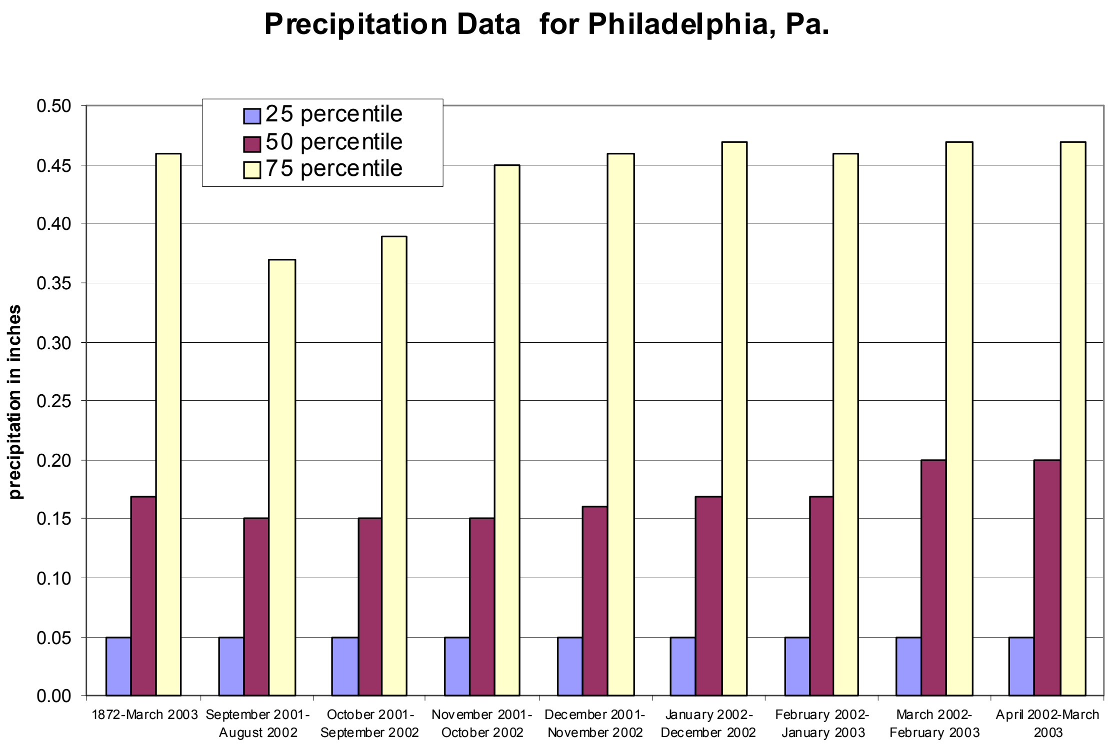


Figure 12: Percentile curves for precipitation data (events > 0.01 inches) for Philadelphia, PA from 1872 to March 2003 compared to the period February 1, 2002 to January 31, 2003.

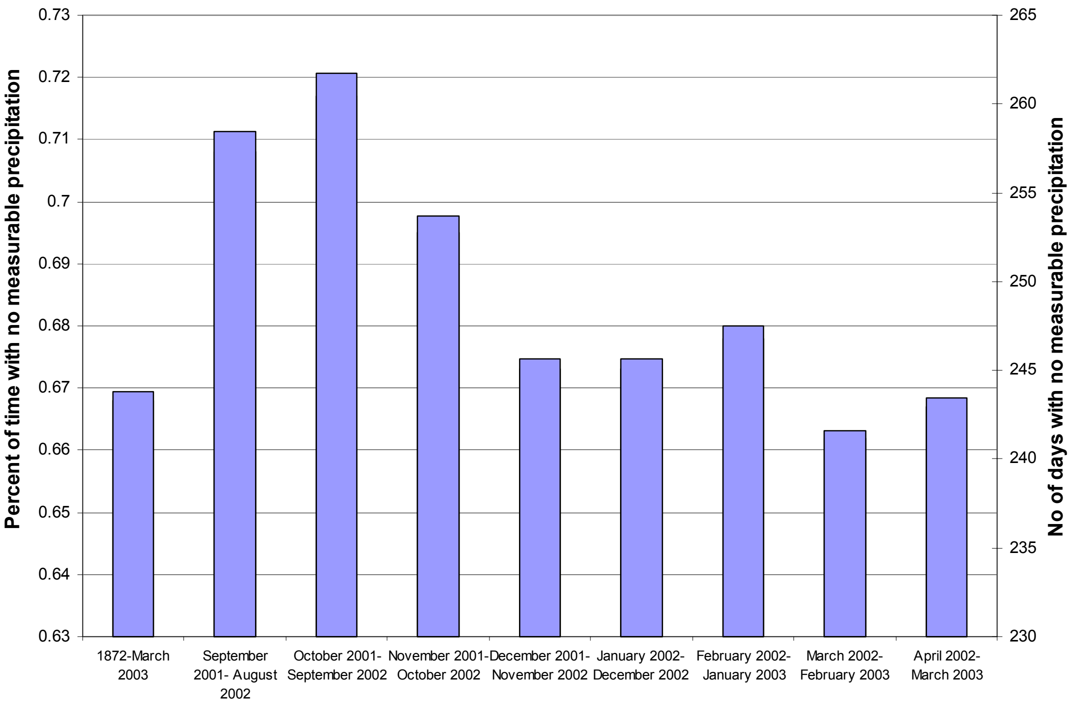


Figure 13: Percentile curves for precipitation data (days with precipitation < 0.01 inches) for Philadelphia, PA from 1872 to March 2003 compared to the period February 1, 2002 to January 31, 2003.

3.2.4.2 Conservative Chemical Water Quality Model

A TOXI5 (water quality) model consisting of 87 water column segments was then linked with the outputs from the calibrated DYNHYD5 hydrodynamic model and calibrated against the chloride concentrations. This model is based upon the U.S. EPA's Water Quality Simulation Program (WASP) Version 5.12., and does not include any fate processes for chlorides or any interaction of the chlorides with the sediment. The main objective in this calibration process was the determination of an advection factor and a set of dispersion coefficients for the water quality model to correctly simulate the dispersive mixing within the Estuary. Review of comparison plots and the results of regression analyses indicated that the model was able to reproduce the temporal and spatial trends, and the magnitude of the chloride concentrations, within a reasonable range throughout the tidal portion of the Delaware River.

3.2.4.3 Penta-PCB and Organic Carbon Water Quality Models

The calibrated hydrodynamic and conservative chemical model are used to drive mass balance models of organic carbon and penta-PCBs (DELPCB). DELPCB is a simulation program enhanced from the U.S. EPA's Water Quality Simulation Program (WASP) Version 5.12, and is fully described in DRBC (2003c). The organic carbon model has two organic carbon state variables and one inorganic solid (IS) as a control state variable. These variables are integrated with the one-dimensional hydrodynamic DYNHYD5 model to dynamically simulate these sorbent variables. The two carbon variables are biotic carbon (BIC), carbon generated internally by phytoplankton, and particulate detrital carbon (PDC) which consists of detritus and other forms of non-living carbon. The model treats the two organic carbon sorbents as non-conservative state variables that are advected and dispersed among water segments, that settle to and erode from benthic segments, and that move between benthic layer segments through net sedimentation.

The model also partitions penta-PCBs into particulate- PCB, truly dissolved-PCB, and dissolved organic carbon (DOC) bound phases treated as individual state variables. The real time model simulates tide-induced flows, and the spatial and temporal distributions of the organic carbon and penta-PCB variables. During the modeling process, using data generated by the hydrodynamic model, DELPCB simulates the spatial and temporal distributions of water quality parameters including BIC, PDC, total penta-PCB, particulate penta-PCB, and truly dissolved PCB, and DOC-bound PCB. The sum of the latter two is total dissolved penta-PCB.

3.2.4.4 Model Inputs

Additional inputs to the models include air and water temperature, wind data and the loadings of penta-PCBs from various source categories for the period February 1, 2002 to January 31, 2003. Water temperature data were obtained from three automatic water quality monitoring stations operated cooperatively by the DRBC and the U.S. Geological Survey at the Ben Franklin Bridge, Chester, PA and Reedy Island. Air temperature and wind speed data were obtained from the National Weather Service at the Philadelphia International Airport station.

Daily loadings of organic carbon and penta -PCBs were estimated for relevant source categories, including contaminated sites, non-point sources, point discharges, atmospheric deposition, and model boundaries, for each day of the one year cycling period. Detailed discussion of load development for each source category is described in Section 2 of the report entitled "Calibration of the PCB Water Quality Model for the Delaware Estuary for Carbon and Penta-PCBs" (DRBC, 2003c).

3.3 Procedure for Establishing TMDLs

3.3.1 Summary

TMDLs for total PCBs for Zones 2 through 5 of the Delaware Estuary are established using a multi-step procedure that incorporated the guiding principles discussed in Section 3.2.1. As discussed in Section 1.4, the existing DRBC water quality standards are used as the basis for the Stage 1 TMDLs. The selection of these standards establishes the transition from a standard of 44.8 pg/L in upper Zone 5 to a standard of 7.9 pg/L in lower Zone 5 as the critical location for ensuring that standards are met throughout the estuary. Standards that are lower than upstream water quality standards typically require ambient water concentrations in upstream waters to be lower than the applicable standards for those waters. In tidal waters such as the Delaware Estuary, downstream waters with less stringent water quality standards can have the same effect on upstream waters depending on the extent of upstream movement during flooding tides. With the use of the existing DRBC water quality standards as the basis for the TMDLs in Stage 1, the critical location occurs where the 7.9 pg/L standard becomes effective (River Mile 68.75, the site of the Delaware Memorial Bridges).

The procedure initially utilizes the conservative chemical model to establish contribution factors for two of the major tributaries to the estuary (the Delaware River at Trenton and the Schuylkill River), and each of the estuary zones. The reasons for utilizing the contribution factor approach and the conservative model are 1) TMDLs are controlled by the value of the standard at the critical location, and 2) computer simulation time is minimized permitting the numerous iterations necessary to perform the procedure (approximately five hours for a 50 year simulation with the penta-PCB water quality model). The factors represent the contribution of each of the six sources in picograms per liter to the concentration of penta-PCBs at the critical compliance location. The loading into each zone is assigned as distributed loadings by utilizing a weighting factor calculated using the surface area of the model segments within the zone. For each of the estuary zones, the contribution factor has the units of pg/L per unit of loading. The unit of loading is relative to magnitude of the water quality standard. For example, conventional pollutants with standards in units of milligrams per liter (parts per million) and toxic pollutants with standards in micrograms per liter (parts per billion), loading is often expressed in kilograms per day. With the standard for PCBs in the picograms per liter range, however, loading is more appropriately expressed in terms of milligrams per day. Different units are used for the two major tributaries since the model calculates the loading of PCBs from these tributaries using the daily flows and the concentration of penta-PCBs. Therefore, the contribution factor for these two sources are expressed in units of pg/L per pg/L of penta-PCBs at the tributary boundary compared to pg/L per 100 mg/day for the loadings from the zones.

TMDLs are calculated in a four step procedure (Figure 14). The four steps are:

1. Calculate the contribution factor for each of the estuary zones and two of the tributary model boundaries to the critical compliance point with the penta-PCB water quality target.
2. Determine the proportion of the water quality target allocated to each of these six sources utilizing the median daily flow contributed by each during the one year model cycling period. Calculate the allowable loadings from each of these sources utilizing the CF and the proportion of the water quality target at the critical location allocated to each source. Then utilize these loadings in the conservative chemical and penta-PCB models to establish the assimilative capacity provided by burial of PCBs into the estuary sediments. Iteratively determine the amount of assimilative capacity (in pg/L) provided by the sediments, and add this concentration to the penta-PCB water quality target. Recalculate the allowable loadings from each of the six sources using this revised water quality target.
3. Utilize the water quality model for penta-PCBs with these allowable loadings to confirm that the sediment concentrations have reached pseudo-steady state, and confirm that the penta-PCB water quality target is met in Zones 2 through 5. Initial

penta-PCB conditions in the water and sediments are updated to shorten the simulation time to reach peudo steady-state in Step 4.

4. Estimate the gas phase concentrations that would be in equilibrium with the penta-PCB water concentrations when the water quality targets are met, include these in the water quality model and then confirm that the water quality targets are still being met. Iteratively adjust the gas phase concentration of penta-PCBs in the air until the water quality target is reached. The air will neither be a source or sink for penta-PCBs when the estuary meets the water quality standard and gas phase concentrations are reduced to the equilibrium concentration.

3.3.2 Step 1

In determining the contribution factor for the two tributary boundaries and the four estuary zones, the boundary of interest is set to 1 pg/L and all other model boundaries except the one of interest are set to zero pg/L. Model simulations are then run for 10 years to ensure that equilibrium conditions are achieved, and the annual median value is then calculated for each model segment in the main stem of the river. Figures 15 through 17 illustrate how the contribution factor is determined for the four model boundaries. These figures indicate the concentration of penta-PCBs at the critical point when a concentration of 1 pg/L is set at the model boundary.

Table 3 lists the contribution factors determined by this analysis for all of the model boundaries and each of the estuary zones.

Table 3: Summary of the contribution factors from the model boundaries and the estuary zones at the criteria critical point (Model segment 24 - River Mile 68.1).

Estuary Zone/Boundary	**Contribution Factor [pg/L] per [100 mg/day]**	**Contribution Factor [pg/L] per [pg/L]**
Zone 2	1.9668	-
Zone 3	2.1428	-
Zone 4	2.2813	-
Zone 5	0.96704	-
Delaware River @ Trenton	-	0.5815
Schuylkill River	-	0.11839
Ocean & C&D Canal	-	-

3.3.3 Step 2

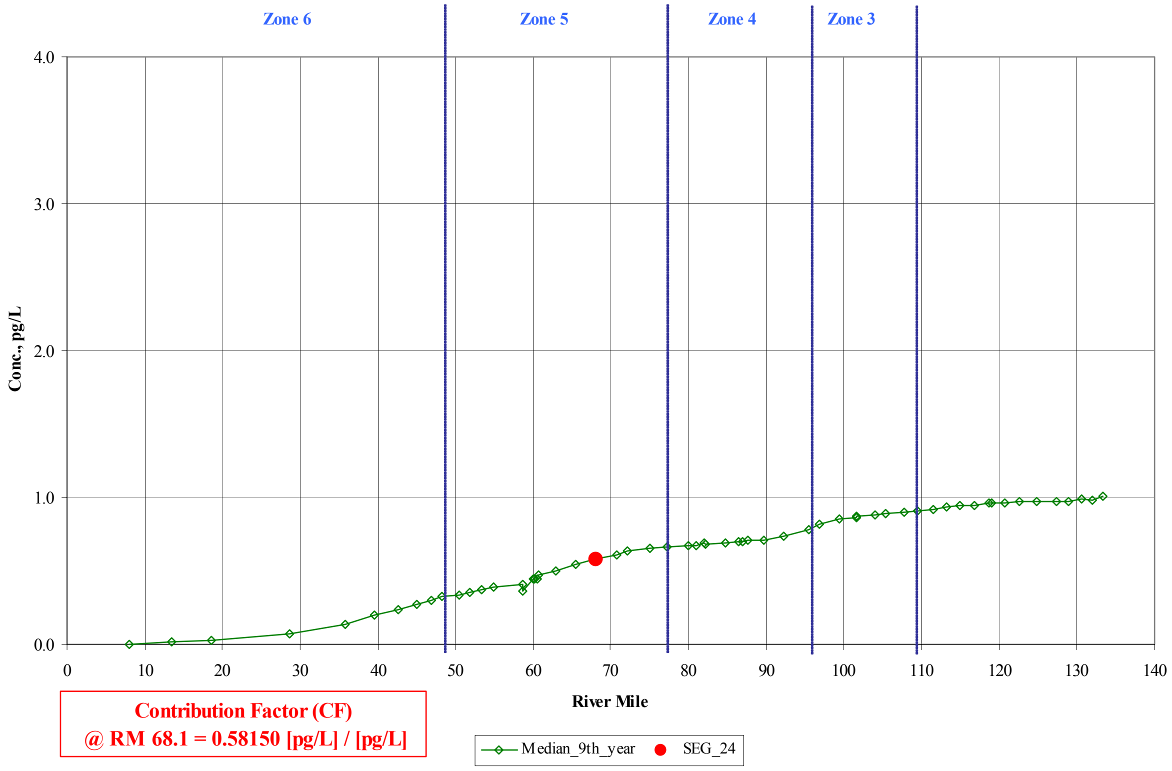
Once the contribution factors are determined, the next step is to determine the allowable loadings from each of these sources that will still ensure that the water quality target is met at the critical location. The following assumptions are made in determining these loadings:

a. The assimilative capacity at the critical location controls the allowable loadings from each source. In concentration units, this assimilative capacity is equal to one-quarter of the applicable water quality standard or 1.975 pg/L of penta-PCBs.

b. The influence from ocean (the mouth of Delaware Bay) and the C&D Canal are treated as background. This is based in part upon their minimal influence at the critical location..

c. Net burial of PCBs into the sediment results in a loss of PCBs from the system. This removal of PCBs provides assimilative capacity that can be utilized by other sources. At the critical location, this additional assimilative capacity is approximately 0.5 pg/L of penta-PCBs.

d. When the concentration of penta-PCBs meets the water quality targets throughout the estuary, the concentration of penta-PCBs in the gas phase will be at equilibrium with the truly dissolved penta-PCBs in the water column, and the net flux of penta-PCBs will be zero. Thus, the air will neither be a source or sink for penta-PCBs when the estuary meets the water quality standard and gas phase are concentrations are reduced to the equilibrium concentration.



Contribution Factor (CF)
@ RM 68.1 = 0.58150 [pg/L] / [pg/L]

Figure 15: Simulated penta-PCB concentrations in the water column when the concentration of the Delaware River at Trenton, NJ is set to 1 picogram per liter.

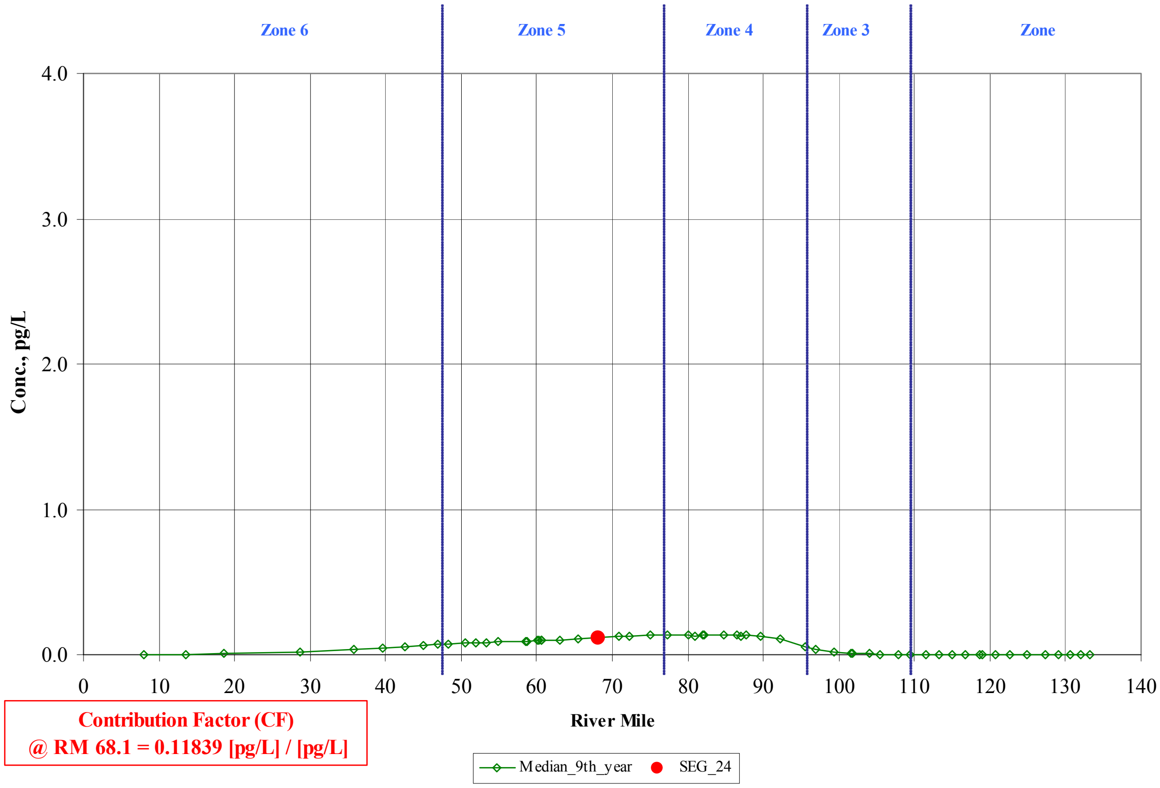


Figure 16: Simulated penta-PCB concentrations in the water column when the concentration of the Schuylkill River is set to 1 picogram per liter.

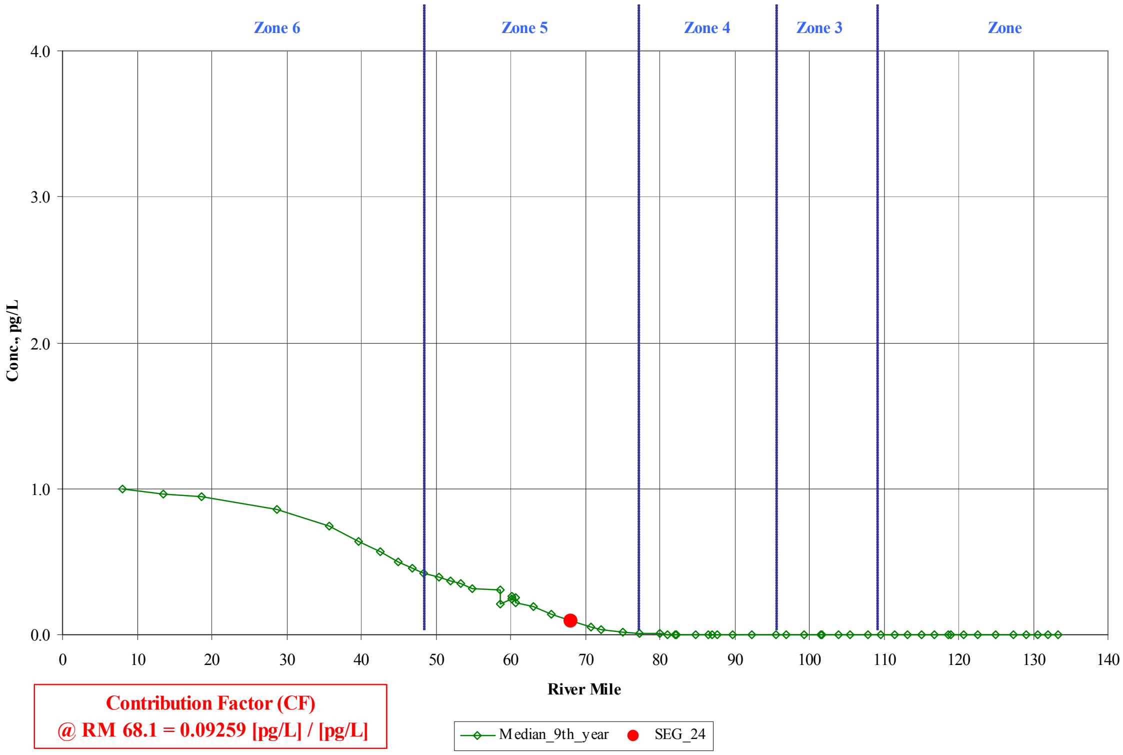


Figure 17: Simulated penta-PCB concentrations in the water column when the concentration at the mouth of Delaware Bay and the C&D Canal is set to 1 picogram per liter.

Using the principle that the assimilative capacity of the two tributary boundaries and each of the zones is based upon the inflow provided by each source, the percentage distribution of the assimilative capacity for each of these sources is established. Table 4 presents the flows for each of the sources during the one year model cycling period and the percentage distribution of the assimilative capacity based upon these flows. This distribution percentage is then applied to the penta-PCB water quality target of 1.975 pg/L to establish the contribution of each of the sources in picograms/liter to the target (Table 4). The influence of the mouth of Delaware Bay and the C&D Canal is first removed since this influence is considered background based in part on their minimal influence at the critical location. The additional assimilative capacity provided by the burial of PCBs into the estuary sediments was then estimated by inserting these loads in the conservative chemical and penta-PCB models. The results of this process was that the additional assimilative capacity was estimated to be 0.5 pg/L. This increased the assimilative capacity to 2.2921 pg/L (1.975 pg/L minus 0.183 pg/L for the background influences, plus 0.500 pg/L additional for burial by sediments) at the critical location. The contribution of each of the sources in picograms/liter to the target was then recalculated and used with the contribution factor to establish the allowable concentration or loadings for each of the tributary boundaries and estuary zones, respectively (Table 4).

At this point, a total allowable loading or assimilative capacity of 94.99 mg/day of penta-PCBs for all six sources was calculated. The majority of this loading was assigned to the two tributary boundaries, the Delaware River at Trenton and the Schuylkill River. Figure 18 graphically presents the available assimilative capacity at the critical location and the apportionment to each of the sources and estuary zones. Figure 19 presents the results of simulations using the conservative chemical model demonstrating that the calculated loadings result in attainment of the revised water quality target of 2.475 pg/L.

Table 4: Summary of Steps 1 and 2 of the Procedure for Establishing TMDLs

Sources of Loadings	**Contribution Factor (CF)**	**Mean Daily Flow During 1 Year Cycling Period**	**Distribution Percentage**	**Concentration at the Critical Location**	**Allowable Concentrations or Loadings.**	**Allowable Loadings (TMDL)**
Units	[pg/L] / [pg/L] or [pg/L] / [100mg/day]		%	pg/L	pg/L or mg/day	mg/day
Trenton	0.581500*	249.19	68.0	1.559	2.68*	57.727
Schuylkill	0.118390*	45.87	12.5	0.287	2.42*	9.609
Zone 2	1.966800	20.79	5.7	0.130	6.61	6.613
Zone 3	2.142800	15.26	4.2	0.095	4.46	4.455
Zone 4	2.281300	16.66	4.5	0.104	4.57	4.569
Zone 5	0.967040	18.57	5.1	0.116	12.02	12.016
Sum		366.3	100	2.2921	-	94.99

* - Units are either [pg/L] / [pg/L] or pg/L.

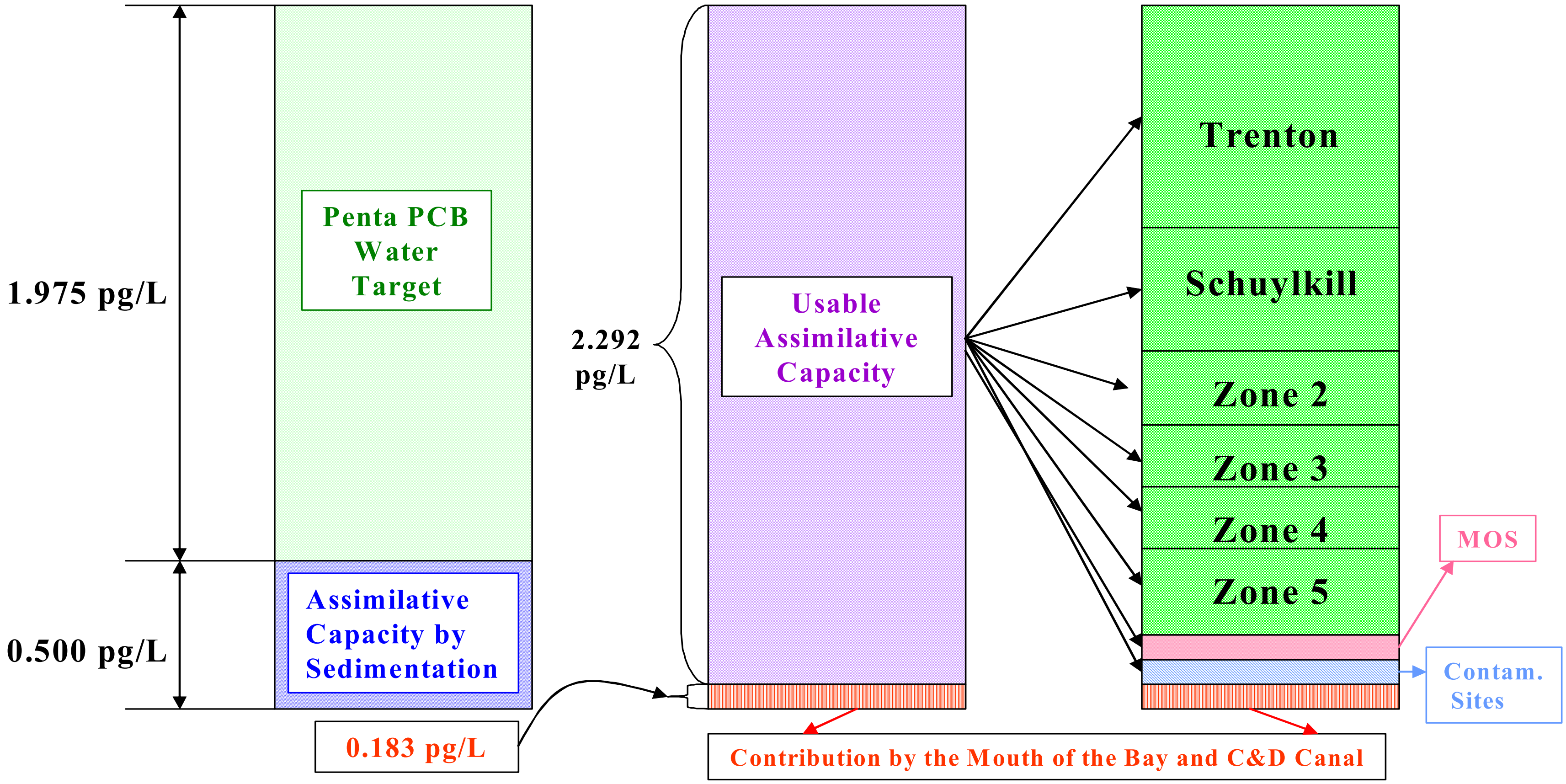


Figure 18: Graphical presentation of the allocation of the assimilative capacity at the critical location.

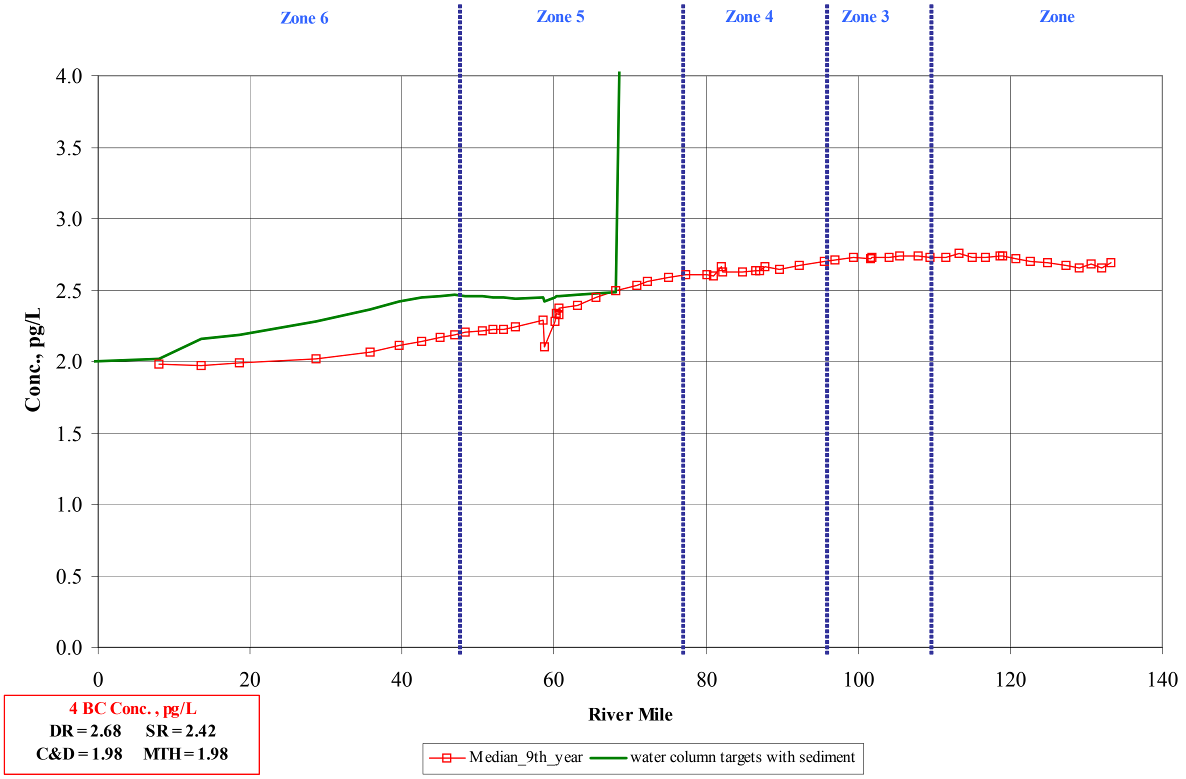


Figure 19: Simulated penta-PCB concentrations in the water column when loadings established in Step1 are used in the conservative chemical model.

3.3.4 Step 3

The next two steps will utilize the water quality model for penta-PCBs to confirm the assimilative capacity that was added due to the loss of PCBs by burial by the sediment, to confirm that sediment concentrations have reached steady-state, and to make final adjustments to account for the exchange of penta-PCBs in the truly dissolved phase with penta-PCBs in the gaseous phase in the estuary airshed.

In this step, the PCB water quality model is run with the initial water column concentrations set to the concentrations described by the final simulation with the conservative chemical model (Figure 19), the loadings from the model boundaries and to each estuary zone that were determined in Step 2, initial penta-PCB concentrations in the sediment, and no air-water exchange of gaseous penta-PCBs. The purpose of this simulation is to determine the sediment concentrations that are in equilibrium with the estuary concentrations that will meet the water quality target of 1.975 pg/L at the critical location. These simulations were run for 50 years to establish the point at which equilibrium was reach between the water column and the sediments. Figure 20 indicates the sediment concentration of penta-PCBs at six locations in the estuary corresponding to a model segment in each of the estuary zones and Delaware Bay. Note that sediment concentrations in all segments reach equilibrium after 20 to 30 years from the assigned initial conditions. The simulated median sediment concentrations at each of the model segments is presented in Figure 21. The amount of assimilative capacity provided by the loss of penta-PCBs to the sediment is illustrated in Figure 22. The figure indicates that the amount of assimilative capacity provided by the sediments varies along the estuary due to the varying burial rates computed by the model. The assimilation capacity provided is about 0.5 pg/L at the critical location.

The penta-PCB model was then rerun for ten years with the initial sediment conditions set to these values along with the loadings from the model boundaries and to each of the estuary zones to confirm that the water quality target at the critical location was being met. Figure 23 presents a plot of the annual median values during the ninth year of the simulation, confirming that the water quality target is being met. Figure 24 demonstrates that the sediments are in equilibrium during the simulation period.

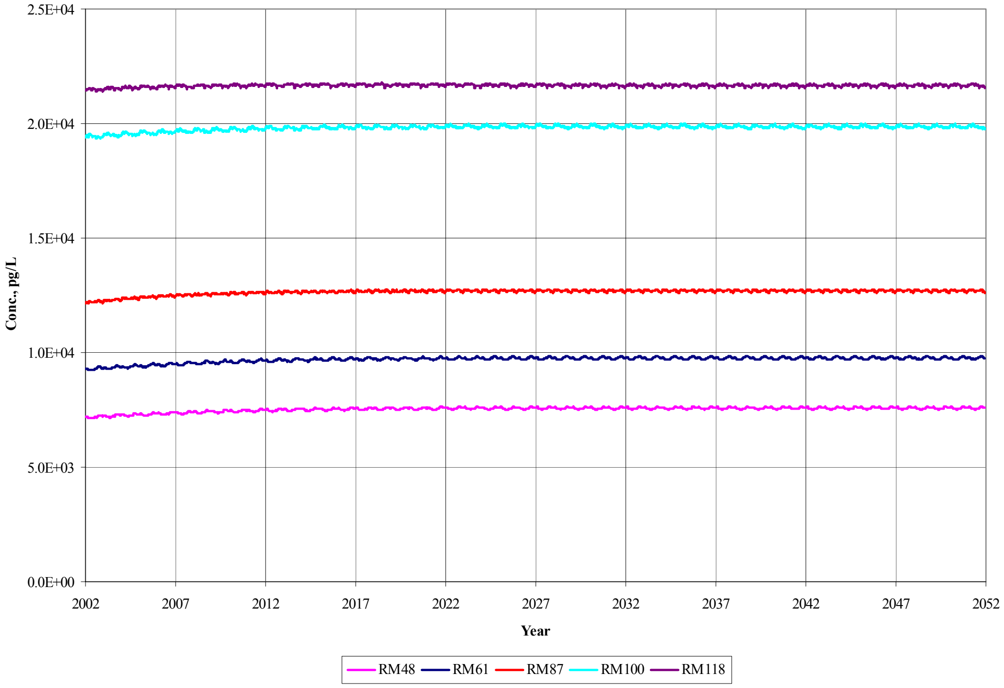


Figure 20: Temporal plot of penta-PCB concentrations in surface sediment layer during a 100 year simulation using the loads established in Step 2.

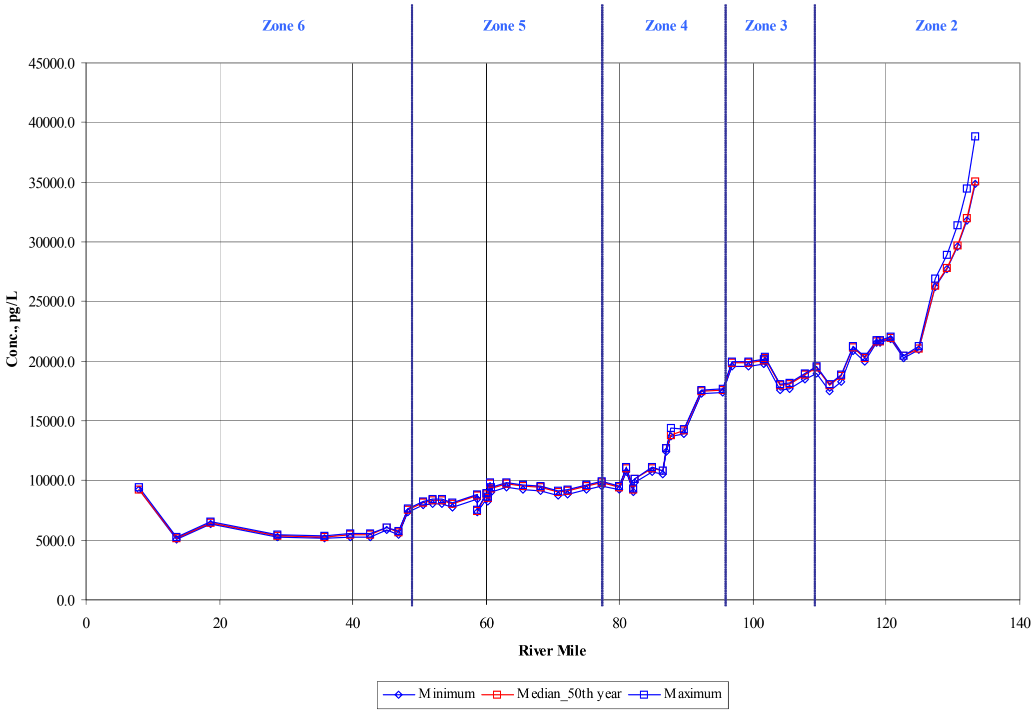


Figure 21: Spatial plot of simulated surface sediment concentrations of penta-PCBs in surface sediment layer during a 50 year simulation using the loads established in Step 2.

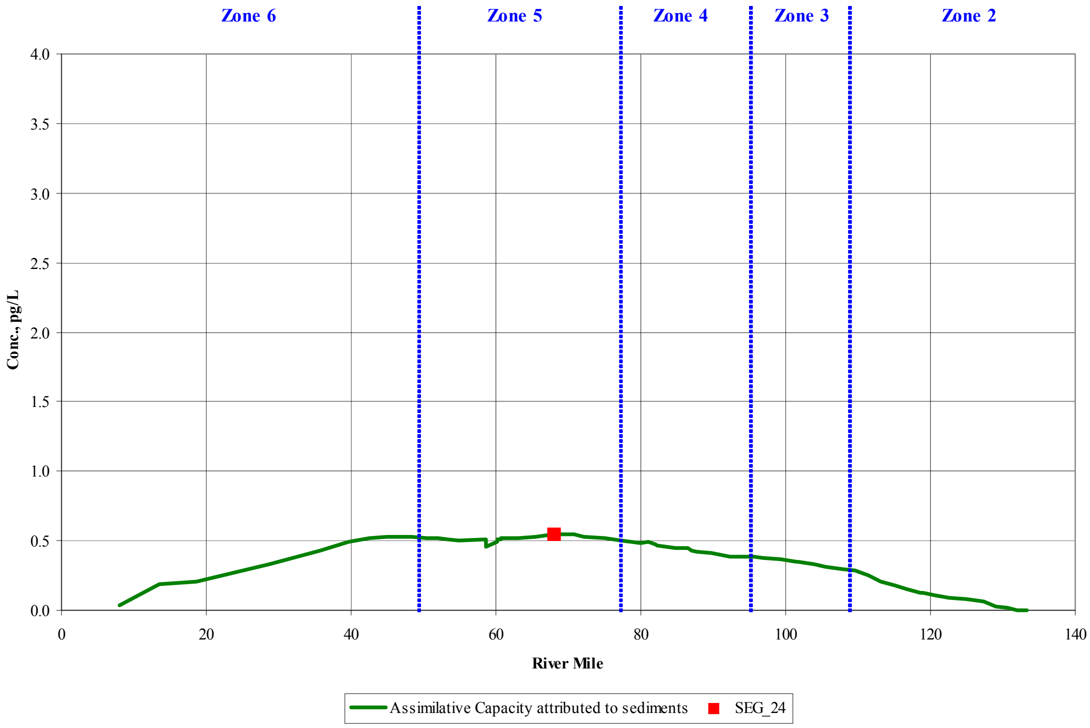


Figure 22: Spatial plot of the assimilative capacity in pg/L provided by the sediment layer.

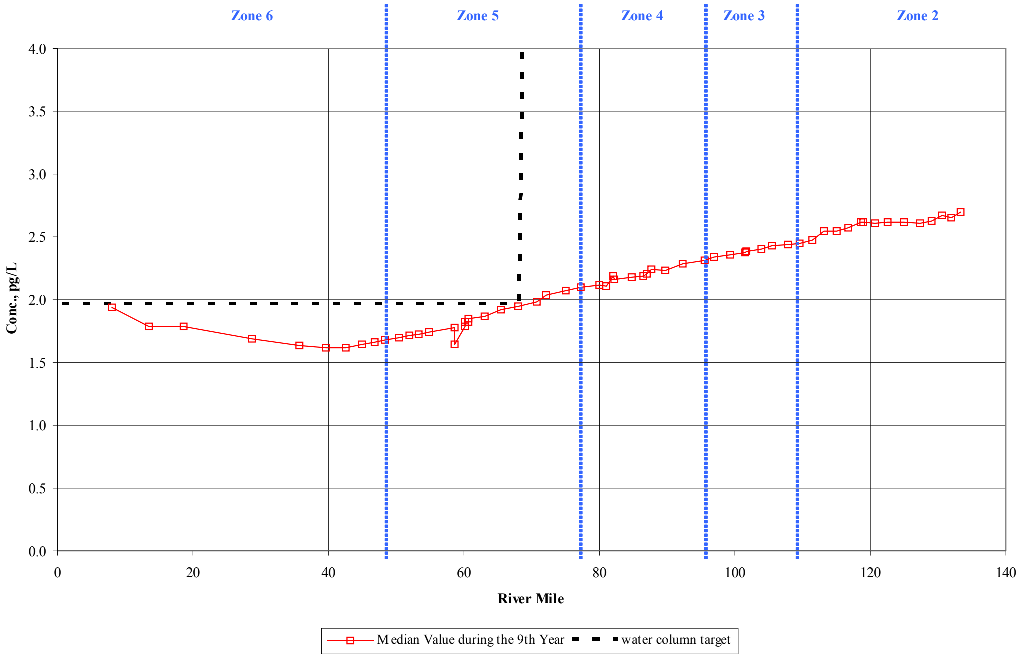


Figure 23: Spatial plot of the penta-PCBs in the water column during a 10 year simulation using the loads established in Step 2 and with new sediment initial conditions.

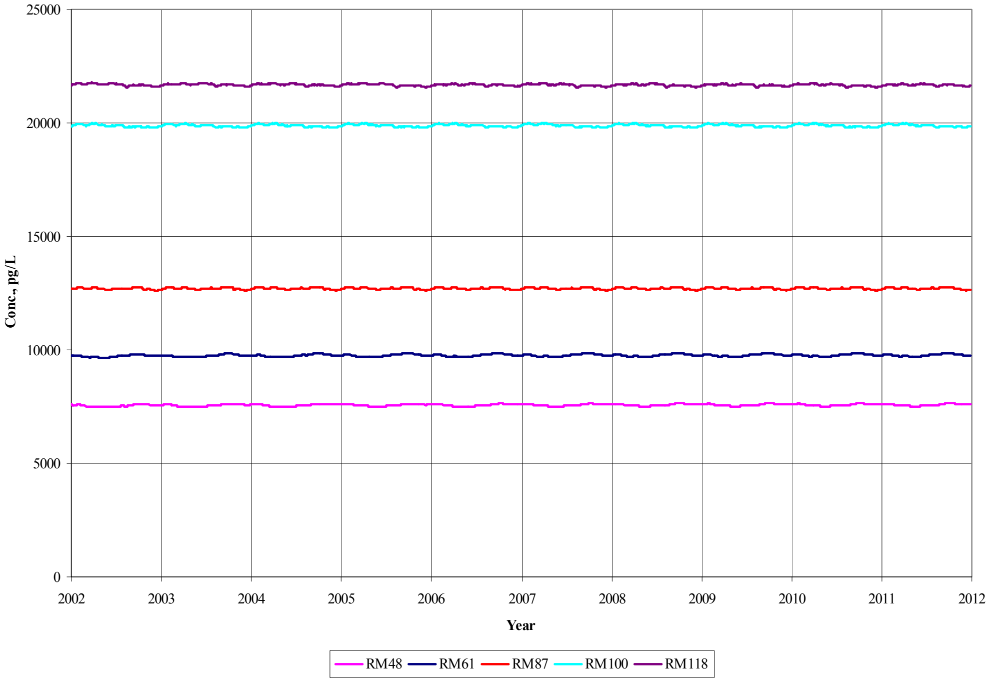


Figure 24: Temporal plot of the concentration of penta-PCBs in the surface sediment layer during a 10 year simulation using the loads established in Step 2 and with new sediment initial conditions.

3.3.5 Step 4

The final step in developing TMDLs for penta-PCBs for Zones 2 through 5 of the Delaware Estuary is to include the exchange of penta-PCBs between the gas phase in the atmosphere and truly dissolved penta-PCBs in the water. In the current model framework, the gas phase air concentrations are assigned, and are not dynamically simulated by the model. However, when the TMDL is achieved there should be close to zero net exchange between the water and air. It was therefore necessary to estimate the gas phase concentration that would be in equilibrium with the water quality targets (Figure 8) and then confirm that the water quality targets are still being met.

The penta-PCB water quality model utilizes the following formula to determine the volatilization rate of a chemical:

$$\frac{\partial C}{\partial t} = \frac{K_V}{D}\left[C_W - \frac{C_A}{H/RT_K}\right]$$

where:
K_V = the transfer rate, meters per day
D = model segment depth in meters
C_W = truly dissolved fraction of the chemical in water, mg/L
C_A = atmospheric gas phase concentration, mg/L
H = Henry's Law Constant, atm-m^3/day
R = universal gas constant
T_K = water temperature in degrees Kelvin

At equilibrium, the volatilization rate will be zero. Therefore:

$$\left[C_W - \frac{C_A}{H/RT_K}\right] = 0$$

Rearranging this formula to calculate the atmospheric gas phase concentration for penta-PCBs:

$$C_W \times H/RT_K = C_A$$

Figure 25 presents the truly dissolved penta-PCB water concentrations predicted by the model from Step 4 and the corresponding equilibrium air concentrations of gaseous phase penta-PCBs for the one year cycling period.

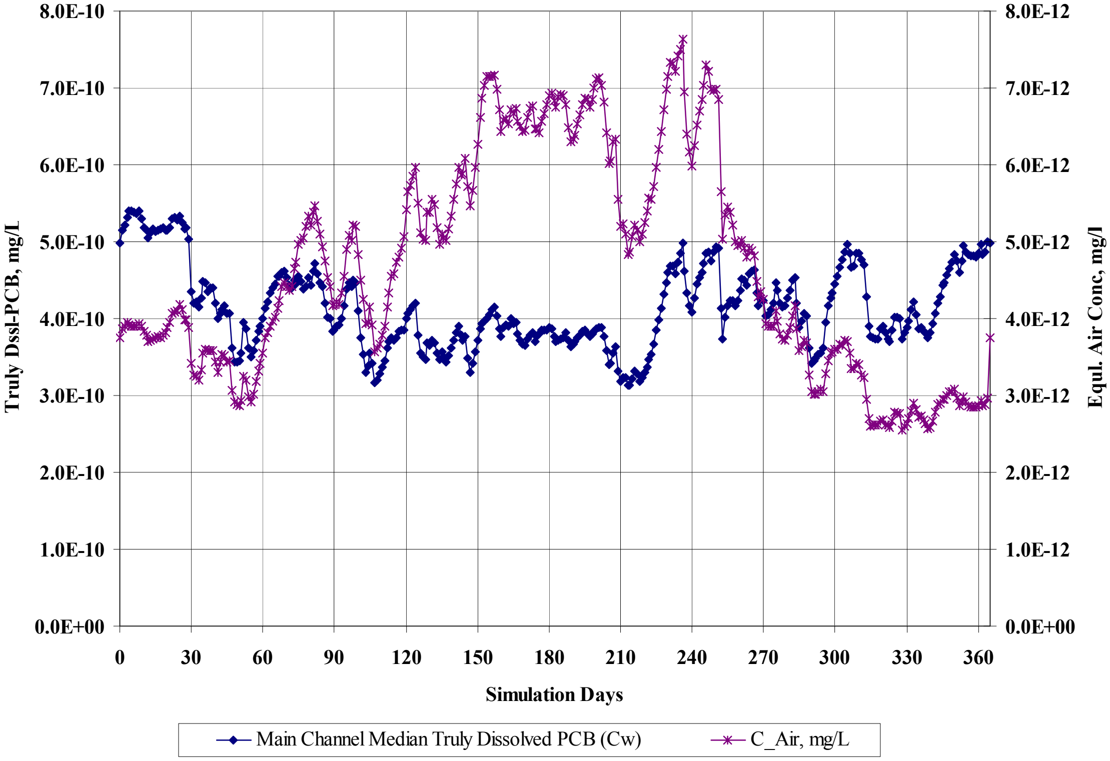


Figure 25: Back-calculated, equilibrium, median, gas phase penta-PCB concentrations during the one year model cycling period.

The penta-PCB water quality model is then run with the conditions obtained from Step 2 and 3 including the loadings from the model boundaries and to each estuary zone, initial penta-PCB concentrations in the sediment (Figure 24), and with back-calculated, equilibrium, median, gas phase penta-PCB concentrations during the one year model cycling period (Figure 25). The purpose of this simulation is to confirm that the penta-PCB concentrations in the sediments and the penta-PCB gas phase air concentrations are in equilibrium with the estuary concentrations that will meet the water quality target of 1.975 pg/L at the critical location when all fate processes are enabled in the model. These simulations were also run for 100 years to establish the point at which equilibrium was reached between the water column and the sediments. Figure 26 indicates the sediment concentration of penta-PCBs at five locations in the estuary corresponding to a model segment in each of the estuary zones and Delaware Bay. Note that sediment concentrations in all segments reach equilibrium after approximately 20 years. The simulated sediment concentrations at each of the model segments is presented in Figure 27. Figure 28 presents a plot of the annual median values during the 99th and 100th year of the simulation, confirming that the water quality target is being met.

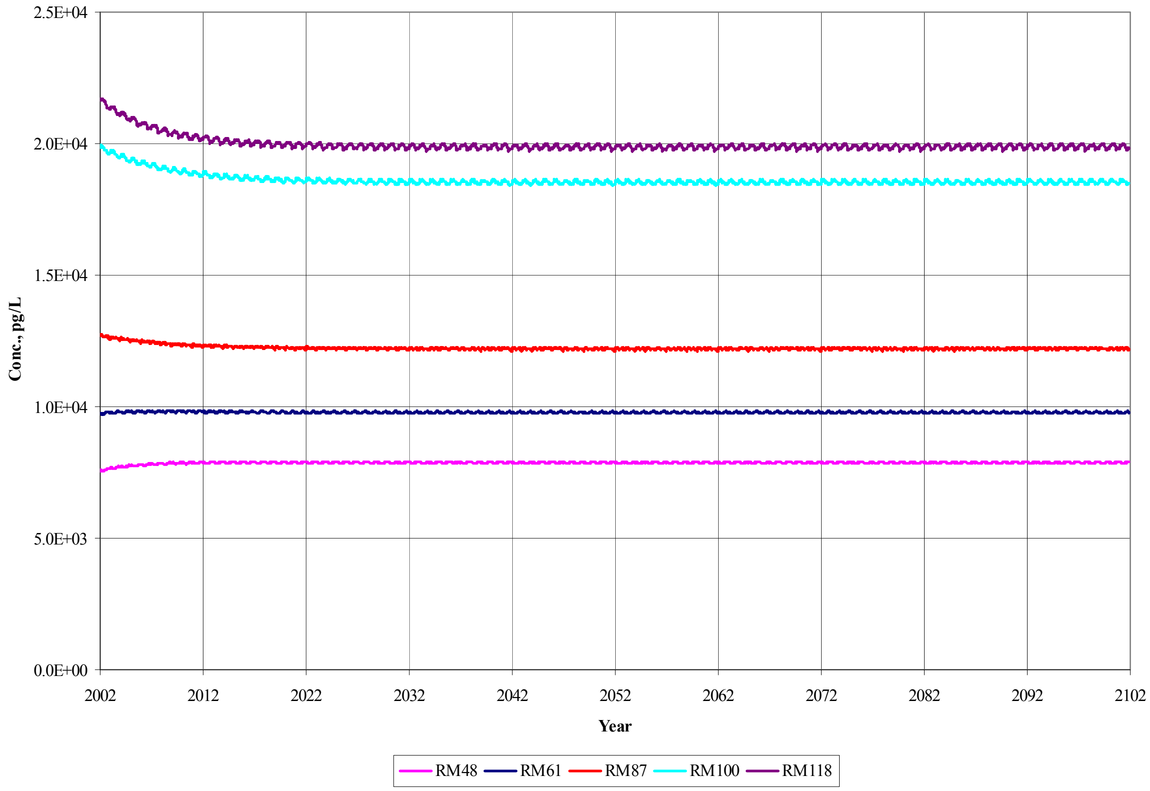


Figure 26: Temporal plot of penta-PCB concentrations in the surface sediment layer during a 100 year simulation with air-water exchange processes enabled.

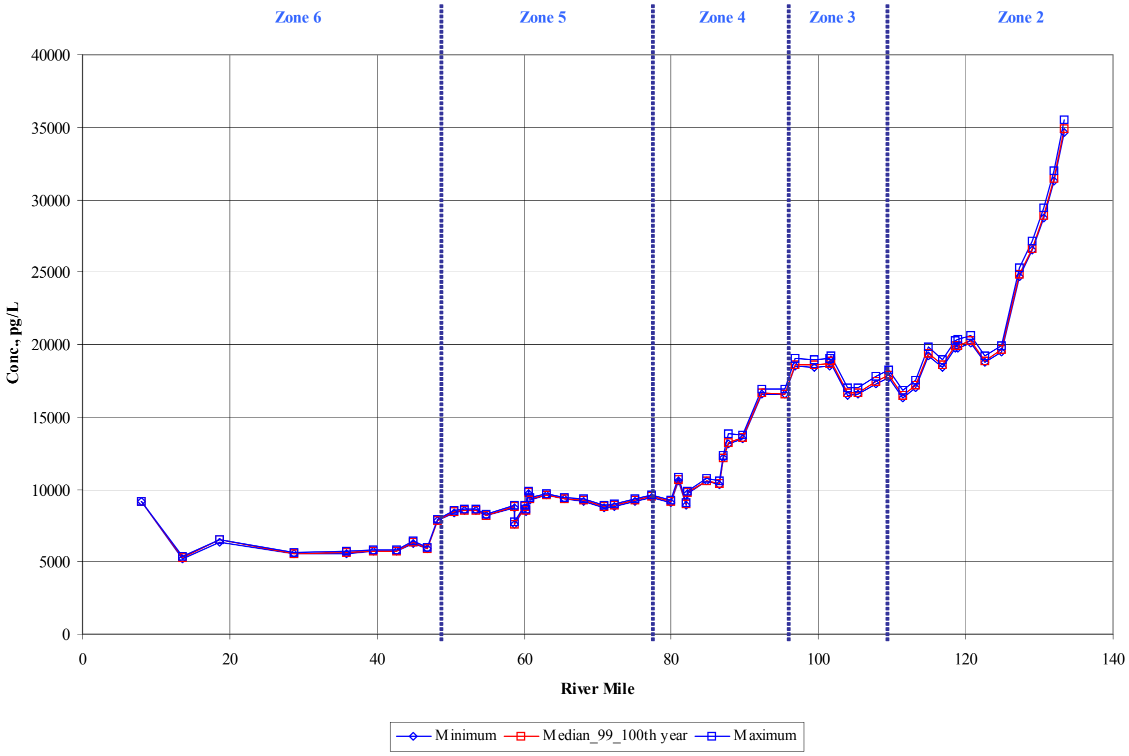


Figure 27: Spatial plot of penta-PCB concentrations in the surface sediment layer during a 100 year simulation with air-water exchange processes.

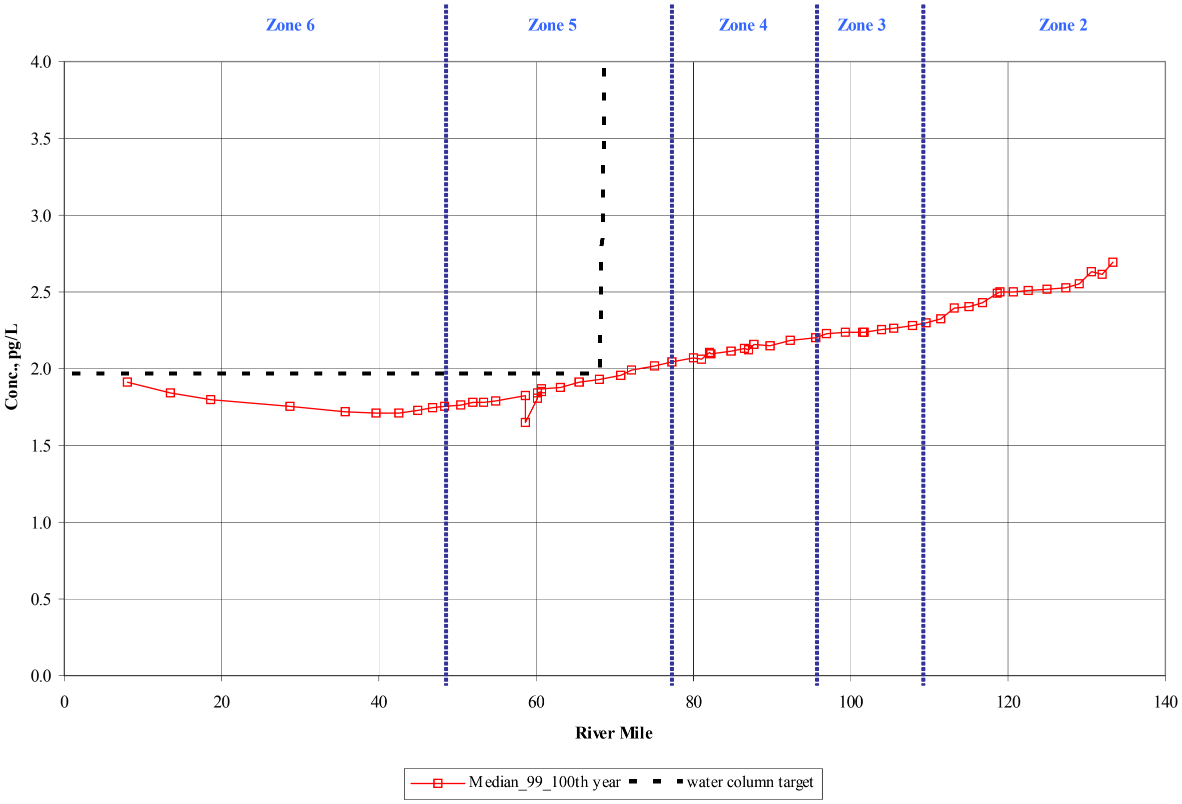


Figure 28: Spatial plot of the penta-PCBs in the water column during a 100 year simulation using the loads established in Step 2, new sediment initial conditions, and with air-water exchange processes enabled

4. TMDLs, WLAs and LAs for Total PCBs for Zones 2 to 5

4.1 TMDLs, WLAs and LAs for Penta- PCBs

Table 5 summarizes the calculated TMDLs (allowable loadings) for penta-PCBs for Zones 2 to 5 of the Delaware Estuary that were derived in Section 3.3.5. The loadings from the Delaware River at Trenton and the Schuylkill River are included in the Zone 2 and 4 TMDLs, respectively. The next step is to allocate the zone-specific TMDLs to a wasteload allocation portion or WLA, a load allocation portion or LA, and a margin of safety.

Table 5: TMDLs for penta-PCBs for Zones 2 through 5 of the Delaware Estuary

Estuary Zone	TMDL (milligrams / day)
Zone 2	**64.3400**
Zone 3	**4.4555**
Zone 4	**14.1779**
Zone 5	**12.0157**
Sum	**94.9891**

The Commission's Toxics Advisory Committee has made several recommendations on the policies and procedures to be used to establish these allocations. Federal regulations at 40 CFR Part 130.7(c)(1) require a margin of safety or MOS to be included in a TMDL to account for any lack of knowledge concerning the relationships between pollutant loadings and receiving water quality. Commission regulations also require that a portion of the TMDL be set aside as a margin of safety, with the proportion reflecting the degree of uncertainty in the data and resulting water quality-based controls. The margin of safety can be incorporated either implicitly in the design conditions used in establishing the TMDLs or explicitly by assigning a proportion of each TMDL. Both of these approaches were considered by the Toxics Advisory Committee who recommended that an explicit margin of safety of 5% be assigned in allocating the zone-specific TMDLs. This recommendation was based upon the use of a one year cycling period for the hydrodynamic and water quality model that mimics the period of record for the two major tributaries to the estuary rather than design tributary flows; and the use of tide data, precipitation data and the actual effluent flows that occurred during the one year cycling period. EPA finds these recommendations reasonable and supported by the evidence, and adopted them in these TMDLs. Table 6 presents the MOS allocation for each of the zones as well as the two tributary boundaries. This is necessary since the loadings from these tributaries are part of the PCB loadings to Zones 2 and 4

Table 6: Allocation of the Zone TMDLs to the 5% Margin of Safety

Sources of Loadings	Contribution Factor (CF)	TMDL	MOS	TMDL - MOS
	[pg/L] / [pg/L] or [pg/L] / [100mg/day]	mg/day	mg/day	mg/day
Delaware River	0.581500	57.727	2.886	54.841
Schuylkill River	0.118390	9.609	0.48	9.129
Zone 2	1.966800	6.613	0.331	6.282
Zone 3	2.142800	4.455	0.223	4.232
Zone 4	2.281300	4.569	0.228	4.341
Zone 5	0.967040	12.016	0.601	11.415
Sum		**94.989**	**4.749**	**90.24**

The committee recommended that for the Stage 1 TMDLs, the proportion of the TMDLS that are allocated to WLAs and LAs should be based upon the current loadings from the various PCB source categories to each of the zones during the one year cycling period (February 1, 2002 to January 31, 2003) used in the TMDL model simulations. EPA finds these recommendations reasonable and adopted them in these TMDLs.

Prior to allocation of the remaining portion of the TMDL between WLA and LA, the portion of the assimilative capacity allocated to contaminated sites was determined since the assimilative capacity for this source must also be shared between the estuary zones and the two boundary tributaries (see Section 3.2.1). Table 7 presents the load allocated to the contaminated sites by source and the remaining assimilative capacity that must still be allocated.

Table 7: Allocation of the Zone TMDLs to Contaminated Sites

Sources of Loadings	TMDL - MOS	% of Total Loading to Zone	Contaminated Site Allocation	TMDL - MOS - CS
	mg/day		mg/day	
Delaware River	54.841	-	0.229	54.612
Schuylkill River	9.129	-	3.473	5.656
Zone 2	6.282	0.42	0.026	6.256
Zone 3	4.233	57.09	2.416	1.816
Zone 4	4.340	38.04	1.651	2.689
Zone 5	11.415	46	5.251	6.164
	94.989	**-**	**13.046**	**77.193**

The remaining assimilative capacity can now be apportioned to WLAs and the rest of the sources that contribute to the LAs (Table 8). The WLA source categories include the continuous point source NPDES discharges, stormwater discharges permitted under the NPDES program, and combined sewer overflows (CSOs), and municipal separate storm sewer systems (MS4s).

EPA's regulations require NPDES-regulated storm water discharges to be addressed by the WLA component of a TMDL. Assessing the estimated loading from such discharges is relatively difficult compared to traditional point source discharges, as storm water discharge is typically calculated by quantifying the area of urban and residential land uses in a basin. For this reason, it is important to have updated land use data and runoff coefficients.

In developing the Stage 1 TMDLs, the existing WLAs were calculated for traditional point source discharges based on effluent concentrations and the actual effluent flows during the one year model cycling period (see Section 3.2.4.1). A November 22, 2002 EPA Memorandum entitled, "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm water Source and NPDES Permit Requirements Based on Those WLAs" clarified existing regulatory requirements for municipal separate storm sewer systems (MS4s) connected with TMDLs. Where a TMDL has been developed, the MS4 community must receive a WLA rather than a LA. The Stage 1 TMDL explicitly assigns a portion of each of the zone WLAs to storm water discharges that do not have an individual NPDES permit. Appendix 6 presents the procedure used to develop each of these zone allocations to MS4s and the resulting MS4 loading in milligrams per day (mg/day).

The LA source categories also include the other smaller tributaries, non-point source loads not permitted under the NPDES program, dry and wet atmospheric deposition. Tables 9 and 10 summarize the categories included in the aggregate allocations to WLAs and LAs in each zone, respectively. Table 11 summarizes the allocations to WLAs, LAs and the MOS. Figures 29 to 32 graphically illustrate the proportion allocated.

Table 8: Summary of Zone TMDLs for penta-PCBs and the allocation to the major source categories for PCBs.

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Sources of Loadings	Contribution Factor (CF)	TMDL	MOS	Contaminated Site Allocation	Remaining Allocation	Allocation to Continuous Point Sources	Allocation to CSOs	Allocation to MS4s	Remaining Portion to the rest of LAs
	[pg/L] / [pg/L] or [pg/L] / [100mg/day]	mg/day	mg/day	mg/day	mg/day	mg/day	mg/day	mg/day	mg/day
Trenton	0.581500	57.727	2.886	0.229	54.611	0.000			
Schuylkill	0.118390	9.609	0.480	3.473	5.656	0.000			
Zone 2	1.966800	6.613	0.331	0.026	6.256	1.241	0.006	1.511	3.498
Zone 3	2.142800	4.455	0.223	2.416	1.816	0.771	0.462	0.185	0.398
Zone 4	2.281300	4.569	0.228	1.651	2.689	0.614	0.677	0.342	1.055
Zone 5	0.967040	12.016	0.601	5.250	6.165	3.132	0.182	0.592	2.259
Sum		94.989	4.749	13.046	77.193	5.758	1.327	2.630	7.211

Table 9: Summary of the Zone WLAs for penta-PCBs and their allocation to source categories.

Estuary Zone	WLA	NPDES continuous discharging point sources	CSOs	Municipal separate stormwater sewer service
	mg/day	mg/day	mg/day	mg/day
Zone 2	2.7574	1.2408	0.0059	1.5107
Zone 3	1.4180	0.7713	0.4620	0.1847
Zone 4	1.6338	0.6143	0.6772	0.3423
Zone 5	3.9062	3.1319	0.1822	0.5922
Sum	9.7155	5.7583	1.3272	2.6300

Table 10: Summary of the Zone LAs for penta-PCBs and their allocation to source categories.

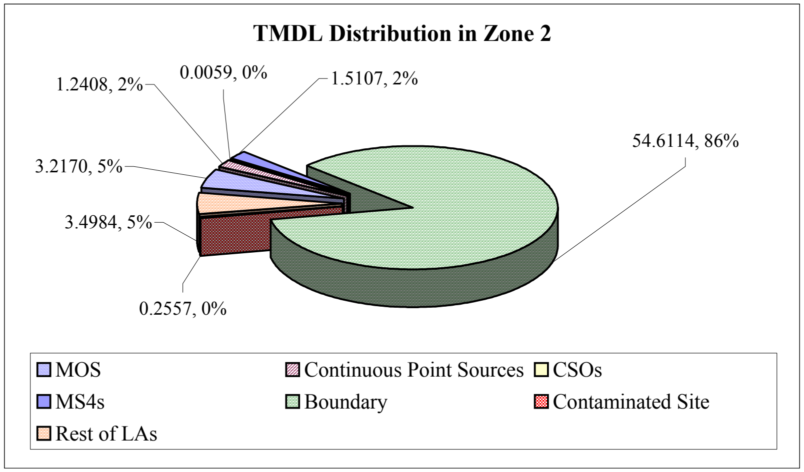
Estuary Zone	LAs	Boundary *	Contaminated Site	Others
	mg/day	mg/day	mg/day	mg/day
Zone 2	58.3656	54.6114	0.2557	3.4984
Zone 3	2.8147	0.0000	2.4164	0.3983
Zone 4	11.8351	5.6558	5.1240	1.0554
Zone 5	7.5087	0.0000	5.2501	2.2586
Sum	80.5242	60.2672	13.0462	7.2107

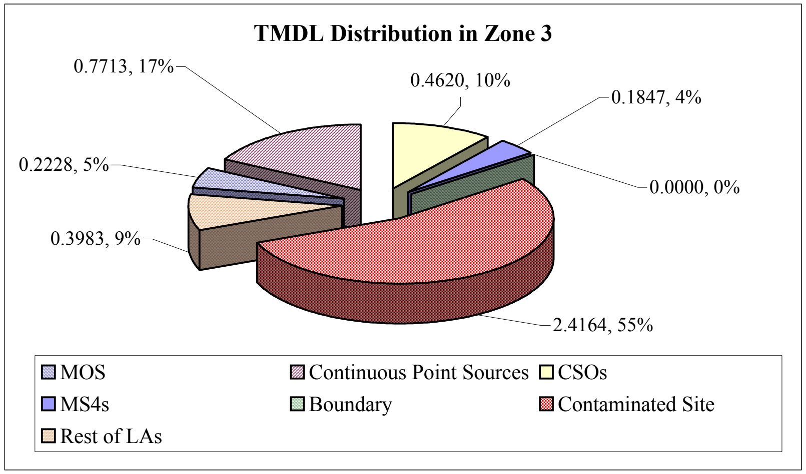
* - The boundary in Zone 2 is the Delaware River at Trenton, and the boundary in Zone 4 is the Schuylkill River.

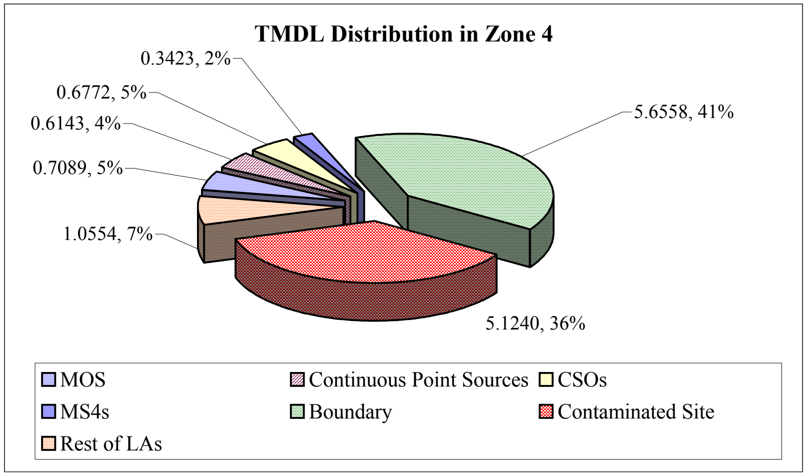
Table 11: Summary of the Zone TMDLs for penta-PCBs and their allocation to WLAs, LAs and a MOS.

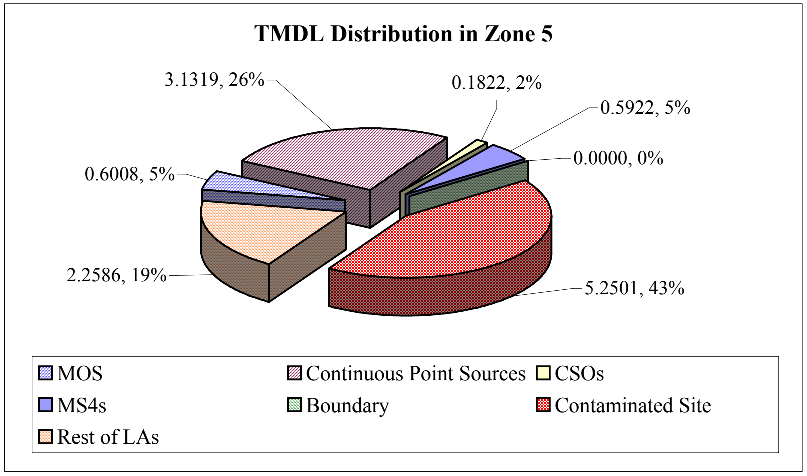
Estuary Zone	TMDL	WLA	LA	MOS
	mg/day	mg/day	mg/day	mg/day
Zone 2	64.3400	2.7574	58.3656	3.2170
Zone 3	4.4555	1.4180	2.8147	0.2228
Zone 4	14.1779	1.6338	11.8351	0.7089
Zone 5	12.0157	3.9062	7.5087	0.6008
Sum	94.9891	9.7155	80.5242	4.7495

Figures 29 - 32: Distribution of Zone TMDLs to Point sources and CSOs, and the Remainder of the Non-Point Sources (tributary boundary loads, the MOS and the Contaminated Site loading excluded).









4.2 TMDLs, WLAs and LAs for Total PCBs

4.2.1 Extrapolation from Penta to Total PCBs

As discussed in Sections 2.2 and 3.2.2, TMDLs for Total PCBs will be extrapolated from penta homolog data using the observed ratio in the Delaware Estuary of the penta homolog to total PCBs. This approach was recommended by the expert panel established by the Commission due to time limitations and the technical difficulty in developing and calibrating a PCB model for each of the ten PCB homologs. Data available to the panel at that time indicated that the proportion of penta-PCBs to Total PCBs at 15 locations sampled in the estuary ranged between 0.2 and 0.3 (20 to 30% of Total PCBs). Figure 33 presents the ratio of penta-PCBs to Total PCBs for each zone based upon data currently available. EPA finds this extrapolation to be reasonable and supported by the best available data.

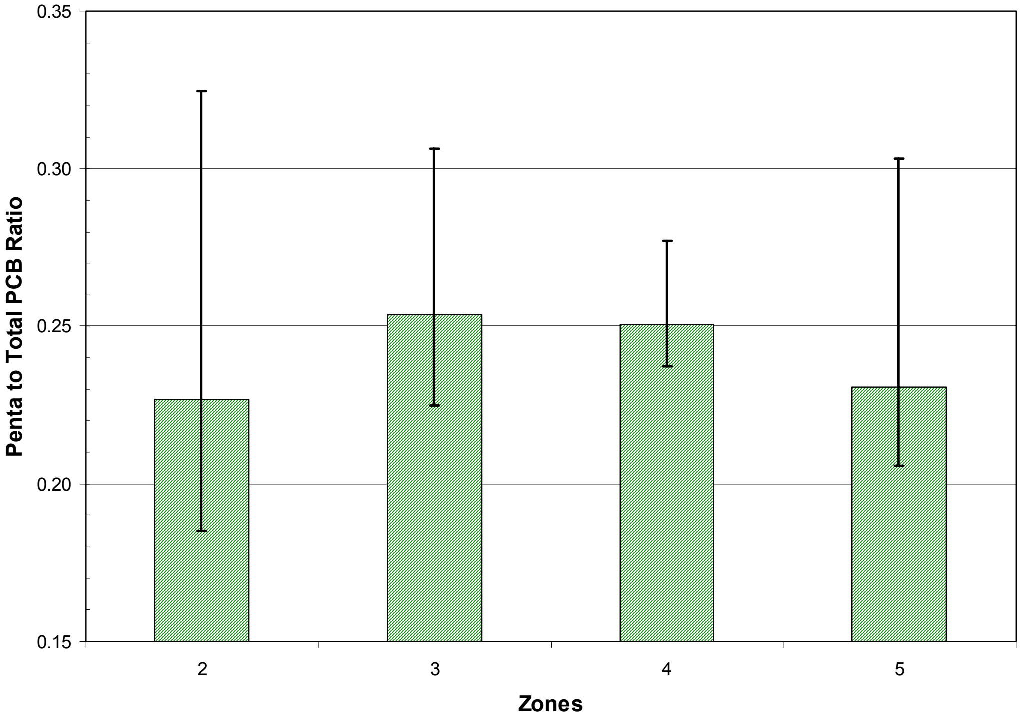


Figure 33: Ratio of Penta-PCBs to Total PCBs in ambient water samples collected from 15 sites in the Delaware Estuary during surveys conducted on September 18, 2001, March 15, 2002, April 11, 2002, October 8, 2002 and March19, 2003. Error bars indicate the minimum and maximum ratios observed at any sampling site during all five surveys.

This data supports the original data and indicates median penta- to total PCB ratios of 0.23, 0.25, 0.25 and 0.23 for Zones 2 to 5, respectively. For Stage 1 TMDLs, a fixed value of 0.25 was used for all zones to scale up the zone-specific TMDLs, WLAs, LAs and MOSs.

4.2.2 TMDLs, WLAs and LAs for Total PCBs

Table 12 summarizes the TMDLs for each estuary zone for total PCBs as well as the allocations to WLAs, LAs and the MOSs.

Table 12: TMDLs, WLAs, LAs and MOSs for Total PCBs for Zones 2 to 5 of the Delaware Estuary.

Estuary Zone	TMDL	WLA	LA	MOS
	mg/day	mg/day	mg/day	mg/day
Zone 2	257.36	11.03	233.46	12.87
Zone 3	17.82	5.67	11.26	0.89
Zone 4	56.71	6.54	47.34	2.84
Zone 5	48.06	15.63	30.04	2.40
Sum	379.96	38.86	322.10	19.00

4.2.3 Uncertainty Analysis for TMDLs, WLAs and LAs for Total PCBs

Uncertainty is associated with three elements of the Stage 1 TMDLs: 1) the use of annual median values for determining compliance with the penta-PCB water quality target, 2) the loading of penta-PCBs for each of the source categories that is used to apportion the TMDLs, and 3) the extrapolation of the penta-PCB TMDLs, aggregate and individual WLAs, and LAs to total PCBs.

As discussed in Section 3.2.1, TMDLs are calculated over a one year period (annual median) to be consistent with both the model simulations and the 70 year exposure used for human health criteria. The estuary, however, is dynamic with ambient PCB concentrations being affected by the amount of inflow from the tributaries, the variation in the tides over lunar and annual time scales, changes in both continuous and precipitation-induced wastewater flows, and the prevailing air and water temperature. Thus, ambient PCB concentrations will vary on both a daily and monthly basis about the annual median. The magnitude of this variation can be seen by plotting the annual minimum and annual maximum values that occur during long-term model simulations like those used to check whether a given set of loading assumptions results in compliance with the penta-PCB water quality target at the critical location (see Figure 28). Figure 34 illustrates the uncertainty associated with the use of annual median values by comparing annual minimum and maximum plots of water column concentrations of penta-PCBs during a 100 year simulation. The figure indicates that the annual variation is approximately +15% to -25%.

The uncertainty in the loading estimates for each of the source categories is discussed in Section 2.7 of the model calibration report (DRBC, 2003c). A Monte Carlo analysis was performed to examine and compare the uncertainty for the loading estimates for each PCB source category that were used in the 577 day model calibration period. This analysis indicated that the greatest uncertainty was associated with the tidal non-point source loads (90th and 10th percentiles of loading were 44.82 and 2.28 kilograms, respectively) followed by the contaminated site loads (90th and 10th percentiles of loading were 24.94 and 4.23 kilograms, respectively). Less uncertainty was associated with the loading from point sources (90th and 10th percentiles of loading were 8.53 and 5.16 kilograms, respectively)

The uncertainty in the extrapolation from penta-PCBs to total PCBs is illustrated in Figure 33. This figure indicates that while the zone ratios of penta-PCBs to total PCBs is close to 0.25, the uncertainty associated with the ratios varies between zones with the largest uncertainty occurring in Zone 2 (0.19 to 0.32) and the smallest occurring in Zone 4 (0.24 to 0.28).

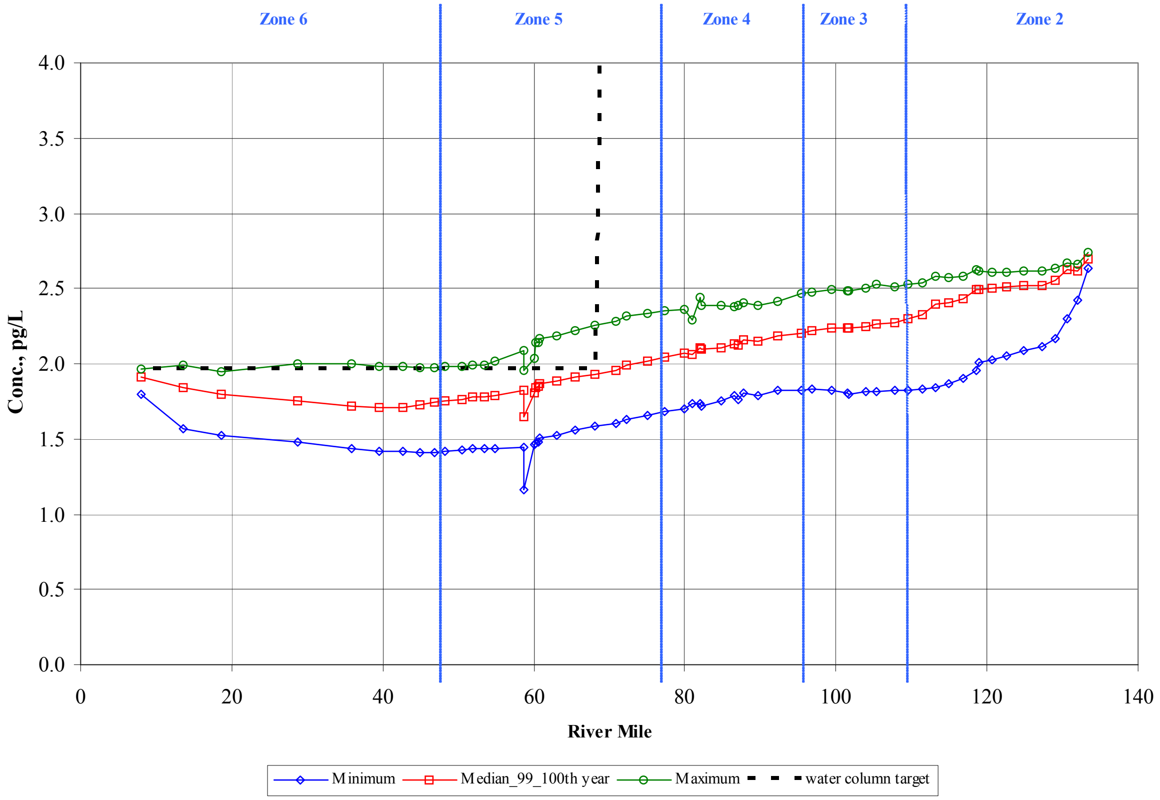


Figure 34: Spatial plots of the annual median, annual minimum and annual maximum values of water column penta-PCB concentrations during a 100 year simulation using the TMDL loads.

5. REFERENCES

Delaware River Basin Commission. 1988. Fish Health and Contamination Study. Delaware Estuary Use Attainability Project. Delaware River Basin Commission. West Trenton, NJ. March 1988.

Delaware River Basin Commission. 1996. Administrative Manual - Part III, Water Quality Regulations. Delaware River Basin Commission. West Trenton, NJ. October 1996.

Delaware River Basin Commission. 1998a. Study of the Loadings of Polychlorinated Biphenyls from Tributaries and Point Sources Discharging to the Tidal Delaware River. Delaware River Basin Commission. West Trenton, NJ. June 1998.

Delaware River Basin Commission. 1998b. Calibration and Validation of a Water Quality Model for Volatile Organics and Chronic Toxicity in the Delaware River Estuary. Delaware River Basin Commission. West Trenton, NJ. December 1998.

Delaware River Basin Commission. 2003a. DYNHYD5 Hydrodynamic Model (Version 2.0) and Chloride Water Quality Model for the Delaware Estuary. Delaware River Basin Commission. West Trenton, NJ. September 2003.

Delaware River Basin Commission. 2003b. PCB Water Quality Model for the Delaware Estuary (DELPCB). Delaware River Basin Commission. West Trenton, NJ. September 2003.

Delaware River Basin Commission. 2003c. Calibration of the PCB Water Quality Model of the Delaware Estuary for Penta-PCBs and Carbon. Delaware River Basin Commission. West Trenton, NJ. September 2003.

Franklin Institute. 2003. Franklin's Forecast. Accessed 30 July 2003. http://www.fi.edu/weather.

Greene R.W. and R.W. Miller. 1994. Summary and Assessment of Polychlorinated Biphenyls and Selected Pesticides in Striped Bass from the Delaware Estuary. Delaware Department of Natural Resources & Environmental Control. Dover, DE. March 1994.

Hauge, P., P. Morton, M. Boriek, J. McClain and G. Casey. 1990. Polychlorinated Biphenyl (PCBs), Chlordane, and DDTs in Selected Fish and Shellfish From New Jersey Waters, 1986-1987: Results from New Jersey's Toxics in Biota Monitoring Program. New Jersey Department of Environmental Protection. Trenton, NJ. 66pp.

Van Ry, D.A., C.L. Gigliotti, T.R. Glenn, E.D. Nelson, L.A. Totten, and S.J. Eisenreich. 2002. Wet Deposition of Polychlorinated Biphenyls in Urban and Background Areas of the Mid-Atlantic States. Envir. Sci. & Tech. 36(15):3201-3209.

U.S. Environmental Protection Agency. 1998. National Recommended Water Quality Criteria; Notice; Republication. Federal Register Vol. 63, No. 237, Pages 68354-68364.

U.S. Environmental Protection Agency. 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000). Office of Water. Office of Science and Technology. Washington, D.C. EPA-822-B-00-004. October 2000.

U.S. Fish & Wildlife Service. 1991. Assessment of Organochlorine and Metal Contamination in the Lower Delaware River Estuary (AFO-C91-04). U.S. Fish and Wildlife Service, Environmental Contaminants Division. Annapolis, MD.

U.S. Fish & Wildlife Service. 1992. Concentrations of Organochlorines and Trace Elements in Fish and Blue Crabs from the Delaware River, Easton to Deepwater. Special Project Report 93-5. U.S. Fish and Wildlife Service. State College, PA.

Appendix 1

REDUCING PCB LOADINGS TO THE DELAWARE ESTUARY:
A Staged Approach to Establishing TMDLs

Documents distributed at the April 29, 2003 meeting convened by the

U.S. Environmental Protection Agency, Regions II and III

Delaware River Basin Commission

Delaware Department of Natural Resources & Environmental Control

New Jersey Department of Environmental Protection

Pennsylvania Department of Environmental Protection

Appendix 2

Individual Wasteload Allocations for NPDES Discharges: Stage 1 TMDLs for Total PCBs for Zones 2 to 5 of the Delaware Estuary

Appendix Table 2-1: Individual wasteload allocations for the point source discharges except CSOs and MS4s.

Serial No.	Serial No. per Zone	Facility Name	NPDES	DSN	ZONE	RM	Model Segment	Potential Group (category)	Current Loadings (Sept. 2003) mg/day	Pent-PCBs WLA mg/day	Total PCBs WLA mg/day
1	1	Morrisville WWTP	PA0026701	001	2	132.9	76	2	65.566	0.057280	0.229120
2	2	Trenton	NJ0020923	001	2	132.2	75	1	243.612	0.212825	0.851301
3	3	PSEG-Mercer	NJ0004995	441A	2	130.4	74	2	0.000	0.000000	0.000000
4	4	PSEG-Mercer	NJ0004995	441C	2	130.4	74	1	5.010	0.004377	0.017508
5	5	MSC Pre Finish Metals	PA0045021	001	2	130.1	74	2	0.646	0.000564	0.002256
6	6	Hamilton Township	NJ0026301	001	2	128.0	73	2	220.791	0.192889	0.771555
7	7	Yates Foil	NJ0004332	001B	2	128.0	73	2	0.070	0.000061	0.000244
8	8	Yates Foil	NJ0004332	002A	2	128.0	73	2	0.000	0.000000	0.000000
9	9	Bordentown Sewerage Authority	NJ0024678	001	2	128.0	71	2	26.292	0.022969	0.091877
10	10	U.S. Steel	PA0013463	002	2	127.4	71	1	61.390	0.053632	0.214527
11	11	U.S. Steel	PA0013463	103	2	127.0	71	1	10.056	0.008785	0.035141
12	12	U.S. Steel	PA0013463	203	2	127.0	71	1	3.787	0.003308	0.013234
13	13	Exelon-Fairless	PA0057088	001	2	126.6	71	2	0.000	0.000000	0.000000
14	14	Waste Management Grows Landfill	PA0043818	001	2	125.5	70	2	1.182	0.001033	0.004131
15	15	Lower Bucks County Municipal Authority	PA0026468	001	2	121.9	69	2	129.179	0.112854	0.451417
16	16	Florence Township	NJ0023701	001	2	121.4	68	2	15.682	0.013700	0.054802
17	17	GEON Company (Burlington) Polyone	NJ0004235	001A	2	120.3	68	2	15.051	0.013149	0.052595
18	18	Bristol Borough	PA0027294	001	2	118.7	66	2	29.383	0.025669	0.102677
19	19	US Pipe & Foundry	NJ0005266	002A	2	118.1	66	1	0.807	0.000705	0.002821
20	20	City of Burlington	NJ0024660	002	2	117.6	64	2	46.336	0.040480	0.161921
21	21	PSEG-Burlington	NJ0005002	WTPA	2	117.4	64	1	0.929	0.000812	0.003246
22	22	Rohm&Haas-Bristol	PA0012769	009	2	117.1	64	1	5.710	0.004988	0.019952

Serial No.	Serial No. per Zone	Facility Name	NPDES	DSN	ZONE	RM	Model Segment	Potential Group (category)	Current Loadings (Sept. 2003) mg/day	Pent-PCBs WLA mg/day	Total PCBs WLA mg/day
23	23	Burlington Township	NJ0021709	001	2	117.0	64	2	34.901	0.030490	0.121961
24	24	Colorite Polymers	NJ0004391	002A	2	117.0	64	2	0.008	0.000007	0.000030
25	25	Colorite Polymers	NJ0004391	003A	2	117.0	64	2	0.740	0.000646	0.002585
26	26	Bristol Township	PA0026450	001	2	116.8	64	2	34.732	0.030342	0.121370
27	27	Beverly Sewerage Authority	NJ0027481	001	2	114.7	63	1	18.890	0.016503	0.066010
28	28	Delran Sewerage Authority	NJ0023507	001	2	110.8	60	2	37.419	0.032691	0.130762
29	29	Mt. Holly Municipal Utilities Authority	NJ0024015	001	2	110.8	61	2	54.904	0.047965	0.191862
30	30	Mt. Laurel Municipal Utilities Authority	NJ0025178	001A	2	110.8	60	2	67.433	0.058911	0.235646
31	31	Riverton Borough	NJ0021610	001	2	110.8	61	1	3.853	0.003366	0.013464
32	32	Willingboro Municipal Utilities Authority	NJ0023361	001	2	110.8	61	2	123.392	0.107798	0.431194
33	33	AFG Industries	NJ0033022	001A	2	109.6	59	1	10.258	0.008962	0.035848
34	34	AFG Industries	NJ0033022	002	2	109.4	59	2	0.092	0.000080	0.000321
35	35	Hoeganaes Corp.	NJ0004375	001A	2	109.4	59	2	0.330	0.000288	0.001151
36	36	Hoeganaes Corp.	NJ0004375	003A	2	109.4	59	2	0.000	0.000000	0.000000
37	37	Cinnaminson Sewerage Authority	NJ0024007	001	2	108.9	59	1	27.980	0.024444	0.097778
38	38	Riverside Sewerage Authority	NJ0022519	001	2	108.8	59	1	124.107	0.108423	0.433693
39	1	Palmyra Borough	NJ0024449	001	3	107.7	58	2	19.235	0.005384	0.021536
40	2	Rohm&Haas-Philadelphia	PA0012777	001	3	106.1	56	2	15.974	0.004471	0.017885
41	3	Rohm&Haas-Philadelphia	PA0012777	003	3	106.1	56	1	2.175	0.000609	0.002435
42	4	Rohm&Haas-Philadelphia	PA0012777	007	3	106.1	56	2	0.003	0.000001	0.000003
43	5	NGC Industries	NJ0004669	001A	3	104.4	55	2	1.528	0.000428	0.001710
44	6	PWD-NE	PA0026689	001	3	104.1	55	1	1238.662	0.346711	1.386845
45	7	Citgo Petroleum	NJ0131342	001A	3	103.4	55	2	0.012	0.000003	0.000014
46	8	Exelon-Delaware	PA0011622	001	3	101.2	52	2	0.044	0.000012	0.000049

Serial No.	Serial No. per Zone	Facility Name	NPDES	DSN	ZONE	RM	Model Segment	Potential Group (category)	Current Loadings (Sept. 2003) mg/day	Pent-PCBs WLA mg/day	Total PCBs WLA mg/day
47	9	Exelon-Delaware	PA0011622	002	3	101.2	52	1	0.655	0.000183	0.000733
48	10	Exelon-Delaware	PA0011622	004	3	101.2	52	2	0.011	0.000003	0.000013
49	11	Exelon-Delaware	PA0011622	006	3	101.1	52	2	0.000	0.000000	0.000000
50	12	CCMUA	NJ0026182	001	3	98.0	49	1	818.459	0.229093	0.916372
51	13	PWD-SE	PA0026662	001	3	96.8	49	1	657.721	0.184101	0.736405
52	1	Coastal Mart / Coastal Eagle Point Oil	NJ0005401	003A	4	94.7	48	2	0.006	0.000002	0.000007
53	2	Coastal Mart / Coastal Eagle Point Oil	NJ0005401	001A	4	94.3	48	2	55.368	0.014863	0.059451
54	3	Metro Machine	PA0057479	DD2	4	93.2	44	1	49.040	0.013164	0.052656
55	4	Metro Machine	PA0057479	DD3	4	93.1	44	2	17.845	0.004790	0.019161
56	5	Kvaerner	PA0057690	019	4	92.8	44	1	0.100	0.000027	0.000108
57	6	Kvaerner	PA0057690	021	4	92.8	44	1	0.100	0.000027	0.000108
58	7	Kvaerner	PA0057690	012	4	92.7	44	1	22.608	0.006069	0.024275
59	8	Kvaerner	PA0057690	047	4	92.5	45	2	0.005	0.000001	0.000005
60	9	Sunoco-GirardPoint	PA0011533	015	4	92.5	45	2	99.167	0.026620	0.106481
61	10	Sunoco-PointBreeze	PA0012629	002	4	92.5	46	2	75.899	0.020374	0.081496
62	11	PWD-SW	PA0026671	001	4	90.7	43	1	1020.466	0.273932	1.095729
63	12	Ausimont	NJ0005185	001A	4	90.7	43	1	0.840	0.000225	0.000902
64	13	Ausimont	NJ0005185	002A	4	90.7	43	1	0.077	0.000021	0.000082
65	14	Chevron	NJ0064696	001A	4	90.5	43	2	0.157	0.000042	0.000169
66	15	Colonial Pipeline	NJ0033952	001A	4	90.5	43	2	0.087	0.000023	0.000094
67	16	BP Paulsboro	NJ0005584	002A	4	89.6	43	2	0.352	0.000095	0.000378
68	17	BP Paulsboro	NJ0005584	003A	4	89.4	43	2	7.006	0.001881	0.007522
69	18	GCUA	NJ0024686	001	4	88.4	43	1	113.497	0.030467	0.121868
70	19	Air Products	NJ0004278	001A	4	88.2	42	2	10.041	0.002695	0.010782

Serial No.	Serial No. per Zone	Facility Name	NPDES	DSN	ZONE	RM	Model Segment	Potential Group (category)	Current Loadings (Sept. 2003) mg/day	Pent-PCBs WLA mg/day	Total PCBs WLA mg/day
71	20	Valero Refining	NJ0005029	001A	4	87.7	42	1	99.473	0.026702	0.106809
72	21	Hercules	NJ0005134	001A	4	87.5	42	1	4.120	0.001106	0.004424
73	22	Greenwich Township	NJ0030333	001	4	87.0	42	2	12.110	0.003251	0.013003
74	23	Dupont-Repauno	NJ0004219	007	4	86.6	42	1	1.433	0.000385	0.001538
75	24	Dupont-Repauno	NJ0004219	001A	4	85.6	38	1	80.773	0.021682	0.086730
76	25	Boeing	PA0013323	002	4	85.4	38	1	158.353	0.042508	0.170032
77	26	Boeing	PA0013323	016	4	85.4	38	1	0.149	0.000040	0.000160
78	27	Tinicum Township	PA0028380	001	4	85.4	40	1	15.450	0.004147	0.016590
79	28	Boeing	PA0013323	001	4	85.2	38	1	29.068	0.007803	0.031212
80	29	Boeing	PA0013323	003	4	85.2	38	1	0.404	0.000108	0.000433
81	30	Boeing	PA0013323	007	4	85.2	38	1	0.235	0.000063	0.000252
82	31	Boeing	PA0013323	008	4	85.2	38	2	0.018	0.000005	0.000019
83	32	Exelon-Eddystone	PA0013716	001	4	85.2	38	1	0.064	0.000017	0.000069
84	33	Exelon-Eddystone	PA0013716	005	4	85.2	38	1	0.509	0.000137	0.000546
85	34	Exelon-Eddystone	PA0013716	007	4	85.2	38	2	0.000	0.000000	0.000000
86	35	Exelon-Eddystone	PA0013716	008	4	85.2	38	2	0.000	0.000000	0.000000
87	36	Kimberly Clark	PA0013081	029	4	83.2	36	1	0.086	0.000023	0.000092
88	37	DeGuessa-Huls Corp.	PA0051713	001	4	82.2	36	2	9.063	0.002433	0.009731
89	38	DELCORA	PA0027103	001	4	80.6	34	1	309.423	0.083061	0.332244
90	39	ConocoPhillips	PA0012637	002	4	80.2	34	2	0.000	0.000000	0.000000
91	40	ConocoPhillips	PA0012637	006	4	80.2	34	2	0.029	0.000008	0.000032
92	41	ConocoPhillips	PA0012637	007	4	80.2	34	1	0.511	0.000137	0.000549
93	42	ConocoPhillips	PA0012637	008	4	80.2	34	1	0.111	0.000030	0.000119
94	43	Harrison Township-Mullica Hill	NJ0020532	001	4	79.8	79	2	6.093	0.001636	0.006543

Serial No.	Serial No. per Zone	Facility Name	NPDES	DSN	ZONE	RM	Model Segment	Potential Group (category)	Current Loadings (Sept. 2003) mg/day	Pent-PCBs WLA mg/day	Total PCBs WLA mg/day
95	44	Safety Kleen	NJ0005240	001A	4	79.8	79	2	7.440	0.001997	0.007989
96	45	Safety Kleen	NJ0005240	002A	4	79.8	79	1	3.512	0.000943	0.003772
97	46	Swedesboro	NJ0022021	001	4	79.8	79	2	3.296	0.000885	0.003539
98	47	ConocoPhillips	PA0012637	101	4	79.6	34	2	0.000	0.000000	0.000000
99	48	ConocoPhillips	PA0012637	201	4	79.6	34	2	48.580	0.013041	0.052163
100	49	Logan Township	NJ0027545	001	4	79.5	34	2	12.114	0.003252	0.013007
101	50	Solutia	NJ0005045	001	4	79.2	34	2	12.228	0.003282	0.013130
102	1	General Chemical	DE0000655	001	5	77.9	33	2	0.000	0.000000	0.000000
103	2	Geon Company (Pedricktown) Polyone	NJ0004286	003	5	75.9	32	2	0.011	0.000007	0.000030
104	3	Geon Company (Pedricktown) Polyone	NJ0004286	001A	5	74.9	32	2	1.690	0.001135	0.004542
105	4	Dupont-Edgemoor	DE0000051	001	5	73.2	31	1	32.214	0.021641	0.086564
106	5	Dupont-Edgemoor	DE0000051	004	5	72.2	31	1	0.153	0.000103	0.000412
107	6	Conectiv-Edgemoor	DE0000558	041	5	71.8	31	2	0.008	0.000005	0.000020
108	7	City of Wilmington	DE0020320	001	5	71.6	31	2	1297.745	0.871802	3.487207
109	8	Carney's Point	NJ0021601	001	5	71.3	25	2	10.265	0.006896	0.027584
110	9	AMTRAK	DE0050962	003	5	70.7	30	1	2.002	0.001345	0.005378
111	10	AMTRAK	DE0050962	004	5	70.7	30	1	35.822	0.024065	0.096259
112	11	Penns Grove Sewer Authority	NJ0024023	001	5	70.7	28	1	23.206	0.015589	0.062357
113	12	Dupont-ChamberWorks	NJ0005100	001A	5	69.8	25	1	138.476	0.093026	0.372103
114	13	Dupont-ChamberWorks	NJ0005100	662A	5	69.8	25	1	102.854	0.069096	0.276383
115	14	Conectiv-Deepwater	NJ0005363	003A	5	69.1	24	2	0.000	0.000000	0.000000
116	15	Conectiv-Deepwater	NJ0005363	005	5	69.1	24	2	0.035	0.000024	0.000094
117	16	Conectiv-Deepwater	NJ0005363	006	5	69.1	24	2	0.006	0.000004	0.000017
118	17	Conectiv-Deepwater	NJ0005363	017	5	69.1	24	1	0.284	0.000191	0.000763

Serial No.	Serial No. per Zone	Facility Name	NPDES	DSN	ZONE	RM	Model Segment	Potential Group (category)	Current Loadings (Sept. 2003) mg/day	Pent-PCBs WLA mg/day	Total PCBs WLA mg/day
119	18	Dupont-ChamberWorks	NJ0005100	011A	5	68.9	24	2	0.004	0.000003	0.000010
120	19	Dupont-ChamberWorks	NJ0005100	013A	5	68.9	24	2	0.000	0.000000	0.000000
121	20	Pennsville Sewerage Authority	NJ0021598	001	5	65.1	23	1	63.353	0.042559	0.170237
122	21	OxyChem	DE0050911	001	5	62.2	81	1	1.798	0.001208	0.004831
123	22	OxyChem	DE0050911	002	5	62.2	81	1	0.168	0.000113	0.000453
124	23	Conectiv-DelawareCity	DE0050601	016	5	61.9	22	2	0.123	0.000082	0.000330
125	24	Conectiv-DelawareCity	DE0050601	033	5	61.9	22	2	0.005	0.000003	0.000012
126	25	Conectiv-DelawareCity	DE0050601	034	5	61.9	22	2	0.015	0.000010	0.000040
127	26	Metachem	DE0020001	002	5	61.9	22	1	1.713	0.001151	0.004604
128	27	Metachem	DE0020001	003	5	61.9	22	1	2.176	0.001462	0.005848
129	28	Metachem	DE0020001	001	5	61.5	21	2	81.182	0.054537	0.218147
130	29	Motiva	DE0000256	001	5	61.5	21	2	0.000	0.000000	0.000000
131	30	Motiva	DE0000256	601	5	61.5	21	1	0.000	0.000000	0.000000
132	31	Kaneka Delaware Corp.	DE0000647	001	5	61.4	21	2	2.266	0.001522	0.006089
133	32	Formosa Plastics	DE0000612	001	5	61.3	21	2	4.885	0.003281	0.013126
134	33	Motiva	DE0000256	101	5	61.0	21	1	2843.225	1.910027	7.640108
135	34	Delaware City STP (New Castle Co.)	DE0021555	001	5	60.1	18	2	4.085	0.002744	0.010976
136	35	City of Salem	NJ0024856	001	5	58.8	15	2	10.062	0.006760	0.027038
137	36	Port Penn STP (New Castle Co.)	DE0021539	001	5	54.8	12	2	0.487	0.000327	0.001308
138	37	PSEG-HopeCreek	NJ0025411	461A	5	52.0	11	2	0.000	0.000000	0.000000
139	38	PSEG-HopeCreek	NJ0025411	461C	5	52.0	11	1	0.915	0.000614	0.002457
140	39	PSEG-HopeCreek	NJ0025413	462A	5	52.0	11	2	0.011	0.000007	0.000029
141	40	PSEG-Salem	NJ0005622	485	5	51.0	77	2	0.000	0.000000	0.000000
142	41	PSEG-Salem	NJ0005622	489	5	51.0	77	1	0.984	0.000661	0.002644

Appendix 3

Permit Implications for NPDES Dischargers resulting from Stage 1 TMDLs for PCBs

The staged approach to establishing TMDLs for PCBs for Zones 2 to 5 of the Delaware Estuary that was presented to interested parties in April 2003 by the regulatory agencies described appropriate NPDES permitting actions that would result following the establishment of the Stage 1 TMDLs by the U.S. Environmental Protection Agency. The criteria that were presented at that time utilized a cumulative loading approach to identify those discharges with the largest loading of penta-PCBs. The criteria have been expanded and refined since that time to include the quality of the penta-PCB data used to develop the loading estimates for the NPDES dischargers.

Approach:

NPDES dischargers (excluding CSOs and MS4s) were divided into two groups based upon the type of analytical method used to measure the 19 penta-PCB congeners, and the number of the penta-PCB congeners that were detected. Five criteria are considered in classifying NPDES point discharges into two groups.

The criteria for grouping the discharges is as follows:

1. Method used:
    a. 1668A
    b. 8082A
2. Discharge consists principally of non-contact cooling water.
3. If Method 1668A was used, the data was submitted at the detection limits specified in the method:
    a. Yes
    b. No
4. Average number of detected penta congeners per sampling event:
    a. 4 or greater
    b. Less than 4
5. Calculated loadings
    a. A discharge using Method 1668A with lower detection limits which is one of a group of discharges whose total cumulative loading is less than 10% of the zone waste load allocation.

<u>Group 1</u>

1. All discharges, except non-contact cooling water discharges, which have detected 4 or more penta PCB congeners per sampling event regardless of the method used and detection limits achieved, with the exception of those discharges using Method 1668A at the method specified detection limits whose cumulative loadings are less than the 10 percent of zone WLAs.

<u>Group 2</u>

1. All discharges with less than 4 congener detected per sampling event.
2. All discharges which have detected 4 or more penta PCB congeners per sampling event using Method 1668A at the method specified detection limits whose cumulative loadings are less than the 10 percent of zone WLAs.
3. All non-contact cooling water, regardless of the number of penta congeners detected, method used, or detection limits.

Permit Requirements:

Federal regulations implementing the NPDES program at 40 CFR Part 122.44(k)(4) allow the use of non-numeric, Best Management Practices-based WQBELs where a BMP approach is the reasonably necessary means to control pollutants to achieve the goals of the Clean Water Act. The uncertainty associated with several elements of the current TMDL development process including the PCB loadings calculations, the model inputs, and the extrapolation from penta-PCBs to total PCBs support this approach for Stage 1. EPA recommends that the groups receive the following permit requirements consisten with state and federal NPDES permit regulations.

Group 1 -	Permit requirements will include waste minimization and reduction programs and additional monitoring with Method 1668A. Both requirements will be performed concurrently, and will be imposed when permit is reissued or modified. DRBC may also impose the requirements.
Group 2 -	Permit requirements will include waste minimization and reduction programs (WMRP) and additional monitoring with Method 1668A. Monitoring will be performed in the first two years to confirm the presence and concentration of PCB congeners followed by the WMRP in the third year if the monitoring results confirm the concentrations and associated loading estimates for penta-PCBs, or result in loading estimates for other PCB homologs that exceed the individual WLAs for total PCBs for the discharge. It is recommended that both requirements will be imposed when permit is reissued or modified. DRBC may also impose the requirements for selected discharges (i.e., non-contact cooling water discharges).

Note: Dischargers in both Groups are receiving individual WLAs. Therefore, the sum of all individual WLAs plus the aggregate WLA for CSOs will equal the proportion of the TMDL for each zone that is allocated to WLAs (Zone WLA).

EPA specifically requested comment and additional information during the public comment period regarding the assignment of discharges to each group. Based upon the comments received, no changes to the group assignments were necessary. The draft TMDL document utilizes data from point discharges that were submitted by April 2003. Some dischargers utilized method 1668A for analysis, however the data reported did not adhere to method detection limits specified by the method. Therefore all dischargers which utilized method 1668A were required to re-submit data at the detection limits specified by the method. As of the April date, some dischargers had resubmitted the data , however, there remained a group of dischargers who did not provide the data by April 2003. Many of these dischargers have provided data since April and the resubmitted data has been used to generate revised loadings and number of penta congeners detected (Appendix Tables 3-2 to 3-5). The resubmitted data had essentially two effects. It typically increased the number of detected congeners and changed the loadings estimates for the discharges.

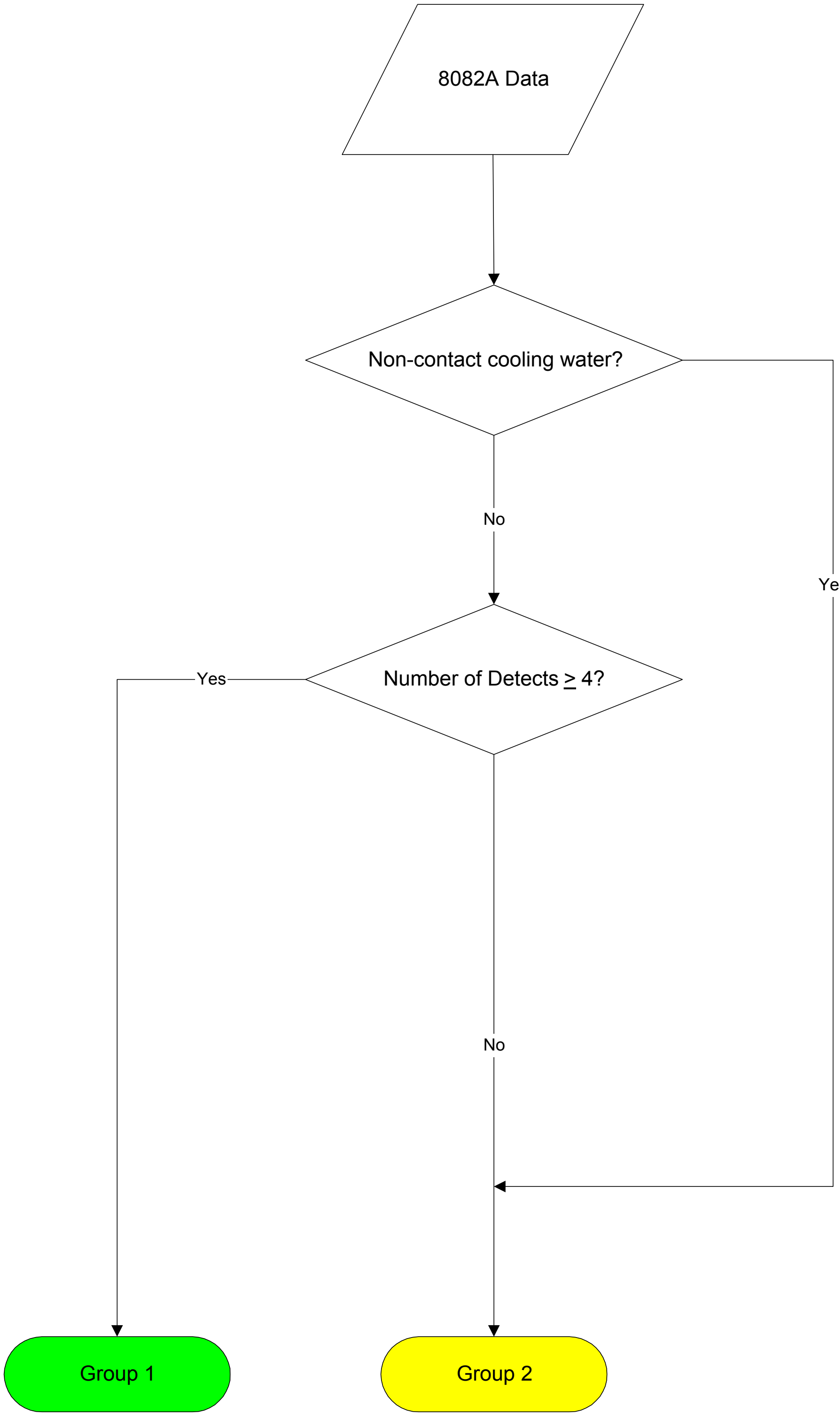
There are however, a small number of dischargers which utilized method 1668A for which we have not received resubmitted data as of September 11, 2003.

As indicated at that time, the identification of significant point source dischargers is a dynamic process that depends on several factors including the availability and extent of PCB congener data for each discharge, the flows used for each discharge, the procedure used to calculate the loadings, the location of the discharge in the estuary, and the proximity and loading of other sources of PCBs. As a result, the list of point source dischargers is subject to change both prior to December 2003 and during the development of the Stage 2 TMDLs.

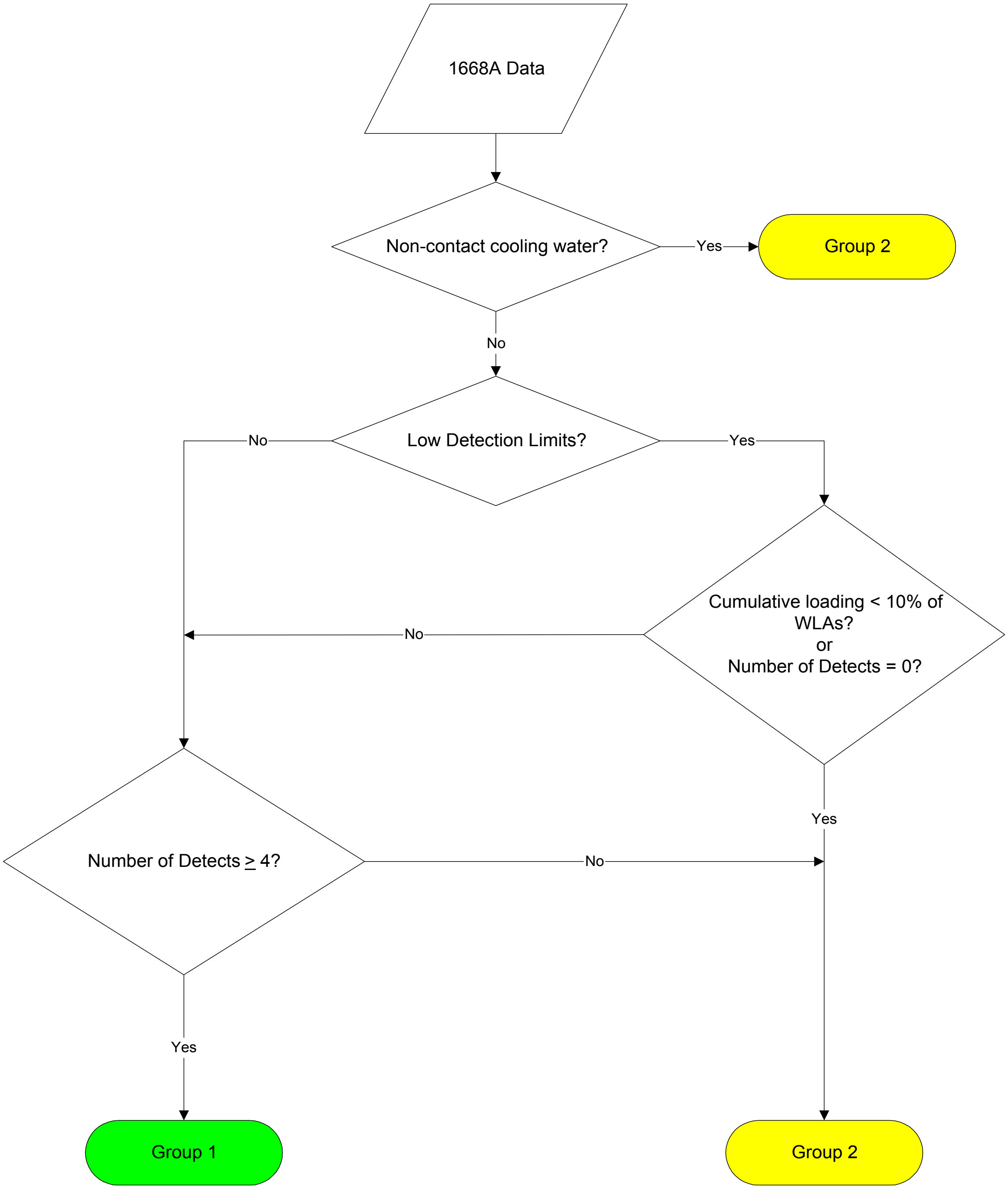
Appendix Tables 3-2 to 3-5 list the discharges assigned to each group as of September 11, 2003. Individual discharges from combined sewer overflows (CSOs) and municipal separate storm sewer systems (MS4s) have not been included in the tables. Table 9 lists the categorical allocation by zone to these two sources. Individual wasteload allocations for the point source dischargers included in the Stage 1 TMDLs are also listed in each table.

Appendix Table 3-1: Distribution of NPDES Discharges to each group in each zone of the Delaware Estuary.

	Number of Discharges				
	Zone 2	Zone 3	Zone 4	Zone 5	Total
Group 1	13	5	25	17	60
Group 2	25	8	25	24	82
Total	38	13	50	41	142



Appendix Figure 3-1: Selection process for permit requirements for NPDES discharges using Method 8082A.



Appendix Figure 3-2: Selection process for permit requirements for NPDES discharges using Method 1668A.

Appendix Table 3-2: Data used to assign the permit requirements for NPDES discharges in Zone 2.

Serial No.	Facility Name	DRBC ID	RM	# of DW SAMPLES	# of WW SAMPLES	Analytical Method 1668a	Submitted data at Method 1668A detection limits	Avg. # of congeners per sampling event (Sept 2003)	Non-Contact Cooling water	Current Loadings (Sept. 2003) mg/day	Cumulative loading percentage to WLA	Potential Group (category)
1	Trenton	NJ0020923-001	132.2	3	3	Yes	Yes	11.2	No	243.612	*	1
2	PSEG-Burlington	NJ0005002-WTPA	117.4	3	1	Yes	Yes	10.3	No	0.929	*	1
3	U.S. Steel	PA0013463-103	127.0	5	1	Yes	Yes	9.7	No	10.056	*	1
4	U.S. Steel	PA0013463-002	127.4	3	1	Yes	Yes	9.5	No	61.390	*	1
5	U.S. Steel	PA0013463-203	127.0	2	1	Yes	Yes	9.3	No	3.787	*	1
6	Rohm&Haas-Bristol	PA0012769-009	117.1	3	0	Yes	Yes	9.0	No	5.710	*	1
7	Riverside Sewerage Authority	NJ0022519-001	108.8	2	0	No	N/A	7.0	No	124.107	*	1
8	Beverly Sewerage Authority	NJ0027481-001	114.7	1	0	No	N/A	7.0	No	18.890	*	1
9	PSEG-Mercer	NJ0004995-441C	130.4	1	0	Yes	Yes	7.0	No	5.010	*	1
10	AFG Industries	NJ0033022-001A	109.6	1	0	No	N/A	6.0	No	10.258	*	1
11	US Pipe & Foundry	NJ0005266-002A	118.1	0	2	No	N/A	5.0	No	0.807	*	1
12	Cinnaminson Sewerage Authority	NJ0024007-001	108.9	3	3	No	N/A	4.0	No	27.980	*	1
13	Riverton Borough	NJ0021610-001	110.8	1	0	No	N/A	4.0	No	3.853	*	1
1	GEON Company (Burlington) Polyone	NJ0004235-001A	120.3	1	1	No	N/A	3.5	No	15.051	*	2
2	Willingboro Municipal Utilities Authority	NJ0023361-001	110.8	3	0	No	N/A	3.0	No	123.392	*	2
3	Hamilton Township	NJ0026301-001	128.0	3	0	No	N/A	2.7	No	220.791	*	2
4	Bristol Borough	PA0027294-001	118.7	3	3	No	N/A	2.3	No	29.383	*	2
5	City of Burlington	NJ0024660-002	117.6	3	0	No	N/A	2.0	No	46.336	*	2
6	Bristol Township	PA0026450-001	116.8	3	3	No	N/A	1.5	No	34.732	*	2
7	AFG Industries	NJ0033022-002	109.4	0	1	No	N/A	1.0	No	0.092	*	2
8	Mt. Holly Municipal Utilities Authority	NJ0024015-001	110.8	3	0	No	N/A	0.7	No	54.904	*	2
9	Delran Sewerage Authority	NJ0023507-001	110.8	3	0	No	N/A	0.3	No	37.419	*	2
10	Burlington Township	NJ0021709-001	117.0	3	0	No	N/A	0.3	No	34.901	*	2
11	Florence Township	NJ0023701-001	121.4	3	0	No	N/A	0.3	No	15.682	*	2
12	Lower Bucks County Municipal Authority	PA0026468-001	121.9	3	3	No	N/A	0.2	No	129.179	*	2

Serial No.	Facility Name	DRBC ID	RM	# of DW SAMPLES	# of WW SAMPLES	Analytical Method 1668a	Submitted data at Method 1668A detection limits	Avg. # of congeners per sampling event (Sept 2003)	Non-Contact Cooling water	Current Loadings (Sept. 2003) mg/day	Cumulative loading percentage to WLA	Potential Group (category)
13	Bordentown Sewerage Authority	NJ0024678-001	128.0	3	3	No	N/A	0.2	No	26.292	*	2
14	Mt. Laurel Municipal Utilities Authority	NJ0025178-001A	110.8	3	0	No	N/A	0.0	No	67.433	*	2
15	Morrisville WWTP	PA0026701-001	132.9	3	0	No	N/A	0.0	No	65.566	*	2
16	Waste Management Grows Landfill	PA0043818-001	125.5	1	0	No	N/A	0.0	No	1.182	*	2
17	MSC Pre Finish Metals	PA0045021-001	130.1	1	0	No	N/A	0.0	No	0.646	*	2
18	Hoeganaes Corp.	NJ0004375-001A	109.4	1	1	No	N/A	0.0	No	0.330	*	2
19	Hoeganaes Corp.	NJ0004375-003A	109.4	0	1	No	N/A	0.0	No	0.000	*	2
20	Exelon-Fairless	PA0057088-001	126.6	3	0	Yes	Yes	9.0	Yes	0.000	*	2
21	PSEG-Mercer	NJ0004995-441A	130.4	3	0	Yes	Yes	6.3	Yes	0.000	*	2
22	Colorite Polymers	NJ0004391-003A	117.0	1	0	Yes	Yes	2.0	No	0.740	65.9	2
23	Colorite Polymers	NJ0004391-002A	117.0	1	1	Yes	Yes	4.0	No	0.008	0.7	2
24	Yates Foil	NJ0004332-002A	128.0	0	1	Yes	Yes	2.0	No	0.000	0.0	2
25	Yates Foil	NJ0004332-001B	128.0	1	0	Yes	Yes	0.0	No	0.070	6.3	2

RM:	River Mile
DW:	Dry Weather
WW:	Wet Weather

* Cumulative loading percentages to Zone WLA (minus portions to CSOs and MS4) are shown up to 100 percent.

Appendix Table 3-3: Data used to assign the permit requirements for NPDES discharges in Zone 3.

Serial No.	Facility Name	DRBC ID	RM	# of DW SAMPLES	# of WW SAMPLES	Analytical Method 1668a	Submitted data at Method 1668A detection limits	Avg. # of congeners per sampling event (Sept 2003)	Non-Contact Cooling water	Current Loadings (Sept. 2003) mg/day	Cumulative loading percentage to WLA	Potential Group (category)
1	PWD-NE	PA0026689-001	104.1	3	3	Yes	Yes	10.5	No	1238.662	*	1
2	CCMUA	NJ0026182-001	98.0	3	3	Yes	Yes	10.0	No	818.459	*	1
3	Exelon-Delaware	PA0011622-002	101.2	3	0	Yes	Yes	9.7	No	0.655	92.5	1
4	PWD-SE	PA0026662-001	96.8	3	3	Yes	Yes	9.7	No	657.721	*	1
5	Rohm&Haas-Philadelphia	PA0012777-003	106.1	1	0	Yes	Yes	7.0	No	2.175	*	1
1	NGC Industries	NJ0004669-001A	104.4	1	1	No	N/A	0.0	No	1.528	*	2
2	Palmyra Borough	NJ0024449-001	107.7	1	0	No	N/A	0.0	No	19.235	*	2
3	Exelon-Delaware	PA0011622-006	101.1	3	0	Yes	Yes	9.3	Yes	0.000	*	2
4	Rohm&Haas-Philadelphia	PA0012777-001	106.1	3	1	Yes	Yes	3.8	No	15.974	*	2
5	Citgo Petroleum	NJ0131342-001A	103.4	1	0	Yes	No	0.0	No	0.012	*	2
6	Rohm&Haas-Philadelphia	PA0012777-007	106.1	1	0	Yes	Yes	6.0	No	0.003	0.4	2
7	Exelon-Delaware	PA0011622-004	101.2	0	1	Yes	Yes	11.0	No	0.011	1.8	2
8	Exelon-Delaware	PA0011622-001	101.2	0	1	Yes	Yes	12.0	No	0.044	7.5	2

RM: River Mile
DW: Dry Weather
WW: Wet Weather

* Cumulative loading percentages to Zone WLA (minus portions to CSOs and MS4) are shown up to 100 percent.

Appendix Table 3-4: Data used to assign the permit requirements for NPDES discharges in Zone 4.

Serial No.	Facility Name	DRBC ID	RM	# of DW SAMPLES	# of WW SAMPLES	Analytical Method 1668a	Submitted data at Method 1668A detection limits	Avg. # of congeners per sampling event (Sept 2003)	Non-Contact Cooling water	Current Loadings (Sept. 2003) mg/day	Cumulative loading percentage to WLA	Potential Group (category)
1	Dupont-Repauno	NJ0004219-007	86.6	0	1	No	N/A	12.0	No	1.433	*	1
2	Exelon-Eddystone	PA0013716-001	85.2	0	1	Yes	Yes	12.0	No	0.064	14.2	1
3	Dupont-Repauno	NJ0004219-001A	85.6	3	1	Yes	Yes	11.5	No	80.773	*	1
4	Boeing	PA0013323-002	85.4	1	1	Yes	Yes	11.5	No	158.353	*	1
5	Kvaerner	PA0057690-019	92.8	0	1	Yes	Yes	11.0	No	0.100	57.0	1
6	Kvaerner	PA0057690-021	92.8	0	1	Yes	Yes	11.0	No	0.100	73.3	1
7	Boeing	PA0013323-001	85.2	1	0	Yes	Yes	11.0	No	29.068	*	1
8	PWD-SW	PA0026671-001	90.7	3	3	Yes	Yes	10.8	No	1020.466	*	1
9	Valero Refining	NJ0005029-001A	87.7	4	1	Yes	Yes	10.6	No	99.473	*	1
10	Exelon-Eddystone	PA0013716-005	85.2	0	1	Yes	Yes	10.0	No	0.509	*	1
11	Ausimont	NJ0005185-001A	90.7	0	1	Yes	Yes	10.0	No	0.840	*	1
12	Boeing	PA0013323-003	85.2	0	1	Yes	Yes	9.0	No	0.404	*	1
13	Boeing	PA0013323-016	85.4	0	1	Yes	Yes	8.0	No	0.149	97.5	1
14	Boeing	PA0013323-007	85.2	0	1	Yes	Yes	8.0	No	0.235	*	1
15	Tinicum Township	PA0028380-001	85.4	3	3	Yes	Yes	8.0	No	15.450	*	1
16	Safety Kleen	NJ0005240-002A	79.8	0	1	No	N/A	7.0	No	3.512	*	1
17	Kvaerner	PA0057690-012	92.7	3	0	Yes	Yes	7.0	No	22.608	*	1
18	DELCORA	PA0027103-001	80.6	3	3	Yes	Yes	6.7	No	309.423	*	1
19	GCUA	NJ0024686-001	88.4	5	0	Yes	Yes	6.4	No	113.497	*	1
20	ConocoPhillips	PA0012637-008	80.2	0	1	No	N/A	6.0	No	0.111	*	1
21	Metro Machine	PA0057479-DD2	93.2	4	0	No	N/A	6.0	No	49.040	*	1
22	Hercules	NJ0005134-001A	87.5	1	1	Yes	Yes	6.0	No	4.120	*	1
23	Kimberly Clark	PA0013081-029	83.2	0	2	Yes	Yes	5.5	No	0.086	40.6	1
24	ConocoPhillips	PA0012637-007	80.2	0	1	No	N/A	5.0	No	0.511	*	1
25	Ausimont	NJ0005185-002A	90.7	1	0	Yes	Yes	5.0	No	0.077	26.7	1

Serial No.	Facility Name	DRBC ID	RM	# of DW SAMPLES	# of WW SAMPLES	Analytical Method 1668a	Submitted data at Method 1668A detection limits	Avg. # of congeners per sampling event (Sept 2003)	Non-Contact Cooling water	Current Loadings (Sept. 2003) mg/day	Cumulative loading percentage to WLA	Potential Group (category)
1	ConocoPhillips	PA0012637-006	80.2	0	1	No	N/A	3.0	No	0.029	*	2
2	Coastal Mart / Coastal Eagle Point Oil	NJ0005401-003A	94.7	0	1	No	N/A	2.0	No	0.006	*	2
3	ConocoPhillips	PA0012637-002	80.2	3	1	No	N/A	1.5	Yes	0.000	*	2
4	ConocoPhillips	PA0012637-101	79.6	3	1	No	N/A	1.0	Yes	0.000	*	2
5	Swedesboro	NJ0022021-001	79.8	1	0	No	N/A	1.0	No	3.296	*	2
6	Logan Township	NJ0027545-001	79.5	1	1	No	N/A	1.0	No	12.114	*	2
7	Safety Kleen	NJ0005240-001A	79.8	3	0	No	N/A	0.7	No	7.440	*	2
8	Metro Machine	PA0057479-DD3	93.1	3	0	No	N/A	0.7	No	17.845	*	2
9	Chevron	NJ0064696-001A	90.5	1	0	No	N/A	0.0	No	0.157	*	2
10	Harrison Township-Mullica Hill	NJ0020532-001	79.8	1	0	No	N/A	0.0	No	6.093	*	2
11	DeGuessa-Huls Corp.	PA0051713-001	82.2	1	0	No	N/A	0.0	No	9.063	*	2
12	Air Products	NJ0004278-001A	88.2	1	0	No	N/A	0.0	No	10.041	*	2
13	Greenwich Township	NJ0030333-001	87.0	1	0	No	N/A	0.0	No	12.110	*	2
14	ConocoPhillips	PA0012637-201	79.6	3	0	No	N/A	0.0	No	48.580	*	2
15	Coastal Mart / Coastal Eagle Point Oil	NJ0005401-001A	94.3	3	0	No	N/A	0.0	No	55.368	*	2
16	Exelon-Eddystone	PA0013716-008	85.2	4	0	Yes	Yes	11.8	Yes	0.000	*	2
17	Exelon-Eddystone	PA0013716-007	85.2	3	0	Yes	Yes	11.7	Yes	0.000	*	2
18	Solutia	NJ0005045-001	79.2	3	0	Yes	No	1.3	No	12.228	*	2
19	Colonial Pipeline	NJ0033952-001A	90.5	0	1	Yes	No	0.0	No	0.087	*	2
20	BP Paulsboro	NJ0005584-002A	89.6	0	1	Yes	No	0.0	No	0.352	*	2
21	BP Paulsboro	NJ0005584-003A	89.4	1	0	Yes	No	0.0	No	7.006	*	2
22	Sunoco-PointBreeze	PA0012629-002	92.5	3	3	Yes	No	0.0	No	75.899	*	2
23	Sunoco-GirardPoint	PA0011533-015	92.5	3	3	Yes	No	0.0	No	99.167	*	2
24	Kvaerner	PA0057690-047	92.5	0	1	Yes	Yes	10.0	No	0.005	0.8	2
25	Boeing	PA0013323-008	85.2	0	1	Yes	Yes	13.0	No	0.018	3.7	2

Appendix Table 3-5: Data used to assign the permit requirements for NPDES discharges in Zone 5.

Serial No.	Facility Name	DRBC ID	RM	# of DW SAMPLES	# of WW SAMPLES	Analytical Method 1668a	Submitted data at Method 1668A detection limits	Avg. # of congeners per sampling event (Sept 2003)	Non-Contact Cooling water	Current Loadings (Sept. 2003) mg/day	Cumulative loading percentage to WLA	Potential Group (category)
1	AMTRAK	DE0050962-003	70.7	0	3	Yes	Yes	12.3	No	2.002	*	1
2	AMTRAK	DE0050962-004	70.7	0	3	Yes	Yes	12.0	No	35.822	*	1
3	OxyChem	DE0050911-002	62.2	0	3	Yes	Yes	11.0	No	0.168	16.8	1
4	Conectiv-Deepwater	NJ0005363-017	69.1	0	1	Yes	Yes	11.0	No	0.284	25.9	1
5	PSEG-Salem	NJ0005622-489	51.0	1	0	Yes	Yes	11.0	No	0.984	86.5	1
6	Metachem	DE0020001-003	61.9	0	4	No	N/A	9.5	No	2.176	*	1
7	Metachem	DE0020001-002	61.9	0	3	No	N/A	9.3	No	1.713	*	1
8	Dupont-Edgemoor	DE0000051-004	72.2	0	3	Yes	Yes	9.0	No	0.153	11.5	1
9	Dupont-Edgemoor	DE0000051-001	73.2	3	0	Yes	Yes	8.7	No	32.214	*	1
10	Dupont-ChamberWorks	NJ0005100-662	69.8	3	0	Yes	Yes	8.7	No	102.854	*	1
11	Dupont-ChamberWorks	NJ0005100-001	69.8	3	0	Yes	Yes	8.0	No	138.476	*	1
12	Motiva	DE0000256-101	61.0	3	3	Yes	Yes	7.5	No	2843.225	*	1
13	OxyChem	DE0050911-001	62.2	3	0	Yes	Yes	7.0	No	1.798	*	1
14	Penns Grove Sewer Authority	NJ0024023-001	70.7	1	0	No	N/A	7.0	No	23.206	*	1
15	PSEG-HopeCreek	NJ0025411-461C	52.0	1	0	Yes	Yes	5.0	No	0.915	55.1	1
16	Motiva	DE0000256-601	61.5	3	0	Yes	Yes	5.0	No	0.000 **	*	1
17	Pennsville Sewerage Authority	NJ0021598-001	65.1	3	0	No	N/A	4.7	No	63.353	*	1
1	Carney's Point	NJ0021601-001	71.3	3	0	No	N/A	2.7	No	10.265	*	2
2	General Chemical	DE0000655-001	77.9	3	3	No	N/A	2.2	Yes	0.000	*	2
3	Port Penn STP (New Castle Co.)	DE0021539-001	54.8	1	0	No	N/A	1.0	No	0.487	*	2
4	Metachem	DE0020001-001	61.5	3	3	No	N/A	1.0	No	81.182	*	2
5	City of Wilmington	DE0020320-001	71.6	3	3	No	N/A	0.8	No	1297.745	*	2
6	Geon Company (Pedricktown) Polyone	NJ0004286-003	75.9	0	1	No	N/A	0.0	No	0.011	*	2
7	Geon Company (Pedricktown) Polyone	NJ0004286-001A	74.9	1	0	No	N/A	0.0	No	1.690	*	2
8	Kaneka Delaware Corp.	DE0000647-001	61.4	1	1	No	N/A	0.0	No	2.266	*	2
9	Delaware City STP (New Castle Co.)	DE0021555-001	60.1	1	0	No	N/A	0.0	No	4.085	*	2

Serial No.	Facility Name	DRBC ID	RM	# of DW SAMPLES	# of WW SAMPLES	Analytical Method 1668a	Submitted data at Method 1668A detection limits	Avg. # of congeners per sampling event (Sept 2003)	Non-Contact Cooling water	Current Loadings (Sept. 2003) mg/day	Cumulative loading percentage to WLA	Potential Group (category)
10	Formosa Plastics	DE0000612-001	61.3	1	0	No	N/A	0.0	No	4.885	*	2
11	City of Salem	NJ0024856-001	58.8	3	0	No	N/A	0.0	No	10.062	*	2
12	PSEG-HopeCreek	NJ0025411-461A	52.0	3	0	Yes	Yes	9.7	Yes	0.000	*	2
13	Dupont-ChamberWorks	NJ0005100-013	68.9	3	0	Yes	Yes	9.3	Yes	0.000	*	2
14	PSEG-Salem	NJ0005622-485	51.0	3	0	Yes	Yes	9.0	Yes	0.000	*	2
15	Motiva	DE0000256-001	61.5	3	0	Yes	Yes	8.7	Yes	0.000	*	2
16	Conectiv-Deepwater	NJ0005363-003A	69.1	1	0	Yes	Yes	8.0	Yes	0.000	*	2
17	Dupont-ChamberWorks	NJ0005100-011	68.9	1	1	Yes	Yes	11.0	No	0.004	0.1	2
18	Conectiv-DelawareCity	DE0050601-033	61.9	0	3	Yes	Yes	11.7	No	0.005	0.3	2
19	Conectiv-Deepwater	NJ0005363-006	69.1	0	1	Yes	Yes	12.0	No	0.006	0.5	2
20	Conectiv-Edgemoor	DE0000558-041	71.8	0	3	Yes	Yes	10.7	No	0.008	0.7	2
21	PSEG-HopeCreek	NJ0025411-462A	52.0	0	1	Yes	Yes	0.0	No	0.011	1.0	2
22	Conectiv-DelawareCity	DE0050601-034	61.9	0	4	Yes	Yes	11.5	No	0.015	1.5	2
23	Conectiv-Deepwater	NJ0005363-005	69.1	0	1	Yes	Yes	10.0	No	0.035	2.6	2
24	Conectiv-DelawareCity	DE0050601-016	61.9	0	3	Yes	Yes	11.7	No	0.123	6.6	2

RM: River Mile
DW: Dry Weather
WW: Wet Weather

* Cumulative loading percentages to Zone WLA (minus portions to CSOs and MS4) are shown up to 100 percent.

** Flow is set to zero in the loading calculation because DSN 601 is an upstream monitoring point of DSN 101.

Appendix 4

Contaminated Sites and Municipalities with Combined Sewer Overflows (CSOs) that were evaluated as part of the Stage 1 TMDLs

Appendix Table 4-1: Contaminated Sites evaluated as part of the Stage 1 TMDLs and their estimated Penta-PCB Load.

Facility	Daily penta-PCB Load (kg/day)	Estimate Prepared by
Castle Ford - DE-192	1.4374E-06	EPA
Forbes Steel & Wire Corp. - DE-165	5.1989E-06	EPA
Rogers Corner Dump - DE-246	1.0465E-04	EPA
Industrial Products - DE-030	5.1129E-05	EPA
Chicago Bridge and Iron - DE-038	3.2768E-03	EPA
ABM-Wade, 58th Street Dump - PA-0179	1.9739E-06	EPA
O'Donnell Steel Drum - PA-0305	3.4939E-07	EPA
Conrail-Wayne Junction - PA-215	2.3043E-03	EPA
CONRAIL, Morrisville Lagoons - PA-441*	5.4056E-06	EPA
Pennwalt Corp. - Cornwells Heights - PA-0031*	3.1227E-07	EPA
Front Street Tanker - PA-2298	1.9914E-06	EPA
8th Street Drum - PA-3272	8.9655E-07	EPA
East 10th Street Site - PA-2869	1.0076E-02	EPA
Metal Bank - PA-2119	9.9092E-05	EPA
Lower Darby Creek Area Site - PA-3424	1.8481E-04	EPA
Roebling Steel Co.	4.9609E-05	EPA
Bridgeport Rental & Oil Services (BROS)	5.8140E-04	EPA
Dana Transport Inc.	3.8523E-08	EPA
Harrison Avenue Landfill	6.2542E-03	EPA
Metal Bank groundwater pathway	9.8312E-07	DRBC
AMTRAK Former Refueling Facility	1.3182E-03	DNREC
Gates Engineering	6.8226E-10	DNREC
AMTRAK Wilmington Railyard	1.6238E-03	DNREC
Diamond State Salvage	0.0000E+00	DNREC
NeCastro Auto Salvage	1.2867E-05	DNREC
Hercules Research Center	4.6121E-06	DNREC
Dravo Ship Yard	5.3216E-05	DNREC
DP&L/Congo Marsh	2.7290E-07	DNREC
American Scrap & Waste	7.4230E-04	DNREC
Pusey & Jones Shipyard	1.6033E-06	DNREC
Delaware Car Company	0.0000E+00	DNREC
Bafundo Roofing	1.5692E-04	DNREC
Kreiger Finger Property	1.5828E-04	DNREC
Clayville Dump	0.0000E+00	DNREC
Electric Hose & Rubber	8.8694E-05	DNREC
Penn Del Metal Recycling	1.1407E-04	DNREC
E. 7th Street North & South	5.7992E-05	DNREC
Delaware Compressed Steel	6.2877E-06	DNREC
Newport City Landfill	0.0000E+00	DNREC
DuPont Louviers – MBNA	9.5516E-08	DNREC
North American Smelting Co.	1.2821E-05	DNREC
RSC Realty	3.4113E-05	DNREC
AMTRAK CNOC	0.0000E+00	DNREC
Wilmington Coal Gas – N	2.2378E-06	DNREC

Facility	Daily penta-PCB Load (kg/day)	Estimate Prepared by
Del Chapel Place	2.2515E-06	DNREC
Kruse Playground	1.0643E-06	DNREC
Budd Metal	6.3450E-06	DNREC
Fox Point Park Phase II	1.1708E-04	DNREC
Bensalem Redev LP (Elf Atochem)	1.7561E-05	PADEP

Appendix Table 4-2: Municipalities or Regional Authorities with Combined Sewer Overflows (CSOs) that were evaluated as part of the Stage 1 TMDLs

Municipality/Regional Authority	NPDES Nos.	Zone
City of Philadelphia Water Department	PA0026662 PA0026671 PA0026689	2, 3 and 4
Camden County Municipal Utilities Authority	NJ0108812 NJ0026182	3 and 4
Delaware County Regional Authority (DELCORA)	PA0027103	4
City of Wilmington	DE0020320	5

Appendix 5

Municipalities in Delaware, New Jersey, and Pennsylvania, designated as Phase II Separate Stormwater Sewer Systems (MS4s) within urbanized areas in the Delaware River Watershed

Appendix Table 5-1: Municipalities with Separate Stormwater Sewer Systems that have the potential to be included in the waste load allocation (LA) for PCBs for Zones 2 to 5 of the Delaware Estuary.

STATE	COUNTY NAME	MUNICIPALITY NAME
DE	KENT	CAMDEN TOWN
DE	KENT	DOVER CITY
DE	KENT	KENT COUNTY
DE	NEW CASTLE	NEWARK CITY
DE	NEW CASTLE/DE DOT	ARDEN
DE	NEW CASTLE/DE DOT	ARDENTOWN
DE	NEW CASTLE/DE DOT	ARDENCROFT
DE	NEW CASTLE/DE DOT	BELLEFONTE
DE	NEW CASTLE/DE DOT	DELAWARE CITY
DE	NEW CASTLE/DE DOT	ELSMERE
DE	NEW CASTLE/DE DOT	MIDDLETOWN
DE	NEW CASTLE/DE DOT	NEWPORT
DE	NEW CASTLE/DE DOT	NEW CASTLE
DE	NEW CASTLE/DE DOT	ODDESSA
DE	NEW CASTLE/DE DOT	TOWNSEND
DE	NEW CASTLE/DE DOT	CITY OF WILMINGTON
DE	KENT	WYOMING TOWN

STATE	COUNTY NAME	MUNICIPALITY NAME
NJ	ATLANTIC	BUENA BORO
NJ	ATLANTIC	BUENA VISTA TWP
NJ	BURLINGTON	BEVERLY CITY
NJ	BURLINGTON	BORDENTOWN CITY
NJ	BURLINGTON	BORDENTOWN TWP
NJ	BURLINGTON	BURLINGTON CITY
NJ	BURLINGTON	BURLINGTON TWP
NJ	BURLINGTON	CHESTERFIELD TWP
NJ	BURLINGTON	CINNAMINSON TWP
NJ	BURLINGTON	CINNAMINSON TWP
NJ	BURLINGTON	DELANCO TWP
NJ	BURLINGTON	DELRAN TWP
NJ	BURLINGTON	EASTAMPTON TWP
NJ	BURLINGTON	EDGEWATER PARK TWP
NJ	BURLINGTON	EVESHAM TWP
NJ	BURLINGTON	EVESHAM TWP
NJ	BURLINGTON	FIELDSBORO BORO
NJ	BURLINGTON	FLORENCE TWP
NJ	BURLINGTON	HAINESPORT TWP
NJ	BURLINGTON	LUMBERTON TWP
NJ	BURLINGTON	MANSFIELD TWP
NJ	BURLINGTON	MAPLE SHADE TWP
NJ	BURLINGTON	MEDFORD LAKES BORO
NJ	BURLINGTON	MEDFORD TWP
NJ	BURLINGTON	MOORESTOWN TWP
NJ	BURLINGTON	MOORESTOWN TWP
NJ	BURLINGTON	MOUNT HOLLY TWP

STATE	COUNTY NAME	MUNICIPALITY NAME
NJ	BURLINGTON	MOUNT LAUREL TWP
NJ	BURLINGTON	MOUNT LAUREL TWP
NJ	BURLINGTON	NEW HANOVER TWP
NJ	BURLINGTON	NORTH HANOVER TWP
NJ	BURLINGTON	PALMYRA BORO
NJ	BURLINGTON	PALMYRA BORO
NJ	BURLINGTON	PEMBERTON BORO
NJ	BURLINGTON	PEMBERTON TWP
NJ	BURLINGTON	RIVERSIDE TWP
NJ	BURLINGTON	RIVERTON BORO
NJ	BURLINGTON	SHAMONG TWP
NJ	BURLINGTON	SOUTHAMPTON TWP
NJ	BURLINGTON	SPRINGFIELD TWP
NJ	BURLINGTON	TABERNACLE TWP
NJ	BURLINGTON	TABERNACLE TWP
NJ	BURLINGTON	WESTAMPTON TWP
NJ	BURLINGTON	WILLINGBORO TWP
NJ	BURLINGTON	WOODLAND TWP
NJ	BURLINGTON	WRIGHTSTOWN BORO
NJ	CAMDEN	AUDUBON BORO
NJ	CAMDEN	AUDUBON PARK BORO
NJ	CAMDEN	BARRINGTON BORO
NJ	CAMDEN	BELLMAWR BORO
NJ	CAMDEN	BERLIN BORO
NJ	CAMDEN	BERLIN TWP
NJ	CAMDEN	BERLIN TWP
NJ	CAMDEN	BROOKLAWN BORO
NJ	CAMDEN	CAMDEN CITY
NJ	CAMDEN	CHERRY HILL TWP
NJ	CAMDEN	CLEMENTON BORO
NJ	CAMDEN	COLLINGSWOOD BORO
NJ	CAMDEN	GIBBSBORO BORO
NJ	CAMDEN	GIBBSBORO BORO
NJ	CAMDEN	GIBBSBORO BORO
NJ	CAMDEN	GLOUCESTER CITY
NJ	CAMDEN	GLOUCESTER CITY
NJ	CAMDEN	GLOUCESTER TWP
NJ	CAMDEN	GLOUCESTER TWP
NJ	CAMDEN	HADDON HEIGHTS BORO
NJ	CAMDEN	HADDON TWP (EAST)
NJ	CAMDEN	HADDON TWP (NORTH)
NJ	CAMDEN	HADDON TWP (SOUTH)
NJ	CAMDEN	HADDONFIELD BORO
NJ	CAMDEN	HI-NELLA BORO
NJ	CAMDEN	LAUREL SPRINGS BORO
NJ	CAMDEN	LAWNSIDE BORO
NJ	CAMDEN	LINDENWOLD BORO
NJ	CAMDEN	MAGNOLIA BORO
NJ	CAMDEN	MERCHANTVILLE BORO
NJ	CAMDEN	MOUNT EPHRAIM BORO
NJ	CAMDEN	OAKLYN BORO
NJ	CAMDEN	PENNSAUKEN TWP
NJ	CAMDEN	PINE HILL BORO
NJ	CAMDEN	PINE HILL BORO
NJ	CAMDEN	PINE VALLEY BORO
NJ	CAMDEN	RUNNEMEDE BORO
NJ	CAMDEN	SOMERDALE BORO
NJ	CAMDEN	STRATFORD BORO
NJ	CAMDEN	TAVISTOCK BORO
NJ	CAMDEN	VOORHEES TWP
NJ	CAMDEN	VOORHEES TWP

STATE	COUNTY NAME	MUNICIPALITY NAME
NJ	CAMDEN	VOORHEES TWP
NJ	CAMDEN	VOORHEES TWP
NJ	CAMDEN	WINSLOW TWP
NJ	CAMDEN	WINSLOW TWP
NJ	CAMDEN	WINSLOW TWP
NJ	CAMDEN	WOODLYNNE BORO
NJ	CAPE_MAY	CAPE MAY POINT BORO
NJ	CAPE_MAY	DENNIS TWP
NJ	CAPE_MAY	LOWER TWP
NJ	CAPE_MAY	LOWER TWP
NJ	CAPE_MAY	MIDDLE TWP
NJ	CAPE_MAY	WEST CAPE MAY BORO
NJ	CAPE_MAY	WOODBINE BORO
NJ	CUMBERLAND	BRIDGETON CITY
NJ	CUMBERLAND	COMMERCIAL TWP
NJ	CUMBERLAND	DEERFIELD TWP
NJ	CUMBERLAND	DOWNE TWP
NJ	CUMBERLAND	FAIRFIELD TWP
NJ	CUMBERLAND	GREENWICH TWP
NJ	CUMBERLAND	HOPEWELL TWP
NJ	CUMBERLAND	LAWRENCE TWP
NJ	CUMBERLAND	MAURICE RIVER TWP
NJ	CUMBERLAND	MILLVILLE CITY
NJ	CUMBERLAND	SHILOH BORO
NJ	CUMBERLAND	STOW CREEK TWP
NJ	CUMBERLAND	UPPER DEERFIELD TWP
NJ	CUMBERLAND	VINELAND CITY
NJ	GLOUCESTER	CLAYTON BORO
NJ	GLOUCESTER	DEPTFORD TWP
NJ	GLOUCESTER	DEPTFORD TWP
NJ	GLOUCESTER	DEPTFORD TWP
NJ	GLOUCESTER	EAST GREENWICH TWP
NJ	GLOUCESTER	ELK TWP
NJ	GLOUCESTER	ELK TWP
NJ	GLOUCESTER	ELK TWP
NJ	GLOUCESTER	FRANKLIN TWP
NJ	GLOUCESTER	GLASSBORO BORO
NJ	GLOUCESTER	GLASSBORO BORO
NJ	GLOUCESTER	GREENWICH TWP
NJ	GLOUCESTER	HARRISON TWP
NJ	GLOUCESTER	LOGAN TWP
NJ	GLOUCESTER	LOGAN TWP
NJ	GLOUCESTER	MANTUA TWP
NJ	GLOUCESTER	MONROE TWP
NJ	GLOUCESTER	MONROE TWP
NJ	GLOUCESTER	MONROE TWP
NJ	GLOUCESTER	NATIONAL PARK BORO
NJ	GLOUCESTER	NEWFIELD BORO
NJ	GLOUCESTER	PAULSBORO BORO
NJ	GLOUCESTER	PITMAN BORO
NJ	GLOUCESTER	SOUTH HARRISON TWP
NJ	GLOUCESTER	SOUTH HARRISON TWP
NJ	GLOUCESTER	SWEDESBORO BORO
NJ	GLOUCESTER	WASHINGTON TWP
NJ	GLOUCESTER	WASHINGTON TWP
NJ	GLOUCESTER	WASHINGTON TWP
NJ	GLOUCESTER	WENONAH BORO
NJ	GLOUCESTER	WEST DEPTFORD TWP
NJ	GLOUCESTER	WEST DEPTFORD TWP
NJ	GLOUCESTER	WESTVILLE BORO

STATE	COUNTY NAME	MUNICIPALITY NAME
NJ	GLOUCESTER	WOODBURY CITY
NJ	GLOUCESTER	WOODBURY CITY
NJ	GLOUCESTER	WOODBURY HEIGHTS BORO
NJ	GLOUCESTER	WOOLWICH TWP
NJ	GLOUCESTER	WOOLWICH TWP
NJ	MERCER	HAMILTON TWP
NJ	MERCER	TRENTON CITY
NJ	MERCER	TRENTON CITY
NJ	MERCER	WASHINGTON TWP
NJ	MONMOUTH	ALLENTOWN BORO
NJ	MONMOUTH	MILLSTONE TWP
NJ	MONMOUTH	UPPER FREEHOLD TWP
NJ	OCEAN	JACKSON TWP
NJ	OCEAN	JACKSON TWP
NJ	OCEAN	JACKSON TWP
NJ	OCEAN	LACEY TWP
NJ	OCEAN	MANCHESTER TWP
NJ	OCEAN	PLUMSTED TWP
NJ	SALEM	ALLOWAY TWP
NJ	SALEM	ALLOWAY TWP
NJ	SALEM	CARNEYS POINT TWP
NJ	SALEM	ELMER BORO
NJ	SALEM	ELSINBORO TWP
NJ	SALEM	LOWER ALLOWAYS CREEK TWP
NJ	SALEM	LOWER ALLOWAYS CREEK TWP
NJ	SALEM	LOWER ALLOWAYS CREEK TWP
NJ	SALEM	MANNINGTON TWP
NJ	SALEM	OLDMANS TWP
NJ	SALEM	PENNS GROVE BORO
NJ	SALEM	PENNSVILLE TWP
NJ	SALEM	PILESGROVE TWP
NJ	SALEM	PITTSGROVE TWP
NJ	SALEM	QUINTON TWP
NJ	SALEM	QUINTON TWP
NJ	SALEM	SALEM CITY
NJ	SALEM	UPPER PITTSGROVE TWP
NJ	SALEM	UPPER PITTSGROVE TWP
NJ	SALEM	WOODSTOWN BORO

STATE	COUNTY NAME	MUNICIPALITY NAME
PA	BUCKS	BENSALEM TWP.
PA	BUCKS	BRISTOL BORO
PA	BUCKS	BRISTOL TWP.
PA	BUCKS	BUCKINGHAM TWP.
PA	BUCKS	BUCKS COUNTY
PA	BUCKS	CHALFONT BORO
PA	BUCKS	DOYLESTOWN BORO
PA	BUCKS	DOYLESTOWN TWP.
PA	BUCKS	EAST ROCKHILL TWP.
PA	BUCKS	FALLS TWP.
PA	BUCKS	HILLTOWN TWP.
PA	BUCKS	HULMEVILLE BORO
PA	BUCKS	IVYLAND BORO
PA	BUCKS	LANGHORNE BORO
PA	BUCKS	LANGHORNE MANOR BORO
PA	BUCKS	LOWER MAKEFIELD TWP.
PA	BUCKS	LOWER SOUTHAMPTON TWP.
PA	BUCKS	MIDDLETOWN TWP.
PA	BUCKS	MORRISVILLE BORO
PA	BUCKS	NEW BRITAIN BORO
PA	BUCKS	NEW BRITAIN TWP.
PA	BUCKS	NEWTOWN BORO
PA	BUCKS	NEWTOWN TWP.
PA	BUCKS	NORTHAMPTON TWP.
PA	BUCKS	PENNDEL BORO
PA	BUCKS	PERKASIE BORO
PA	BUCKS	PLUMSTEAD TWP.
PA	BUCKS	SELLERSVILLE BORO
PA	BUCKS	SILVERDALE BORO
PA	BUCKS	SOLEBURY TWP.
PA	BUCKS	TULLYTOWN BORO

STATE	COUNTY NAME	MUNICIPALITY NAME
PA	BUCKS	UPPER MAKEFIELD TWP.
PA	BUCKS	UPPER SOUTHAMPTON TWP.
PA	BUCKS	WARMINSTER TWP.
PA	BUCKS	WARRINGTON TWP.
PA	BUCKS	WARWICK TWP.
PA	BUCKS	WEST ROCKHILL TWP.
PA	BUCKS	WRIGHTSTOWN TWP.
PA	BUCKS	YARDLEY BORO
PA	CHESTER	AVONDALE BORO
PA	CHESTER	BIRMINGHAM TWP.
PA	CHESTER	CALN TWP.
PA	CHESTER	CHARLESTOWN TWP.
PA	CHESTER	CHESTER COUNTY
PA	CHESTER	COATESVILLE CITY
PA	CHESTER	DOWNINGTOWN BORO
PA	CHESTER	EAST BRADFORD TWP.
PA	CHESTER	EAST BRANDYWINE TWP.
PA	CHESTER	EAST CALN TWP.
PA	CHESTER	EAST FALLOWFIELD TWP.
PA	CHESTER	EAST GOSHEN TWP.
PA	CHESTER	EAST MARLBOROUGH TWP.
PA	CHESTER	EAST PIKELAND TWP.
PA	CHESTER	EAST VINCENT TWP.
PA	CHESTER	EAST WHITELAND TWP.
PA	CHESTER	EASTTOWN TWP.
PA	CHESTER	FRANKLIN TWP.
PA	CHESTER	HONEYBROOK TWP.
PA	CHESTER	KENNETT SQUARE BORO
PA	CHESTER	KENNETT TWP.
PA	CHESTER	LONDON BRITAIN TWP.
PA	CHESTER	LONDON GROVE TWP.

STATE	COUNTY NAME	MUNICIPALITY NAME	STATE	COUNTY NAME	MUNICIPALITY NAME
PA	CHESTER	MALVERN BORO	PA	CHESTER	WESTTOWN TWP.
PA	CHESTER	MODENA BORO	PA	CHESTER	WILLISTOWN TWP.
PA	CHESTER	NEW GARDEN TWP.	PA	DELAWARE	ALDAN BORO
PA	CHESTER	NEW LONDON TWP.	PA	DELAWARE	ASTON TWP.
PA	CHESTER	NEWLIN TWP.	PA	DELAWARE	BETHEL TWP.
PA	CHESTER	PARKESBURG BORO	PA	DELAWARE	BROOKHAVEN BORO
PA	CHESTER	PENN TWP.	PA	DELAWARE	CHADDS FORD TWP.
PA	CHESTER	PENNSBURY TWP.	PA	DELAWARE	CHESTER CITY
PA	CHESTER	PHOENIXVILLE BORO	PA	DELAWARE	CHESTER HEIGHTS BORO
PA	CHESTER	POCOPSON TWP.	PA	DELAWARE	CHESTER TWP.
PA	CHESTER	SADSBURY TWP.	PA	DELAWARE	CLIFTON HEIGHTS BORO
PA	CHESTER	SCHUYLKILL TWP.	PA	DELAWARE	COLLINGDALE BORO
PA	CHESTER	SOUTH COATESVILLE BORO	PA	DELAWARE	COLWYN BORO
PA	CHESTER	SPRING CITY BORO	PA	DELAWARE	CONCORD TWP.
PA	CHESTER	THORNBURY TWP.	PA	DELAWARE	DARBY BORO
PA	CHESTER	TREDYFFRIN TWP.	PA	DELAWARE	DARBY TWP.
PA	CHESTER	UPPER OXFORD TWP.	PA	DELAWARE	DELAWARE COUNTY
PA	CHESTER	UPPER UWCHLAN TWP.	PA	DELAWARE	EAST LANSDOWNE BORO
PA	CHESTER	UWCHLAN TWP.	PA	DELAWARE	EDDYSTONE BORO
PA	CHESTER	VALLEY TWP.	PA	DELAWARE	EDGEMONT TWP.
PA	CHESTER	WALLACE TWP.	PA	DELAWARE	FOLCROFT BORO
PA	CHESTER	WEST BRADFORD TWP.	PA	DELAWARE	GLENOLDEN BORO
PA	CHESTER	WEST BRANDYWINE TWP.	PA	DELAWARE	HAVERFORD TWP.
PA	CHESTER	WEST CALN TWP.	PA	DELAWARE	LANSDOWNE BORO
PA	CHESTER	WEST CHESTER BORO	PA	DELAWARE	LOWER CHICHESTER TWP.
PA	CHESTER	WEST GOSHEN TWP.	PA	DELAWARE	MARCUS HOOK BORO
PA	CHESTER	WEST GROVE BORO	PA	DELAWARE	MARPLE TWP.
PA	CHESTER	WEST PIKELAND TWP.	PA	DELAWARE	MEDIA BORO
PA	CHESTER	WEST SADSBURY TWP.	PA	DELAWARE	MIDDLETOWN TWP.
PA	CHESTER	WEST VINCENT TWP.	PA	DELAWARE	MILLBOURNE BORO
PA	CHESTER	WEST WHITELAND TWP.	PA	DELAWARE	MORTON BORO

State	**County Name**	**Municipality Name**
PA	Delaware	Nether Providence Twp.
PA	Delaware	Newtown Twp.
PA	Delaware	Norwood Boro
PA	Delaware	Parkside Boro
PA	Delaware	Prospect Park Boro
PA	Delaware	Radnor Twp.
PA	Delaware	Ridley Park Boro
PA	Delaware	Ridley Twp.
PA	Delaware	Rose Valley Boro
PA	Delaware	Rutledge Boro
PA	Delaware	Sharon Hill Boro
PA	Delaware	Springfield Twp.
PA	Delaware	Swarthmore Boro
PA	Delaware	Thornbury Twp.
PA	Delaware	Tinicum Twp.
PA	Delaware	Trainer Boro
PA	Delaware	Upland Boro
PA	Delaware	Upper Chichester Twp.
PA	Delaware	Upper Darby Twp.
PA	Delaware	Upper Providence Twp.
PA	Delaware	Yeadon Boro
PA	Montgomery	Abington Twp.
PA	Montgomery	Ambler Boro
PA	Montgomery	Bridgeport Boro
PA	Montgomery	Bryn Athyn Boro
PA	Montgomery	Cheltenham Twp.
PA	Montgomery	Collegeville Boro
PA	Montgomery	Conshohocken Boro
PA	Montgomery	East Greenville Boro
PA	Montgomery	East Norriton Twp.
PA	Montgomery	Franconia Twp.
PA	Montgomery	Green Lane Boro
PA	Montgomery	Hatboro Boro
PA	Montgomery	Hatfield Boro
PA	Montgomery	Hatfield Twp.
PA	Montgomery	Horsham Twp.
PA	Montgomery	Jenkintown Boro
PA	Montgomery	Lansdale Boro
PA	Montgomery	Limerick Twp.
PA	Montgomery	Lower Frederick Twp.
PA	Montgomery	Lower Gwynedd Twp.
PA	Montgomery	Lower Merion Twp.
PA	Montgomery	Lower Moreland Twp.
PA	Montgomery	Lower Pottsgrove Twp.
PA	Montgomery	Lower Providence Twp.
PA	Montgomery	Lower Salford Twp.
PA	Montgomery	Marlborough Twp.
PA	Montgomery	Montgomery Twp.
PA	Montgomery	Narberth Boro
PA	Montgomery	Norristown Boro
PA	Montgomery	North Wales Boro
PA	Montgomery	Pennsburg Boro
PA	Montgomery	Perkiomen Twp.
PA	Montgomery	Plymouth Twp.
PA	Montgomery	Red Hill Boro
PA	Montgomery	Rockledge Boro
PA	Montgomery	Royersford Boro
PA	Montgomery	Salford Twp.
PA	Montgomery	Schwenksville Boro
PA	Montgomery	Skippack Twp.
PA	Montgomery	Souderton Boro
PA	Montgomery	Springfield Twp.

STATE	COUNTY NAME	MUNICIPALITY NAME
PA	MONTGOMERY	TELFORD BORO
PA	MONTGOMERY	TOWAMENCIN TWP.
PA	MONTGOMERY	TRAPPE BORO
PA	MONTGOMERY	UPPER DUBLIN TWP.
PA	MONTGOMERY	UPPER FREDERICK TWP.
PA	MONTGOMERY	UPPER GWYNEDD TWP.
PA	MONTGOMERY	UPPER HANOVER TWP.
PA	MONTGOMERY	UPPER MERION TWP.
PA	MONTGOMERY	UPPER MORELAND TWP.
PA	MONTGOMERY	UPPER PROVIDENCE TWP.
PA	MONTGOMERY	UPPER SALFORD TWP.
PA	MONTGOMERY	WEST CONSHOHOCKEN BORO.
PA	MONTGOMERY	WEST NORRITON TWP.
PA	MONTGOMERY	WHITEMARSH TWP.
PA	MONTGOMERY	WHITPAIN TWP.
PA	MONTGOMERY	WORCESTER TWP.
PA	PHILADELPHIA	PHILADELPHIA CITY
PA	PHILADELPHIA	PHILADELPHIA COUNTY

Appendix 6

Wasteload Allocation Estimates for Municipal Separate Storm Sewer Systems (MS4s)

A November 22, 2002 EPA Memorandum entitled, "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm water Source and NPDES Permit Requirements Based on Those WLAs" clarified existing regulatory requirements for municipal separate storm sewer systems (MS4s) connected with TMDLs, i.e. that where a TMDL has been developed, the MS4 community must receive a WLA rather than a LA. In the draft TMDL document, EPA identified two options for assigning MS4 WLAs. This Appendix outlines the method used to assign each zone with a single categorical WLA for multiple point sources of storm water discharges.

EPA's regulations require NPDES-regulated storm water discharges to be addressed by the WLA component of a TMDL. In order to estimate the portion of the Load Allocation (LA) that corresponds to separate storm sewer systems (MS4) so that these MS4 allocations could be converted to Wasteload Allocations (WLAs) we considered the land uses within each zone, downstream of the tributary monitoring locations. In order to be consistent with the WLAs, we only considered MS4's likely to discharge to the mainstem Delaware or tidal portions of tributaries. Since delineated MS4 service areas have not been identified for many communities, we assumed that approximately 90% of areas categorized as *High Intensity Residential* area, and 70% of areas categorized as either *Low Intensity Residential* or *Commercial / Industrial / Transportation* are served by MS4 systems. We assumed that the entire PCB load associated with MS4s would correspond to the Non-Point Source Runoff category previously defined. Appendix Figure 6-1 below shows the Non-Point Source area contributing to each Zone. Zone 6 is not included in this analysis, since no Zone 6 WLAs are being developed as part of this TMDL.

Appendix Figure 6-1. Non-point Source Areas by Zone.

In order to determine what portion of Non-Point Source Runoff volume corresponds to MS4 service areas, we computed both MS4 and non-MS4 runoff volumes for the 19 month continuous simulation period using the methodologies contained in *Urban Hydrology for Small Watersheds, Technical Release 55,* Soil Conservation Service (currently, Natural Resources Conservation Service), June 1986. Appendix Table 6-1 below shows the computation of the composite Curve Number (CN) for both the MS4 and non-MS4 areas by zone. Land use categories corresponding to wetlands and open water were not included in the calculation of composite CNs.

Appendix Table 6-1. Computation of Composite Curve Numbers for MS4 and Non-MS4 Areas by Zone.

	Land Use Value	Land Use Category	area (m^2)	CN	% MS4	MS4 Area (m^2)	Non-MS4 Area (M2)	CN x MS4 Area	Composite MS4 CN	CN x Non-MS4 Area	Composite Non-MS4 CN
zone 2	21	Low Intensity Residential	149,942,000	80	70.00%	104,959,400	44,982,600	8,396,752,000		3,598,608,000	
	22	High Intensity Residential	35,470,900	90	90.00%	31,923,810	3,547,090	2,873,142,900		319,238,100	
	23	Commercial/Industrial/Transportation	51,066,300	94	70.00%	35,746,410	15,319,890	3,360,162,540		1,440,069,660	
	32	Quarries/Strip Mines/Gravel Pits	13,057,200	95	0.00%	0	13,057,200	0		1,240,434,000	
	33	Transitional	3,193,340	91	0.00%	0	3,193,340	0		290,593,940	
	41	Deciduous Forest	110,273,000	76	0.00%	0	110,273,000	0		8,380,748,000	
	42	Evergreen Forest	3,564,690	76	0.00%	0	3,564,690	0		270,916,440	
	43	Mixed Forest	52,161,800	76	0.00%	0	52,161,800	0		3,964,296,800	
	81	Pasture/Hay	180,362,000	79	0.00%	0	180,362,000	0		14,248,598,000	
	82	Row Crops	54,280,000	82	0.00%	0	54,280,000	0		4,450,960,000	
	85	Urban/Recreational Grasses	8,976,360	79	0.00%	0	8,976,360	0		709,132,440	
			662,347,590			172,629,620	489,717,970	14,630,057,440	84.75	38,913,595,380	79.46
zone3	21	Low Intensity Residential	43,022,200	80	70.00%	30,115,540	12,906,660	2,409,243,200		1,032,532,800	
	22	High Intensity Residential	52,358,200	90	90.00%	47,122,380	5,235,820	4,241,014,200		471,223,800	
	23	Commercial/Industrial/Transportation	37,042,800	94	70.00%	25,929,960	11,112,840	2,437,416,240		1,044,606,960	
	32	Quarries/Strip Mines/Gravel Pits	104,987	95	0.00%	0	104,987	0		9,973,765	
	33	Transitional	8,749	91	0.00%	0	8,749	0		796,149	
	41	Deciduous Forest	8,324,080	76	0.00%	0	8,324,080	0		632,630,080	
	42	Evergreen Forest	67,075	76	0.00%	0	67,075	0		5,097,685	
	43	Mixed Forest	2,448,720	76	0.00%	0	2,448,720	0		186,102,720	
	81	Pasture/Hay	1,076,110	79	0.00%	0	1,076,110	0		85,012,690	
	82	Row Crops	1,238,450	82	0.00%	0	1,238,450	0		101,552,900	
	85	Urban/Recreational Grasses	2,780,200	79	0.00%	0	2,780,200	0		219,635,800	
			148,471,571			103,167,880	45,303,691	9,087,673,640	88.09	3,789,165,349	83.64
zone4	21	Low Intensity Residential	118,875,000	80	70.00%	83,212,500	35,662,500	6,657,000,000		2,853,000,000	
	22	High Intensity Residential	30,808,700	90	90.00%	27,727,830	3,080,870	2,495,504,700		277,278,300	
	23	Commercial/Industrial/Transportation	65,573,900	94	70.00%	45,901,730	19,672,170	4,314,762,620		1,849,183,980	
	32	Quarries/Strip Mines/Gravel Pits	1,148,050	95	0.00%	0	1,148,050	0		109,064,750	
	33	Transitional	4,413,330	91	0.00%	0	4,413,330	0		401,613,030	
	41	Deciduous Forest	143,833,000	76	0.00%	0	143,833,000	0		10,931,308,000	
	42	Evergreen Forest	4,900,350	76	0.00%	0	4,900,350	0		372,426,600	
	43	Mixed Forest	46,163,000	76	0.00%	0	46,163,000	0		3,508,388,000	
	81	Pasture/Hay	98,138,200	79	0.00%	0	98,138,200	0		7,752,917,800	
	82	Row Crops	37,478,300	82	0.00%	0	37,478,300	0		3,073,220,600	
	85	Urban/Recreational Grasses	15,321,200	79	0.00%	0	15,321,200	0		1,210,374,800	
			566,653,030			156,842,060	409,810,970	13,467,267,320	85.87	32,338,775,860	78.91
zone5	21	Low Intensity Residential	86,418,600	80	70.00%	60,493,020	25,925,580	4,839,441,600		2,074,046,400	
	22	High Intensity Residential	12,247,500	90	90.00%	11,022,750	1,224,750	992,047,500		110,227,500	
	23	Commercial/Industrial/Transportation	48,787,700	94	70.00%	34,151,390	14,636,310	3,210,230,660		1,375,813,140	
	32	Quarries/Strip Mines/Gravel Pits	5,088,940	95	0.00%	0	5,088,940	0		483,449,300	
	33	Transitional	1,818,800	91	0.00%	0	1,818,800	0		165,510,800	
	41	Deciduous Forest	151,311,000	76	0.00%	0	151,311,000	0		11,499,636,000	
	42	Evergreen Forest	8,114,110	76	0.00%	0	8,114,110	0		616,672,360	
	43	Mixed Forest	62,097,600	76	0.00%	0	62,097,600	0		4,719,417,600	
	81	Pasture/Hay	141,668,000	79	0.00%	0	141,668,000	0		11,191,772,000	
	82	Row Crops	198,928,000	82	0.00%	0	198,928,000	0		16,312,096,000	
	85	Urban/Recreational Grasses	18,823,700	79	0.00%	0	18,823,700	0		1,487,072,300	
			735,303,950			105,667,160	629,636,790	9,041,719,760	85.57	50,035,713,400	79.47

Using the composite CNs for MS4 and Non-MS4 areas and daily 24-hour precipitation totals, we computed daily runoff volumes. The daily 24-hour precipitation totals are daily means of the recorded totals from the Wilmington, Philadelphia, and Neshaminy precipitation gages. As indicated in Appendix Table 6-2 below, only storm events exceeding the computed initial abstraction (Ia) for each area result in runoff. Similarly, only days with measurable precipitation are included in Appendix Table 6-2. We summed the total runoff depth for the 19-month continuous simulation period and multiplied by the area to compute a total runoff volume. We computed the percentage of the total volume associated with the MS4 areas by dividing the MS4 runoff volume by the total of the MS4 and Non-MS4 runoff volumes. The percentage of the MS4 runoff volume is shown at the bottom of Appendix Table 6-2 below.

Appendix Table 6-2. Computation of Runoff Volume Generated by MS4s.

		Zone 2		Zone 3		Zone 4		Zone 5	
		MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4	MS4	Non-MS4
	CN	84.75	79.46	88.09	79.46	88.09	83.64	85.87	79.47
	Area (m^2)	172,629,620	489,717,970	103,167,880	45,303,691	156,842,060	409,810,970	105,667,160	629,636,790
	Area (ft^2)	1,858,169,693	5,271,280,154	1,110,489,775	487,644,849	1,688,233,818	4,411,168,398	1,137,391,800	6,777,353,740
	S	1.80	2.58	1.35	2.58	1.35	1.96	1.65	2.58
	Ia	0.36	0.52	0.27	0.52	0.27	0.39	0.33	0.52
Date	Precip. (in)	Runoff (in)							
9/4/2001	0.72	0.060	0.015	0.112	0.015	0.112	0.047	0.075	0.015
9/10/2001	0.02	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9/14/2001	0.63	0.036	0.005	0.077	0.005	0.077	0.027	0.047	0.005
9/20/2001	0.31	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000
9/21/2001	0.13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9/24/2001	0.27	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9/25/2001	0.22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
…	…	…	…	…	…	…	…	…	…
2/21/2003	0.20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2/22/2003	1.96	0.751	0.515	0.936	0.515	0.936	0.696	0.809	0.515
2/23/2003	0.30	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000
2/27/2003	0.02	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2/28/2003	0.05	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3/2/2003	0.83	0.099	0.035	0.165	0.035	0.165	0.082	0.118	0.035
3/5/2003	0.34	0.000	0.000	0.003	0.000	0.003	0.000	0.000	0.000
3/6/2003	0.60	0.029	0.003	0.066	0.003	0.066	0.021	0.039	0.003
3/13/2003	0.04	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3/16/2003	0.04	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3/17/2003	0.04	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3/20/2003	1.55	0.472	0.293	0.620	0.293	0.620	0.429	0.518	0.294
3/21/2003	0.08	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3/26/2003	0.27	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3/28/2003	0.03	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3/29/2003	0.34	0.000	0.000	0.003	0.000	0.003	0.000	0.000	0.000
3/30/2003	0.20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Runoff (in)	4.997	2.397	7.866	2.397	7.866	4.293	5.818	2.399
	Runoff (ft)	0.416447206	0.199708498	0.655529917	0.199708498	0.655529917	0.357726343	0.484831079	0.199887138
	Runoff (ft3)	773,829,578	1,052,719,443	727,959,270	97,386,821	1,106,687,774	1,577,991,140	551,442,894	1,354,705,843
% of Runoff from MS4		**42%**		**88%**		**41%**		**29%**	

The current MS4 loads for the cycling one year period are calculated using the runoff volume ratio as shown in Appendix Table 6-2 and non-point source runoff loads. Then, proportions of MS4 loads to total loads are calculated. Note that the total loads are defined as sum of point and non-point source loads excluding Trenton and Schuylkill boundary and contaminated site loads for this calculation. The existing MS4 load proportions are summarized in Appendix Table 6-3.

Appendix Table 6-3. Existing loads and proportions of MS4 loads by Zone for the cycling one year period.

Estuary Zone	NPS plus MS4 Loads	MS4 Loads	Total Loads* (Point plus Non-Point sources)	Proportion of MS4 loads to Total Loads*
	kg/365days	kg/365days	kg/365days	%
2	1.545	1.545 x 42 % = 0.649	2.688	24.15
3	0.275	0.275 x 88 % = 0.242	2.376	10.17
4	1.186	1.186 x 41 % = 0.486	3.820	12.73
5	1.129	1.129 x 29 % = 0.327	3.409	9.61

** Total loads, indicated here, are defined excluding Trenton and Schuylkill boundary and contaminated sites loads.*

Appendix Table 6-4 shows the Zone TMDLs excluding Trenton and Schuylkill boundary loads. In addition, the Table contains Zone specific MOS, allocations to contaminated site loads and allocatable portion to the rest of point and non-point source categories. The allocations to MS4s are calculated by proportion of MS4 loads to Total Loads shown in Appendix Table 6-3 and Allocatable portion to the rest of categories shown in Appendix Table 6-4. Summary of categorical WLAs and LAs are presented in Table 9 and Table 10 of the main text.

Appendix Table 6-4. Summary of the Zone TMDLs for penta-PCBs excluding Trenton and Schuylkill boundaries.

Estuary Zone	TMDL	MOS	Contaminated Site	Allocatable portion to the rest of categories	Allocations to MS4s
	mg/day	mg/day	mg/day	mg/day	mg/day
Zone 2	6.613	0.331	0.026	6.256	1.511
Zone 3	4.455	0.223	2.416	1.816	0.185
Zone 4	4.569	0.228	1.651	2.689	0.342
Zone 5	12.016	0.601	5.250	6.165	0.592

Amendment to the
Lower Delaware Water Quality Management Plan,
Mercer County Water Quality Management Plan,
Monmouth County Water Quality Management Plan,
Ocean County Water Quality Management Plan, and
Tri-County Water Quality Management Plan

Total Maximum Daily Loads for Fecal Coliform to Address 27 Streams in the Lower Delaware Water Region

Watershed Management Area 17
(Maurice, Salem, and Cohansey Rivers)
Watershed Management Area 18
(Big Timber, Mantua, Oldmans, Pennsauken, Raccoon, and Woodbury Creeks and Cooper River)
Watershed Management Area 19
(Rancocas Creek)
Watershed Management Area 20
(Assiscunk, Crosswicks, and Doctors Creeks)

Proposed: April 21, 2003
Established: June 27, 2003
Approved (by EPA Region 2): September 29, 2003
Adopted:

New Jersey Department of Environmental Protection
Division of Watershed Management
P.O. Box 418
Trenton, New Jersey 08625-0418

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1.0 Executive Summary

In accordance with Section 305(b) of the Federal Clean Water Act (CWA), the State of New Jersey developed the *2002 Integrated List of Waterbodies*, addressing the overall water quality of the State's waters and identifying impaired waterbodies for which Total Maximum Daily Loads (TMDLs) may be necessary. The *2002 Integrated List of Waterbodies* identified several waterbodies in the Lower Delaware Water Region as being impaired by pathogens, as indicated by the presence of fecal coliform concentrations in excess of standards. This report, developed by the New Jersey Department of Environmental Protection (NJDEP), establishes twenty-seven TMDLs addressing fecal coliform loads to the waterbodies identified in Table 1.

Table 1 **Fecal coliform-impaired stream segments in the Lower Delaware Water Region, identified in Sublist 5 of the 2002 Integrated List of Waterbodies, for which fecal coliform TMDLs are being established.**

TMDL Number	WMA	Station Name/Waterbody	Site ID	County(s)	River Miles
1	17	Little Ease Run at Porchtown	01411458	Gloucester	9.2
2	17	Indian Branch near Malaga	01411466	Gloucester	5.2
3	17	Maurice River at Norma	01411500	Salem	10.5
4	17	Maurice River near Millville	01411800	Cumberland	2.1
5	17	Cohansey River at Seeley	01412800	Salem, Cumberland	33.8
6	17	Salem River at Woodstown	01482500	Salem	17.9
7	17	Salem River at Courses Landing	01482537	Salem	13.9
8	17	Two Penny Run near Danceys Corner	01482560	Salem	8.9
9	18	North Branch Pennsauken Creek near Morrestown	01467069	Burlington	10.1
10	18	South Branch Pennsauken Creek at Cherry Hill	01467081	Camden, Burlington	8.5
11	18	Cooper River at Lidenwold	01467120	Camden	1.6
12	18	Cooper River at Haddonfield	01467150	Camden	14.6
13	18	North Branch Cooper River at Kresson	01467155	Camden, Burlington	9.0
14	18	South Branch Big Timber Creek at Glenloch	01467327	Camden, Gloucester	3.9
15	18	South Branch Big Timber Creek at Blackwood Terrace	01467329	Camden, Gloucester	9.8
16	18	North Branch Big Timber Creek at Glendora	01467359	Camden, Gloucester	18.1
17	18	Still Run near Mickelton	01476600	Gloucester	5.9
18	18	Raccoon Creek near Swedesboro	01477120	Gloucester	8.2
19	18	Oldmans Creek at Jessups Mill	01477440	Salem, Gloucester	7.2
20	18	Oldmans Creek at Porches Mill	01477510	Salem, Gloucester	16.2
21	19	Sharps Run at Rt 541 at Medford	01465884	Burlington	4.1
22	19	North Branch Rancocas Creek at Pine St at Mt Holly	01467006	Burlington	6.5
23	20	Crosswicks Creek at Groveville Rd.	01464504	Monmouth, Mercer, Burlington, Ocean	12.4
24	20	Doctors Creek at Allentown	01464515	Monmouth, Mercer	15.7
25	20	Bacons Creek near Mansfield Square	01464529	Burlington	7.4
26	20	Annaricken Brook near Jobstown	01464578	Burlington	3.7
27	20	North Branch Barkers Brook near Jobstown	01464583	Burlington	4.8

TMDL Number	WMA	Station Name/Waterbody	Site ID	County(s)	River Miles
Total River Miles					270

These twenty-seven TMDLs will serve as management approaches or restoration plans aimed at identifying the sources of fecal coliform and for setting goals for fecal coliform load reductions in order to attain applicable surface water quality standards (SWQS).

As stated in N.J.A.C. 7:9B-1.14(c) of the New Jersey Surface Water Quality Standards, "Fecal coliform levels shall not exceed a geometric average of 200 CFU/100 ml nor should more than 10 percent of the total sample taken during any 30-day period exceed 400 CFU/100 ml in FW2 waters." Nonpoint and stormwater point sources are the primary contributors to fecal coliform loads in these streams and can include storm-driven loads transporting fecal coliform from sources such as geese, farms, and domestic pets to the receiving water. Nonpoint sources also include steady-inputs from sources such as failing sewage conveyance systems and failing or inappropriately located septic systems. Because the total point source contribution other than stormwater (i.e. Publicly-Owned Treatment Works, POTWs) is an insignificant fraction of a percent of the total load, these fecal coliform TMDLs will not impose any change in current practices for POTWs and will not result in changes to existing effluent limits.

Using ambient water quality data monitoring conducted during the water years 1994-2002, summer and all season geometric means were determined for each Category 5 listed segment. Given the two surface water quality criteria of 200 CFU/100 ml and 400 CFU/100 ml in FW2 waters, computations were necessary for both criteria and resulted in two values for percent reduction for each stream segment. The higher (more stringent) percent reduction value was selected as the TMDL and will be applied to nonpoint and stormwater point sources as a whole or apportioned to categories of nonpoint and stormwater point sources within the study area. The extent to which nonpoint and stormwater point sources have been identified or need to be identified or verified varies by segment based on data availability, watershed size and complexity, and pollutant sources. Implementation strategies to achieve SWQS are addressed in this report.

Each TMDL shall be proposed and adopted by the Department as an amendment to the appropriate area wide water quality management plan(s) in accordance with N.J.A.C. 7:15-3.4(g).

This TMDL Report is consistent with the United States Environmental Protection Agency's (USEPA's) May 20, 2002 guidance document entitled: "Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992," (Suftin, 2002) which describes the statutory and regulatory requirements for approvable TMDLs.

2.0 Introduction

Sublist 5 (also known as Category 5 or, traditionally, the 303(d) List) of the State of New Jersey's proposed *2002 Integrated List of Waterbodies* identified several waterbodies in the Lower Delaware Water Region as being impaired by pathogens, as evidenced by the presence of high fecal coliform concentrations. This report establishes twenty-seven TMDLs, which address fecal coliform loads to the identified waterbodies. These TMDLs serve as management approaches or restoration plans aimed toward reducing loadings of fecal coliform from various sources in order to attain applicable surface water quality standards for the pathogen indication. Several of these waterbodies are listed in Sublist 5 for impairment caused by other pollutants. These TMDLs address only fecal coliform impairments. Separate TMDL evaluations will be developed to address the other pollutants of concern. The waterbodies will remain on Sublist 5 with respect to these pollutants until such time as TMDL evaluations for all pollutants have been completed and approved by USEPA. With respect to the fecal coliform impairment, the waterbodies will be moved to Sublist 4 following approval of the TMDLs by USEPA.

3.0 Background

In accordance with Section 305(b) of the Federal Clean Water Act (CWA) (33 U.S.C. 1315(B)), the State of New Jersey is required to biennially prepare and submit to the USEPA a report addressing the overall water quality of the State's waters. This report is commonly referred to as the 305(b) Report or the Water Quality Inventory Report.

In accordance with Section 303(d) of the CWA, the State is also required to biennially prepare and submit to USEPA a report that identifies waters that do not meet or are not expected to meet surface water quality standards (SWQS) after implementation of technology-based effluent limitations or other required controls. This report is commonly referred to as the 303(d) List. In November 2001, USEPA issued guidance that encouraged states to integrate the 305(b) Report and the 303(d) List into one report. This integrated report assigns waterbodies to one of five categories. In general, Sublists 1 through 4 include waterbodies that are unimpaired, have limited assessment or data availability or have a range of designated use impairments, whereas Sublist 5 constitutes the traditional 303(d) List for waters impaired or threatened by one or more pollutants. The Department chose to develop an Integrated Report for New Jersey. New Jersey's proposed *2002 Integrated List of Waterbodies* is based upon these five categories and identifies water quality limited surface waters in accordance with N.J.A.C. 7:15-6 and Section 303(d) of the CWA. Water quality limited waterbodies require total maximum daily load (TMDL) evaluations.

A Total Maximum Daily Load (TMDL) represents the assimilative or carrying capacity of a waterbody, taking into consideration point and nonpoint sources of pollutants of concern, natural background and surface water withdrawals. A TMDL quantifies the amount of a pollutant a water body can assimilate without violating a state's water quality standards and allocates that load capacity to known point and nonpoint sources in the form of wasteload allocations (WLAs), load allocations (LAs), and a margin of safety. A TMDL is developed as a mechanism for identifying all the contributors to surface water quality impacts and setting goals for load reductions for pollutants of concern as necessary to meet the SWQS.

Recent EPA guidance (Suftin, 2002) describes the statutory and regulatory requirements for approvable TMDLs, as well as additional information generally needed for USEPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations. The Department believes that the TMDLs in this report address the following items in the May 20, 2002 guideline document:

1. Identification of waterbody(ies), pollutant of concern, pollutant sources and priority ranking.
2. Description of applicable water quality standards and numeric water quality target(s).
3. Loading capacity – linking water quality and pollutant sources.
4. Load allocations.
5. Wasteload allocations.
6. Margin of safety.
7. Seasonal variation.
8. Reasonable assurances.
9. Monitoring plan to track TMDL effectiveness.
10. Implementation (USEPA is not required to and does not approve TMDL implementation plans).
11. Public Participation.

4.0 Pollutant of Concern and Area of Interest

The pollutant of concern for these TMDLs is pathogens, the presence of which is indicated by elevated concentrations of fecal coliform bacteria. Fecal coliform concentrations were found to exceed New Jersey's Surface Water Quality Standards (SWQS), published at N.J.A.C. 7-9B et seq., for the segments in the Lower Delaware Water Region identified in Table 2. As reported in the proposed *2002 Integrated List of Waterbodies*, also identified in Table 2 are the river miles and management response associated with each listed segment. All of these waterbodies have a high priority ranking, as described in the *2002 Integrated List of Waterbodies*.

Table 2 **Abridged Sublist 5 of the 2002 Integrated List of Waterbodies, listed for fecal coliform impairment in the Lower Delaware Water Region.**

TMDL No.	WMA	Station Name/Waterbody	Site ID	River Miles	Management Response
1	17	Little Ease Run at Porchtown	1411458	9.2	establish TMDL
2	17	Indian Branch near Malaga	1411466	5.2	establish TMDL
3	17	Maurice River at Norma	1411500	10.5	establish TMDL
4	17	Maurice River near Millville	1411800	2.1	establish TMDL
	17	Buckshutem Creek near Laurel Lake	1411950	11.5	water quality monitoring needed to identify if an impairment exists;

TMDL No.	WMA	Station Name/Waterbody	Site ID	River Miles	Management Response
					move to Sublist 3
5	17	Cohansey River at Seeley	1412800	33.8	establish TMDL
6	17	Salem River at Woodstown	1482500	17.9	establish TMDL
7	17	Salem River at Courses Landing	1482537	13.9	establish TMDL
8	17	Two Penny Run near Danceys Corner	1482560	8.9	establish TMDL
9	18	North Branch Pennsauken Creek near Morrestown	1467069	10.1	establish TMDL
10	18	South Branch Pennsauken Creek at Cherry Hill	1467081	8.5	establish TMDL
11	18	Cooper River at Lidenwold	1467120	1.6	establish TMDL
12	18	Cooper River at Haddonfield	1467150	14.6	establish TMDL
13	18	North Branch Cooper River at Kresson	1467155	9.0	establish TMDL
14	18	South Branch Big Timber Creek at Glenloch	1467327	3.9	establish TMDL
15	18	South Branch Big Timber Creek at Blackwood Terrace	1467329	9.8	establish TMDL
16	18	North Branch Big Timber Creek at Glendora	1467359	18.1	establish TMDL
17	18	Still Run near Mickelton	1476600	5.9	establish TMDL
18	18	Raccoon Creek near Swedesboro	1477120	8.2	establish TMDL
19	18	Oldmans Creek at Jessups Mill	1477440	7.2	establish TMDL
20	18	Oldmans Creek at Porches Mill	1477510	16.2	establish TMDL
21	19	Sharps Run at Rt 541 at Medford	1465884	4.1	establish TMDL
	19	North Branch Rancocas Creek at Browns Mills	1465970	3.3	water quality monitoring needed to identify if an impairment exists; move to Sublist 3.
22	19	North Branch Rancocas Creek at Pine St at Mt Holly	1467006	6.5	establish TMDL
23	20	Crosswicks Creek at Groveville Rd.	1464504	12.4	establish TMDL
24	20	Doctors Creek at Allentown	1464515	15.7	establish TMDL
25	20	Bacons Creek near Mansfield Square	1464529	7.4	establish TMDL
26	20	Annaricken Brook near Jobstown	1464578	3.7	establish TMDL
27	20	North Branch Barkers Brook near Jobstown	1464583	4.8	establish TMDL

These twenty-seven TMDLs will address 270 river miles or approximately 95% of the total river miles listed as impaired relative to fecal coliform (285 total fecal coliform impaired river miles) in the Lower Delaware watershed region. Based on a detailed county hydrography stream coverage, 748 stream miles, or 15% of the stream segments in the Lower Delaware region (5164 total miles) are directly affected by the TMDLs due to the fact that the implementation plans cover entire watersheds; not just impaired waterbody segments.

Table 2, identifies two segments (the North Branch Rancocas Creek at Browns Mills #01465970 and Buckshutem Creek near Laurel Lake #01411950) for which TMDLs will not be developed at this time based on investigations following the *2002 Integrated List of Waterbodies* proposal. These segments are identified as needing further monitoring to confirm impairment and will be moved to Sublist 3 of the 2002 Integrated List of Waterbodies. Appendix A provides a further discussion of these segments.

4.1. Description of the Lower Delaware Water Region and Sublist 5 Waterbodies

The Lower Delaware Region includes the Delaware River, Delaware Bay and numerous tributaries from Trenton to southern Cumberland County. The Lower Delaware Region is one of diversity, comprised of a mixture of suburban areas, urban centers, agricultural land, rural towns, forests, and the protected Pinelands ecosystem.

Included in the Lower Delaware Region are large portions of Burlington, Camden, Cumberland, Gloucester, and Salem Counties, as well as parts of Mercer, Monmouth, Ocean and Atlantic Counties. These counties are divided into Watershed Management Area (WMA) 17 (Maurice, Salem, Cohansey), WMA 18 (Lower Delaware Tributaries), WMA 19 (Rancocas Creek) and WMA 20 (Assiscunk, Crosswicks, Doctors Creeks).

4.1.1. Watershed Management Area 17

WMA 17 includes the Cohansey River, Maurice River, Salem River and Alloway, Dividing, Manantico, Manumuskin, Miles, Mill, Stow and Whooping Creeks. This area includes portions of Atlantic, Cumberland, Gloucester, and Salem counties, over 39 municipalities and encompasses 885 square miles.

The Cohansey River, which drains 105 square miles of eastern Salem County, is nearly 30 miles long from its headwaters to Delaware Bay. From the headwaters in Salem County, through Bridgeton, an urban center in Cumberland County, to its mouth in Delaware Bay, it is the second largest river in Cumberland County. The Cohansey River watershed is an area of very low relief, which results in numerous small tributaries. Sunset Lake and Mary Elmer Lake are among 20 major impoundments in this drainage basin. The majority of the land use in this watershed is agriculture, while much of the undeveloped area remains forested.

The Maurice River has a drainage area of 386 square miles and meanders south for 50 miles through Cumberland County to the Delaware Bay. The major tributaries of this river are Scotland Run, Manantico Creek, Muskee Creek, Muddy Run, and the Manumuskin River. Agriculture is also the principal land use in this watershed. Land use in the upper portion of the basin is 48% forested, 27% agricultural, and 25% developed or barren. Portions of the river have been nationally designated as Wild and Scenic. The main stem and tributaries flow through Vineland and Millville, which are local centers of development.

The Salem River drains an area of 114 square miles and flows 32 miles from Upper Pittsgrove Township west to Deepwater, then south to the Delaware River. Much of the lower portions of the river are tidal. Major tributaries of the Salem River include Mannington Creek, Game Creek, Majors Run, and Fenwick Creek. Land use is 43% agricultural, 10% forested and 33% wetlands, and 13% urban/suburban. The major urban center is Salem City.

Sublist 5 Waterbodies in WMA 17

Eight of the twenty-seven impaired waterbody segments addressed in this report are located in WMA 17. Included are the Little Ease Run (#01411458), Indian Branch (#01411466), Maurice River (#01411500 and #01411800), Cohansey River (#01412800), Salem River (#01482500 and #01482537), and Two Penny Run (#01482560). The spatial extent of each segment is identified in Figure 1 and described in Table 3. River miles, watershed sizes and land use/land cover by percent area associated with each segment are listed in Table 4.

Figure 1 Spatial extent of Sublist 5 segments for which TMDLs are being developed in WMA 17.

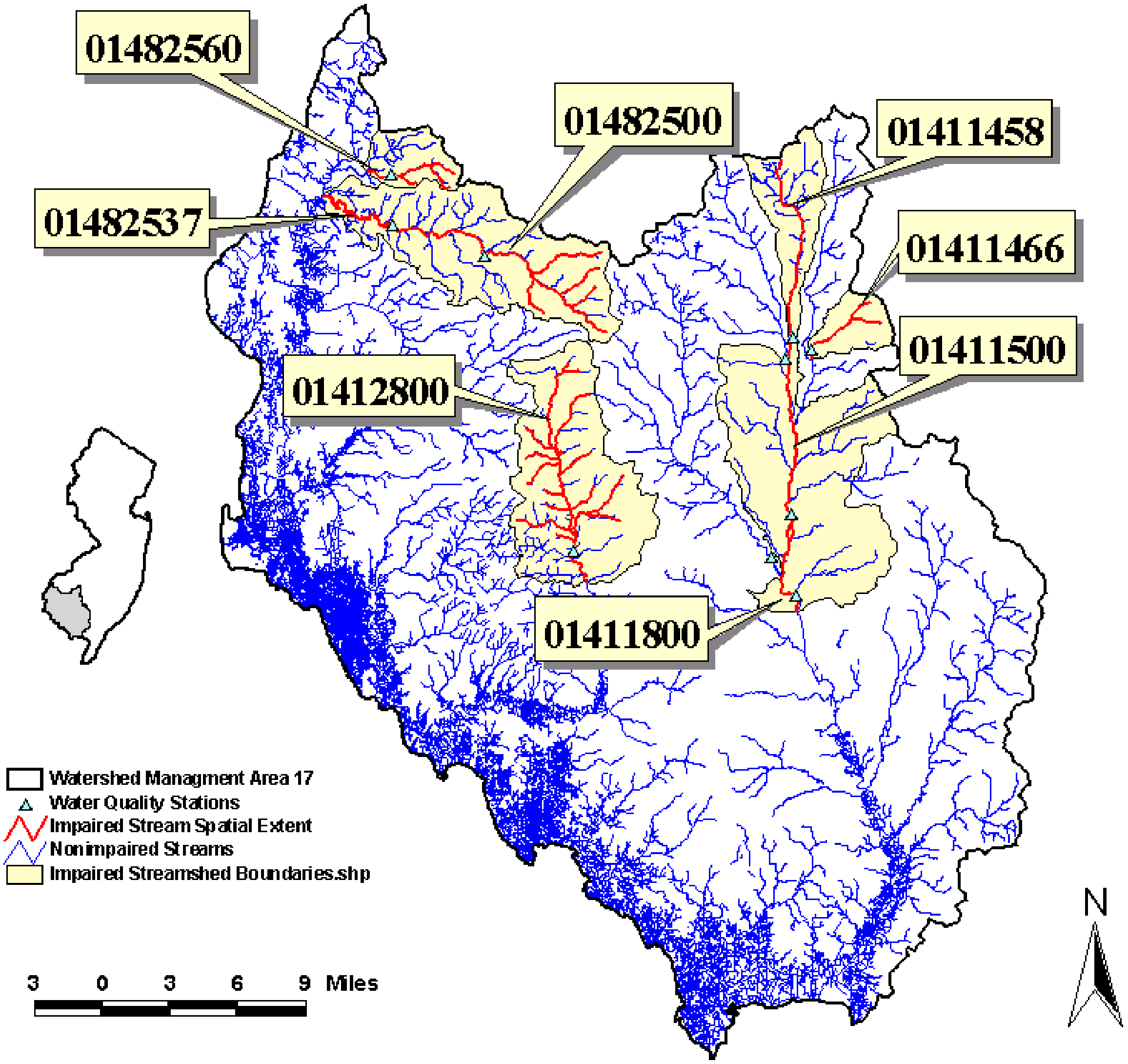


Table 3 **Description of the spatial extent for each Sublist 5 segment, listed for fecal coliform, in WMA 17.**

Segment ID	Watershed area associated with impaired stream segments
01411458, 01411500, 01411800	Mainstem Maurice River watershed upstream of Union Lake.
01411466	The Indian Branch watershed upstream of Malaga Lake.
01412800	The Cohansey River watershed upstream of Sunset Lake
01482500, 01482537	Salem River watershed upstream of its confluence with Game Creek.
01482560	Two Penny Run watershed downstream to Laytons Lake

Table 4 **River miles, Watershed size, and Anderson Land Use classification for eight Sublist 5 segments, listed for fecal coliform, in WMA 17.**

	Segment ID				
	01411458, 01411500, 01411800	**01411466**	**01412800**	**01482500 01482537**	**01482560**
Sublist 5 impaired river miles (miles)	21.9	5.2	33.8	31.8	8.9
Total river miles within the delineated watershed and included in the implementation plan (miles)	88.2	5.9	67.4	73.5	178
Watershed size (acres)	44270	4235	26907	27211	4989
Land Use/ Land Cover					
Agriculture	18.0%	8.4%	69.4%	65.7%	55.4%
Barren Land	1.2%	0.1%	0.3%	0.1%	0.3%
Forest	34.1%	46.3%	12.7%	9.8%	9.7%
Urban	27.9%	16.5%	9.9%	9.9%	8.0%
Water	0.9%	0.0%	0.6%	1.4%	1.2%
Wetlands	17.9%	28.7%	7.2%	13.2%	25.4%

4.1.2. Watershed Management Area 18

WMA 18 includes the Cooper River, Big Timber, Mantua, Newton, Oldmans, Pennsauken, Pompeston, Raccoon, Repaupo, and Woodbury Creeks, as well as Baldwin Run, Swede Run and Maple Swamp. WMA 18 covers all or parts of Burlington, Camden and Gloucester counties, including 68 municipalities covering 391 square miles.

The Cooper River is 16 miles long, and its watershed encompasses an area of 40 square miles. The river flows through Camden County to the Delaware River at Camden City. The largest tributaries are the North Branch Cooper River and Tindale Run. Extensive development exists along the main stem and areas adjacent to the North Branch. Major impoundments are present such as Cooper River Lake, Kirkwood Lake, Evans Pond, Linden Lake, Hopkins Pond, and Square Circle Lake. The land use within the Cooper River watershed is primarily urban and suburban.

Big Timber Creek drains an area of 63 square miles. The main stem and most of the South Branch divide Gloucester and Camden counties before flowing into the Delaware River near Brooklawn, south of Camden City. Major tributaries include Otter Creek, Beaver Brook, and Almonesson Creek. Major impoundments are Blackwood Lake, Grenloch Lake, Hirsch Pond, and Nash's Lake. This watershed is primarily urban/suburban with forested areas at the headwaters and urban areas at the mouth of Big Timber Creek.

Mantua Creek drains an area of 50.9 square miles of land. From its headwaters in Glassboro, Mantua Creek flows 18.6 miles northwest to the Delaware River at Paulsboro. Major tributaries include the Chestnut Branch (7 miles long), Edwards Run (6.9 miles long) and Duffield Run which drains 2.3 square miles (Information provided by the Federation of Gloucester County Watersheds). Land use is urban/suburban along the main branch and most of Chestnut Branch, and agriculture along Edwards Run.

Oldmans Creek drains an area of 44 square miles and flows to the Delaware River. This creek is 20 miles long and marks the boundary between Gloucester and Salem counties. Tidal marshes exist at the mouth of this creek, while the western third of Oldmans Creek is tidal. Major tributaries include Kettle Run and Beaver Creek. For the most part, Oldmans Creek watershed is agricultural and forested, with some residential and industrial development.

The Pennsauken Creek drains 33 square miles of southwestern Burlington County and northern Camden County. This creek flows into the Delaware River near Palmyra. The North Branch of the Pennsauken is in Burlington County, while the South Branch is the boundary between Burlington and Camden Counties. Industry is concentrated at the mouth of the Pennsauken Creek. Much of the watershed is developed as urban/suburban development, with the remainder divided between agricultural and forested land.

The Raccoon Creek watershed is approximately 40 square miles and drains central Gloucester County. The creek itself is 19 miles long and flows from Elk Township to the Delaware River. While there are several minor tributaries, the most significant of these is the South Branch of the Raccoon Creek. Much of the lower half of Raccoon Creek is tidal, and at the mouth are a number of tidal marshes. Evan Lake, Mullica Hill Pond, and Swedesboro Lake are among the many small lakes and ponds in this area. The land use is primarily agricultural, with industrial areas located along the creek's tidal sections.

Woodbury Creek is approximately five miles in length and drains an area of 18 square miles. Woodbury Creek contains two major tributaries: Hessian Run and Matthews Branch. Land use in the Woodbury Creek watershed is characterized by commercial, urban and suburban development. Woodbury Creek is the most densely developed watershed in Gloucester County. Much of the land along the main stem is publicly owned and is used for parks, lakes, active recreation, and conservation areas.

Sublist 5 Waterbodies in WMA 18

Twelve of the twenty-seven TMDLs in the Lower Delaware Region are located in WMA 18. Impaired stream segments include: Pennsauken Creek (#01467069, #01467081), Cooper River (#01467120, #01467150, #01467155), Big Timber Creek (#01467327, #01467329, #01467359), Still Run, (#01476600), Raccoon Creek (#01477120), and Oldmans Creek (#01477440, #01477510). Several of these stream segments are geographically located in close proximity, thus, when these segments were found to contain similar levels of bacteria contamination (geometric mean value), water quality data from these segments were grouped when calculating the TMDL. The spatial extent of each segment is identified in Figure 2 and described in Table 5. River miles, watershed sizes and land use/land cover by percent area associated with each segment are listed in Table 6.

Figure 2 Spatial extent of Sublist 5 segments for which TMDLs are being developed in WMA 18

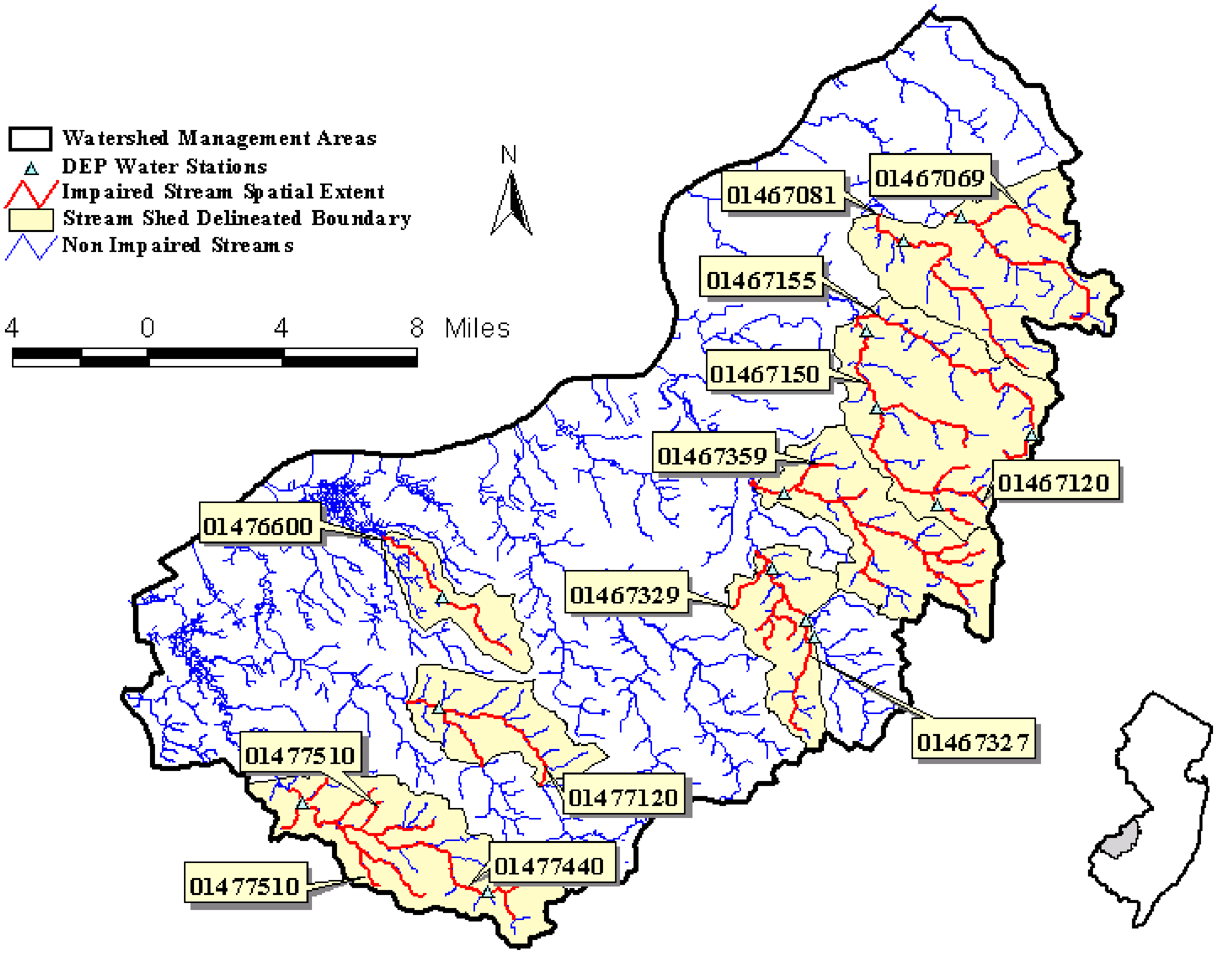


Table 5 **Description of the spatial extent for each Sublist 5 segment, listed for fecal coliform, in WMA 18.**

Segment ID	Watershed area associated with impaired stream segments
01467081, 01467069	North Branch Pennsauken Creek and South Branch Pennsauken Creek watersheds from their respective headwaters to the head-of-tide in each stream.
01467120, 01467150, 01467155	The Cooper River and North Branch Cooper River watersheds upstream of the confluence of the Cooper River with the North Branch Cooper River.
01467327, 01467329	The South Branch of Big Timber Creek watershed upstream of the head-of-tide.
01467359	The North Branch Big Timber Creek watershed upstream of the confluence

	of the North and South Branches of Big Timber Creek.
01476600	Still Run watershed to the confluence of London Branch with Still Run (also named "Repaupo Creek).
01477120	From the head of tide on Raccoon Creek approximately 6 miles upstream on Raccoon Creek and approximately 2.2 miles upstream on the South Branch Raccoon Creek.
01477440, 01477510	Oldmans Creek watershed to the head-of-tide downstream of Jessups Mill

Table 6 River miles, Watershed size, and Anderson Land Use classification for twelve Sublist 5 segments, listed for fecal coliform, in WMA 18.

	Segment ID						
	01467081 01467069	**01467120 01467150 01467155**	**01467327 01467329**	**01467359**	**01476600**	**01477120**	**01477440 01477510**
Sublist 5 impaired river miles (miles)	28.8	25.2	13.7	18.1	5.9	8.2	23.5
Total river miles within the delineated watershed and included in the implementation plan (miles)	42.5	45.2	20.7	31.4	15.3	19.3	37.6
Watershed size (acres)	16584	18484	7151	12560	4634	7265	14897
<u>Land Use/ Land Cover</u>							
Agriculture	4.0%	2.3%	5.8%	1.2%	56.8%	45.5%	53.2%
Barren Land	1.0%	2.2%	2.6%	2.5%	0.2%	2.1%	0.7%
Forest	7.9%	15.3%	20.1%	23.3%	11.9%	19.2%	18.5%
Urban	71.2%	67.8%	59.3%	62.5%	15.2%	24.0%	13.8%
Water	0.8%	0.7%	1.1%	1.0%	1.3%	0.4%	0.6%
Wetlands	15.2%	11.8%	11.1%	9.5%	14.6%	8.8%	13.2%

4.1.3. Watershed Management Area 19

WMA 19, the Rancocas Creek Watershed, is the largest watershed in south central New Jersey and is comprised of Mill Creek and the North Branch, South Branch and main stem of Rancocas Creek. Portions of Burlington, Camden and Ocean counties, and approximately 33 municipalities, are within this management area which covers 360 square miles, and reaches deep into the Pinelands Preservation Area.

Of the 360 square miles, the North Branch drains 167 square miles, and 144 miles is drained by the South Branch. The North Branch, 31 miles in length, is fed by the Greenwood Branch, McDonalds Branch and Mount Misery Brook. The major tributaries of the South Branch include the Southwest Branch Rancocas Creek, Jade Run, Haynes Creek, and Friendship Creek. The South/Southwest Branches are approximately 13 miles long. The drainage area is 144 square miles.

The main stem of Rancocas Creek flows approximately 8 miles, draining an area of about 49 square miles before emptying into the Delaware River at Delanco and Riverside. Tidal influence occurs for about 15 stream miles, extending through the entire length of the main stem (8 miles) to the dam at Mount Holly on the North Branch, Vincentown on the South Branch, and Kirby Mills on the Southwest Branch. Land use within the Rancocas Creek Watershed is 40% forested, with the remainder comprised of 30% developed land and 17% devoted to agricultural use, including cranberry cultivation.

Sublist 5 Waterbodies in WMA 19

Two of the twenty-seven TMDLs in this report are located in WMA 19. Included are Sharps Run, a tributary to the South Branch Rancocas Creek (#01465884), and a segment of the North Branch Rancocas Creek (#01467006). The spatial extent of each segment is identified in Figure 3 and described in Table 7. River miles, watershed sizes and land use/land cover by percent area associated with each segment are listed in Table 8.

Figure 3 **Spatial extent of Sublist 5 segments for which TMDLs are being developed in WMA 19**

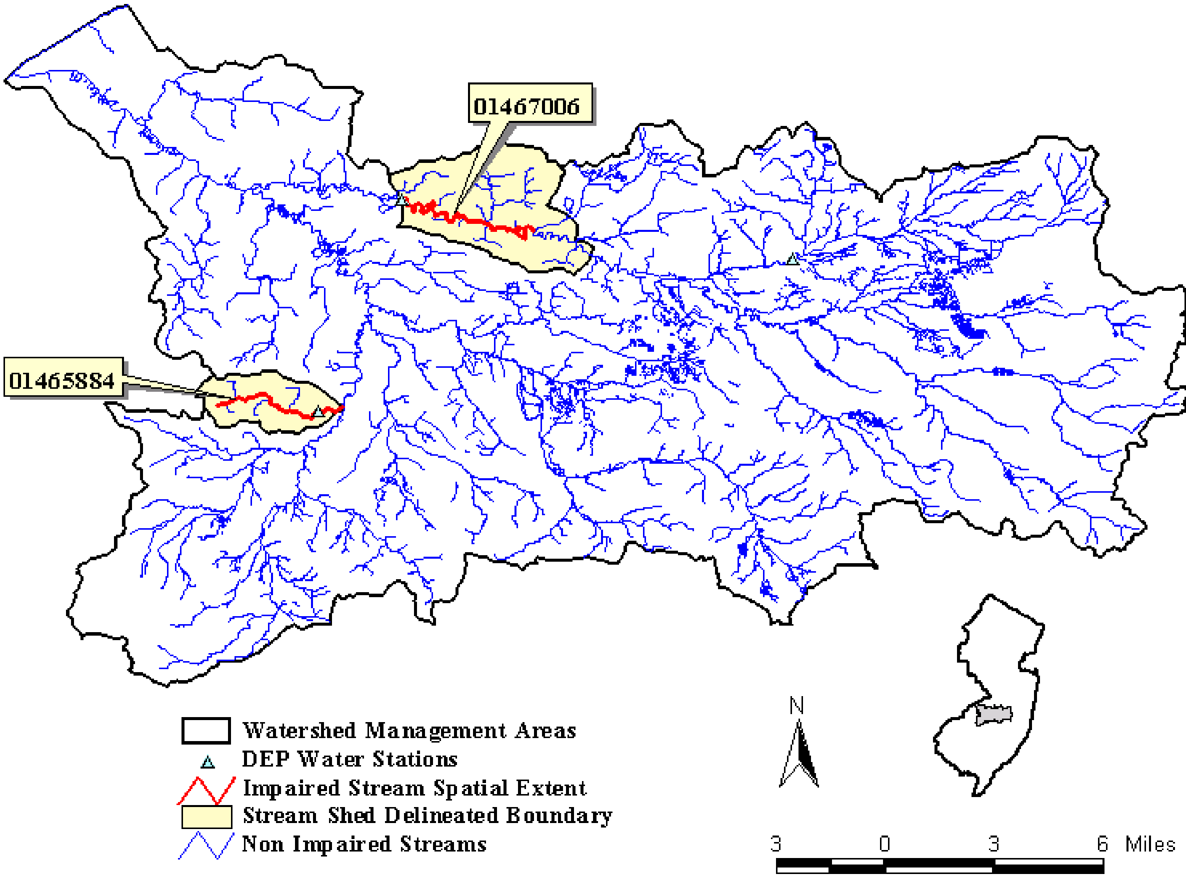


Table 7 **Description of the spatial extent for each Sublist 5 segment, listed for fecal coliform, in WMA 19.**

Segment ID	**Watershed area associated with impaired stream segments**
01465884	Sharps Run watershed downstream to the confluence of Sharps Run with the South Branch Rancocas Creek.
01467006	The North Branch Rancocas Creek watershed area contained between the confluence of Indian Run with the North Branch Rancocas Creek to the town of Mount Holly.

Table 8 **River miles, Watershed size, and Anderson Land Use classification for two Sublist 5 segments, listed for fecal coliform, in WMA 19.**

	Segment ID	
	01465884	**01467006**
Sublist 5 impaired river miles (miles)	4.1	6.5
Total river miles within the delineated watershed and included in the implementation plan (miles)	7.3	27.1
Watershed size (acres)	3079	8256
Land Use/Land Cover		
Agriculture	19.9%	34.7%
Barren Land	0.4%	2.9%
Forest	7.3%	14.9%
Urban	23.3%	24.3%
Water	0.3%	1.5%
Wetlands	48.9%	21.7%

4.1.4. Watershed Management Area 20

WMA 20 includes the Assiscunk, Blacks, Crafts, Crosswicks, Doctors, Duck and Mill Creeks. This watershed management area is comprised of 26 municipalities spanning four counties: Burlington, Mercer, Monmouth and Ocean encompassing 253 square miles. Crosswicks Creek, entering the Delaware River at Bordentown, is 25 miles long and drains an area of 146 square miles. Major tributaries include Jumping Brook, Lahaway Creek, North Run and Doctors Creek. Tides affect this stream up to the Crosswicks Mill Dam. Allentown Lake, Oxford Lake, Prospertown Lake, and Imlaystown Lake are major impoundments in the Crosswicks Creek Watershed. Important land uses in this watershed include agriculture, residential/commercial development and military installations, with the remainder covered by woodland areas.

Sublist 5 Waterbodies WMA 20

Five of the twenty-seven TMDLs in this report are located in WMA 20. Included are segments in the Crosswicks Creek (#01464504), Doctors Creek (#01464515), Bacons Creek (#01464529), Annaricken Brook (#01464578), and North Branch Barkers Brook (#01464583). The spatial extent of each segment is identified in Figure 4 and described in Table 9. River miles, watershed sizes and land use/land cover by percent area associated with each segment are listed in Table 10.

Figure 4 **Spatial extent of Sublist 5 segments for which TMDLs are being developed in WMA 20**

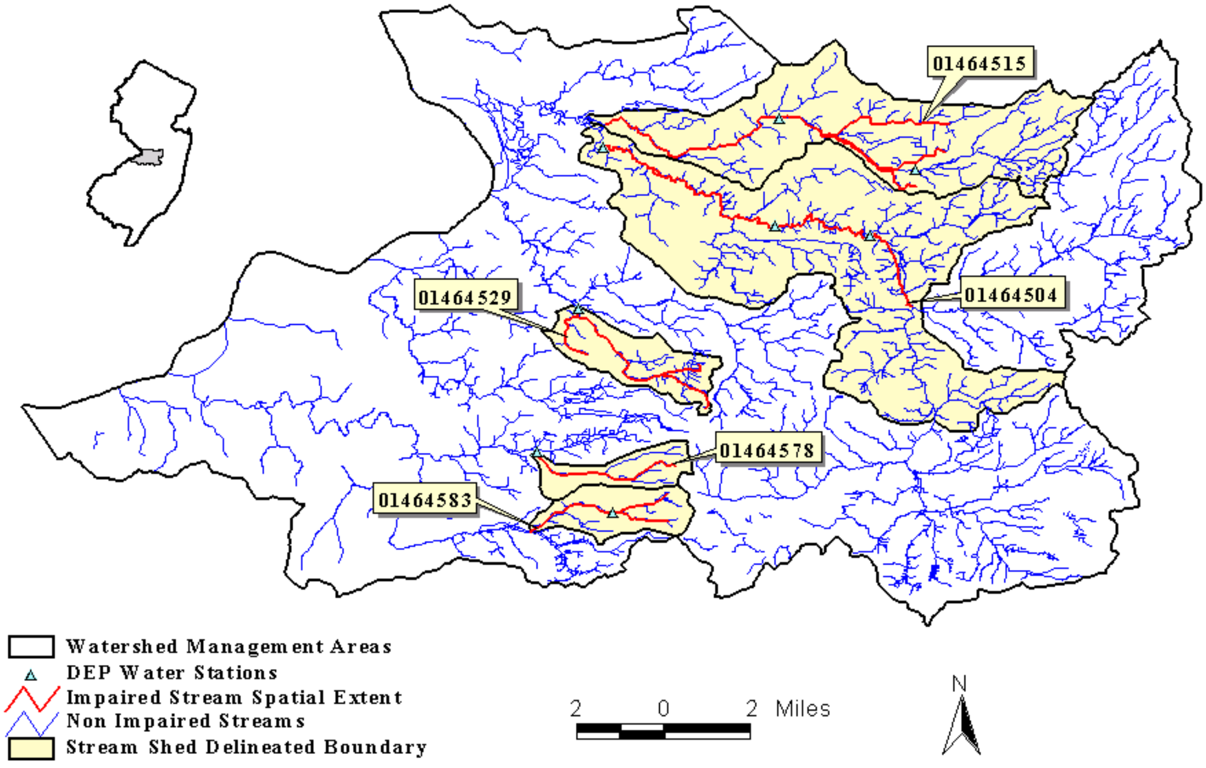


Table 9 **Description of the spatial extent for each Sublist 5 segment, listed for fecal coliform, in WMA 20.**

Segment ID	Watershed area associated with impaired stream segments
01464504	Watershed area begins at Crosswicks Creek near New Egypt and extends downstream to the confluence of Doctors Creek with Crosswicks Creek. Tributaries included in this watershed include Beaverdam Brook, Deep Run, Miry Run, Pleasant Run, Schoolhouse Brook, Shoppen Run, and Stony Ford Brook.
01464515	Doctors Creek watershed from headwaters, near Nelsonville, extending west to approximately 0.5 miles upstream from the confluence of Doctors and Crosswicks Creeks. Tributaries included in this watershed include Buckhole Creek and Negro Run
01464529	Bacons Creek watershed upstream of its confluence with Blacks Creek.
01464578	Annaricken Brook watershed upstream of the confluence of Annaricken Brook and the Assiscunk Creek.
01464583	North Branch of Barkers Brook watershed upstream of the confluence of the North and South Branches of Barkers Brook.

Table 10 **River miles, Watershed size, and Anderson Land Use classification for five Sublist 5 segments, listed for fecal coliform, in WMA 20.**

	Segment ID				
	01464504	01464515	01464529	01464578	01464583
Sublist 5 impaired river miles (miles)	12.4	15.7	7.4	3.7	4.8
Total river miles within the delineated watershed and included in the implementation plan (miles)	118.5	69.5	21.8	14.4	8.9
Watershed size (acres)	22762	13389	3613	2607	2365
Land Use/Land Cover					
Agriculture	50.3%	49.5%	50.8%	40.2%	44.6%
Barren Land	0.3%	0.6%	0.0%	0.3%	1.6%
Forest	14.0%	13.1%	9.2%	6.6%	13.4%
Urban	14.5%	14.5%	11.6%	9.6%	6.5%
Water	0.8%	1.3%	0.1%	0.0%	0.3%
Wetlands	20.2%	21.1%	28.3%	43.3%	33.7%

4.2. Data Sources

The Department's Geographic Information System (GIS) was used extensively to describe the Lower Delaware watershed characteristics. In concert with USEPA's November 2001 listing guidance, the Department is using Reach File 3 (RF3) in the 2002 Integrated Report to represent rivers and streams. The following is general information regarding the data used to describe the watershed management area:

- Land use/Land cover information was taken from the 1995/1997 Land Use/Land cover Updated for New Jersey DEP, published 12/01/2000 by Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), delineated by watershed management area.
- 2002 Assessed Rivers coverage, NJDEP, Watershed Assessment Group, unpublished coverage.
- County Boundaries: Published 11/01/1998 by the NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), "NJDEP County Boundaries for the State of New Jersey." Online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/stco.zip
- Detailed stream coverage (RF3) by County: Published 11/01/1998 by the NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA). "Hydrography of XXX County, New Jersey (1:24000)." Online at: http://www.state.nj.us/dep/gis/digidownload/zips/strm/

- NJDEP 14 Digit Hydrologic Unit Code delineations (DEPHUC14), published 4/5/2000 by Department of Environmental Protection (NJDEP), New Jersey Geological Survey (NJGS) Online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/dephuc14.zip
- NJPDES Surface Water Discharges in New Jersey, (1:12,000), published 02/02/2002 by Division of Water Quality (DWQ), Bureau of Point Source Permitting - Region 1 (PSP-R1).
- Dams statewide coverage. Published 5/16/2000 by Dam Safety Section. Titled "NJDEP Dams for the State of New Jersey." New Jersey Department of Environmental Protection(NJDEP).
  Online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/dams.zip

5.0 Applicable Water Quality Standards

5.1. New Jersey Surface Water Quality Standards for Fecal Coliform

As stated in N.J.A.C. 7:9B-1.14(c) of the New Jersey SWQS, the following are the criteria for freshwater fecal coliform:

> "Fecal coliform levels shall not exceed a geometric average of 200 CFU/100 ml nor should more than 10 percent of the total samples taken during any 30-day period exceed 400 CFU/100 ml in FW2 waters".

All of the waterbodies covered under these TMDLs have a FW2 classification (NJAC 7:9B-1.12). The designated use, i.e. surface water uses, both existing and potential, that have been established by the Department for waters of the State, for all of the waterbodies in the Lower Delaware Water Region is as stated below:

In all FW2 waters, the designated uses are:

1. Maintenance, migration and propagation of the natural and established aquatic biota;
2. Primary and secondary contact recreation;
3. Industrial and agricultural water supply;
4. Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation and sedimentation, resulting in substantial particulate removal but no consistent removal of chemical constituents) and disinfection; and
5. Any other reasonable uses.

5.2. Pathogen Indicators in New Jersey's Surface Water Quality Standards (SWQS)

A subset of total coliform, fecal coliform originates from the intestines of warm-blooded animals. Therefore, because they do not include organisms found naturally in soils, fecal coliform is preferred over total coliform as a pathogen indicator. In 1986, USEPA published a document entitled *"Implementation Guidance for Ambient Water Quality Criteria for Bacteria –*

1986" that contained their recommendations for water quality criteria for bacteria to protect bathers from gastrointestinal illness in recreational waters. The water quality criteria established levels of indicator bacteria *Escherichia coli* (*E. coli*) for fresh recreational water and enterococci for fresh and marine recreational waters in lieu of fecal coliforms. Historically, New Jersey has listed water bodies for exceedances of the fecal coliform criteria. Therefore, the Department is obligated to develop TMDLs for Sublist 5 water bodies based upon fecal coliform, until New Jersey makes the transition to *E. coli* and enterococci in its SWQS and sufficient data have been collected to assess impairment in accordance with the revised indicators.

6.0 Source Assessment

In order to evaluate and characterize fecal coliform loadings in the waterbodies of interest in these TMDLs, and thus propose proper management responses, source assessments are warranted. Source assessments include identifying the types of sources and their relative contributions to fecal coliform loadings, in both time and space variables.

6.1. Assessment of Point Sources other than Stormwater

Point sources of fecal coliform, namely sewage treatment discharges, for these TMDLs are listed in Appendix B. Sewage treatment plants, whether municipal or industrial, are required to disinfect effluent prior to discharge and to meet surface water quality criteria for fecal coliform in their effluent. In addition, New Jersey's Surface Water Quality Standards at N.J.A.C. 7:9B-1.5(c)4 reads "No mixing zones shall be permitted for indicators of bacterial quality including, but not limited to, fecal coliforms and enterococci". This mixing zone policy is applicable to both municipal and industrial sewage treatment plants.

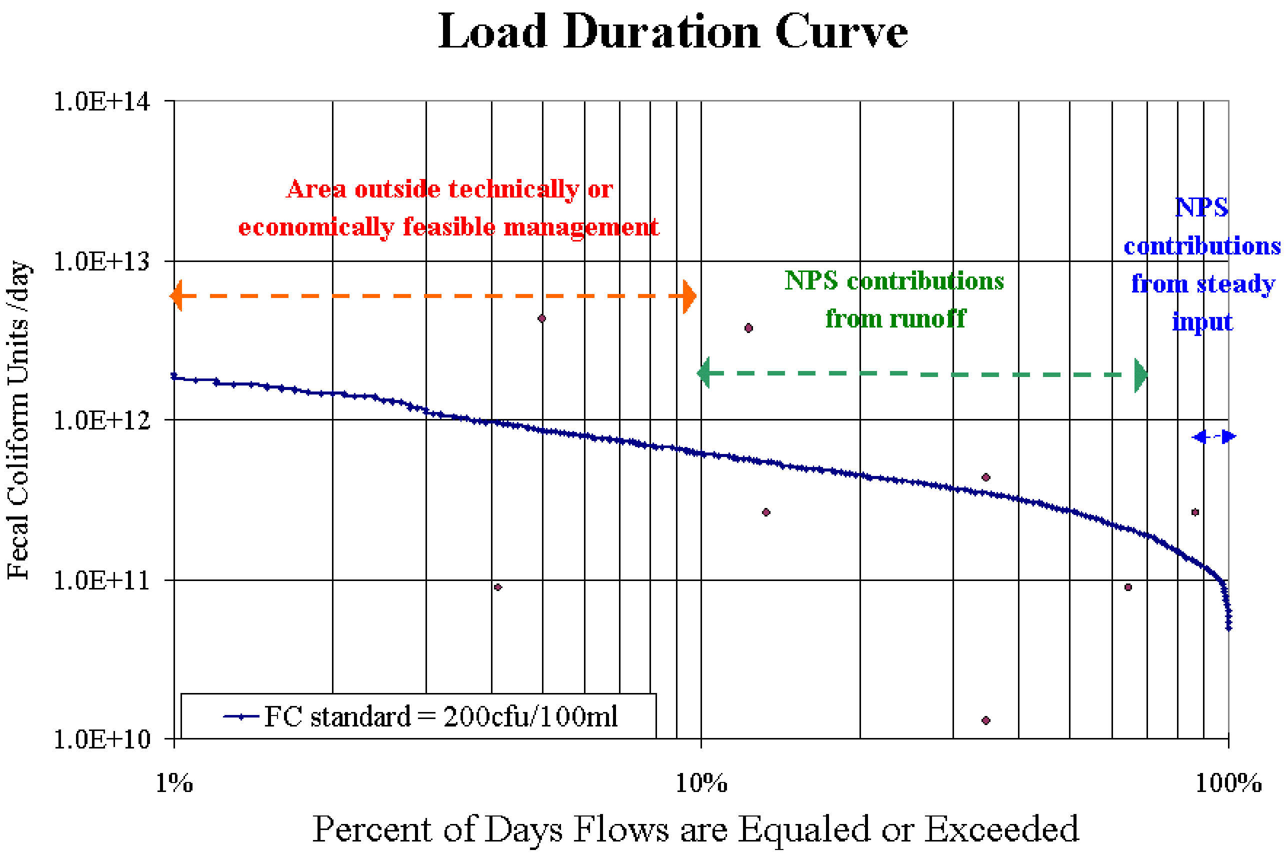
Since sewage treatment plants routinely achieve essentially complete disinfection (less than 20 CFU/100ml), the requirement to disinfect results in fecal coliform concentrations well below the criteria and permit limit. The percent of the total point source contribution is an insignificant fraction of the total load. Consequently, these fecal coliform TMDLs will not impose any change in current practices for POTWs and industrial treatment plants and will not result in changes to existing effluent limits.

6.2. Assessment of Nonpoint and Stormwater Point Sources

Nonpoint and stormwater point sources include storm-driven loads such as runoff from various land uses that transport fecal coliform from sources such as geese, farms, and domestic pets to the receiving water. Domestic pet waste, geese waste, as well as loading from storm water detention basins will be addressed by the Phase II MS4 program. Nonpoint sources also include steady-inputs from "illicit" sources such as failing sewage conveyance systems, sanitary sewer overflows (SSOs), and failing or inappropriately located septic systems. When "illicit" sources are identified, either through the Phase II MS4 requirements or trackdown studies conducted by the Department, appropriate enforcement measures will be taken to eliminate them.

When streamflow gage information is available, a load duration curve (LDC) is useful in identifying and differentiating between storm-driven and steady-input sources. As an example, Figure 5 represents a LDC using the 200 CFU/100 ml criterion.

Figure 5 **Example Load Duration Curve (LDC)**



The load duration curve method is based on comparison of the frequency of a given flow event with its associated water quality load. A LDC can be developed using the following steps:

1. Plot the Flow Duration Curve, Flow vs. % of days flow exceeded.
2. Translate the flow-duration curve into a LDC by multiplying the water quality standard, the flow and a conversion factor; the result of this multiplication is the maximum allowable load associated with each flow.
3. Graph the LDC, maximum allowable load vs. percent of time flow is equaled or exceeded.
4. Water quality samples are converted to loads (sample water quality data multiplied by daily flow on the date of sample).
5. Plot the measured loads on the LDC.

Values that plot below the LDC represent samples below the concentration threshold whereas values that plot above represent samples that exceed the concentration threshold. Loads that plot above the curve and in the region between 85 and 100 percent of days in which flow is exceeded indicate a steady-input source contribution. Loads that plot in the region between 10 and 70 percent suggest the presence of storm-driven source contributions. A combination of both storm-driven and steady-input sources occurs in the transition zone between 70 and 85 percent. Loads that plot above 99 percent or below 10 percent represent values occurring during either extreme low or high flows conditions and are thus considered to be outside the region of technically and economically feasible management. In this report, LDCs are used only for TMDL implementation and not in calculating TMDLs.

LDCs for listed segments in the Lower Delaware region are located in Appendix D. In each case, thirty (30) years of USGS gage flow data (water years 1970-2000), from the listed station, were used in generating the curve. When a recent 30-year period was not available at the listed station, an adjacent station was selected based on station correlation information in US Geological Survey Open File Report 81-1110 (USGS, 1982). When an adjacent station was used in the manner, flows were adjusted to the station of interest based on a ratio of watershed size. LDCs were not developed for stations in which a satisfactory correlation could not be found.

7.0 Water Quality Analysis

Relating pathogen sources to in-stream concentrations is distinguished from quantifying that relationship for other pollutants given the inherent variability in population size and dependence not only on physical factors such as temperature and soil characteristics, but also on less predictable factors such as re-growth media. Since fecal coliform loads and concentrations can vary many orders of magnitude over short distances and over time at a single location, dynamic model calibrations can be very difficult to calibrate. Options available to control nonpoint sources of fecal coliform typically include measures such as goose management strategies, pet waste ordinances, agricultural conservation management plans, and septic system replacement and maintenance. However, the effectiveness of these control measures is not easily measured. Given these considerations, detailed water quality modeling may not provide adequate insight or guidance toward the development of implementation plans for fecal coliform reductions.

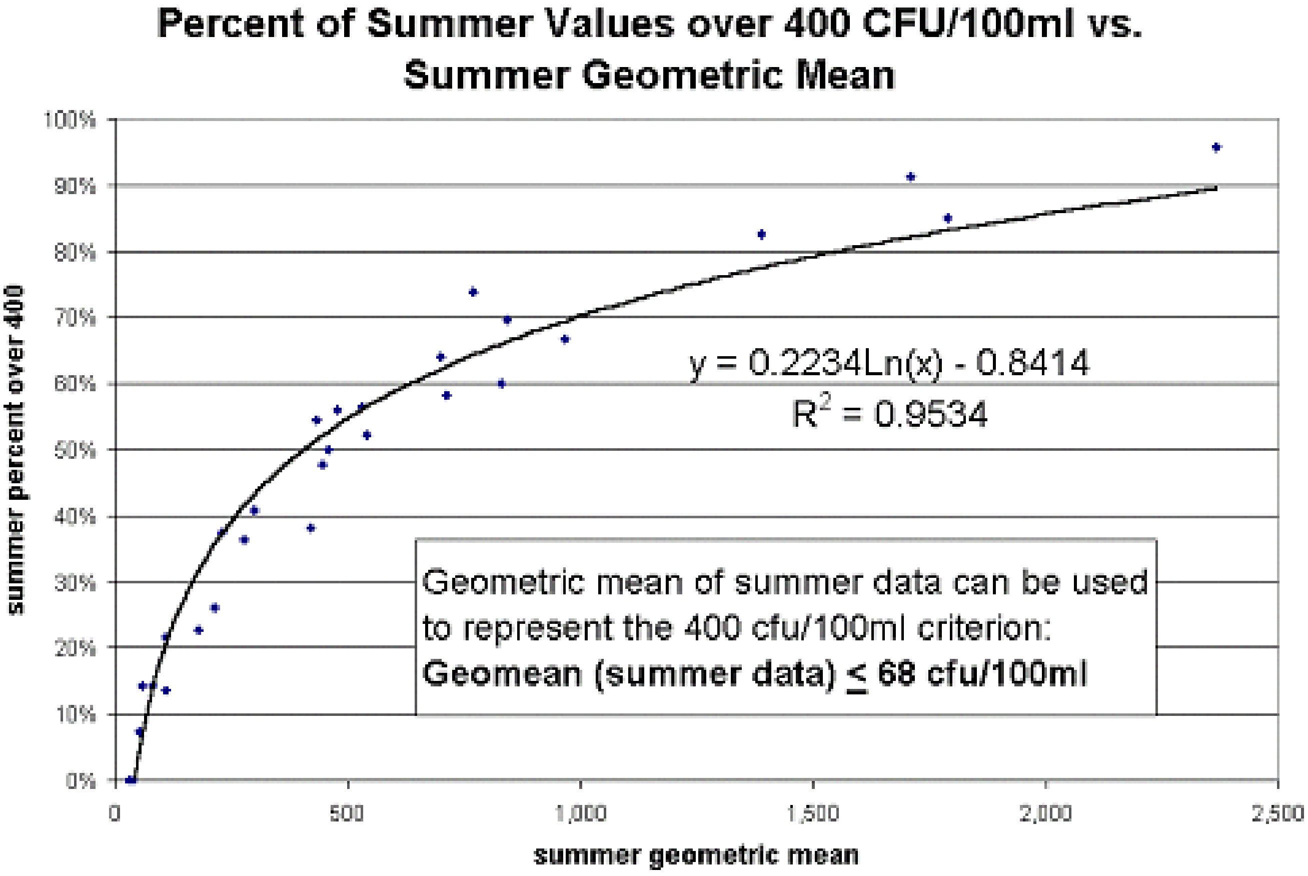
As described in EPA guidance, a TMDL identifies the loading capacity of a waterbody for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a waterbody can receive without violating water quality standards (40 C.F.R. 130.2). The loadings are required to be expressed as either mass-per-time, toxicity, or other appropriate measures (40 C.F.R. 130.2(i)). For these TMDLs, the load capacity is expressed as a concentration set to meet the state water quality standard. For bacteria, it is appropriate and justifiable to express the components of a TMDL as percent reduction based on concentration. The rationale for this approach is that:

- expressing a bacteria TMDL in terms of concentration provides a direct link between existing water quality and the numeric target;
- using concentration in a bacteria TMDL is more relevant and consistent with the water quality standards, which apply for a range of flow and environmental conditions; and
- follow-up monitoring will compare concentrations to water quality standards.

Given the two criteria of 200 CFU/100 ml and 400 CFU/100 ml in FW2 waters, computations were necessary for both criteria and resulted in two percent reduction values. The higher percent reduction value was applied in the TMDL so that both the 200 CFU/100 ml and 400 CFU/100 ml criteria were satisfied.

To satisfy the 200 CFU/100ml criteria, the geometric mean of all available data between water years 1994-2002 was compared to an adjusted target concentration. The adjusted target accounts for an explicit margin of safety and is equal to 200 minus the margin of safety. A calculation incorporating all available data is generally conservative since most samples are taken during the summer when fecal coliform is generally higher. A geometric mean of summer data was used to develop a percent reduction to satisfy the 400 CFU/100 ml criteria. A summer geometric mean can be used to represent the 400 criteria by regressing the percent over 400 CFU/100 ml against the geometric mean (Figure 6). Thus, each datapoint on Figure 6 represents all the data from one individual monitoring station. Sites with 20 or more summer data points were used to develop this regression, in order to make use of more significant values for percent exceedance. A statewide regression was used rather than regional regressions because the regression shape was not region-specific and the strength of the correlation was highest when all statewide data were included. The resulting regression has an r-squared value of 0.9534. Solving for X when Y is equal to 10% yields a geometric mean threshold of 68 CFU/100ml. This means that, using summer data, a geometric mean of 68 can be used to represent the 400 CFU/100ml criterion. Since the geometric mean is a more reliable statistic than percentile when limited data are available, 68 CFU/100ml was used to represent the 400 CFU/100ml criterion for all sites. The inclusion of all data from summer months (May through September) to compare with the 30-day criterion is justified because summer represents the critical period when primary and secondary contact with water bodies is most prevalent. A more detailed justification for using summer data can be found in Section 7.1, "Seasonal Variation and Critical Conditions."

Figure 6 **Percent of summer values over 400 CFU/100ml as a function of summer geometric mean values**



$y = 0.2234\mathrm{Ln}(x) - 0.8414$ Equation 1

$R^2 = 0.9534$

Geometric mean, and summer geometric mean, and percent reductions were determined at each location for both criteria using Equations 2 through 4. To satisfy the 200 CFU/100ml criteria, equations 2 and 3 were applied. Equations 2 and 4 were used in satisfying the 400 CFU/100ml criteria.

$$Geometric\ Mean\ for\ 200CFU\ criteria = \sqrt[n]{y_1 y_2 y_3 y_4 \ldots y_n} \qquad \text{Equation 2}$$

where:
y = sample measurement
n = total number of samples

$$200\ CFU\ criteria\ Percent\ \mathrm{Re}duction = \frac{(Geometric\ mean - (200 - e))}{Geometric\ mean} \times 100\ \% \qquad \text{Equation 3}$$

$$400\ CFU\ criteria\ Percent\ \mathrm{Re}duction = \frac{(SummerGeometric\ mean - (68 - e))}{SummerGeometric\ mean} \times 100\ \% \qquad \text{Equation 4}$$

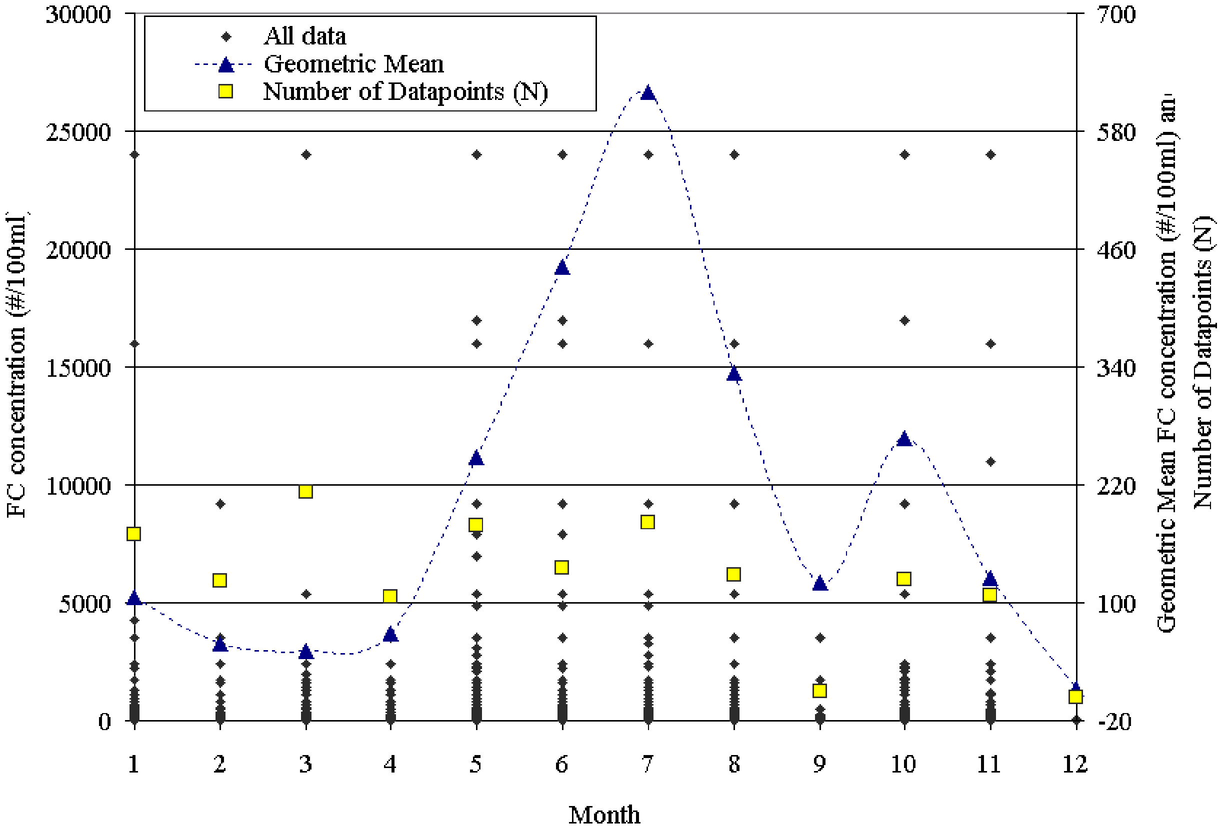
where:
e = (margin of safety)

This percent reduction can be applied to nonpoint and stormwater point sources as a whole or be apportioned to categories of nonpoint and stormwater point sources within the study area. The extent to which nonpoint and stormwater point sources have been identified or need to be identified varies by study area based on data availability, watershed size and complexity, and pollutant sources.

7.1. Seasonal Variation/Critical Conditions

These TMDLs will attain applicable surface water quality standards year round. The approach outlined in this paper is conservative given that in most cases fecal coliform data were collected during the summer months, a time when in-stream concentrations are typically the highest. This relationship is evidenced when calculating, on a monthly basis, the geometric mean of fecal coliform data collected statewide. Statewide fecal coliform geometric means during water years 1994-1997 were compared on a monthly basis and are shown in Figure 7. The 1994-1997 period was chosen for this analysis so that the significance of the number of individual datapoints for any given month was minimized. During the 1994-1997 period year-round sampling for fecal coliform was conducted by sampling four times throughout the year. Following 1997, the fecal coliform sampling protocol was changed to five samples during a 30-day period in the summer months. As evident in Figure 7, higher monthly geometric means are observed between May and September with the highest values occurring during mid-summer. This relationship is also evident when using the entire 1994-2002 dataset or datasets from individual water years. Given this relationship, summer is considered the critical period for violating fecal coliform SWQS and, as such, sampling during this period is considered adequate for meeting year round protections and designated uses.

Figure 7 **Statewide monthly fecal coliform geometric means during water years 1994-1997 using USGS/NJDEP data.**



7.2. Margin of Safety

A Margin of Safety (MOS) is provided to account for "lack of knowledge concerning the relationship between effluent limitations and water quality" (40 CFR 130.7(c)). For these TMDLs calculations, both an implicit and explicit Margin of Safety (MOS) are incorporated. Implicitly, a MOS is inherent in the estimates of current pollutant loadings, the targeted water quality goals (New Jersey's SWQS) and the allocations of loading. This was accomplished by taking conservative assumptions throughout the TMDL evaluation and development. Examples of some of the conservative assumptions include treating fecal coliform as a conservative substance, applying the fecal coliform criteria to stormwater point sources, and applying the fecal coliform criteria to the stream during all weather conditions. Fecal coliforms decay in the environment (i.e. outside the fecal tract) relatively rapidly, yet this analysis assumes a linear relationship between fecal load and instream concentration. Furthermore, it is generally recognized that fecal contamination from stormwater poses much less risk of illness than fecal contamination from sewage or septic system effluent (Cabelli, 1989). Finally, much of the fecal coliform is flushed into the system during rainfall events and passes through the system in a short time. Primary and secondary recreation generally occur during dry periods.

An explicit MOS is provided by incorporating a confidence level multiplier associated with log-normal distributions in the calculation of the load reduction for both the 200 and 400 standards. Using this method, the 200 and 400 targets are reduced based on the number of data points and the variability within each data set. For these TMDLs, a confidence level of 90% was used in calculating the MOS. As a result, and as identified in Appendix C, the target value will be different for each stream segment or grouped segments. The explicit margin of safety is calculated using the following steps:

1- fecal coliform data (x) will transformed to Log form data (y),
2- the mean of the Log- transformed data (y) is determined, $\bar{y}$
3- Determine the standard deviation of the Log-transformed data, S_y using the following equation:

$$S_y = \sqrt{\frac{\sum_i (y_i - \bar{y})^2}{N-1}}$$

4- Determine the Geometric mean of the fecal coliform data (GM)
5- Determine the standard deviation of the mean (standard error of the mean), $s_{\bar{y}}$, using the following equation:

$$s_{\bar{y}} = \frac{s_y}{\sqrt{N}}$$

6- For the 200 standard (x_{standard}), $y_{\text{standard}} =$ Log(200)= 2.301, thus for a confidence level of 90%, the target value will be the lower confidence limit (n= -1.64), $y_{target} = y_{std} - n \cdot s_{\bar{y}}$, for example, the 200 criteria: $y_{\text{target}} = 2.301 - n^* s_{\bar{y}}$
7- The target value for x, $x_{\text{target}} = 10^{y\ \text{target}}$
8- The margin of safety (e) therefore will be $e = x_{\text{standard}} - x_{\text{target}}$
9- Finally, the load reduction = $\frac{GM - x_{target}}{GM} \cdot 100\%$, for example the 200 criteria will be defined as: $\frac{(GM - (200 - e))}{GM} \cdot 100\%$

The 400 criteria would be defined as: $\frac{(GM - (68 - e))}{GM} \cdot 100\%$

8.0 TMDL Calculations

Because these TMDLs are calculated based on ambient water quality data, the allocations are provided in terms of percent reductions. In the same way, the loading capacity of each stream is expressed as a function of the current load:

$LC = (1 - PR) \times L_o$, where

LC = loading capacity for a particular stream;
PR = percent reduction as specified in Tables 7-10;

L_o = current load.

8.1. Wasteload Allocations and Load Allocations

For the reasons discussed previously, these TMDLs do not include WLAs for traditional point sources (POTWs, industrial, etc.). WLAs are hereby established for all NJPDES-regulated point sources (including NJPDES-regulated stormwater), while LAs are established for all stormwater sources that are not subject to NJPDES regulation, and for all nonpoint sources. Both WLAs and LAs are expressed as percentage reductions for particular stream segments.

Table 11 identifies the required percent reduction necessary for each stream segment or group of segments to meet the fecal coliform SWQS. The reductions reported in these tables include a margin of safety factor and represent the higher percent reduction (more stringent) required of the two criteria. Reductions that are required under each criteria are located in Appendix C. In all cases, the 400 CFU/100ml criteria was the more stringent of the two criteria, thus values reported in Table 11 were equal to the percent required to meet the 400 CFU/100ml criteria.

Table 11 TMDLs for fecal coliform-impaired stream segments in the Lower Delaware Water Region as identified in Sublist 5 of the 2002 Integrated List of Waterbodies. The reductions reported in this table represent the higher, or more stringent, percent reduction required of the two fecal colifom criteria.

TMDL Number	WMA	303(d) Category 5 Segments	Water Quality Stations	Station Names	Load Allocation (LA) and Margin of Safety (MOS)					Wasteload Allocation (WLA)
					Summer N	Summer geometric mean CFU/100ml	MOS as a percent of the target concentration	Percent reduction without MOS	Percent reduction with MOS	
1	17	01411466	01411466	Indian Branch near Malaga	20	70	47%	3%	49%	49%
2 3 4	17	01411458 01411500 01411800	01411458 01411500 01411800	Little Ease Run at Porchtown, Maurice River at Norma, Maurice River near Millville	30	130	36%	48%	67%	67%
5	17	01412800	01412800	Cohansey River at Seeley	27	122	39%	44%	66%	66%
6 7	17	01482500 01482537	01482500 01482537	Salem River at Woodstown, Salem River at Courses Landing	29	251	39%	73%	84%	84%
8	17	01482560	01482560	Two Penny Run near Danceys Corner	5	408	39%	83%	90%	90%

TMDL Number	WMA	303(d) Category 5 Segments	Water Quality Stations	Station Names	Load Allocation (LA) and Margin of Safety (MOS)					Wasteload Allocation (WLA)
					Summer N	Summer geometric mean CFU/100ml	MOS as a percent of the target concentration	Percent reduction without MOS	Percent reduction with MOS	
9 10	18	01467069 01467081	01467069 01467081	North Branch Pennsauken Creek near Morrestown, South Branch Pennsauken Creek at Cherry Hill	8	17677	54%	99.6%	99.8%	99.8%
11 12 13	18	01467120 01467150 01467155	01467120 01467150 01467155	Cooper River at Lidenwold, Cooper River at Haddonfield, North Branch Cooper River at Kresson	36	1473	33%	95%	97%	97%
14 15	18	01467327 01467329	01467327 01467329	South Branch Big Timber Creek at Glenloch, South Branch Big Timber Creek at Blackwood Terrace	18	298	36%	77%	85%	85%
16	18	01467359	01467359	North Branch Big Timber Creek at Glendora	14	928	41%	93%	96%	96%
17	18	01476600	01476600	Still Run near Mickelton	5	249	32%	73%	82%	82%
18	18	01477120	01477120	Raccoon Creek near Swedesboro	28	387	30%	82%	88%	88%
19 20	18	01477440 01477510	01477440 01477510	Oldmans Creek at Jessups Mill, Oldmans Creek at Porches Mill	13	774	43%	91%	95%	95%
21	19	01465884	01465884	Sharps Run at Rt 541 at Medford	5	264	52%	74%	88%	88%
22	19	01467006	01467006	North Branch Rancocas Creek at Pine St at Mt Holly	5	417	60%	84%	94%	94%
23	20	01464504	01464500 01464504 014644202	Crosswicks Creek at Extonville, Crosswicks Creek at Groveville Rd. at Groveville, Crosswicks Creek near New Egypt, Crosswicks Creek at Walnford Rd In Upper Freehold	42	380	22%	82%	86%	86%
24	20	01464515	014645153	Doctors Creek at Allentown, Doctors Creek at Route 539 In Upper Freehold	33	346	27%	80%	86%	86%
25	20	01464529	01464529	Bacons Creek near Mansfield Square	5	399	61%	83%	93%	93%
26	20	01464578	01464578	Annaricken Brook near Jobstown	6	432	68%	84%	95%	95%
27	20	01464583	01464583	North Branch Barkers Brook near Jobstown	10	813	54%	92%	96%	96%

[1] MOS as a percent of target is equal to: $\frac{e}{200\ CFU/100ml}$ or $\frac{e}{68\ CFU/100ml}$ where "e" is defined as the MOS in Section 7.2

8.2. Reserve Capacity

Reserve capacity is an optional means of reserving a portion of the loading capacity to allow for future growth. Reserve capacities are not included at this time. The loading capacity of each stream is expressed as a function of the current load (Section 8.0), and both WLAs and LAs are expressed as percentage reductions for particular stream segments (Section 8.1). Therefore, the percent reductions from current levels must be attained in consideration of any new sources that may accompany future development. Strategies for source reduction will apply equally well to new development as to existing development.

9.0 Follow - up Monitoring

In association with the Water Resources Division of the U.S. Geological Survey, the NJDEP have cooperatively operated the Ambient Stream Monitoring Network (ASMN) in New Jersey since the 1970s. The ASMN currently includes approximately 115 stations that are routinely monitored on a quarterly basis. Bacteria monitoring, as part of the ASMN network, are conducted five times during a consecutive 30-day summer period each year. The data from this network has been used to assess the quality of freshwater streams and percent load reductions. Although other units also perform monitoring functions, the ASMN will remain a principal source of fecal coliform monitoring.

10.0 Implementation

Management measures are "economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint and stormwater sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint and stormwater source pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives" (USEPA, 1993).

Development of effective management measures depends on accurate source assessment. Fecal coliform is contributed to the environment from a number of categories of sources including human, domestic or captive animals, agricultural practices, and wildlife. Fecal coliform from these sources can reach waterbodies directly, through overland runoff, or through sewage or stormwater conveyance facilities. Each potential source will respond to one or more management strategies designed to eliminate or reduce that source of fecal coliform. Each management strategy has one or more entities that can take lead responsibility to effect the strategy. Various funding sources are available to assist in accomplishing the management strategies. The Department will address the sources of impairment through systematic source trackdown, matching strategies with sources, selecting responsible entities and aligning available resources to effect implementation.

For example, the stormwater discharged to the impaired segments through "small municipal separate storm sewer systems" (small MS4s) will be regulated under the Department's proposed Phase II NJPDES stormwater rules for the Municipal Stormwater Regulation Program. Under those proposed rules and associated draft general permits, many municipalities (and various county, State, and other agencies) in the Lower Delaware Region will be required to implement various control measures that should substantially reduce bacteria loadings, including measures to eliminate "illicit connections" of domestic sewage and other waste to the small MS4, adopt and enforce a pet waste ordinance, prohibit feeding of unconfined wildlife on public property, clean catch basins, perform good housekeeping at maintenance yards, and provide related public education and employee training. Sewage conveyance facilities are potential sources of fecal coliform in that equipment failure or operational problems may result in the release of untreated sewage. These sources, once identified, can be eliminated through appropriate corrective measures that can be effected through the Department's enforcement authority. Inadequate on-site sewage disposal can also be a source of fecal coliform. Systems that were improperly designed, located or maintained may result in surfacing of effluent and illicit remedies such as connections to storm sewers or streams add human waste directly to waterbodies. Once these problems have been identified through local health departments, sanitary surveys or other means, alternatives to address the problems can be evaluated and the best solution implemented. The Department has committed a portion of its CWA 319(h) pass through grant funds to assist municipalities in meeting Phase II requirements. In addition, The New Jersey Environmental Infrastructure Financing Program, which includes New Jersey's State Revolving Fund, provides low interest loans to assist in correction of water quality problems related to stormwater and wastewater management.

Agricultural activities are another example of potential sources of fecal coliform. Possible contributors are direct contributions from livestock permitted to traverse streams and stream corridors, manure management from feeding operations, or use of manure as a soil fertilizer/amendment. Implementation of conservation management plans and best management practices are the best means of controlling agricultural sources of fecal coliform. Several programs are available to assist farmers in the development and implementation of conservation management plans and best management practices. The Natural Resource Conservation Service is the primary source of assistance for landowners in the development of resource management pertaining to soil conservation, water quality improvement, wildlife habitat enhancement, and irrigation water management. The USDA Farm Services Agency performs most of the funding assistance. All agricultural technical assistance is coordinated through the locally led Soil Conservation Districts. The funding programs include:

- **The Environmental Quality Incentive Program (EQIP)** is designed to provide technical, financial, and educational assistance to farmers/producers for conservation practices that address natural resource concerns, such as water quality. Practices under this program include integrated crop management, grazing land management, well sealing, erosion control systems, agri-chemical handling facilities, vegetative filter strips/riparian buffers, animal waste management facilities and irrigation systems.

- **The Conservation Reserve Program (CRP)** is designed to provide technical and financial assistance to farmers/producers to address the agricultural impacts on water quality and to maintain and improve wildlife habitat. CRP practices include the establishment of filter strips, riparian buffers and permanent wildlife habitats. This program provides the basis for the Conservation Reserve Enhancement Program (CREP). The New Jersey Departments of Environmental Protection and Agriculture, in partnership with the Farm Service Agency and Natural Resources Conservation Service, has recently submitted a proposal to the USDA to offer financial incentives for agricultural landowners to voluntarily implement conservation practices on agricultural lands through CREP. NJ CREP will be part of the USDA's Conservation Reserve Program (CRP). The enrollment of farmland into CREP in New Jersey is expected to improve stream health through the installation of water quality conservation practices on New Jersey farmland.

- **The Soil & Water Conservation Cost-Sharing Program** is available to participants in a Farmland Preservation Program pursuant to the Agriculture Retention and Development Act. A Farmland Preservation Program (FPP) means any voluntary FPP or municipally approved FPP, the duration of which is at least 8 years, which has as its principal purpose as long term preservation of significant masses of reasonably contiguous agricultural land within agricultural development areas. The maintenance and support of increased agricultural production must be the first priority use of the land. Eligible practices include erosion control, animal waste control facilities, and water management practices. Cost sharing is provided for up to 50% of the cost to establish eligible practices.

10.1. Source Trackdown

Through the watershed management process and New Jersey Watershed Ambassador Program, river assessments and visual surveys of the impaired segment watersheds were conducted to identify potential sources of fecal coliform. Watershed partners, who are intimately familiar with local land use practices, were able to share information relative to potential fecal coliform sources. The New Jersey Watershed Ambassadors Program is a community-oriented AmeriCorps environmental program designed to raise awareness about watershed issues in New Jersey. Through this program, AmeriCorps members are placed in watershed management areas across the state to serve their local communities. Watershed Ambassadors monitor the rivers of New Jersey through River Assessment Teams (RATs) and Biological Assessment Teams (BATs) volunteer monitoring programs. Supplemental training was provided through the fall/winter of 2002 to prepare the members to perform river assessments on the impaired segments. Each member was provided with detailed maps of the impaired segments within their watershed management area. The Department worked with and through watershed partners and AmeriCorps members to conduct RATs surveys in fall of 2002. The Department reviewed monitoring data, RATs surveys, other information supplied by watershed partners, load duration curves, and aerial photography of the impaired segments to formulate segment specific strategies. Segment specific monitoring strategies in combination with generic strategies appropriate to the sources in each segment will lead to reductions in fecal coliform loads in order to attain SWQS.

10.2. Short Term Management Strategies

Short term management measures include projects recently completed, underway or planned that are designed to address the targeted impairment. Pertinent projects in the Lower Delaware are as follows:

WMA 17

- **Parvin Branch and Tarklin Brook Assessment and Monitoring**
  Citizens United to Protect the Maurice River and its Tributaries was awarded a $56,450 319(h) grant for a project that targets two moderately impaired AMNET monitoring sites in an area where the surrounding tributaries are all listed as unimpaired. This project will help to identify the root causes of these impairments via intensive physical, biological and chemical monitoring, and attempt to remediate them through extensive education and outreach on NPS pollution. Parvin Branch and Tarklin Brook are tributaries to the Maurice River in Cumberland County.

WMA 18

- **Nonpoint Source Pollution Control and Management, Strawbridge Lake Watershed Burlington County**
  The American Littoral Society - Delaware Riverkeeper Network were awarded $161,250 in 319(h) grant money to complete the above project. The project includes four components which were identified as needed in the Strawbridge Lake TMDL. The components include 1.) characterization of existing phosphorus and bacteria loadings from various land uses and long-term sedimentation, b.) a completed stormwater inventory and land use mapping for the Strawbridge Lake watershed, c.) the development of a restoration master plan, and d.) an assessment of the effectiveness of BMPs currently constructed in this watershed.

- **Retrofitting Stormwater Management Facilities**
  Moorestown Board of Education was awarded $64,000 in 319(h) money to complete a project that will retrofit several detention basins and drainage swales associated with Moorestown Twp. Schools, Burlington County. In addition to the retrofits, these basins will be used to serve as "living classrooms" for students attending Moorestown's schools. Work anticipated is to begin Spring of 2003.

WMA 19

- **Rutgers Cooperative Extension Buffer Project**
  The Forestry Extension Program of Rutgers Cooperative Extension was awarded a $110,000 319(h) grant to complete this four-phase project. An inventory of the existing riparian butters was completed and priority areas were identified. Best management practices were implemented by planting two three-zone multi-species riparian buffer

systems. Throughout the project education and outreach to the community and to other agencies to promote riparian forest buffer systems were performed. The project was completed in Fall 2002 resulting in 30,000 feet of new riparian buffer consisting of over 1100 native trees and 15000 native plants.

- **Riparian Forest Buffer, Streambank Stabilization & Education Program for the Mill Dam/Ironworks Park along the Rancocas Creek, Burlington County**
  In January of 2000 Burlington County SCD was awarded $ 250,000 in State funds to build on the previous work of Rutgers Cooperative Extension and to implement streambank stabilization measures and extend the riparian buffer that was installed along the Rancocas Creek in Ironworks Park, Mount Holly Township. The stabilization and buffer installation are complete with ongoing maintenance to ensure vitality of the plants.

- **Woolman Lake Restoration Plan, Mount Holly Twp, Burlington County**
  The Heritage Conservancy was awarded a $ 83,000 319(h) grant in 1998 to decrease the NPS pollution Woolman Lake in the Buttonwood Tributary to the Rancocas Creek. The project resulted in the restoration of 1000 feet of shoreline to its natural habitat through implementation of various BMPs. Nonstructural BMPs were used including the use of coconut fiber rolls, biodegradable erosion control mats and native plant species to create a vegetative riparian buffer along the lake shoreline.

- **Biofilter Wetland at Woolman Lake, Mount Holly**
  Mount Holly Township received $145,215 in 319(h) money to design and contruct a biofilter wetland to treat NPS pollution and reduce loadings to the Rancocacas Creek. The wetland at Woolman Lake will be designed and built to treat stromwater that currently discharges directly into the lake. A second objective of this project is the evauluation of the "Drop-In Drain-Inceptors", that can be retrofit to existing stormwater catch basins. Two of these devices will be deployed and the pollution removal capability evaluated.

WMA 20

- **Crosswicks Creek - Oakford Lake and Paradise Park Streambank Restoration**
  Oakford Lake is upstream of a moderately impaired AMNET monitoring site. Both parks have a growing Canada Goose problem since they provide ideal habitat for resident Canada geese and have severe erosion problems due to human and waterfowl activities. Plumstead Township was awarded a $96,925 319(h) grant to create a vegetated stream bank buffer to stabilize the stream banks, block waterfowl access and to serve as a biofilter for stormwater run-off.

10.3. Long–Term Management Strategies

Long term strategies include source trackdown as well as selection and implementation of specific management measures that will address the identified sources. Source categories and responses are summarized below:

Source Category	Responses	Potential	Funding options

		Responsible Entity	
Human Sources			
Inadequate (per design, operation, maintenance, location, density) on-site disposal systems	Confirm inadequate condition; evaluate and select cost effective alternative, such as rehabilitation or replacement of systems, or connection to centralized treatment system	Municipality, MUA, RSA	CWA 604(b) for confirmation of inadequate condition; Environmental Infrastructure Financing Program for construction of selected option
Inadequate or improperly maintained stormwater facilities; illicit connections	Measures required under Phase II Stormwater permitting program plus Alternative measures as determined needed through TMDL process	Municipality, State and County regulated entities, stormwater utilities	CWA 319(h)
Malfunctioning sewage conveyance facilities	Identify through source trackdown	Owner of malfunctioning facility--compliance issue	User fees
Domestic/captive animal sources			
Pets	Pet waste ordinances	Municipalities for ordinance adoption and compliance	
Horses, livestock, zoos	Confirm through source trackdown: SCD/NRCS develop conservation management plans	Property owner	EQIP, CRP, CREP (when approved),
Agricultural practices	Confirm through source trackdown; SCD/NRCS develop conservation management plans	Property owner	EQIP, CRP, CREP (when approved)
Wildlife			
Nuisance concentrations, e.g. resident Canada geese	Feeding ordinances; Goose Management BMPs	Municipalities for ordinance; Community Plans for BMPs	CBT, CWA 319(h)

Source Category	Responses	Potential Responsible Entity	Funding options
Indigenous wildlife	Confirm through trackdown; consider revising designated uses	State	NA

10.4. Segment Specific Recommendations

10.4.1. Watershed Management Area 17

Little Ease Run at Porchtown (Site ID # 01411458)

Geese observed at Franklinville Lake. There are many older homes on septic along the stream corridor as well as surrounding Franklinville Lake. Additionally there is a cattle farm and a sheep farm next to Franklinville Lake. Load duration curve inconclusive. Response: Monitoring: fecal coliform to narrow the scope of impairment; coliphage to determine if septic systems are a source. Strategies: prioritize for EQIP funds to install agricultural BMPs; organize local community based goose management programs.

Indian Branch Near Malaga (Site ID # 01411466)

Majority of the land use is forest. Small horse farms and cattle farms observed near DEP monitoring site as well as some homes on septic systems, possibly cesspools. Response: Monitoring: coliphage to determine if septic systems are a source. Strategies: prioritize for EQIP funds to install agricultural BMPs.

Maurice River at Norma (Site ID # 01411500)

Majority of the reach flows through a forested area with good riparian buffers. Bathing beach and park on Almond Road, in summer dogs observed in lake. Horse farms, poultry processing plant and animal shelter within the watershed. Load duration curve consistent with rainfall induced sources. Strategies: prioritize for EQIP funds to install agricultural BMPs.

Maurice River at Millville (Site ID # 01411800)

The impaired segment flows through the Union Lake Wildlife Management Area with no potential sources other than wildlife. There are residential areas with the possibility of associated pets; geese were observed throughout the watershed. Basis for listing is old data. Response: verify impairment through monitoring.

Cohansey River (Site ID # 01412800)

The land use of the watershed is 69% agriculture with poor riparian buffers. Many cow, horse and chicken farms observed, as well as livestock in the stream. Upstream of monitoring site there are old homes on septic systems around Seeley Lake. This lake also attracts a large Canada Goose population. Load duration curve consistent with storm driven sources. Strategies: prioritize for EQIP funds to install agricultural BMPs; organize local community based goose management programs.

Salem River at Woodstown (Site ID# 01482500) and Courses Landing (Site ID #01482537)

There are horse farms, dairy farms, a poultry farm, an agricultural products operation, and a rodeo in the watershed. Cattle were observed in the stream. Both Woodstown Lake and Avis Mill Pond attract large Canada Goose population. The Township of Woodstown receives sewer service; the remainder of the watershed is on septic systems. Monitoring: Long segment would benefit from fecal coliform sampling to narrow scope of impairment.

Two Penny Run (Site ID # 01482560)

Majority of watershed is agricultural land, good buffer on one side of stream. Many horse farms as well as a large cow and sheep farm observed. Potential septic impacts from home on septic systems, including trailer parks. Monitoring: coliphage to determine if septic systems are a source. Strategies: prioritize for EQIP funds to install agricultural BMPs.

10.4.2. Watershed Management Area 18

North Branch Pennsauken Creek near Moorestown (Site ID # 01467069) & South Branch Pennsauken Creek at Cherry Hill (Site ID # 01467081)

This watershed is highly urbanized. Strawbridge Lake in Moorestown as well as golf courses and athletic fields throughout the watershed attract Canada geese. Due to the large amount of residential areas, domestic pets are a potential fecal source. Strategies: Phase II stormwater program.

Cooper River at Lindenwold (Site ID #01467120), Cooper River at Haddonfield (Site ID #01467150), and North Branch Cooper River at Kresson (Site ID # 01467155)

This watershed is also highly urbanized. There are 10 lakes throughout the watershed and multiple public parks. Potential fecal sources include Canada geese and domestic pets. Strategies: Phase II stormwater program.

South Branch Big Timber Creek at Glenloch (Site ID # 01467327) and South Branch Big Timber Creek at Blackwood Terrace (Site ID # 01467329)

Predominant land use in the watershed is residential. Glenloch Lake attracts large populations of Canada geese. Strategies: Phase II stormwater program; encourage community based goose management programs.

North Branch Big Timber Creek at Glendora (Site ID # 01467359)

This primary land use within this watershed is urban. There are at least nine lakes within this watershed that may attract Canada geese. Potential fecal sources would include geese and domestic pets. Strategies: Phase II stormwater program; encourage community based goose management programs.

Still Run near Mickleton (Site ID # 1476600)

The predominant land use of this watershed is agriculture. Potential fecal sources include geese and livestock, and possibly septic systems. Monitoring: coliphage to determine if septic systems are a source. Strategies: prioritize for EQIP funds to install agricultural BMPs; encourage community based goose management programs.

Raccoon Creek near Swedesboro (Site ID # 1477120)

The predominant land uses of this watershed are agriculture with good riparian buffers and residential. There are at least 5 lakes within the watershed that may attract Canadian geese. Load duration curve consistent with storm driven sources. Strategies: prioritize for EQIP funds to install agricultural BMPs; encourage community based goose management programs; Phase II stormwater program.

Oldmans Creek at Jessups Mill (Site ID # 1477440) and Porches Mill (Site ID #1477510)

The predominant land use of this watershed is agriculture and there are several lakes. Streamside land uses include crops, raising livestock, pastureland for horses, scattered homes and open space. Monitoring: coliphage to determine if septic systems are a source. Strategies: prioritize for EQIP funds to install agricultural BMPs; encourage community based goose management programs.

10.4.3. Watershed Management Area 19

Sharps Run at Rt. 541 at Medford (Site ID #1465884)

Large amount of residential development on sewers with potential for pet impacts. Canada geese observed on athletic fields and inactive farm fields. At least 2 large horse farms present within the watershed. Strategies: prioritize for EQIP funds to install agricultural BMPs; encourage community based goose management programs; Phase II stormwater program.

North Branch Rancocas Creek at Pine St at Mt Holly (Site ID # 01467006)

Potential septic system impacts from streamside homes located in the Ewansville section of Southampton Township. Multiple properties housing livestock also observed in Ewansville. Trailer parks located off Route 206 also potential septic impacts. Geese and evidence of geese as well as dog walking observed at Mill Dam Park in Mount Holly Township. Monitoring: coliphage to determine if septic systems are a source. Strategies: prioritize for EQIP funds to install agricultural

BMPs; encourage community based goose management programs; Phase II stormwater program.

10.4.4. Watershed Management Area 20

Annaricken Brook near Jobstown (Site ID # 0146478)

The watershed that drains to this segment is approximately 40 percent agricultural land with poor riparian buffers. There are horse farms, including a large horseracing track located within 300 feet of the stream. Strategies: prioritize for EQIP funds to install agricultural BMPs.

North Branch Barkers Brook near Jobstown (Site ID # 01464583)

Watershed is largely agricultural with cultivation and pasturing up to the water's edge. Large flocks of Canada geese and birds were observed on farm fields and in ponds found on the farms. Strategies: prioritize for EQIP funds to install agricultural BMPs; encourage community based goose management programs.

Bacons Creek near Mansfield Square (Site ID # 01464529)

Watershed is over 50 percent agricultural land, some of which supports livestock. Significant portion of the impaired reach was bordered by homes on septic systems. Within the headwater portion of the watershed, horse farms where observed. Monitoring: fecal survey to narrow scope of impairment; coliphage to determine if septic systems are a source. Strategies: prioritize for EQIP funds to install agricultural BMPs.

Doctors Creek at Allentown (Site ID # 01464515)

Large amount of Canada geese observed on Conines Millpond in Allentown. Agricultural lands supporting livestock observed, along with residential areas. Load duration curve consistent with storm driven sources. Strategies: prioritize for EQIP funds to install agricultural BMPs; encourage community based goose management programs.

Crosswicks Creek at Groveville Rd. (Site ID# 01464504)

Stream has a well-developed buffer throughout the reach, ranging from 23 to over 300 feet. Downstream portions of the creek flow through a highly residential area that receives sewer service. In the upstream portion of the segment between Extonville Road in Extonville to Arneytown-Hornerstown Road in Hornerstown there are areas of residential homes on septic and pastureland for horses streamside. Load duration curve is consistent with storm driven sources. Strategies: prioritize for EQIP funds to install agricultural BMPs; Phase II stormwater program.

10.5. Pathogen Indicators and Bacterial Source Tracking

Advances in microbiology and molecular biology have produced several methodologies that discriminate among sources of fecal coliform and thus more accurately identify pathogen sources. The numbers of pathogenic microbes present in polluted waters are few and not readily isolated nor enumerated. Therefore, analyses related to the control of these pathogens must rely upon indicator microorganisms. The commonly used pathogen indicator organisms are the coliform groups of bacteria, which are characterized as gram-negative, rod-shaped bacteria. Coliform bacteria are suitable indicator organism because they are generally not found in unpolluted water, are easily identified and quantified, and are generally more numerous and more resistant than pathogenic bacteria (Thomann and Mueller, 1987).

Tests for fecal organisms are conducted at an elevated temperature (44.5°C), where the growth of bacteria of non-fecal origin is suppressed. While correlation between indicator organisms and diseases can vary greatly, as seen in several studies performed by the EPA and others, two indicator organisms *Esherichia coli* (*E. coli*) and enterococci species showed stronger correlation with incidence of disease than fecal coliform (USEPA, 2001). Recent advances have allowed for more accurate identification of pathogen sources. A few of these methods, including, molecular, biochemical, and chemical are briefly described in the following paragraph.

Molecular (genotype) methods are based on the unique genetic makeup of different strains, or subspecies, of fecal bacteria (Bowman et al, 2000). An example of this method includes "DNA fingerprinting" (i.e., a ribotype analysis which involves analyzing genomic DNA from fecal *E. coli* to distinguish human and non-human specific strains of *E. coli*.). Biochemical (phenotype) methods include those based on the effect of an organism's genes actively producing a biochemical substance (Graves et al., 2002; Goya et al 1987). An example of this method is multiple antibiotic resistance (MAR) testing of fecal *E. coli.* In MAR testing, *E. coli* are isolated from fecal samples and exposed to 10-15 different antibiotics. In theory, *E. coli* originating from wild animals should show resistance to a smaller number of antibiotics than *E. coli* originating from humans or pets. Given this general trend, MAR patterns or '"signatures" can be defined for each class of *E. coli* species. Chemical methods are based on finding chemical compounds associated with human wastewater, and useful in determining if the sources are human or non-human. Such methods measure the presence of optical brighteners, which are contained in all laundry detergents, and soap surfactants in the water column. Unlike the optical brightener method, the measurement of surfactants may allow for some quantification of the source.

BST methods have already been successfully employed at the NJDEP in the past decade. Since 1988, the Department's Bureau of Marine Water Monitoring has worked cooperatively with the University of North Carolina in developing and determining the application of RNA coliphage as a pathogen indicator. This research was funded through USEPA and Hudson River Foundation grants. These studies showed that the RNA coliphages are useful as an indicator of fecal contamination, particularly in chlorinated effluents and that they can be serotyped to distinguish human and animal fecal contamination. Through these studies, the Department has developed an extensive database of the presence of coliphages in defined contaminated areas (point human, non-point human, point animal, and non-point animal). More recently, MAR and DNA fingerprinting analyses of *E. coli* are underway in the Manasquan estuary to identify potential pathogen sources (Palladino and Tiedemann, 2002). These studies along with additional sampling within the watershed will be used to implement the necessary percent load reduction.

10.6. Reasonable Assurance

With the implementation of follow-up monitoring, source identification and source reduction as described for each segment, the Department has reasonable assurance that New Jersey's Surface Water Quality Standards will be attained for fecal coliform. The Department proposes to undertake the identified monitoring responses beginning in 2003-2004. As a generalized strategy, the Department proposes the following with regard to categorical sources: 1) As septic system sources are identified through the monitoring responses, municipalities will be encouraged to enter the Environmental Infrastructure Financing Program, which includes New Jersey's State Revolving Fund, to evaluate, select and implement the best overall solution to such problems; 2) To address storm water point sources, the Phase II stormwater permitting program will require control measures to be phased in from the effective date of authorization to 60 months from that date; 3) The locations of impaired segments with significant agricultural land uses will be provided to the State Technical Committee for consideration in the FFY 2004 round of EQIP project selection; 4) Through continuing engagement of watershed partners, measures to identify and address other sources will be pursued, including encouragement and support of community based goose management programs, where appropriate. The Department has dedicated a portion of its Corporate Business Tax and FY 2002 Clean Water Act Section 319(h) funds to carry out the segment specific source trackdown recommendations. A portion of FY 2003 319(h) funds will be dedicated to assisting municipalities in implementing the requirements of the Phase II municipal stormwater permitting program.

The fecal coliform reductions proposed in these TMDLs assume that existing NJPDES permitted municipal facilities will continue to meet New Jersey's Surface Water Quality Standard requirements for disinfection. Any future facility will be required to meet water quality standards for disinfection.

The Department's ambient monitoring network will be the means to determine if the strategies identified have been effective. Where trackdown monitoring has been recommended, the results of this monitoring as well as ambient monitoring will be evaluated to determine if additional strategies for source reduction are needed.

11.0 Public Participation

The Water Quality Management Planning Rules NJAC 7:15-7.2 require the Department to initiate a public process prior to the development of each TMDL and to allow public input to the Department on policy issues affecting the development of the TMDL. Further, the Department shall propose each TMDL as an amendment to the appropriate areawide water quality management plan in accordance with procedures at N.J.A.C. 7:15-3.4(g). As part of the public participation process for the development and implementation of the TMDLs for fecal coliform in the Lower Delaware Water Region, the Department worked collaboratively with a series of stakeholder groups throughout New Jersey as part of the Department's ongoing watershed management efforts.

The Department's watershed management process includes a comprehensive stakeholder process that includes of members from major stakeholder groups, (agricultural, business and industry, academia, county and municipal officials, commerce and industry, purveyors and dischargers, and environmental groups). As part of this watershed management planning process, Public Advisory Committees (PACs) and Technical Advisory Committees (TACs) were created in all 20 WMAs. The PACs serve in an advisory capacity to the Department, examining and commenting on a myriad of issues in the watersheds. The TACs are focused on scientific, ecological, and engineering issues relevant to the issues of the watershed, including water quality impairments and management responses to address them.

Through a series of presentations and discussions the Department engaged the WMA 17, 18, 19 and 20 PACs and TACs in a process that culminated in the development of the 27 TMDLs for Streams Impaired by Fecal Coliform in the Lower Delaware Water Region. One or two meetings, as specified below, were held in each WMA. At the PAC meetings, the expedited fecal coliform TMDL protocols and the executed Memorandum of Agreement between the Department and EPA Region 2 were described, including the associated schedule for completing TMDLs. The PACs were asked to review impaired segments and provide local insights as to fecal coliform sources. Maps with aerial photography and topography of the impaired segments were provided to facilitate the conversation. In most cases, a second meeting was held with the TAC and/or a smaller working group to identify potential sources of impairment based on their local knowledge. The impaired segment maps were marked to indicate any areas of concern and TAC members were encouraged to provide any additional source information through the formal comment period after advertisement of the TMDL proposal in the New Jersey Register. The dates of the meetings were as follows:

WMA	**PAC Meeting**	**TAC Meeting**
17	December 10, 2002	January 22, 2003
18	December 3, 2002	December 3, 2002
19	November 13, 2002	December 10, 2002
20	November 13, 2002	December 3, 2002

Additional input was received through the NJ EcoComplex (NJEC). The Department contracted with NJEC in July 2001. The NJEC consists of a review panel of New Jersey University professors whose role is to provide comments on the Department's technical approaches for development of TMDLs and management strategies. The New Jersey

Statewide Protocol for Developing Fecal TMDLs was presented to NJEC on August 7, 2002 and was subsequently reviewed and approved. The protocol was also presented at the SETAC Fall Workshop on September 13, 2002 and met with approval.

Amendment Process

In accordance with N.J.A.C. 7:15–7.2(g), these TMDLs are hereby proposed by the Department as an amendment to Lower Delaware Water Quality Management Plan (WQMP), Mercer, Monmouth and Ocean Counties WQMP, and Tri-County WQMP.

Notice proposing these TMDLs was published April 21, 2003 in the New Jersey Register and in newspapers of general circulation in the affected area in order to provide the public an opportunity to review the TMDLs and submit comments. In addition, a public hearing will be held on May 22, 2003. Notice of the proposal and the hearing has also been provided to applicable designated planning agencies and to affected municipalities.

References

Bowman, A.M., C. Hagedorn, and K. Hix. 2000. Determining sources of fecal pollution in the Blackwater River watershed. p. 44-54. In T. Younos and J. Poff (ed.), Abstracts, Virginia Water Research Symposium 2000, VWRRC Special Report SR-19-2000, Blacksburg.

Cabelli, V. 1989. Swimming-associated illness and recreational water quality criteria. Wat. Sci. Tech. 21:17.

Alexandria K. Graves, Charles Hagedorn, Alison Teetor, Michelle Mahal, Amy M. Booth, and Raymond B. Reneau, Jr. Antibiotic Resistance Profiles to Determine Sources of Fecal Contamination in a Rural Virginia Watershed. Journal of Environmental Quality. 2002 31: 1300-1308.

National Research Council. 2001. Assessing the TMDL Approach to water quality management. National Academy Press, Washington, D.C.

New Jersey Department of Environmental Protection. 1998. Identification and Setting of Priorities for Section 303(d) Water Quality Limited Waters in New Jersey, Office of Environmental Planning

New Mexico Environmental Department. 2002. TMDL for Fecal Coliform on three Cimarron River Tributaries in New Mexico.
Online at: http://www.nmenv.state.nm.us/swqb/CimarronTMDL.html

Palladino, M. A., and Tiedemann, J. (2001) Differential Identification of E. coli in the Manasquan River Estuary by Multiple Antibiotic Resistance Testing and DNA Fingerprinting Analysis. Monmouth University, NJ

Goyal, S.M. 1987. Methods in Phage Ecology. pp. 267-287. In: Phage Ecology, S.M. Goyal, C.P. Gerba and G. Bitton (Eds.) John Wiley and Sons, New York.

Saunders, William and Maidment, David. 1996. A GIS Assessment of Nonpoint Source Pollution in the San Antonio- Nueces Coastal Basin. Center for Research in Water Resources. Online Report 96-1:

Stiles, Thomas C. (2001). A Simple Method to Define Bacteria TMDLs in Kansas. Presented at the WEF/ASIWPCA TMDL Science Issues Conference, March 7, 2001.

Sutfin, C.H. 2002. Memo: EPA Review of 2002 Section 303(d) Lists and Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992. Office of Wetlands, Oceans and Watersheds, U.S.E.P.A.

Thomann, R.V. and J.A. Mueller. 1987. Principles of Surface Water Quality Modeling and Control, Harper & Row, Publishers, New York.

USEPA. 1986. Implementation Guidance for Ambient Water Quality Criteria for Bacteria. EPA-823-D-00-001. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1993. Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters. EPA-840-B-92-002. Washington, DC.

USEPA. 1997. Compendium of tools for watershed assessment and TMDL development. EPA841-B-97-006. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 2001. Protocol for Developing Pathogen TMDLs. EPA841-R-00-002. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

U.S. Geological Survey. 1982. Low - Flow Characteristics and Flow Duration of New Jersey Streams. Open-File Report 81-1110.

Appendix A: Explanation of stream segments in Sublist 5 of the *2002 Integrated List of Waterbodies* for which TMDLs will not be developed in this report.

River segments to be moved from Sublist 5 to Sublist 3 for fecal coliform.

- **#01465970, North Branch Rancocas Creek at Browns Mills**
- **#01411950, Buckshutem Creek near Laurel Lake**

Station #01465970 was included on Sublist 5 based on its inclusion on previous 303(d) lists (based on water quality data prior 1991) with no recent data to assess their current attainment status. Station #01411950 was included on Sublist 5 of the 2002 Integrated List based on less than five data points. Therefore, further monitoring will be needed to confirm impairment and to establish TMDL for these streams.

Appendix B: Municipal POTWs Located in the TMDLs' Project Areas

WMA	Station #	NJPDES	Facility Name	Discharge Type[a]	Receiving waterbody
17	1482500	NJ0022250.001A	Woodstown SA	MMI	Salem River
17	1482560	NJ0022250.001A	Woodstown SA	MMI	Salem River
18	1467081	NJ0024040.001A	Evesham Twp MUA - Woodstream	MMJ	Pennsauken Creek S B
18	1467081	NJ0024040.SL3A	Evesham Twp MUA - Woodstream	MMJ	Sludge Application
18	1467081	NJ0024040.SL3B	Evesham Twp MUA - Woodstream	MMJ	Sludge Application
18	1467081	NJ0024040.SL3M	Evesham Twp MUA - Woodstream	MMJ	Sludge Application
18	1467081	NJ0025071.001A	Cherry Hill Twp - Kingston	MMJ	Pennsauken Creek South Branch
18	1467081	NJ0025089.002A	Cherry Hill Twp - Pennsauken	MMJ	Pennsauken Creek South Branch
18	1467081	NJ0025089.001A	Cherry Hill Twp - Pennsauken	MMJ	Pennsauken Creek South Branch
18	1467081	NJ0031879.001A	Maple Shade - Kings Hwy WTP	MMI	Pennsauken Ck South Branch
18	1477120	NJ0020532.001A	Harrison Twp - Mullica Hill STP	MMI	Racoon Creek
18	1467359	NJ0020320.001A	Clementon Boro	MMJ	Big Timber Creek North Branch via storm sewer
18	1467359	NJ0022624.001A	Stratford S A	MMJ	Big TImber Creek North Branch
18	1467359	NJ0026468.001A	Gloucester Twp MUA - Chewa Landing	MMJ	Big Timber Creek North Branch
18	1467150	NJ0025046.002A	Cherry Hill Twp - Barclay Farms	MMJ	Cooper River
18	1467150	NJ0025046.001A	Cherry Hill Twp - Barclay Farms	MMJ	Cooper River
18	1467150	NJ0025054.001A	Cherry Hill Twp - Old Orchard	MMJ	Cooper River
19	1467006	NJ0024821.001A	Pemberton Twp MUA	MMJ	Rancocas Creek N B
19	1467006	NJ0028665.001A	Mobile Estates of Southhampton	MMI	Rancocas River via unnamed trib
20	1464504	NJ0026719.001A	NJDC - A C Wagner	MMI	Crosswicks Creek via unnamed trib
20	1464529	NJ0022381.001A	North Burlington County BOE - High School	MMI	Bacons Run
20	1464515	NJ0020206.001A	Allentown Boro WTP	MMI	Doctors Creek
20	1464515	NJ0020737.001A	NJ Tpk Auth - Hamilton Twp	MMI	Doctors Creek via storm sewer

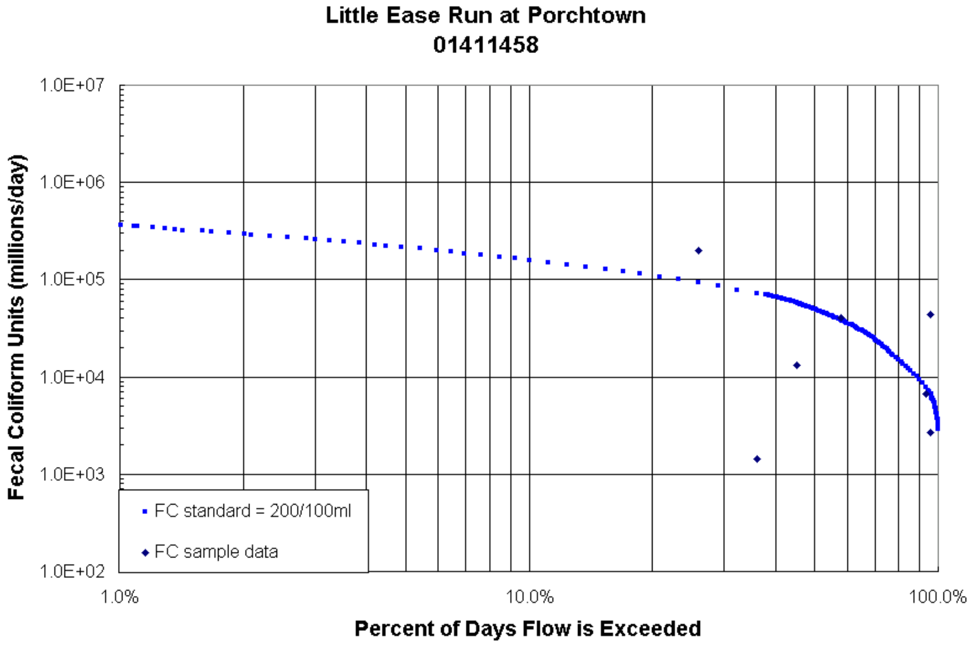
[a] “MMI” indicates a Municipal Minor discharge and “MMJ” indicates Municipal Major discharge.

Appendix C: TMDL Calculations

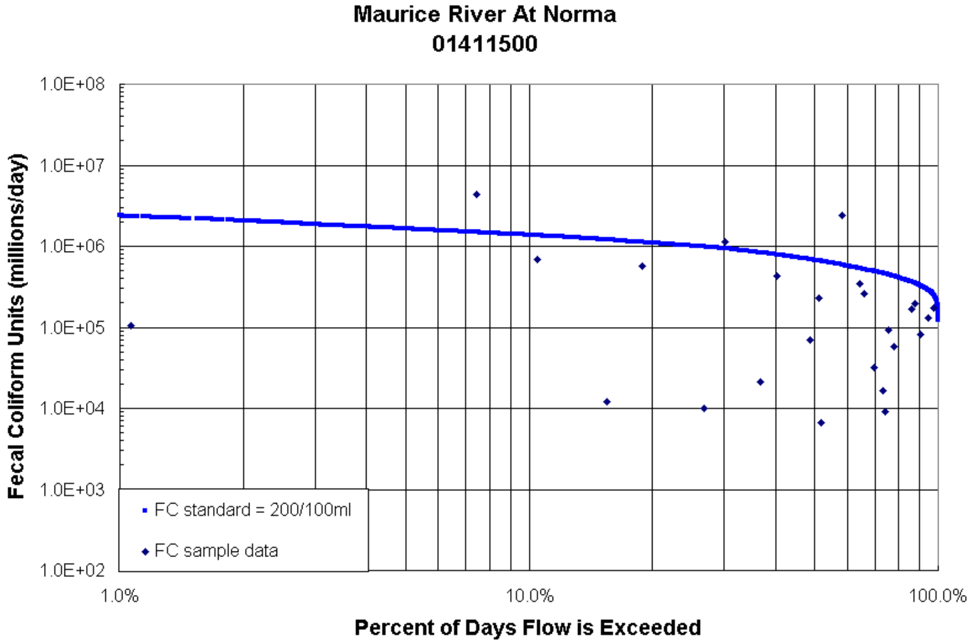
WMA	303(d) Category 5 Segments	Water Quality Stations	Station Names	Load Allocation (LA) and Margin of Safety (MOS)										Wasteload Allocation (WLA)	Period of record used in analysis
				200 FC/100ml Standard					400 FC/100ml Standard						
				N (# of values)	Geometric mean CFU/100ml	MOS as a percent of the target concentration	Percent reduction without MOS	Percent reduction with MOS	Summer N	Summer geometric mean CFU/100ml	MOS as a percent of the target concentration	Percent reduction without MOS	Percent reduction with MOS		
17	01411466	01411466	Indian Branch near Malaga	20	70	47%	-187%	-51%	20	70	47%	3%	49%	49%	6/4/98 - 8/7/01
17	01411458, 01411500, 01411800	01411458, 01411500, 01411800	Little Ease Run at Porchtown, Maurice River at Norma, Maurice River near Millville	42	54	36%	-273%	-139%	30	130	36%	48%	67%	67%	2/9/94 - 7/26/01
17	01412800	01412800	Cohansey River at Seeley	37	93	39%	-115%	-32%	27	122	39%	44%	66%	66%	2/16/94 - 7/26/01
17	01482500, 01482537	01482500, 01482537	Salem River at Woodstown, Salem River	39	277	39%	28%	56%	29	251	39%	73%	84%	84%	2/17/94 - 7/12/01
17	01482560	01482560	Two Penny Run near Danceys Corner	5	408	39%	51%	70%	5	408	39%	83%	90%	90%	7/5/00 - 8/1/00
18	01467069, 01467081	01467069, 01467081	NB Pennsauken Creek near Morrestown, SB Pennsauken Creek at Cherry Hill	19	2917	54%	93%	97%	8	17677	54%	99.6%	99.8%	99.8%	2/17/94 - 7/23/97
18	01467120, 01467150, 01467155	01467120, 01467150, 01467155	Cooper River at Lidenwold, Cooper River at Haddonfield, NB Cooper River at Kresson,	46	1103	33%	82%	88%	36	1473	33%	95%	97%	97%	2/15/94 - 7/5/01
18	01467327, 01467329	01467327, 01467329	SB Big Timber Creek at Glenloch, SB Big Timber Creek at Blackwood	28	227	36%	12%	44%	18	298	36%	77%	85%	85%	2/15/94 - 8/31/99
18	01467359	01467359	NB Big Timber Creek at Glendora	14	928	41%	78%	87%	14	928	41%	93%	96%	96%	6/9/98 - 7/5/01
18	01476600	01476600	Still Run near Mickelton	5	249	32%	20%	46%	5	249	32%	73%	82%	82%	7/15/99 - 8/12/99
18	01477120	01477120	Raccoon Creek near Swedesboro	38	274	30%	27%	49%	28	387	30%	82%	88%	88%	2/17/94 - 8/7/01

				Load Allocation (LA) and Margin of Safety (MOS)											
				200 FC/100ml Standard					400 FC/100ml Standard						
WMA	**303(d) Category 5 Segments**	**Water Quality Stations**	**Station Names**	N (# of values)	Geometric mean CFU/100ml	MOS as a percent of the target concentration	Percent reduction without MOS	Percent reduction with MOS	Summer N	Summer geometric mean CFU/100ml	MOS as a percent of the target concentration	Percent reduction without MOS	Percent reduction with MOS	**Wasteload Allocation (WLA)**	**Period of record used in analysis**
18	01477440, 01477510	01477440, 01477510	Oldmans Creek at Jessups Mill, Oldmans Creek at Porches Mill	23	307	43%	35%	63%	13	774	43%	91%	95%	95%	2/17/94 - 8/1/00
19	01465884	01465884	Sharps Run at Rt 541 at Medford	5	264	52%	24%	64%	5	264	52%	74%	88%	88%	8/2/99 - 8/30/99
19	01467006	01467006	NB Rancocas Creek at Pine St at Mt Holly	5	417	60%	52%	81%	5	417	60%	84%	94%	94%	6/9/98 - 7/22/98
20	01464504	01464500, 01464504, 01464420, 2	Crosswicks Creek at Extonville, Crosswicks Creek at Groveville Rd. at Groveville, Crosswicks Creek near New Egypt, Crosswicks Creek at Walnford Rd In Upper Freehold	74	220	22%	9%	29%	42	380	22%	82%	86%	86%	2/14/94 - 6/11/01
20	01464515	01464515, 3	Doctors Creek at Allentown, Doctors Creek at Route 539 In Upper Freehold	64	174	27%	-15%	16%	33	346	27%	80%	86%	86%	2/15/94 - 8/30/01
20	01464529	01464529	Bacons Creek near Mansfield Square	5	399	61%	50%	81%	5	399	61%	83%	93%	93%	8/2/99 - 8/30/99
20	01464578	01464578	Annaricken Brook near Jobstown	6	432	68%	54%	85%	6	432	68%	84%	95%	95%	6/18/98 - 9/9/98
20	01464583	01464583	NB Barkers Brook near Jobstown	10	813	54%	75%	89%	10	813	54%	92%	96%	96%	6/2/98 - 8/30/99

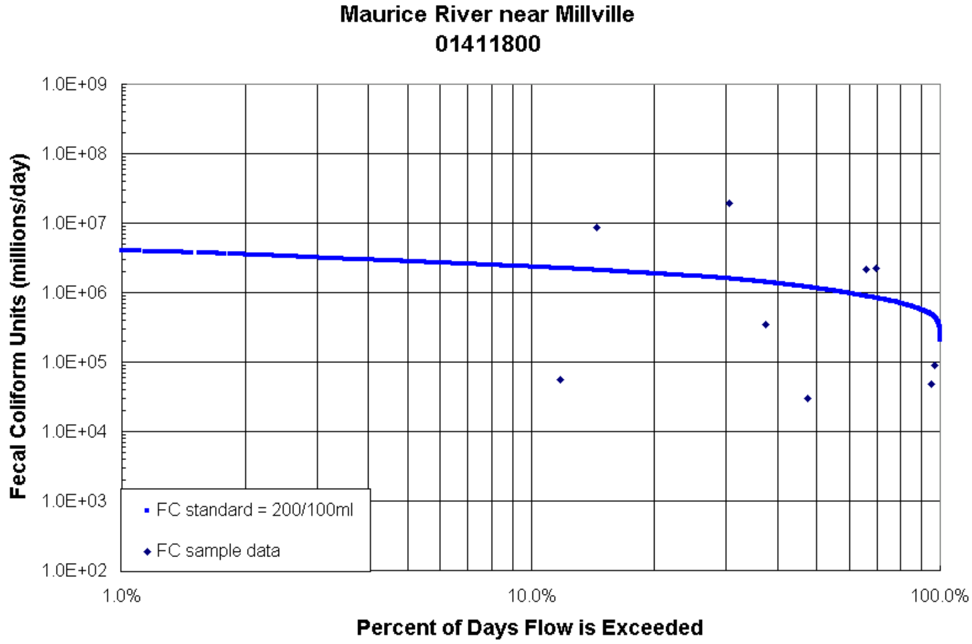
Appendix D: Load Duration Curves for selected listed waterbodies



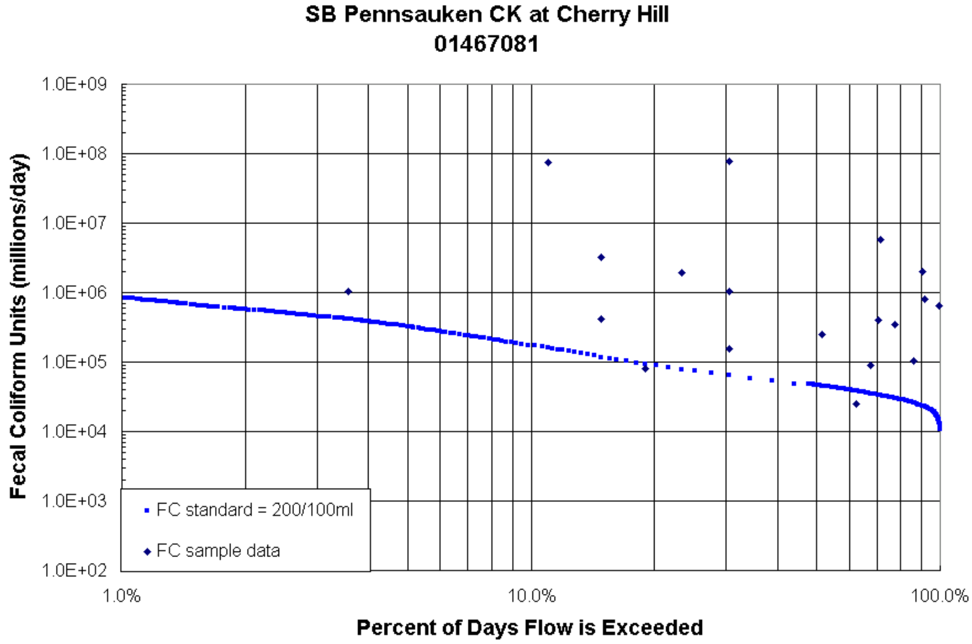
Load Duration Curve for Little Ease Run at Porchtown. Fecal coliform data from USGS station # 01411458 during the period 2/9/94 through 9/17/98. Water years 1970-2001 from USGS station # 01411456 (Little Ease Run near Clayton) were used in
generating the FC standard curve.



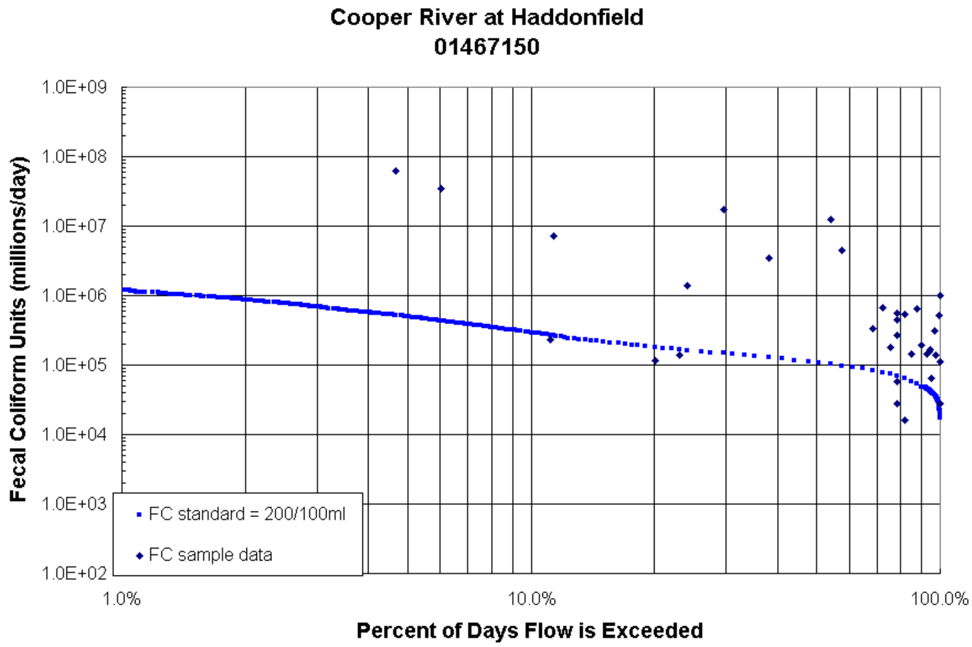
Load Duration Curve for Maurice River at Norma. Fecal coliform data from USGS station # 01411500 during the period 2/9/94 through 7/26/01. Water years 1970-2001 from USGS station # 01411500 were used in generating the FC standard curve.



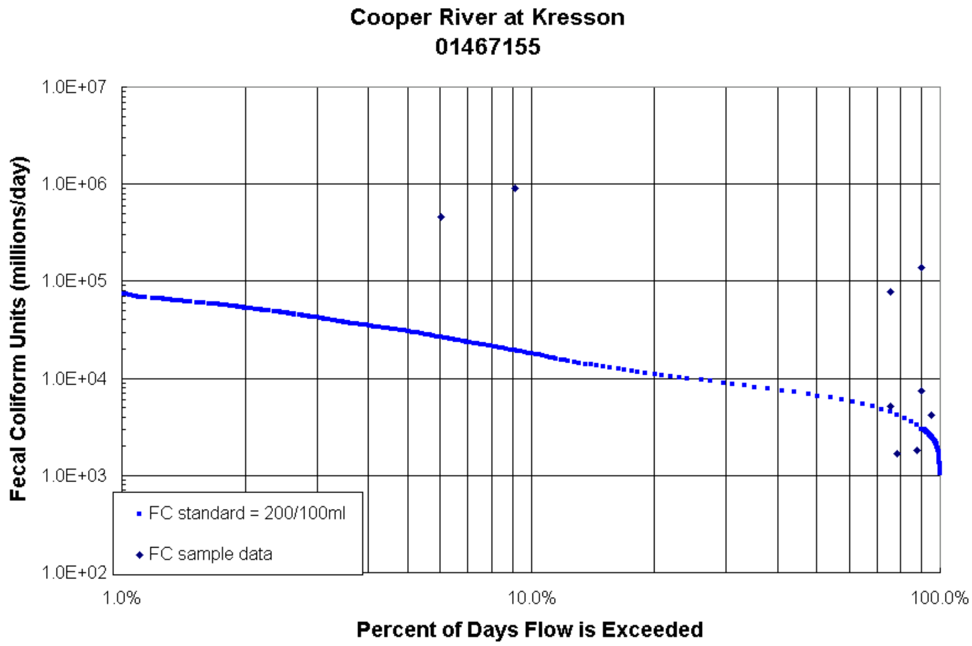
Load Duration Curve for Maurice River near Millville. Fecal coliform data from USGS station # 01411800 during the period 2/16/94 through 9/17/98. Water years 1970-2001 from USGS gaging station # 01411500 (Maurice River at Norma) were used in generating the FC standard curve.



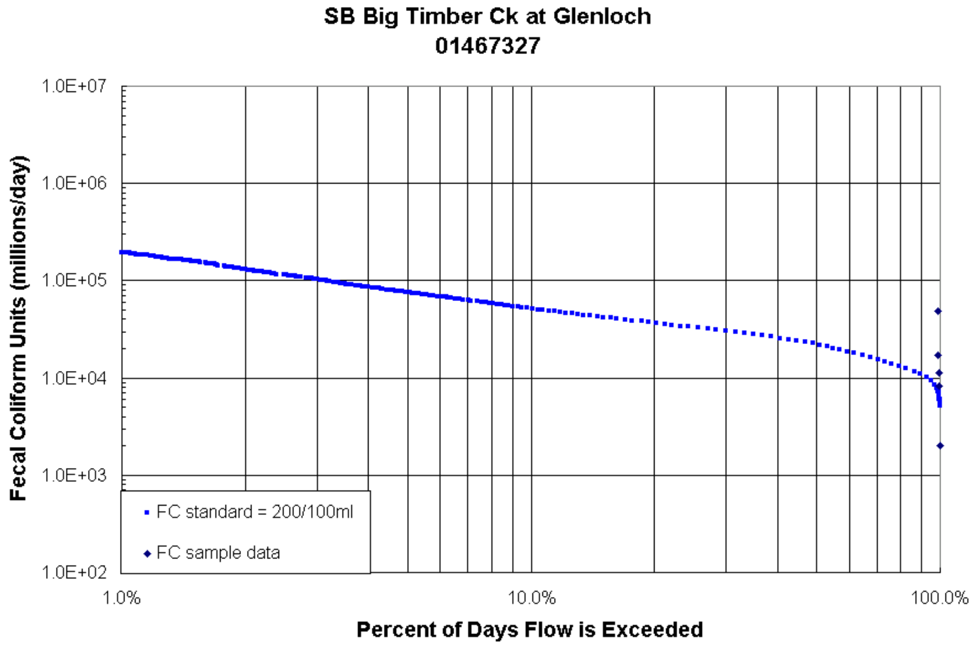
Load Duration Curve for SB Pennsauken CK at Cherry Hill. Fecal coliform data from USGS station # 01467081 during the period 2/17/94 through 7/23/97. Water years 1970-2001 from USGS gaging station # 01467081 were used in generating the FC standard curve



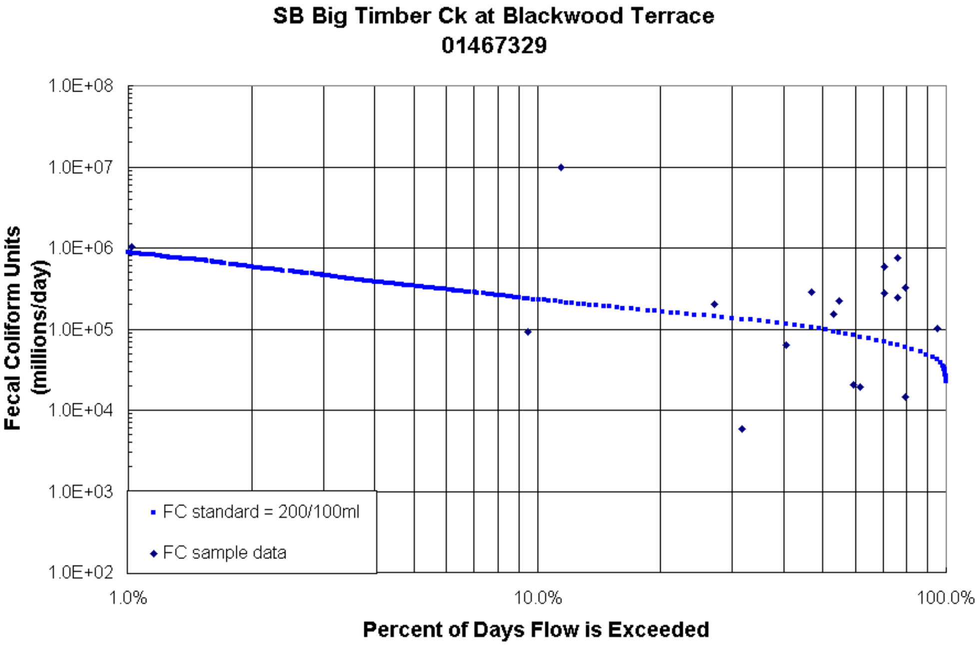
Load Duration Curve for Cooper River At Haddonfield. Fecal coliform data from USGS station # 01467150 during the period 2/15/94 through 7/53/01. Water years 1970-2001 from USGS gaging station # 01467150 were used in generating the FC standard curve



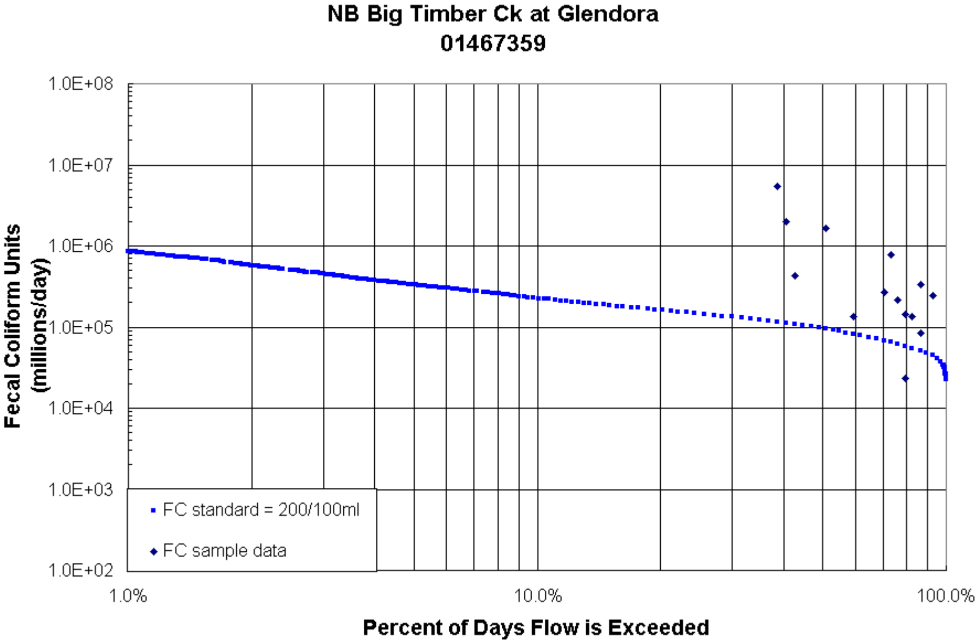
Load Duration Curve for Cooper River At Kresson. Fecal coliform data from USGS station # 01467155 during the period 6/1/98 through 7/5/01. Water years 1970-2001 from USGS gaging station # 01467150 (Cooper River at Haddonfield) were used in generating the FC standard curve



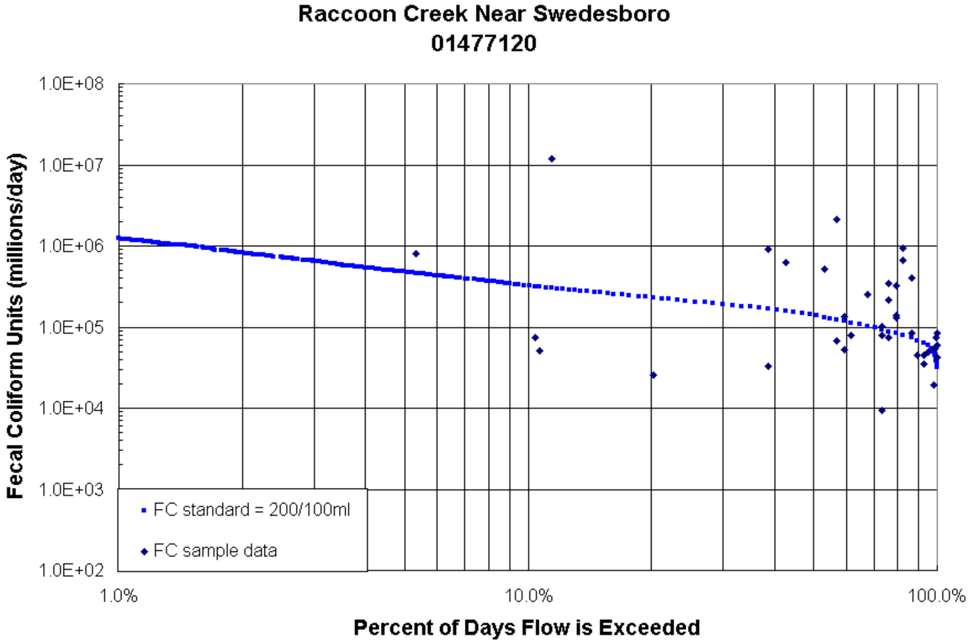
Load Duration Curve for SB Big Timber CK at Glenloch. Fecal coliform data from USGS station # 01467327 during the period 8/1/99 through 8/31/99. Water years 1970-2001 from USGS gaging station # 01477120 (Raccoon CK at Swedesboro) were used in generating the FC standard curve



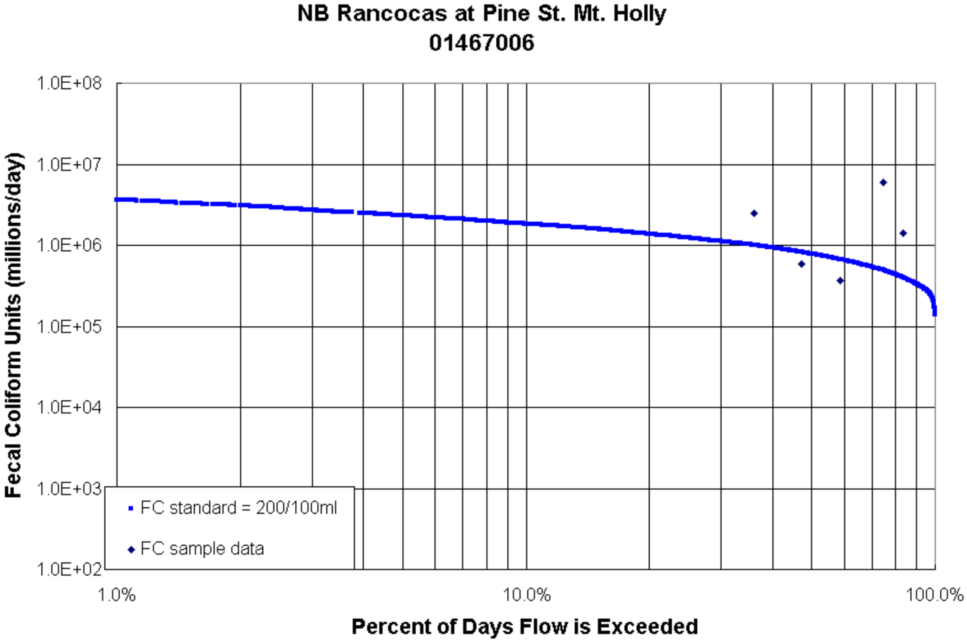
Load Duration Curve for SB Big Timber CK at Blachwood Terrace. Fecal coliform data from USGS station # 01467329 during the period 2/15/94 through 8/4/97. Water years 1970-2001 from USGS gaging station # 01477120 (Raccoon CK at Swedesboro) were used in generating the FC standard curve



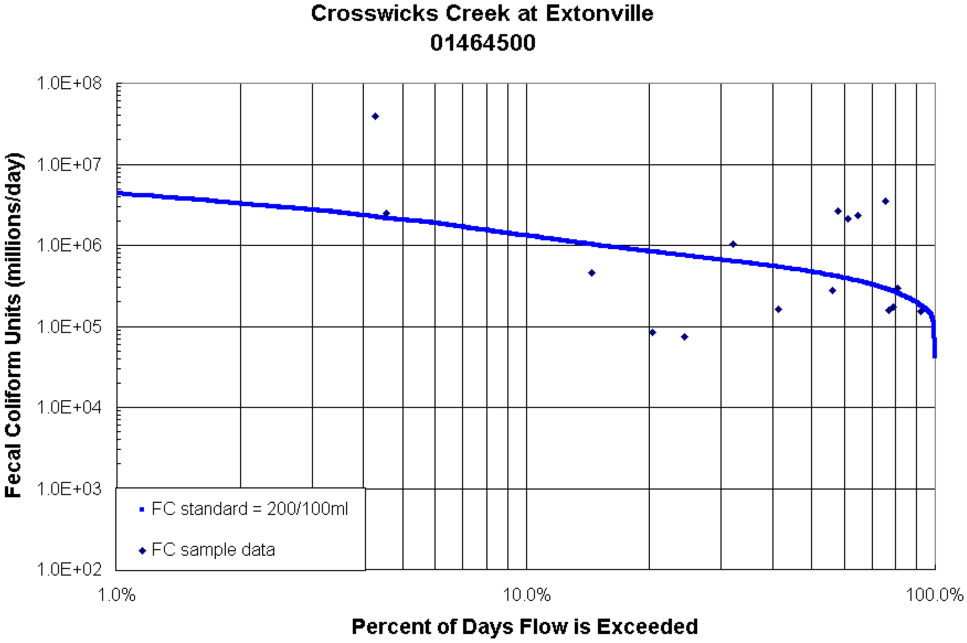
Load Duration Curve for NB Big Timber CK at Glendora. Fecal coliform data from USGS station # 01467359 during the period 6/9/98 through 7/5/01. Water years 1970-2001 from USGS gaging station # 01477120 (Raccoon CK near Swedesboro) were used in generating the FC standard curve



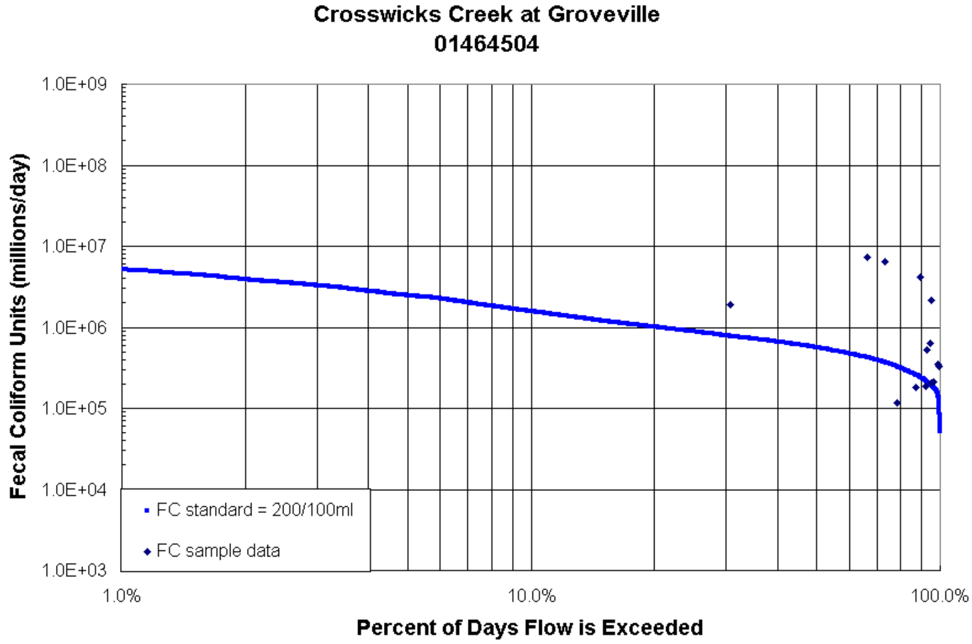
Load Duration Curve for Raccoon CK near Swedesboro. Fecal coliform data from USGS station # 01477120 during the period 2/17/94 through 8/7/01. Water years 1970-2001 from USGS gaging station # 01477120 (Raccoon CK near Swedesboro) were used in generating the FC standard curve



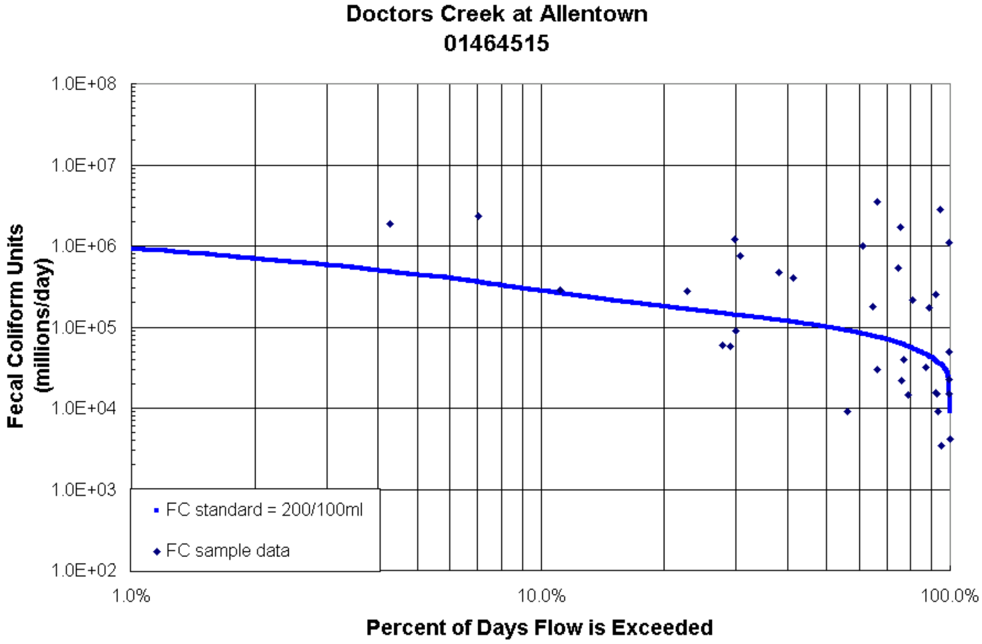
Load Duration Curve for NB Rancocas at Pine St. Mt. Holly. Fecal coliform data from USGS station # 01467006 during the period 6/9/98 through 7/22/98. Water years 1970-2001 from USGS gaging station # 01467000 (NB Rancocas CK at Pemberton) were used in generating the FC standard curve



Load Duration Curve for Crosswicks Creek at Extonville. Fecal coliform data from USGS station # 01464500 during the period 2/14/94 through 7/31/97. Water years 1970-2001 from USGS gaging station # 01464500 were used in generating the FC standard curve



Load Duration Curve for Crosswicks Creek at Groveville. Fecal coliform data from USGS station # 01464504during the period 6/8/98 through 8/3/00. Water years 1970-2001 from USGS gaging station # 01464500 (Crosswicks Creek at Extonville) were used in generating the FC standard curve



Load Duration Curve for Doctors Creek at Allentown. Fecal coliform data from USGS station # 01464515 during the period 2/15/94 through 8/30/01. Water years 1970-2001 from USGS gaging station # 01464500 (Crosswicks Creek at Extonville) were used in generating the FC standard curve

Amendment to the
Atlantic County Water Quality Management Plan
Lower Delaware Water Quality Management Plan
Mercer County Water Quality Management Plan
Monmouth County Water Quality Management Plan
Tri-County Water Quality Management Plan

Total Maximum Daily Loads for Phosphorus To Address 13 Eutrophic Lakes in the Lower Delaware Water Region

BELL LAKE, GLOUCESTER COUNTY
BETHEL LAKE, GLOUCESTER COUNTY
BLACKWOOD LAKE, CAMDEN AND GLOUCESTER COUNTIES
BURNT MILL POND, CUMBERLAND COUNTY
GIAMPIETRO LAKE, CUMBERLAND COUNTY
HARRISONVILLE LAKE, GLOUCESTER AND SALEM COUNTIES
IMLAYSTOWN LAKE, MONMOUTH COUNTY
KIRKWOOD LAKE, CAMDEN COUNTY
MARY ELMER LAKE, CUMBERLAND COUNTY
MEMORIAL LAKE, SALEM COUNTY
SPRING LAKE, MERCER COUNTY
SUNSET LAKE, CUMBERLAND COUNTY
WOODBURY LAKE, GLOUCESTER COUNTY

Watershed Management Area 17
(Maurice, Salem, and Cohansey Watersheds)
Watershed Management Area 18
(Lower Delaware Watershed)
Watershed Management Area 20
(Assiscunk, Crosswicks, and Doctors Watersheds)

Proposed:	April 21, 2003
Established:	June 27, 2003
Approved (by EPA Region 2):	September 30, 2003
Adopted:	

New Jersey Department of Environmental Protection
Division of Watershed Management
P.O. Box 418
Trenton, New Jersey 08625-0418

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Contents

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Tables

1.0 Executive Summary

The State of New Jersey's *2002 Integrated List of Waterbodies* identified several lakes in the Northwest Water Region as being eutrophic. This report establishes total maximum daily loads (TMDLs) for total phosphorus (TP) that address eutrophication of the lakes listed in Table 1.

Table 1 Eutrophic Lakes for which Phosphorus TMDLs are being established

TMDL	Lake Name	Municipality	WMA	Acres
1	Burnt Mill Pond	Vineland City, Cumberland County	17	22.0
2	Giampietro Lake	Vineland City, Cumberland County	17	14.4
3	Mary Elmer Lake	Hopewell Township, Bridgeton City; Cumberland County	17	22.2
4	Memorial Lake	Woodstown Boro, Salem County	17	21.7
5	Sunset Lake	Hopewell, Upper Deerfield Townships; Bridgeton City; Cumberland County	17	87.0
6	Bell Lake	Woodbury City, Gloucester County	18	18.0
7	Bethel Lake	Mantua, Washington Townships; Gloucester County	18	1.8
8	Blackwood Lake	Washington Township, Gloucester County; Gloucester Township, Camden County	18	9.6
9	Harrisonville Lake	South Harrison Township, Gloucester County; Pilesgrove Township, Salem County	18	6.2
10	Kirkwood Lake	Voorhees Township, Lindenwold Boro; Camden County	18	24.9
11	Woodbury Lake	Woodbury City, Deptford Township; Gloucester County	18	46.8
12	Imlaystown Lake	Upper Freehold Township, Monmouth County	20	15.9
13	Spring Lake	Hamilton Township, Mercer County	20	21.8

These TMDLs serve as the foundation on which restoration plans will be developed to restore eutrophic lakes and thereby attain applicable surface water quality standards. A TMDL is developed as a mechanism for identifying all the contributors to surface water quality impacts and setting goals for load reductions for pollutants of concern as necessary to meet Surface Water Quality Standards (SWQS). The pollutant of concern for these TMDLs is phosphorus, since phosphorus is generally the nutrient responsible for overfertilization of inland lakes leading to cultural eutrophication. The Department's Geographic Information System (GIS) was used extensively to describe the lakes and lakesheds (drainage basins of the lakes).

In order to prevent excessive primary productivity[1] and consequent impairment of recreational, water supply and aquatic life designated uses, the SWQS define both numerical and narrative criteria that address eutrophication in lakes due to overfertilization. Phosphorus sources were characterized on an annual scale (kg TP/yr) for both point and nonpoint sources. Runoff from land surfaces comprises a substantial source of phosphorus into lakes. An empirical model was used to relate annual phosphorus load and steady-state in-lake concentration of total phosphorus. To achieve the TMDLs, overall load reductions were calculated for at least eight and, depending on the amount of information available, up to 14 source categories. In order to track effectiveness of remediation measures (including TMDLs) and to develop baseline and trend information on lakes, the Department will

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[1] Primary productivity refers to the growth rate of primary producers, namely algae and aquatic plants, which form the base of the food web.

augment its ambient monitoring program to include lakes on a rotating schedule. The implementation plan also calls for the collection of additional monitoring data and the development of a Lake Restoration Plan for each lake for which TMDLs are being established. These plans will consider what specific measures are necessary to achieve the nutrient reductions required by the TMDL, as well as what in-lake measures need to be taken to supplement the nutrient reductions required by the TMDL. Each TMDL shall be proposed and adopted by the Department as an amendment to the appropriate areawide water quality management plan(s) in accordance with N.J.A.C. 7:15-3.4(g).

This TMDL Report is consistent with EPA's May 20, 2002 guidance document entitled: "Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992," (Suftin, 2002) which describes the statutory and regulatory requirements for approvable TMDLs.

2.0 Introduction

Sublist 5 (also known as List 5 or, traditionally, the 303(d) List) of the State of New Jersey's *2002 Integrated List of Waterbodies* identified several lakes in the Lower Delaware Water Region (WMAs 17, 18, 19, and 20) as being eutrophic, as evidenced by elevated total phosphorus (TP), elevated chlorophyll-*a,* and/or macrophyte density that impairs recreational use (a qualitative assessment). This report establishes 13 total maximum daily loads (TMDLs) that address total phosphorus loads to the identified lakes. These TMDLs serve as the foundation on which management approaches or restoration plans will be developed to restore eutrophic lakes and thereby attain applicable surface water quality standards. Several of the lakes are listed on Sublist 5 for impairments caused by other pollutants. These TMDLs address only the impairment of lakes due to eutrophication. Separate TMDL evaluations will be developed to address the other pollutants of concern. The waterbodies will remain on Sublist 5 until such time as TMDL evaluations for all pollutants have been completed and approved by the United States Environmental Protection Agency (USEPA).

A TMDL is considered "proposed" when NJDEP publishes the TMDL Report as a proposed Water Quality Management Plan Amendment in the New Jersey Register (NJR) for public review and comment. A TMDL is considered to be "established" when NJDEP finalizes the TMDL Report after considering comments received during the public comment period for the proposed plan amendment and formally submits it to EPA Region 2 for thirty (30)-day review and approval. The TMDL is considered "approved" when the NJDEP-established TMDL is approved by EPA Region 2. The TMDL is considered to be "adopted" when the EPA-approved TMDL is adopted by NJDEP as a water quality management plan amendment and the adoption notice is published in the NJR.

3.0 Background

3.1 305(b) Report and 303(d) List

In accordance with Section 305(b) of the Federal Clean Water Act (CWA) (33 U.S.C. 1315(B)), the State of New Jersey is required to biennially prepare and submit to the United States Environmental Protection Agency (USEPA) a report addressing the overall water quality of the State's waters. This report is commonly referred to as the 305(b) Report or the Water Quality Inventory Report.

In accordance with Section 303(d) of the CWA, the State is also required to biennially prepare and submit to USEPA a report that identifies waters that do not meet or are not expected to meet surface water quality standards (SWQS) after implementation of technology-based effluent limitations or other required controls. This report is commonly referred to as the 303(d) List. The listed waterbodies are considered water quality-limited and require total maximum daily load (TMDLs) evaluations. For waterbodies identified on the 303(d) List, there are three possible scenarios that may result in a waterbody being removed from the 303(d) List:

Scenario 1: A TMDL is established for the pollutant of concern;
Scenario 2: A determination is made that the waterbody is meeting water quality standards (no TMDL is required); or
Scenario 3: A determination is made that a TMDL is not the appropriate mechanism for achieving water quality standards and that other control actions will result in meeting standards.

Where a TMDL is required (Scenario 1), it will: 1) specify the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards; and 2) allocate pollutant loadings among point and nonpoint pollutant sources.

Recent EPA guidance (Suftin, 2002) describes the statutory and regulatory requirements for approvable TMDLs, as well as additional information generally needed for USEPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations. The Department believes that this TMDL report, which includes 13 TMDLs, addresses the following items in the May 20, 2002 guideline document:

1. Identification of waterbody(ies), pollutant of concern, pollutant sources and priority ranking.
2. Description of applicable water quality standards and numeric water quality target(s).
3. Loading capacity – linking water quality and pollutant sources.
4. Load allocations.
5. Wasteload allocations.
6. Margin of safety.
7. Seasonal variation.
8. Reasonable assurances.

9. Monitoring plan to track TMDL effectiveness.
10. Implementation (USEPA is not required to and does not approve TMDL implementation plans).
11. Public Participation.
12. Submittal letter.

3.2 Total Maximum Daily Loads (TMDLs)

A TMDL represents the assimilative or carrying capacity of a waterbody, taking into consideration point and nonpoint source of pollutants of concern, natural background and surface water withdrawals. A TMDL quantifies the amount of a pollutant a water body can assimilate without violating a state's water quality standards and allocates that load capacity to known point sources in the form of wasteload allocations (WLAs), nonpoint sources in the form of load allocations (LAs), and a margin of safety. A TMDL is developed as a mechanism for identifying all the contributors to surface water quality impacts and setting goals for load reductions for pollutants of concern as necessary to meet SWQS.

Once one of the three possible delisting scenarios, noted above, is completed, states have the option to remove the waterbody and specific pollutant of concern from the 303(d) List or maintain the waterbody on the 303(d) list until SWQS are achieved. The State of New Jersey will be removing lakes from the 303(d) List for eutrophication once their TMDLS are approved by USEPA.

3.3 Integrated List of Waterbodies

In November 2001, USEPA issued guidance that encouraged states to integrate the 305(b) Report and the 303(d) List into one report. This integrated report assigns waterbodies to one of five categories. In general, Categories 1 through 4 include a range of designated use impairments with a discussion of enforceable management strategies, whereas Sublist 5 constitutes the traditional 303(d) List for waters impaired or threatened by a pollutant for which one or more TMDL evaluations are needed. Where more than one pollutant is associated with the impairment for a given waterbody, that waterbody will remain on Sublist 5 until one of the three possible delisting scenarios is completed. In the case of an Integrated List, however, the waterbody is not delisted but moved to one of the other categories.

Following USEPA's guidance, the Department chose to develop an Integrated Report for New Jersey. New Jersey's *2002 Integrated List of Waterbodies* is based upon these five categories and identifies water quality limited surface waters in accordance with N.J.A.C. 7:15-6 and Section 303(d) of the CWA. These TMDLs address eutrophic lakes, as listed on Sublist 5 of the State of New Jersey's *2002 Integrated List of Waterbodies.*

4.0 Pollutant of Concern and Area of Interest

Lakes were designated as impaired due to Nutrients/Sedimentation (Eutrophic) on Sublist 5 of the 2002 Integrated List of Waterbodies as a result of evaluations performed through the State's Clean Lakes Program. Indicators used to determine trophic status included elevated total phosphorus (TP), elevated chlorophyll-a, and/or macrophyte density. The impairment was designated as "Nutrients/Sedimentation" because these are the broad causes of eutrophication. The applicable surface water quality standards are listed in section 5. While sedimentation is important, no criterion exists for sedimentation and therefore none was applied to these lakes to determine their impairment status. Sedimentation can be biogenic in origin, caused by the deposition of organic matter in an excessively productive system, or it can result from excessive sediment loads from the watershed of a lake. Phosphorus control addresses both origins of sedimentation, since much of the runoff load of phosphorus is particulate and phosphorus in the lake controls the level of biological productivity. Also, stormwater controls intended to minimize phosphorus are more effective at controlling sediment than phosphorus. Due to the lack of criterion for sedimentation and to the overall importance of phosphorus, these TMDLs were developed around phosphorus budgets.

The pollutant of concern for these TMDLs is therefore total phosphorus. The mechanism by which phosphorus can cause use impairment is via excessive primary productivity. Phosphorus is an essential nutrient for plants and algae, but is considered a pollutant because it can stimulate excessive growth (primary production). Phosphorus is most often the major nutrient in shortest supply relative to the nutritional requirements of primary producers in freshwater lakes; consequently, phosphorus is frequently a prime determinant of the total biomass in a lake. Furthermore, of the major nutrients, phosphorus is the most effectively controlled through engineering technology and land use management (Holdren et al, 2001). Eutrophication has been described as the acceleration of the natural aging process of surface waters. It is characterized by excessive loading of silt, organic matter, and nutrients, causing high biological production and decreased basin volume (Cooke et al, 1993). Symptoms of eutrophication (primary impacts) include oxygen supersaturation during the day, oxygen depletion during night, and high sedimentation (filling in) rate. Algae and aquatic plants are the catalysts for these processes. Secondary biological impacts can include loss of biodiversity and structural changes to communities. Phosphorus is generally the nutrient responsible for overfertilization of inland lakes leading to eutrophication.

As reported in the *2002 Integrated List of Waterbodies*, the Department identified the following lakes in Northwest Water Region as being eutrophic for a total of 423 acres. These 13 TMDLs will address 312 acres or 74%of the total impaired acres in this region (Table 2). Both eutrophic lakes and aquatic life impairments are ranked as Low Priority in the *2002 Integrated List of Waterbodies* because they are not directly related to human health issues; however, both issues are environmentally important.

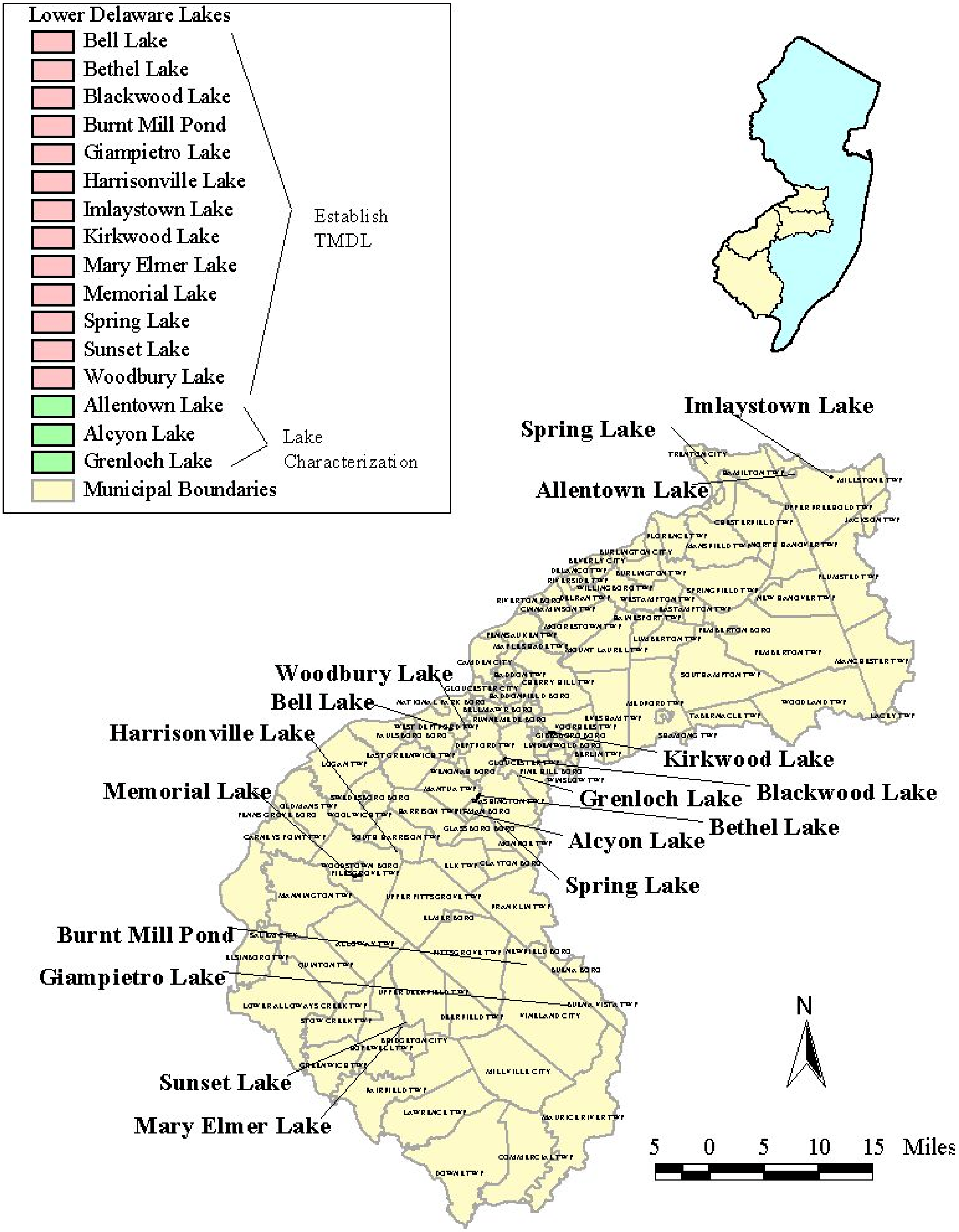
Table 2 Abridged Sublist 5 of the 2002 Integrated List of Waterbodies, eutrophic lakes

WMA	Lake[a]	Lake Acres	Lakeshed Acres	Management Response
17	Burnt Mill Pond	22.0	4411.5	Establish TMDL
17	Giampietro Lake	14.4	3645.6	Establish TMDL
17	Mary Elmer Lake	22.2	4828.2	Establish TMDL
17	Memorial Lake	21.7	9335.2	Establish TMDL
17	Sunset Lake	87.0	29305.8	Establish TMDL
18	Alcyon Lake	21.2	2800[b]	Lake Characterization
18	Bell Lake	1.8	275.2	Establish TMDL
18	Bethel Lake	9.6	4770.7	Establish TMDL
18	Blackwood Lake	6.2	12121.3	Establish TMDL
18	Grenloch Lake	19.3	9000[b]	Lake Characterization
18	Harrisonville Lake	18.0	5638.5	Establish TMDL
18	Kirkwood Lake	24.9	3252.7	Establish TMDL
18	Woodbury Lake	46.8	3208.6	Establish TMDL
20	Allentown Lake	23.3	7793.2	Lake Characterization
20	Imlaystown Lake	15.9	848.9	Establish TMDL
20	Spring Lake	21.8	115.0	Establish TMDL

[a] All of the waterbodies covered under these TMDLs have a FW2 classification.

[b] Lakesheds of these two lakes were estimated based on hydrology, not actually delineated.

Figure 1 Eutrophic lakes in the Lower Delaware Water Region on Sublist 5 of 2002 Integrated List



These TMDLs will address a total of 312 acres of lakes with a corresponding total of 81,800 acres of land within the affected lakesheds.

The Department's Geographic Information System (GIS) was used extensively to describe the lakes and lakesheds (watersheds of the lakes), specifically the following data coverages:

- 1995/97 Land use/Land cover Update, published 12/01/2000 by NJDEP Bureau of Geographic Information and Analysis , delineated by watershed management area.
- NJDEP Statewide Lakes (Shapefile) with Name Attributes (from 95/97 Land Use/Land Cover) in New Jersey, published 7/13/2001 by NJDEP - Bureau of Freshwater and Biological Monitoring, http://www.state.nj.us/dep/gis/digidownload/zips/statewide/njlakes.zip.
- Lakesheds were delineated based on 14-digit hydrologic unit code coverage (HUC-14) and elevation contours.
    - NJDEP 14 Digit Hydrologic Unit Code delineations (DEPHUC14), published 4/5/2000 by New Jersey Geological Survey, http://www.state.nj.us/dep/gis/digidownload/zips/statewide/dephuc14.zip.
    - Statewide Elevation Contours (10 Foot Intervals), unpublished, auto-generated from: 7.5 minute Digital Elevation Models, published 7/1/1979 by U.S. Geological Survey.
    - NJDEP Statewide Elevation Contours (20 Foot Intervals), published 1987 by Bureau of Geographic Information and Analysis (BGIA), http://www.state.nj.us/dep/gis/digidownload/zips/statewide/stcon.zip.
- NJPDES Surface Water Discharges in New Jersey, (1:12,000), published 02/02/2002 by Division of Water Quality (DWQ), Bureau of Point Source Permitting - Region 1 (PSP-R1).

4.1 Alcyon Lake, Grenloch Lake, Allentown Lake

Alcyon Lake, Grenloch Lake, and Allentown Lake are relatively small waterbodies (21, 20, and 23 acres, respectively) formed by stream impoundments that drain extremely large watersheds[2] relative to the size of the lakes (130, 470, 330 times the size of the lakes, respectively). Land use is largely urban throughout the lakesheds of Alcyon and Grenloch Lakes, while the lakeshed of Allentown Lake is largely agricultural. Both urban and agricultural land uses can contribute substantial loads of phosphorus, supporting the anecdotal evidence from local sampling programs that indicates these three waterbodies are impaired due to eutrophication. Hydrologic budgets have not been developed for these lakes, making it impossible to develop TMDLs at this time. Nevertheless, the Department has included these three lakes in the implementation plan in order to require both characterization and restoration plans for each lake.

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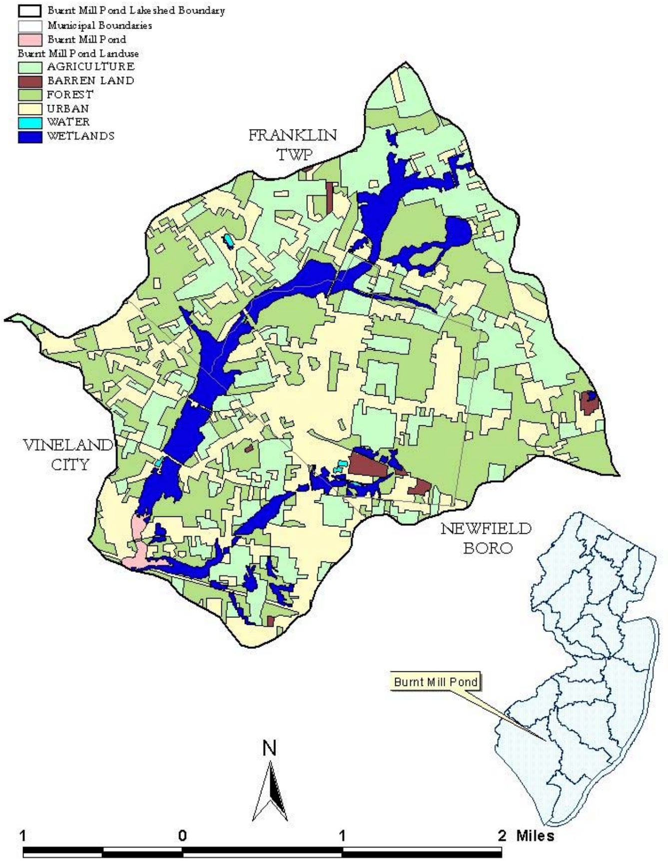
[2] A lakeshed seven times the area of its lake is considered small, whereas a lakeshed ten times the area of its lade is considered large (Holdren *et al*, 2002).

4.2 Burnt Mill Pond

Historically, the Burnt Mill Pond area was a natural cranberry bog and cedar swamp. Cedar was logged from this area until the sawmill burnt down in the early 1900's, thus giving it the name Burnt Mill Pond. In 1986, the Estate of the late Frank H. Stewart donated the pond and land to the City of Vineland. Since that time, the land has been dedicated for use as public parks, recreation areas, game refuges, fishing, bird sanctuaries, or grounds for wildlife protection (F.X. Brown, 1993).

The Burnt Mill Pond watershed is 4400 acres in size and is located in Cumberland and Gloucester Counties. The primary sources of water to the lake include two tributaries, Manaway Branch and Hudson Branch, and stormwater runoff from surrounding areas. Burnt Mill Pond itself is 22 acres, thus giving it a watershed to water surface area ratio of 200:1. The pond has a volume of 65,500 m^3, a mean depth of 2.4 feet, a maximum depth of 5.1 feet, a mean discharge of 8.1 cfs, and a mean hydraulic residence time of 3 days (depth and discharge from F.X. Brown, 1993).

Figure 2 **Lakeshed of Burnt Mill Pond**



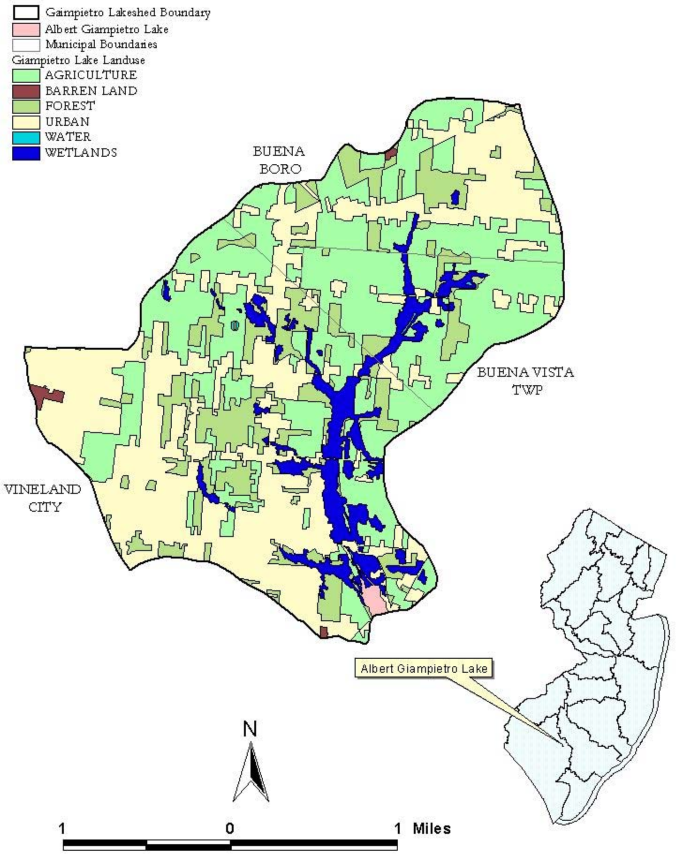
4.3 Giampietro Lake

In the mid-1800s, the area now occupied by the Giampietro Park and lake was the site of Coopers Mill. In 1960 the land was acquired by the City of Vineland and during the mid-1960s a great deal of interest was shown in developing the park and improving the landscaping. Concerns as to the conditions of the lake in Giampietro Park resulted in the adoption of Resolution Number 87-184 by the Vineland City Council in April 1987 which authorized for a Phase I Diagnostic-Feasibilty study of the lake. Today, the park today consists of approximately sixty acres of parklands and multipurpose areas, including a lake, a wetland area, and recreational facilities. The lake is an aesthetic focal point of the park where fishing and wildlife are enjoyed (F.X. Brown, 1989).

Giampietro Park Lake is a 14.4 acre rectangular lake with a mean depth of 3.7 feet, a maximum depth of 6 ft, a lake volume of 65,900 ft^3, a mean discharge of 8.6 cfs, and a mean hydraulic residence time of 3 days. The primary tributary sources to the lake, Bear Branch and Cedar Branch, are branches of Manantico Creek and join just before entering the lake. Other inputs include stormwater collection systems and direct runoff from the park area. Outflow is below the dam (southwest corner) to Cedar Branch (F.X. Brown, 1989).

The Giampietro Park lakeshed includes a 5.3 square mile area in Cumberland and Atlantic Counties. The entire lakeshed extends over 3600 acres, making it extremely large relative to the lake (250:1). Much of the lakeshed contains agriculture and urban land uses.

Figure 3 Lakeshed of Giampietro Lake

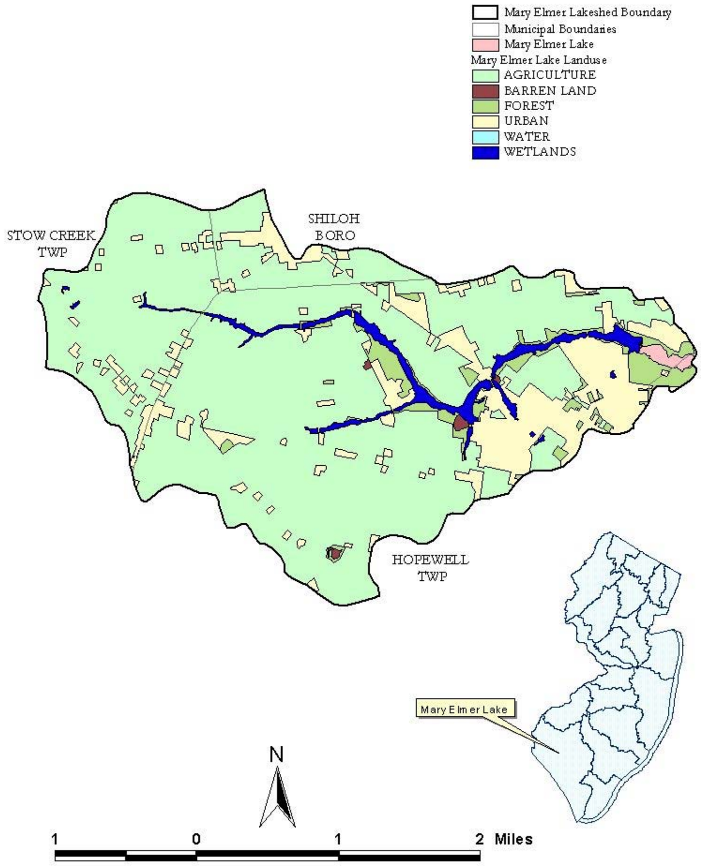


4.4 Mary Elmer lake

Mary Elmer Lake is a small protozoan shaped lake located in Hopewell Township Cumberland County. Mean depth has been estimated at 6 feet reaching a maximum of 10 feet. Total lake volume is about 164,000 m3. The lake's surface area is 22 acres and the lakeshed area is 4,800 acres making the watershed-to-lake surface area ratio approximately 218:1. The estimated mean detention time is about 6 days Depth and discharge information taken from NJEP, 1983). The lake is an impoundment of Barret Run a tributary of the Cohansey River and is also a headwater of Sunset Lake.

Much of the land use within the Mary Elmer lakeshed consists of agriculture, although substantial residential development also exists. Historically efforts have been made to improve the condition of the lake by performing restorative techniques such as drawdowns and dredging. Recreational uses of the lake included boating fishing and swimming. Today although fishing still occurs, the bathing beach has been closed.

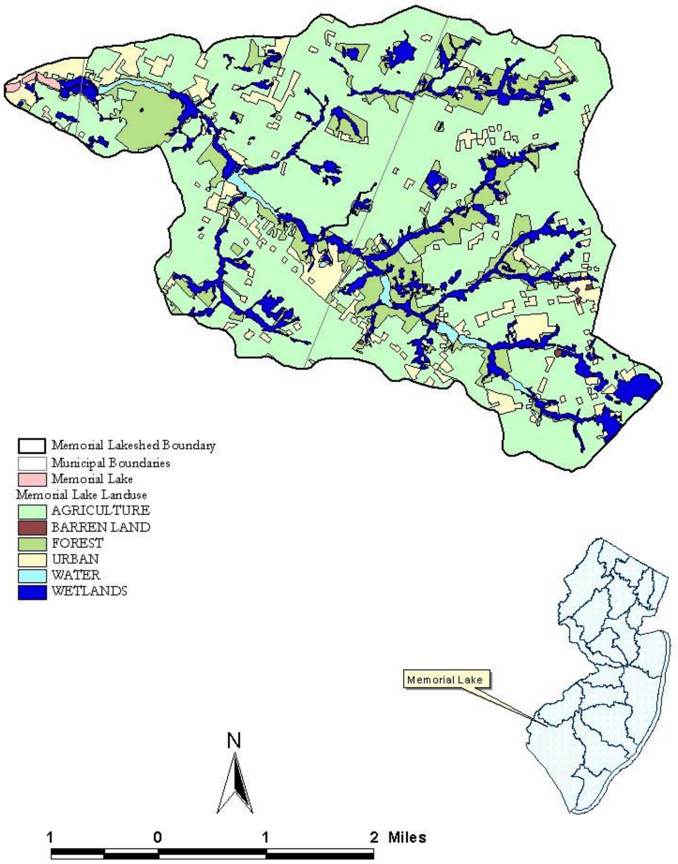
Figure 4 **Lakeshed of Lake Mary Elmer Lake**



4.5 Memorial Lake

Memorial Lake, an impoundment of the Salem River, is located in Woodstown, Salem County. This boomerang shaped lake has a mean depth of 4 feet with maximum depths reaching 6 feet. The total lake volume is 107,000 m^3, with total annual discharge estimated at 25,000,000 m^3 (depth and discharge taken from NJDEP, 1983). The lake's area is 22 acres and the total lakeshed area is 9300 acres, making lakeshed 15 times the area of the lake. The estimated mean detention time is 1.5 days, making this a rapidly flushing system. Land use throughout the lakeshed is dominated by agriculture. There are no known point sources to memorial lake but agricultural run-off specifically from livestock may be significant. Recreational uses include fishing, boating and ice skating.

Figure 5 **Lakeshed of Memorial Lake**

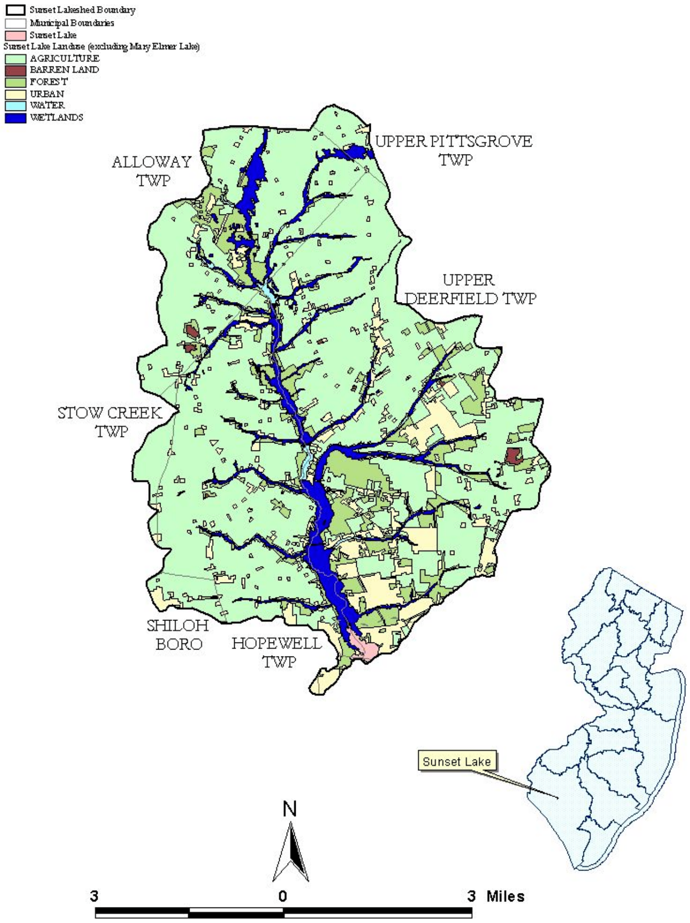


4.6 Sunset Lake

Sunset Lake is located on the Cohansey River in Upper Deerfield, Cumberland County. Sunset Lake has displayed symptoms of accelerated eutrophication since as early as the 1940's. The lake provides swimming, boating and fishing, however the quality of the lake's recreational potential has diminished. While numbers of fish individuals per species is low, the species diversity of the lake's fishery is good (NJDEP, 1983).

The watershed area of Sunset Lake is over 29,000 acres, resulting in an extremely large watershed area to surface area ratio of about 300 to 1. Sunset Lake itself is approximately 89 acres in size with mean and maximum depths of 2.0 and 3.4 meters, respectively, and a total volume of approximately 700,000 m^3. Groundwater seepage is assumed to contribute the difference between discharge (66,000,000 m^3/yr) and inflow (58,000,000 m^3/yr). Hydraulic detention time has been estimated at about 4 days. Depth and discharge information were taken from NJDEP, 1983.

Figure 6 **Lakeshed of Sunset Lake**



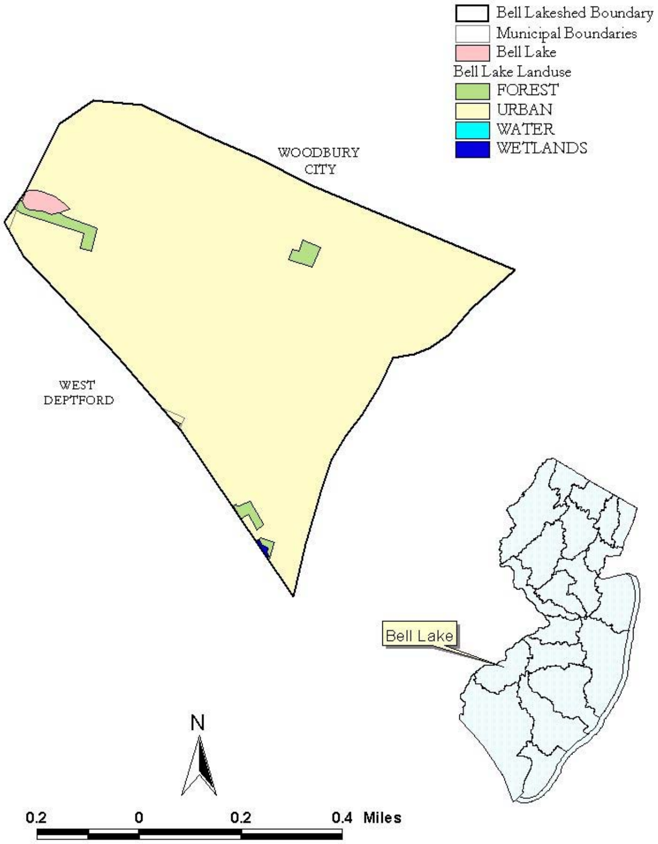
4.7 Bell Lake

Bell Lake is located in the City of Woodbury in Gloucester County. Historically Bell Lake and the surrounding park were part of a farm owned by Samuel Bell Jr. In 1937, after the death of Mr. Bell, some homes were constructed at this site and then the remaining land near the lake was deeded to the City of Woodbury for the creation of a public park. In the same year, a portion of the dam had deteriorated, lowering the level of the lake. After complaints from residents, the dam was repaired and the banks of the lake were filled resulting in the Bell Lake that exists today. (F.X. Browne Associates, Inc., 1989)

Bell Lake is a shallow bean shaped lake with a mean depth of 2.6 feet reaching a maximum of 5.4 feet. The lake is primarily stormwater feed through the storm sewer system of the city and discharges into the Matthews Branch of Woodbury Creek. The drainage basin area of the lake is about 275 acres lying entirely within the city boundaries and the surface area of the lake is 1.8 acres, making the drainage area to lake surface area ratio about 150:1. Total Lake volume is estimated to be 5,800 m^3. Mean discharge is approximately 409,000 m^3 / yr, making the mean hydraulic residence time for the lake 5.2 days. (depth and discharge taken from F.X. Browne Associates, Inc., 1989).

The major land use within the Bell Lake watershed is urban comprising of over 93% of the area. The majority of the urban land is single family homes with the remainder consisting of multi family apartments as well as industrial and manufacturing uses. There are no point source discharges in the Bell Lake Watershed; therefore the primary source of pollutants to the waterbody are nonpoint sources, specifically urban run-off.

Figure 7 Lakeshed of Bell Lake

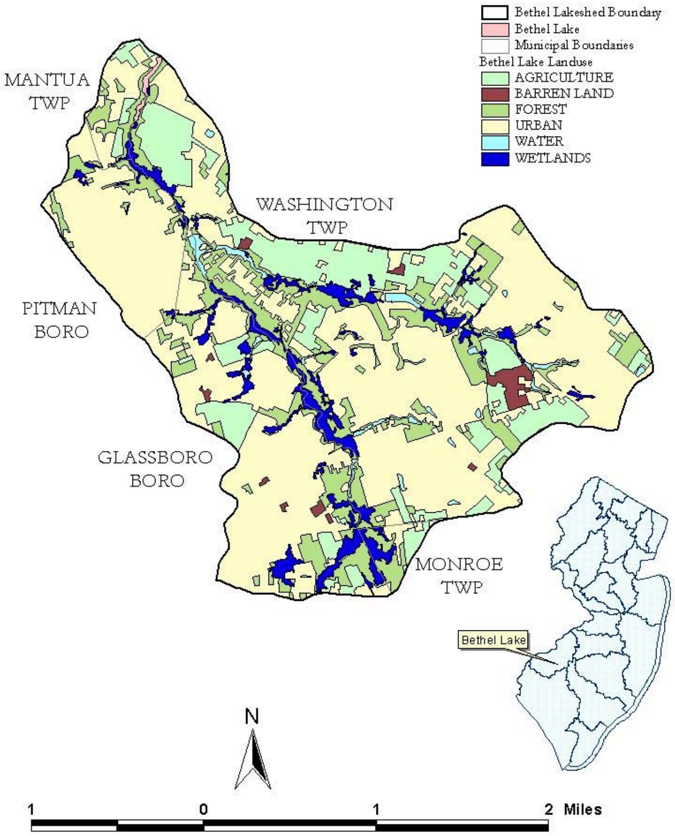


4.8 Bethel Lake

Bethel Lake is located in Mantau, Gloucester County, within the Mantau Creek watershed. Historically, Bethel Lake has provided a variety of recreational opportunities including fishing, boating, and swimming.

Bethel lake has a surface area of 9.6 acres, a volume of 120,000 m^3, a mean depth of 3.0 meters, and a detention time estimated at 3 days (depth and discharge taken from NJDEP, 1983). The lakeshed of Bethel Lake is almost 4800 acres, about 500 times the area of the lake. Furthermore, the lakeshed is largely urban. A number of small lakes are located within the watershed of Bethel Lake and serve as headwaters to either Mantau Creek or Duffield Run, the two main tributaries of Bethel Lake. Included are Lake Oberst, Senior Lakes, Kandle Lake, Ward Lake, Spring Lake (not the same Spring Lake discussed in section 4.14), and Kressey Lake. While the majority of the lake's inflow is attributable to Mantau Creek and Duffield Run, significant hydrologic and nutrient inputs are also supplied by storm runoff from the high-density residential areas of Pitman. A fish survey published in the 1983 report revealed an overall high level of fish diversity but with a low number of resident species.

Figure 8 **Lakeshed of Bethel Lake**



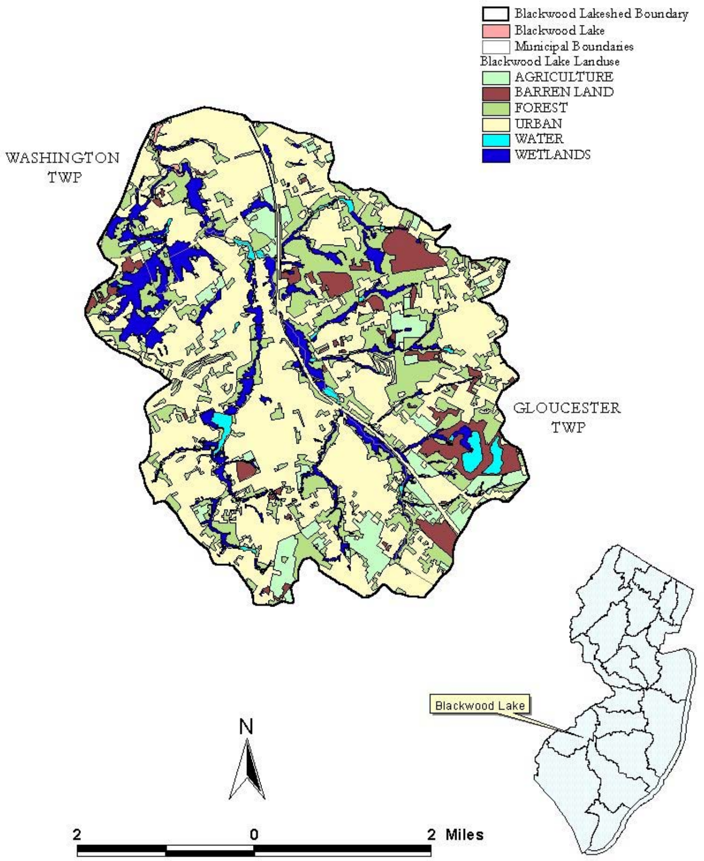
4.9 Blackwood Lake

Blackwood Lake is a small waterbody impoundment located on the South Branch of Timber Creek, between the County and Township lines of Gloucester Township, Camden County and Washington Township, Gloucester County. Studies conducted in 1992 (F. X. Brown Associates, Inc.) indicated that significant sedimentation had occurred in the lake and that water depth average was 1.3 feet in depth with a maximum depth of 3.3 feet.

While the original surface area of Blackwood Lake was approximately 67.0 acres, aerial photographs in 1995 show the surface area to be about 16 acres. The lakeshed, much of which is urban, totals 12,000 acres, resulting in an enormous watershed to lake surface area ratio of almost 800:1. The lake volume is about 25,000, with a mean discharge of 36.3 cfs, and a mean hydraulic residence time of 0.3 days (depth and discharge taken from F.X Browne, 1992).

Blackwood Lake supports a natural population of bass, pickerel, bullheads and other game fish and is heavily used for fishing (Remington & Vernick, 1998). While it is fed primarily by the South Branch of Timber Creek and Farrow’s Run, other inputs include drainage from stormwater and direct runoff from a local park area.

Figure 9 Lakeshed of Blackwood Lake

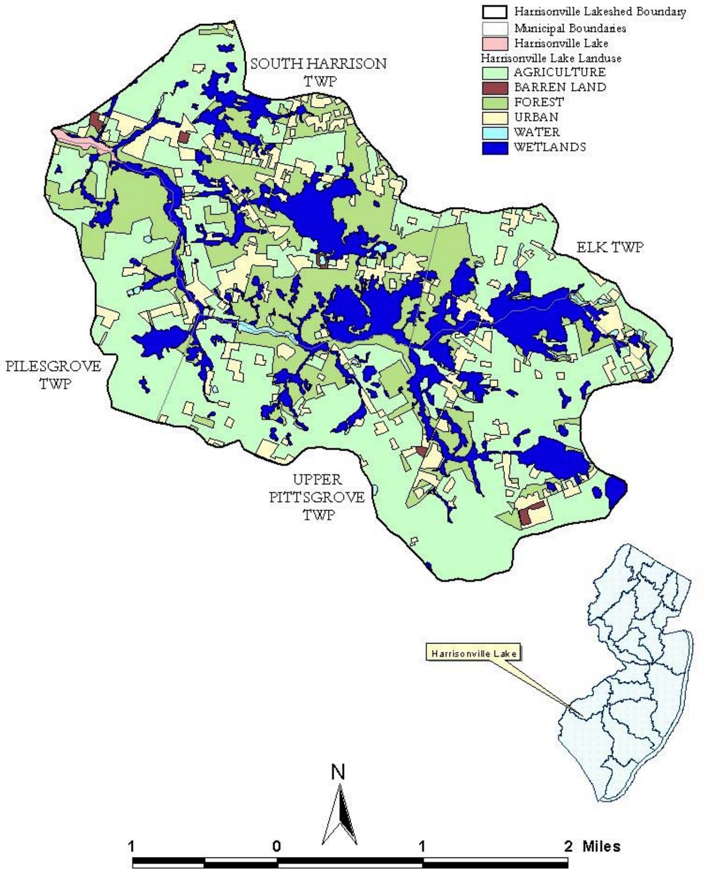


4.10 Harrisonville Lake

Harrisonville lake is a 18 acre cylindrically-shaped impoundment on Oldmans Creek. Water from the lake flows over a man-made dam via Oldmans Creek to wetlands associated with the Delaware River. The lake is owned by the New Jersey Division of Fish and Wildlife. Over the past several decades Harrisonville Lake has developed a severe eutrophication problem that progressively worsens in late summer.

In April 2001 a bathymetric survey and hydrologic analysis of Harrison Lake was conducted by Princeton Hydro and revealed: a mean depth of 3.08 ft, maximum depth of 7.4 ft, lake volume of 6.8 x 10^4 m^3, mean discharge of 13.2 x 10^6 m^3/yr, and a hydraulic residence time of 1.9 days. From this survey, the total amount of unconsolidated sediments was estimated to be approximately 28 acre-ft (34,441 cubic meters or 45,049 cubic yards) (Princeton Hydro, LLC, 2003). The watershed associated with Harrison Lake is 5,600 acres resulting in an extremely large watershed area/lake surface area ratio of over 300 to 1.

Figure 10 **Lakeshed of Harrisonville Lake**

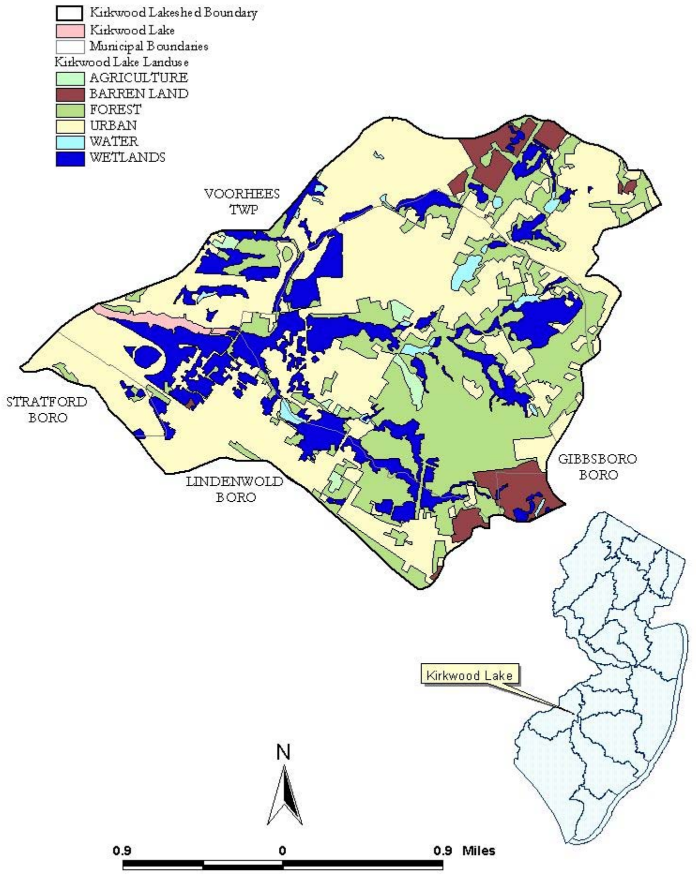


4.11 Kirkwood Lake

Kirkwood Lake is a small, narrow lake approximately 0.75 miles in length and is located on the boundary of Voorhhes and Lindenwold, Camden County. Historically, the lake has been used for fishing, boating and swimming purposes. More recently, these uses have lessened with the associated decrease in water quality. It has a total surface area of 25 acres, a volume of 215,000 m^3, a mean depth of 2.1 m, and a hydraulic detention time of around 8 days (depth and discharge taken from NJDEP 1983). The 3250-acre lakeshed is about 130 times the size of the lake and has a high percentage of urban land use.

The primary tributaries to Kirkwood Lake include the Cooper River, Millard Creek, and Nicholson Branch. The lake also receives additional input from two small tributaries that flow directly to the lake. Urban stormwater contributes a substantial portion of the water load to the lake.

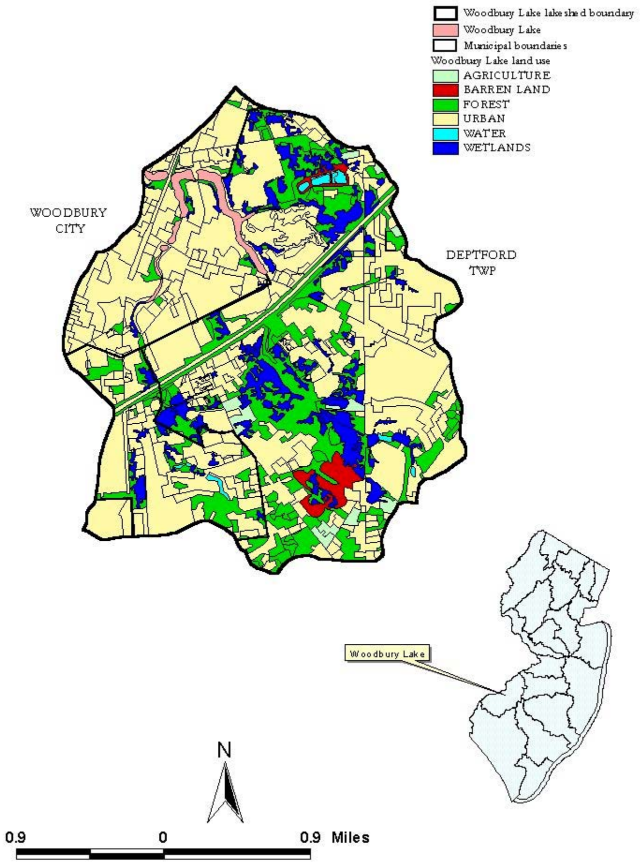
Figure 11 **Lakeshed of Kirkwood Lake**



4.12 Woodbury Lake

Woodbury Lake (also known as Stewart Lake) is a 47-acre lake located on Woodbury Creek in Woodbury, Gloucester County. Woodbury Lake has two main tributaries, Woodbury Creek and an unnamed tributary flowing into the western section of the lake. The lake consists of two long, narrow arms divided into an interconnected series of small impoundments. Mean depth (1.52 meters) and total annual inflow (7,780,000 m^3) were obtained from NJDEP, 1983. Detention time is estimated to be about 14 days. The lake's 3200-acre watershed area (69 times the lake area) is predominately composed of urban landuse.

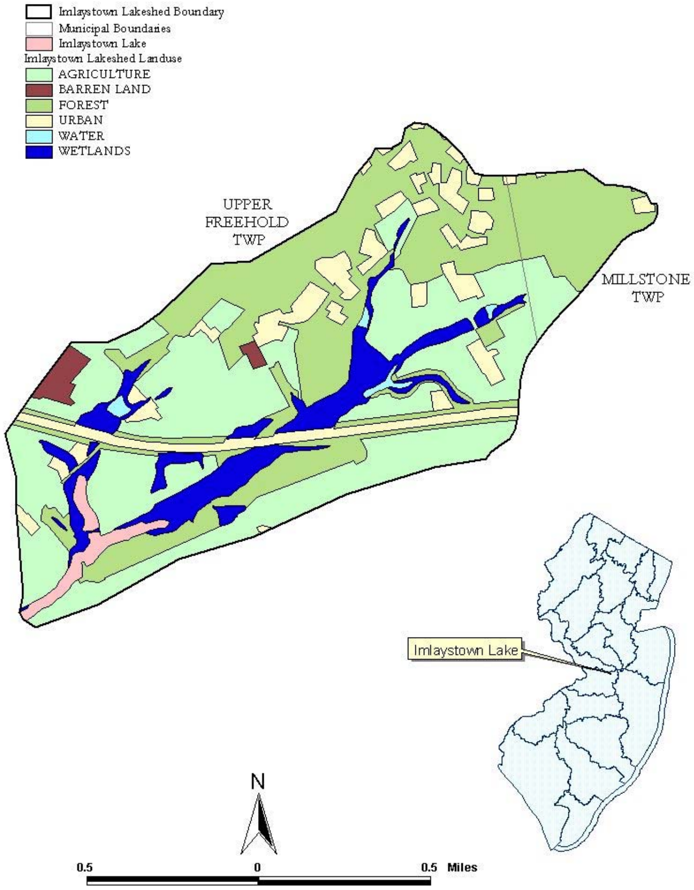
Figure 12 **Lakeshed of Woodbury Lake**



4.13 Imlaystown Lake

Imlaystown Lake is a 16-acre located in Upper Freehold, Monmouth County that drains a lakeshed area of 850 acres. Historically, this lake was used for boating, swimming, fishing, and ice-skating. Imlaystown Lake is fed by Doctor's Creek and its numerous tributaries. The lakeshed/lake area ratio is large at about 50:1. The lake is shallow (mean depth is 1.22 meters) with high annual discharge (20,300,000 m^3), resulting in a hydraulic detention time of 1.4 days (depth and discharge from NJDEP, 1983). The landuse within this watershed is predominantly agriculture and forest.

Figure 13 **Lakeshed of Imlaystown Lake**

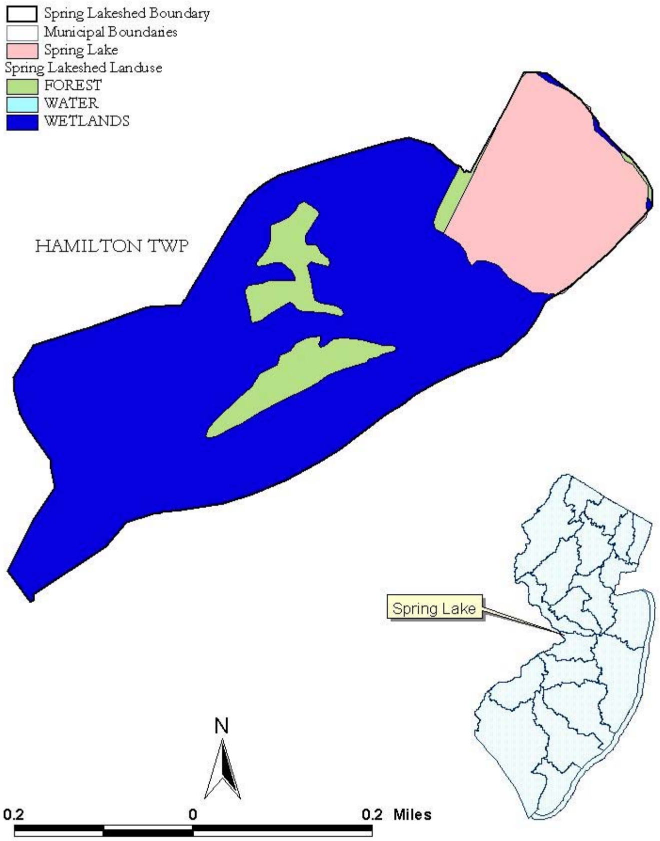


4.14 Spring Lake

Spring Lake is a 22-acre lake located in Hamilton, Mercer County. The lake drains a small portion (115 acres) of the Trenton Marshes, an extensive wetland area that borders the Delaware River. The lakeshed is very small, only 5.3 times the area of the lake, and consists entirely of forest and wetland. Spring Lake was once part of a small amusement park, serving primarily an aesthetic purpose, and has been used for fishing; however, more recently excessive weed growth has interfered with its use.

The majority of inflow into the lake is through groundwater seepage and springs. Lake mean depth (1.22 meters) and total outflow (379,000 m^3) were taken from NJDEP (1983). Lake volume and detention time were estimated to be 107000 m^3 and 103 days, respectively. For the purposes of this TMDL analysis, 75% of the water load was assumed to be due to groundwater infiltration.

Figure 14 **Lakeshed of Spring Lake**



5.0 Applicable Surface Water Quality Standards

In order to prevent excessive primary productivity and consequent impairment of recreational, water supply and aquatic life designated uses, the Surface Water Quality Standards (SWQS, N.J.A.C. 7:9B) define both numerical and narrative criteria that address eutrophication in lakes due to overfertilization. The total phosphorous (TP) criterion for freshwater lakes at N.J.A.C. 7:9B – 1.14(c)5 reads as follows:

> For freshwater 2 classified lakes, Phosphorus as total phosphorus shall not exceed 0.05 mg/l in any lake, pond or reservoir or in a tributary at the point where it enters such bodies of water, except where site-specific criteria are developed to satisfy N.J.A.C. 7:9B-1.5(g)3.

N.J.A.C. 7:9B-1.5(g)3 states:

> The Department may establish site-specific water quality criteria for nutrients in lakes, ponds, reservoirs or stream, in addition to or in place of the criteria in N.J.A.C. 7:9B-

> 1.14, when necessary to protect existing or designated uses. Such criteria shall become part of the SWQS.

Presently, no site-specific criteria apply to any of these lakes.

Also at N.J.A.C. 7:9B-1.5(g)2, the following is discussed:

> Except as due to natural conditions, nutrients shall not be allowed in concentrations that cause objectionable algal densities, nuisance aquatic vegetation, or otherwise render the waters unsuitable for the designated uses.

These TMDLs are designed to meet both numeric and narrative criteria of the SWQS.

All of the waterbodies covered under these TMDLs have a FW2 classification. The designated uses, both existing and potential, that have been established by the Department for waters of the State classified as such are as stated below:

In all FW2 waters, the designated uses are (N.J.A.C. 7:9B-1.12):
1. Maintenance, migration and propagation of the natural and established aquatic biota;
2. Primary and secondary contact recreation;
3. Industrial and agricultural water supply;
4. Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation and sedimentation, resulting in substantial particulate removal but no consistent removal of chemical constituents) and disinfection; and
5. Any other reasonable uses.

Finally, N.J.A.C 7:9B-1.5(c)1 states:

> "The natural water quality shall be used in place of the promulgated water quality criteria of N.J.A.C. 7:9B-1.14 for all water quality characteristics that do not meet the promulgated water quality criteria as a result of natural causes."

6.0 Source Assessment

Phosphorus sources were characterized on an annual scale (kg TP/yr). Long-term pollutant loads are typically more critical to overall lake water quality than the load at any particular short-term time period (e.g. day). Storage and recycling mechanisms in the lake, such as luxury uptake and sediments dynamics, allow phosphorus to be used as needed regardless of the rate of delivery to the system. Also, empirical lake models use annual loads rather than daily or monthly loads to estimate in-lake concentrations.

6.1 Assessment of Point Sources other than Stormwater

Point sources of phosphorus other than stormwater were identified using the Department's GIS. All Major Municipal (MMJ), Minor Municipal (MMI), and Combined Sewer Overflow (CSO) discharges within each lakeshed were identified as point sources of phosphorus, as were all other discharger types with a limit for phosphorus in their NJPDES permit, including both "monitor only " and numeric limits. Other types of discharges, such as Industrial, were not included because their contribution, if any, is negligible compared to municipal discharges and runoff from land surfaces. No point sources exist anywhere within the lakesheds any of the Lower Delaware Region lakes for which TMDLs are being proposed.

6.2 Assessment of Nonpoint Sources and Stormwater

Runoff from land surfaces comprises most of the nonpoint and stormwater sources of phosphorus into lakes. Watershed loads for total phosphorus were therefore estimated using the Unit Areal Load (UAL) methodology, which applies pollutant export coefficients obtained from literature sources to the land use patterns within the watershed, as described in USEPA's Clean Lakes Program guidance manual (Reckhow,1979b). Land use was determined using the Department's GIS system using the 1995/1997 land use coverage. The Department reviewed phosphorus export coefficients from an extensive database (Appendix B) and selected the land use categories and values shown in Table 3.

Table 3 Phosphorus export coefficients (Unit Areal Loads)

land use / land cover	LU/LC codes[3]	UAL (kg TP/ha/yr)
medium / high density residential	1110, 1120, 1150	1.6
low density / rural residential	1130, 1140	0.7
Commercial	1200	2.0
Industrial	1300, 1500	1.7
mixed urban / other urban	other urban codes	1.0
Agricultural	2000	1.5
forest, wetland, water	4000, 6000, 5000	0.1
barren land	7000	0.5

Units: 1 hectare (ha) = 2.47 acres
1 kilogram (kg) = 2.2 pounds (lbs)
1 kg/ha/yr = 0.89 lbs/acre/yr

For all lakes in this TMDL document, a UAL of 0.07 kg TP/ha/yr was used to estimate air deposition of phosphorus directly onto the lake surface. This value was developed from statewide mean concentrations of total phosphorus from the New Jersey Air Deposition Network (Eisenreich and Reinfelder, 2001). For Sunset Lake, land use runoff loads were only calculated for the immediate watershed downstream of Mary Elmer Lake. An additional annual tributary load from Mary Elmer Lake into Sunset Lake was estimated by multiplying

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[3] LU/LC code is an attribute of the land use coverage that provides the Anderson classification code for the land use. The Anderson classification system is a hierarchical system based on four digits. The four digits represent one to four levels of classification, the first digit being the most general and the fourth digit being the most specific description.

the annual discharge from the lake by the mean phosphorus concentration as calculated under Current Condition in section 7.1 below. Land uses and calculated runoff loading rates for each of the lakes are shown in Tables 4-6. Also included in Tables 4-6 are estimates of loading rates from septic systems, waterfowl and from internal sources (sediment regeneration, macrophyte decomposition) where such estimates had already been developed previously for each of the lakes. Finally, groundwater loads were estimated for lakes known to have a substantial groundwater flow component. The annual groundwater flow was multiplied by a phosphorus concentration of 0.1 mg TP/l and then converted to kg TP/yr.

Table 4 Nonpoint and Stormwater Sources of Phosphorus Loads

Nonpoint Source	**Burnt Mill Pond**		**Giampietro Lake**		**Mary Elmer Lake**		**Memorial Lake**		**Sunset Lake**	
	acres	**kg/yr**	**acres**	**kg/yr**	**acres**	**kg/yr**	**acres**	**kg/yr**	**acres**	**kg/yr**
land use loads										
medium / high density residential	179	116	466	302	196	127	22.8	14.7	461	298
low density / rural residential	774	219	444	126	426	121	485	137	2160	613
commercial	75.6	61.2	149	121	58.7	47.5	62.2	50.4	200	162
industrial	121	83.3	34.5	23.7	1.5	1.0	73.9	50.9	65.7	45.2
mixed urban / other urban	217	87.9	277	112	103	41.7	185	74.9	640	259
agricultural	1170	707	1470	895	3690	2240	6530	3970	20500	12400
forest, wetland, water	1810	73.1	769	31.1	315	12.8	1930	78.1	5120	207
barren land	51.6	10.4	17.7	3.6	14.3	2.9	20.7	4.2	95.2	19.3
other loads										
septic systems	n/a		n/a		n/a		n/a		n/a	
waterfowl				8.0						
internal load										
tributary load										1990
natural loads										
air deposition	22.0	0.6	14.4	0.4	22.2	0.6	21.7	0.6	87.0	2.5
groundwater	n/a		n/a		n/a		n/a		n/a	80.0
TOTAL	**4410**	**1360**	**3650**	**1620**	**4830**	**2600**	**9340**	**4380**	**29300**	**16100**

Table 5 Nonpoint and Stormwater Sources of Phosphorus Loads (cont'd)

Nonpoint Source	Bell Lake		Bethel Lake		Blackwood Lake		Harrisonville Lake		Kirkwood Lake	
	acres	kg/yr	acres	kg/yr	acres	kg/yr	acres	kg/yr	acres	kg/yr
land use loads										
medium / high density residential	194	126	1620	1050	3450	2230	9.8	6.3	742	481
low density / rural residential	2.3	0.7	505	143	1040	295	567	161	212	60.1
commercial	58.6	47.5	227	184	727	588	8.7	7.0	260	211
industrial	1.7	1.1	63.5	43.7	109	75.1	4.3	3.0	38.6	26.6
mixed urban / other urban	11.5	4.6	476	193	1200	486	61.1	24.7	342	139
agricultural	0.0	0.0	740	449	770	467	2780	1690	39.3	23.9
forest, wetland, water	5.0	0.2	1070	43.4	4100	166	2170	88	1410	57.0
barren land	0.0	0.0	62.8	12.7	713	144	23.2	4.7	184	37.3
other loads										
septic systems	n/a		n/a		n/a		n/a	157	n/a	
waterfowl										
internal load								5.2		
tributary load										
natural loads										
air deposition	1.8	0.1	9.6	0.3	15.5	0.4	18.0	0.5	24.9	0.7
groundwater	n/a		n/a		n/a		n/a	71.0	n/a	
TOTAL	**275.2**	**180**	**4770**	**2110**	**12100**	**4460**	**5640**	**2210**	**3250**	**1040**

Table 6 Nonpoint and Stormwater Sources of Phosphorus Loads (cont'd)

Nonpoint Source	Woodbury Lake		Imlaystown Lake		Spring Lake - 20	
	acres	kg/yr	acres	kg/yr	acres	kg/yr
land use loads						
medium / high density residential	995	644	0.0	0.0	0.0	0.0
low density / rural residential	464	132	62.2	17.6	0.0	0.0
commercial	249	201	0.0	0.0	0.0	0.0
industrial	66.4	45.7	0.0	0.0	0.0	0.0
mixed urban / other urban	328	133	31.9	12.9	0.0	0.0
agricultural	55.4	33.6	343	208	0.0	0.0
forest, wetland, water	932	37.7	386	15.6	93.3	3.8
barren land	72.4	14.6	10.9	2.2	0.0	0.0
other loads						
septic systems	n/a		n/a		n/a	
waterfowl						
internal load						
tributary load						
natural loads						
air deposition	46.8	1.3	15.9	0.5	21.8	0.6
groundwater	n/a		n/a		n/a	2.8
TOTAL	**3210**	**1240**	**849**	**257**	**115**	**7.2**

7.0 Water Quality Analysis

Empirical models were used to relate annual phosphorus load and steady-state in-lake concentration of total phosphorus. These empirical models consist of equations derived from simplified mass balances that have been fitted to large datasets of actual lake measurements. The resulting regressions can be applied to lakes that fit within the range of hydrology, morphology and loading of the lakes in the model database. The Department surveyed the commonly used models in Table 7.

Table 7 Empirical models considered by the Department

reference	steady-state TP concentration in lake (mg/l)	Secondary term	Application
Rast, Jones and Lee, 1983	$1.81 \times NPL^{0.81}$	$NPL = \left(\frac{P_a \times {}^{DT}\!/_{D_m}}{1+\sqrt{DT}} \right)$	Expanded database of mostly large lakes
Vollenweider and Kerekes, 1982	$1.22 \times NPL^{0.87}$	$NPL = \left(\frac{P_a \times {}^{DT}\!/_{D_m}}{1+\sqrt{DT}} \right)$	mostly large natural lakes
Reckhow, 1980	$\frac{P_a}{13.2}$	none	Upper bound for closed lake
Reckhow, 1979a	$\frac{P_a}{(11.6+1.2\times Q_a)}$	$Q_a = \frac{Q_i}{A_l}$	General north temperate lakes, wide range of loading concentration, areal loading, and water load

reference	steady-state TP concentration in lake (mg/l)	Secondary term	Application
Walker, 1977	$\frac{P_a \times DT/D_m}{(1+0.824\times DT^{0.454})}$	none	oxic lakes with $D_m/DT < 50$ m/yr
Jones and Bachmann, 1976	$\frac{0.84\times P_a}{(D_m \times (0.65+DT^{-1}))}$	none	may overestimate P in shallow lakes with high D_m/DT
Vollenweider, 1975	$\frac{P_a}{(D_m \times (DT^{-1}+S))}$	$S = 10/D_m$	Overestimate P lakes with high D_m/DT
Dillon-Kirchner, 1975	$\frac{P_a}{\left(13.2 + D_m/DT\right)}$	none	low loading concentration range
Dillon-Rigler, 1974	$P_a \times DT/D_m \times (1-R)$	R = phosphorus retention coefficient	General form
Ostrofksy, 1978	Dillon-Rigler, 1974	$R = 0.201\times e^{(-0.0425\times Q_a)}$ $+0.5743\times e^{-0.00949*Q_a}$	lakes that flush infrequently
Kirchner-Dillon, 1975	Dillon-Rigler, 1974	$R = 0.426\times e^{\left(-0.271\times D_m/DT\right)}$ $+0.5743\times e^{-0.00949*D_m/DT}$	General application
Larsen-Mercier, 1975	Dillon-Rigler, 1974	$R = \frac{1}{1+\sqrt{1/DT}}$	Unparameterized form

where:
NPL = normalized phosphorus loading
P_a = areal phosphorus loading ($g/m^2/yr$)
DT = detention time (yr)
D_m = mean depth (m)
Qa = areal water load (m/yr) [4]
Q_i = total inflow (m^3/yr)
A_l = area of lake (m^2)
S = settling rate (per year)

Reckhow (1979a) model was selected because it has the broadest range of hydrologic, morphological and loading characteristics in its database. Also, the model includes an uncertainty estimate that was used to calculate a Margin of Safety. The Reckhow (1979a) model is described in USEPA Clean Lakes guidance documents: Quantitative Techniques for the Assessment of Lake Quality (Reckhow, 1979b) and Modeling Phosphorus Loading and Lake Response Under Uncertainty (Reckhow *et al*, 1980). The derivation of the model is

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[4] Areal water load is defined as the annual water load entering a lake divided by the area of the lake. Since, under steady-state conditions, the water coming in to the lake is equal to the water leaving the lake, either total inflow or total outflow can be used to calculate areal water load. If different values were reported for total inflow and total outflow, the Department used the higher of the two to calculate areal water load.

summarized in Appendix C. The model relates TP load to steady state TP concentration, and is generally applicable to north temperate lakes, which exhibit the following ranges of characteristics (see Symbol definitions after Table 7):

phosphorus concentration: $0.004 < P < 0.135$ mg/l
average influent phosphorus concentration: $P_a*DT/D_m < 0.298$ mg/l
areal water load: $0.75 < Q_a < 187$ m/yr
areal phosphorus load: $0.07 < P_a < 31.4$ g/m^2/yr

For comparison, Table 8 below summarizes the characteristics for each lake based on their current and target conditions as described below. The above ranges of characteristics apply to most of the lakes covered under these TMDLs; however, the areal water loads for Memorial Lake, Bethel Lake, and Blackwood Lake are outside the calibration range (284, 373, and 518 m/year, respectively). Nevertheless, the model still remains the best choice since it has the broadest range of lake characteristics in its database. While the target concentration for each lake (section 7) is well within the range, the areal phosphorus load provides a better representation of a lake's intrinsic loading characteristics. Also, it is the model's prediction of target condition that is being used to calculate the TMDL; if current loads are higher than the range that can produce reliable model results, this has no affect on the model's reliability to predict target condition under reduced loads. It should also be noted that no attempt was made to recalibrate the Reckhow (1979a) model for lakes in New Jersey or in this Water Region, since sufficient lake data were not available to make comparisons with model predictions of steady-state in-lake concentration of total phosphorus. The model was already calibrated to the dataset on which it is based, and is generally applicable to north temperate lakes that exhibit the range of characteristics listed previously.

Table 8 Hydrologic and loading characteristics of lakes

Lake	Current Avg Influent [TP] (mg/l)	Target Avg Influent [TP] (mg/l)	Current Areal TP load (g/m²/yr)	Target Areal TP load (g/m²/yr)	Areal Water Load (m/year)
Burnt Mill Pond	0.187	0.027	15.24	2.17	81.4
Giampietro Lake	0.211	0.026	27.74	3.36	131
Mary Elmer Lake	0.266	0.026	28.95	2.82	109
Memorial Lake	0.175	0.025	49.74	7.00	284
Sunset Lake	0.244	0.025	45.74	4.73	187
Bell Lake	0.440	0.028	24.49	1.56	55.7
Bethel Lake	0.145	0.024	54.29	9.13	373
Blackwood Lake	0.137	0.025	71.22	12.77	518
Harrisonville Lake	0.168	0.025	30.41	4.55	181
Kirkwood Lake	0.109	0.026	10.27	2.47	94.0
Woodbury Lake	0.160	0.029	6.56	1.21	41.1
Imlaystown Lake	0.013	0.013	3.98	3.98	315
Spring Lake	0.019	0.019	0.08	0.08	4.3

7.1 Current Condition

Using these estimated physical parameters and current loads, the predicted steady-state phosphorus concentration of each lake was calculated using the Reckhow (1979a) formulation and listed in Table 9. The current phosphorus load distribution for each lake is shown in Figures 15 to 27 below.

Figure 15 **Current distribution of phosphorus load for Burnt Mill Pond**

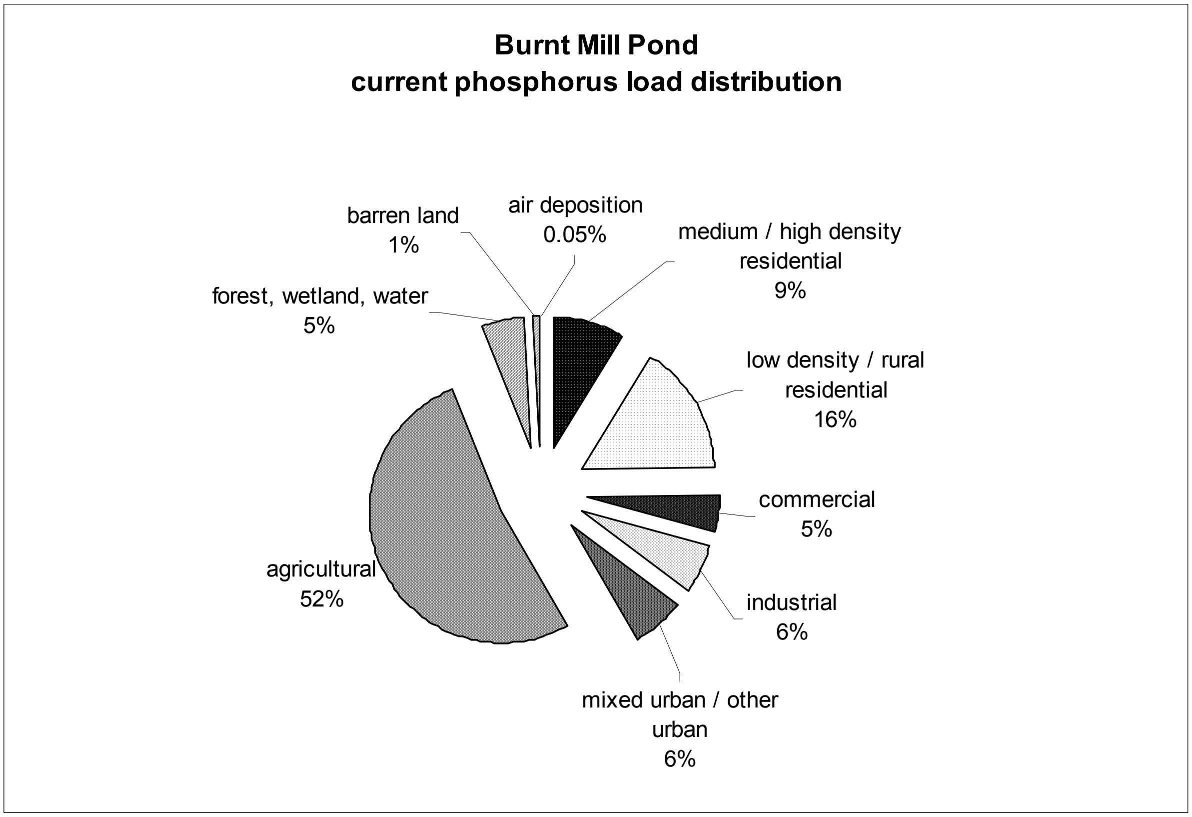


Figure 16 Current distribution of phosphorus load for Giampietro Lake

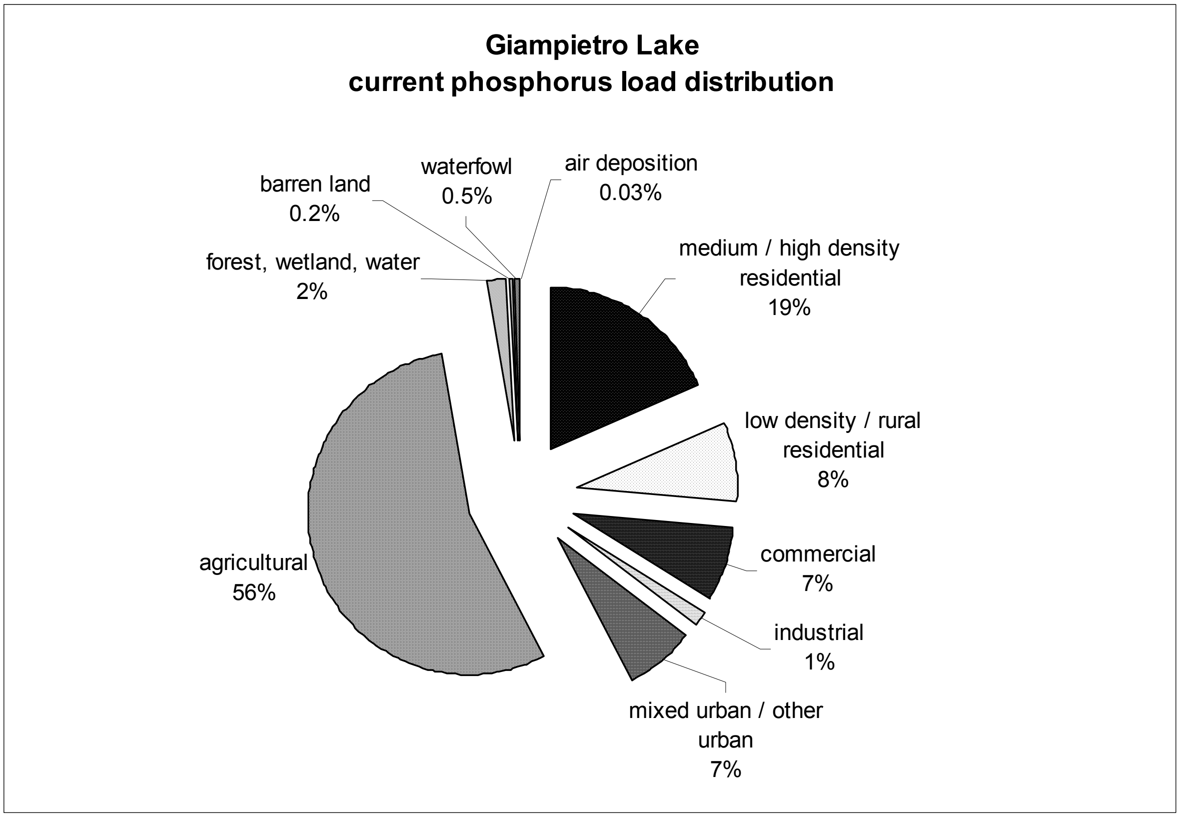


Figure 17 Current distribution of phosphorus load for Mary Elmer Lake

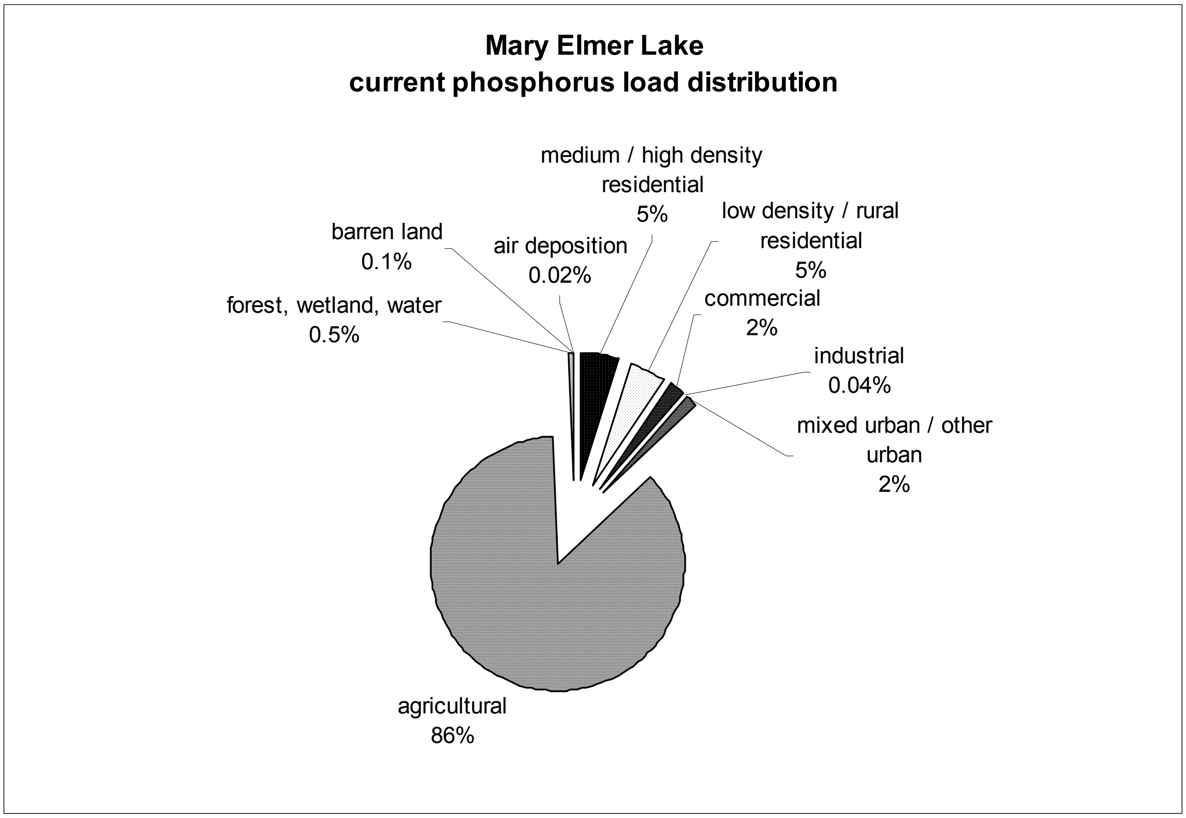


Figure 18 Current distribution of phosphorus load for Memorial Lake

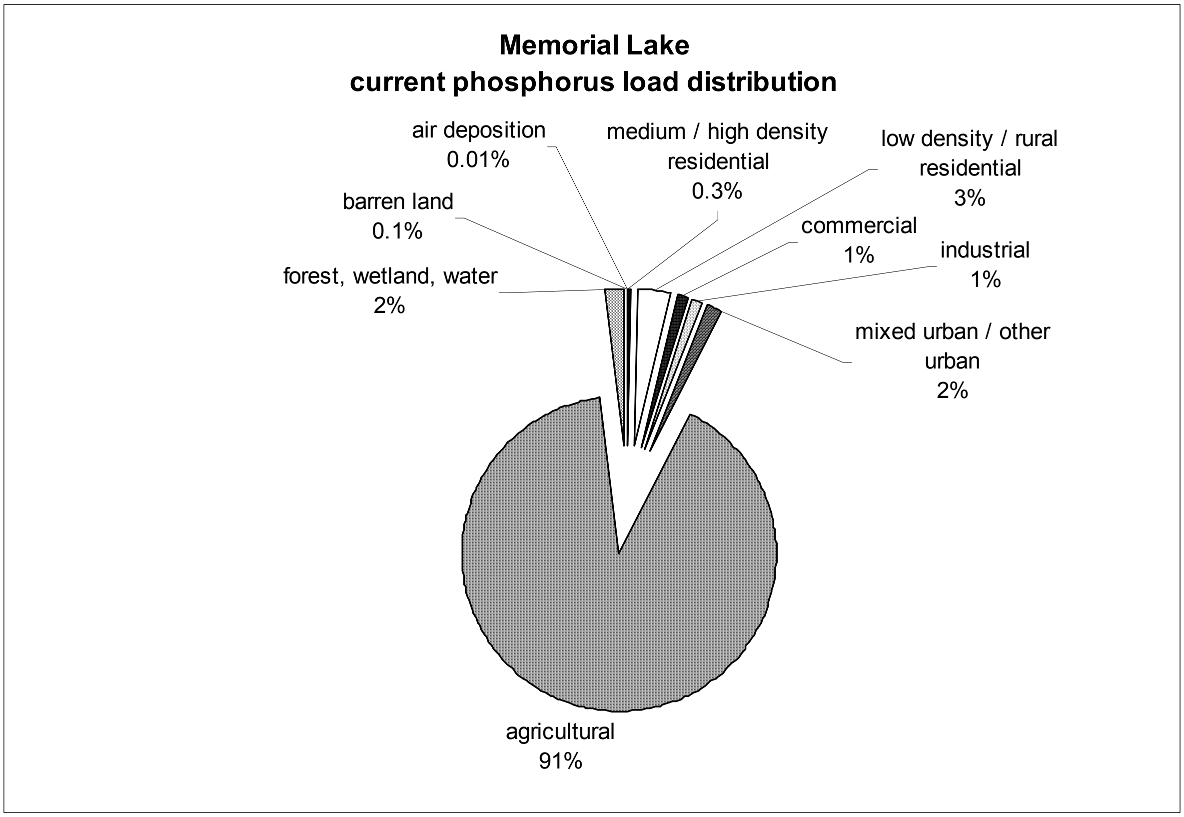


Figure 19 Current distribution of phosphorus load for Sunset Lake

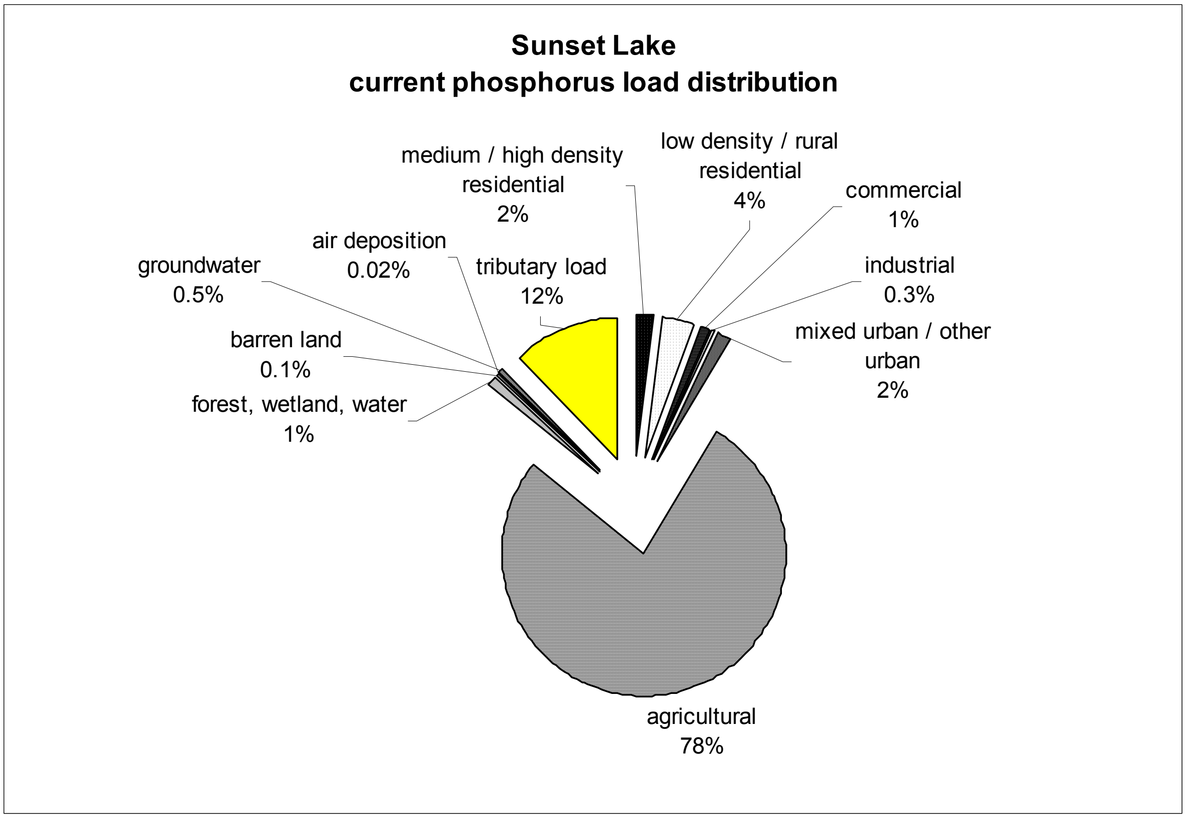


Figure 20 Current distribution of phosphorus load for Bell Lake

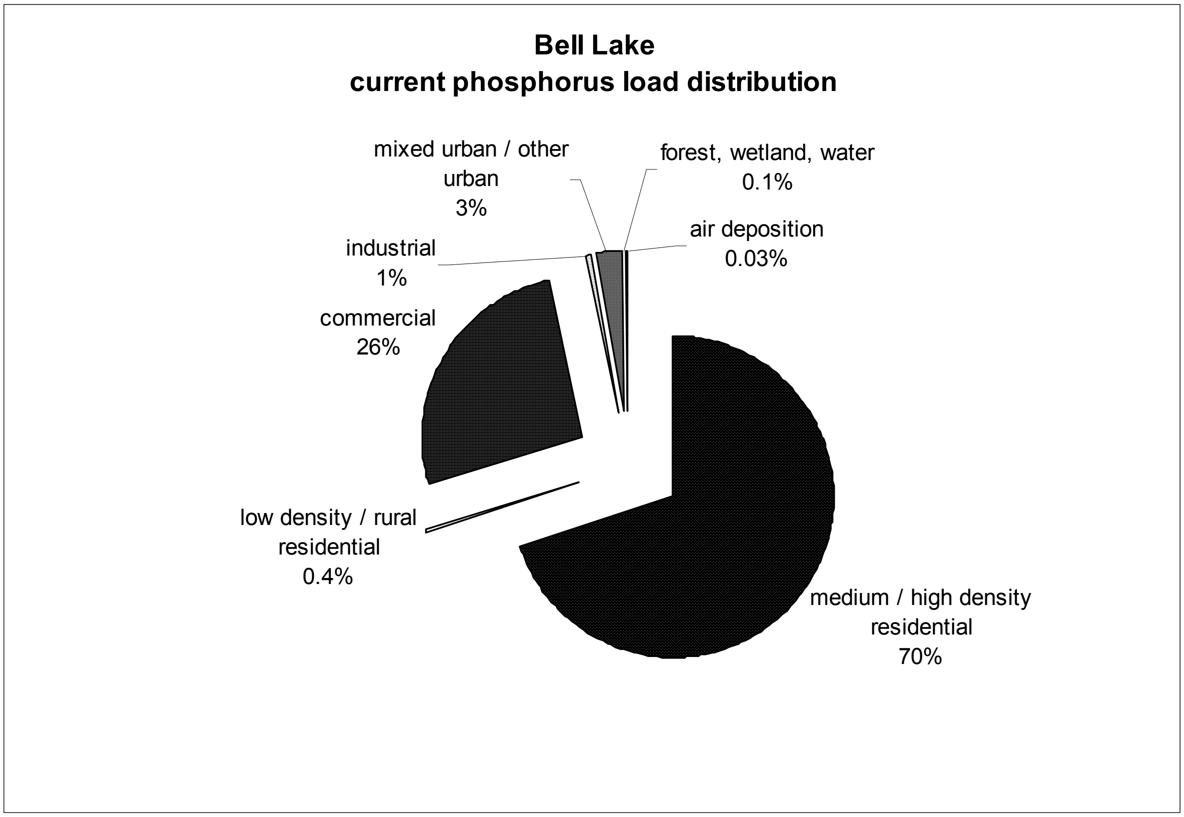


Figure 21 Current distribution of phosphorus load for Bethel Lake

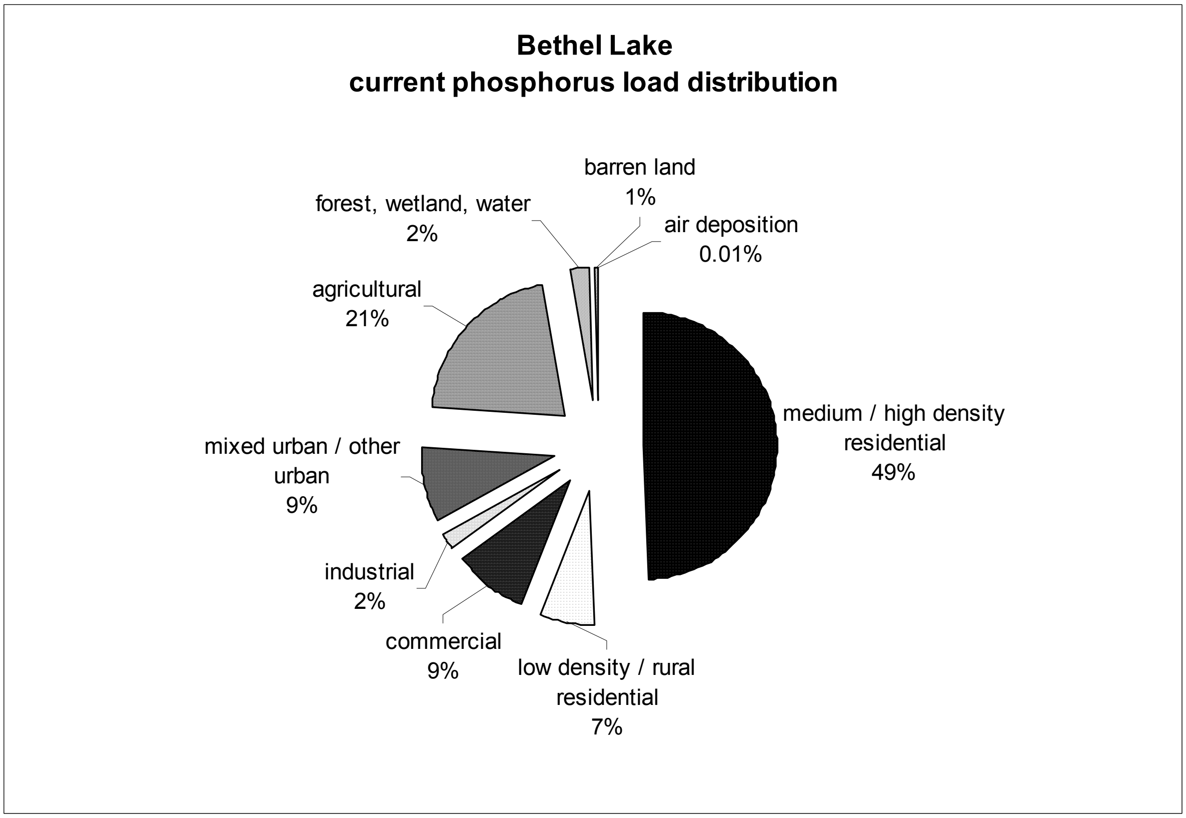


Figure 22 Current distribution of phosphorus load for Blackwood Lake

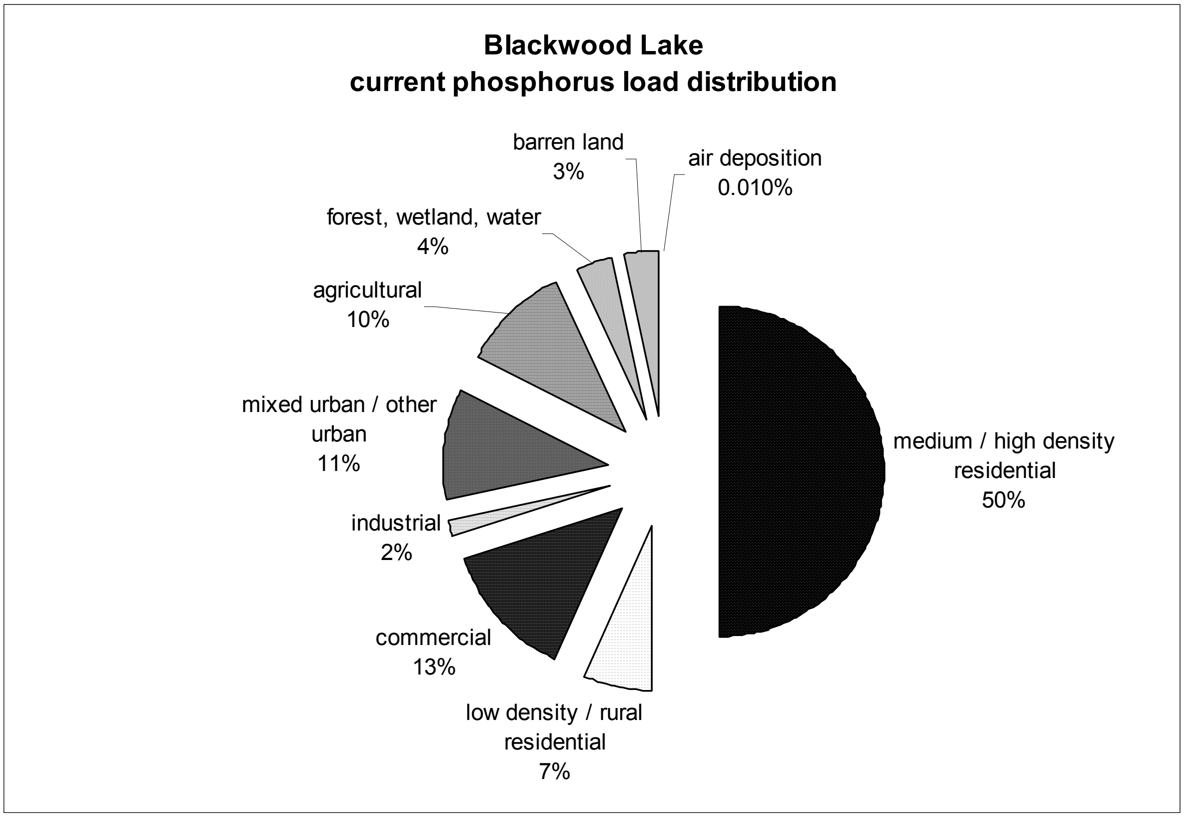


Figure 23 Current distribution of phosphorus load for Harrisonville Lake

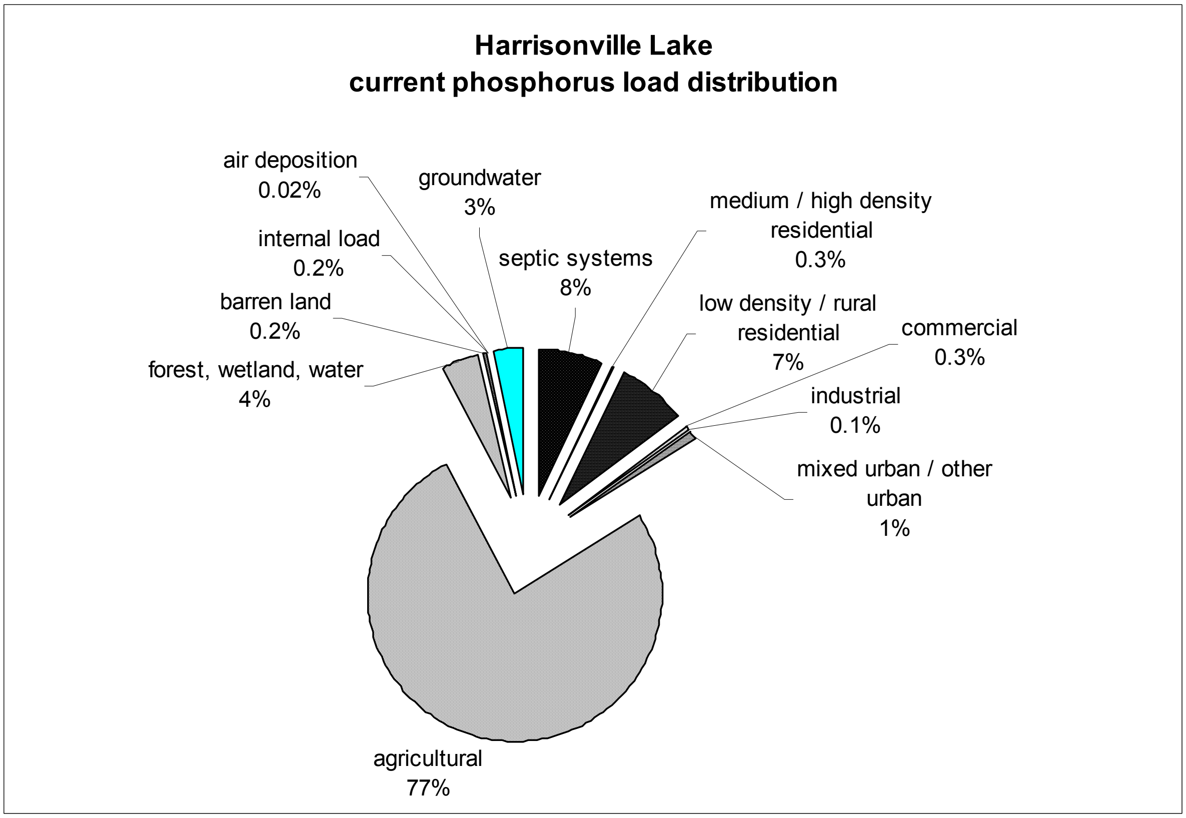


Figure 24 **Current distribution of phosphorus load for Kirkwood Lake**

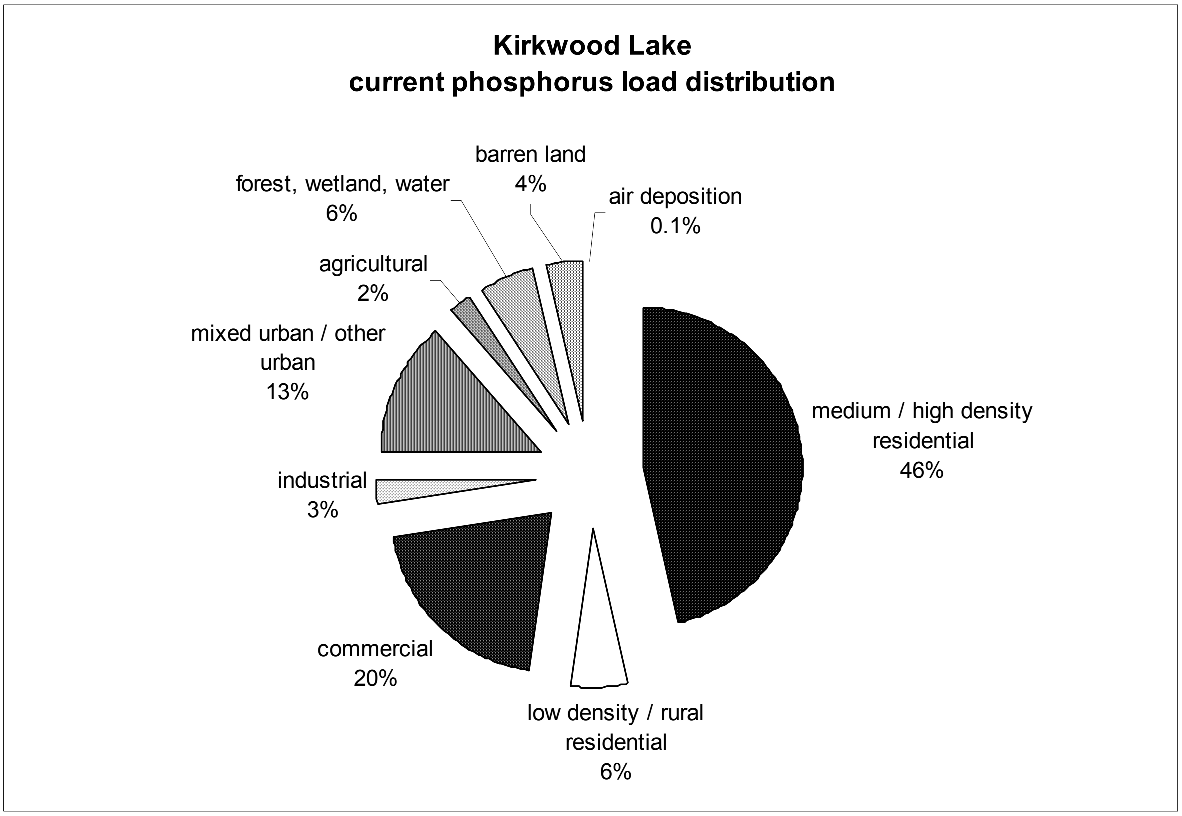


Figure 25 **Current distribution of phosphorus load for Woodbury Lake**

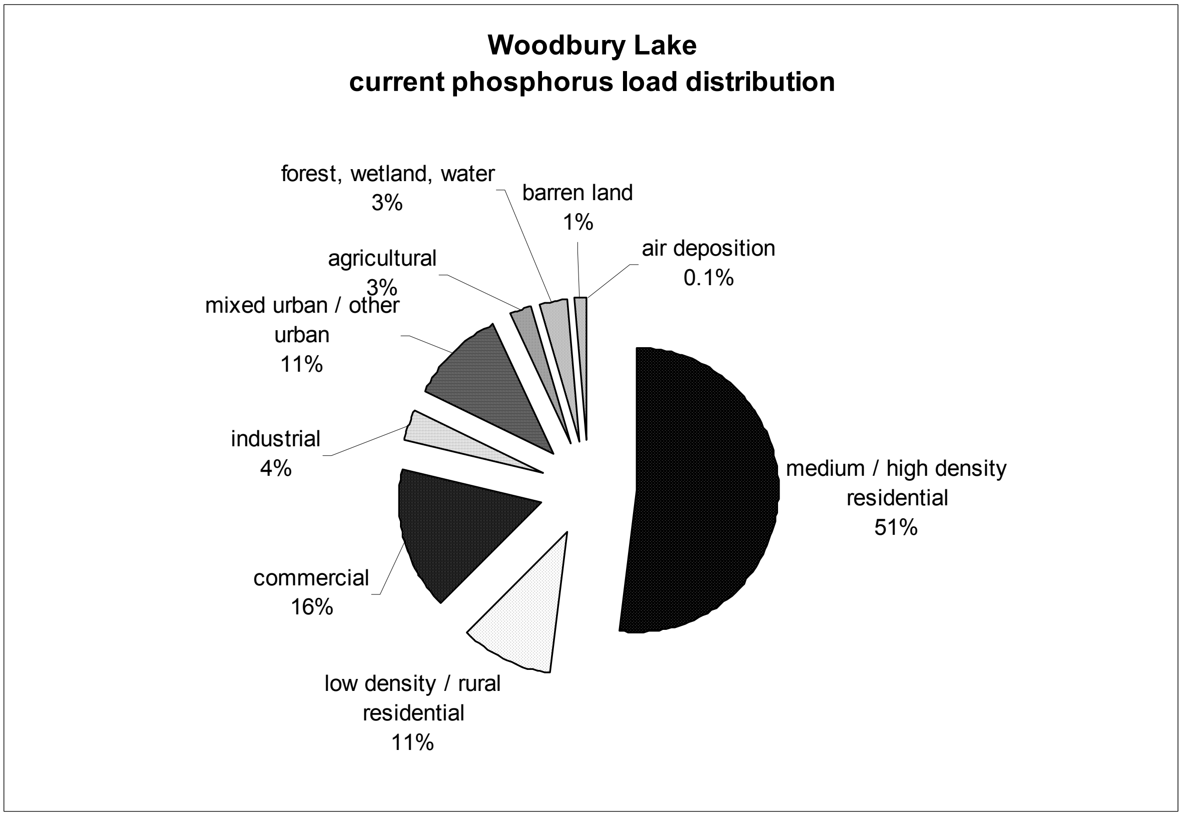


Figure 26 Current distribution of phosphorus load for Imlaystown Lake

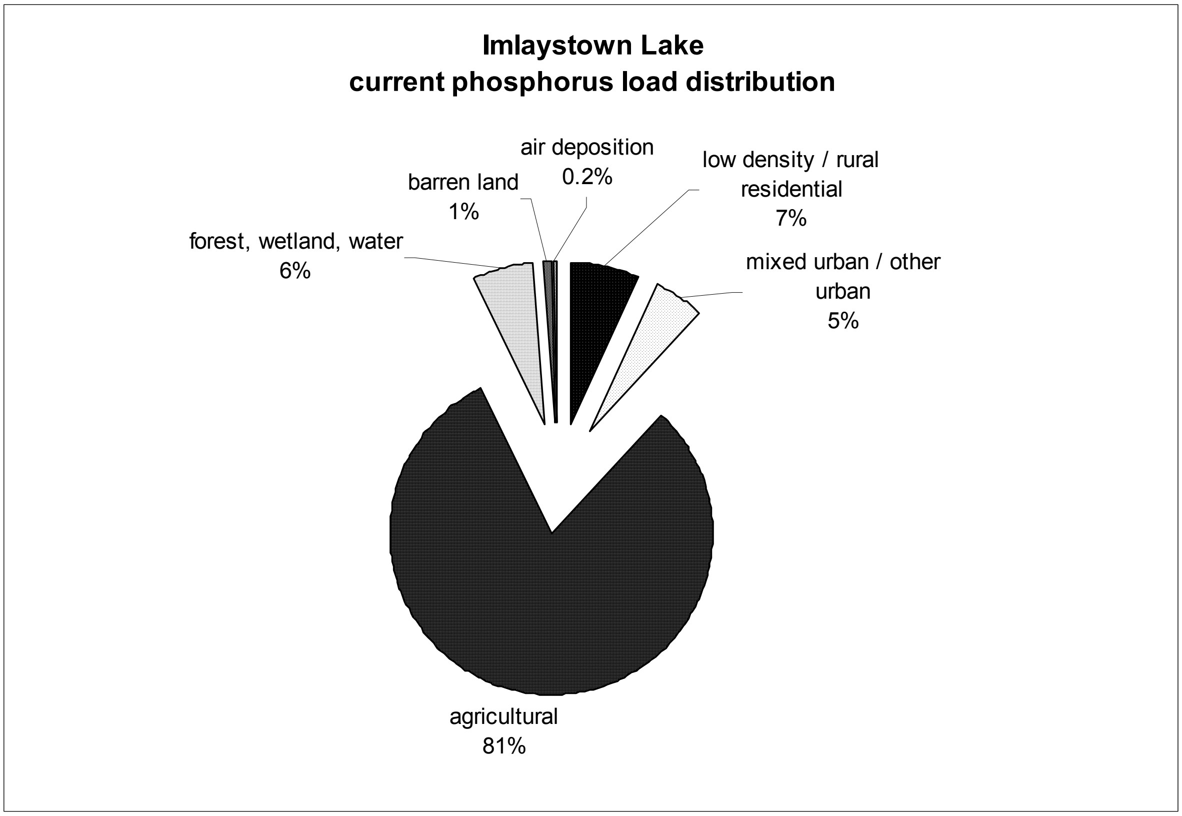
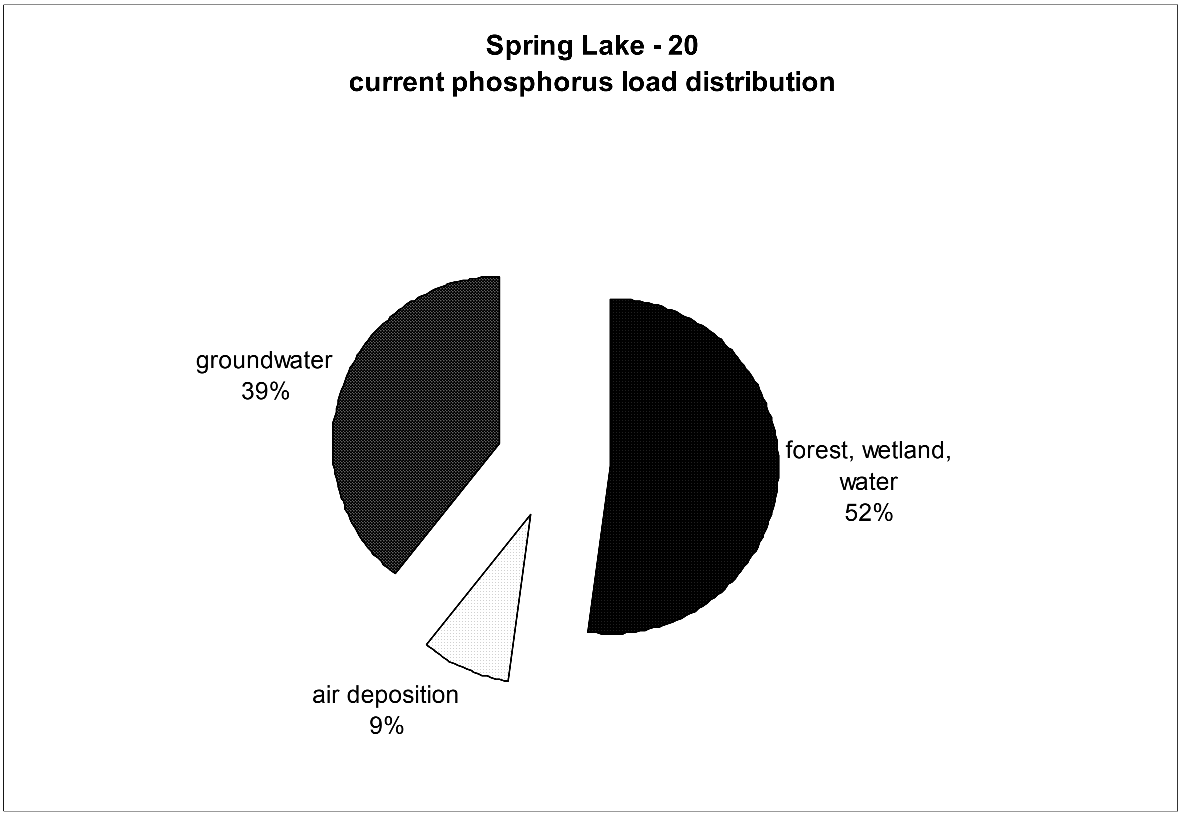


Figure 27 Current distribution of phosphorus load for Spring Lake



7.2 Reference Condition

A reference condition for each lake was estimated by calculating external loads as if the land use throughout the lakeshed were completely forest and wetlands. Estimates of air deposition and groundwater loads were included to calculate the reference condition. Using the same physical parameters and external loads from forest and wetlands, a reference steady-state phosphorus concentration was calculated for each lake using the Reckhow (1979a) formulation and listed in Table 9.

7.3 Seasonal Variation/Critical Conditions

These TMDLs will attain applicable surface water quality standards year round. The Reckhow model predicts steady-state phosphorus concentration. To account for data variability, the Department generally interprets threshold criteria as greater than 10% exceedance for the purpose of defining impaired waterbodies. Data from two lakes in New Jersey for which the Department had ready access to data (Strawbridge Lake, NJDEP 2000a; Sylvan Lake, NJDEP 2000b) exhibit peak (based on the 90th percentile) to mean ratios of 1.56 and 1.48, resulting in target phosphorus concentrations of 0.032 and 0.034 mg TP/l, respectively. Since the peak to mean ratios were close and the target concentration not very sensitive to differences in peak to mean ratios, the Department determined that a target phosphorus concentration of 0.03 mg TP/l is reasonably conservative. The seasonal variation was therefore assumed to be 67%, resulting in a target phosphorus concentration of 0.03 mg TP/l. Since it is the annual pollutant load rather than the load at any particular time that determines overall lake water quality (section 6), the target phosphorus concentration of 0.03 mg TP/l accounts for critical conditions.

7.4 Margin of Safety

A Margin of Safety (MOS) is provided to account for “lack of knowledge concerning the relationship between effluent limitations and water quality.” (40 CFR 130.7(c)). A MOS is required in order to account for uncertainty in the loading estimates, physical parameters and the model itself. The margin of safety, as described in USEPA guidance (Sutfin, 2002), can be either explicit or implicit (i.e., addressed through conservative assumptions used in establishing the TMDL). For these TMDL calculations, an implicit as well as explicit Margin of Safety (MOS) is provided.

These TMDLs contain an implicit margin of safety by using conservative critical conditions, over-estimated loads, and total phosphorus. Each conservative assumption is further explained below.

Critical conditions are accounted by comparing peak concentrations to mean concentrations and adjusting the target concentration accordingly (0.03 mg TP/l instead of 0.05 mg TP/l). In addition to the conservative approach used for critical conditions, the land use export methodology does not account for the distance between the land use and the lake, which will result in phosphorus reduction due to adsorption onto land surfaces and in-stream kinetic processes. Furthermore, the lakesheds are based on topography without accounting for the diversion of stormwater from lakes, which is common in urban areas. Neither are any reductions assumed due to the addition of lakeside vegetative buffer construction or other management practices aimed at minimizing phosphorus loads. Finally, the use of total phosphorus, as both the endpoint for the standard and in the loading estimates, is a conservative assumption. Use of total phosphorous does not distinguish readily between dissolved orthophosphorus, which is available for algal growth, and unavailable forms of phosphorus (e.g. particulate). While many forms of phosphorus are converted into orthophosphorus in the lake, many are captured in the sediment, for instance, and never made available for algal uptake.

In addition to the multiple conservative assumptions built in to the calculation, an additional explicit margin of safety was included to account for the uncertainty in the model itself. As described in Reckhow *et al* (1980), the Reckhow (1979a) model has an associated standard error of 0.128, calculated on log-transformed predictions of phosphorus concentrations. Transforming the terms in the model error analysis from Reckhow *et al* (1980) yields the following (Appendix D):

$$MoS_p = \sqrt{1 / ((1-\rho) * 4.5)} \times \left(10^{0.128} - 1\right),$$

where: MoS_p = margin of safety as a percentage over the predicted phosphorus concentration;
ρ = the probability that the real phosphorus concentration is less than or equal to the predicted phosphorus concentration plus the margin of safety as a concentration.

Setting the probability to 90% yields a margin of safety of 51% when expressed as a percentage over predicted phosphorus concentration or estimated external load. The external load for each lake was therefore multiplied by 1.51 to calculate an "upper bound" estimate of steady-state phosphorus concentration. An additional explicit margin of safety was included in the analyses by setting the upper bound calculations equal to the target phosphorus concentration of 0.3 mg TP/l, as described in the next section and shown in Table 9. Note that the explicit Margin of Safety is equal to 51% when expressed as a percentage over the predicted phosphorus concentration; when expressed as a percentage of total loading capacity, the Margin of Safety is equal to 34%:

$$\left(MoS_{lc} = \frac{MoS_p \times P}{P + \left(MoS_p \times P\right)} = \frac{MoS_p}{1 + MoS_p} = \frac{0.51}{1.51} = 0.34 \right),$$

where: MoS_p = margin of safety expressed as a percentage over the predicted phosphorus concentration or external load;
MoS_{lc} = margin of safety as a percentage of total loading capacity;
P = predicted phosphorus concentration (or external load).

7.5 Target Condition

As discussed above, the current steady state concentration of phosphorus in each lake must be reduced to a steady state concentration of 0.03 mg/l to avoid exceeding the 0.05 mg/l phosphorus criterion. Using the Reckhow (1979a) formulation, the target conditions were calculated by reducing the loads as necessary to make the upper bound predictions (which incorporate the Margin of Safety) equal to the target phosphorus concentration of 0.03 mg TP/l. The target conditions for Imlaystown Lake and Spring Lake was set equal to the current condition, since the upper bound prediction assuming current loads is already less than the target phosphorus concentration of 0.03 mg TP/l. The target condition for Mary Elmer Lake was used to calculate the tributary load for the target condition of Sunset Lake. Overall reductions necessary to attain the target steady state concentration of total phosphorus in each lake were calculated by comparing the current condition to the target condition (Table 9). Because most of these lakes drain very large watersheds, the reference condition is very close to the target condition; overall load reduction necessary to achieve the target conditions are therefore quite substantial.

Table 9 Current condition, reference condition, target condition and overall percent reduction for each lake

Lake	current condition [TP] (mg/l)	reference condition [TP] (mg/l)	upper bound target condition [TP] (mg/l)	target condition [TP] (mg/l)	% overall TP load reduction
Burnt Mill Pond	0.139	0.018	0.030	0.020	86%
Giampietro Lake	0.164	0.015	0.030	0.020	88%
Mary Elmer Lake	0.204	0.015	0.030	0.020	90%
Memorial Lake	0.141	0.012	0.030	0.020	86%
Sunset Lake	0.193	0.018	0.030	0.020	90%
Bell Lake	0.312	0.019	0.030	0.020	94%
Bethel Lake	0.118	0.011	0.030	0.020	83%
Blackwood Lake	0.112	0.012	0.030	0.020	82%
Harrisonville Lake	0.133	0.018	0.030	0.020	85%
Kirkwood Lake	0.083	0.011	0.030	0.020	76%
Woodbury Lake	0.108	0.011	0.030	0.020	82%
Imlaystown Lake	0.010	0.001	0.015	0.010	0%
Spring Lake	0.005	0.005	0.007	0.005	0%

8.0 TMDL Calculations

8.1 Loading Capacity

The Reckhow (1979a) model was used to solve for loading rate given the upper bound target concentration of 0.03 mg/l (which incorporates the Margin of Safety). Reducing the current loading rates by the percentages in Table 9 yields the same results. The acceptable loading capacity for each lake is provided in Tables 11-15.

8.2 Reserve Capacity

Reserve capacity is an optional means of reserving a portion of the loading capacity to allow for future growth. Reserve capacities are not included at this time. Therefore, the loading capacities and accompanying WLAs and LAs must be attained in consideration of any new sources that may accompany future development. The primary means by which future growth could increase phosphorus load is through the development of forest land within the lakesheds. The implementation plan includes the development of Lake Restoration Plans that require the collection of more detailed information about each lakeshed. If the development of forest with the watershed of a particular lake is planned, the issue of reserve capacity to account for the additional runoff load of phosphorus may be revisited.

8.3 Allocations

USEPA regulations at 40 CFR § 130.2(i), state that "pollutant loadings may be expressed in terms of either mass per time, toxicity, or other appropriate measure." For lake nutrient TMDLs, it is appropriate to express the TMDL on a yearly basis. Long-term average pollutant loadings are typically more critical to overall lake water quality due to the storage and recycling mechanisms in the lake. Also, most available empirical lake models, such as the Reckhow model used in this analysis, use annual loads rather than daily loads to estimate in-lake concentrations.

The TMDLs for total phosphorus are therefore calculated as follows (Tables 11-15):

TMDL = loading capacity
= Sum of the wasteload allocations (WLAs) + load allocations (LAs) + margin of safety.

WLAs are hereby established for all NJPDES-regulated point sources within each source category, while LAs are established for stormwater sources that are not subject to NJPDES regulation and for all nonpoint sources. This distribution of loading capacity between WLAs and LAs is consistent with recent EPA guidance that clarifies existing regulatory requirements for establishing WLAs for stormwater discharges (Wayland, November 2002). Stormwater discharges are captured within the runoff sources quantified according to land use, as described previously. Distinguishing between regulated and unregulated stormwater is necessary in order to express WLAs and LAs numerically; however, "EPA recognizes that these allocations might be fairly rudimentary because of data limitations and variability within the system." (Wayland, November 2002, p.1) While the Department does not have the data to actually delineate lakesheds according to stormwater drainage areas subject to NJPDES regulation, the land use runoff categories previously defined can be used to estimate between them. Therefore allocations are established according to source categories as shown in Table 10. This demarcation between WLAs and LAs based on land use source categories is not perfect, but it represents the best estimate defined as narrowly as data allow. The Department acknowledges that there may be stormwater sources in the residential, commercial, industrial and mixed urban runoff source categories that are not NJPDES-regulated. Nothing in these TMDLs, including Table 10, shall be construed to require the Department to regulate a stormwater source under NJPDES that would not already be regulated as such, nor shall anything in these TMDLs be construed to prevent the Department from regulating a stormwater source under NJPDES. WLAs are hereby established for all NJPDES-regulated point sources, including stormwater, according to their source category. Quantifying WLAs and LAs according to source categories provides the best estimation defined as narrowly as data allow. However it is clearly noted that WLAs are hereby established for all NJPDES-regulated point sources within each source category, while LAs are established for stormwater sources that are not subject to NJPDES regulation and for all nonpoint sources. The WLAs and LAs in Tables 11-15 are not themselves "Additional Measures" under proposed N.J.A.C. 7:14A-25.6 or 25.8.

Table 10 **Distribution of WLAs and LAs among source categories**

Source category	TMDL allocation
Point Sources other than Stormwater	WLA
Nonpoint and Stormwater Sources	
medium / high density residential	WLA
low density / rural residential	WLA
commercial	WLA
industrial	WLA
Mixed urban / other urban	WLA
agricultural	LA
forest, wetland, water	LA
barren land	LA
air deposition onto lake surface	LA
septic systems	LA
internal load	LA
tributary load	LA

In order to attain the TMDLs, the overall load reductions shown in Table 9, or those determined through additional monitoring, must be achieved. Since loading rates have been defined for at least eight source categories, countless combinations of source reductions could be used to achieve the overall reduction target. The selected scenarios focus on land use and septic sources that can be affected by BMP implementation or NJPDES regulation, requiring equal percent reductions from each in order to achieve the necessary overall load reduction (Tables 11-15). The Lake Restoration Plans developed for each lake as part of the TMDL implementation (section 10) may revisit the distribution of reductions among the various sources in order to better reflect actual implementation projects. The resulting TMDLs, rounded to two significant digits, are shown in Tables 11-15 and illustrated in Figures 28 to 40.

Table 11 TMDL calculations for each lake (annual loads and percent reductions[a])

lake	Burnt Mill Pond		% reduction	Giampietro Lake		% reduction	Mary Elmer Lake		% reduction
	kg TP/yr	% of IC		kg TP/yr	% of IC		kg TP/yr	% of IC	
loading capacity (LC)	290	100%	n/a	300	100%	n/a	380	100%	n/a
Point Sources other than Stormwater									
minor municipal	n/a			n/a			n/a		
Nonpoint and Stormwater Sources									
medium / high density residential	9.9	3.4%	91%	31	10%	90%	12	3.0%	91%
low density / rural residential	19	6.4%	91%	13	4.3%	90%	11	2.9%	91%
commercial	5.3	1.8%	91%	12	4.1%	90%	4.4	1.1%	91%
industrial	7.1	2.4%	91%	2.4	0.8%	90%	0.1	0.02%	91%
Mixed urban / other urban	7.5	2.6%	91%	11	3.8%	90%	3.8	1.0%	91%
agricultural	61	21%	91%	91	31%	90%	210	54%	91%
forest, wetland, water	73	25%	0%	31	11%	0%	13	3.3%	0%
barren land	10	3.6%	0%	3.6	1.2%	0%	2.9	0.8%	0%
septic systems									
waterfowl				0.8	0.3%	90%			
internal load									
tributary load	n/a			n/a			n/a		
Natural Sources / Background									
air deposition onto lake surface	0.6	0.2%	0%	0.4	0.1%	0%	0.6	0.2%	0%
groundwater									
Other Allocations									
explicit Margin of Safety	99	34%	n/a	100	34%	n/a	129	34%	n/a

a Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 9.

Table 12 TMDL calculations for each lake (annual loads and percent reductions[a], cont'd)

lake	Memorial Lake		% reduction	Sunset Lake		% reduction	Bell Lake		% reduction
	kg TP/yr	% of IC		kg TP/yr	% of IC		kg TP/yr	% of IC	
loading capacity (LC)	930	100%	n/a	2500	100%	n/a	17	100%	n/a
Point Sources other than Stormwater									
minor municipal	n/a			n/a			n/a		
Nonpoint and Stormwater Sources									
medium / high density residential	1.8	0.2%	88%	25	1.0%	92%	7.8	45%	94%
low density / rural residential	17	1.8%	88%	52	2.1%	92%	0.04	0.2%	94%
commercial	6.3	0.7%	88%	14	0.5%	92%	3.0	17%	94%
industrial	6.3	0.7%	88%	3.8	0.2%	92%	0.1	0.4%	94%
Mixed urban / other urban	9.3	1.0%	88%	22	0.9%	92%	0.3	1.7%	94%
agricultural	490	53%	88%	1000	42%	92%		0.0%	94%
forest, wetland, water	78	8.4%	0%	210	8.2%	0%	0.2	1.2%	0%
barren land	4.2	0.5%	0%	19	0.8%	0%			
septic systems									
waterfowl									
internal load									
tributary load	n/a			190	7.7%	90%	n/a		
Natural Sources / Background									
air deposition onto lake surface	0.6	0.1%	0%	2.5	0.1%	0%	0.1	0.3%	0%
groundwater				80	3.2%	0%			
Other Allocations									
explicit Margin of Safety	310	34%	n/a	850	34%	n/a	5.8	34%	n/a

a Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 9.

Table 13 **TMDL calculations for each lake (annual loads and percent reductions[a], cont'd)**

lake	Bethel Lake		% reduction	Blackwood Lake		% reduction	Harrisonville Lake		% reduction
	kg TP/yr	% of IC		kg TP/yr	% of IC		kg TP/yr	% of IC	
loading capacity (LC)	540	100%	n/a	1200	100%	n/a	500	100%	n/a
Point Sources other than Stormwater									
minor municipal	n/a			n/a			n/a		
Nonpoint and Stormwater Sources									
medium / high density residential	150	28%	85%	260	21.8%	88%	0.5	0.1%	92%
low density / rural residential	21	3.9%	85%	35	2.9%	88%	13	2.6%	92%
commercial	27	5.0%	85%	69	5.7%	88%	0.6	0.1%	92%
industrial	6.4	1.2%	85%	8.8	0.7%	88%	0.2	0.1%	92%
Mixed urban / other urban	28	5.2%	85%	57	4.7%	88%	2.0	0.4%	92%
agricultural	65	12%	85%	55	4.6%	88%	134	28%	92%
forest, wetland, water	43	8.1%	0%	170	13.7%	0%	88	18%	0%
barren land	13	2.4%	0%	140	12.0%	0%	4.7	0.9%	0%
septic systems							12	2.5%	92%
waterfowl									
internal load							5.2	1.0%	0%
tributary load	n/a			n/a			n/a		
Natural Sources / Background									
air deposition onto lake surface	0.3	0.1%	0%	0.4	0.04%	0%	0.5	0.1%	0%
groundwater							71	14%	0%
Other Allocations									
explicit Margin of Safety	180	34%	n/a	410	34%	n/a	170	34%	n/a

a Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 9.

Table 14 TMDL calculations for each lake (annual loads and percent reductions[a], cont'd)

lake	Kirkwood Lake		%	Woodbury Lake		%	Imlaystown Lake		%
	kg TP/yr	% of IC	reduction	kg TP/yr	% of IC	reduction	kg TP/yr	% of IC	reduction
loading capacity (LC)	380	100%	n/a	350	100%	n/a	390	100%	n/a
Point Sources other than Stormwater									
minor municipal	n/a			n/a			n/a		
Nonpoint and Stormwater Sources									
medium / high density residential	79	21%	84%	95	27.5%	85%			
low density / rural residential	9.8	2.6%	84%	19	5.6%	85%	18	4.5%	0%
commercial	34	9.2%	84%	30	8.6%	85%			
industrial	4.4	1.2%	84%	6.7	1.9%	85%			
Mixed urban / other urban	23	6.0%	84%	20	5.7%	85%	13	3.3%	0%
agricultural	3.9	1.0%	84%	5.0	1.4%	85%	210	54%	0%
forest, wetland, water	57	15%	0%	38	10.9%	0%	16	4.0%	0%
barren land	37	9.9%	0%	15	4.2%	0%	2.2	0.6%	0%
septic systems									
waterfowl									
internal load									
tributary load	n/a			n/a			n/a		
Natural Sources / Background									
air deposition onto lake surface	0.7	0.2%	0%	1.3	0.4%	0%	0.5	0.1%	0%
groundwater									
Other Allocations									
explicit Margin of Safety	130	34%	n/a	120	34%	n/a	130	34%	n/a

[a] Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 9.

Table 15 TMDL calculations for each lake (annual loads and percent reductions^a, cont'd)

lake	Spring Lake		% reduction
	kg TP/yr	% of IC	
loading capacity (LC)	11	100%	n/a
Point Sources other than Stormwater			
minor municipal	n/a		
Nonpoint and Stormwater Sources			
medium / high density residential			
low density / rural residential			
commercial			
industrial			
Mixed urban / other urban			
agricultural			
forest, wetland, water	3.8	35%	0%
barren land			
septic systems			
waterfowl			
internal load			
tributary load	n/a		
Natural Sources / Background			
air deposition onto lake surface	0.6	5.6%	0%
groundwater	2.8	26%	0%
Other Allocations			
explicit Margin of Safety	3.7	34%	n/a

a Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 9.

Figure 28 Phosphorus allocations for Burnt Mill Pond TMDL

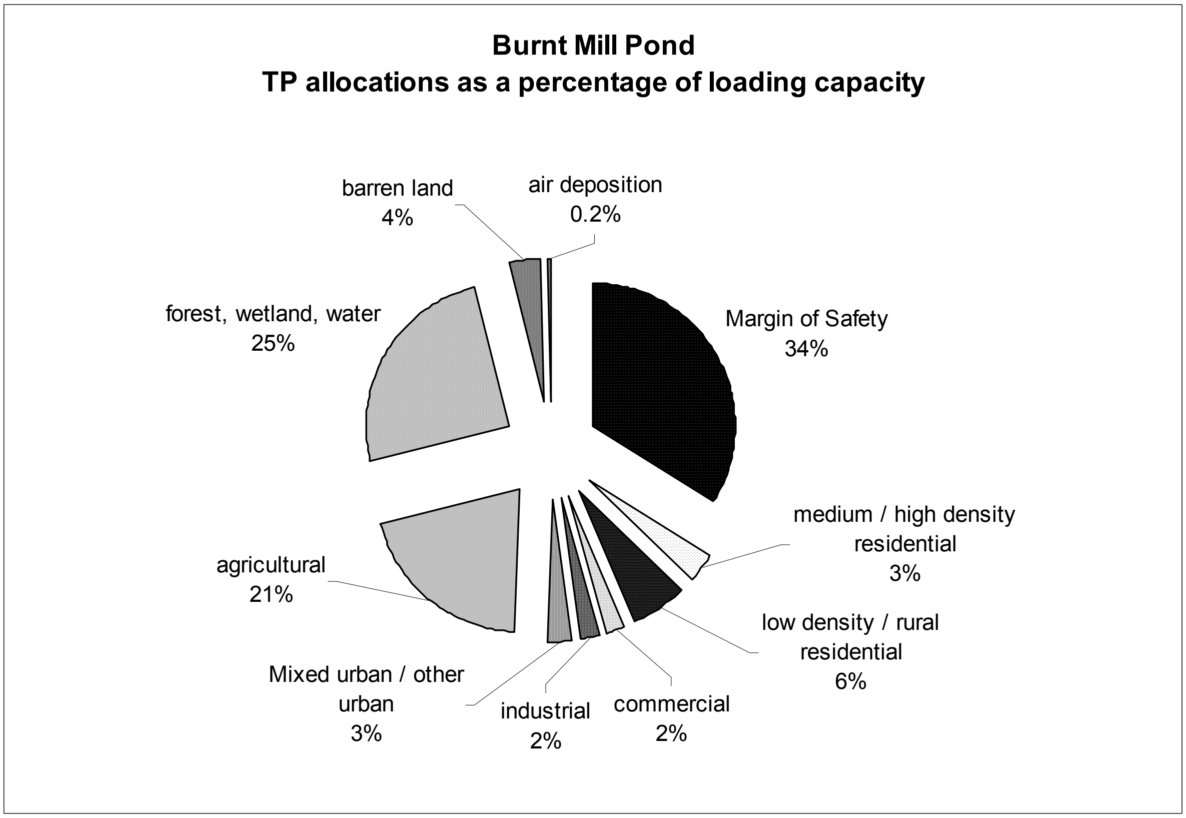


Figure 29 **Phosphorus allocations for Giampietro Lake**

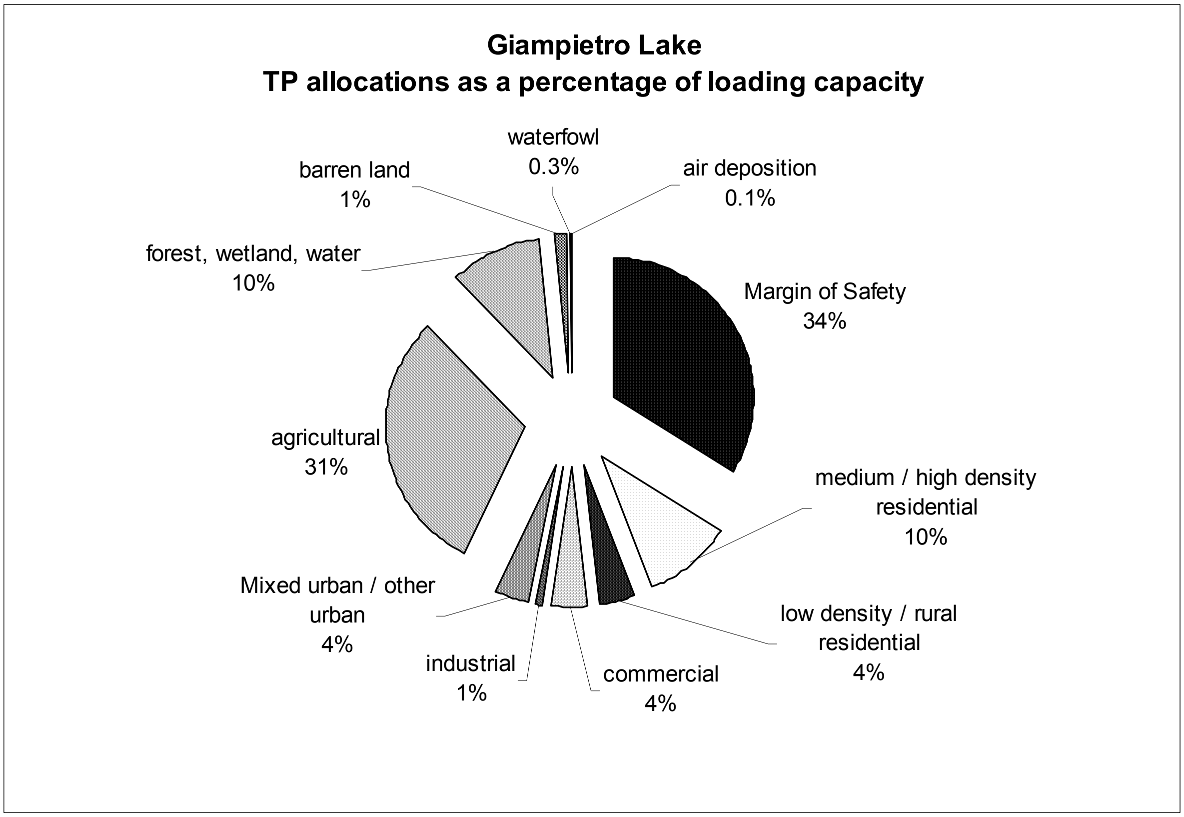


Figure 30 **Phosphorus allocations for Mary Elmer Lake**

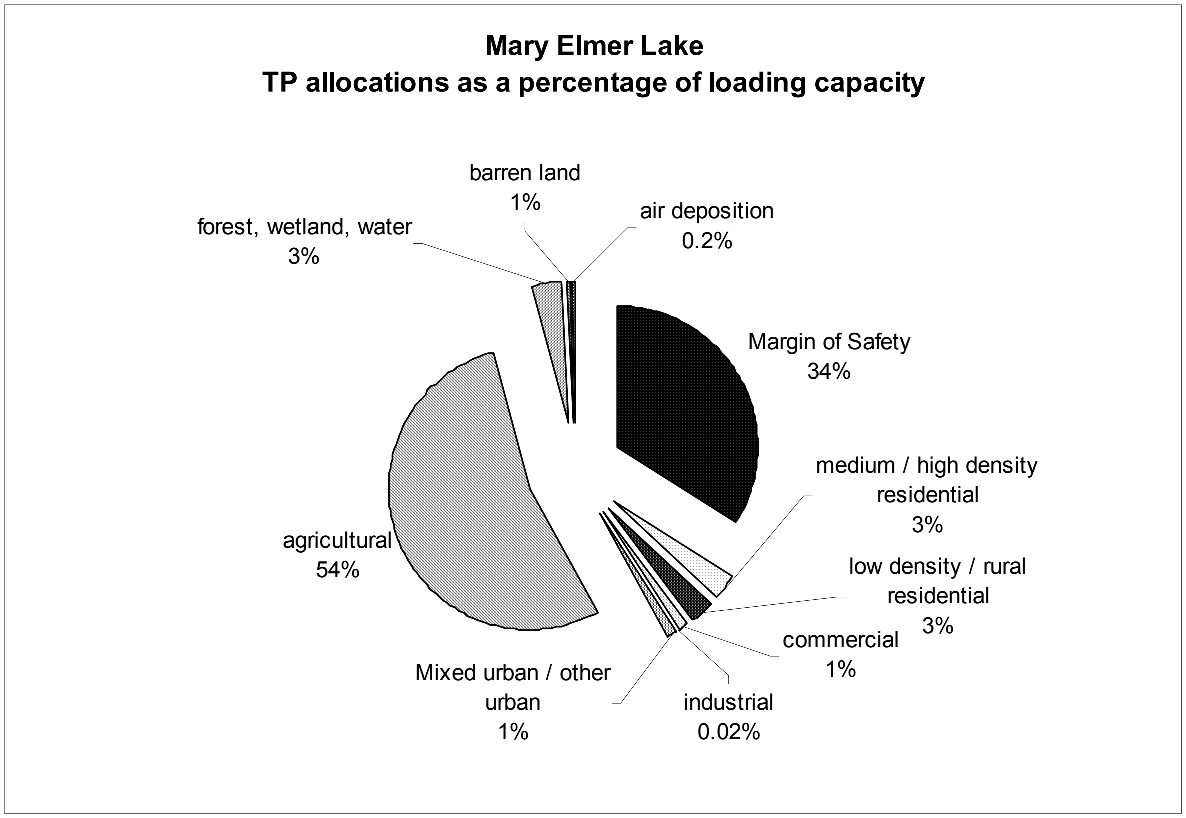


Figure 31 **Phosphorus allocations for Memorial Lake**

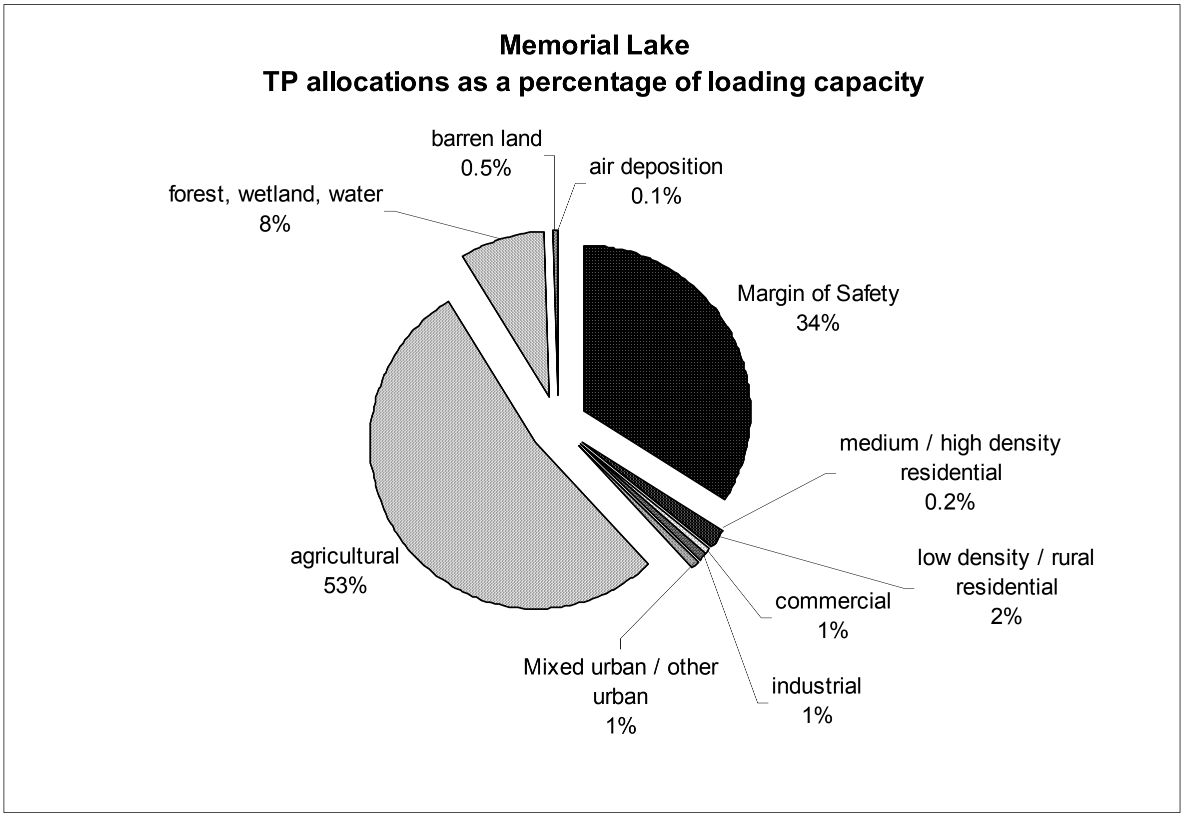


Figure 32 **Phosphorus allocations for Sunset Lake**

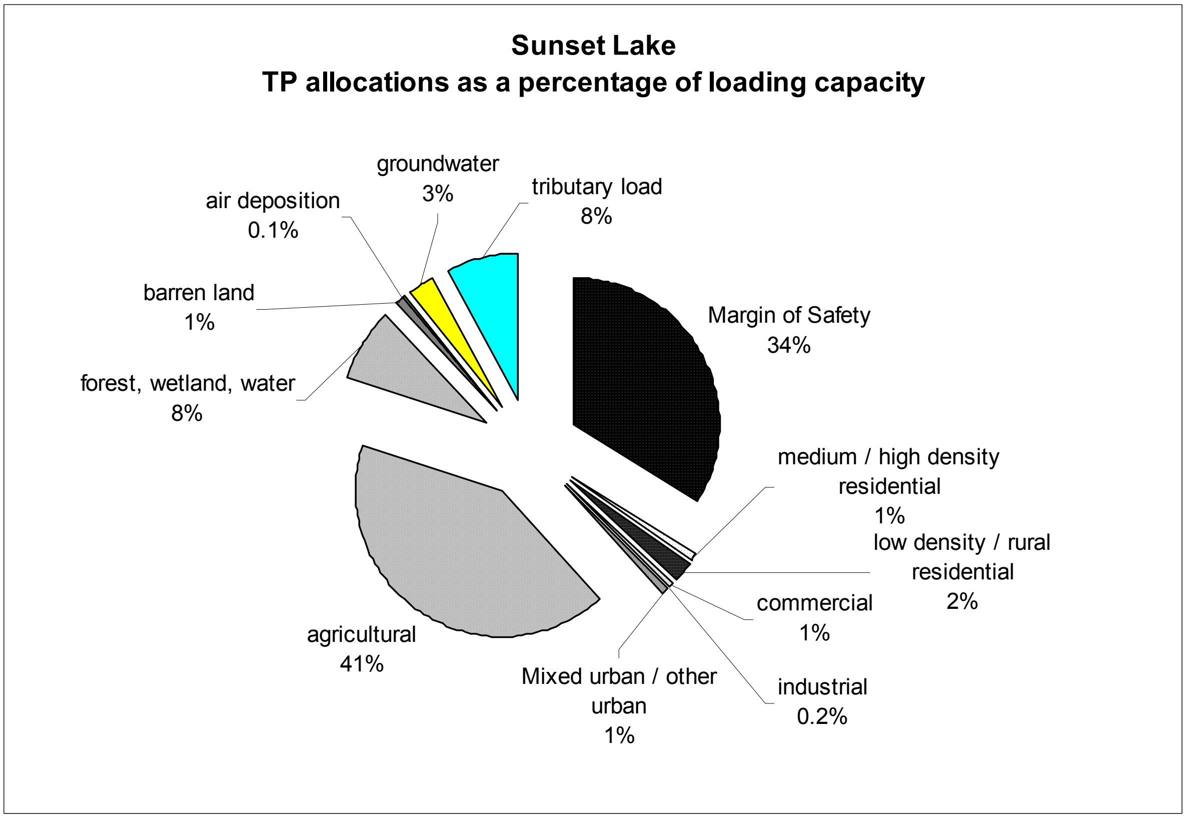


Figure 33 **Phosphorus allocations for Bell Lake**

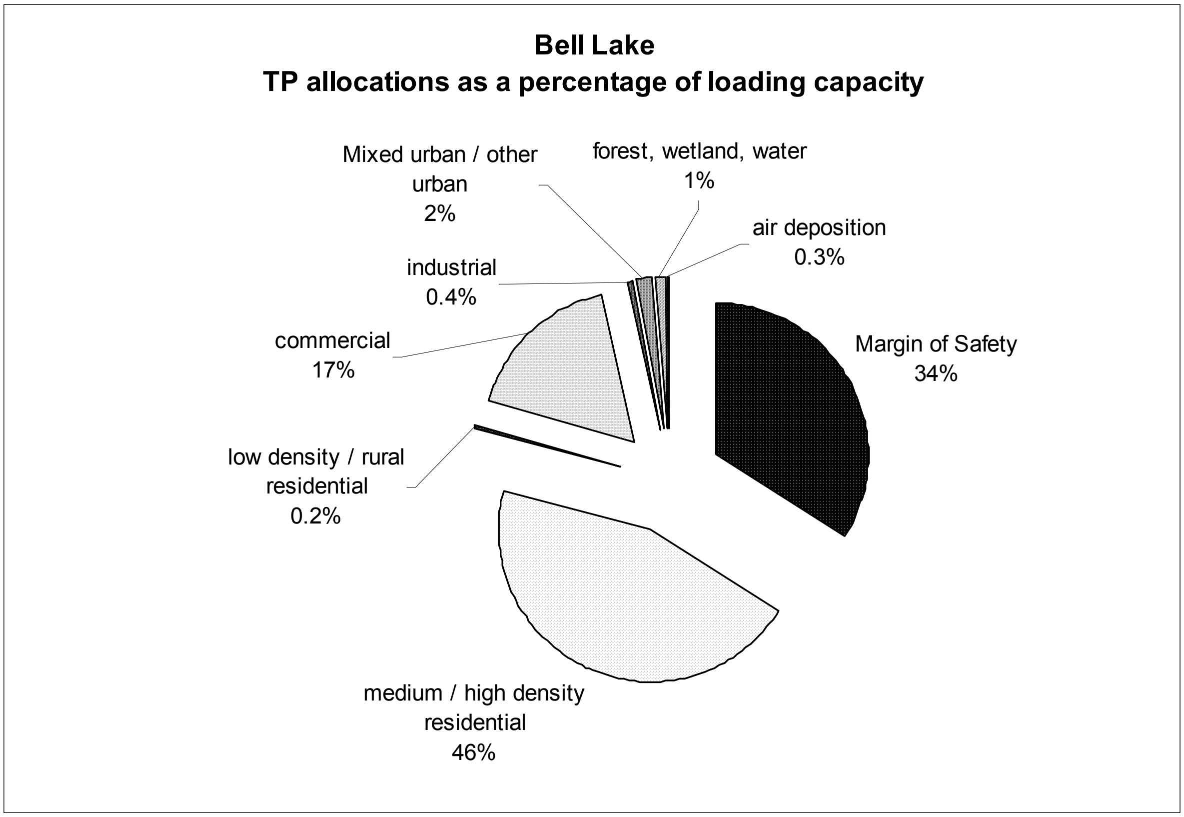


Figure 34 **Phosphorus allocations for Bethel Lake**

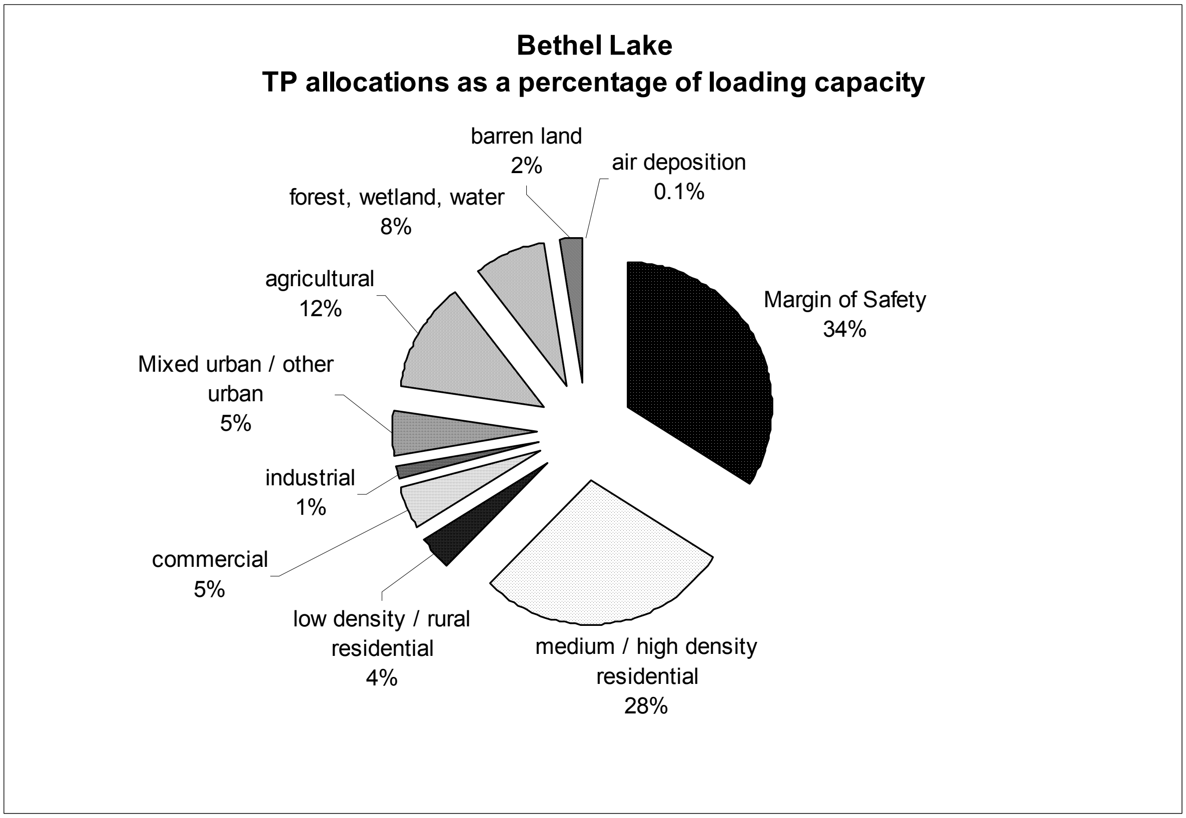


Figure 35 **Phosphorus allocations for Blackwood Lake**

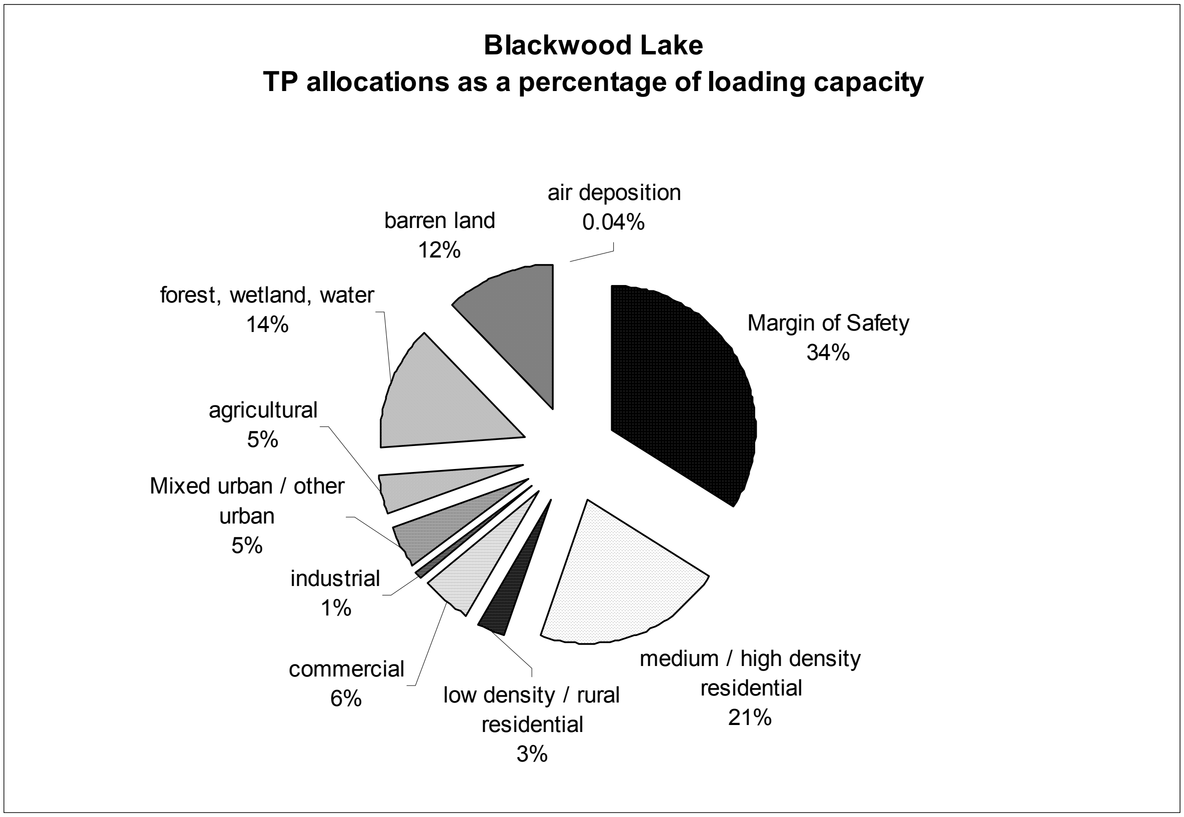


Figure 36 **Phosphorus allocations for Harrisonville Lake**

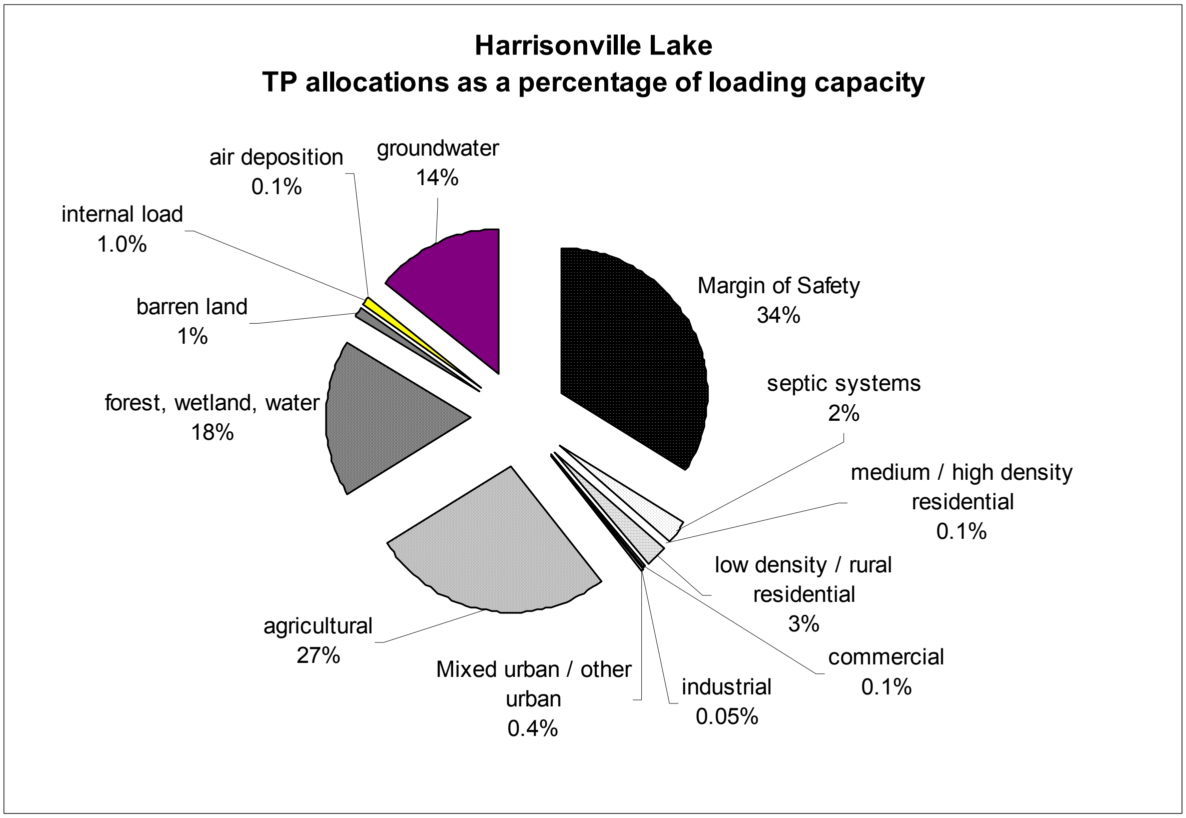


Figure 37 **Phosphorus allocations for Kirkwood Lake**

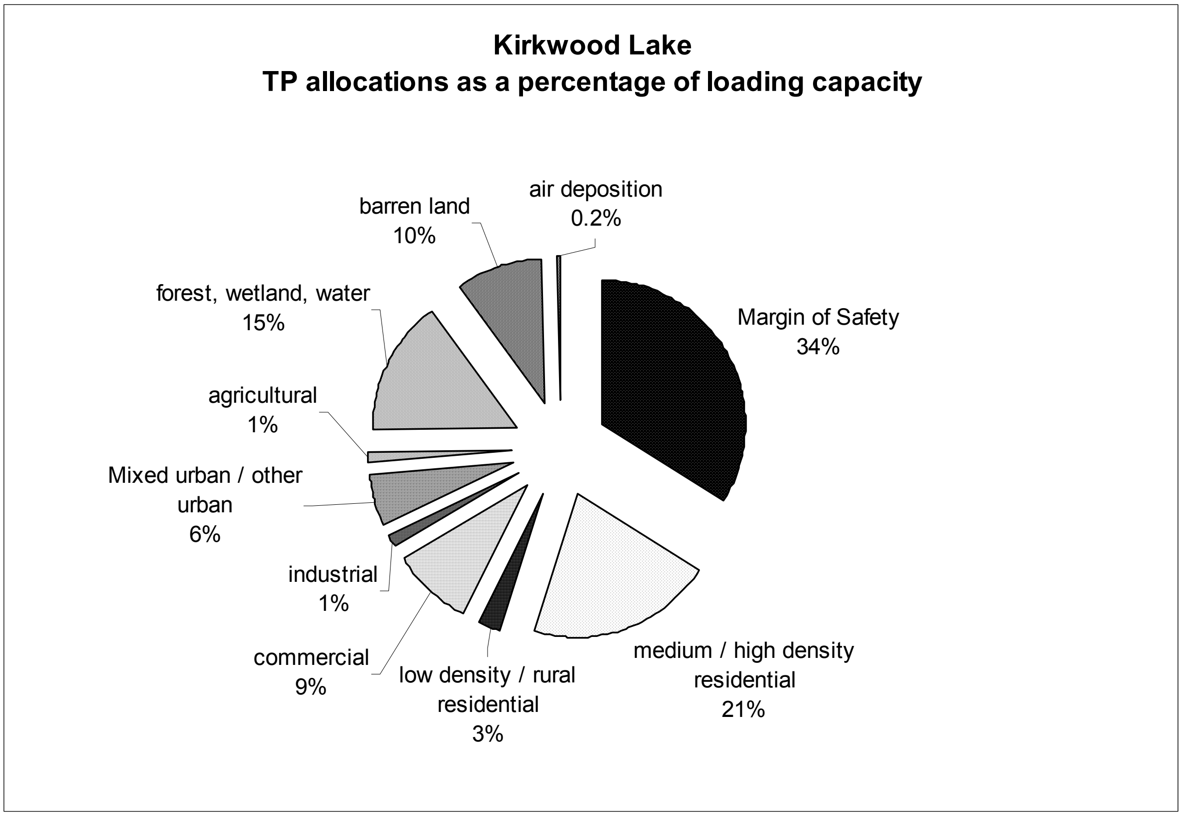


Figure 38 **Phosphorus allocations for Woodbury Lake**

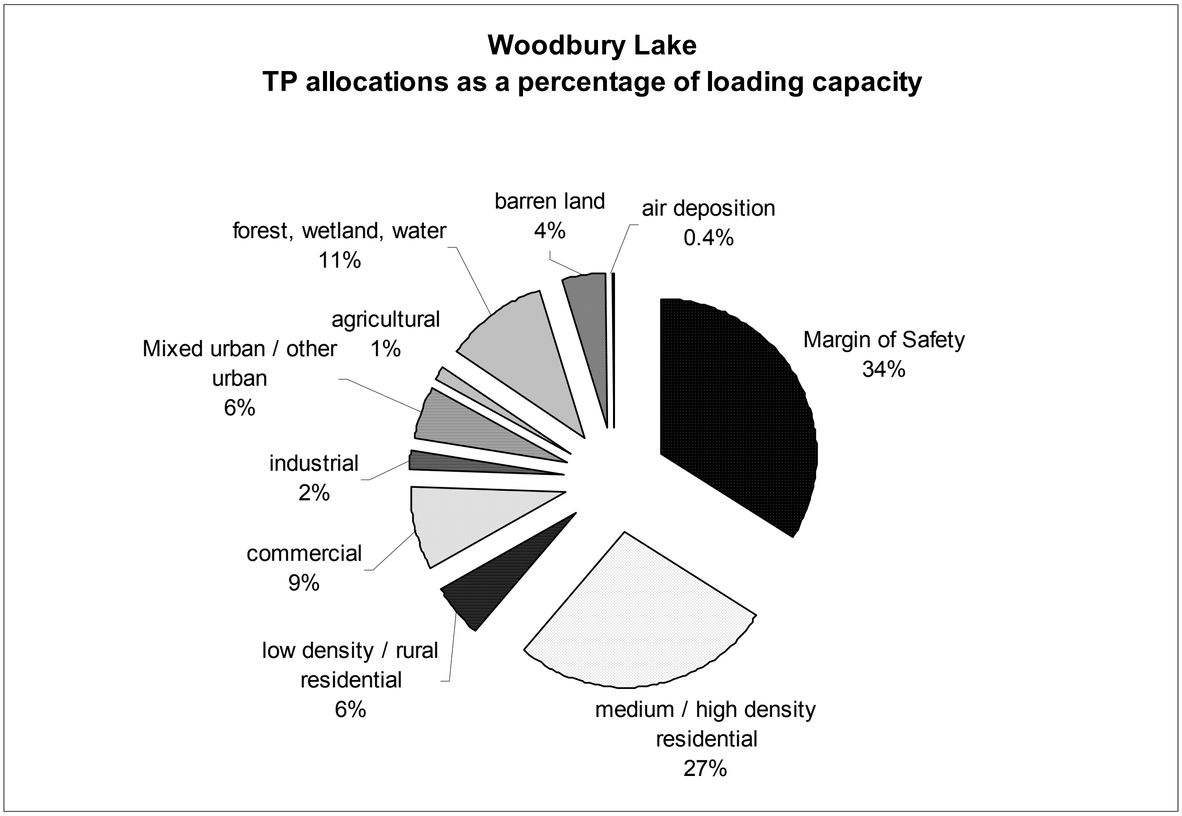


Figure 39 Phosphorus allocations for Imlaystown Lake TMDL

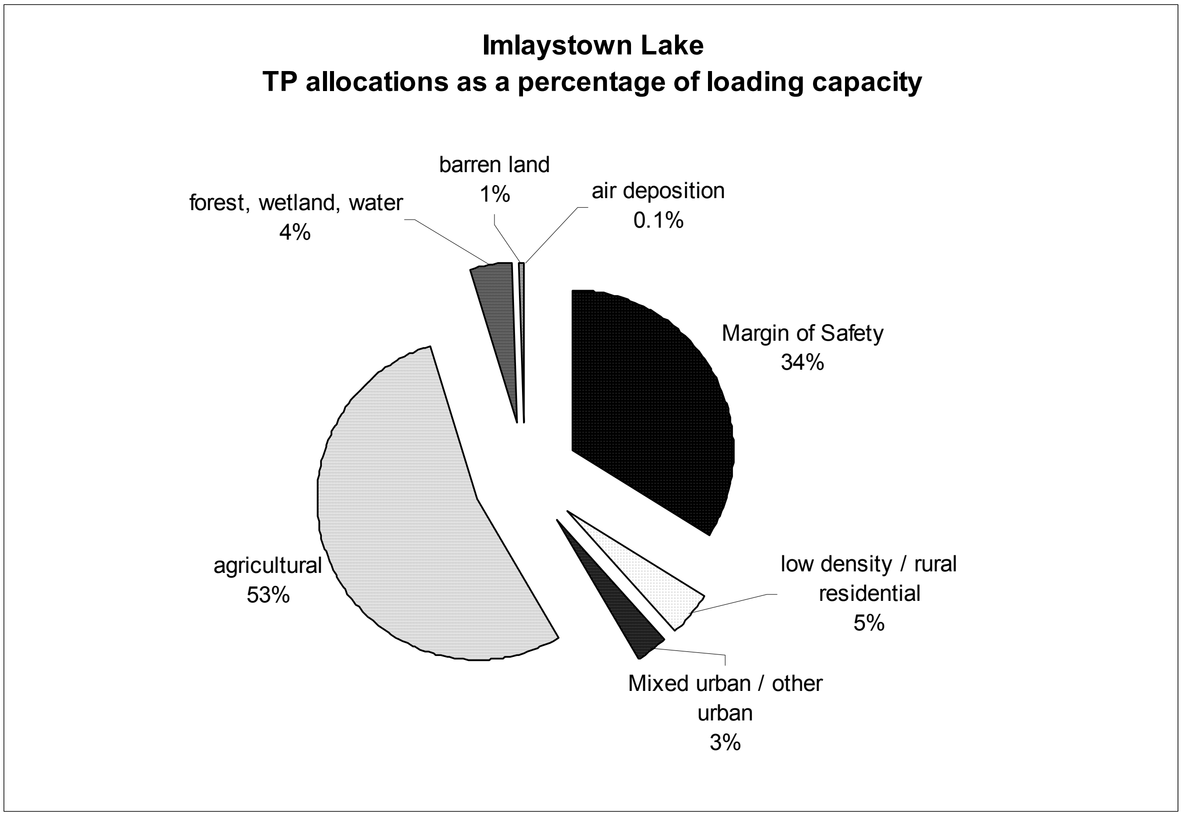
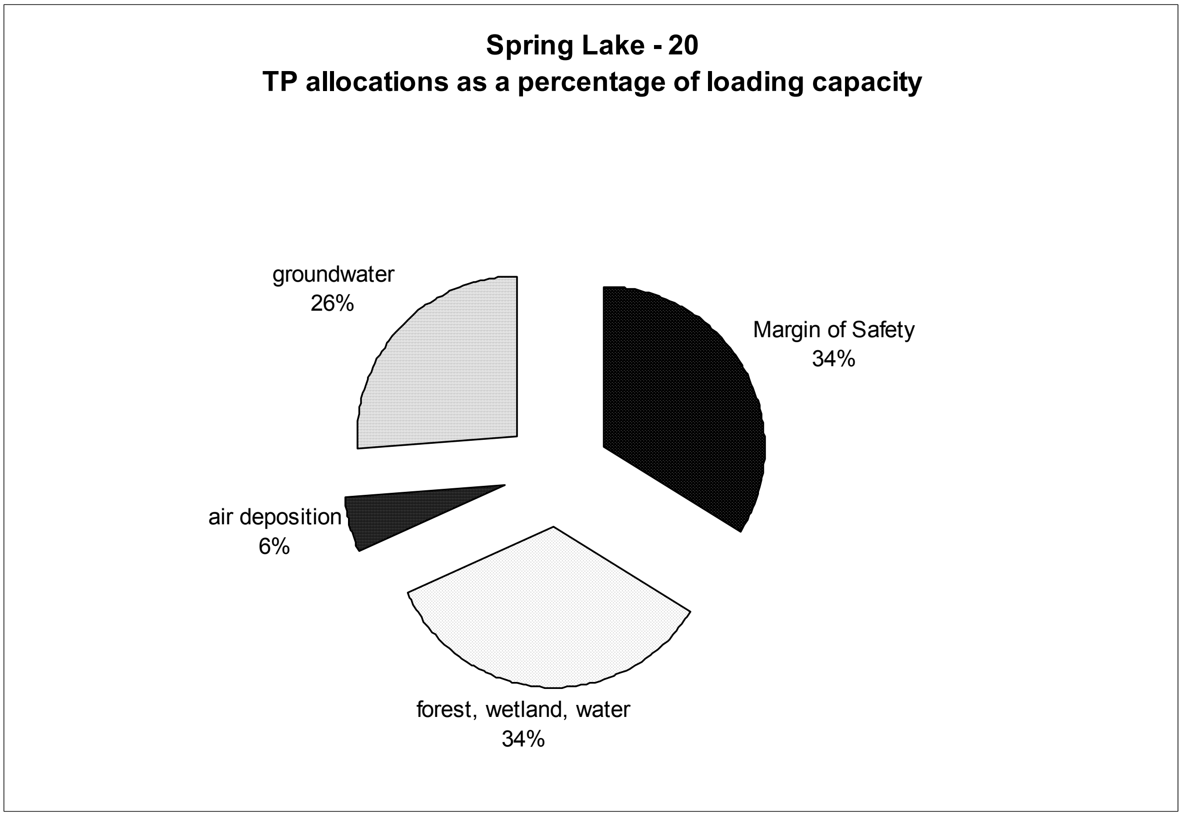


Figure 40 Phosphorus allocations for Spring Lake TMDL



9.0 Follow-up Monitoring

In order to track effectiveness of remediation measures (including TMDLs) and to develop baseline and trend information on lakes, the Department will augment its ambient monitoring program to include lakes on a rotating schedule. The details of a new Lakes Monitoring Network will be published by December 31, 2003. Lakes for which remediation measures have been performed will be given top priority on whatever rotating schedule is developed.

Follow-up monitoring will include evaluations (qualitative using a field index or quantitative) of algal blooms (presence, severity, extent) and aquatic vegetation (density, extent, diversity). Measurements such as secchi depths, nutrient concentrations, and chlorophyll-*a* will be included, in addition to dissolved oxygen, temperature and pH profiles. Basic hydrologic and morphometric information will be measured as necessary to obtain current data, including discharge and bathymetry. The details as to what data will be collected by the Lakes Monitoring Network will be included in the network description.

10.0 Implementation

The next steps toward implementation are preparation of lake characterizations and lake restoration plans, where they have not already been developed. In the development of these plans, the loads by source will be revised, as necessary, to reflect refinements in source contributions. It will be on the basis of refined source estimates that specific strategies for reduction will be developed. These will consider issues such as cost and feasibility when specifying the reduction target for any source or source type. As appropriate, WLAs or other measures to be applied to traditional or stormwater point sources through NJPDES permits will be adopted by the Department as amendments to the applicable areawide Water Quality Management Plan.

The Department recognizes that TMDLs alone are not sufficient to restore eutrophic lakes. The TMDL establishes the required nutrient reduction targets and provides the regulatory framework to effect those reductions. However, the nutrient load only affects the eutrophication potential of a lake. The implementation plan therefore calls for the collection of additional monitoring data and the development of a Lake Restoration Plan for each lake. The plans will consider in-lake measures that need to be taken to supplement the nutrient reduction measures required by the TMDL. In addition, the plans will consider the ecology of the lake and adjust the eutrophication indicator target as necessary to protect the designated uses.

For instance, all of these lakes are shallow lakes, as defined by having a mean depth less than 3 meters. For a lake to be shallow means that most of the lake volume is within the photic zone and therefore more able to support aquatic plant growth (Holdren *et al*, 2001). Shallow lakes are generally characterized by either abundant submerged macrophytes and clear water or by abundant phytoplankton and turbid water. From an aquatic life and biodiversity perspective, it is desirable for shallow lakes to be dominated by aquatic plants rather than algae, especially phytoplankton. While lower nutrient concentrations favor the clear/plant state, either state can persist over a wide range of nutrient concentrations. Shallow lakes have ecological stabilizing mechanisms that tend to resist switches from clear/plant state to turbid/algae state, and vice-versa. The clear/plant state is more stable at lower nutrient concentrations and irreversible at very low nutrient concentrations; the turbid/algae state is more stable at higher nutrient concentrations. The Lake Restoration Plans for each lake will need to consider the ecological nuances of shallow and deep lakes.

The State of New Jersey has adopted a watershed approach to water quality management. That plan divides the state into five watershed management regions, one of which is the Lower Delaware Region. The Department recognizes that lake restoration requires a watershed approach. Lake Restoration Plans will be used as a basis to address overfertilization and sedimentation issues in watersheds that drain to these sensitive lakes. In addition, the Department will direct research funds to understand and demonstrate biomanipulation and other techniques that can be applied in New Jersey lakes to promote the establishment of healthy and diverse aquatic plant communities in shallow lakes. Finally, public education efforts will focus on the benefits of aquatic plants in shallow lakes and the balance of aquatic life uses with recreational uses of these lakes. With the combination of New Jersey's strong commitment to the collection and use of high quality data to support environmental decisions and regulatory programs, including TMDLs, the Department is reasonably assured compliance with the total phosphorus criteria applicable to these eutrophic lakes.

10.1 Lake Characterization

Additional monitoring may be performed in order to develop the Lake Restoration Plans to implement these TMDLs. The level of characterization necessary to plan restoration will be specific to individual lakes depending on the remedial options being considered. During at least one or two summer trips, the following information may be collected as necessary.

- for shallow lakes, vegetation mapping using shore to center transects, measuring density and composition (emergents, rooted floaters, submergents, free-floating plants, submerged macro-algae)
- 1-5 mid-lake sampling stations as needed to characterize the lake
    - at least 2 samples per station per day; min 4 samples per trip
    - secchi depths
- chemistry (nutrients, chlorophyll-*a*, etc.)
    - surface, metalimnion, hypolimnion, and bottom if stratified
    - otherwise surface and bottom
- biology (integrated sample from mixed surface layer)
    - algal abundance and composition (greens, diatoms, blue-greens)
    - zooplankton abundance, composition and size ranges
- DO, temperature and pH profiles (hourly throughout day)

Where necessary, flow and water quality measurements of influent and effluent streams will be taken periodically from Spring to Fall, and fish abundance and composition will be assessed in early autumn.

The schedules for lake characterization and development of Lake Restoration Plans to implement these TMDLs are provided in Table 16.

Table 16 Implementation Schedule

Lake	Lake Characterization	Lake Restoration Plan
Burnt Mill Pond[a]	Summer 2008	Spring 2009
Giampietro Lake[a]	Summer 2009	Spring 2010
Mary Elmer Lake	Summer 2004	Spring 2005
Memorial Lake	Summer 2006	Spring 2007
Sunset Lake	Summer 2004	Spring 2005
Alcyon Lake	Summer 2005	Spring 2006
Bell Lake[a]	Summer 2009	Spring 2010
Bethel Lake	Summer 2006	Spring 2007
Blackwood Lake[a]	Summer 2008	Spring 2009
Grenloch Lake	Summer 2005	Spring 2006
Harrisonville Lake[b]	Completed 2002	Completed March 2003
Kirkwood Lake	Summer 2006	Spring 2007
Woodbury Lake	Summer 2007	Spring 2008
Allentown Lake	Summer 2005	Spring 2006
Imlaystown Lake[c]	Summer 2007	Spring 2008
Spring Lake[c]	Summer 2007	Spring 2008

a The Diagnostic / Feasibility studies for these lakes (F.X. Browne; 1993, 1989, 1989, 1992) provide some of the Lake Characterization information necessary to develop the Lake Restoration Plan. This schedule provides for additional biological monitoring and evaluation in order to restore a clear-water condition in the lake.

b The Diagnostic / Feasibility study of Harrisonville Lake (Princeton Hydro, 2003) fulfills the TMDL requirements for lake characterization and lake restoration planning.

c Nutrient reductions are not required for these lakes. However, this schedule provides for additional biological monitoring and evaluation in order to restore a clear-water condition in the lake.

10.2 Reasonable Assurance

Reasonable assurance for the implementation of these TMDLs has been considered for point and nonpoint sources for which phosphorus load reductions are necessary. These TMDLs obligate the Department to routinely monitor lake water quality as well as characterize and develop specific restoration plan for these particular lakes according to the schedule in Table 16. Moreover, stormwater sources for which WLAs have been established will be regulated as NJPDES point sources.

With the implementation of follow-up monitoring and development of Lake Restoration Plans through watershed management process, the Department is reasonably assured that New Jersey's Surface Water Quality Standards will be attained for these lakes. Activities directed in the watersheds to reduce nutrient loadings shall include a whole host of options, included but not limited to education projects that teach best management practices, approval of projects funded by CWA Section 319 Nonpoint Source (NPS) Grants, recommendations for municipal ordinances regarding feeding of wildlife, and pooper-scooper laws, and stormwater control measures.

11.0 Public Participation

The Water Quality Management Planning Rules NJAC 7:15-7.2 require the Department to initiate a public process prior to the development of each TMDL and to allow public input to the Department on policy issues affecting the development of the TMDL. Further, the Department shall propose each TMDL as an amendment to the appropriate areawide water quality management plan in accordance with procedures at N.J.A.C. 7:15-3.4(g). As part of the public participation process for the development and implementation of the TMDLs for phosphorus to address eutrophic lakes in the Lower Delaware Water Region, the Department worked collaboratively with a series of stakeholder groups throughout New Jersey as part of the Department's ongoing watershed management efforts.

The Department's watershed management process includes a comprehensive stakeholder process that includes of members from major stakeholder groups, (agricultural, business and industry, academia, county and municipal officials, commerce and industry, purveyors and dischargers, and environmental groups). As part of this watershed management planning process, Public Advisory Committees (PACs) and Technical Advisory Committees (TACs) were created in all 20 WMAs. The PACs serve in an advisory capacity to the Department, examining and commenting on a myriad of issues in the watersheds. The TACs are focused on scientific, ecological, and engineering issues relevant to the issues of the watershed, including water quality impairments and management responses to address them.

Through a series of presentations and discussions the Department engaged the WMA 17, 18, 19 and 20 PACs and TACs in a process that culminated in the development of 13 phosphorus TMDLs for eutrpohic Lakes in the Lower Delaware Water Region. One or two meetings, as specified below, were held in each WMA. At the PAC meetings, the expedited eutrhopic lake TMDL protocols and the executed Memorandum of Agreement between the Department and EPA Region 2 were described, including the associated schedule for completing TMDLs. The PACs were asked to review the list of lakes and provide local insight. Maps with aerial photography and topography of the lakes were provided to facilitate the conversation. In most cases, a second meeting was held with the TAC and/or a smaller working group to identify areas of concern based on their local knowledge. TAC members were encouraged to provide any additional source information through the formal comment period after advertisement of the TMDL proposal in the New Jersey Register. The dates of the meetings were as follows:

WMA	**PAC Meeting**	**TAC Meeting**
17	December 10, 2002	January 22, 2003
18	December 3, 2002	December 3, 2002
19	November 13, 2002	December 10, 2002
20	November 13, 2002	December 3, 2002

Additional input was received through the NJ EcoComplex (NJEC). The Department contracted with NJEC in July 2001. The NJEC consists of a review panel of New Jersey University professors whose role is to provide comments on the Department's technical approaches for development of TMDLs and management strategies. The New Jersey Statewide Protocol for Developing Fecal TMDLs was presented to NJEC on August 7, 2002 and was subsequently reviewed and approved. The protocol was also presented at the SETAC Fall Workshop on September 13, 2002 and met with approval.

Appendix A: References

Annadotter, H., G. Cronberg, R. Aagren, B. Lundstedt, P.-A. Nilsson and S. Ströbeck, 1999. Multiple techniques for lake restoration. Hydrobiologia 395/396:77-85.

Birch, S. and J. McCaskie, 1999. Shallow urban lakes: a challenge for lake management. Hydrobiologia 395/396:365-377.

Center for Watershed Protection, 2001. *Watershed Protection Techniques: Urban Lake Management*. T.R. Schueler, Ed.in Chief. Ellicott City, MD. www.cwp.org.

Cooke, G.D., P. Lombardo and C. Brant, 2001. Shallow and deep lakes: determining successful maangement options. Lakeline, Spring 2001, 42-46.

Cooke, G.D., E.B. Welch, S.A. Peterson, P.R. Newroth. 1993. Restoration and Management of Lakes and Reservoirs. Lewis Publishers.

Dillon, P.J. and F.H. Rigler, 1974. A test of a simple nutrient budget model predicting the phosphorus concentration in lake water. J. Fish. Res. Board Can. 31:1771-1778.

Donabaum, K., M. Schagerl and M.T. Dokulil, 1999. Integrated management to restore macrophyte domination. Hydrobiologia 395/396:87-97.

Eisenreich, S.J. and J. Reinfelder. 2001. The New Jersey Air Deposition Network: Interim Report. Department Environmental Sciences, Rutgers University.

F. X. Brown Associates, Inc. 1993. Diagnostic/Feasibility Study of Burnt Mill Pond. Prepared for the City of Vineland. Vineland, New Jersey. December 1993.

F. X. Brown Associates, Inc. 1992. Diagnostic/Feasibility Study for Blackwood Lake. Gloucester Township, Camden County, New Jersey. FXB Project Number 1217-01.

F. X. Brown Associates, Inc. 1989. Diagnostic-Feasibility Study of Bell Lake. Prepared for the City of Woodbury, New Jersey. June 1989.

F. X. Brown Associates, Inc. 1989. Diagnostic/Feasibility Study of Giampietro Park Lake. Prepared for the City of Vineland. Vineland, New Jersey. May 1989.

Holdren, C., W. Jones, and J. Taggart, 2001. Managing Lakes and Reservoirs. North American Lake Management Society and Terrene Institute, in cooperation with U.S. Environmental Protection Agency. Madison, WI.

Hosper, S.H., 1998. Stable states, buffer and switches: an ecosystem approach to the restoration and management of shallow lakes in The Netherlands. Water Science Technology 37(3):151-164.

Madgwick, F.J., 1999. Strategies for conservation management of lakes. Hydrobiologia 395/396:309-323.

Melzer, A., 1999. Aquatic macrophytes as tools for lake management. Hydrobiologia 395/396:181-190.

Moss, B., J. Madgwick, G. Phillips, 1996. A Guide to the restoration of nutrient-enriched shallow lakes. Norfolk Broads Authority, 18 Colegate, Norwich, Norfolk NR133 1BQ, Great Britain.

Moss, B., M. Beklioglu, L. Carvalho, S. Kilinc, S. McGowan and D. Stephen. Vertically-challenged limnology; contrasts between deep and shallow lakes. Hydrobiologia 342/343:257-267.

National Research Council, Assessing the TMDL Approach to water quality management. National Academy Press, Washington, D.C. 2001

New Jersey Department of Environmental Protection. 2001. Status of Use Impairment of Public Lakes. Bureau of Freshwater and Biological Monitoring, Lakes Management Program.

New Jersey Department of Environmental Protection. 2000a. Report on the Establishment of TMDL for Phosphorus in Strawbridge Lake. Amendment to Tri-County WQMP.

New Jersey Department of Environmental Protection. 2000b. Report on the Establishment of TMDL for Phosphorus in Lower Sylvan Lake. Amendment to Tri-County WQMP.

New Jersey Department of Environmental Protection. 1998. Identification and Setting of Priorities for Section 303(d) Water Quality Limited Waters in New Jersey, Office of Environmental Planning.

New Jersey Department of Environmental Protection. 1983. New Jersey Lakes Management Program Lakes Classification Study: Bethel Lake, Mantua, Gloucester County. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

New Jersey Department of Environmental Protection. 1983. New Jersey Lakes Management Program Lakes Classification Study: Imlaystown Lake, Imlaystown, Monmouth County. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

New Jersey Department of Environmental Protection. 1983. New Jersey Lakes Management Program Lakes Classification Study: Kirkwood Lake, Lindenwold, Camden County. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

New Jersey Department of Environmental Protection. 1983. New Jersey Lakes Management Program Lakes Classification Study: Mary Elmer Lake, Hopewell, Cumberland County. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

New Jersey Department of Environmental Protection. 1983. New Jersey Lakes Management Program Lakes Classification Study: Memorial Lake, Woodstown, Salem County. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

New Jersey Department of Environmental Protection. 1983. New Jersey Lakes Management Program Lakes Classification Study: Spring Lake, Hamilton, Mercer County. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

New Jersey Department of Environmental Protection. 1983. New Jersey Lakes Management Program Lakes Classification Study: Sunset Lake, Upper Deerfield, Cumberland County. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

New Jersey Department of Environmental Protection. 1983. New Jersey Lakes Management Program Lakes Classification Study: Woodbury Lake, Woodbury, Gloucester County. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

Ostrofsky, M.L., 1978. Modification of phosphorus retention models for use with lakes with low areal water loading. J. Fish. Res. Bd. Can. 35(12):1532-1536.

Perrow, M.R., A.J.D. Jowitt, J.H. Stansfield, G.L. Phillips, 1999. The practical importance of the interaction between fish, zooplankton and macrophytes in shallow lake restoration. Hydrobiologia 395/396:199-210.

Phillips, G., A. Bramwell, J. Pitt, J. Stansfield and M. Perrow, 1999. Practical application of 25 years' research into the management of shallow lakes. Hydrobiologia 395/395:61-76.

Princeton Hydro, LLC. 2003. Phase I Diagnostic / Feasibility Study of Harrisonville Lake, Gloucester and Salem Counties, New Jersey. Prepared for New Jersey Department of Fish & Game, Bureau of Freshwater Fisheries. Project No. 208.01.

Rast, W., A. Jones and G.F. Lee, 1983. Predictive capability of U.S. OECD phosphorus loading-eutrophication response models. Journal WPCF 55(7):990-1002.

Reckhow, K.H., 1979a. Uncertainty analysis applied to Vollenweider's phosphorus loading criterion. J. Water Pollution Control Federation 51(8):2123-2128.

Reckhow, K.H., 1979b. Quantitative Techniques for the Assessment of Lake Quality. EPA-440/5-79-015.

Reckhow, K.H., 1977. Phosphorus Models for Lake Management. Ph.D. dissertation, Harvard University.

Reckhow, K.H., M.N. Beaulac and J.T. Simpson, 1980. Modeling phosphorus loading and lake response under uncertainty: a manual and compilation of export coefficients. EPA 440/5-80-011.

Remington & Vernick Engineers. 1998. An Application for a New Jersey Department of Environmental Protection Lake Management Program. Phase II – Implementation Projects for the Restoration of Blackwood Lake. February.

Rodiek, R.K., 1979. Some watershed analysis tools for lake management. In Lake Restoration, EPA 400/5-79-001.

Scheffer, M., 1990. Multiplicity of stable states in freshwater systems. Hydrobiologia 200/201:475-486.

Soil Conservation Service. 1959. Soil Survey of Gloucester County, New Jersey. In cooperation with: New Jersey Agricultural Experiment Station and Cook College, Rutgers University.

Sutfin, C.H. May, 2002. Memo: EPA Review of 2002 Section 303(d) Lists and Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992. Office of Wetlands, Oceans and Watersheds, U.S.E.P.A.

U.S.E.P.A., 1999. Protocol for Developing Nutrient TMDLs. Watershed Branch, Assessment and Watershed Protection Division, Washington, DC.

Vollenweider, R.A., and J. Kerekes, 1982. Eutrophication of Waters: Monitoring, Assessment and Control. Organization for Economic Cooperation and Development (OECD), Paris. 156 p.

Wayland, R.H. III. November 22, 2002. Memo: Establishing Total Maximum Daily Load (TMDL) Wasteload Aloocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs. Office of Wetlands, Oceans and Watersheds, U.S.E.P.A.

Appendix B: Database of Phosphorus Export Coefficients

In December 2001, the Department concluded a contract with the USEPA, Region 2, and a contracting entity, TetraTech, Inc., the purpose of which was to identify export coefficients applicable to New Jersey. As part of that contract, a database of literature values was assembled that includes approximately four-thousand values accompanied by site-specific characteristics such as location, soil type, mean annual rainfall, and site percent-impervious. In conjunction with the database, the contractor reported on recommendations for selecting values for use in New Jersey. Analysis of mean annual rainfall data revealed noticeable trends, and, of the categories analyzed, was shown to have the most influence on the reported export coefficients. Incorporating this and other contractor recommendations, the Department took steps to identify appropriate export values for these TMDLs by first filtering the database to include only those studies whose reported mean annual rainfall was between 40 and 51 inches per year. From the remaining studies, total phosphorus values were selected based on best professional judgement for eight land uses categories.

The sources incorporated in the database include a variety of governmental and non-governmental documents. All values used to develop the database and the total phosphorus values in this document are included in the below reference list.

Export Coefficient Database Reference List

Allison, F.E., E.M. Roller, and J.E. Adams, 1959. Soil Fertility Studies in Lysimeters Containing Lakeland Sand. Tech. Bull. 1199, U.S. Dept. of Agriculture, Washington, D.C. p. 1-62.

Apicella, G., 2001. Urban Runoff, Wetlands and Waterfowl Effects on Water Quality in Alley Creek and Little Neck Bay. TMDL Science Issues Conference, WEF Specialty Conference.

Athayde, D. N, P. E. Shelly, E. D. Driscoll, D. Gaboury and G.B. Boyd, 1983. Results of the Nationwide Urban Runoff Program: Final Report. USEPA Water Planning Division. Washington, DC.

Avco Economic Systems Corporation, 1970. Storm Water Pollution from Urban Land Activity. Rep.11034 FKL 07/70, Federal Water Qual. Adm., U.S. Dept. of Interior, Washington, D.C. p. 325.

Bannerman, R., K. Baun, M. Bohm, P. E. Hughes, and D. A. Graczyk, 1984. Evaluation of Urban Nonpoint Source Pollution Management in Milwaukee, County, Eisconsin, Report No. PB84-114164, U.S. Environmental Protection Agency, Region V, Chicago, IL.

Bengtson, R.L. and C.E. Carter, 1989. Simulating Soil Erosion in the Lower Mississippi Valley with the CREAMS Model. From: Application of Water Quality Models for Agricultural and Forested Watersheds, edited by D.B. Beasley and D.L Thomas. Southern Cooperative Series Bulletin No. 338.

Broadbent, F.E., and H.D. Chapman, 1950. A Lysimeter Investigation of Gains, Losses and Balance of Salts and Plant Nutrients in an Irrigated Soil. Soil Sci. Soc. Amer. Proc. 14:261-269.

Carter, Gail P., 1998. Estimation of Nonpoint Source Phosphorus and Nitrogen Loads in Five Watersheds in New Jersey's Atlantic Coastal Drainage Basin. Surveying and Land Information Systems, Vol. 58, no 3. pp167-177.

CH2M Hill, 2000. Technical Memorandum 1, Urban Stormwater Pollution Assessment, prepared for North Carolina Department of Environment and Natural Resources, Division of Water Quality.

Claytor, R.A. and T.R. Schueler, 1996. “Design of Stormwater Filtering Systems,” The Center for Watershed Protection, Prepared for Chesapeake Research Consortium, Inc.

Corsi, S.R., D.J. Graczyk, D.W. Owens, R.T. Bannerman, 1997. Unit-Area Loads of Suspended Sediment, Suspended Solids, and Total Phosphorus From Small Watersheds of Wisconsin. USGS FS-195-97.

Delaware Valley Regional Planning Commission, 1977. Average Pollutant Concentrations Associated with Urban Agriculture and Forest Land Use. Working Paper 5.01-1, Extent of NPS Problems.

Eck, P., 1957. Fertility Erosion Selectiveness on Three Wisconsin Soils. Ph. D. Thesis, Univ. of Wisconsin, Madison, WI.

F.X. Brown, Inc., 1993. Diagnostic-Feasibility Study of Strawbridge Lake. FXB Project Number NJ1246-01.

Frink, C.R., 1991. Estimating Nutrient Exports to Estuaries. Journal of Environmental Quality. 20:717-724.

Horner, R., B. W. Mar, L. E. Reinelt, J. S. Richey, and J. M. Lee, 1986. Design of monitoring programs for determination of ecological change resulting from nonpoint source water pollution in Washington State. University of Washington, Department of Civil Engineering, Seattle, Washington.

Horner, R.R., 1992. Water Quality Criteria/Pollutant Loading Estimation/Treatment Effectiveness Estimation. In R.W. Beck and Associates. Covington Master Drainage Plan. King County Surface Water Management Division., Seattle, WA.

Horner, Richard R., Joseph J. Skupien, Eric H. Livingston, and H. Earl Shaver, 1994. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. Prepared by the Terrene Institute, Washington, DC, in cooperation with the U.S. Environmental Protection Agency. EPA/840/B-92/002.

Johnston, W.R., F. Ittihadieh, R.M. Daum, and A.F. Pillsbury, 1965. Nitrogen and Phosphorus in Tile Drainage Effluent. Soil Sci. Soc. Amer. Proc. 29:287-289.

Knoblauch, H.C., L. Kolodny, and G.D. Brill, 1942. Erosion Losses of Major Plant Nutrients and Organic Matter from Collington Sandy Loam. Soil Sci. 53:369-378.

Loehr, R.C., 1974. Characteristics and comparative magnitude of non-point sources. Journal of WPCF 46(11):1849-1872.

Lopes, T.J., S.G. Dionne, 1998. A Review of Semivolatile and Volatile Organic Compounds in Highway Runoff and Urban Stormwater. U.S. Geological Survey, U.S. Department of Interior.

Marsalek, J., 1978. Pollution Due to Urban Runoff: Unit Loads and Abatement Measure, Pollution from Land Use Activities Reference Group. International Joint Commission, Windsor, Ontario.

McFarland, Anne M.S and L. M. Hauck, 2001. Determining Nutrient Export Coefficients and Source Loading Uncertainty Using In-stream Monitoring Data. Journal of the American Water Resources Association, pp. 223, 37. No. 1, February.

Menzel, R. G., E. D. Rhoades, A. E. Olness, and S. J. Smith, 1978. Variability of Annual Nutrient and Sediment Discharges in Runoff from Oklahoma Cropland and Rangeland. Journal of Environmental Quality, 7:401-406.

Mills, W.B., D.B. Porcella, M.J. Ungs, S.A. Gherini, K.V. Summers, L. Mok, G.L. Rupp, G.L. Bowie, 1985. Water Quality Assessment – A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water – Part I and II. EPA-600/6-85-002A&B.

Minshall, N.E., M.S. Nichols, and S.A. Witzel, 1969. Plant Nutrients in Base Flow of Streams in Southwestern Wisconsin. Water Resources. 5(3):706-713.

Mundy, C., M. Bergman, 1998. Technical Memorandum No. 29, The Pollution Load Screening Model: A tool for the 1995 District Water Management Plan and the 1996 Local Government Water Resource Atlases, Department of Water Resources, St. Johns River Water Management District.

NCDWQ, 1998. Neuse River Basinwide Water Quality Plan, Chapter 5, Section A.

Nelson, M.E., 1989. Predicting Nitrogen Concentrations in Ground Water An Analytical Model. IEP, Inc.

Northeast Florida Water Management District, 1994. St. Marks and Wakulla Rivers Resource Assessment and Greenway Protection Plan. Appendix 4.

Northern Virginia Planning District Commision, 1979. Guidebook for Screening Urban Nonpoint Pollution Management Strategies. Prepared for the Metropolitan Washington Council of Governments.

Novotny, V., H. Olem, 1994. Water Quality: Prevention, Identification, and Management of Diffuse Pollution. Van Nostrand Reinhold, NY

Omernik, J. M., 1976. The influence of land use on stream nutrient levels, US EPA January. EPA-60/3-76-014

Omni Environmental Corporation, 1991. Literature Search on Stormwater Pollutant Loading Rates. Literature cited from DVRPC 1977; Wanielista et al. 1977; Whipple and Hunter 1977; NVPDC 1980; USEPA 1983; Mills et al. 1985; Nelson 1989; Walker et al. 1989.

Omni Environmental Corporation, 1999. Whippany River Watershed Program Stormwater Model Calibration and Verification Report.

Overcash, M. R., F. J. Humenik, and J. R. Miner, 1983. Livestock Waste Management, Vol. II, CRC Press, Inc., Boca Raton, Florida.

Pacific Northwest Environmental Research Laboratory, 1974. Relationships Between Drainage Area Characteristics and Non-Point Source Nutrients in Streams. Prepared for the National Environmental Research Center, August 1974.

Panuska, J.C. and R.A. Lillie, 1995. Phosphorus Loadings from Wisconsin Watersheds: Recommended Phosphorus Export Coefficients for Agricultural and Forested Watersheds. Research Management Findings, Bureau of Research, Wisconsin Department of Natural Resources, Number 38.

Pitt, R.E., 1991. Nonpoint Source Water Pollution Management. Dep. Civil Eng., Univ. Alabama, Birmingham, AL.

Polls, Irwin and Richard Lanyon, 1980. Pollutant Concentrations from Homogeneous Land Uses. Journal of the Environmental Engineering Division.

Prey, J., D. Hart, A. Holy, J. Steuer, J. Thomas, 1996. A Stormwater Demonstration Project in Support of the Lake Superior Binational Program: Summary. Wisconsin Dept. of Natural Resources. (http://www.dnr.state.wi.us/org/water/wm/nps/tpubs/summary/lakesup.htm)

Rast, W. and G.F. Lee, 1978. Summary Analysis of the North American (U.S. Portion) OECD Eutrophication Project: Nutrient Loading -- Lake Response Relationships and Trophic State Indices., EPA-600/3-78-008.

Reckhow, K.H., M.N. Beaulac and J.T. Simpson, 1980. Modeling of Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients. Report No. EPA 440/5-80-011. U.S. EPA, Washington, D.C.

Ryding, S. and W. Rast, 1989. The Control of Eutrophication of Lakes and Reservoirs. Man and the Biosphere Series, United Nations Educational Scientific and Cultural Organization, Paris, France.

Schueler, T.R., 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Prepared for the Metropolitan Washington Council of Governments.

Sonzogni, W.C. and G.F. Lee, 1974. Nutrient Sources for Lake Mendota - 1972. Trans. Wisc. Acad. Sci. Arts Lett. 62:133-164.

Uchrin, C.G. and T.J. Maldanato, 1991. Evaluation of Hydrocarbons in Urban Runoff and in Detention Basins. Water Writes. Water Research Institute, Division of Coastal and Environmental Studies, Rutgers University.

United States Geological Survey, U.S. Department of the Interior, 1998. Comparison of NPDES Program Findings for Selected Cities in the United States, USGS Fact Sheet, January

USEPA, 1987. Guide to Nonpoint Source Pollution Control. U.S. EPA, Criteria and Standards Division, Washington D.C.

USEPA, 1993. Urban Runoff Pollution Prevention and Control Planning (handbook). EPA/625/R-93/004.

USEPA, 2000. Watershed Analysis and Management (WAM) Guide for Tribes. (http://www.epa.gov/owow/watershed/wacademy/wam/)

Uttormark, P.D., J.D. Chapin, and K.M. Green, 1974. Estimating nutrient loadings of lakes from non-point sources. U.S. Environmental Protection Agency, Washington, D.C. 112 p. (WRIL 160609). EPA-660/3-74-020.

Walker, J.F., 1989. Spreadsheet Watershed Modeling for Nonpoint Source Pollution Management in a Wisconsin Basin, Water Resources Bulletin, Vol. 25, no. 1, pp. 139-147.

Wanielista, M.P., Y.A. Yousef, and W.M. McLellon, 1977. Nonpoint Source Effects on Water Quality, Journal Water Pollution Control Federation, Part 3, pp. 441-451.

Washington State Department of Ecology, 2000. Stormwater Management Manual for Western Washington: Volume I Minimum Technical Requirements. Publication No. 99-11.

Weidner, R.B., A.G. Christianson, S.R. Weibel, and G.G. Robeck, 1969. Rural Runoff as a Factor in Stream Pollution. J. Water Pollution. Con. Fed. 36(7):914-924.

Whipple, W. and J.V. Hunter, 1977. Nonpoint Sources and Planning for Water Pollution Control. Journal Water Pollution Control Federation. pp. 15-23.

Whipple, W., et al., 1978. Effect of Storm Frequency on Pollution from Urban Runoff, J. Water Pollution Control Federation. 50:974-980.

Winter, J.G. and H.C. Duthie, 2000. Export Coefficient Modeling to assess phosporus loading in an urban watershed. Journal of American Water Resources Association. Vol. 36 No. 5.

Zanoni, A.E., 1970. Eutrophic Evaluation of a Small Multi-Land Use Watershed. Tech. Completion Rep. OWRR A-014-Wis., Water Resources Center, Univ. of Wisconsin, Madison, WI.

Appendix C: Summary of Reckhow (1979a) model derivation

The following general expression for phosphorus mass balance in lake assumes the removal of phosphorus from a lake occurs through two pathways, the outlet (M_o) and the sediments (ϕ):

$$V \cdot \frac{dP}{dt} = M_i - M_o - \phi \qquad \textbf{Equation 1}$$

where:
V = lake volume (10^3 m^3)
P = lake phosphorus concentration (mg/l)
M_i = annual mass influx of phosphorus (kg/yr)
M_o = annual mass efflux of phosphorus (kg/yr)
ϕ = annual net flux of phosphorus to the sediments (kg/yr).

The sediment removal term is a multidimensional variable (dependent on a number of variables) that has been expressed as a phosphorus retention coefficient, a sedimentation coefficient, or an effective settling velocity. All three have been shown to yield similar results; Reckhow's formulation assumes a constant effective settling velocity, which treats sedimentation as an areal sink.

Assuming the lake is completely mixed such that the outflow concentration is the same as the lake concentration, the phosphorus mass balance can be expressed as:

$$V \cdot \frac{dP}{dt} = M_i - v_s \cdot P \cdot A - P \cdot Q \qquad \textbf{Equation 2}$$

where:
v_s = effective settling velocity (m/yr)
A = area of lake (10^3 m^2)
Q = annual outflow (10^3 m^3/yr).

The steady-state solution of Equation 2 can be expressed as:

$$P = \frac{P_a}{v_s + {}^{z}\!/_{T}} = \frac{P_a}{v_s + Q_a} \qquad \textbf{Equation 3}$$

where:
P_a = areal phosphorus loading rate (g/m^2/yr)
z = mean depth (m)
T = hydraulic detention time (yr)
Q_a = ${}^{Q}\!/_{A}$ = areal water load (m/yr).

Using least squares regression on a database of 47 north temperate lakes, Reckhow fit the effective settling velocity using a function of areal water load: $P = \frac{P_a}{11.6 + 1.2 \cdot Q_a}$. **Equation 4**

Appendix D: Derivation of Margin of Safety from Reckhow *et al* (1980)

As described in Reckhow *et al* (1980), the Reckhow (1979a) model has an associated standard error of 0.128, calculated on log-transformed predictions of phosphorus concentrations. The model error analysis from Reckhow *et al* (1980) defined the following confidence limits:

$$P_L = P - h \cdot \left(10^{(\log P - 0.128)} - P\right)$$

$$P_U = P + h \cdot \left(10^{(\log P + 0.128)} - P\right)$$

$$\rho \geq 1 - \frac{1}{2.25 \cdot h^2}$$

where:

P_L = lower bound phosphorus concentration (mg/l);
P_U = upper bound phosphorus concentration (mg/l);
P = predicted phosphorus concentration (mg/l);
h = prediction error multiple
ρ = the probability that the real phosphorus concentration lies within the lower and upper bound phosphorus concentrations, inclusively.

Assuming an even-tailed probability distribution, the probability (ρ_u) that the real phosphorus concentration is less than or equal to the upper bound phosphorus concentration is:

$$\rho_u = \rho + \frac{1-\rho}{2} = \rho + \frac{1}{2} - \frac{\rho}{2} = \rho \cdot \left(1 - \frac{1}{2}\right) + \frac{1}{2} = \frac{1}{2} \cdot \rho + \frac{1}{2}$$

Substituting for ρ as a function of *h*:

$$\rho_u = \frac{1}{2} \cdot \left(1 - \frac{1}{2.25 \cdot h^2}\right) + \frac{1}{2} = \frac{1}{2} - \frac{1}{4.5 \cdot h^2} + \frac{1}{2} = 1 - \frac{1}{4.5 \cdot h^2}$$

Solving for *h* as a function of the probability that the real phosphorus concentration is less than or equal to the upper bound phosphorus concentration:

$$\frac{1}{4.5 \cdot h^2} = 1 - \rho_u$$

$$h^2 = \frac{1}{4.5(1 - \rho_u)}$$

$$h = \sqrt{\frac{1}{4.5(1 - \rho_u)}}$$

Expressing Margin of Safety (*MoS*$_p$) as a percentage over the predicted phosphorus concentration yields:

$$MoS_p = \frac{P_U}{P} - 1 = \frac{P_U - P}{P}$$

Substituting the equation for P_U:

$$MoS_p = \frac{P + h\cdot\left(10^{(\log P+0.128)} - P\right) - P}{P} = \frac{h\cdot\left(10^{(\log P+0.128)} - P\right)}{P}$$

$$P\cdot MoS_p = h\cdot\left(10^{(\log P+0.128)} - P\right)$$

$$\frac{P\cdot MoS_p}{h} = 10^{(\log P+0.128)} - P$$

$$\frac{P\cdot MoS_p}{h} + P = 10^{(\log P+0.128)}$$

Taking the log of both sides and solving for margin of safety:

$$\log\left(\frac{P\cdot MoS_p}{h} + P\right) = \log P + 0.128$$

$$\log\left(\frac{P\cdot MoS_p}{h} + P\right) - \log P = 0.128$$

$$\log\left(P\left(\frac{MoS_p}{h} + 1\right)\right) - \log P = 0.128$$

$$\log P + \log\left(\frac{MoS_p}{h} + 1\right) - \log P = 0.128$$

$$\log\left(\frac{MoS_p}{h} + 1\right) = 0.128$$

$$\frac{MoS_p}{h} + 1 = 10^{0.128}$$

$$\frac{MoS_p}{h} = 10^{0.128} - 1$$

$$MoS_p = h\left(10^{0.128} - 1\right)$$

Finally, substituting for *h* yields Margin of Safety (*MoS*$_p$) as a percentage over the predicted phosphorus concentration, expressed as a function of the probability (ρ_u) that the real phosphorus concentration is less than or equal to the upper bound phosphorus concentration:

$$MoS_p = \sqrt{1 \big/ \left((1-\rho_u)*4.5\right)} \times \left(10^{0.128} - 1\right)$$

Amendment to the Lower Delaware, Monmouth County and Tri-County Water Quality Management Plans

Total Maximum Daily Loads for Phosphorus to Address 5 Stream Segments in the Lower Delaware Water Region

WMA 17, WMA 18 and WMA 20
(Cohansey River, Big Timber Creek, Oldmans Creek,
and Blacks CreekWatersheds)

Proposed:	July 5, 2005
Established:	August 31, 2005
Approved:	September 30, 2005
Adopted:	

New Jersey Department of Environmental Protection
Division of Watershed Management
P.O. Box 418
Trenton, New Jersey 08625-0418

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1.0 Executive Summary

In accordance with Section 305(b) and 303(d) of the Federal Clean Water Act (CWA), the State of New Jersey, Department of Environmental Protection (Department) developed the *2004 Integrated List of Waterbodies* addressing the overall water quality of the State's waters and, in Sublist 5, identifying the list of impaired waterbodies. On October 4, 2004, the Department adopted the *2004 Integrated List of Waterbodies* as an amendment to the Statewide Water Quality Management Plan, pursuant to the Water Quality Planning Act at N.J.S.A.58:11A-7 and the Statewide Water Quality Management Planning rules at N.J.A.C. 7:15-6.4(a). In the Lower Delaware Water Region, the *2004 Integrated List of Waterbodies* Sublist 5 identifies the waterbodies identified in Table 1 as impaired with respect to phosphorus, as indicated by the presence of phosphorus concentrations in excess of standards. A TMDL is required to be developed for each impairment listed on Sublist 5. A TMDL is developed to identify all the contributors of a pollutant of concern and the load reductions necessary to meet the Surface Water Quality Standards (SWQS) relative to that pollutant. TMDLs are established to address the phosphorus impairment in the waterbodies identified in Table 1.

Table 1 Impaired stream segments identified on the *2004 Integrated List of Waterbodies* to be addressed in this TMDL report.

TMDL Number	WMA	Station Name/Waterbody	Site ID	Sublist	Proposed Action
1	17	Barrett Run at Bridgeton	01413013	5	Establish TMDL
2	17	Cohansey River at Seeley	01412800	5	Establish TMDL
3	18	Big Timber Creek S Br at Blackwood Terrace	01467329	5	Establish TMDL
4	18	Oldmans Creek at Porches Mill	01477510	5	Establish TMDL
5	20	Blacks Creek at Chesterfield - Georgetown Rd	01464527	5	Establish TMDL

This TMDL report includes implementation strategies to achieve SWQS for phosphorus, including an additional measure, which will be included in the municipal stormwater permits for municipalities within the affected watersheds, to adopt a low phosphorus fertilizer ordinance. The TMDLs in this report have been proposed and will be adopted by the Department as amendments to the appropriate area-wide water quality management plans in accordance with N.J.A.C. 7:15-3.4(g). This TMDL report was developed consistent with the United States Environmental Protection Agency's (USEPA's) May 20, 2002 guidance document entitled: "Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992," (Sutfin, 2002) which describes the statutory and regulatory requirements for approvable TMDLs.

2.0 Introduction

In accordance with Section 303(d) of the Federal Clean Water Act (CWA) (33 U.S.C. 1315(B)), the State of New Jersey is required biennially to prepare and submit to the USEPA a report that identifies waters that do not meet or are not expected to meet SWQS after implementation of technology-based effluent limitations or other required controls. This report is commonly referred to as the 303(d) List. In accordance with Section 305(b) of the CWA, the State of New Jersey is also required biennially to prepare and submit to the USEPA a report addressing the overall water quality of the State's waters. This report is commonly referred to as the 305(b) Report or the Water Quality Inventory Report. The *Integrated List of Waterbodies* combines these two assessments and assigns waterbodies to one of five sublists. Sublists 1 through 4 include waterbodies that are generally unimpaired (Sublist 1 and 2), have limited assessment or data availability (Sublist 3), are impaired due to pollution rather than pollutants or have had a TMDL or other enforceable management measure approved by EPA (Sublist 4). Sublist 5 constitutes the traditional 303(d) list for waters impaired or threatened by one or more pollutants, for which a TMDL may be required.

A TMDL represents the assimilative or carrying capacity of a waterbody, taking into consideration point and nonpoint sources of pollutants of concern, natural background and surface water withdrawals. A TMDL quantifies the amount of a pollutant a water body can assimilate without violating a state's water quality standards and allocates that loading capacity to known point and nonpoint sources in the form of Waste Load Allocations (WLAs) for point sources, Load Allocations (LAs) for nonpoint sources, and a margin of safety (MOS).

This report establishes 5 TMDLs that address phosphorus impairment in 87.0 river miles with respect to the waterbodies identified in Table 2. These TMDLs include management approaches to reduce loadings of phosphorus from various sources in order to attain applicable surface water quality standards for phosphorus. With respect to the phosphorus impairment, the waterbodies will be moved to Sublist 4 following approval of the TMDLs by EPA. Blacks Creek at Chesterfield (Site ID # 01464527, AN0132), Barrett Run in Bridgeton (Site ID # 01413013, AN0714) and the Cohansey River (Site ID # 01412800, AN0712) stream segments also appears on Sublist 5 as being impaired for benthic macroinvertabrates and the Cohansey River at Seeley stream segment (Site ID# 01412800) also appears on Sublist 5 as being impaired for both lead and pH. These impairments will be addressed in future TMDL documents.

Recent EPA guidance (Sutfin, 2002) describes the statutory and regulatory requirements for approvable TMDLs, as well as additional information generally needed for EPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations. The Department believes that the TMDLs in this report address the following items in the May 20, 2002 guideline document:

1. Identification of waterbody(ies), pollutant of concern, pollutant sources and priority ranking.
2. Description of applicable water quality standards and numeric water quality target(s).
3. Loading capacity – linking water quality and pollutant sources.

4. Load allocations.
5. Waste load allocations.
6. Margin of safety.
7. Seasonal variation.
8. Reasonable assurances.
9. Monitoring plan to track TMDL effectiveness.
10. Implementation (USEPA is not required to and does not approve TMDL implementation plans).
11. Public Participation.

3.0 Pollutant of Concern and Area of Interest

Pollutant of Concern

The pollutant of concern for these TMDLs is phosphorus. For the segments in the Lower Delaware Water Region identified in Table 2, phosphorus concentrations were found to exceed New Jersey's SWQS, found at N.J.A.C. 7-9B. These waterbodies were given a "medium" priority ranking in the 2004 Integrated Water Quality Monitoring and Assessment Report.

Table 2 Waterbodies listed for phosphorus impairment in the Lower Delaware Water Region for which TMDLs are being Established

TMDL Number	WMA	Station Name/Waterbody	Site ID	County(s)	River Miles
1	17	Barrett Run at Bridgeton	01413013	Cumberland	8.5
2	17	Cohansey River at Seeley	01412800	Cumberland, Salem	31.9
3	18	Big Timber Creek S Br at Blackwood Terrace	01467329	Gloucester, Camden	9.4
4	18	Oldmans Creek at Porches Mill	01477510	Gloucester, Salem	16.4
5	20	Blacks Creek at Chesterfield	01464527	Burlington, Monmouth	20.8
Total River Miles:					**87.0**

Applicable Water Quality Standards

As stated in N.J.A.C. 7:9B-1.14(c) of the SWQS for Fresh Water 2 (FW2) waters, the standards for phosphorus are as follows:

Phosphorus, Total (mg/l):

i. Lakes: Phosphorus as total P shall not exceed 0.05 in any lake, pond, reservoir, or in a tributary at the point where it enters such bodies of water, except where site-specific criteria are developed pursuant to N.J.A.C. 7:9B-1.5(g)3.

> ii. Streams: Except as necessary to satisfy the more stringent criteria in paragraph i. above or where site-specific criteria are developed pursuant to N.J.A.C. 7:9B1.5(g)3, phosphorus as total P shall not exceed 0.1 in any stream, unless it can be demonstrated that total P is not a limiting nutrient and will not otherwise render the waters unsuitable for the designated uses.

Also as stated in N.J.A.C. 7:9B-1.5(g)2:

> Nutrient policies are as follows:
>
> Except as due to natural conditions, nutrients shall not be allowed in concentrations that cause objectionable algal densities, nuisance aquatic vegetation, abnormal diurnal fluctuations in dissolved oxygen or pH, changes to the composition of aquatic ecosystems, or otherwise render the waters unsuitable for the designated uses.

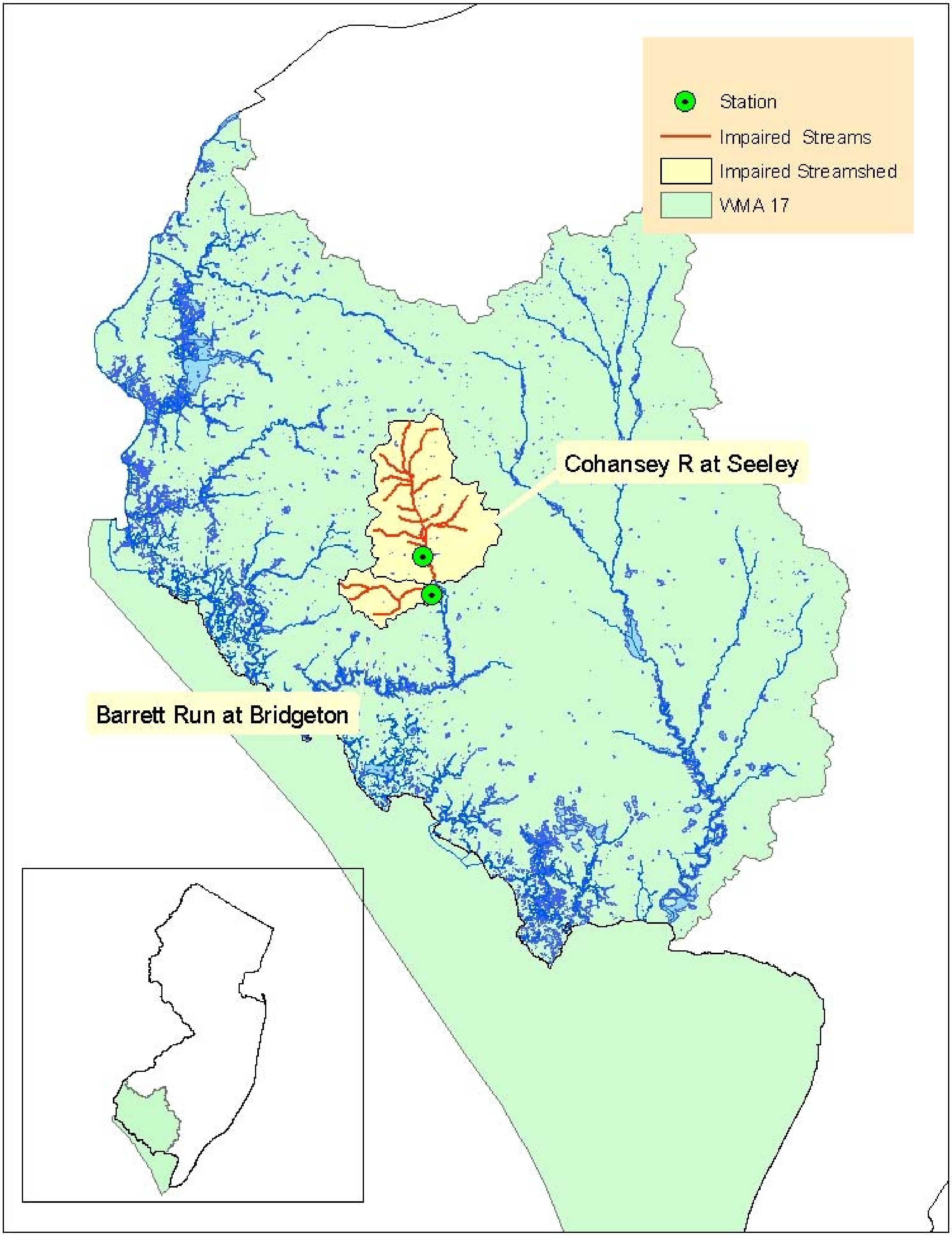
In all FW2 waters, the designated uses are (NJAC 7:9B-1.12):

> 1. Maintenance, migration and propagation of the natural and established aquatic biota;
> 2. Primary and secondary contact recreation;
> 3 Industrial and agricultural water supply;
> 4. Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation and sedimentation, resulting in substantial particulate removal but no consistent removal of chemical constituents) and disinfection; and
> 5. Any other reasonable uses.

Area of Interest

These TMDLs address 87.0 impaired river miles within the Lower Delaware Water Region. Based on the detailed county hydrography stream coverage, 128.3 overall stream miles are affected by the TMDLs due to the fact that the implementation plans cover entire watersheds, not just impaired waterbody segments. The spatial extent of the impaired segments and the affected drainage areas are depicted in Figures 1-7.

Figure 1 Spatial extent of impaired segments and affected drainage area: WMA 17



WMA 17:

Watershed Management Area 17 includes the Cohansey River, Maurice River, Salem River and Alloway, Dividing, Manantico, Manumuskin, Miles, Mill, Stow and Whooping Creeks. This area includes portions of Atlantic, Cumberland, Gloucester, and Salem counties, over 39 municipalities and encompasses 885 square miles.

The Cohansey River, which includes the impaired segments, is nearly 30 miles long, draining 105 square miles of eastern Salem County to the Delaware Bay. This is an area of very low relief, which results in numerous small tributaries. Sunset Lake and Mary Elmer Lake are among 20 major impoundments in this drainage basin. Agriculture and forest are the main land uses of the overall watershed; agriculture is predominant in the impaired watersheds. Land use in the affected drainage area is presented in Table 3 and depicted in Figures 2 and 3.

Table 3 River miles, Watershed size, and Area by Anderson Land Use Classification

	Barrett Run at Bridgeton Site ID 01413013	**Cohansey River at Seeley Site ID 01412800**
River miles and drainage area		
Sublist 5 impaired river miles	8.5	31.9
Total river miles within watershed and included in the implementation plan	15.8	61.8
Watershed size (acres)	4945	23941
Landuse/Landcover (acres)		
Agriculture	3663.9	16626.2
medium / high density residential	261.7	164.5
low density / rural residential	442.2	1602.8
commercial	60.7	128.8
industrial	1.5	64.2
mixed urban / other urban	99.1	516.5
barren	10.8	70.8
forest	233.2	2948.5
wetlands	149.3	1707.8
water	22.4	110.9
Total	**4945**	**23941**

Figure 2 Land Use of Barrett Run at Bridgeton (Site ID# 01413013)

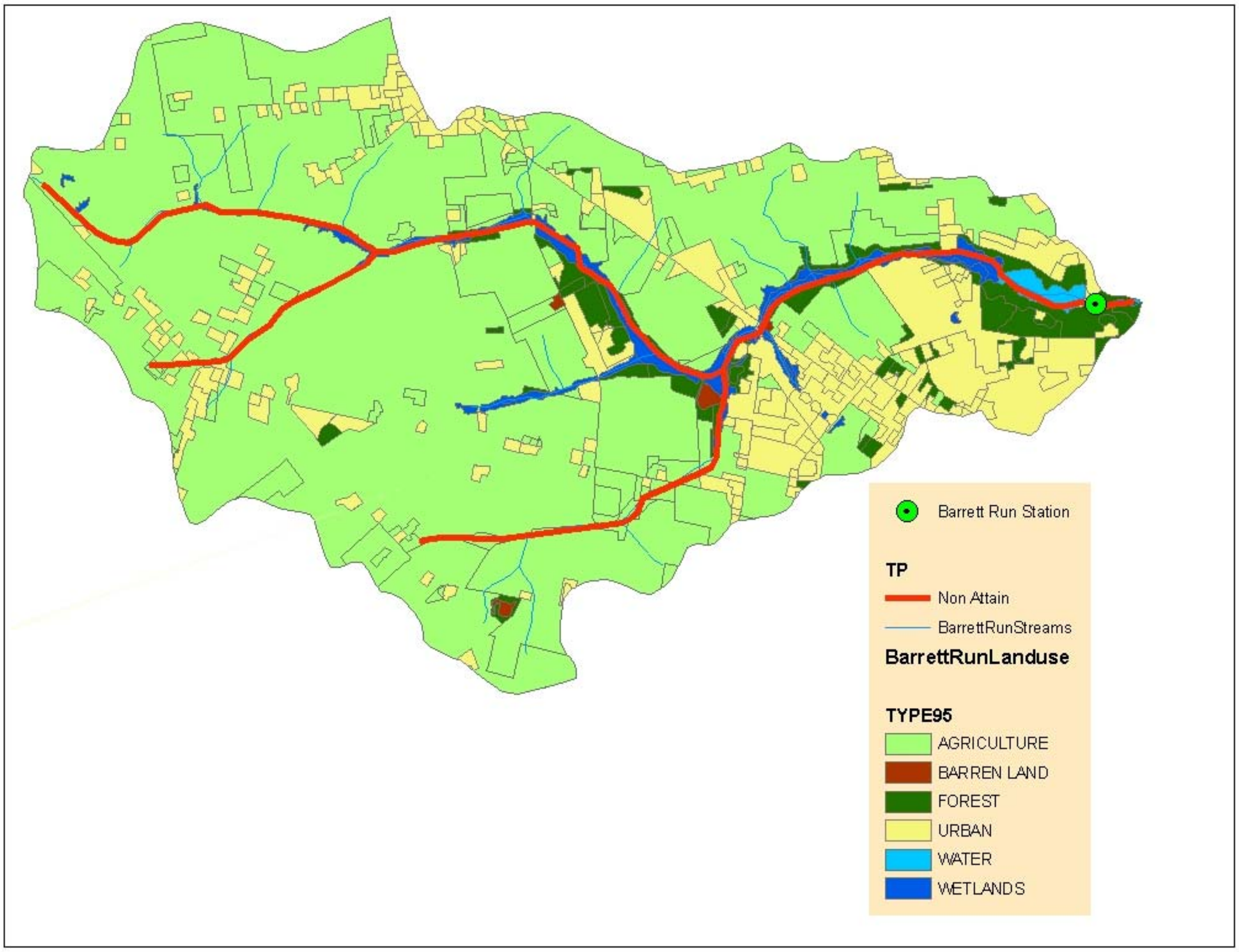

Barrett Run Station
TP
Non Attain
BarrettRunStreams
BarrettRunLanduse
TYPE95
AGRICULTURE
BARREN LAND
FOREST
URBAN
WATER
WETLANDS

Figure 3 Land Use of Cohansey River at Seeley (Site ID 01412800)

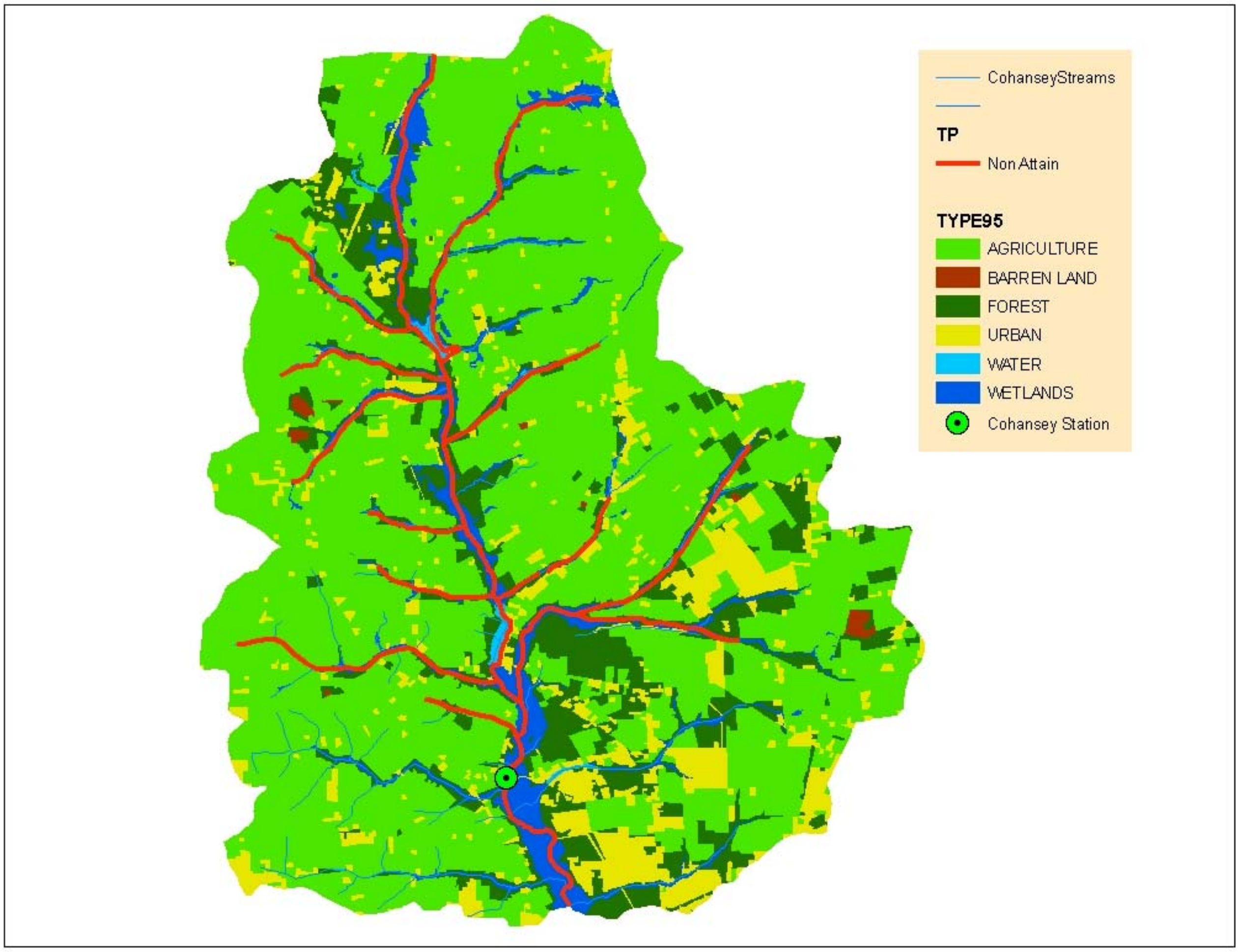
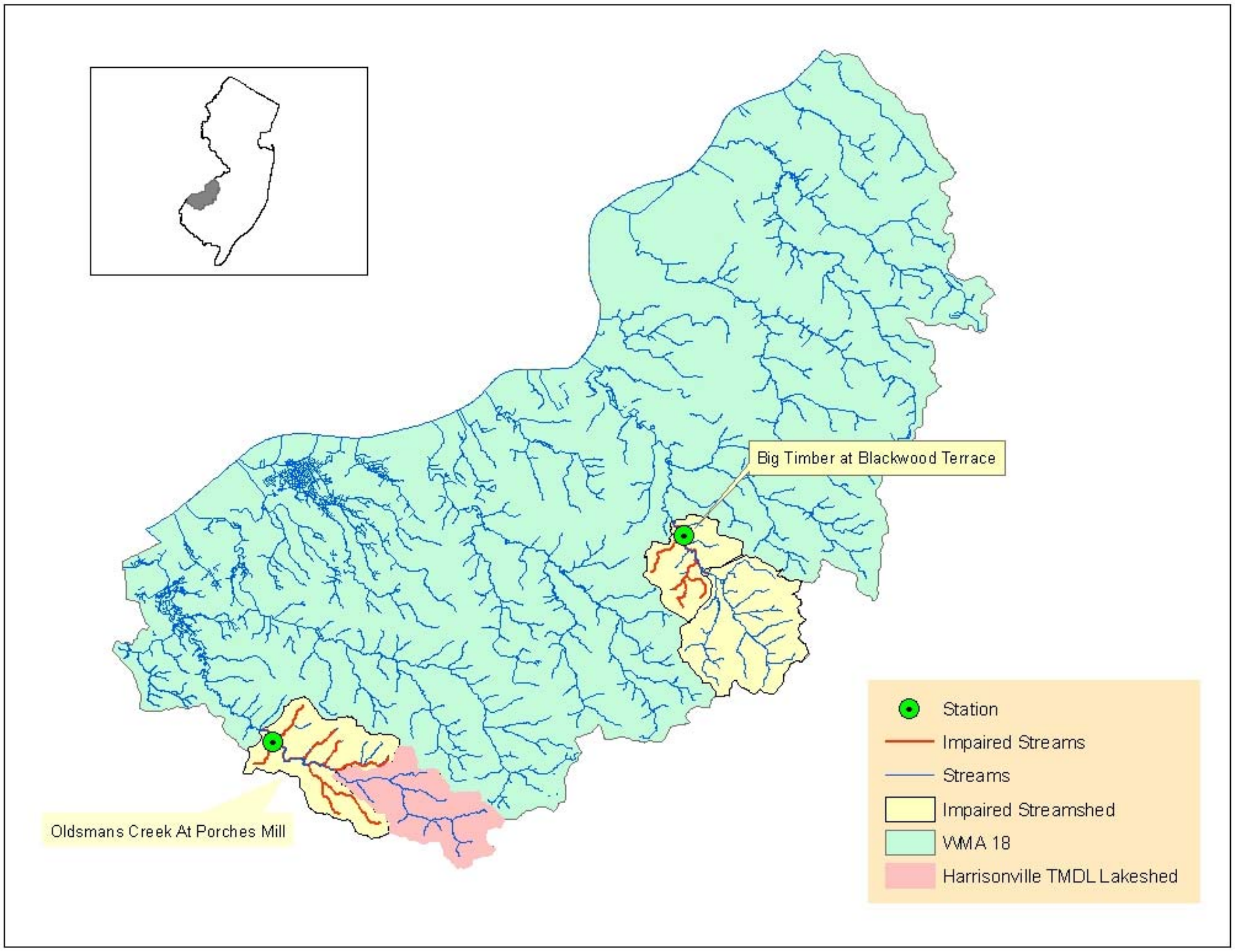


Figure 4 Spatial extent of impaired segments and affected drainage areas: WMA 18



WMA 18:

Watershed Management Area 18 includes Cooper River, Big Timber, Mantua, Newton, Oldmans, Pennsauken, Pompeston, Raccoon, Repaupo, and Woodbury Creeks, as well as Baldwin Run, Swede Run and Maple Swamp. This management area covers all or parts of Burlington, Camden and Gloucester counties, including 68 municipalities encompassing 391 square miles.

Big Timber Creek drains an area of 63 miles. The mainstem and most of the south branch divide Gloucester and Camden Counties before flowing into the Delaware River near Brooklawn, south of Camden. Major tributaries include Otter Creek, Beaver Brook, and Almonesson Creek. Major impoundments are Blackwood Lake, Grenloch Lake, Hirsch Pond, and Nash's Lake. This watershed is primarily urban/suburban with forests at the headwaters and cities at the mouth of Big Timber Creek.

Oldmans Creek drains an area of 44 square miles and flows on the Coastal Plain to the Delaware River. This Creek, 20 miles long, marks the boundary between Gloucester and Salem Counties. Tidal marshes exist at the mouth of this creek, while the western third of the creek is tidal. Major tributaries include Kettle Run and Beaver Creek. For the most part the watershed is agricultural and forested, with some residential and industrial development.

Land use in the affected drainage areas are presented in Table 4 and depicted in Figures 5 and 6.

Table 4 River miles, Watershed size, and Area by Anderson Land Use Classification

	Big Timber Creek Site ID 01467329	Oldmans Creek Site ID 01477510
River miles and drainage area		
Sublist 5 impaired river miles	9.4	16.3
Total river miles within watershed and included in the implementation plan	12.7	20.5
Watershed size (acres)	13451	7471
Landuse/Landcover (acres)		
agriculture	885.8	4343.58
medium / high density residential	3695.5	15.2
low density / rural residential	1224.4	894.3
commercial	778.9	18.4
industrial	161.7	9.3
mixed urban / other urban	1264.9	171.2
barren	751.0	83.23
forest	3255.9	1168.75
wetlands	1229.1	737.93
water	203.9	28.70
Total	**13451**	**7471**

Figure 5 Land Use of Big Timber Creek at Blackwood Terrace (Site ID# 01467329)

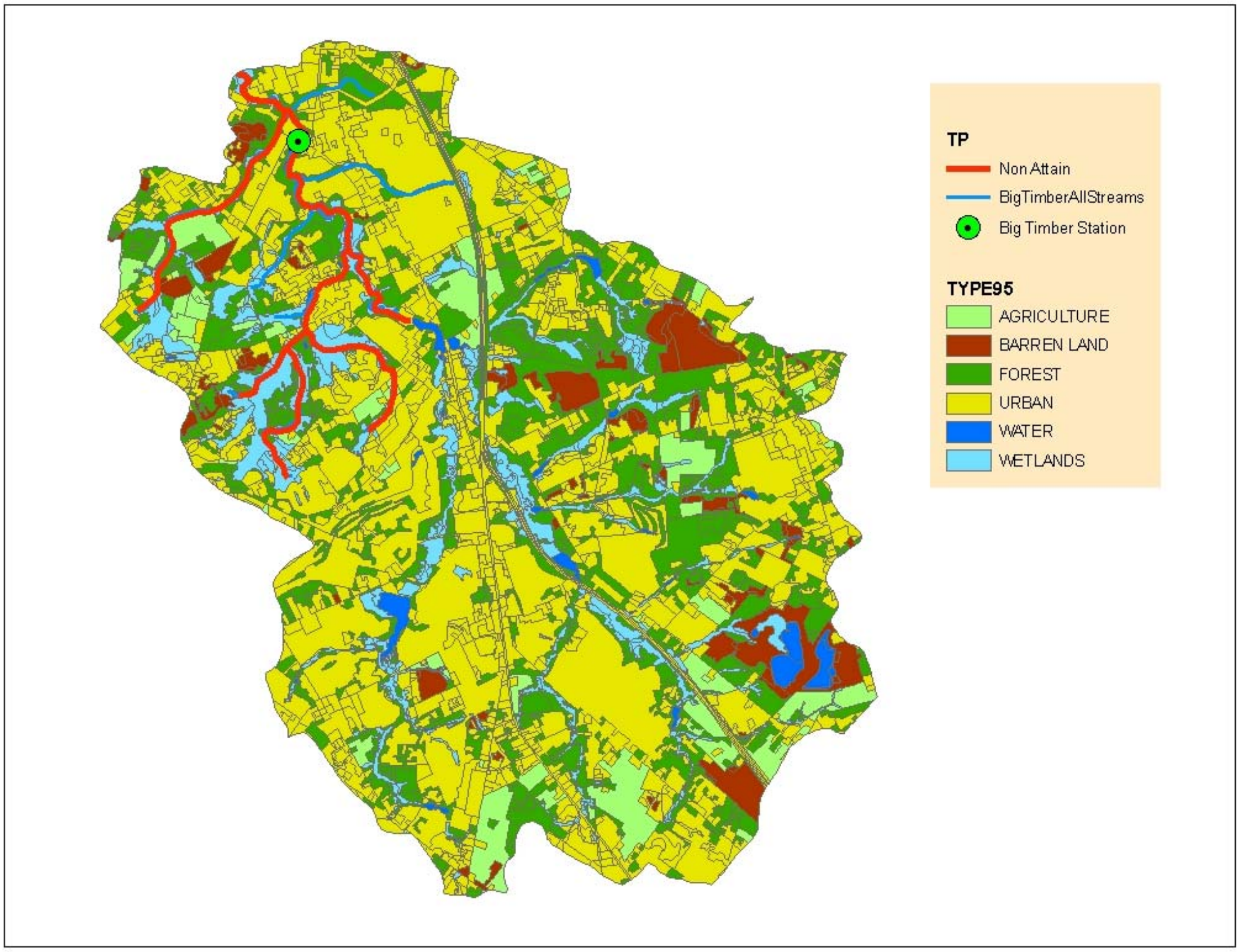


Figure 6 Land Use of Oldmans Creek at Porches Mill (Site ID # 01477510)

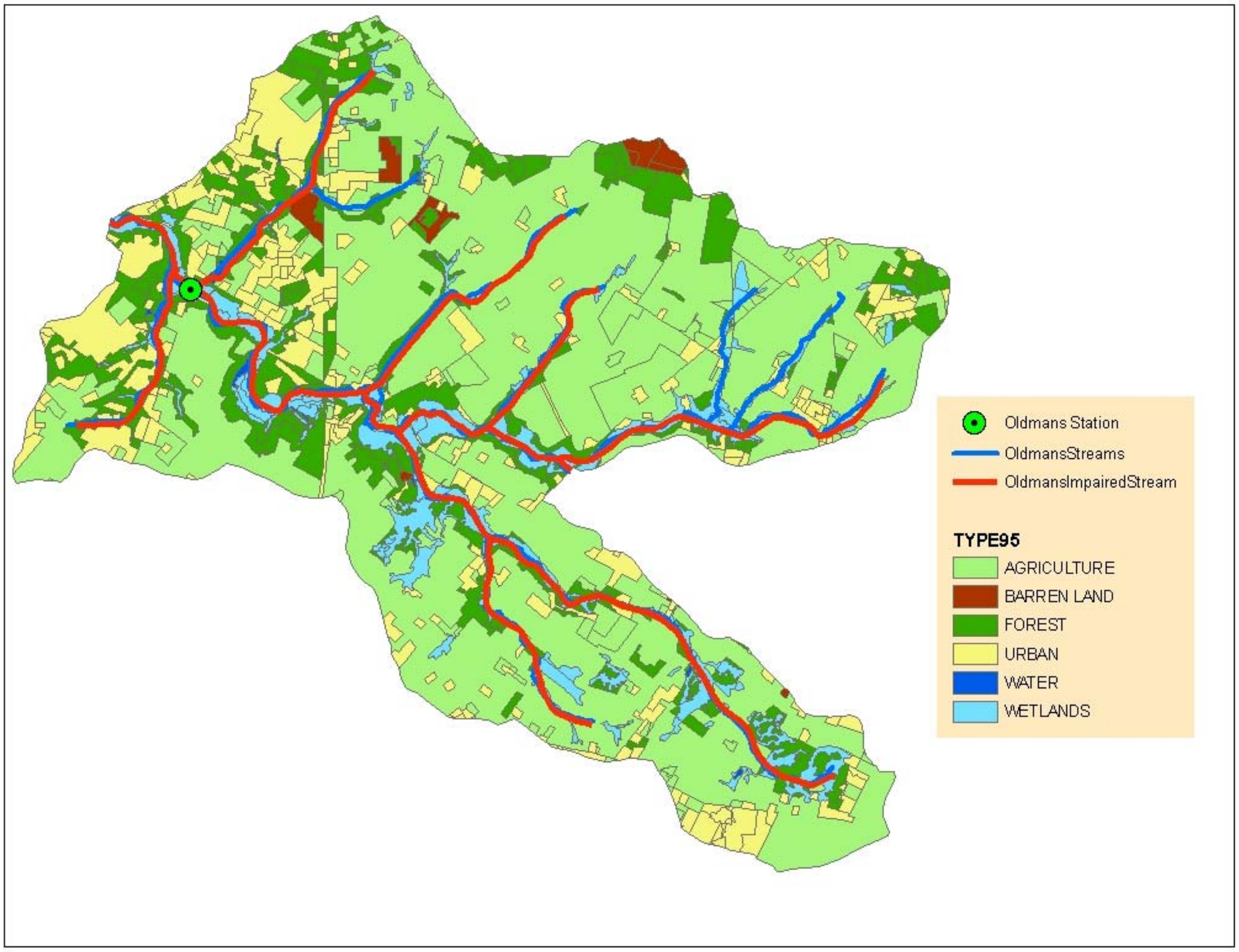
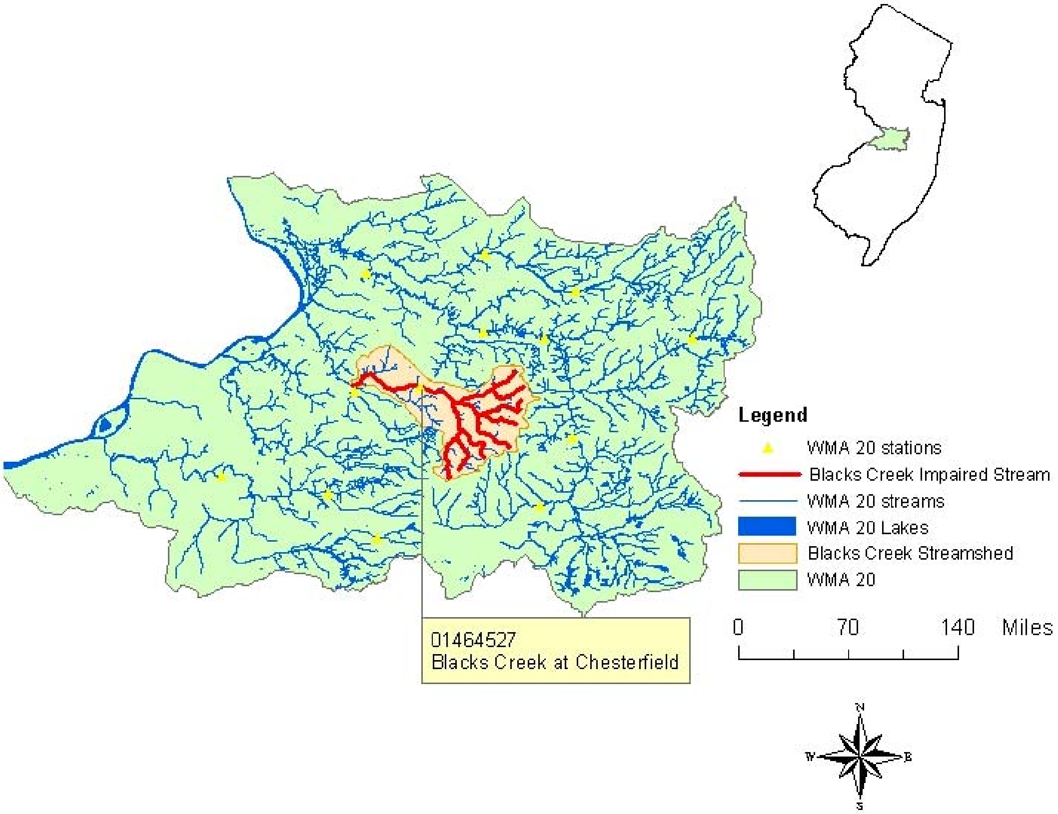


Figure 7 Spatial extent of impaired segment and affected drainage area: WMA 20



WMA 20:

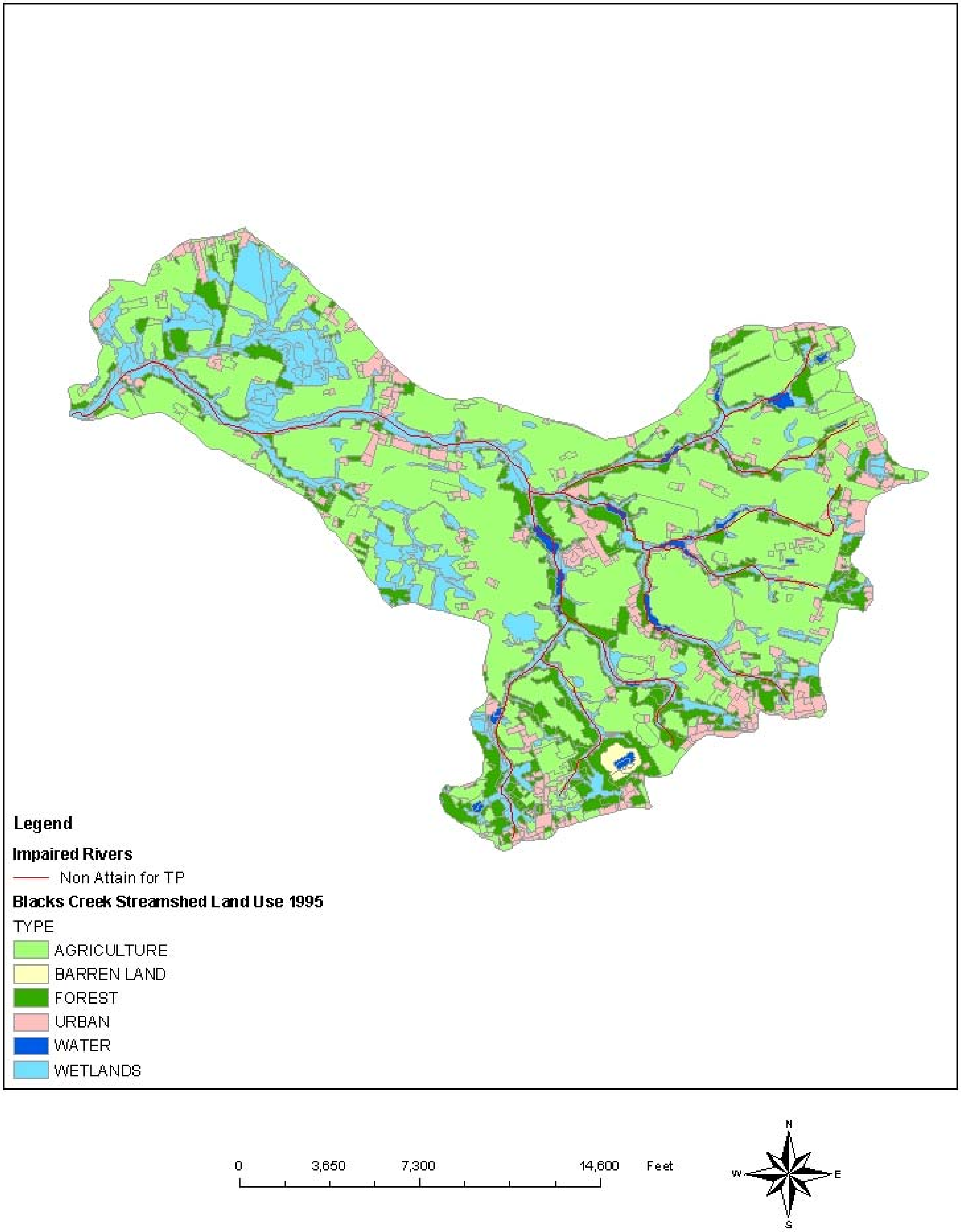
Watershed Management Area 20 includes the Assiscunk, Blacks, Crafts, Crosswicks, Doctors, Duck and Mill Creeks. This management area includes 26 municipalities spanning four counties: Burlington, Mercer, Monmouth and Ocean encompassing 253 square miles.

Crosswicks Creek is 25 miles long and drains an area of 146 square miles to the Delaware River at Bordentown. Major tributaries include Jumping Brook, Lahaway Creek, North Run and Doctors Creek. Tides affect this stream up to the Crosswicks Mill Dam. Allentown Lake, Oxford Lake, Prospertown Lake and Imlaystown Lake are major impoundments in the Crosswicks Creek Watershed. Important land uses in this watershed include agriculture, forest, residential/commercial and military installations. Land use in the affected drainage area is presented in Table 5 and depicted in Figure 8

Table 5 River miles, Watershed size, and Area by Anderson Land Use Classification WMA 20

	Blacks Creek at Chesterfield Site ID 01464527
River miles and drainage area	
Sublist 5 impaired river miles	20.8
Total river miles within watershed and included in the implementation plan	38.2
Watershed size (acres)	8645
Landuse/Landcover (acres)	
agriculture	4976
medium / high density residential	12.2
low density / rural residential	590.5
commercial	17.3
industrial	6.0
mixed urban / other urban	88.1
barren	30.5
forest	1199.5
wetlands	1621.0
water	103.6
Total	**8645**

Figure 8 Blacks Creek Land Use



The Department's Geographic Information System (GIS) was used to describe characteristics of the affected drainage area. The following is general information regarding the data used:

- Land use/Land cover was taken from: "NJDEP 1995/97 Land use/Land cover Update for New Jersey (by WMA)", published 12/01/2000 by the NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), and delineated by watershed management area.

- "NJDEP 2004 Integrated Report Results for Non-Tidal Rivers", published 6/2004 by NJDEP, Watershed Assessment Group (WAT). Online at: http://www.state.nj.us/dep/gis/digidownload/images/ir2004/ir_river_conventionals2004.gif

- "NJDEP Streams of New Jersey (1:24000)", published 11/01/1998 by NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA). Online at: http://www.state.nj.us/dep/gis/strmshp.html

- "NJDEP 14 Digit Hydrologic Unit Code delineations for New Jersey (DEPHUC14)", published 4/5/2000 by NJDEP, New Jersey Geological Survey (NJGS). Online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/dephuc14.zip

- "NJDEP Total Maximum Daily Loads (TMDL) for Eutrophic Lakes", published 9/29/2003 by NJDEP, Bureau of Environmental Analysis and Restoration (BEAR). Online at http://www.state.nj.us/dep/gis/digidownload/zips/statewide/tmdl_lakes.zip

- "NJDEP TMDL Lakesheds", unpublished created by NJDEP, Bureau of Environmental Analysis and Restoration.

- "NJDEP 11 Digit Hydrologic Unit Code delineations for New Jersey (DEPHUC11)", published 4/5/2000 by NJDEP, New Jersey Geological Survey (NJGS). Online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/dephuc11.zip

- "NJDEP 2004 Integrated Report Stations on Non-Tidal Rivers (Conventionals and Toxics)", published 6/2004 by NJDEP, Water Assessment Team (WAT). Online at:

  http://www.state.nj.us/dep/gis/digidownload/images/ir2004/ir_stations_river2004.gif

- "NJDEP Digital Elevation Grid for New Jersey (10 meter)", published 10/1/2004 by NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information Systems (BGIS). Online at: http://www.nj.gov/dep/gis/wmalattice.html

- "Dams in New Jersey", created 6/2003 by NJDEP, Division of Watershed Management (DWM). Unpublished.

- "NJDEP County Boundaries for the State of New Jersey", published 01/23/2003 by NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), Online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/stco.zip

- "NJDEP Municipality Boundaries for the State of New Jersey", published 01/23/2003 by NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information Systems (BGIS). Online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/stmun.zip

- "NJDEP Head of Tide Points for Watercourses of New Jersey", published 1986 by NJDEP, Office of Environmental Analysis (OEA), Coast Survey Ltd. (CTD). Online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/hot.zip

- New Jersey Environmental Management System (NJEMS)

4.0 Source Assessment

In order to evaluate and characterize phosphorus loadings in the waterbodies of interest in these TMDLs, and thus propose proper management responses, source assessments are critical. Source assessments include identifying the types of sources and their relative contributions to phosphorus loadings, in both time and space variables.

For the purposes of TMDL development, point sources include domestic and industrial wastewater treatment plants that discharge to surface water, as well as stormwater discharges subject to regulation under the National Pollutant Discharge Elimination System (NPDES). This includes facilities with individual or general industrial stormwater permits and Tier A municipalities and state and county facilities regulated under the New Jersey Pollutant Discharge Elimination System (NJPDES) municipal stormwater permitting program. Point sources contributing phosphorus loads within the affected drainage area are limited to stormwater point sources, including the Tier A municipalities listed in Appendix B. Stormwater point sources, like nonpoint sources, derive their pollutant load from runoff from land surfaces and load reduction is accomplished through BMPs. The distinction is that stormwater point sources are regulated under the Clean Water Act.

For the purposes of TMDL development, potential nonpoint sources include stormwater discharges that are not subject to regulation under NPDES, such as Tier B municipalities, which are regulated under the NJPDES municipal stormwater permitting program, and direct stormwater runoff from land surfaces, as well as malfunctioning sewage conveyance systems, failing or inappropriately located septic systems, and direct contributions from wildlife, livestock and pets. Tier B municipalities that are within the impaired stream segments are listed in Appendix B.

The phosphorus loads in the affected watersheds are contributed by stormwater point sources and nonpoint sources. These loads are effectively estimated using loading coefficients for land uses present in the watersheds. Therefore, watershed loads for total phosphorus were estimated using the Unit Areal Load (UAL) methodology, which applies pollutant export coefficients obtained from literature sources to the land use patterns within the watershed, as described in USEPA's Clean Lakes Program guidance manual (Reckhow, 1979b). Land use was determined using the Department's GIS system from the 1995/1997 land use coverage. The Department reviewed phosphorus export coefficients from an extensive database (Appendix A) and selected the land use categories and values shown in Table 6.

Table 6: Phosphorus export coefficients (Unit Areal Loads)

land use / land cover	**LU/LC codes[1]**	**UAL (kg TP/ha/yr)**
Mixed density residential	1100	1.2
medium / high density residential	1110, 1120, 1150	1.6
low density / rural residential	1130, 1140	0.7
Commercial	1200	2.0
Industrial	1300, 1500	1.7
mixed urban / other urban	other urban codes	1.0
Agricultural	2000	1.5
forest, wetland, water	1750, 1850, 2140, 2150, 4000, 5000, 6000, 7430, 8000	0.1
barren land	7000	0.5

Units:

1 hectare (ha) = 2.47 acres
1 kilogram (kg) = 2.2 pounds (lbs)
1 kg/ha/yr = 0.89 lbs/acre/yr

5.0 Water Quality Analysis

The United States Geological Survey (USGS) in collaboration with NJDEP has collected monitoring data on the Cohansey River at Seeley (01412800), Big Timber Creek S Br at Blackwood Terrace (01467329) and Oldmans Creek at Porches Mill (01477510) since 1975. Data for Barrett Run at Bridgeton (01413013) and Blacks Creek at Chesterfield (01464527) has been collected beginning in 2000. An outlier was found in the Big Timber data set and was removed for the TMDL calculation (see Appendix C). Although the monitored stations and

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[1] LU/LC code is an attribute of the land use coverage that provides the Anderson classification code for the land use. The Anderson classification system is a hierarchical system based on four digits. The four digits represent one to four levels of classification, the first digit being the most general and the fourth digit being the most specific description.

monitoring schedule have changed over the years, the historical data were reviewed to understand changes and trends in water quality, the most recent data was chosen for the TMDL calculations as best reflecting the current condition of the waterbodies. Thus, data that was collected before 1990 was excluded from the TMDL calculation. A summary of the data utilized in the TMDL is presented in Table 7, actual data is included in Appendix D

Table 7 Summary of Total Phosphorus sampling data

Water Quality Sample Locations	Site Number	Date Years	# of samples	Average (mg/L)	% exceeding 0.05 mg/L	% exceeding 0.1 mg/L
Barrett Run at Bridgeton	01413013	2000-2002	8	0.07	25 %	25%
Cohansey River at Seeley	01412800	1975-2003	65	0.06	53.8%	13.8%
Big Timber Creek S Br at Blackwood Terrace	01467329	1975-1997	41	0.11	82.5%	26.8%
Oldmans Creek at Porches Mill	01477510	1975-1997	40	0.11		32.5%
Blacks Creek at Chesterfield	01464527	2000-2003	12	0.15		66.7%

Figure 9 Location of monitoring site on Barrett Run at Bridgeton (Site ID # 01413013)

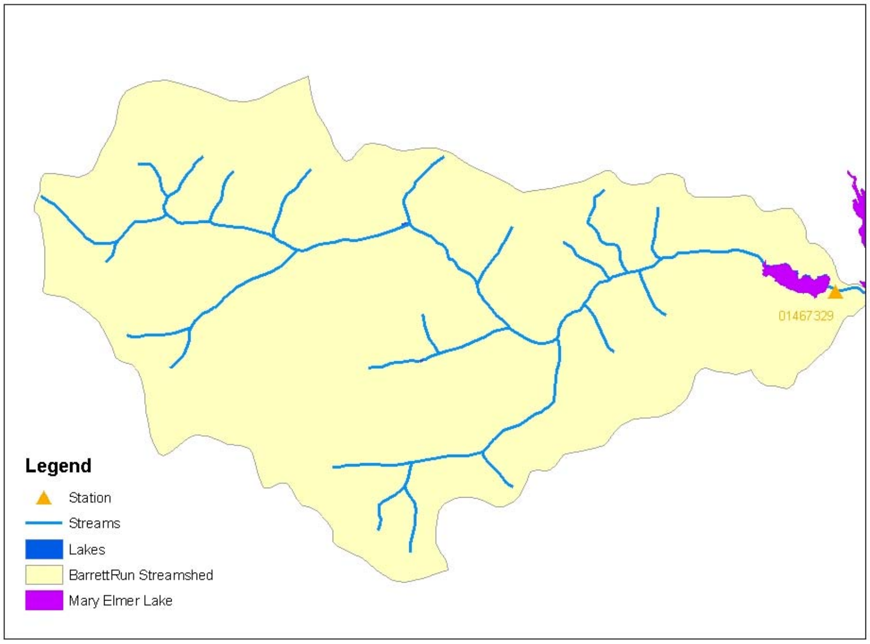


Figure 10 Location of monitoring site on Cohansey River at Seeley (Site ID # 01412800)

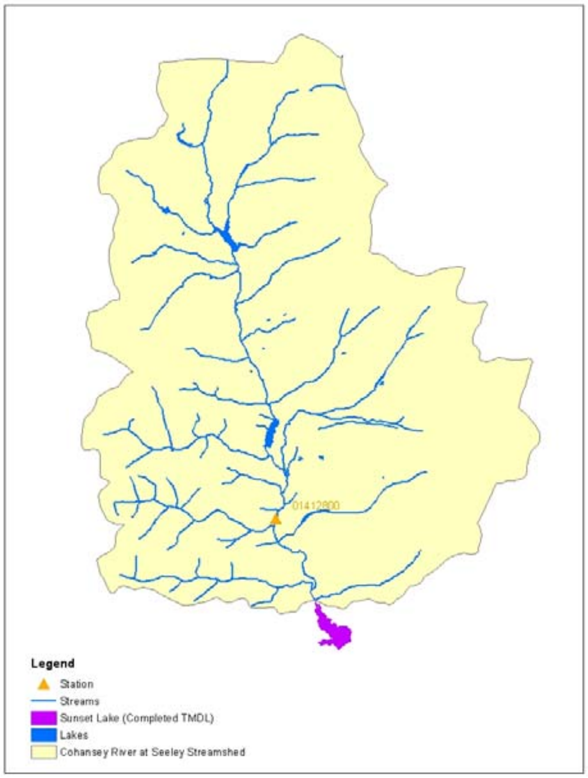


Figure 11 Location of monitoring site on Big Timber Creek SB at Blackwood Terrace (Site ID # 01467329)

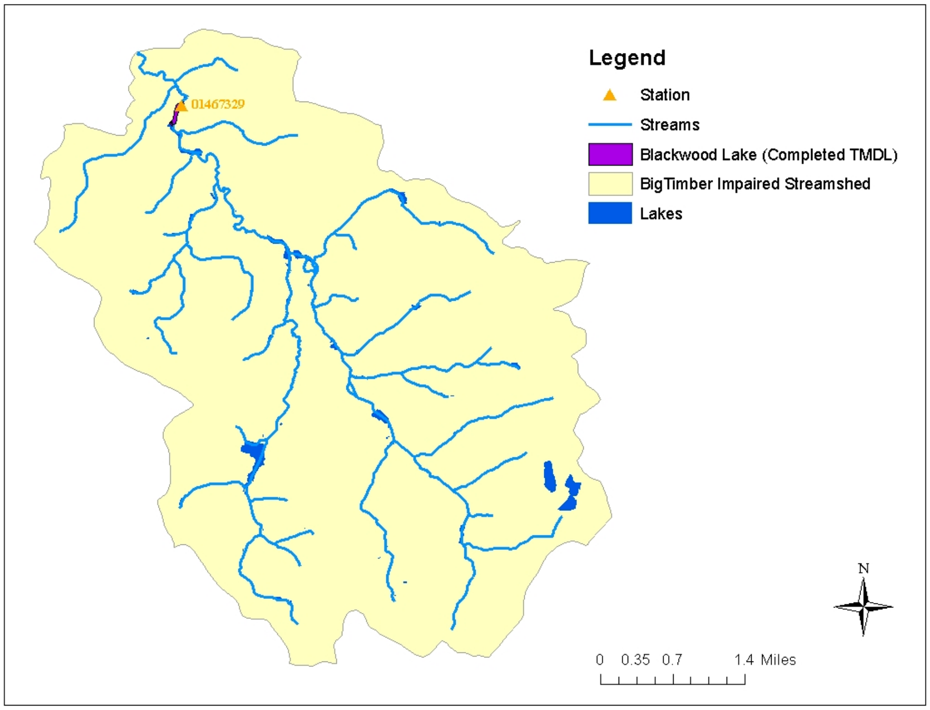


Figure 12 Location of monitoring site on Oldmans Creek at Porches Mill (Site ID # 01477510)

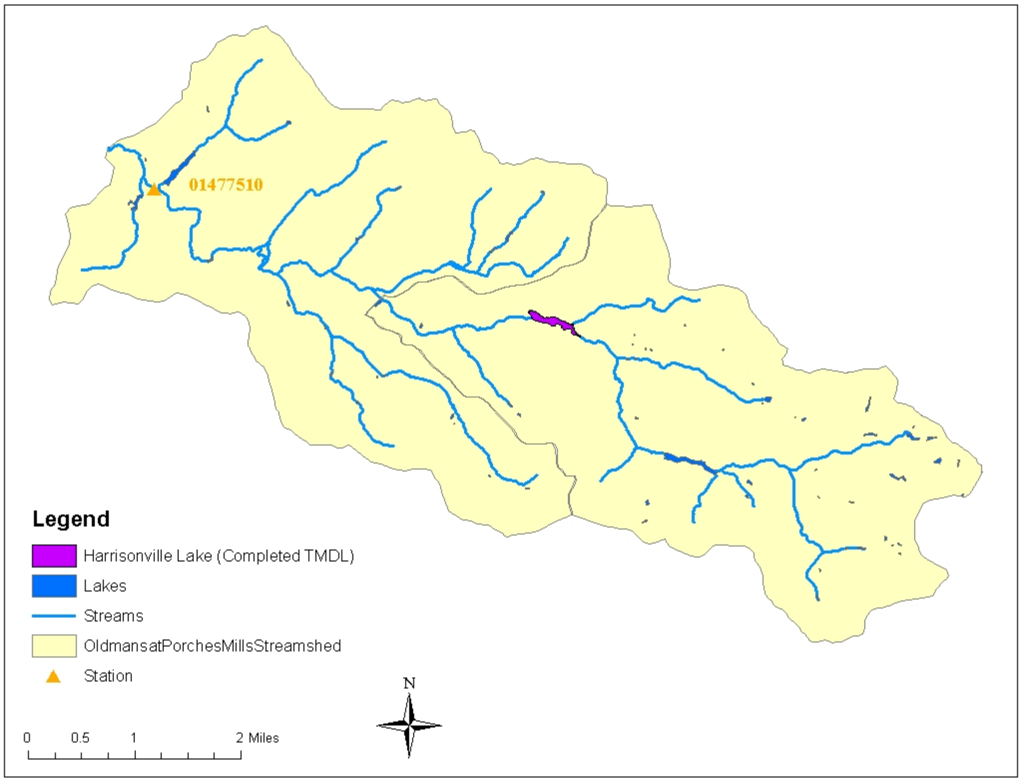
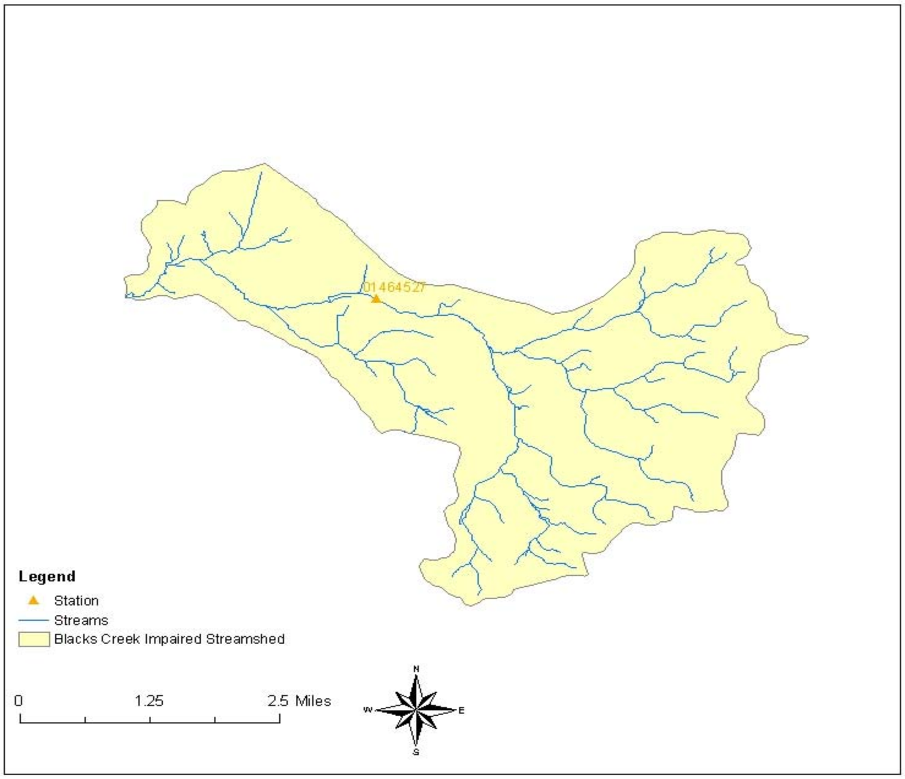
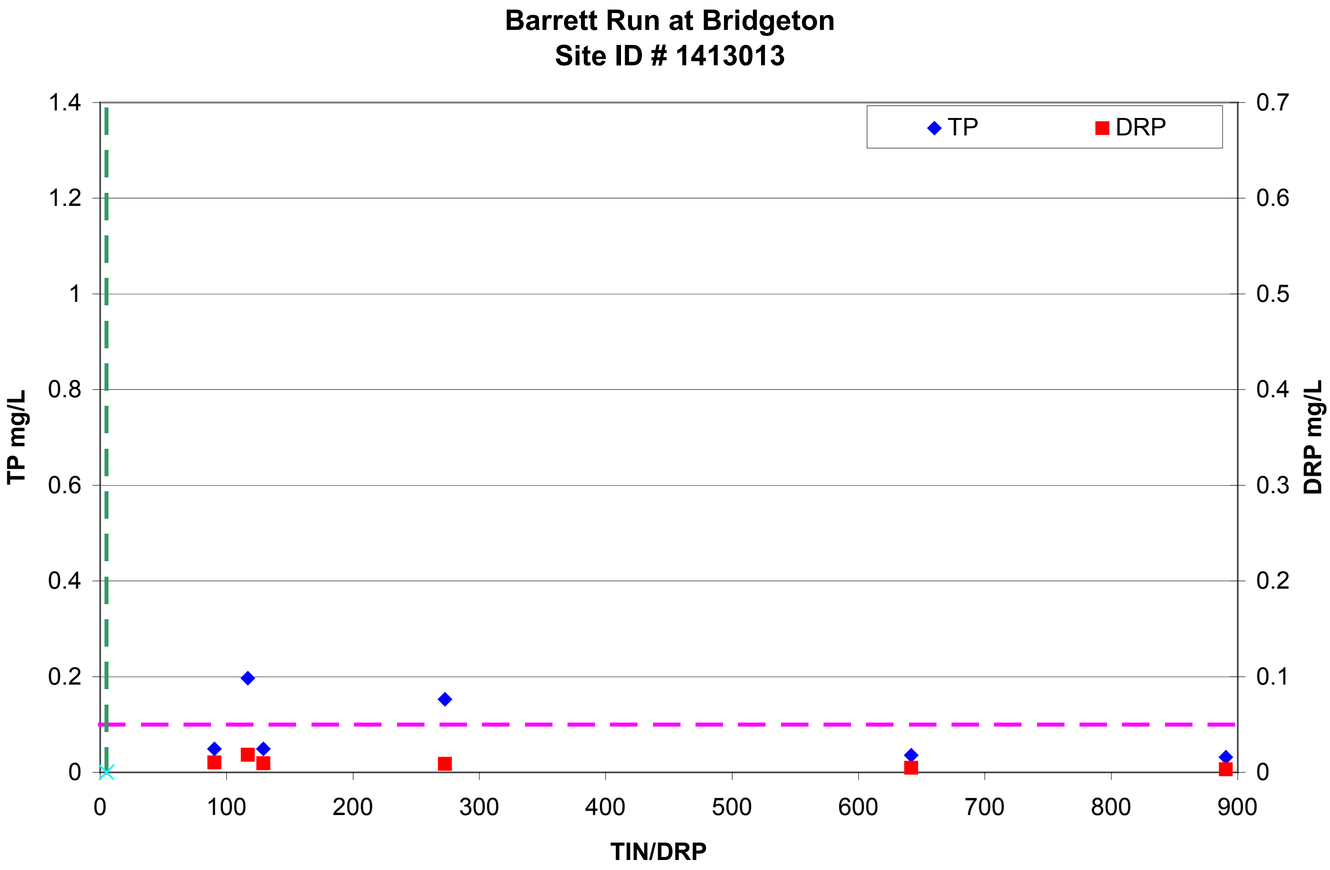


Figure 13 Location of the monitoring site on Blacks Creek (Site ID #01464527)



The Department's March 2003 guidance document, entitled *"Technical Manual for Phosphorus Evaluations (N.J.A.C. 7:9B-1.14(c)) for NJPDES Discharge to Surface Water Permits"*, recommends considering ratios of nitrogen and phosphorus to suggest whether phosphorus is the limiting nutrient. When the ratio of total inorganic nitrogen (TIN) to total orthophosphate (TOP) or dissolved reactive phosphorus (DRP) is smaller than or equal to 5, then phosphorus is not limiting the system. This document may be downloaded from the Department's web page at www.state.nj.us/dep/dwq/techmans/phostcml.pdf. This analysis was performed on all the waterbodies for which this data was available and Figures 14-18 depict the relationship of these two key nutrients at for each of the impaired stream segments. A more detailed explanation of the nitrogen-phosphorus relationship is given in Appendix E.

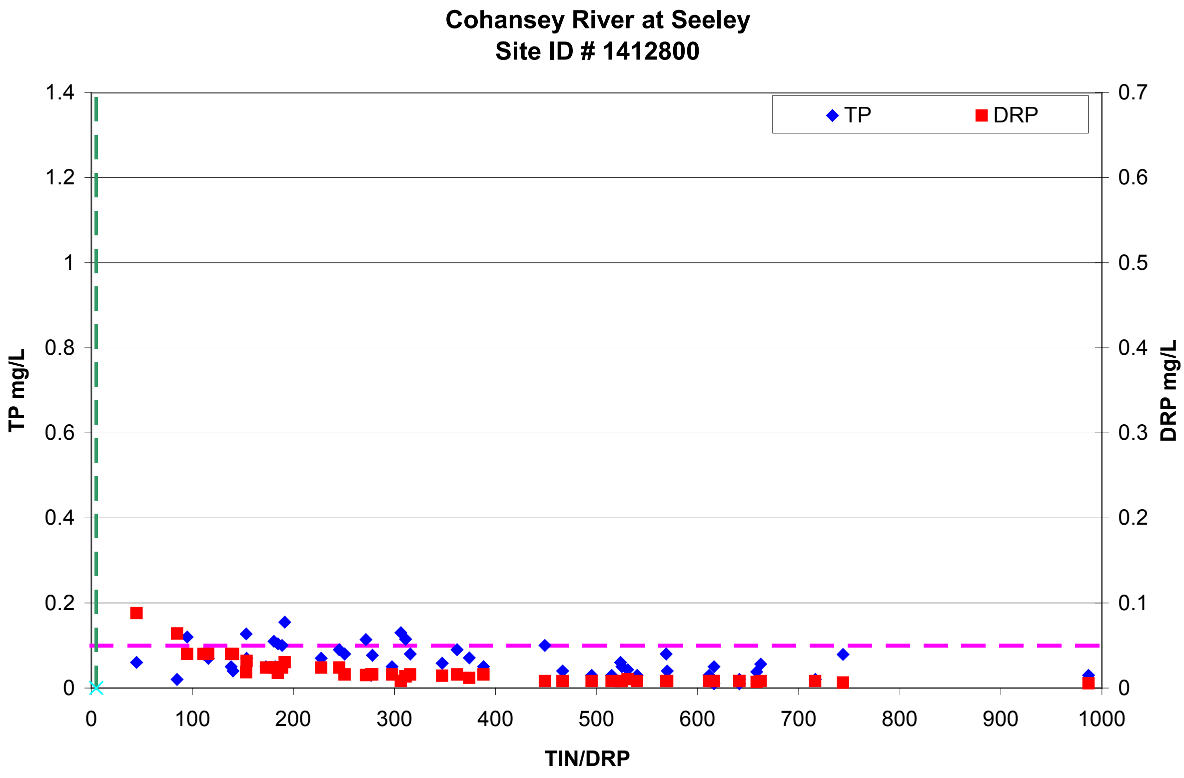
Figure 14 Limiting Nutrient Analysis for Barrett Run at Bridgeton (01413013)



TIN = dissolved nitrite, nitrate and ammonia. TIN calculated as: a sum of dissolved ammonia (P00608) & dissolved nitrite and nitrate (P00631) or a sum of total ammonia (P00610) and total nitrite & nitrate (P00630)
DRP = dissolved reactive phosphorus: orthophosphorus (P00671) if available, or 80% dissolved phosphorus (P00666)

The above figure depicts the relationship of these two key nutrients at Barrett Run at Bridgeton Station. At this station, when the total phosphorus exceeded 0.1 mg/L and the DRP < 0.05 mg/L, the ratio TIN/DRP greatly exceeds 5. This suggests that phosphorus is the limiting nutrient and the criterion applies.

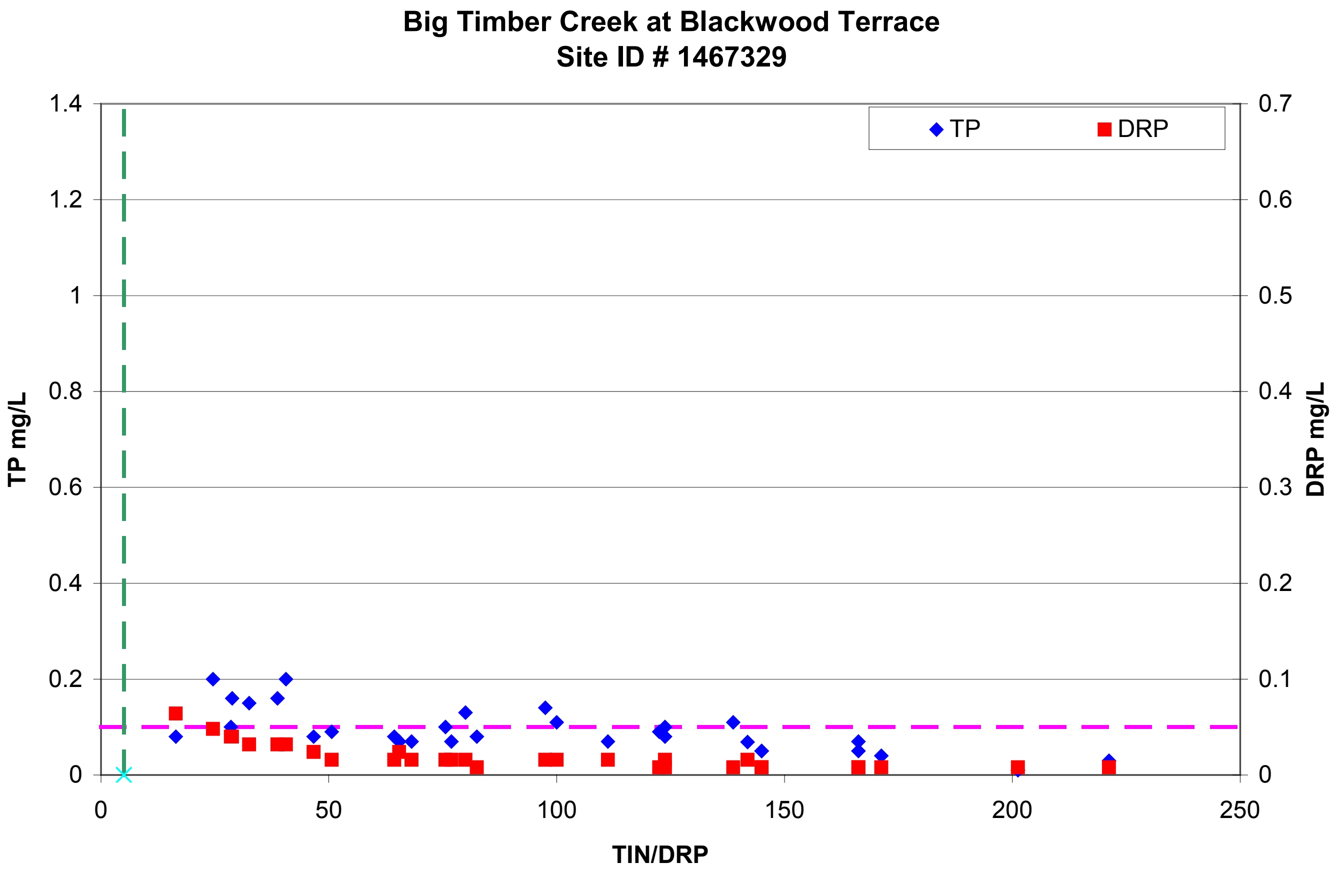
Figure 15 Limiting Nutrient Analysis for Cohansey River at Seeley (01412800)



TIN = dissolved nitrite, nitrate and ammonia. TIN calculated as: a sum of dissolved ammonia (P00608) & dissolved nitrite and nitrate (P00631) or a sum of total ammonia (P00610) and total nitrite & nitrate (P00630)
DRP = dissolved reactive phosphorus: orthophosphorus (P00671) if available, or 80% dissolved phosphorus (P00666)

The above figure depicts the relationship of these two key nutrients at the Cohansey River at Seeley Station. At this station, when the total phosphorus exceeded 0.1 mg/L and the DRP < 0.05 mg/L, the ratio TIN/DRP greatly exceeds 5. This suggests that phosphorus is the limiting nutrient and the criterion applies.

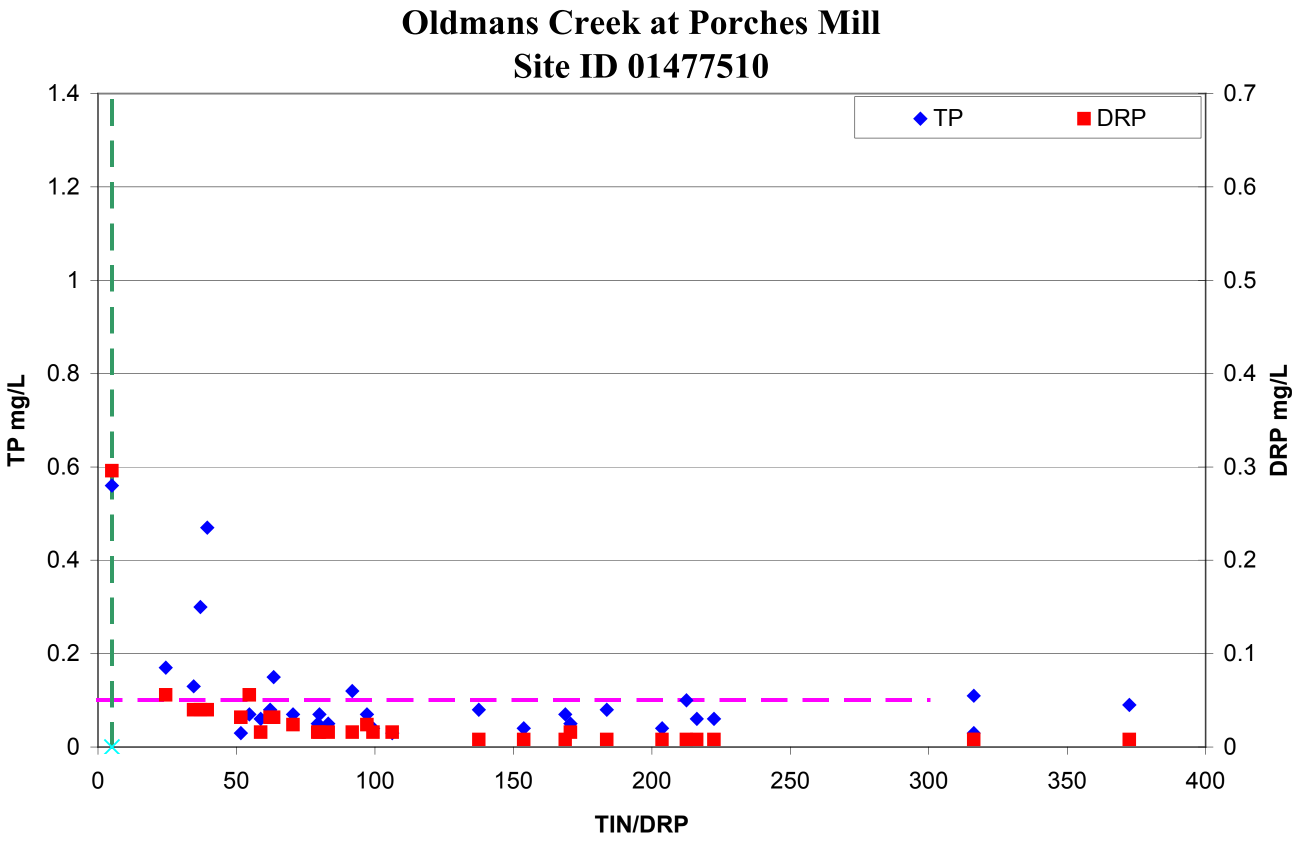
Figure 16 Limiting Nutrient Analysis for Big Timber Creek (01467329)



TIN = dissolved nitrite, nitrate and ammonia. TIN calculated as: a sum of dissolved ammonia (P00608) & dissolved nitrite and nitrate (P00631) or a sum of total ammonia (P00610) and total nitrite & nitrate (P00630)
DRP = dissolved reactive phosphorus: orthophosphorus (P00671) if available, or 80% dissolved phosphorus (P00666)

The above figure depicts the relationship of these two key nutrients at the Big Timber Creek at Blackwood Terrace Station. At this station, when the total phosphorus exceeded 0.1 mg/L and the DRP < 0.05 mg/L, the ratio TIN/DRP greatly exceeds 5. This suggests that phosphorus is the limiting nutrient and the criterion applies.

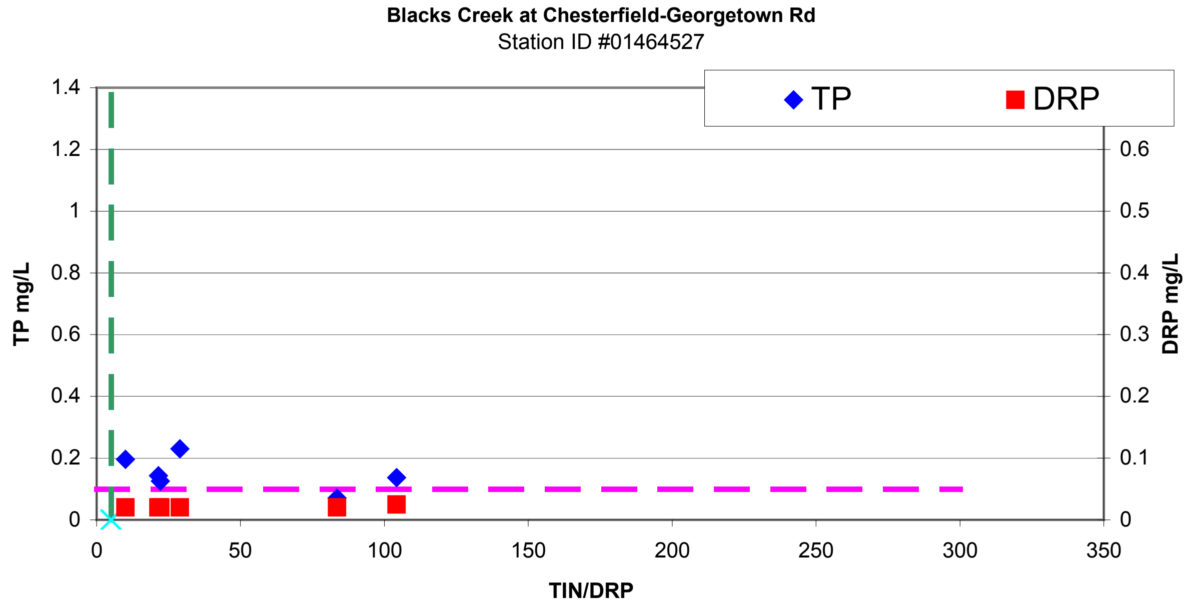
Figure 17 Limiting Nutrient Analysis for Oldmans at Porches Mill Station ID # (01477510)



TIN = dissolved nitrite, nitrate and ammonia. TIN calculated as: a sum of dissolved ammonia (P00608) & dissolved nitrite and nitrate (P00631) or a sum of total ammonia (P00610) and total nitrite & nitrate (P00630)
DRP = dissolved reactive phosphorus: orthophosphorus (P00671) if available, or 80% dissolved phosphorus (P00666)

The above figure depicts the relationship of these two key nutrients at the Oldmans Creek at Porches Mills Station. At this station, when the total phosphorus exceeded 0.1 mg/L and the DRP < 0.05 mg/L, the ratio TIN/DRP greatly exceeds 5. This suggests that phosphorus is the limiting nutrient and the criterion applies.

Figure 18 Limiting Nutrient Analysis for Blacks Creek at Chesterfield-Georgetown Rd Station ID # (01464527)



TIN = dissolved nitrite, nitrate and ammonia. TIN calculated as: a sum of dissolved ammonia (P00608) & dissolved nitrite and nitrate (P00631) or a sum of total ammonia (P00610) and total nitrite & nitrate (P00630)
DRP = dissolved reactive phosphorus: orthophosphorus (P00671) if available, or 80% dissolved phosphorus (P00666)

The above figure depicts the relationship of these two key nutrients at the Blacks Creek at Chesterfield-Georgetown Road. At this station, when the total phosphorus exceeded 0.1 mg/L and the DRP < 0.05 mg/L, the ratio TIN/DRP exceeds 5. This suggests that phosphorus is the limiting nutrient and the criterion applies.

Seasonal Variation/Critical Conditions

The application of a flow-integrated regression technique for determining loading reductions for impaired segments works well in watersheds that exhibit most of the loading exceedances from nonpoint and stormwater point sources of pollution. The analytical technique used to calculate these TMDLs represents the entire range of flows and all seasons for which the total phosphorus data were collected. Since the technique uses data from annual monitoring programs, seasonal variation and critical conditions are incorporated into the analysis by assessing the loadings over the entire range of flows. Therefore, the method implicitly represents all seasonal meteorological and hydrological conditions. The loading reduction calculated to attain SWQS will do so under all conditions, according to the data available. In this way, the TMDL addresses seasonal variation and critical conditions.

6.0 TMDL Calculations

A regression technique, derived from a load duration method (Stiles 2002), was developed by the Department for data-limited TMDLs where nonpoint and stormwater point sources are predominant. For this technique, linear regression is used to develop a flow-integrated relationship between measured pollutant concentrations and the associated flows at a single monitoring site. The method, known as the Flow-Integrated Reduction of Exceedances (FIRE), provides an accurate estimation of the load that will not cause an exceedance of the water quality standard. The FIRE method is applied over the entire range of flows, eliminating the need to establish a single target flow to estimate an average annual loading reduction. For this approach, calculated phosphorus loads based on actual data are plotted against corresponding flows. The regression relationship between the load and flow for exceedances of the SWQS is established and the regression line drawn. The target load line corresponding with the TP concentration of 0.1 mg/L is plotted on the same graph with the linear exceedance regression line. For this technique, a zero-intercept for the regression line is assumed. The zero intercept is within the 95 percent confidence interval, so the zero intercept cannot be rejected as the point of origin. In addition, given the predominance of nonpoint sources, at zero flow there would be zero load. Given parallel slopes, the difference between the two lines is equal to the per cent load reduction needed to attain SWQS. The resultant percent reduction is the same whether the y-axis is expressed as pounds per day, pounds per year, or as metric units of kilograms per day or per year.

A Margin of Safety (MOS) must be provided to account for “lack of knowledge concerning the relationship between effluent limitations and water quality” (40 CFR 130.7(c)). A MOS accounts for uncertainty in the loading estimates, physical parameters and the model itself. The MOS, as described in USEPA guidance (Sutfin, 2002), can be either explicit or implicit (i.e., addressed through conservative assumptions used in establishing the TMDL). For this TMDL calculation, an explicit MOS has been incorporated as described below.

A percent loading reduction that includes a margin of safety is estimated by taking the difference between the upper 95 percent confidence limit of the slope of the exceedance regression line and the slope of the target loading. The margin of safety component is the difference between the exceedance regression line and the 95 percent confidence limit for the regression.

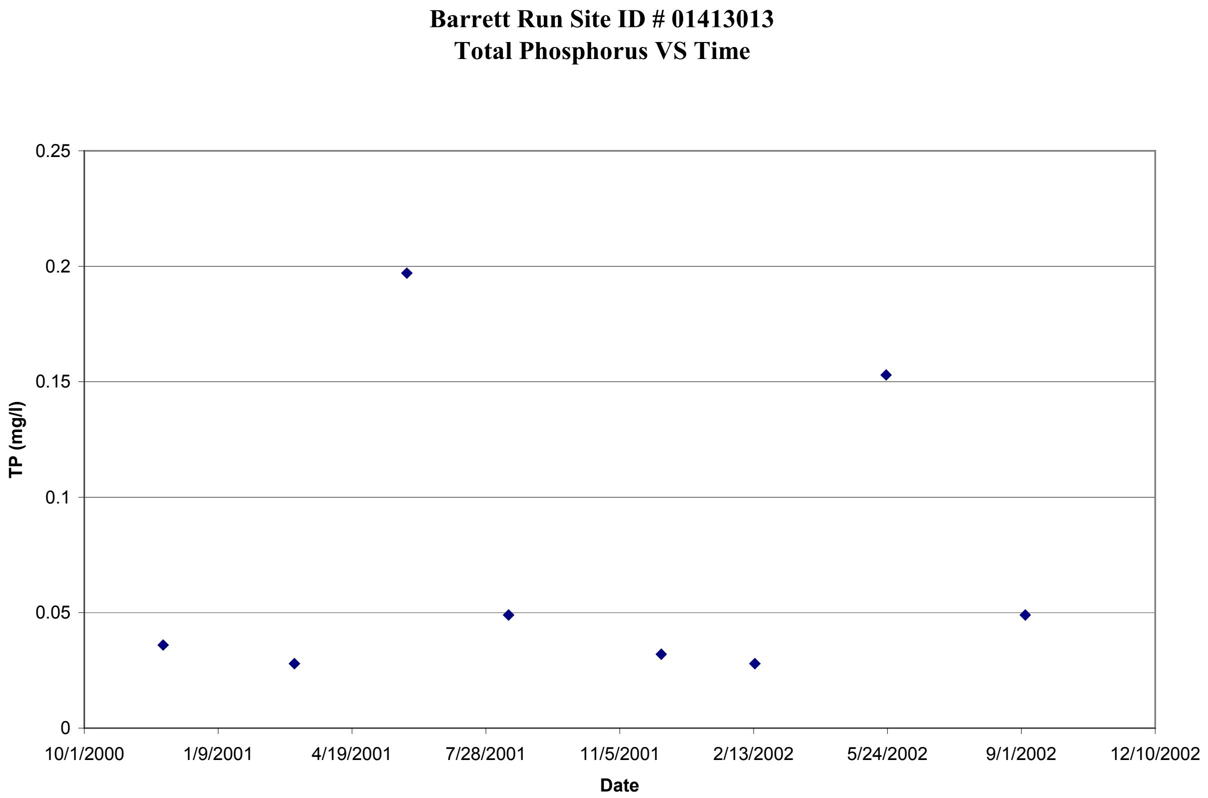
Results from applying the technique for Cohansey River at Seeley, Big Timber at Blackwood Terrace, Oldmans Creek at Porches Mills and Blacks Creek at Chesterfield-Georgetown Rd impairements are presented below. For Barrett Run at Bridgeton the regression technique discussed above could not be used, due to the lack of flow data. An alternative method was used in this segment and is explained below.

Watershed Management Area 17:

Barrett Run at Bridgeton:

The Barrett Run stream segment lies within the watershed of Mary Elmer Lake, which has an approved lake TMDL. The segment was evaluated to determine if the loading reduction needed to meet the in-stream criterion or that which was calculated to be needed to meet the lake criterion in the previous TMDL would drive stream segment TMDL. For the Barrett Run stream segment, (01413013), the FIRE method could not be applied because of the lack of flow data. The load reduction that would be needed to attain compliance in the stream was tested by assuming a linear relationship between load reduction and in-stream concentration exists. The load reduction needed to attain the SWQS for streams was calculated, based on the highest recorded data point. The station lies at the outlet of Mary Elmer Lake; because this lake has an approved TMDL it is expected that the water quality at this station will be reflective of attainment of the lake criterion, and therefore 0.05mg/l was used as the target concentration. Data for these stations is presented in Figure 19.

Figure 19 Barrett Run Estimated Percent Reduction Using an Alternative Method



The reduction required to achieve a SWQS of 0.05 mg/L for the highest TP concentration result (0.197 mg/L) is 74.6 %. The total phosphorus reduction, as calculated from the Reckhow model for the Mary Elmer Lakeshed, is 91%. It is concluded that the 91% load reduction needed to address the impairment in Mary Elmer Lakeshed, will attain the in stream SWQS of 0.1 mg/L TP, and the expected water quality of 0.05 mg/L because the station is at the lake outlet.

Cohansey River at Seeley:

The Cohansey River at Seeley stream segment lies within the watershed of Sunset Lake, which has an approved lake TMDL. The station is a tributary to the lake and, to be conservative, the 0.05 mg/l criterion that applies as the tributary enter the lake, was used as the endpoint. The segment was evaluated to determine if the loading reduction to meet the in-stream criterion or the loading reduction to meet the lake criterion from the approved TMDL would drive the stream segment TMDL. For the Cohansey River stream segment, (01412800), the load reduction needed to attain the endpoint for the stream was calculated, using the FIRE Method presented in Figure 20 and Table 8.

Figure 20 **Estimated Percent Reduction for the Cohansey River at Seeley Using a Regression Method**

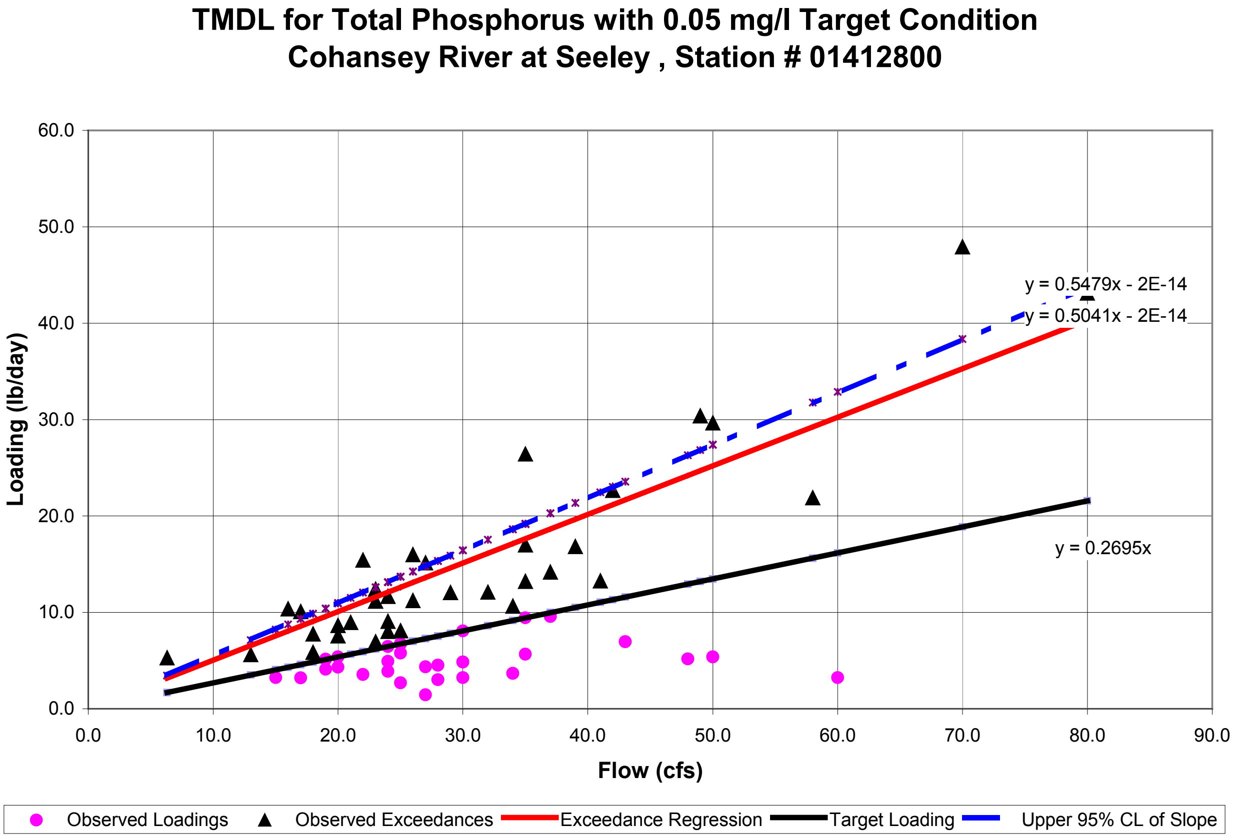


Table 8 Cohansey River at Seeley

Results from Regression Analysis		
Target Loading Slope	=	0.2695
Exceedance Regression Slope	=	0.5041
Upper 95% Confidence Limit of Slope	=	0.5479

To achieve SWQS within the Cohansey impaired segment, the required reductions are as follows:

Target Load (lb/day) for the given TP endpoint:

= 0.2695 x flow (cfs)

Overall Percent TP Loading Reduction, including MOS

$$(1-\frac{0.2695}{0.5479})x100\% = 0.5081x100\% = 50.8\%$$

The MOS portion of the reduction is calculated as follows:

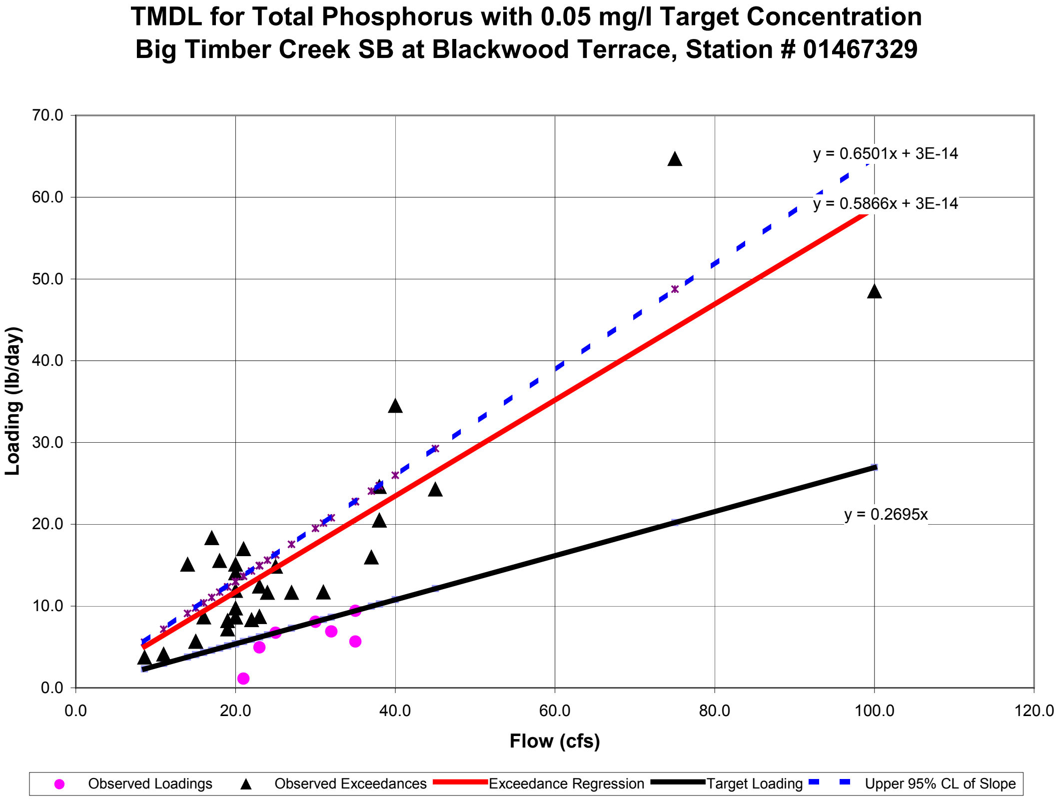
$$\text{MOS} = (1-\frac{0.5041}{0.5479})x100\% = 0.0799x100\% = 7.99\%$$

The reduction required to achieve the 0.05 mg/l TP endpoint in the stream using the FIRE method is 50.8%. The total phosphorus reduction required as calculated from the Reckhow model for the Sunset Lake Lakeshed is 92%. It is concluded that the 92% load reduction needed to address the impairment in Sunset Lakes will attain the endpoint of 0.05 mg/L TP in stream and, therefore the Lake TMDL will apply.

Watershed Management Area 18:

Big Timber Creek SB at Blackwood Terrace:

The Big Timber Creek at Blackwood Terrace stream segment lies within the watershed of Blackwood Lake, which has an approved lake TMDL. The segment was evaluated to determine if the reduction to meet the criterion in-stream or the reduction to meet the lake criterion from the approved TMDL would drive the stream segment TMDL. The station is located at the outlet of the lake; because this lake has an approved TMDL it is expected that the water quality at this station will be reflective of the lake quality and therefore 0.05mg/l was used as an endpoint. For the Big Timber Creek stream segment, (01467329), the load reduction needed to attain the endpoint was calculated, using the FIRE Method presented in Figure 21 and Table 9.



TMDL for Total Phosphorus with 0.05 mg/l Target Concentration
Big Timber Creek SB at Blackwood Terrace, Station # 01467329

Figure 21 Estimated Percent Reduction for Big Timber Creek SB at Blackwood Terrace Using a Regression Method

Table 9 Big Timber Creek at Blackwood Terrace

Results from Regression Analysis	
Target Loading Slope	= 0.2695
Exceedance Regression Slope	= 0.5866
Upper 95% Confidence Limit of Slope	= 0.6501

To achieve SWQSs within the Big Timber Creek impaired segment, the required reductions are as follows:

Target Load (lb/day) for the given TP endpoint:

= 0.2695 x flow (cfs)

Overall Percent TP Loading Reduction, including MOS:

$$(1-\frac{0.2695}{0.6501})x100\% = 0.5854x100\% = 58.54\%$$

The MOS portion of the reduction is calculated as follows:

$$\text{MOS} = (1-\frac{0.5866}{0.6501})x100\% = 0.0977x100\% = 9.77\%$$

The reduction required to achieve the 0.05 mg/l of phosphorus endpoint in stream using the FIRE method is 58.5%. The total phosphorus reduction required, as calculated from the Reckhow model for the Blackwood Lake Lakeshed, is 88%. It is concluded that the 88% load reduction needed to address the impairment in Blackwood Lake will attain the endpoint of 0.05 mg/L TP in stream; therefore; the Lake TMDL will apply.

Oldmans Creek at Porches Mill:

Figure 22 Estimated Percent Reduction for Oldmans Creek at Porches Mills Using a Regression Method

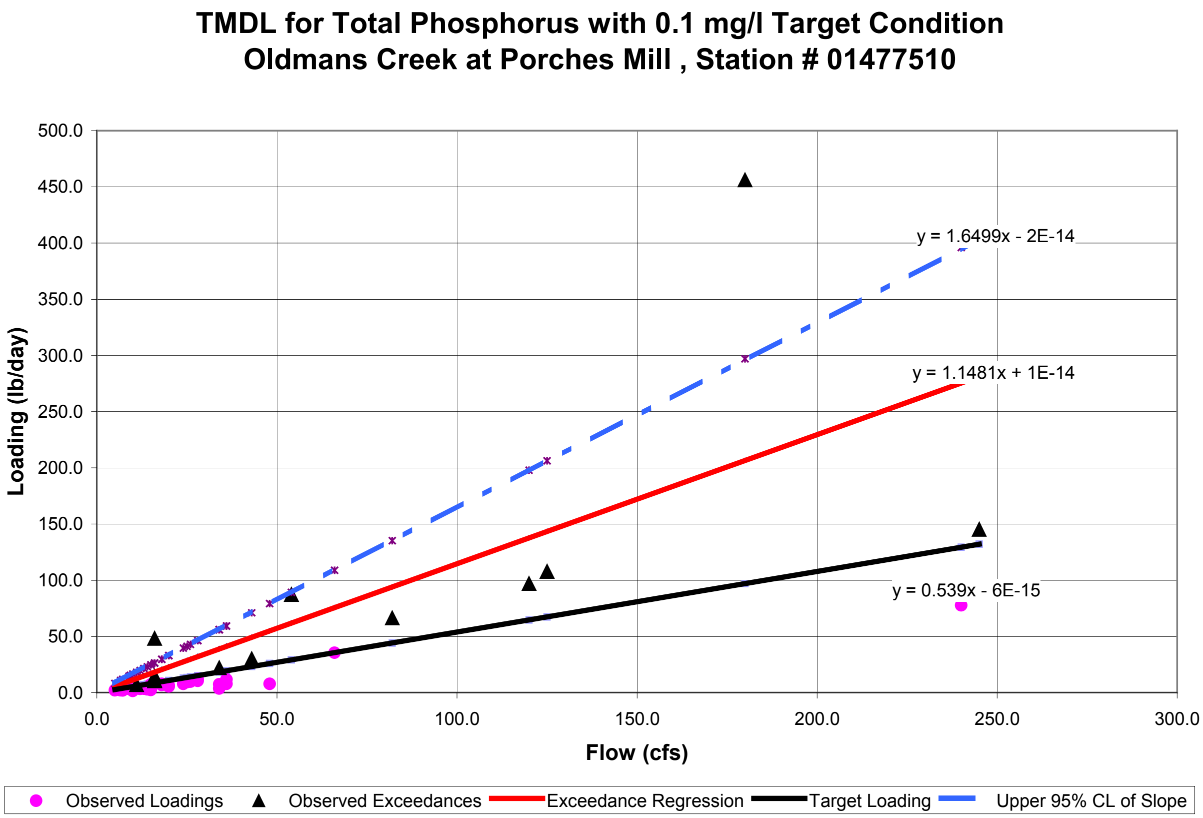


Table 10: Oldmans Creek at Porches Mills

Results from Regression Analysis		
Target Loading Slope	=	0.5390
Exceedance Regression Slope	=	1.1481
Upper 95% Confidence Limit of Slope	=	1.6499

To achieve SWQSs within the Oldmans Creek impaired segment, the required reductions are as follows:

Target Load (lb/day) for the given TP SWQS:

= 0.539 x flow (cfs)

Overall Percent TP Loading Reduction, including MOS:

$$(1-\frac{0.539}{1.6499})x100\% = 0.6733x100\% = 67.3\%$$

The MOS portion of the reduction is calculated as follows:

$$\text{MOS} = (1-\frac{1.1481}{1.6499})x100\% = 0.3042x100\% = 30.4\%$$

Watershed Management Area 20:

<u>Blacks Creek at Chesterfield:</u>

Figure 23 Estimated Percent Reduction for Blacks Creek at Chesterfield-Georgetown Rd. Using a Regression Method

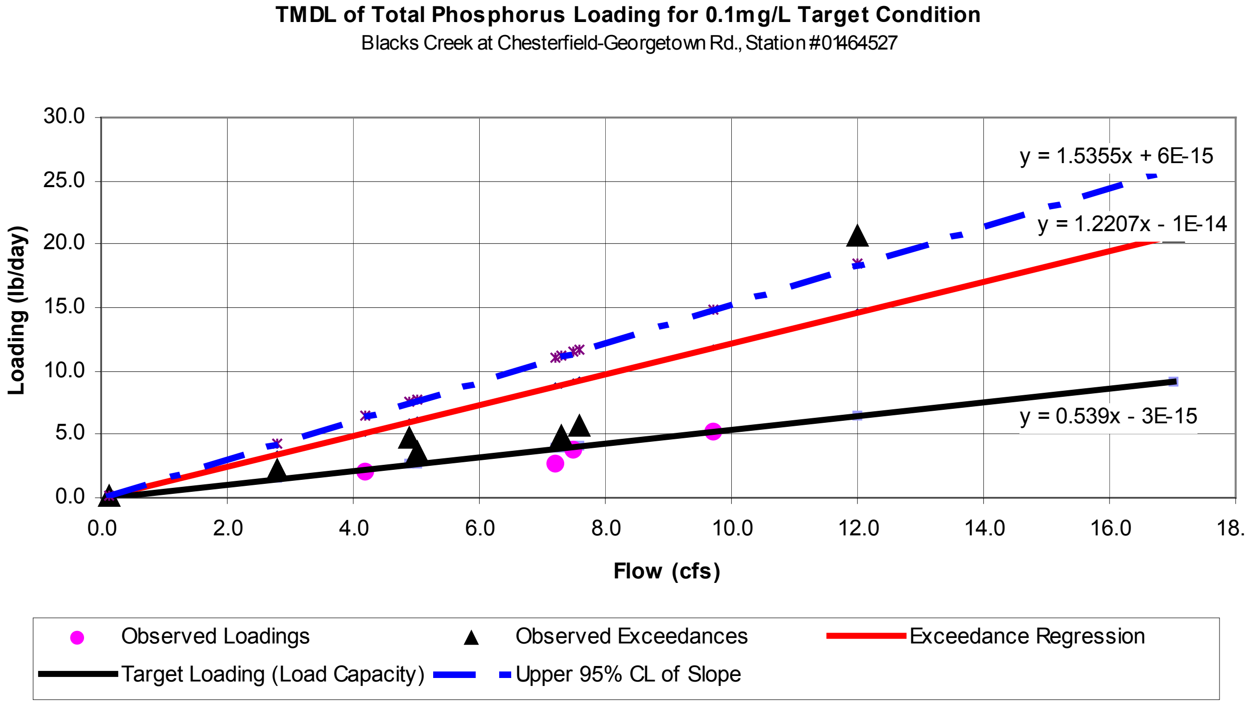


Table 11 Blacks Creek at Chesterfield-Georgetown Rd. (01464527)

Results from Regression Analysis	
Target Loading Slope (Load Capacity)	= 0.5390
Exceedance Regression Slope	= 1.2207
Upper 95% Confidence Limit of Slope	= 1.5355

To achieve SWQSs within the Blacks Creek impaired segment, the required reductions are as follows:

Target Load (lb/day) for the given TP SWQS:

$$= 0.539 \text{ x flow (cfs)}$$

Overall Percent TP Loading reduction, including MOS:

$$(1 - \frac{0.539}{1.5355})x100\% = 0.6489x100\% = 64.9\%$$

MOS component of reduction is calculated as follows:

$$\text{MOS} = (1 - \frac{1.2207}{1.5355})x100\% = 0.2050x100\% = 20.5\%$$

To determine the TMDL for each stream segment, the target load is calculated as shown above. The load that corresponds to the MOS is calculated and then subtracted from the target load. The result is the allocable load. Loads from some land uses, specifically forest, wetland, water and barren land, are not adjustable because there are no measures that can reasonably be applied to runoff from these sources to reduce the loads generated. As a result, existing loads from these sources are equal to the future loads. Therefore, in order to achieve the TMDL, the load reduction from land uses for which reduction measures can reasonably be applied must be increased proportionally. Additional detail on the method used to derive load reductions that are assigned to each land use from the FIRE outputs is provided in Appendix F.

Wasteload Allocations and Load Allocations

WLAs are established for all point sources, while LAs are established for nonpoint sources, as these terms are defined in "Source Assessment." There are no point sources, other than stormwater point sources, in the affected streamsheds. Both WLAs and LAs are expressed as percent reductions for particular stream segments, and are differentiated as discussed below.

Stormwater discharges can be a point source or a nonpoint source, depending on NJPDES regulatory jurisdiction, yet the suite of measures to achieve reduction of loads from stormwater discharges is the same, regardless of this distinction. Stormwater point sources receiving a WLA are distinguished from stormwater generating areas receiving a LA on the basis of land use. This distribution of loading capacity between WLAs and LAs is consistent with recent EPA guidance that clarifies existing regulatory requirements for establishing

WLAs for stormwater discharges (Wayland, November 2002). Stormwater discharges are captured within the runoff sources quantified according to land use, as described previously. Distinguishing between regulated and unregulated stormwater is necessary in order to express WLAs and LAs numerically; however, "EPA recognizes that these allocations might be fairly rudimentary because of data limitations and variability within the system" (Wayland, November 2002, p.1). Therefore allocations are established according to source categories as shown in Table 12. This demarcation between WLAs and LAs based on land use source categories is not perfect, but it represents the best estimate defined as narrowly as data allow. The Department acknowledges that there may be stormwater sources in the residential, commercial, industrial and mixed urban runoff source categories that are not NJPDES-regulated. Nothing in these TMDLs shall be construed to require the Department to regulate a stormwater source under NJPDES that would not already be regulated as such, nor shall anything in these TMDLs be construed to prevent the Department from regulating a stormwater source under NJPDES.

Table 12 Distribution of WLAs and LAs among source categories

Source category	**TMDL allocation**
Nonpoint and Stormwater Sources	
medium / high density residential	WLA
low density / rural residential	WLA
commercial	WLA
industrial	WLA
Mixed urban / other urban	WLA
agricultural	LA
forest, wetland, water	LA
barren land	LA

Wasteload allocations and load allocations for sources within the drainage area of the impaired segments are presented in Tables 13 through 19 and Figures 24 through 30.

Watershed Management Area 17

Barrett Run at Bridgeton

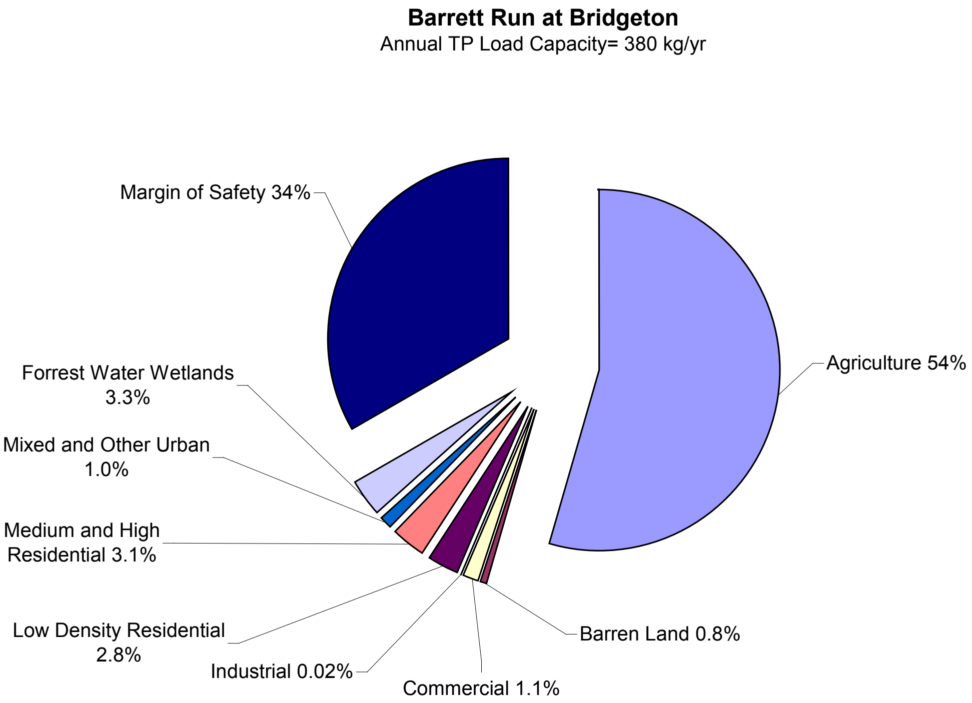
Table 13 Final TMDL calculations for Barrett Run (from Mary Elmer Lake TMDL Approved 9/30/2003)

	Barrett Run		**% reduction**
	kg TP/yr / (lb/yr)	**% of LC**	
Loading capacity (LC)	380 (836)	100%	n/a
Load allocation			
Point Sources other than Stormwater	N/a		
Nonpoint and Stormwater Sources			
medium / high density residential	12 (26.4)	3.0%	91%
low density / rural residential	11 (24.2)	2.9%	91%

	Barrett Run		% reduction
	kg TP/yr / (lb/yr)	% of LC	
commercial	4.4 (9.68)	1.1%	91%
industrial	0.1 (.22)	0.02%	91%
mixed urban / other urban	3.8 (8.36)	1.0%	91%
agricultural	210 (462)	54%	91%
forest, wetland, water	13 (28.6	3.3%	0%
barren land	2.9 (6.38)	0.8%	0%
Lake Deposition	0.6 (1.23)	0.2%	0%
Margin of Safety	129 (284)	34 %	n/a

*Percent reductions shown for individual sources are necessary to achieve overall reductions
+ Loadings and reductions were not recalculated but were taken from the Approved TMDL

Figure 24 Final Phosphorus Allocations for Barrett Run at Bridgeton



Cohansey River at Seeley

TMDL calculations using both the FIRE Method (Table 14, Figure 25) and Reckhow Model (Table 15, Figure 26) are shown below. As previously stated the TMDL calculations for Sunset Lake using the Reckhow Model is more stringent and therefore represents the final TMDL for the Cohansey at Seeley stream segment.

Table 14 TMDL calculations for Cohansey River at Seeley Stream Segment using FIRE Method

	Cohansey River			
	Kg TP/yr (lbs/yr)	**kg TP/yr (lbs/yr)**	**% of LC**	Percent Reduction
Loading capacity (LC)	11218.2	5998 (13,195.6)	100%	n/a
	Existing Load	Load Allocation		
Point Sources	N/A			
Nonpoint and Stormwater Sources				
medium / high density residential	106.52	51.38 (114.0)	0.9%	51.8 %
low density / rural residential	454.07	219.0 (481.8)	3.7%	51.8 %
commercial	104.25	50.3 (110.7)	0.8%	51.8 %
industrial	44.18	21.3 (46.9)	0.4%	51.8 %
mixed urban / other urban	209.04	100.8 (221.8)	1.7%	51.8 %
agricultural	10092.9	4868.3 (10710.3)	81.2%	51.8 %
forest, wetland, water	192.93	192.9 (424.4)	3.0%	0%
barren land	14.33	14.3 (31.5)	0.2%	0%
Margin of Safety	N/A	479.5 (1054.9)	8.0%	n/a

*Percent reductions shown for individual sources are necessary to achieve overall reductions

Figure 25 Phosphorus Allocations for Cohansey at Seeley Stream Segment

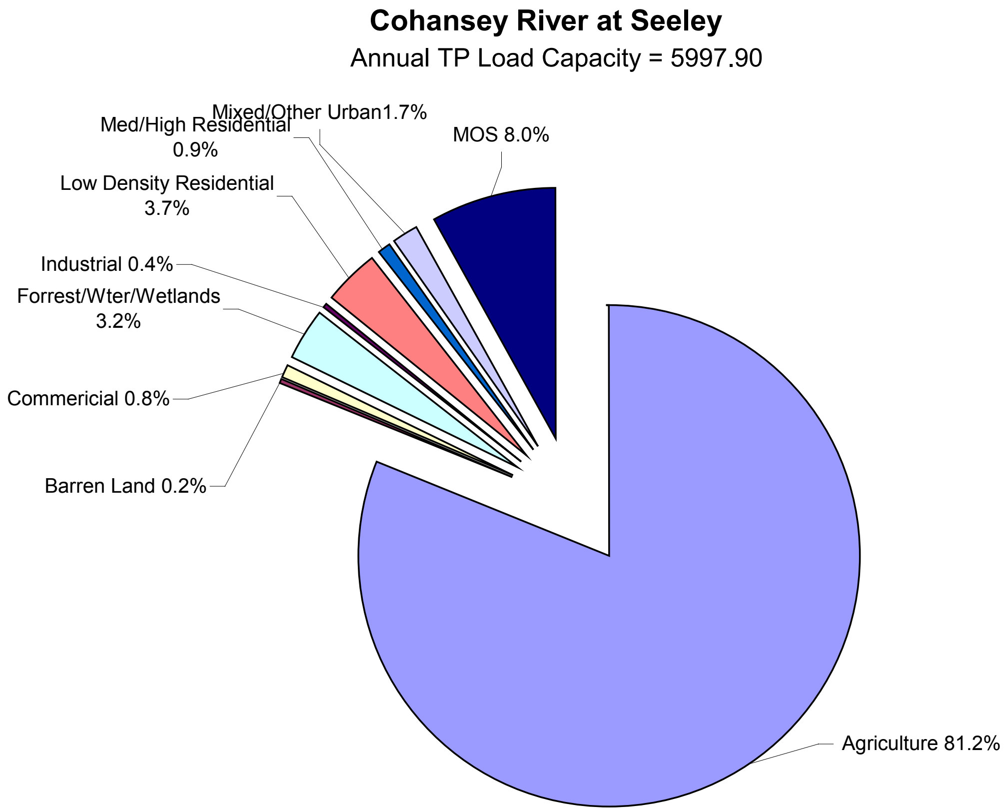
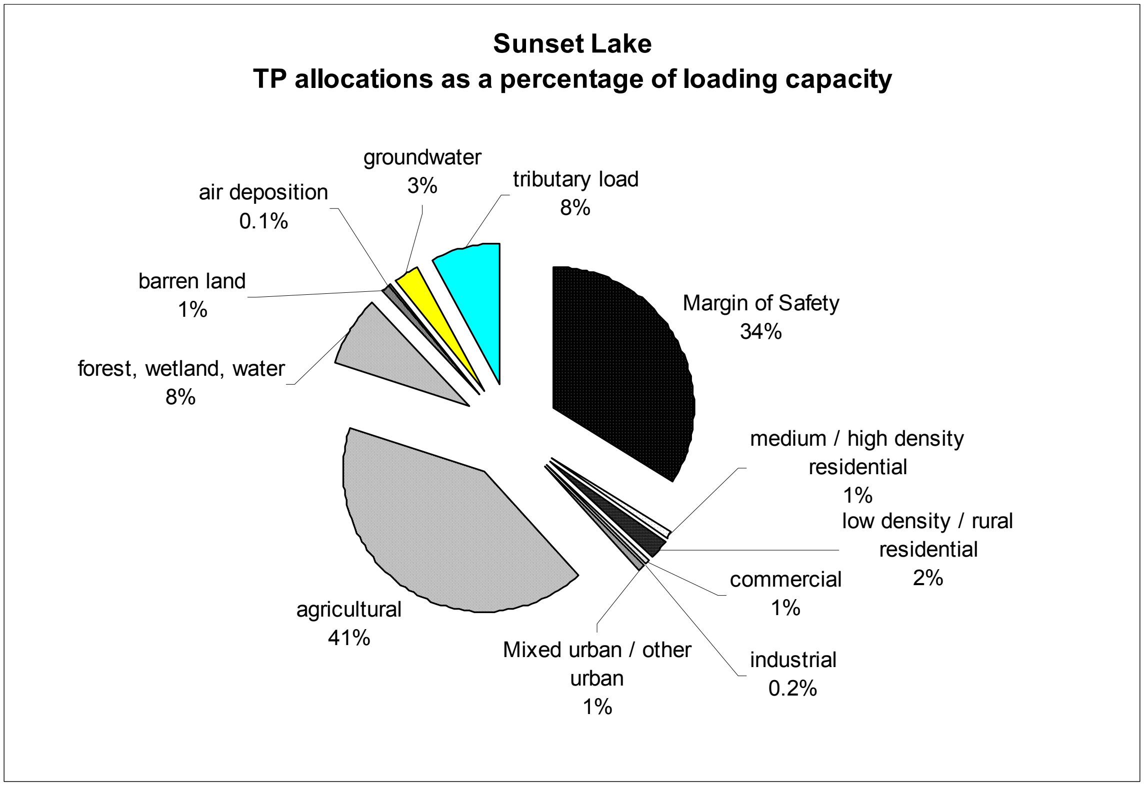


Table 15 Final TMDL Calculations for Cohansey River at Seeley based on the Sunset Lake TMDL (Approved 9/30/2003)

	% reduction	Sunset Lake	
Lake	kg TP/yr (lbs/yr)	% of IC	
loading capacity (LC)	2500 (5500)	100%	n/a
Point Sources other than Stormwater			
minor municipal	n/a		
Nonpoint and Stormwater Sources			
medium / high density residential	25 (55.0)	1.0%	92%
low density / rural residential	52 (114.4)	2.1%	92%
Commercial	14 (30.8)	0.5%	92%
Industrial	3.8 (8.36)	0.2%	92%
Mixed urban / other urban	22 (48.4)	1.0%	92%
Agricultural	1000 (2200)	53%	92%
forest, wetland, water	210 (462)	8.4%	0%
barren land	19 (41.8)	0.5%	0%
septic systems			
Waterfowl			
internal load			
tributary load	190 (418)		
Natural Sources / Background			
air deposition onto lake surface	2.5 (5.5)	0.1%	0%
Groundwater	80(176)		
Other Allocations			
explicit Margin of Safety	850 (1870)	34%	n/a

+ Loadings and reductions were not recalculated but were taken from the Approved TMDL

Figure 26 Final Phosphorus Allocations for Cohansey River at Seeley from Sunset Lake TMDL (Approved 9/30/2003)



Big Timber Creek SB at Blackwood Terrace

TMDL calculations using both the FIRE Method (Table 16, Figure 27) and Reckhow Model (Table 17, Figure 28) are shown below. As previously stated the TMDL calculations for Blackwood Lake using the Reckhow Model results in a more stringent loading reduction and therefore represents the final TMDL for the Big Timber Creek stream segment.

Table 16 TMDL calculations for Big Timber Creek Stream Segment using FIRE Method

	Big Timber Creek			
	Kg TP/yr (lbs/yr)	**kg TP/yr (lbs/yr)**	**% of LC**	Percent Reduction
Loading capacity (LC)	1569.3	720.91 (1586)	100%	n/a
	Existing Load	Load Allocation		
Point Sources	N/A			
Nonpoint and Stormwater Sources				
medium / high density residential	682.50	**246.53 (542.4)**	**34.2%**	**63.88%**
low density / rural residential	97.23	**35.12 (77.3)**	**4.9%**	**63.88%**
commercial	217.41	**78.53 (172.8)**	**10.9%**	**63.88%**
industrial	60.93	**22.01 (48.4)**	**3.1%**	**63.88%**
mixed urban / other urban	214.31	**77.41 (170.3)**	**10.7%**	**63.88%**
agricultural	165.84	**59.90 (131.8)**	**8.3%**	**63.88%**
forest, wetland, water	78.68	**78.68 (173)**	**10.9%**	**0 %**
barren land	52.38	**52.38 (115.2)**	**7.3%**	**0%**
Margin of Safety	N/A	**70.35 (154.8)**	**10%**	n/a

*Percent reductions shown for individual sources are necessary to achieve overall reductions

Figure 27 Phosphorus allocations for Big Timber Creek Stream Segment

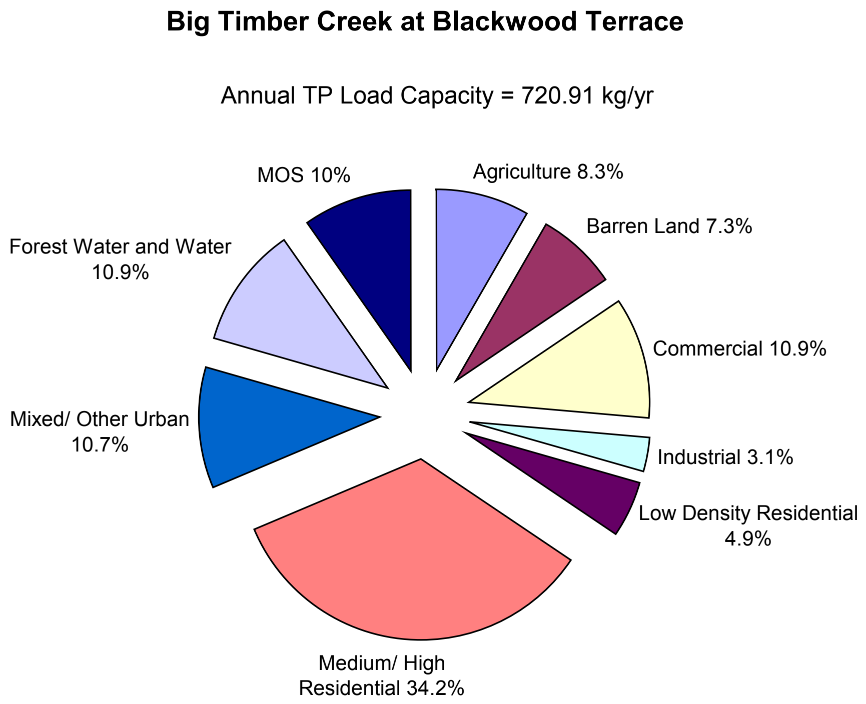
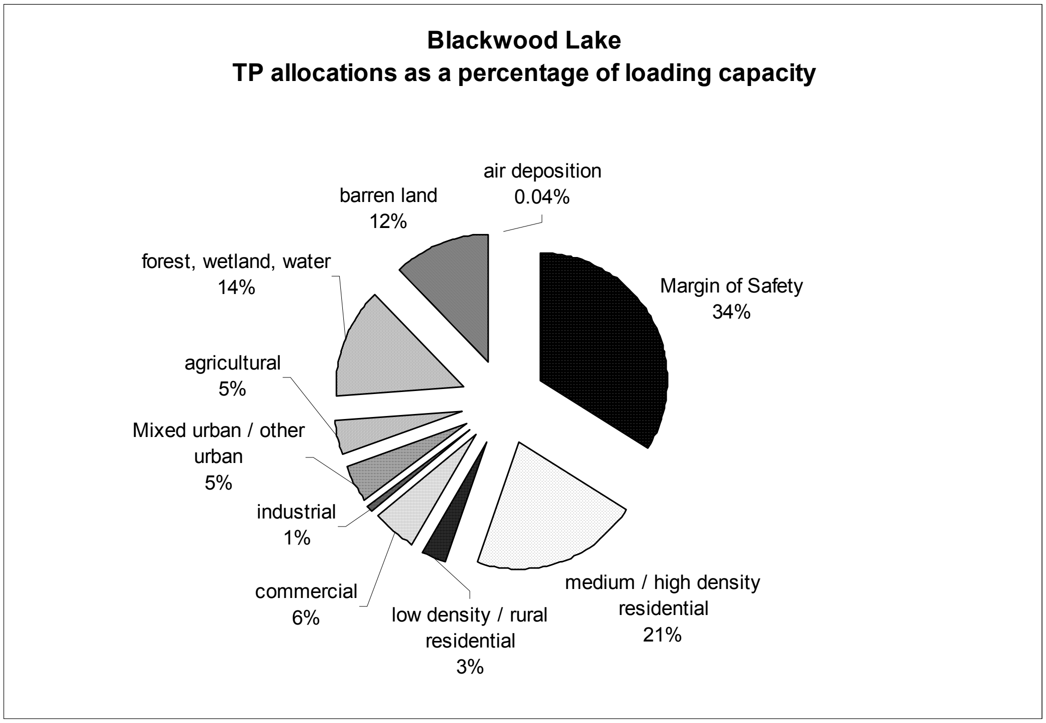


Table 17 Blackwood Lake TMDL Calculation (Approved 9/30/2003)

	Blackwood Lake		% reduction
lake	**kg TP/yr /(lb/yr)**	**% of IC**	
loading capacity (LC)	1200 (2640)	100%	n/a
Nonpoint and Stormwater Sources			
medium / high density residential	260 (572)	21.8%	88%
low density / rural residential	35 (77)	2.9%	88%
Commercial	69 (152)	5.7%	88%
Industrial	8.8 (19.4)	0.7%	88%
Mixed urban / other urban	57 (125)	4.7%	88%
Agricultural	55 (121)	4.6%	88%
forest, wetland, water	170 (374)	13.7%	0%
Barren land	140 (308)	12.0%	0%
septic systems			
Waterfowl			
Internal load			
Tributary load	n/a		
Natural Sources / Background			
air deposition onto lake surface	0.4 (.88)	0.04%	0%
Groundwater			
Other Allocations			

explicit Margin of Safety	410 (902)	34%	n/a

Figure 28 Phosphorus Allocations for Big Timber at Blackwood Terrace from the Blackwood Lake Lake TMDL (Approved 9/30/2003)



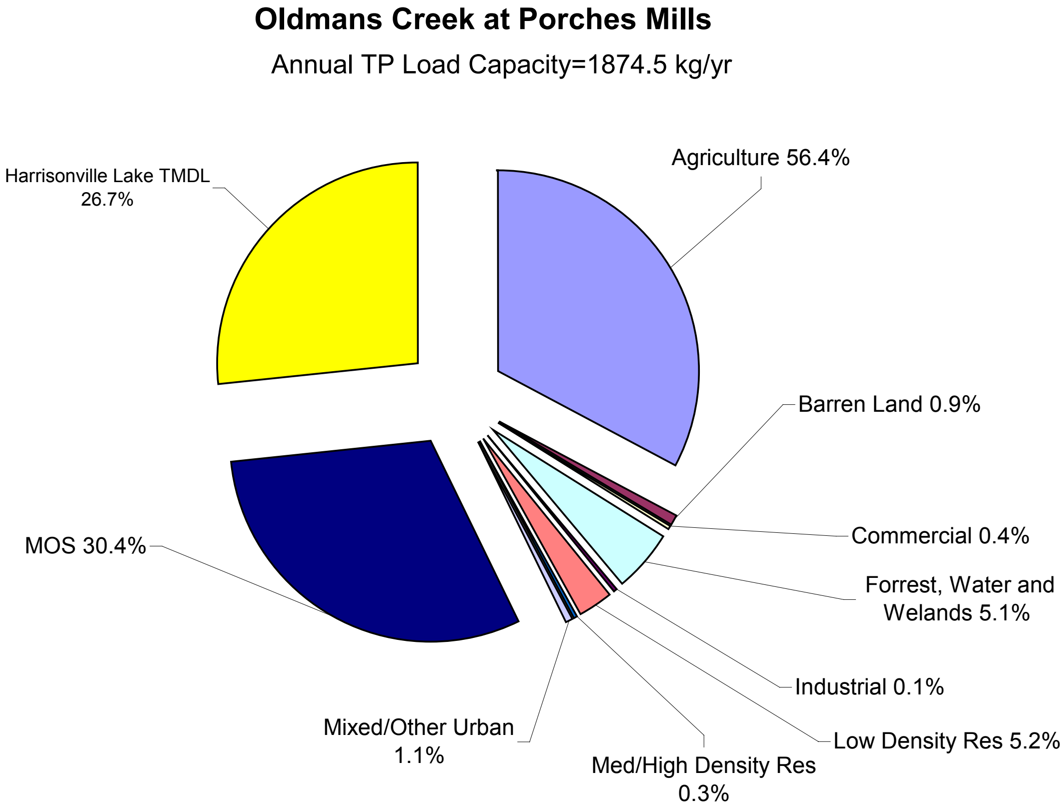
Oldmans Creek at Porches Mill

Table 18 TMDL calculations for Oldmans Creek at Porches Mill

	Oldmans Creek			
	Kg TP/yr (lbs/yr)	kg TP/yr (lbs/yr)	% of LC	Percent Reduction
Loading capacity (LC)	3992.5	1874.5 (4123.9)	100%	n/a
	Existing Load	Load Allocation		
Point Sources	N/A			
Nonpoint and Stormwater Sources				
medium / high density residential	17.09 (37.59)	3.50 (7.7)	0.2%	79.55 %
low density / rural residential	277.08 (609.57)	56.7 (124.7)	3.0%	79.55%
commercial	19.28 (42.41)	3.9 (8.6)	0.2%	79.55%
industrial	6.39 (14.06)	1.3 (2.9)	0.1%	79.55%
mixed urban / other urban	60.84 (133.86)	12.4 (27.3)	0.7%	79.55%
agricultural	2998.79 (6597.34)	613.4 (1349.5)	32.7%	79.55%
forest, wetland, water	96.51 (212.3)	96.5 (212.3)	5.1%	0%
barren land	16.57 (36.5)	16.6 (36.5)	0.9%	0%
Harrisonville Lake TMDL *	500 (1100)	500 (1100)	26.7%	0%
Margin of Safety	N/A	570.2 (1254.4)	30.4%	n/a

*** The upstream watershed of Oldmans Creek has an approved Lake TMDL therefore the Loading Capacity from the lake TMDL was used as the loading of the upstream watershed.**

Figure 29 Phosphorus Allocations for Oldmans Creek at Porches Mills



Watershed Management Area 20

Blacks Creek at Chesterfield-Georgetown rd.

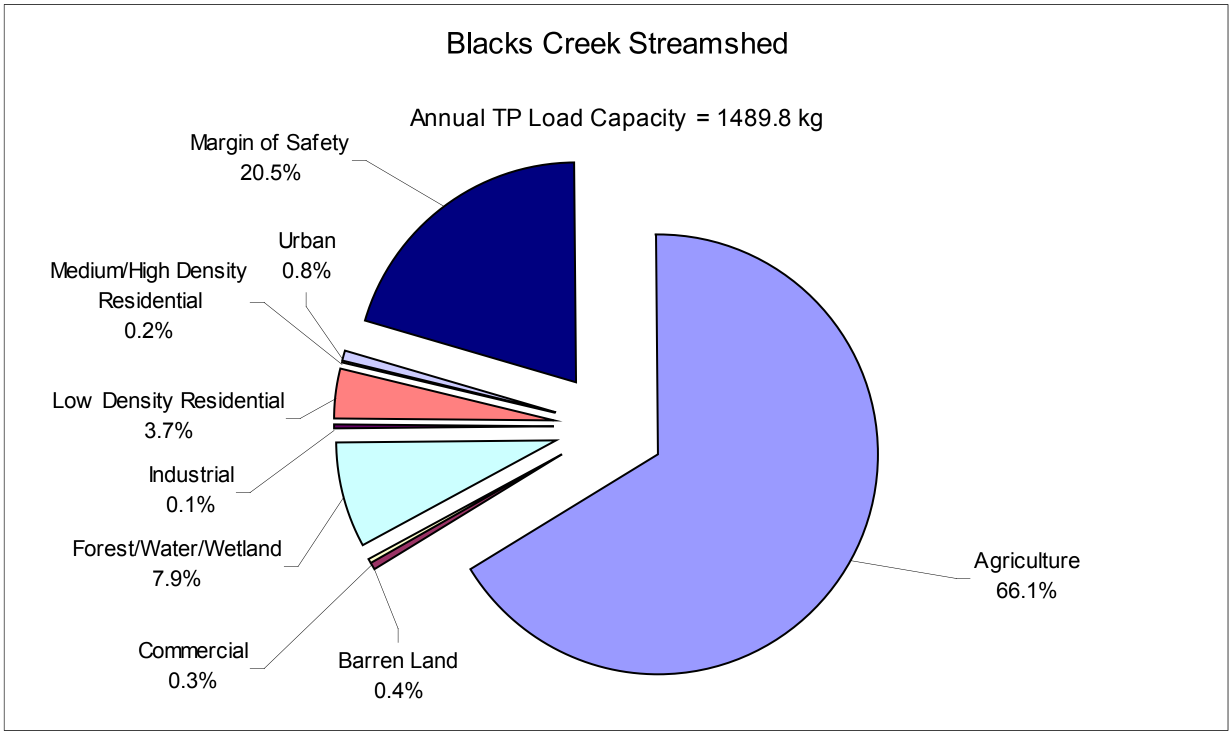
Table 19 TMDL calculations for Blacks Creek

	Blacks Creek		% reduction	Existing Load
	kg TP/yr (lb/yr)	% of LC		kg TP/yr (lb/yr)
Loading capacity (LC)	1489.8 (3277.6)	100%	n/a	3374.1 (7423.0)
Load allocation				
Point Sources other than Stormwater	n/a			
Nonpoint and Stormwater Sources				
medium / high density residential	2.6 (5.7)	0.2	67.4%	7.88 (17.3)
low density / rural residential	54.6 (120.1)	3.7	67.4%	167.3 (368.1)
commercial	4.6 (10.1)	0.3	67.4%	14.0 (30.8)
industrial	1.3 (2.9)	0.1	67.4%	4.11 (9.04)
mixed urban / other urban	11.6 (25.5)	0.8	67.4%	35.7 (78.5)
agricultural	985.2 (2167.4)	66.1	67.4%	3020.6 (6645.3)
forest, wetland, water	118.3 (260.2)	7.9	0%	118.3 (260.3)
barren land	6.2 (13.6)	0.4	0%	6.2 (13.6)
Margin of Safety	305.4 (671.9)	20.5	n/a	n/a

	Blacks Creek		**% reduction**	**Existing Load**
	kg TP/yr (lb/yr)	**% of LC**		**kg TP/yr (lb/yr)**

*Percent reductions shown for individual sources are necessary to achieve overall reductions

Figure 30 Phosphorus allocations for Blacks Creek



Reserve Capacity

Reserve capacity is an optional means of reserving a portion of the loading capacity to allow for future growth. Reserve capacities are not included at this time. The loading capacity of each stream is expressed as a function of the current load, and both WLAs and LAs are expressed as percentage reductions for particular stream segments. Therefore, the percent reductions from current levels must be attained in consideration of any new sources that may accompany future development.

7.0 Follow-up Monitoring

The Water Resources Division of the U.S. Geological Survey and the Department have cooperatively operated the Ambient Stream Monitoring Network (ASMN) in New Jersey since the 1970s. The ASMN currently includes approximately 115 stations that are routinely monitored on a quarterly basis. A second ambient monitoring network, DEP's Supplemental Ambient Surface Water Network (100 stations), has improved spatial coverage for water quality monitoring in New Jersey. The data from this these networks have been used to assess the quality of freshwater streams and percent load reductions. The ambient networks, as well as targeted studies, will be the means to determine the effectiveness of TMDL implementation and the need for additional management strategies.

8.0 Implementation Plan

Management measures are "economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint and stormwater sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint and stormwater source pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives" (USEPA, 1993).

The Department recognizes that TMDLs alone are not sufficient to restore impaired stream segments. The TMDL establishes the required pollutant reduction targets while the implementation plan identifies some of the regulatory and non-regulatory tools to achieve the reductions, matches management measures with sources, and suggests responsible entities for non-regulatory tools. This provides a basis for aligning available resources to assist with implementation activities. Projects proposed by the State, local government units and other stakeholders that would implement the measures identified within the impaired watershed are a priority for available State (for example, CBT) and federal (for example, 319(h)) funds. In addition, the Department's ongoing watershed management initiative will develop detailed watershed restoration plans for impaired stream segments in a priority order that will identify more specific measures to achieve the identified load reductions.

Urban and agricultural land use sources must be the focus for implementation. Urban land use will be addressed primarily by stormwater regulation. Agricultural land uses will be addressed by implementation of conservation management practices tailored to each farm. Other measures are discussed further below.

Stormwater measures

The stormwater facilities subject to regulation under NPDES in this watershed must be assigned WLAs. The WLAs for these point sources are expressed in terms of the required percent reduction for nonpoint sources and are applied to the land use categories that correspond to the areas regulated under industrial and municipal stormwater programs. The BMPs required through stormwater permits, including the additional measure discussed below, are generally expected to achieve the required load reductions. The success of these measures will be assessed through follow up monitoring. As needed through adaptive management, other additional measures may need to be identified and included in stormwater permits. Follow up monitoring or watershed restoration plans may determine that other additional measures are required, which would then be incorporated into Phase II permits. Additional measures that may be considered include, for example, more frequent street sweeping and inlet cleaning, or retrofit of stormwater management facilities to include nutrient removal. A more detailed discussion of stormwater source control measures follows.

On February 2, 2004 the Department promulgated two sets of stormwater rules: The Phase II New Jersey Pollutant Discharge Elimination System (NJPDES) Stormwater Rules, N.J.A.C. 7:14A and the Stormwater Management Rules, N.J.A.C. 7:8

The Phase II NJPDES rules for the Municipal Stormwater Regulation Program require municipalities, highway agencies, and regulated "public complexes" to develop stormwater management programs consistent with the NJPDES permit requirements. The stormwater discharged through "municipal separate storm sewer systems" (MS4s) is regulated under the Department's Phase II NJPDES stormwater rules. Under these rules and associated general permits, Tier A municipalities are required to implement various control measures that should substantially reduce phosphorus loadings in the impaired watersheds. These control measures include adoption and enforcement of a pet waste disposal ordinance, prohibiting the feeding of unconfined wildlife on public property, cleaning catch basins, performing good housekeeping at maintenance yards, and providing related public education and employee training. These basic requirements will provide for a measure of load reduction from existing development.

Each impaired watershed was assessed for the applicability of a mandatory low phosphorous fertilizer ordinance to aid in the reduction of phosphorus loading from nonpoint sources. If the watershed contained a high percentage of agricultural land uses, it was determined that the greatest nonpoint source reductions would be achieved through the implementation of agricultural BMPs, and therefore the low phosphorus fertilizer ordinance for urban land uses was not required as an additional measure. However, in those subwatersheds which contained a small percentage of agricultural land uses, and a high percentage of urban land uses, it was determined that the low phosphorus fertilizer ordinance was necessary in order to effectively reduce the phosphorus load originating from the urban land uses.

In the Big Timber Creek Watershed it was determined that the low phosphorus fertilizer ordinance was required based on the guidelines provided above.

The municipalities identified in Appendix B as needing an additional measure will be required to adopt an ordinance as an additional measure that prohibits the outdoor application of fertilizer other than low phosphorus fertilizer, consistent with a model ordinance provided by the Department. Fertilizer does not include animal or vegetable manure or compost. This model ordinance has been posted on www.njstormwater.org. The additional measure is as follows:

> *Low Phosphorus Fertilizer Ordinance*
>
> Minimum Standard – Municipalities as noted in Appendix B shall adopt and enforce an ordinance, consistent with a model ordinance provided by the Department, to prohibit the outdoor application of fertilizer other than low phosphorus fertilizer, except:
>
> Any application of fertilizer at a commercial farm that is exempted by the Right to Farm Act, N.J.S.A. 4:1C-1 et seq.
>
> Any application of fertilizer needed for establishing new vegetation after land disturbance in accordance with the requirements established under the Soil Erosion and Sediment Control Act, N.J.S.A. 4:24-39 et seq. and implementing rules.
>
> Measurable Goal - Municipalities as noted in Appendix B shall certify annually that they have met the Low Phosphorus Fertilizer Ordinance minimum standard.
>
> Implementation - Within 6 months from adoption of the TMDL, municipalities listed in Appendix B shall have fully implemented the Low Phosphorus Fertilizer Ordinance minimum standard.

The Stormwater Management Rules have been updated for the first time since their original adoption in 1983. These rules establish statewide minimum standards for stormwater management in new development, and the ability to analyze and establish region-specific performance standards targeted to the impairments and other stormwater runoff related issues within a particular drainage basin through regional stormwater management plans. The Stormwater Management Rules are currently implemented through the Residential Site Improvement Standards (RSIS) and the Department's Land Use Regulation Program (LURP) in the review of permits such as freshwater wetlands, stream encroachment, CAFRA, and Waterfront Development.

The Stormwater Management Rules focus on the prevention and minimization of stormwater runoff and pollutants in the management of stormwater. The rules require every project to evaluate methods to prevent pollutants from becoming available to stormwater runoff and to design the project to minimize runoff impacts from new development through better site design, also known as low impact development. Some of the issues that are required to be assessed for the site are the maintenance of existing vegetation, minimizing and disconnecting impervious surfaces, and pollution prevention techniques. In addition, performance standards are established to address existing groundwater that contributes to baseflow and aquifers, to prevent increases to flooding and erosion, and to provide water quality treatment through stormwater management measures for TSS and nutrients.

As part of the requirements under the municipal stormwater permitting program, municipalities are required to adopt and implement municipal stormwater management plans and stormwater control ordinances consistent with the requirements of the stormwater management rules. As such, in addition to changes in the design of projects regulated through the RSIS and LURP, municipalities will also be updating their regulatory requirements to provide the additional protections in the Stormwater Management Rules within approximately two years of the issuance of the NJPDES General Permit Authorization.

Furthermore, the New Jersey Stormwater Management Rules establish a 300-foot special water resource protection area (SWRPA) around Category One (C1) waterbodies and their intermittent and perennial tributaries, within the HUC 14 subwatershed. In the SWRPA, new development is typically limited to existing disturbed areas to maintain the integrity of the C1 waterbody. C1 waters receive the highest form of water quality protection in the state, which prohibits any measurable deterioration in the existing water quality. There are no C1 waters located within the impaired watersheds of the stream segments addressed in this document. Definitions for surface water classifications, detailed segment description, and designated uses may be found in various amendments to the Surface Water Quality Standards at www.state.nj.us/dep/wmm/sgwqt/sgwqt.html.

Agricultural and other measures

Generic management strategies for nonpoint source categories, beyond those that will be implemented under the Phase II stormwater management program, and responses are summarized below.

Table 20 Nonpoint source management measures

Source Category	Responses	Potential Responsible Entity	Possible Funding options
Human Sources	Septic system management programs	Municipalities, residents, watershed stewards, property owner	319(h), State sources
Non-Human Sources	Goose management programs, riparian buffer restoration	Municipalities, residents, watershed stewards, property owner	319(h), State sources
Agricultural practices	Develop and implement conservation plans or resource management plans	Property owner	EQIP, CRP, CREP

Human and Non-Human measures

Where septic system service areas are located in close proximity to impaired waterbodies, septic surveys should be undertaken to determine if there are improper effluent disposal practices that need to be corrected. Septic system management programs should be implemented in municipalities with septic system service areas to ensure proper design, installation and maintenance of septic systems. Where resident goose populations are excessive, community based goose management programs should be supported. Through stewardship programs, areas such as commercial/corporate lawns should be converted to alternative landscaping that minimizes goose habitat and areas requiring intensive landscape maintenance. Where existing developed areas have encroached on riparian buffers, riparian buffer restoration projects should be undertaken where feasible.

Agricultural measures

Several programs are available to assist farmers in the development and implementation of conservation management plans and resource management plans. The Natural Resource Conservation Service is the primary source of assistance for landowners in the development of resource management pertaining to soil conservation, water quality improvement, wildlife habitat enhancement, and irrigation water management. The USDA Farm Services Agency performs most of the funding assistance. All agricultural technical assistance is coordinated through the locally led Soil Conservation Districts. The funding programs include:

> **The Environmental Quality Incentive Program (EQIP**) is designed to provide technical, financial, and educational assistance to farmers/producers for conservation practices that address natural resource concerns, such as water quality. Practices under this program include integrated crop management, grazing land management, well sealing, erosion control systems, agri-chemical handling facilities, vegetative filter strips/riparian buffers, animal waste management facilities and irrigation systems.

The Conservation Reserve Program (CRP) is designed to provide technical and financial assistance to farmers/producers to address the agricultural impacts on water quality and to maintain and improve wildlife habitat. CRP practices include the establishment of filter strips, riparian buffers and permanent wildlife habitats. This program provides the basis for the Conservation Reserve Enhancement Program (CREP).

Conservation Reserve Enhancement Program (CREP) The New Jersey Departments of Environmental Protection and Agriculture, in partnership with the Farm Service Agency and Natural Resources Conservation Service, signed a $100 million CREP agreement earlier this year. This program matches $23 million of State money with $77 million from the Commodity Credit Corp. within USDA. Through CREP, financial incentives are offered for agricultural landowners to voluntarily implement conservation practices on agricultural lands. NJ CREP will be part of the USDA's Conservation Reserve Program (CRP). There will be a ten-year enrollment period, with CREP leases ranging between 10-15 years. The State intends to augment this program to make these leases permanent easements. The enrollment of farmland into CREP in New Jersey is expected to improve stream health through the installation of water quality conservation practices on New Jersey farmland.

Implementation Projects

WMA 17

- The Gloucester County Department of Parks and Recreation received $19,000 in 319(h) funding in FY 2000 for a Backyard BMPs and Wildlife Habitat Project. This project encouraged residents to manage their properties in a manner that would improve water quality and provide habitat for local wildlife.

- The Salem County Department of Planning received $101,000 in 319(h) funding in FY 2000 to develop a Salem County Greenkeepers Plan.

- Rutgers Univeristy in cooperation with Rutgers Cooperative Extension and Cumberland County Soil Conservation District completed the Upper Cohansey Watershed Management Project. This study focused on the approximately two miles of the Cohansey River located in Alloway Township, Salem County and Upper Deerfield Township, Cumberland County, from Beal Road in Salem County to Seeley Pond in Cumberland County. The objective of the Upper Cohansey River Watershed Management Project was to monitor water quality, identify locations where water quality was degraded, and to enhance water quality through the adoption of conservation and management practices adapted to nursery and other agricultural operations. Surface water quality was monitored and evaluated at four locations in the Upper Cohansey River Watershed. A nursery operation was monitored and evaluated to determine its impact on water quality prior to and after a tailwater recovery system was installed. The locations of non-point source contaminants were identified, and options were developed to reduce non-point source contaminants through the development and adoption of attenuation procedures. Conservation practices have been installed and continue to be installed in areas where agricultural non-point sources have been identified.

Priority Stream Segment Restoration Plans

In addition to the generic and specific, current and future implementation measures identified above, the Department, through its watershed management program, is undertaking the development of watershed restoration plans for priority stream segments. These restoration plans will identify specific measures and the means to accomplish them, beyond those identified in this TMDL report, that will assist in attainment of the required load reductions. Due to the number of TMDLs recently generated, the Department must prioritize which stream segments will be the focus of initial consideration. The Department's nutrient policy states that, "Except as due to natural conditions, nutrients shall not be allowed in concentrations that cause objectionable algal densities, nuisance aquatic vegetation, abnormal diurnal fluctuations in dissolved oxygen or pH, changes to the composition of aquatic ecosystems, or otherwise render the water unsuitable for the designated uses (N.J.A.C. 7:9B-1.5(g)3)." With respect to nutrient TMDLs, the initial priority will be given to those streams where use impairments exist in the impaired stream or downstream lakes, beyond simple exceedance of the water quality criterion. Other priority considerations include:

- Headwater area;
- Proximity to drinking water supply;
- Proximity to recreation area;
- Possibility of adverse human health conditions;
- Proximity to a lake intake;
- Existence of eutrophication;
- Phosphorus is identified as the limiting nutrient;
- Existence of use impairments;
- Ability to create a measurable change;
- Probability of human source;
- Stream Classifications;
- High success level.

9.0 Reasonable Assurance

Commitment to carry out the activities described in the implementation plan to reduce phosphorus loads provides reasonable assurance that the SWQS will be attained for phosphorus in the impaired segments. Follow-up monitoring will identify if the strategies implemented are completely, or only partially successful. It will then be determined if other management measures can be implemented to fully attain the SWQS or if it will be necessary to consider other approaches, such as use attainability.

10.0 Public Participation

The Water Quality Management Planning Rules at NJAC 7:15-7.2 require the Department to initiate a public process prior to the development of each TMDL and to allow public input to the Department on policy issues affecting the development of the TMDL. Further, the Department shall propose each TMDL as an amendment to the appropriate area-wide water quality management plan in accordance with procedures at N.J.A.C. 7:15-3.4(g).). Electronic maps showing the spatial extent of the impaired segments and a PowerPoint presentation describing the TMDL process and method used were posted online at http://www.state.nj.us/dep/watershedmgt/tmdl_segments.htm on June 1st, 2005 and public comment was solicited.

In accordance with N.J.A.C. 7:15–7.2(g), these TMDLs were proposed by the Department as an amendment to the Lower Delaware, Monmouth County and the Tri-County WQMPs. The notice proposing the TMDLs was published on July 5, 2005 in the New Jersey Register and in Burlington County Times, The Asbury Park Press, Gloucester County Times, Today's Sunbeam, and the Bridgeton Evening News. Notice of the proposal and the hearing was also provided to affected municipalities and DPAs. The TMDL documents were made available at the Department, upon request by mail, and on the Department's website. The Department conducted non-adversarial public hearings on August 10, 2005 and August 11, 2005 at Rutgers Cooperative Extension Salem County in Woodstown, New Jersey and the Cherry Hill Department of Recreation, Cherry Hill, NJ. Each hearing was preceded by an informational presentation explaining the development of the TMDLs. The public comment period ended on August 26, 2005.

Department initiated changes include the following:

1. The New Jersey Environmental Management System (NJEMS), which contains NJPDES permitted facility information evaluated during TMDL development, has been listed under "Data Sources". This has been added to the document.
2. Addition of the priority designation for the subject TMDLs on Sublist 5 of the Integrated List.
3. Addition of an addendum demonstrating the methodology to convert the percent reductions obtained from applying FIRE to percent reductions per land use category.
4. Addition of an explanation regarding selection of municipalities that will be required to adopt a low phosphorus fertilizer ordinance.
5. Addition of a column identifying existing loads in the tables of load allocation for each segment.

One comment letter was received on the proposed TMDLs, from Don Kirchhoffer, New Jersey Conservation Foundation. Fourteen people attended the public hearing on August 10, 2005 (John Brandt, Gary Ziegler, Robert Widdifield, David Lee, Dan Mull, Wil Ward, Nancy Norton, Mil Yonker, Don Kirchhoffer, John Bibeau, George Bradford, Jay Perry, Bernie Lodge, Jasen Berkowitz) ; 6 testified (John Brandt, Wil Ward, John Bibeau, George Bradford, Bernie Lodge, Don Kirchhoffer) no members of the public attended the public hearing on August 11, 2005.

A summary of the comments to the proposal, and the Department's response to the comments follows. The number in parentheses following each comment corresponds to the number of the commenter below.

Oral testimony (August 10, 2005):

1. George W. Bradford
   Municipality of Oldmans
   P.O. Box 416
   Pedricktown, NJ 08067

2. John Brandt
   Citizen
   266 Shell Rd
   Carney's Point, NJ 08069

3. John Bibeau
   CP Sewage
   189 Delaware
   Carney's Point, NJ 08069

4. Don Kirchhoffer (Written)
   New Jersey Conservation Foundation
   200 Lees Lane
   Collingswood, NJ 08108

5. Jay Perry
   Oldmans Planning Board
   290 Perkintown Rd
   Perdricktown, NJ 08067

6. Will Ward
   Greensward Farm
   56 Commissioners Pike
   Woodstown, NJ 08098

<u>Comment 1.</u> Commenter stated that the explanation at the hearing of the background analysis that preceded the proposal was impressive and offered compliments to the Department for its work. (4)

<u>Response 1.</u>
The Department appreciates the support.

Comment 2.
What will be done to implement the TMDL and eventually get phosphorus levels for Oldmans Creek to acceptable levels, given the difficulties in reducing non-point source pollution in streams flowing through agricultural and residential land. (4)

Response 2.
The Department anticipates that the reductions needed from agricultural land uses, which are extensive in the Oldmans Creek watershed, will be obtained by working with farmers, through the Department of Agriculture and the NRCS, to develop and implement, with assistance from EQIP, CRP and CREP funding sources, conservation and resource management plans that have been designed to reduce phosphorus loads to the streams. The municipalities in the Oldmans Creek watershed are categorized as Tier B under the municipal stormwater permitting program and have not been identified at this time as being required to adopt low phosphorus fertilizer ordinances. Reductions from this land use rely upon measures that will be effected through watershed management initiatives and water quality management plan amendments, such as goose management, riparian restoration and septic system management programs. If, through follow-up monitoring, it is determined that these measures are insufficient to achieve the surface water quality standards, then additional measures will be identified and implemented, as needed.

Comment 3
The Department identifies agricultural as a source but not septic systems.

Response 3
To clarify, the Department does recognize that septic systems are a potential source of phosphorus and lists them as such in the nonpoint source assessment section of the TMDL document. Areas reliant upon septic systems are identified as targets for septic system management programs, which would be implemented through water quality management plan amendments as wastewater management plans are developed for the affected area.

Comment 4
Commenter requested clarification as to why one stream segment is ranked higher than another. (2)

Response 4.
To clarify, the list that the commenter is referring to was not intended to suggest a ranking; it is a list of the stream segments for which Total Phosphorus TMDLs are being established numbered in alphabetical order.

Comment 5
Commenters do not understand why the Department is developing a TMDL for phosphorus when it has not moved forward with approving a Water Allocation Permit and a Water Quality Management Plan amendment in Carneys Point. (1, 2, 3, 5)

Response 5

The Department is obligated to develop TMDLs for impaired waterways that appear on the 303(d) list. Development of these TMDLs does not interfere with processing WQMP amendments that are administratively and technically complete. The subject amendment is deficient, but addressing this issue is outside the scope of this hearing and response. The Department's WQMP program should be contacted in this regard.

Comment 6

How will the TMDL affect farmers in the drainage area, especially those that have already implemented significant BMPs to improve water quality. (6)

Response 6

Implementation of agricultural BMPs will be accomplished in partnership with the Department of Agriculture/NRCS, identifying agricultural areas still in need of conservation or resource management plans and using funding sources such as EQIP, CRP and CREP.

Comment 7

Commenter expressed concerned about enforcement activities as well as water quality monitoring activities occuring on private agricultural lands.

Response 7

Water quality monitoring activities

References:

Eisenreich, S.J. and J. Reinfelder. 2001. The New Jersey Air Deposition Network: Interim Report. Department Environmental Sciences, Rutgers University.

BASIN - New Jersey, Version 1.0. December 2004. Prepared by Tetra-Tech, Inc.

Kratzer, Todd W., Flow-Integrated Load Reduction Estimation Technique for TMDLs, Water Environment Federation, June 2005.

National Research Council, Assessing the TMDL Approach to water quality management. National Academy Press, Washington, D.C. 2001

New Jersey Department of Environmental Protection. 2003. *'Technical Manual for Phosphorus Evaluation for NJPDES Discharge to Surface Water Permits"*, Division of Water Quality, N.J.A.C. 7:9b-1.14(c).

New Jersey Department of Environmental Protection. 2003. Total Maximum Daily Load for Phosphorus to Address 13 Eutrophic Lakes in the Lower Delaware Water Region.

New Jersey Department of Environmental Protection. 2004. Surface Water Quality Standards. Water Monitoring and Standards.

New Jersey Department of Environmental Protection. 2004. New Jersey 2004 Integrated Water Quality Monitoring and Assessment Report. Water Monitoring and Standards.

New Jersey Department of Environmental Protection. 1998. Identification and Setting of Priorities for Section 303(d) Water Quality Limited Waters in New Jersey, Office of Environmental Planning

Stiles, T., Cleland, B., Martin, C., Sullivan, A., May 2002. TMDL Development Using Load Duration Curves. Presented at an Association of State and Interstate Water Pollution Control Administrators (ASIWPCA) TMDL "Brown Bag" seminar

Sutfin, C.H. May, 2002. Memo: EPA Review of 2002 Section 303(d) Lists and Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992. Office of Wetlands, Oceans and Watersheds, U.S.E.P.A.

Thomann, R.V. and J.A. Mueller. 1987. Principles of Surface Water Quality Modeling and Control, Harper & Row, Publishers, New York.

USEPA. 1993. Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters. EPA-840-B-92-002. Washington, DC.

USEPA. 1997. Compendium of tools for watershed assessment and TMDL development. EPA841-B-97-006. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

U.S.E.P.A., 1999. Protocol for Developing Nutrient TMDLs. Watershed Branch, Assessment and Watershed Protection Division, Washington, DC.

U.S.E.P.A., 2003. Guidance for 2004 Assessment, Listing and Reporting Requirements Pursuant to Section 303(d) and 305(b) of the Clean Water Act.

Vollenweider, R.A., and J. Kerekes, 1982. Eutrophication of Waters: Monitoring, Assessment and Control. Organization for Economic Cooperation and Development (OECD), Paris. 156 p.

Wayland, R.H. III. November 22, 2002. Memo: Establishing Total Maximum Daily Load (TMDL) Wasteload Aloocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs. Office of Wetlands, Oceans and Watersheds, U.S.E.P.A.

Appendices

Appendix A: Database of Phosphorus Export Coefficients

In December 2001, the Department concluded a contract with the USEPA, Region 2, and a contracting entity, TetraTech, Inc., the purpose of which was to identify export coefficients applicable to New Jersey. As part of that contract, a database of literature values was assembled that includes approximately four-thousand values accompanied by site-specific characteristics such as location, soil type, mean annual rainfall, and site percent-impervious. In conjunction with the database, the contractor reported on recommendations for selecting values for use in New Jersey. Analysis of mean annual rainfall data revealed noticeable trends, and, of the categories analyzed, was shown to have the most influence on the reported export coefficients. Incorporating this and other contractor recommendations, the Department took steps to identify appropriate export values for these TMDLs by first filtering the database to include only those studies whose reported mean annual rainfall was between 40 and 51 inches per year. From the remaining studies, total phosphorus values were selected based on best professional judgment for eight land uses categories.

The sources incorporated in the database include a variety of governmental and non-governmental documents. All values used to develop the database and the total phosphorus values in this document are included in the below reference list.

Export Coefficient Database Reference List

Allison, F.E., E.M. Roller, and J.E. Adams, 1959. Soil Fertility Studies in Lysimeters Containing Lakeland Sand. Tech. Bull. 1199, U.S. Dept. of Agriculture, Washington, D.C. p. 1-62.

Apicella, G., 2001. Urban Runoff, Wetlands and Waterfowl Effects on Water Quality in Alley Creek and Little Neck Bay. TMDL Science Issues Conference, WEF Specialty Conference.

Athayde, D. N, P. E. Shelly, E. D. Driscoll, D. Gaboury and G.B. Boyd, 1983. Results of the Nationwide Urban Runoff Program: Final Report. USEPA Water Planning Division. Washington, DC.

Avco Economic Systems Corporation, 1970. Storm Water Pollution from Urban Land Activity. Rep.11034 FKL 07/70, Federal Water Qual. Adm., U.S. Dept. of Interior, Washington, D.C. p. 325.

Bannerman, R., K. Baun, M. Bohm, P. E. Hughes, and D. A. Graczyk, 1984. Evaluation of Urban Nonpoint Source Pollution Management in Milwaukee, County, Eisconsin, Report No. PB84-114164, U.S. Environmental Protection Agency, Region V, Chicago, IL.

Bengtson, R.L. and C.E. Carter, 1989. Simulating Soil Erosion in the Lower Mississippi Valley with the CREAMS Model. From: Application of Water Quality Models for Agricultural and Forested Watersheds, edited by D.B. Beasley and D.L Thomas. Southern Cooperative Series Bulletin No. 338.

Broadbent, F.E., and H.D. Chapman, 1950. A Lysimeter Investigation of Gains, Losses and Balance of Salts and Plant Nutrients in an Irrigated Soil. Soil Sci. Soc. Amer. Proc. 14:261-269.

Carter, Gail P., 1998. Estimation of Nonpoint Source Phosphorus and Nitrogen Loads in Five Watersheds in New Jersey's Atlantic Coastal Drainage Basin. Surveying and Land Information Systems, Vol. 58, no 3. pp167-177.

CH2M Hill, 2000. Technical Memorandum 1, Urban Stormwater Pollution Assessment, prepared for North Carolina Department of Environment and Natural Resources, Division of Water Quality.

Claytor, R.A. and T.R. Schueler, 1996. “Design of Stormwater Filtering Systems,” The Center for Watershed Protection, Prepared for Chesapeake Research Consortium, Inc.

Corsi, S.R., D.J. Graczyk, D.W. Owens, R.T. Bannerman, 1997. Unit-Area Loads of Suspended Sediment, Suspended Solids, and Total Phosphorus From Small Watersheds of Wisconsin. USGS FS-195-97.

Delaware Valley Regional Planning Commission, 1977. Average Pollutant Concentrations Associated with Urban Agriculture and Forest Land Use. Working Paper 5.01-1, Extent of NPS Problems.

Eck, P., 1957. Fertility Erosion Selectiveness on Three Wisconsin Soils. Ph. D. Thesis, Univ. of Wisconsin, Madison, WI.

F.X. Brown, Inc., 1993. Diagnostic-Feasibility Study of Strawbridge Lake. FXB Project Number NJ1246-01.

Frink, C.R., 1991. Estimating Nutrient Exports to Estuaries. Journal of Environmental Quality. 20:717-724.

Horner, R., B. W. Mar, L. E. Reinelt, J. S. Richey, and J. M. Lee, 1986. Design of monitoring programs for determination of ecological change resulting from nonpoint source water pollution in Washington State. University of Washington, Department of Civil Engineering, Seattle, Washington.

Horner, R.R., 1992. Water Quality Criteria/Pollutant Loading Estimation/Treatment Effectiveness Estimation. In R.W. Beck and Associates. Covington Master Drainage Plan. King County Surface Water Management Division., Seattle, WA.

Horner, Richard R., Joseph J. Skupien, Eric H. Livingston, and H. Earl Shaver, 1994. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. Prepared by the Terrene Institute, Washington, DC, in cooperation with the U.S. Environmental Protection Agency. EPA/840/B-92/002.

Johnston, W.R., F. Ittihadieh, R.M. Daum, and A.F. Pillsbury, 1965. Nitrogen and Phosphorus in Tile Drainage Effluent. Soil Sci. Soc. Amer. Proc. 29:287-289.

Knoblauch, H.C., L. Kolodny, and G.D. Brill, 1942. Erosion Losses of Major Plant Nutrients and Organic Matter from Collington Sandy Loam. Soil Sci. 53:369-378.

Loehr, R.C., 1974. Characteristics and comparative magnitude of non-point sources. Journal of WPCF 46(11):1849-1872.

Lopes, T.J., S.G. Dionne, 1998. A Review of Semivolatile and Volatile Organic Compounds in Highway Runoff and Urban Stormwater. U.S. Geological Survey, U.S. Department of Interior.

Marsalek, J., 1978. Pollution Due to Urban Runoff: Unit Loads and Abatement Measure, Pollution from Land Use Activities Reference Group. International Joint Commission, Windsor, Ontario.

McFarland, Anne M.S and L. M. Hauck, 2001. Determining Nutrient Export Coefficients and Source Loading Uncertainty Using In-stream Monitoring Data. Journal of the American Water Resources Association, pp. 223, 37. No. 1, February.

Menzel, R. G., E. D. Rhoades, A. E. Olness, and S. J. Smith, 1978. Variability of Annual Nutrient and Sediment Discharges in Runoff from Oklahoma Cropland and Rangeland. Journal of Environmental Quality, 7:401-406.

Mills, W.B., D.B. Porcella, M.J. Ungs, S.A. Gherini, K.V. Summers, L. Mok, G.L. Rupp, G.L. Bowie, 1985. Water Quality Assessment – A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water – Part I and II. EPA-600/6-85-002A&B.

Minshall, N.E., M.S. Nichols, and S.A. Witzel, 1969. Plant Nutrients in Base Flow of Streams in Southwestern Wisconsin. Water Resources. 5(3):706-713.

Mundy, C., M. Bergman, 1998. Technical Memorandum No. 29, The Pollution Load Screening Model: A tool for the 1995 District Water Management Plan and the 1996 Local Government Water Resource Atlases, Department of Water Resources, St. Johns River Water Management District.

NCDWQ, 1998. Neuse River Basinwide Water Quality Plan, Chapter 5, Section A.

Nelson, M.E., 1989. Predicting Nitrogen Concentrations in Ground Water An Analytical Model. IEP, Inc.

Northeast Florida Water Management District, 1994. St. Marks and Wakulla Rivers Resource Assessment and Greenway Protection Plan. Appendix 4.

Northern Virginia Planning District Commision, 1979. Guidebook for Screening Urban Nonpoint Pollution Management Strategies. Prepared for the Metropolitan Washington Council of Governments.

Novotny, V., H. Olem, 1994. Water Quality: Prevention, Identification, and Management of Diffuse Pollution. Van Nostrand Reinhold, NY

Omernik, J. M., 1976. The influence of land use on stream nutrient levels, US EPA January. EPA-60/3-76-014

Omni Environmental Corporation, 1991. Literature Search on Stormwater Pollutant Loading Rates. Literature cited from DVRPC 1977; Wanielista et al. 1977; Whipple and Hunter 1977; NVPDC 1980; USEPA 1983; Mills et al. 1985; Nelson 1989; Walker et al. 1989.

Omni Environmental Corporation, 1999. Whippany River Watershed Program Stormwater Model Calibration and Verification Report.

Overcash, M. R., F. J. Humenik, and J. R. Miner, 1983. Livestock Waste Management, Vol. II, CRC Press, Inc., Boca Raton, Florida.

Pacific Northwest Environmental Research Laboratory, 1974. Relationships Between Drainage Area Characteristics and Non-Point Source Nutrients in Streams. Prepared for the National Environmental Research Center, August 1974.

Panuska, J.C. and R.A. Lillie, 1995. Phosphorus Loadings from Wisconsin Watersheds: Recommended Phosphorus Export Coefficients for Agricultural and Forested Watersheds. Research Management Findings, Bureau of Research, Wisconsin Department of Natural Resources, Number 38.

Pitt, R.E., 1991. Nonpoint Source Water Pollution Management. Dep. Civil Eng., Univ. Alabama, Birmingham, AL.

Polls, Irwin and Richard Lanyon, 1980. Pollutant Concentrations from Homogeneous Land Uses. Journal of the Environmental Engineering Division.

Prey, J., D. Hart, A. Holy, J. Steuer, J. Thomas, 1996. A Stormwater Demonstration Project in Support of the Lake Superior Binational Program: Summary. Wisconsin Dept. of Natural Resources. (http://www.dnr.state.wi.us/org/water/wm/nps/tpubs/summary/lakesup.htm)

Rast, W. and G.F. Lee, 1978. Summary Analysis of the North American (U.S. Portion) OECD Eutrophication Project: Nutrient Loading -- Lake Response Relationships and Trophic State Indices., EPA-600/3-78-008.

Reckhow, K.H., M.N. Beaulac and J.T. Simpson, 1980. Modeling of Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients. Report No. EPA 440/5-80-011. U.S. EPA, Washington, D.C.

Ryding, S. and W. Rast, 1989. The Control of Eutrophication of Lakes and Reservoirs. Man and the Biosphere Series, United Nations Educational Scientific and Cultural Organization, Paris, France.

Schueler, T.R., 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Prepared for the Metropolitan Washington Council of Governments.

Sonzogni, W.C. and G.F. Lee, 1974. Nutrient Sources for Lake Mendota - 1972. Trans. Wisc. Acad. Sci. Arts Lett. 62:133-164.

Uchrin, C.G. and T.J. Maldanato, 1991. Evaluation of Hydrocarbons in Urban Runoff and in Detention Basins. Water Writes. Water Research Institute, Division of Coastal and Environmental Studies, Rutgers University.

United States Geological Survey, U.S. Department of the Interior, 1998. Comparison of NPDES Program Findings for Selected Cities in the United States, USGS Fact Sheet, January

USEPA, 1987. Guide to Nonpoint Source Pollution Control. U.S. EPA, Criteria and Standards Division, Washington D.C.

USEPA, 1993. Urban Runoff Pollution Prevention and Control Planning (handbook). EPA/625/R-93/004.

USEPA, 2000. Watershed Analysis and Management (WAM) Guide for Tribes. (http://www.epa.gov/owow/watershed/wacademy/wam/)

Uttormark, P.D., J.D. Chapin, and K.M. Green, 1974. Estimating nutrient loadings of lakes from non-point sources. U.S. Environmental Protection Agency, Washington, D.C. 112 p. (WRIL 160609). EPA-660/3-74-020.

Walker, J.F., 1989. Spreadsheet Watershed Modeling for Nonpoint Source Pollution Management in a Wisconsin Basin, Water Resources Bulletin, Vol. 25, no. 1, pp. 139-147.

Wanielista, M.P., Y.A. Yousef, and W.M. McLellon, 1977. Nonpoint Source Effects on Water Quality, Journal Water Pollution Control Federation, Part 3, pp. 441-451.

Washington State Department of Ecology, 2000. Stormwater Management Manual for Western Washington: Volume I Minimum Technical Requirements. Publication No. 99-11.

Weidner, R.B., A.G. Christianson, S.R. Weibel, and G.G. Robeck, 1969. Rural Runoff as a Factor in Stream Pollution. J. Water Pollution. Con. Fed. 36(7):914-924.

Whipple, W. and J.V. Hunter, 1977. Nonpoint Sources and Planning for Water Pollution Control. Journal Water Pollution Control Federation. pp. 15-23.

Whipple, W., et al., 1978. Effect of Storm Frequency on Pollution from Urban Runoff, J. Water Pollution Control Federation. 50:974-980.

Winter, J.G. and H.C. Duthie, 2000. Export Coefficient Modeling to assess phosporus loading in an urban watershed. Journal of American Water Resources Association. Vol. 36 No. 5.

Zanoni, A.E., 1970. Eutrophic Evaluation of a Small Multi-Land Use Watershed. Tech. Completion Rep. OWRR A-014-Wis., Water Resources Center, Univ. of Wisconsin, Madison, WI.

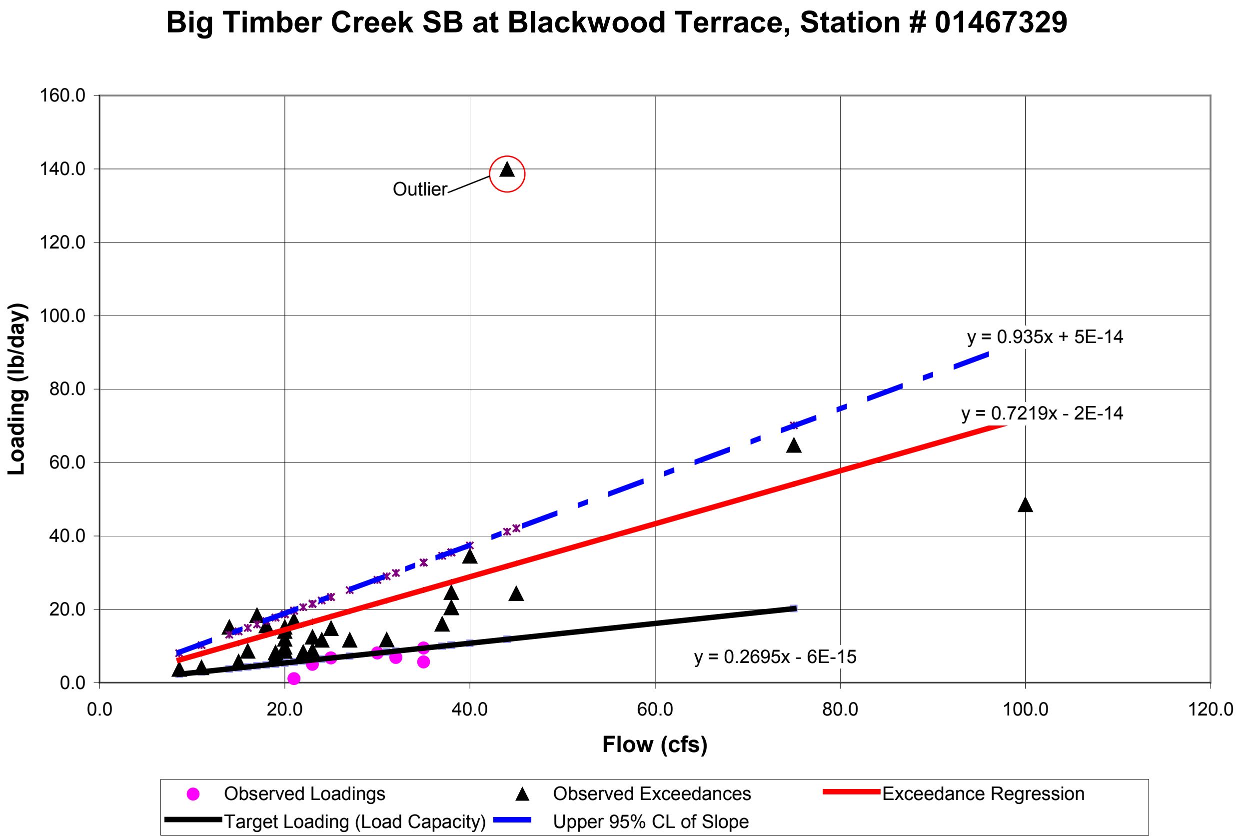
Appendix B: Tier A and B Municipality Designations

WMA	Segment	NJPDES Permit Number	Municipality	Discharge Type	Additional Measures
17	Barrett Run	NJG0154903	Hopewell TWP	Tier B	None
		NJG0154962	Stow Creek TWP	Tier B	None
		NJG0154857	Shiloh Boro	Tier B	None
		NJG0147826	Bridgeton City	Tier A	None
17	Cohansey at Seeley	NJG0155110	Upper Pittsgrove Twp	Tier B	None
		NJG0152731	Alloway Twp	Tier B	None
		NJG0149624	Upper Deerfield Twp	Tier B	None
		NJG0154903	Hopewell Twp	Tier B	None
		NJG0154962	Stow Creek Twp	Tier B	None
		NJG0154857	Shiloh Boro	Tier B	None
18	Big Timber	NJG0152153	Deptford Township	Tier A	Low phosphorus ordinance
		NJG0148695	Gloucester Township	Tier A	Low phosphorus ordinance
		NJG0153664	Washington Township	Tier A	Low phosphorus ordinance
18	Oldmans Creek	NJG0150738	Woolwich Twp	Tier B	None
		NJG0152226	South Harrison Twp	Tier B	None
		NJG0152714	Pilesgrove Twp	Tier B	None
20	Blacks Creek	NJG0153559	Chesterfield Twp	Tier B	None
	Blacks Creek	NJG0148156	North Hanover Twp	Tier B	None

	Blacks Creek	NJG0	Upper Freehold Twp	Tier B	None

Appendix C: Big Timber Outlier

The data point that occurred on May 31, 1990 which consisted of a TP concentration of 0.59 mg/l and a flow of 44 cfs, was tested and found to be an outlier. This data point lies outside both the 95 % and the 99% confidence limit. Figure 1.



Appendix D: Total Phosphorus Data by sampling date, expressed in mg/L

Barrett Run at Bridgeton

11/29/2000	0.036
3/7/2001	0.028
5/30/2001	0.197
8/14/2001	0.049
12/6/2001	0.032
2/14/2002	0.028
5/23/2002	0.153
9/4/2002	0.049

Cohansey River at Seeley

1/31/1990	0.14
4/24/1990	0.03
5/23/1990	0.05
7/19/1990	0.09
8/9/1990	0.1
10/25/1990	0.02
1/28/1991	0.02
4/15/1991	0.02
5/22/1991	0.08
8/6/1991	0.06
11/12/1991	0.02
2/13/1992	0.05
4/27/1992	0.03
6/1/1992	0.07
7/21/1992	0.11
11/19/1992	0.08
2/17/1993	0.11
4/13/1993	0.06
6/17/1993	0.07
8/11/1993	0.08
11/4/1993	0.05
2/16/1994	0.09
4/13/1994	0.1
6/22/1994	0.05
8/11/1994	0.05
11/9/1994	0.03
2/16/1995	0.09
4/5/1995	0.01
5/31/1995	0.03
7/27/1995	0.04
11/2/1995	0.05
2/20/1996	0.07
3/26/1996	0.05

6/3/1996	0.08
7/24/1996	0.06
11/6/1996	0.02
1/23/1997	0.02
3/18/1997	0.01
6/4/1997	0.03
6/18/1997	0.13
8/6/1997	0.07
12/11/1997	0.07
3/11/1998	0.1
6/2/1998	0.03
8/27/1998	0.04
12/8/1998	0.05
2/16/1999	0.04
5/20/1999	0.12
8/18/1999	0.08
11/23/1999	0.056
2/8/2000	0.062
5/15/2000	0.038
8/21/2000	0.079
11/27/2000	0.058
2/26/2001	0.048
5/22/2001	0.115
8/29/2001	0.077
12/11/2001	0.043
2/14/2002	0.035
6/18/2002	0.114
8/22/2002	0.155
11/21/2002	0.104
2/26/2003	0.127
5/20/2003	0.03
9/8/2003	0.071

Big Timber at Blackwood Terrace

1/31/1990	0.12
4/5/1990	0.10
5/31/1990	0.59
7/23/1990	0.10
8/22/1990	0.08
10/10/1990	0.07
1/28/1991	0.04
3/21/1991	0.07
5/21/1991	0.09
8/1/1991	0.13
10/22/1991	0.07
1/22/1992	0.069
4/16/1992	0.07
5/21/1992	0.14

7/22/1992	0.16
11/17/1992	0.10
1/20/1993	0.07
4/19/1993	0.08
6/14/1993	0.10
8/3/1993	0.20
10/25/1993	0.08
2/15/1994	0.08
4/18/1994	0.16
6/23/1994	0.20
8/9/1994	0.15
11/14/1994	0.07
2/1/1995	0.01
4/4/1995	0.11
5/30/1995	0.07
7/31/1995	0.08
11/21/1995	0.05
2/21/1996	0.16
4/2/1996	0.09
6/5/1996	0.11
7/25/1996	0.09
11/6/1996	0.05
1/21/1997	0.03
3/25/1997	0.05
6/2/1997	0.10
6/16/1997	0.04
8/4/1997	0.08

Oldmans Creek at Porches Mill

2/5/1990	0.15
3/29/1990	0.02
5/29/1990	0.13
7/30/1990	0.12
8/8/1990	0.07
10/23/1990	0.12
2/4/1991	0.06
3/25/1991	0.06
5/30/1991	0.05
8/7/1991	0.07
10/24/1991	0.04
2/6/1992	0.05
4/16/1992	0.03
6/2/1992	0.17
8/3/1992	0.06
12/3/1992	0.07
2/17/1993	0.15
4/20/1993	0.3

6/21/1993	0.56
8/2/1993	0.05
11/4/1993	0.05
2/17/1994	0.07
4/14/1994	0.47
6/22/1994	0.03
8/10/1994	0.13
11/17/1994	0.04
2/15/1995	0.09
3/27/1995	0.06
5/30/1995	0.12
8/1/1995	0.08
11/20/1995	0.06
2/21/1996	0.16
3/28/1996	0.07
5/30/1996	0.08
7/24/1996	0.08
11/13/1996	0.04
1/27/1997	0.11
3/25/1997	0.03
6/3/1997	0.1
8/7/1997	0.07

Blacks Creek at Chesterfield-Georgetown Rd

12/21/2000	0.32
2/22/2001	0.1
5/14/2001	0.137
8/16/2001	0.182
11/28/2001	0.093
2/5/2002	0.088
5/7/2002	0.143
8/22/2002	0.196
11/20/2002	0.137
2/10/2003	0.07
5/20/2003	0.126
8/18/2003	0.23

Appendix E Is Phosphorus Limiting?

The limiting nutrient can be evaluated using available nutrient concentrations by using the following thresholds to exclude phosphorus as the limiting nutrient (The acronyms TIN and DRP refer to biologically-available forms of nitrogen and phosphorus, respectively: TIN = dissolved nitrite, nitrate and ammonia; DRP = dissolved reactive phosphorus):

IF	[DRP] $\geq$ 0.05 mg/l
OR	TIN/DRP $\leq$ 5
THEN	phosphorus can be excluded as the limiting nutrient

Figures 2 and 3 show examples of how to plot pairs of TP and DRP data along a TIN/DRP axis to visually evaluate the phosphorus limitation thresholds at a particular location. By making the TP range twice the DRP range, the thresholds of 0.1 mg/l TP and 0.05 mg/l DRP coincide, simplifying the interpretation. Episodes when TP > 0.1 mg/l AND DRP $\leq$ 0.05 mg/l and TIN/DRP $\geq$ 5 can be identified by seeing TP in the upper right quadrant while DRP is in the lower right quadrant. If phosphorus cannot be excluded as the limiting nutrient for more than 10% of the samples that exceed the 0.1 mg/l threshold (a minimum of 2 samples), then the 0.1 mg/l criterion is applicable.

Figure 2: Example of site where 0.1 mg/l criterion is applicable and exceeded

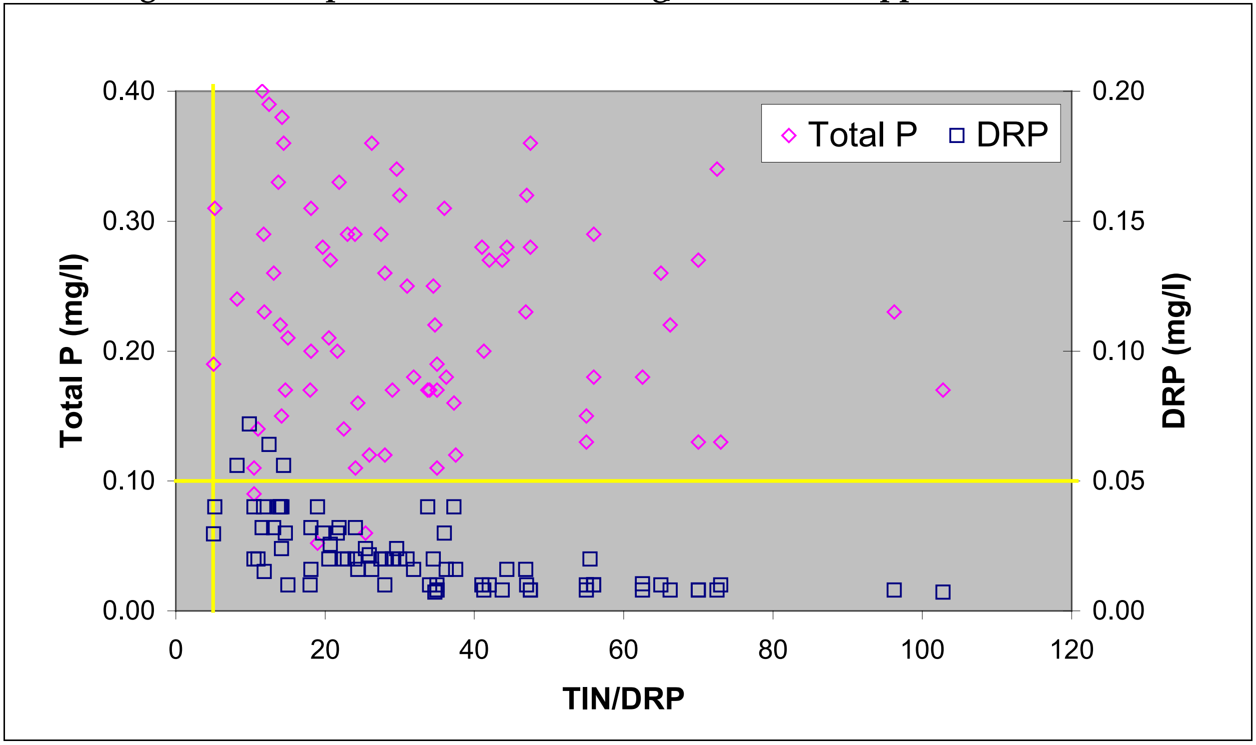
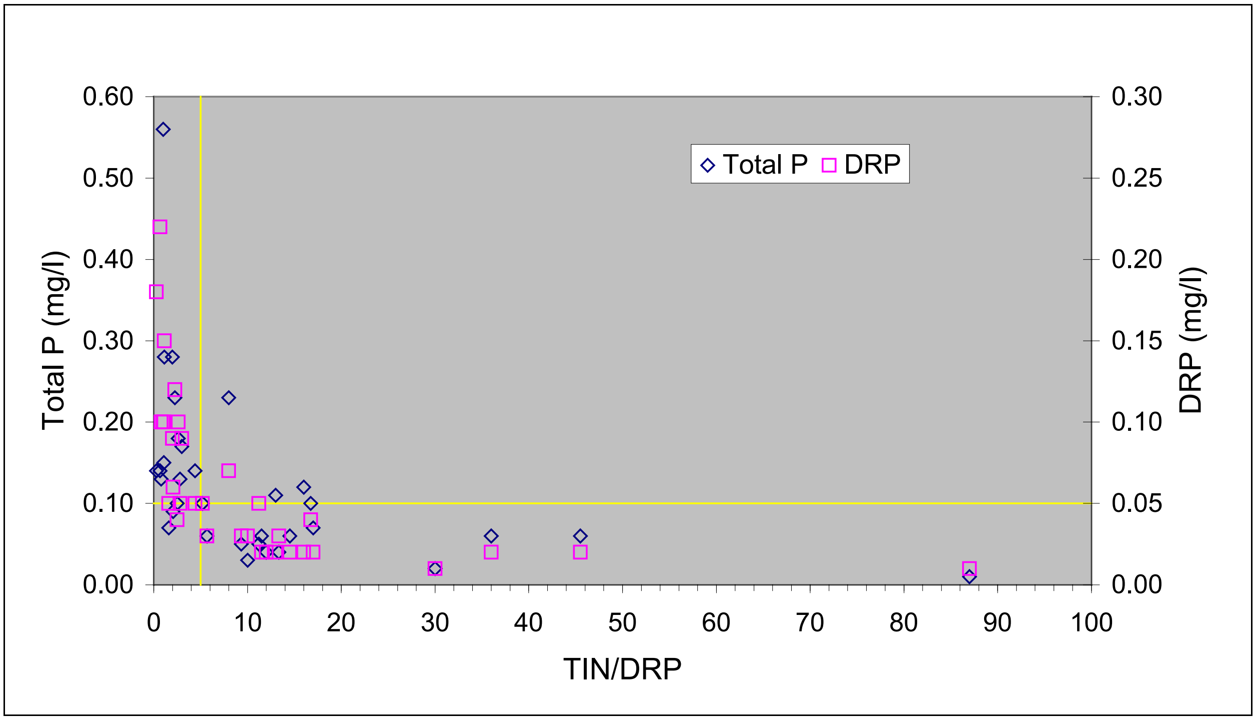


Figure 3: Example of site where phosphorus is not limiting algal growth when 0.1 mg/l threshold is exceeded



Appendix F Methodology for Applying Percentage reductions to Land Use Loadings

The outputs of the FIRE method establish a percent reduction needed to meet the target load (that which will attain the applicable SWQS) and a margin of safety. These values are then applied to the existing land use loadings within the impaired streamshed to determine the load allocations for various land uses.

Existing loads are determined as follows. GIS is used to determine the area in acres of each of the land uses in the impaired watershed. The loading coefficients identified in the TMDL report are applied to the acres of land use to calculate an existing load for each land use in the impaired streamshed. Existing loads for point sources, other than stormwater point sources (essentially, wastewater treatment plants), if any, in the impaired streamshed are calculated using the average flow and concentration data from the discharge monitoring reports for the facilities. This load is added to the existing TP load calculated from land use.

To calculate the overall target load the percent reduction (the difference between the target load and the exceedance regression) as determined through FIRE is applied to the total existing load. The load associated with the margin of safety as determined through FIRE (the difference between the 95% confidence interval and the exceedance regression) is then removed from the overall target load (target loading line), leaving a reduced amount of loading now available to allocate. The load from any discharges is determined by taking the full permitted flow and assigning an effluent concentration. This load is also removed from the potential allocable load leaving a further reduced amount of allocable load for land uses.

There are a number of land uses from which a reduction in current load cannot be taken. These land uses include Forest, Water, Wetlands, and Barren land. The current loads for these land uses as calculated for existing load are carried over entirely as a component of the future load allocations. Therefore, for these land uses, the existing load and future load are equal. The sum of the non-reduceable land use loads is then removed from the reduced allocable land use load leaving the final allocable land use load to be allocated among the land uses that are amenable to load reduction (urban and agricultural). This final allocable land use load is then applied to each land use category in proportion to the amount of each land use in the watershed.

The final percent reduction is calculated by comparing the final WLA or LA for each land use to the existing loads of those land uses. Because of the adjustments made in removing the loads associated with the MOS, the non-reduceable land uses, and discharges, the percent reduction associated with the final allocable land use load is higher than that which appears as an output to FIRE.

Example:

Land- Use	**Existing Load**	**Percent Reduction**	**Allocation**
Agriculture	100	88.85%	11.15
Barren	15	0%	15.00
Commercial	300	88.85%	33.45
Forest	125	0%	125.00
Low Density	40	88.85%	4.46
High Density	250	88.85%	27.88
Other Urban	15	88.85%	1.67
Water	100	0%	100.00
Wetlands	30	0%	30.00
Discharger A	25	0%	25.00
MOS			95.87
TOTAL	**1000**		**469.5**

Output from FIRE

Margin of Safety		**= 20.42%**
Target Loading		**= 46.95%**

Target Load

Target Load = 0.4695 * Existing Load
= 0.4695 * 1000
Target Load = 469.5 lb/yr

Margin of Safety

MOS = 0.2042* Target Load
= 0.2042* 469.5 lb/yr
= 95.87 lb/yr

Allocable Load

AL = Target Load – MOS
= 469.5 –95.87
= 373.63 lb/yr

Allocable Land Use Load

ALUL = AL- Future Discharge Load
= 373.6 – 25
= 348.63 lb/yr

SUM of Non Reducable Land Use Loads

Non Reduceable Land use Load = Existing Forest + Water & Wetlands Load + Barren Land Load
= 125 + 100 + 30 + 15
= 270 kg/yr

Final Allocable Land use Load

Final Allocable Land use Load = Allocable Land use Load – Non Reduceable Land use Load
= 348.6 – 270
= 78.6 lb/yr

Final Percent Reduction

Final Percent Reduction = 1 – (Final allocable Land use load / Sum of existing load of reducable land uses)
= 1 – (78.6/ 15+250+40+300+100)
= 1 – (78.6/705)
= 0.8885
= 88.85 %

Amendment to the Atlantic, Cape May, Lower Delaware, Lower Raritan-Middlesex, Mercer, Monmouth, Northeast, Ocean, Sussex, Tri-County, Upper Delaware and Upper Raritan Water Quality Management Plans

Total Maximum Daily Load for Mercury Impairments Based on Concentration in Fish Tissue Caused Mainly by Air Deposition to Address 122 HUC 14s Statewide

Proposed: June 15, 2009
Established: September 10, 2009
Approved: September 25, 2009
Adopted: June 10, 2010

New Jersey Department of Environmental Protection
Division of Watershed Management
P.O. Box 418
Trenton, New Jersey 08625-0418

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Executive Summary

In accordance with Section 305(b) and 303(d) of the Federal Clean Water Act (CWA), the State of New Jersey, Department of Environmental Protection (Department or NJDEP) published the *2008 Integrated Water Quality Monitoring and Assessment Report*, which provides information on water quality conditions and trends, and various management strategies and actions being employed to protect and improve water quality. The report includes the List of Water Quality Limited Waters, also known as the 303(d) List, which identifies waters that do not attain an applicable designated use because of a known pollutant and for which a TMDL must be established. On March 3, 2008, the Department proposed the *2008 List of Water Quality Limited Waters* (40NJR4835(c)) as an amendment to the Statewide Water Quality Management Plan, pursuant to the Water Quality Planning Act at N.J.S.A.58:11A-7 in accordance with the Water Quality Management Planning rules at N.J.A.C. 7:15-6.4(a). The Environmental Protection Agency has approved this list. The *2008 List of Water Quality Limited Waters* identifies 256 waters as impaired with respect to mercury, as indicated by the presence of mercury concentrations in fish tissue in excess of New Jersey fish consumption advisories and/or not complying with the Surface Water Quality Standards (SWQS) for mercury at N.J.A.C. 7:9B.

A TMDL has been developed to address mercury impairment in 122 waters identified in Table 1 below. These are waters whose main source of contamination is air deposition. Waters that are tidal, where there are other significant sources of mercury or where cooperative efforts have been or are expected to be undertaken are not addressed in this TMDL pending additional study.

Table 1. Assessment Units Covered by this TMDL

Watershed Management Area (WMA)	Assessment Unit ID	Waterbody Name	2006 Integrated list	2008 Integrated list
01	02040104090020	Clove Brook (Delaware R)	Sublist 5	Sublist 5
01	02040104130010	Little Flat Brook (Beerskill and above)	Sublist 5	Sublist 5
01	02040104140010	Big Flat Brook (above Forked Brook)	Sublist 5	Sublist 5
01	02040105030020	Swartswood Lake and tribs	Sublist 5	Sublist 5
01	02040105030030	Trout Brook	Sublist 5	Sublist 5
01	02040105050040	Yards Creek	Sublist 3	Sublist 3*
01	02040105090040	Mountain Lake Brook	Sublist 5	Sublist 5
01	02040105140040	Merrill Creek	Sublist 5	Sublist 5
01	02040105140060	Pohatcong Ck (Springtown to Merrill Ck)	Sublist 3	Sublist 3*
01	02040105150020	Lake Hopatcong	Sublist 5	Sublist 5
01	02040105150060	Cranberry Lake / Jefferson Lake & tribs	Sublist 5	Sublist 5
02	02020007040040	Highland Lake/Wawayanda Lake	Sublist 5	Sublist 5
03	02030103050020	Pacock Brook	Sublist 5	Sublist 5
03	02030103050030	Pequannock R (above OakRidge Res outlet)	Sublist 5	Sublist 5
03	02030103050040	Clinton Reservior/Mossmans Brook	Sublist 5	Sublist 5

03	02030103050060	Pequannock R(Macopin gage to Charl'brg)	Sublist 5	Sublist 5
03	02030103050080	Pequannock R (below Macopin gage)	Sublist 5	Sublist 5
03	02030103070030	Wanaque R/Greenwood Lk(aboveMonks gage)	Sublist 5	Sublist 5
03	02030103070050	Wanaque Reservior (below Monks gage)	Sublist 5	Sublist 5
03	02030103110020	Pompton River	Sublist 5	Sublist 5
06	02030103010170	Passaic R Upr (Rockaway to Hanover RR)	Sublist 5	Sublist 5
06	02030103020040	Whippany R(Lk Pocahontas to Wash Val Rd)	Sublist 5	Sublist 5
06	02030103020080	Troy Brook (above Reynolds Ave)	Sublist 5	Sublist 5
06	02030103030030	Rockaway R (above Longwood Lake outlet)	Sublist 5	Sublist 5
06	02030103030040	Rockaway R (Stephens Bk to Longwood Lk)	Sublist 5	Sublist 5
06	02030103030070	Rockaway R (74d 33m 30s to Stephens Bk)	Sublist 5	Sublist 5
06	02030103030090	Rockaway R (BM 534 brdg to 74d 33m 30s)	Sublist 5	Sublist 5
06	02030103030110	Beaver Brook (Morris County)	Sublist 5	Sublist 5
06	02030103030140	Rockaway R (Stony Brook to BM 534 brdg)	Sublist 5	Sublist 5
06	02030103030150	Rockaway R (Boonton dam to Stony Brook)	Sublist 5	Sublist 5
06	02030103030170	Rockaway R (Passaic R to Boonton dam)	Sublist 5	Sublist 5
08	02030105010030	Raritan River SB(above Rt 46)	Sublist 5	Sublist 5
08	02030105010040	Raritan River SB(74d 44m 15s to Rt 46)	Sublist 3	Sublist 3*
08	02030105010050	Raritan R SB(LongValley br to 74d44m15s)	Sublist 3	Sublist 3*
08	02030105010060	Raritan R SB(Califon br to Long Valley)	Sublist 3	Sublist 3*
08	02030105020040	Spruce Run Reservior / Willoughby Brook	Sublist 5	Sublist 5
08	02030105020090	Prescott Brook / Round Valley Reservior	Sublist 5	Sublist 5
08	02030105020100	Raritan R SB(Three Bridges-Prescott Bk)	Sublist 3	Sublist 3*
08	02030105040010	Raritan R SB(Pleasant Run-Three Bridges)	Sublist 3	Sublist 3*
08	02030105040040	Raritan R SB(NB to Pleasant Run)	Sublist 3	Sublist 3*
09	02030105080020	Raritan R Lwr (Rt 206 to NB / SB)	Sublist 3	Sublist 3*
09	02030105080030	Raritan R Lwr (Millstone to Rt 206)	Sublist 3	Sublist 3*
09	02030105120080	South Fork of Bound Brook	Sublist 3	Sublist 3*
09	02030105120100	Bound Brook (below fork at 74d 25m 15s)	Sublist 3	Sublist 3*
09	02030105120140	Raritan R Lwr(I-287 Piscatway-Millstone)	Sublist 5	Sublist 5
09	02030105130050	Lawrence Bk (Church Lane to Deans Pond)	Sublist 3	Sublist 3*
09	02030105130060	Lawrence Bk (Milltown to Church Lane)	Sublist 3	Sublist 3*

09	02030105140020	Manalapan Bk(incl LkManlpn to 40d16m15s)	Sublist 3	Sublist 3*
09	02030105140030	Manalapan Brook (below Lake Manalapan)	Sublist 5	Sublist 5
09	02030105160030	Duhernal Lake / Iresick Brook	Sublist 3	Sublist 3*
10	02030105090050	Stony Bk(Province Line Rd to 74d46m dam)	Sublist 3	Sublist 3*
10	02030105100130	Bear Brook (below Trenton Road)	Sublist 3	Sublist 5
10	02030105110020	Millstone R (HeathcoteBk to Harrison St)	Sublist 3	Sublist 5
10	02030105110110	Millstone R (BlackwellsMills to BedenBk)	Sublist 3	Sublist 3*
10	02030105110140	Millstone R(AmwellRd to BlackwellsMills)	Sublist 3	Sublist 3*
10	02030105110170	Millstone River (below Amwell Rd)	Sublist 3	Sublist 3*
12	02030104060020	Matawan Creek (above Ravine Drive)	Sublist 3	Sublist 3*
12	02030104060030	Matawan Creek (below Ravine Drive)	Sublist 5	Sublist 5
12	02030104070070	Swimming River Reservior / Slope Bk	Sublist 3	Sublist 3*
12	02030104070090	Nut Swamp Brook	Sublist 3	Sublist 5
12	02030104090030	Deal Lake	Sublist 3	Sublist 3*
12	02030104090080	Wreck Pond Brook (below Rt 35)	Sublist 3	Sublist 5
12	02030104100050	Manasquan R (gage to West Farms Rd)	Sublist 5	Sublist 5
13	02040301030040	Metedeconk R SB (Rt 9 to Bennetts Pond)	Sublist 5	Sublist 5
13	02040301060050	Dove Mill Branch (Toms River)	Sublist 5	Sublist 5
13	02040301070010	Shannae Brook	Sublist 5	Sublist 5
13	02040301070030	Ridgeway Br (Hope Chapel Rd to HarrisBr)	Sublist 5	Sublist 5
13	02040301070040	Ridgeway Br (below Hope Chapel Rd)	Sublist 5	Sublist 5
13	02040301070080	Manapaqua Brook	Sublist 3	Sublist 5
13	02040301070090	Union Branch (below Blacks Br 74d22m05s)	Sublist 5	Sublist 5
13	02040301080030	Davenport Branch (above Pinewald Road)	Sublist 3	Sublist 5
13	02040301090050	Cedar Creek (GS Parkway to 74d16m38s)	Sublist 5	Sublist 5
13	02040301130030	Mill Ck (below GS Parkway)/Manahawkin Ck	Sublist 3	Sublist 3*
13	02040301130050	Westecunk Creek (above GS Parkway)	Sublist 5	Sublist 5
13	02040301140020	Mill Branch (below GS Parkway)	Sublist 3	Sublist 3*
13	02040301140030	Tuckerton Creek (below Mill Branch)	Sublist 3	Sublist 3*
14	02040301150080	Batsto R (Batsto gage to Quaker Bridge)	Sublist 5	Sublist 5
14	02040301160030	Mullica River (Rt 206 to Jackson Road)	Sublist 5	Sublist 5
14	02040301160140	Mullica River (39d40m30s to Rt 206)	Sublist 5	Sublist 5
14	02040301160150	Mullica R (Pleasant Mills to 39d40m30s)	Sublist 5	Sublist 5
14	02040301180060	Oswego R (Andrews Rd to Sim Place Resv)	Sublist 3	Sublist 3*
14	02040301180070	Oswego River (below Andrews Road)	Sublist 5	Sublist 5

14	02040301190050	Wading River WB (Jenkins Rd to Rt 563)	Sublist 5	Sublist 5
14	02040301200010	Beaver Branch (Wading River)	Sublist 5	Sublist 5
14	02040301200050	Bass River EB	Sublist 3	Sublist 3*
15	02040302030020	GEHR (AC Expressway to New Freedom Rd)	Sublist 5	Sublist 5
15	02040302040050	Collings Lakes trib (Hospitality Branch)	Sublist 5	Sublist 5
15	02040302040130	GEHR (Lake Lenape to Mare Run)	Sublist 5	Sublist 5
15	02040302050120	Middle River / Peters Creek	Sublist 3	Sublist 3*
16	02040206210050	Savages Run (above East Creek Pond)	Sublist 5	Sublist 5
16	02040206210060	East Creek	Sublist 5	Sublist 5
17	02040206030010	Salem River (above Woodstown gage)	Sublist 5	Sublist 5
17	02040206070030	Canton Drain (above Maskell Mill)	Sublist 5	Sublist 5
17	02040206080050	Cohansey R (incl CornwellRun - BeebeRun)	Sublist 3	Sublist 5
17	02040206090030	Cohansey R (Rocaps Run to Cornwell Run)	Sublist 5	Sublist 5
17	02040206100060	Nantuxent Creek (above Newport Landing)	Sublist 3	Sublist 3*
17	02040206130010	Scotland Run (above Fries Mill)	Sublist 5	Sublist 5
17	02040206130040	Scotland Run (below Delsea Drive)	Sublist 5	Sublist 5
17	02040206140010	MauriceR(BlkwtrBr to/incl WillowGroveLk)	Sublist 5	Sublist 5
17	02040206150050	Muddy Run (incl ParvinLk to Palatine Lk)	Sublist 3	Sublist 3*
17	02040206180050	Menantico Creek (below Rt 552)	Sublist 3	Sublist 3*
18	02040202100020	Pennsauken Ck NB (incl StrwbrdgLk-NJTPK)	Sublist 3	Sublist 5
18	02040202110030	Cooper River (above Evesham Road)	Sublist 5	Sublist 5
18	02040202110040	Cooper R (Wallworth gage to Evesham Rd)	Sublist 5	Sublist 5
18	02040202110050	Cooper River (Rt 130 to Wallworth gage)	Sublist 5	Sublist 5
18	02040202120010	Big Timber Creek NB (above Laurel Rd)	Sublist 5	Sublist 5
18	02040202120020	Big Timber Creek NB (below Laurel Rd)	Sublist 5	Sublist 5
18	02040202120030	Big Timber Creek SB (above Lakeland Rd)	Sublist 5	Sublist 5
18	02040202120040	Big T Ck SB(incl Bull Run to LakelandRd)	Sublist 5	Sublist 5
18	02040202120050	Big Timber Creek SB (below Bull Run)	Sublist 5	Sublist 5
18	02040202120060	Almonesson Creek	Sublist 5	Sublist 5
18	02040202120090	Newton Creek (LDRV-Kaighn Ave to LT Ck)	Sublist 5	Sublist 5
18	02040202120100	Woodbury Creek (above Rt 45)	Sublist 5	Sublist 5
18	02040202130030	Chestnut Branch (above Sewell)	Sublist 5	Sublist 5
18	02040202150020	Raccoon Ck (Rt 45 to/incl Clems Run)	Sublist 3	Sublist 3*
18	02040202150040	Raccoon Ck (Russell Mill Rd to Rt 45)	Sublist 5	Sublist 5
19	02040202030050	Bucks Cove Run / Cranberry Branch	Sublist 5	Sublist 5
19	02040202050050	Friendship Ck (below/incl Burrs Mill Bk)	Sublist 3	Sublist 3*

19	02040202050060	Rancocas Creek SB(above Friendship Ck)	Sublist 3	Sublist 3*
19	02040202050080	Rancocas Ck SB (Vincentown-FriendshipCk)	Sublist 3	Sublist 3*
19	02040202050090	Rancocas Ck SB (BobbysRun to Vincentown)	Sublist 3	Sublist 3*
20	02040201090030	LDRV tribs (Assiscunk Ck to Blacks Ck)	Sublist 5	Sublist 5

* Data became available in these assessment units after the 2008 list was approved indicating fish tissue levels that would result in listing of these waters in accordance with the current listing methodology; therefore, these assessment units will also be addressed in this TMDL.

The target for the TMDL is a concentration of 0.18 μg/g in fish tissue, which is the concentration at which the recommended rate of fish consumption for the high risk population is not more than 1 meal per week of top trophic level fish. At this concentration unlimited consumption is appropriate for the general population. An overall reduction of 84.3% in existing mercury loads is required to achieve the target. In its *New Jersey Mercury Reduction Plan*, the Department outlines measures needed to achieve these reductions.

The TMDLs in this report were proposed on June 15, 2009 and, having completed the public participation process, shall be adopted by the Department as amendments to the Atlantic, Cape May, Lower Delaware, Lower Raritan-Middlesex, Mercer, Monmouth, Northeast, Ocean, Sussex, Tri-County, Upper Delaware and Upper Raritan Water Quality Management Plans in accordance with N.J.A.C. 7:15-6.4. This TMDL report was developed consistent with the United States Environmental Protection Agency's (USEPA or EPA) May 20, 2002 guidance document entitled, "Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992" (Sutfin, 2002), which describes the general statutory and regulatory requirements for approvable TMDLs, as well as EPA's more specific guidance memo for the subject type of TMDL, dated September 29, 2008 and entitled "Elements of Mercury TMDLs Where Mercury Loadings are Predominantly from Air Deposition" (Hooks, 2008).

1.0. Introduction

Mercury is a persistent, bio-accumulative toxin that can be found in solid, liquid, or vapor form. Mercury can cause a variety of harmful health effects including damage to the brain, central nervous system, and kidneys and is particularly harmful to children and pregnant and nursing women. Mercury comes from various natural and anthropogenic sources, including volcanic activity, burning of some forms of coal, use in dental procedures and manufacturing, use and disposal of products containing mercury. Most often, mercury enters the environment in gas or particulate form and is deposited on surfaces, often through precipitation, which washes deposited mercury into waterways. There it undergoes a natural chemical process and is converted to a more toxic form – methyl mercury. The methyl mercury builds up in the tissues of fish and animals, increasing its concentration as it moves up through the food chain, which results in high levels of mercury in some of the foods we eat. At certain levels, fish consumption advisories are triggered.

Mercury contamination in the environment is ubiquitous, not only in New Jersey, but worldwide. Mercury contamination is a global issue because the overwhelming source of mercury is air deposition. Consequently, mercury pollution will not be abated on a state by state basis alone, but must be controlled by regional, national and international efforts. In recognition of this, the New England Interstate Water Pollution Control Commission (NEIWPCC) established the *Northeast Regional Mercury Total Maximum Daily Load* dated October 24, 2007 (Northeast Regional TMDL), a regional TMDL for the states of Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont which addressed impairments due to mercury contamination of waterbodies where the main source of mercury contamination is air deposition. It was approved by EPA on December 20, 2007. As EPA has approved establishment of regional TMDLs for mercury impairments where the primary source is air deposition using the NEIWPCC approach, the Department has determined that it is appropriate for New Jersey to develop a similar TMDL for comparable impairments in New Jersey, not only to recommend a course of action to reduce mercury contamination in New Jersey, but to further emphasize that substantial source reductions from outside New Jersey will be needed to achieve water quality objectives. Therefore, New Jersey has developed a statewide TMDL that will complement the Northeast Regional TMDL developed for the northeast states.

In accordance with Section 303(d) of the Federal Clean Water Act (CWA) (33 U.S.C. 1315(B)), the State of New Jersey is required biennially to prepare and submit to the USEPA a report that identifies waters that do not meet or are not expected to meet Surface Water Quality Standards (SWQS) after implementation of technology-based effluent limitations or other required controls. This report is commonly referred to as the 303(d) List. In accordance with Section 305(b) of the CWA, the State of New Jersey is also required biennially to prepare and submit to the USEPA a report addressing the overall water quality of the State's waters. This report is commonly referred to as the 305(b) Report or the Water Quality Inventory Report. The Department combines these reports into the Integrated Water Quality Monitoring and Assessment Report and assigns each designated use within the assessment unit to one of five sublists. An assessment unit is listed as Sublist 1 if all designated uses are assessed and attained. (The Department does not include the fish consumption use for this sublist.) If some but not all uses are attained, an assessment unit is placed on Sublist 2 for attained uses. If the Department did not have data to assess a use, the assessment unit is placed on Sublist 3 for that use. If a use is not attained, the assessment unit will be placed on Sublist 5, or Sublist 4 if there is an approved TMDL, there are other enforceable management measures in effect or the impairment is due to pollution, not a pollutant. Sublist 5 constitutes the list of waters for which a TMDL may be required, also known as the 303(d) list. In accordance with the *2008 Integrated Water Quality Monitoring and Assessment Methods*, although there is a State-wide fish consumption advisory for mercury, only waters with actual fish tissue monitoring data that exceed the threshold which results in a consumption restriction (greater than 0.07 mg/kg) are placed on Sublist 5. All other assessment units are listed on Sublist 3 for this use. Based on the TMDL analysis, which demonstrates that reduction of natural sources of mercury would be needed in order to achieve the level necessary to allow unlimited consumption for high risk populations, the Department intends to revise its Assessment Method when developing future Integrated Water Quality Monitoring and Assessment Reports to allow that a limit of 1 meal per week for the high risk population would be considered as attaining the use with respect to mercury-based fish consumption (listing threshold would be results greater than 0.18 μg/g).

The *2008 List of Water Quality Limited Waters* currently identifies 256 Assessment Units as impaired due to mercury in surface water and/or fish tissue. This report establishes 122 TMDLs for mercury contamination based on fish tissue concentration whose source is largely air deposition. Waters where there are other significant sources of mercury in a waterbody, as indicated by a water column concentration in excess of the Surface Water Quality Standards, documentation of high levels of mercury in ground water or the presence of hazardous waste sites where mercury is a contaminant of concern, are deferred at this time, pending additional study. Tidal waters are also excluded because the approach used in this TMDL is intended for waters not affected by tidal dynamics. In addition, areas that are included in the spatial extent of the on-going interstate effort to address mercury impairments in the New York/New Jersey Harbor are excluded from this TMDL. A similar interstate effort is an appropriate means of addressing mercury impairments in the shared waters of the Atlantic Ocean and the Delaware River and Estuary, and these waters are deferred as well.

A TMDL represents the assimilative or carrying capacity of a waterbody, taking into consideration point and nonpoint sources of pollutants of concern, natural background and surface water withdrawals. A TMDL quantifies the amount of a pollutant a water body can assimilate without violating a state's water quality standards and allocates that load capacity to known point and nonpoint sources in the form of waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and a margin of safety (MOS).

EPA guidance (Sutfin, 2002) describes the statutory and regulatory requirements for approvable TMDLs, as well as additional information generally needed for EPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations. EPA has also issued guidance for the development of TMDLs for mercury impairments that are due primarily to air deposition (Hooks, 2008).

2.0. Pollutant of Concern, Applicable Surface Water Quality Standards, and Area of Interest

2.1 Pollutant of Concern

The pollutant of concern for these TMDLs is mercury. According to the current assessment methodology, an assessment unit is listed as impaired for mercury if the data show water column concentrations in excess of the Surface Water Quality Standards (SWQS) or fish tissue concentrations that would result in any limitations on fish consumption. These advisories are not SWQS, but they do indicate a limitation on the use of the waters. As previously discussed, this TMDL is limited to assessment units where impairment is attributed to fish tissue in excess of advisory thresholds, where the mercury is primarily from air deposition. The assessment units addressed are identified in Table 1. These listings have a medium priority ranking in the *2008 List of Water Quality Limited Waters* (40NJR4835(c)).

2.2 Applicable Surface Water Quality Standards and Fish Consumption Advisory Criteria

Most of the waters addressed in this report are classified in the Surface Water Quality Standards (SWQS) at N.J.A.C. 7:9B as Fresh Water 2 (FW2), either Non-Trout (NT), Trout Maintenance (TM) or Trout Production (TP). Some waters are classified as Pinelands (PL) or Freshwater 1 (FW1). A few Assessment Units include waters classified as FW2-NT/SE1 or FW2-NT/SE2. If the measured salinity is less than 3.5 parts per thousand at mean high tide, the FW2-NT classification applies. The TMDL does not apply to fresh or saline tidal waters. If the majority of the waters in the HUC 14 subwatershed are fresh and non-tidal, that assessment unit was included in this TMDL. Therefore, even though portions of some assessment units are noted as including the SE (Saline Estuarine) designation, these designations are not affected and are not discussed below. Table 2 below lists the surface water classifications for the assessment units addressed in this document and Table 3 provides the numeric criteria for mercury.

Table 2. Surface Water Classifications for the Assessment Units Addressed Under this TMDL

WMA	Assessment Unit ID	Waterbody Name	Surface Water Classifications
01	2040104090020	Clove Brook (Delaware River)	FW1, FW1-TP, FW2-TPC1, FW2-TPMC1
01	2040104130010	Little Flat Brook (Beerskill And Above)	FW1, FW2-TP, FW2-TPC1, FW2-NTC1
01	2040104140010	Big Flat Brook (Above Forked Brook)	FW1, FW2-NTC1
01	2040105030020	Swartswood Lake And Tributaries	FW2-TM, FW2-TMC1, FW2-NT, FW2-NTC1
01	2040105030030	Trout Brook	FW2-TPC1, FW2-NT
01	2040105050040	Yards Creek	FW2-TPC1, FW2-NT
01	2040105090040	Mountain Lake Brook	FW2-TM, FW2-NT

01	2040105140040	Merrill Creek	FW2-TPC1, FW2-TM
01	2040105140060	Pohatcong Creek (Springtown To Merrill Creek)	FW2-TPC1, FW2-TMC1
01	2040105150020	Lake Hopatcong	FW2-TM, FW2-NT
01	2040105150060	Cranberry Lake / Jefferson Lake & Tributaries	FW2-TMC1, FW2-NT, FW2-NTC1
02	2020007040040	Highland Lake/Wawayanda Lake	FW2-NT, FW2-NTC1
03	2030103050020	Pacock Brook	FW1, FW1-TP, FW2-NTC1
03	2030103050030	Pequannock River (Above Oak Ridge Reservoir Outlet)	FW1-TP, FW1-TM, FW2-TP, FW2-TPC1, FW2-TMC1, FW2-NT
03	2030103050040	Clinton Reservior/Mossmans Brook	FW1, FW2-TPC1, FW2-TP, FW2-TMC1, FW2-NTC1
03	2030103050060	Pequannock River (Macopin Gage To Charl'brg)	FW1-TM, FW2-TPC1, FW2-TP, FW2-TM, FW2-TMC1, FW2-NT
03	2030103050080	Pequannock River (Below Macopin Gage)	FW2-TPC1, FW2-TP, FW2-NTC1, FW2-TM, FW2-NT
03	2030103070030	Wanaque River /Greenwood Lake (Above Monks Gage)	FW2-TPC1, FW2-TM, FW2-TMC1, FW2-NT, FW2-NTC1
03	2030103070050	Wanaque Reservoir (Below Monks Gage)	FW2-TPC1, FW2-TMC1, FW2-NTC1
03	2030103110020	Pompton River	FW2-NT
06	2030103010170	Passaic River Upper (Rockaway To Hanover Rr)	FW2-NT
06	2030103020040	Whippany River(Lake Pocahontas To Washington Valley Rd)	FW2-TM, FW2-NT
06	2030103020080	Troy Brook (Above Reynolds Ave)	FW2-NT
06	2030103030030	Rockaway River (Above Longwood Lake Outlet)	FW2-NTC1
06	2030103030040	Rockaway River (Stephens Brook To Longwood Lake)	FW2-NTC1
06	2030103030070	Rockaway RIVER (74d 33m 30s To Stephens Brook)	FW1, FW2-NTC1, FW2-TPC1, FW2-TMC1
06	2030103030090	Rockaway River (BM 534 Bridge To 74d 33m 30s)	FW2-NTC1, FW2-NT
06	2030103030110	Beaver Brook (Morris County)	FW2-TPC1, FW2-TMC1, FW2-NTC1
06	2030103030140	Rockaway River (Stony Brook To BM 534 Bridge)	FW2-NTC1
06	2030103030150	Rockaway River (Boonton Dam To Stony Brook)	FW2-TMC1, FW2-NTC1, FW2-NT
06	2030103030170	Rockaway River (Passaic River To Boonton Dam)	FW2-NT
08	2030105010030	Raritan River South Branch (Above Route 46)	FW2-NT, FW2-TM, FW2-NTC1
08	2030105010040	Raritan River South Branch(74d 44m 15s To Route 46)	FW2-NTC1, FW2-TPC1, FW2-NT, FW2-TMC1

08	2030105010050	Raritan River South BRANCH(Longvalley Brook To 74d44m15s)	FW2-TPC1, FW2-NT
08	2030105010060	Raritan River South Branch(Califon Brook To Long Valley)	FW2-TPC1, FW2-NT
08	2030105020040	Spruce Run Reservior / Willoughby Brook	FW2-TPC1, FW2-TMC1, FW2-TM, FW2-NT
08	2030105020090	Prescott Brook / Round Valley Reservoir	FW2-TPC1, FW2-TM, FW2-NT
08	2030105020100	Raritan River South Branch(Three Bridges-Prescott Brook)	FW2-TM, FW2-NT
08	2030105040010	Raritan River South Branch(Pleasant Run-Three Bridges)	FW2-NT
08	2030105040040	Raritan River South Branch(North Branch To Pleasant Run)	FW2-NT
09	2030105080020	Raritan River Lower (Route 206 To North Branch / South Branch)	FW2-NT
09	2030105080030	Raritan River Lower (Millstone To Route 206)	FW2-NT
09	2030105120080	South Fork Of Bound Brook	FW2-NT
09	2030105120100	Bound Brook (Below Fork At 74d 25m 15s)	FW2-NT
09	2030105120140	Raritan River Lwr(I-287 Piscatway-Millstone)	FW2-NT
09	2030105130050	Lawrence Brook (Church Lane To Deans Pond)	FW2-NT
09	2030105130060	Lawrence Brook (Milltown To Church Lane)	FW2-NT
09	2030105140020	Manalapan Brook(Incl Lakemanlpn To 40d16m15s)	FW2-NT
09	2030105140030	Manalapan Brook (Below Lake Manalapan)	FW2-NT
09	2030105160030	Duhernal Lake / Iresick Brook	FW2-NT
10	2030105090050	Stony Brook(Province Line Rd To 74d46m Dam)	FW2-NT
10	2030105100130	Bear Brook (Below Trenton Road)	FW2-NT
10	2030105110020	Millstone River (Heathcotebk To Harrison St)	FW2-NT
10	2030105110110	Millstone River (Blackwellsmills To Beden Brook)	FW2-NT
10	2030105110140	Millstone River(Amwellrd To Blackwellsmills)	FW2-NT
10	2030105110170	Millstone River (Below Amwell Rd)	FW2-NT
12	2030104060020	Matawan Creek (Above Ravine Drive)	FW2-NT/SE1
12	2030104060030	Matawan Creek (Below Ravine Drive)	FW2-NT/SE1
12	2030104070070	Swimming River Reservoir / Slope Brook	FW2-NTC1
12	2030104070090	Nut Swamp Brook	FW2-NT/SE1
12	2030104090030	Deal Lake	FW2-NT/SE1
12	2030104090080	Wreck Pond Brook (Below Route 35)	FW2-NT, FW2-NT/SE1
12	2030104100050	Manasquan River (Gage To West Farms Road)	FW2-TMC1, FW2-NTC1

13	2040301030040	Metedeconk River South Branch (Rt 9 To Bennetts Pond)	FW2-TMC1, FW2-NTC1
13	2040301060050	Dove Mill Branch (Toms River)	FW2-NTC1, PL
13	2040301070010	Shannae Brook	FW2-NT, PL
13	2040301070030	Ridgeway Brook (Hope Chapel Rd To Harrisbrook)	PL
13	2040301070040	Ridgeway Brook (Below Hope Chapel Rd)	PL, FW2-NT/SE1
13	2040301070080	Manapaqua Brook	PL, FW2-NT/SE1
13	2040301070090	Union Branch (Below Blacks Brook 74d22m05s)	PL, FW2-NT/SE1
13	2040301080030	Davenport Branch (Above Pinewald Road)	PL
13	2040301090050	Cedar Creek (GS Parkway To 74d16m38s)	PL
13	2040301130030	Mill Creek (Below Gs Parkway)/Manahawkin Creek	PL, FW2-NT, FW2-NTC1/SE1
13	2040301130050	Westecunk Creek (Above Garden State Parkway)	PL
13	2040301140020	Mill Branch (Below Garden State Parkway)	FW2-NT/SE1
13	2040301140030	Tuckerton Creek (Below Mill Branch)	PL, FW2-NTC1/SE1, FW2-NT/SE1
14	2040301150080	Batsto River (Batsto Gage To Quaker Bridge)	FW1, PL
14	2040301160030	Mullica River (Route 206 To Jackson Road)	PL
14	2040301160140	Mullica River (39d40m30s To Rt 206)	PL
14	2040301160150	Mullica RIVER (Pleasant Mills To 39d40m30s)	PL
14	2040301180060	Oswego River (Andrews Rd To Sim Place Reservoir)	PL
14	2040301180070	Oswego River (Below Andrews Road)	PL
14	2040301190050	Wading River West Branch (Jenkins Road To Route 563)	PL
14	2040301200010	Beaver Branch (Wading River)	PL
14	2040301200050	Bass River East Branch	PL, FW1
15	2040302030020	Great Egg Harbor (Atlantic City Expressway To New Freedom Road)	PL, FW2-NT
15	2040302040050	Collings Lakes Tributary (Hospitality Branch)	PL
15	2040302040130	Great Egg Harbor (Lake Lenape To Mare Run)	PL
15	2040302050120	Middle River / Peters Creek	FW1, /SE1 C1, FW2-NTC1/SE1
16	2040206210050	Savages Run (Above East Creek Pond)	FW1, PL,
16	2040206210060	East Creek	FW1, PL, FW2-NTC1/SE1, FW2-NT/SE1
17	2040206030010	Salem River (Above Woodstown Gage)	FW2-NTC1, FW2-NT
17	2040206070030	Canton Drain (Above Maskell Mill)	FW2-NT/SE1

17	2040206080050	Cohansey River (Including Cornwell Run – Beebe Run)	FW2-NT/SE1
17	2040206090030	Cohansey R (Rocaps Run To Cornwell Run)	FW2-NT/SE1
17	2040206100060	Nantuxent Creek (Above Newport Landing)	FW1, FW2-NTC1/SE1, FW2-NT/SE1
17	2040206130010	Scotland Run (Above Fries Mill)	FW2-NT
17	2040206130040	Scotland Run (Below Delsea Drive)	FW2-NT
17	2040206140010	Mauriceriver(Blackwater Book To Include Willow Grovelake)	FW2-NT, FW2-NTC1
17	2040206150050	Muddy Run (Including Parvin Lake To Palatine Lake)	FW2-NT, FW2-NTC1
17	2040206180050	Menantico Creek (Below Route 552)	FW2-NT, FW2-NTC1
18	2040202100020	Pennsauken Creek North Branch (Including Strawbridge Lake-Njtpk)	FW2-NT
18	2040202110030	Cooper River (Above Evesham Road)	FW2-NT
18	2040202110040	Cooper River (Wallworth Gage To Evesham Road)	FW2-NT
18	2040202110050	Cooper River (Route 130 To Wallworth Gage)	FW2-NT
18	2040202120010	Big Timber Creek North Branch (Above Laurel Road)	FW2-NT
18	2040202120020	Big Timber Creek North Branch (Below Laurel Road)	FW2-TPC1, FW2-NT
18	2040202120030	Big Timber Creek South Branch (Above Lakeland Road)	FW2-NT
18	2040202120040	Big Timber Creek South Branch(Including Bull Run To Lakeland Road)	FW2-NT
18	2040202120050	Big Timber Creek South Branch (Below Bull Run)	FW2-NT
18	2040202120060	Almonesson Creek	FW2-NT
18	2040202120090	Newton Creek (Ldrv-Kaighn Ave To Lt Creek)	FW2-NT
18	2040202120100	Woodbury Creek (Above Rt 45)	FW2-NT/SE2
18	2040202130030	Chestnut Branch (Above Sewell)	FW2-NT/SE2
18	2040202150020	Raccoon Creek (Rt 45 To/Include Clems Run)	FW2-NT/SE2
18	2040202150040	Raccoon Creek (Russell Mill Road To Route 45)	FW2-NT/SE2
19	2040202030050	Bucks Cove Run / Cranberry Branch	PL
19	2040202050050	Friendship Creek (Below/Including Burrs Mill Brook)	PL
19	2040202050060	Rancocas Creek South Branch(Above Friendship Creek)	PL
19	2040202050080	Rancocas Creek South Branch (Vincentown-Friendship Creek)	PL, FW2-NT
19	2040202050090	Rancocas Creek South Branch (Bobbys Run To Vincentown)	FW2-NT
20	2040201090030	Lower Delaware River Tributaries (Assiscunk Creek To Blacks Creek)	FW2-NT

C1 refers to Category One, a specific category of water relevant with respect to the antidegradation policies in the SWQS.

In all FW1 waters, the designated uses are (NJAC 7:9B-1.12):

1. Set aside for posterity to represent the natural aquatic environment and its associated biota;
2. Primary and secondary contact recreation;
3. Maintenance, migration and propagation of the natural and established aquatic biota; and
4. Any other reasonable uses.

In all FW2 waters, the designated uses are (NJAC 7:9B-1.12):

1. Maintenance, migration and propagation of the natural and established aquatic biota;
2. Primary and secondary contact recreation;
3. Industrial and agricultural water supply;
4. Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation and sedimentation, resulting in substantial particulate removal but no consistent removal of chemical constituents) and disinfection; and
5. Any other reasonable uses.

In all PL waters, the designated uses are (NJAC 7:9B-1.12):

1. Cranberry bog water supply and other agricultural uses;
2. Maintenance, migration and propagation of the natural and established biota indigenous to this unique ecological system;
3. Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation, and sedimentation, resulting in substantial particulate removal but no consistent removal of chemical constituents) and disinfection;
4. Primary and secondary contact recreation; and
5. Any other reasonable uses.

Table 3. Mercury Water Column Criteria (µg/l)

Toxic substance	Fresh Water (FW2) Criteria		
	Aquatic		Human Health
	Acute	Chronic	
Mercury	1.4(d) (s)	0.77(d) (s)	0.05(h)(T)

d = criterion expressed as a function of the water effects ratio
T = total
h = noncarcinogenic effect-based human health criteria
s = dissolved

Surface water quality criteria for FW1 waters are that they shall be maintained as to quality in their natural state. PL waters shall be maintained as to quality in their existing state or that quality necessary to attain or protect the designated uses, whichever is more stringent.

In addition N.J.A.C. 7:9B-1.5(a) 4 includes the requirement that “Toxic substances in water shall not be at levels that are toxic to humans or the aquatic biota so as to render them unfit for human consumption.”

Fish consumption advisories are jointly issued by the New Jersey Department of Environmental Protection and the New Jersey Department of Health and Senior Services. They provide advice to the general population and high-risk individuals (for example, women of childbearing age and children) concerning the number of meals that represent safe levels of consumption of recreational fish from New Jersey waters. Fish consumption advisories for mercury include information on how to limit risk by providing guidance on the types and sizes of fish and the number of meals to eat. They are not promulgated standards, but they are used for determining whether the fish consumption use is met. Where fish tissue levels exceed the advisory thresholds, a waterbody is listed on the 303(d) list. The New Jersey fish consumption advisories are as follows:

Table 4. New Jersey Fish Consumption Advisory Thresholds (from Toxics in Biota Committee 1994)

Advisories for the high risk population*	
Mercury (TR) Concentration in Fish Tissue	**Advisory**
Greater than 0.54 µg/g (ppm)	Do not eat
Between 0.19 and 0.54 µg/g (ppm)	One meal per month
Between 0.08 and 0.18 µg/g (ppm)	One meal per week
0.07 µg/g (ppm) or less	Unlimited consumption
Advisories for the general population	
Mercury (TR) Concentration in Fish Tissue	**Advisory**
Greater than 2.81 µg/g (ppm)	Do not eat
Between 0.94 and 2.81 µg/g (ppm)	One meal per month
Between 0.35 and 0.93 µg/g (ppm)	One meal per week
0.34 µg/g (ppm) or less	Unlimited consumption

TR – Total Recoverable Mercury

* The high risk population consists of women of childbearing years, pregnant and nursing mothers and children.

Under the current assessment methodology, an assessment unit was listed as not attaining the fish consumption use if fish tissue data indicated that any restriction of consumption would be necessary, in other words if the fish tissue concentration was above 0.07 µg/g. However, based on this TMDL analysis, this level in fish tissue can be caused solely by natural sources of mercury in some waters (see Section 5 *TMDL Calculations* below). Therefore, the Department intends to revise the assessment methodology in the development of future lists (2010) to reflect a minimal level of consumption advisory for the high risk population. It is expected that the future assessment method will use a tissue concentration of greater than 0.18 µg/g as the listing threshold, which would allow consumption by the high risk population of one meal per week. Therefore, the target for this TMDL is 0.18 µg/g total mercury fish tissue concentration. Big Timber Creek would not have been listed using this listing threshold, however, because it is listed on the 2008 303(d) list, it will be included in this TMDL document. All other waters included in this TMDL exceed the 0.18 ug/g fish tissue target.

Because fish consumption advisories are not SWQS and a TMDL must demonstrate attainment of the applicable SWQS, it is necessary to demonstrate that using this fish tissue target will also attain the applicable SWQS for mercury. This is done using bioaccumulation factors (BAFs), to convert the levels found in the fish tissue to a water column value so there can be a direct comparison with the State's current water quality criterion of 0.050 µg/L as total mercury. There is no numerical standard for waters classified as PL or FW1. The 0.18 ug/g fish tissue target is a human health endpoint which is protective of all waters, regardless of a waterbody's designation. NJAC 7:9B-1.5(a) 4's narrative standard regarding toxic substances is applicable to all waters. Absent a numeric standard for FW1 and PL waters, the narrative standard was applied and implemented using the 0.18 ug/g mercury fish tissue target. In addition the target of 0.18 µg/L requires the reduction of mercury to near natural background levels (see TMDL calculations in section 5 below) and as such is protective of waters with PL and FW1 designations.

New Jersey is engaged in an ongoing effort to develop regional BAFs. As this work is not complete, the EPA national default values will be used for this TMDL. A BAF of 1,690,000 L/kg was selected, which is based on the averaging of EPA national default values for trophic level 3 and trophic level 4 fish of 2,700,000 and 680,000 L/kg, respectively. Averaging the two values assumes a diet of 50% of these higher trophic level fish. This BAF is for methyl mercury. A further conversion to a corresponding total mercury concentration in the water column can be calculated by using the ratio of dissolved methyl mercury to total mercury. Data available from the various regions of New Jersey show that the ratios range from 0.059 to 0.005 (pers. comm. G. A. Buchanan, NJDEP, May 5, 2009). A ratio of 0.055 can be calculated from national data (EPA, 1997). The water column mercury concentration, 0.021 ug/L, expressed as total mercury using the selected BAF and the most conservative conversion factor (0.005) is lower than the mercury surface water criterion of 0.050 ug/L. Therefore, the use of a fish tissue criterion as a TMDL target ensures that the SWQS will be met if the TMDL fish tissue target is met.

The following formula was used for this comparison:

WCV (µg/L) =[Fish Tissue Value (mg/kg)/BAF (L/kg) x 1000 µg/mg] / dissolved MeHg to total Hg

Where:

WCV = water column mercury concentration
Fish Tissue Value = 0.18 mg/kg
BAF = 1,690,000 L/kg

Therefore:

WCV (µg/L)(as total Hg) = [$\underline{\text{0.18 mg/Kg/1,690,000 L/kg}}$ x 1000 µg/mg]/ 0.005 = **0.021 µg/L total Hg**

In other words, when a fish tissue target of 0.18 mg/kg is met, the water column mercury concentration would be 0.021 μg/L, which is below the surface water quality criterion of 0.050 μg/L).

2.3 Area of Interest

In accordance with the *2008 Integrated Water Quality Monitoring and Assessment Methods*, although there is a State-wide fish consumption advisory for mercury, only waters with actual fish tissue monitoring data that exceed the threshold which results in a consumption restriction (greater than 0.07 mg/kg) are placed on Sublist 5. All other assessment units are listed on Sublist 3 for this use.

The *2008 List of Water Quality Limited Waters* currently identifies 256 assessment units as impaired due to mercury in surface water and/or fish tissue. This report establishes 122 TMDLs for mercury contamination based on fish tissue concentration whose source is largely air deposition. Waters where there are other significant sources of mercury in a waterbody, as indicated by a water column concentration in excess of the Surface Water Quality Standards (61 listings), documentation of high levels of mercury in ground water (15 listings) or the presence of hazardous waste sites where mercury is a contaminant of concern (8), are deferred at this time, pending additional study. Tidal waters (35) are also excluded because the approach used in this TMDL is intended for waters not affected by tidal dynamics. In addition, areas that are included in the spatial extent of the on-going interstate effort to address mercury impairments in the New York/New Jersey Harbor are excluded from this TMDL (6). A similar interstate effort is an appropriate means of addressing mercury impairments in the shared waters of the Atlantic Ocean (37) and the Delaware River and Estuary (9) and these waters are deferred as well. See Appendix A for a listing of the deferred assessment units.

Additional fish tissue data not available when the *2008 List of Water Quality Limited Waters* was developed were evaluated and 37 additional assessment units were found to have fish tissue concentrations that would have resulted in listing of those assessment units under the current assessment methodology (see those indicated with an asterisk in Table 1). These assessment units also meet the other criteria for being addressed under this TMDL (no other significant sources, non-tidal, outside the spatial extent of interstate study). Therefore, these assessment units will be addressed under this TMDL.

As additional fish tissue data is obtained, it is expected that other assessment units will be identified that conform to the parameters established for this TMDL approach and would appropriately be addressed by this TMDL, had the data been available. Therefore, in addition to the impaired waters listed Table 1, this TMDL may, in appropriate circumstances, also apply to waterbodies that are identified in the future as being impaired for mercury. For such waterbodies, this TMDL may apply if, after listing the waters for mercury impairment and taking into account all relevant comments submitted on the Impaired Waters List, the Department determines, with EPA approval of the list, that this TMDL should apply to future mercury impaired waterbodies. Under these circumstances, the assessment units will be placed on Sublist 4.

The assessment units addressed in this TMDL are listed in Table 1 and depicted in Figure 1. The assessment units encompass 724,236 acres throughout the state.

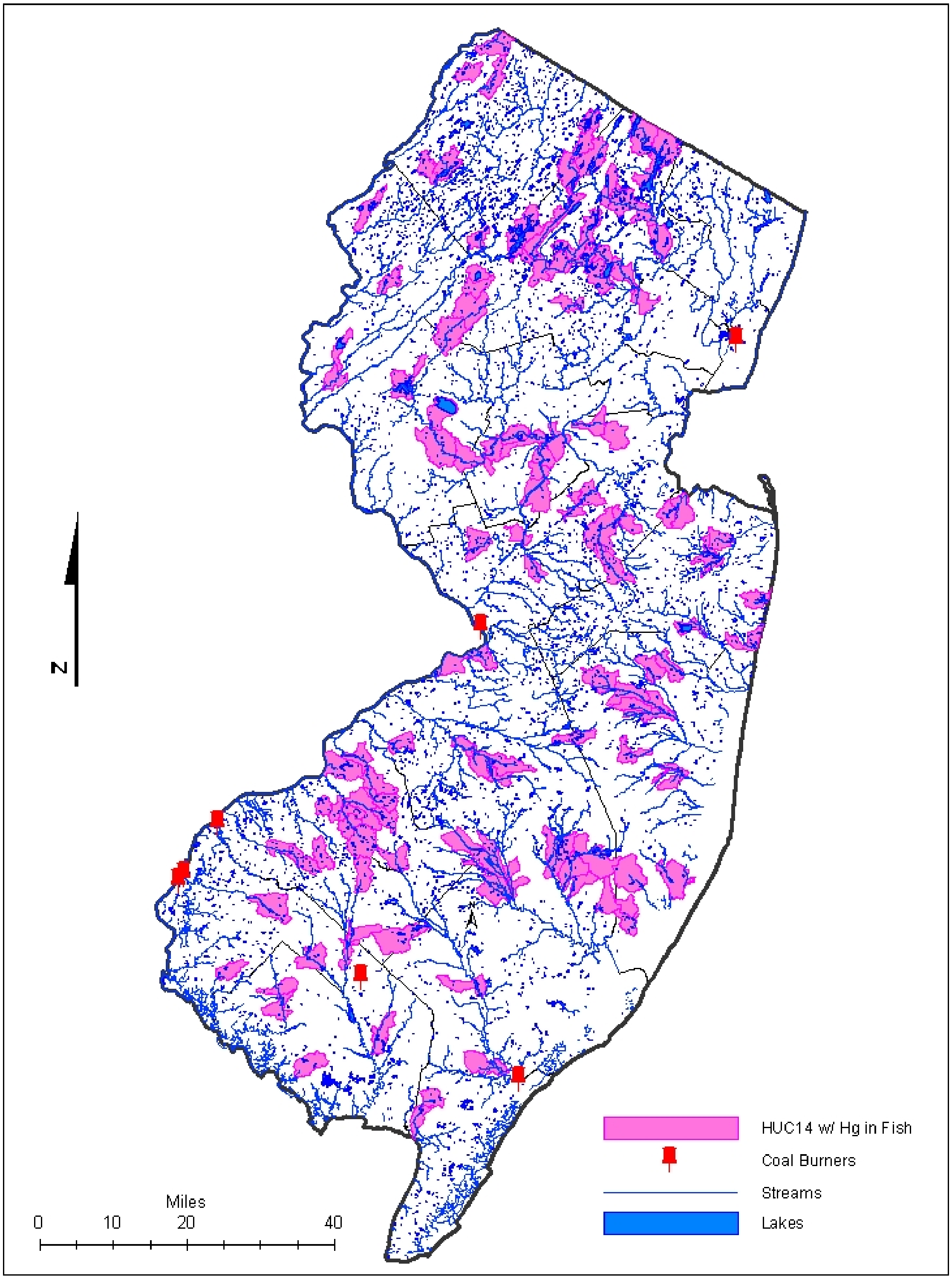


Figure 1. **Assessment Units Addressed in this TMDL**

3.0. Data Analysis

3.1 Fish Tissue Data

Beginning in 1994, research on freshwater fish found mercury concentrations exceeding the risk-based health advisories established by the State of New Jersey. Additional data were developed and reported in Academy of Natural Sciences, Philadelphia (ANSP) (1999), Ashley and Horwitz (2000), Horwitz et al. (2005) and Horwitz et al. (2006). The Department's Routine Monitoring Program for fish tissue began in 2002. The purpose of this monitoring program is to enhance waterbody assessments; amend existing advisories or, if necessary, develop new advisories; assist the NJDEP in evaluating trends in contaminant concentrations of these selected species; and to determine the need for additional research and monitoring studies. The sampling program is based on a rotating assessment of contamination in five regions of the state on a 5-year cycle. The regions consist of:

1. Passaic River Region;
2. Marine/Estuarine Coastal Region;
3. Raritan River Region;
4. Atlantic Coastal Inland Waterways Region; and
5. Upper and Lower Delaware River Region.

Sampling in the Passaic Region was conducted in 2002-2003 and the Marine/Estuarine Region in 2004-06. The results were reported in Horwitz, et al. (2005 and 2006). In the third year of the cycle, the Raritan River Region was sampled for freshwater fish, blue crabs and marine fish. In 2006-2007, species important to recreational anglers in the Raritan estuaries and adjacent oceanic waters and in two southern New Jersey coastal bays were sampled.

The initial data set consulted included 2,474 samples that had been analyzed for mercury in fish tissue in the waters of New Jersey collected through the above sampling programs and from localized investigations. All fish were analyzed using microwave digestion and cold vapor atomic absorption. Based on an evaluation of data quality, all samples before 1990 were excluded because of issues with background contamination in the labs analyzing samples. A small number of fish tissue samples were derived from whole fish samples. Only samples where the fillets were analyzed were retained to ensure a consistent basis for comparison. Locations with known mercury contamination from other sources were eliminated to avoid influences beyond air deposition (water column exceedances, presence of hazardous sites with mercury, groundwater levels with elevated mercury). All tidal areas were excluded, including those from the areas of on-going or anticipated interstate studies (New York/New Jersey Harbor, Atlantic Ocean and Delaware River and Bay). The final data set used for this TMDL analysis included 1,368 samples from 26 different species (see Appendix B).

This TMDL is based on the linear relationship between mercury levels in the air and water and that a BAF can relate fish tissue concentration to water column concentration. This means that if the existing load is responsible for the observed mercury levels in fish, then one can calculate the load that will result in the target concentration in fish and the associated water column concentration using the BAF, to ensure the SWQS are attained. The steady state bioaccumulation equation is:

$$C_{\text{fish t1}} = \text{BAF} * C_{\text{water t1}}$$

where:
$C_{\text{fish t1}}$ and $C_{\text{water t1}}$ represent methyl mercury concentration in fish and water at time t_l, respectively;
BAF represents the bioaccumulation factor, which is constant for a given age and length fish in a specific water body.

For a future time, t_2, when mercury concentrations have changed, but all other parameters remain constant, the following equation applies:

$$C_{\text{fish t2}} = \text{BAF} * C_{\text{water t2}}.$$

Combining both equations produces the following:

$$C_{\text{fish t1}}/C_{\text{fish t2}} = C_{\text{water t1}}/C_{\text{water t2}}.$$

Then, with methyl mercury water column concentrations being proportional to mercury air deposition load, therefore:

$$C_{\text{fish t1}}/C_{\text{fish t2}} = L_{\text{air t1}}/L_{\text{air t2}}$$

where:
$L_{\text{air t1}}$ and $L_{\text{air t2}}$ represent mercury loads from the air deposition at time 1 and time 2.

Mercury concentration in fish increases with both age and length (see Figure 2). In order to derive a representative existing fish tissue concentration as a basis to calculate the load reduction required to achieve the target concentration, it is necessary to statistically standardize the data. The fish tissue mercury concentrations were statistically adjusted to a “standard-length fish”. Because many fish are larger than the standard length and therefore higher in mercury, the TMDL analysis targets the 90th percentile mercury tissue concentration of the distribution of all length-standardized fish evaluated. This will provide an implicit margin of safety and be more protective than using a mean or median concentration value. In addition, because growth rates and levels of mercury accumulation will vary between waterbodies, using the 90th percentile tissue concentration will be protective of waterbodies with higher levels of accumulation.

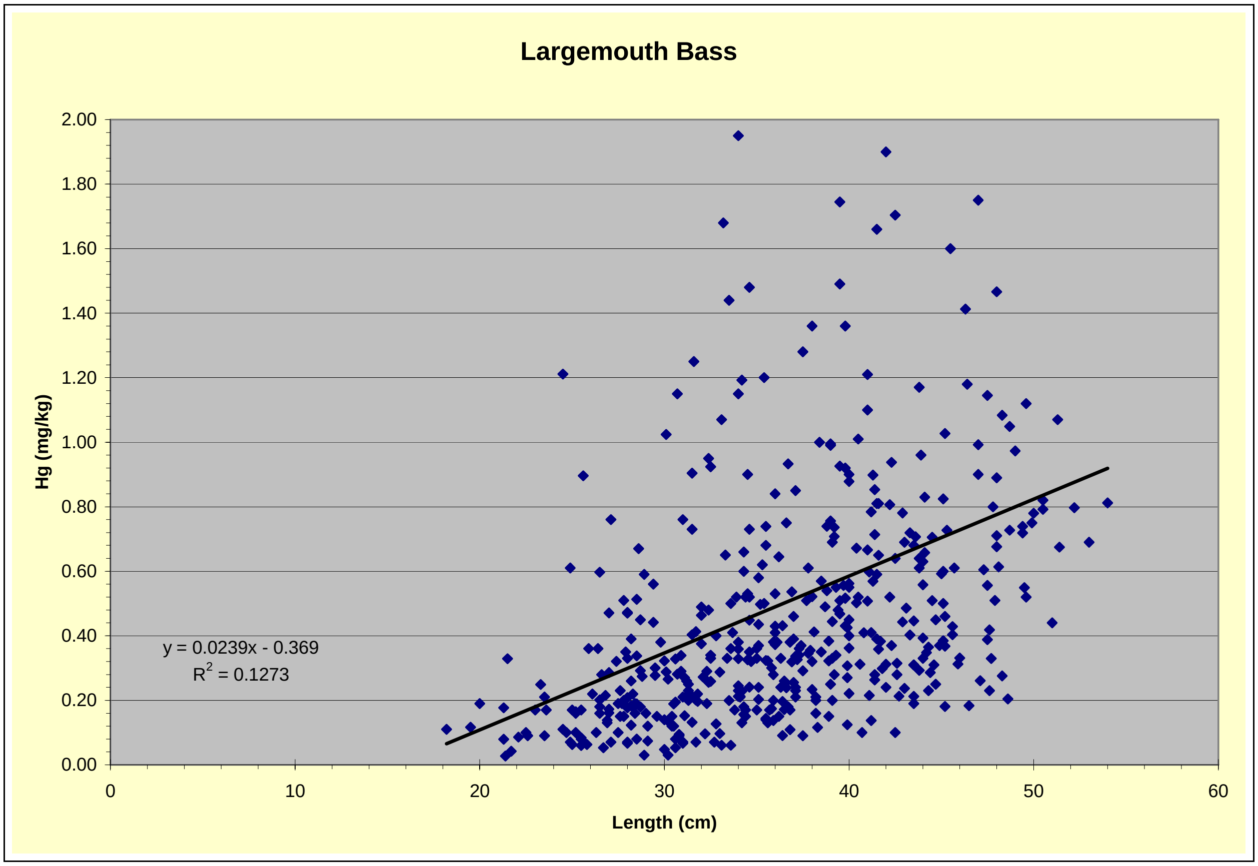


Figure 2. Relationship Between Length and Mercury Concentration in Fish Tissue

The Northeast Regional TMDL analyzed four different species of top trophic level fish, comparing the mean, 80th and 90th percentile concentrations. The authors chose the smallmouth bass (*Micropterous dolomieu*), because of the rate of bioaccumulation of mercury and its ubiquitous distribution throughout the Northeast States. The smallmouth bass is not well distributed throughout New Jersey, therefore it was not an appropriate indicator species for this TMDL. However, the largemouth bass (*Micropterus salmoides*), of the same genus and with the same diet of crayfish, frogs and fish, is well distributed throughout New Jersey. Samples are available from 69% of the listed assessment areas. The chain pickerel was also considered because it is represented by the second largest number of samples in the data set and has a high average mercury concentration (see tables 5 and 6 below). Its diet consists of invertebrates and fish. However, it is not as well distributed throughout New Jersey. Because of the larger sample size and better distribution, the largemouth bass was chosen to be the indicator for this TMDL effort. Using either fish yields a similar reduction factor.

Table 5. Data on Methyl Mercury Concentration in Fish Fillet Samples (n = number of samples, Average = arithmetic mean concentration)

Species List	2000-2007		1990-1999	
	n	Average	n	Average
American Eel	72	0.4	6	0.47
Black Crappie	15	0.15	32	0.19
Bluegill	75	0.14	2	0.03
Bluegill Sunfish	3	0.07	20	0.18
Brown Bullhead	32	0.07	79	0.19
Brown Trout	2	0.08	1	0.2
Chain Pickerel	82	0.658	166	0.685
Channel Catfish	9	0.22	10	0.15
Common Carp	36	0.11	5	0.04
Hybrid Striped Bass	0		6	0.27
Lake Trout	5	0.14	12	0.46
Largemouth Bass	152	0.54	224	0.56
Mud sunfish	0		3	1.01
Northern Pike	6	0.29	6	0.24
Pike	0		3	0.39
Pumpkinseed Sunfish	0		19	0.37
Rainbow Trout	0		6	0.11
Redbreast Sunfish	16	0.16	4	0.24
Rock Bass	19	0.33	4	0.46
Smallmouth Bass	13	0.34	22	0.47
Striped x White Bass Hybrid	5	0.29	0	
Walleye	10	0.4	6	0.74
White Catfish	8	0.19	15	0.27
White perch	12	0.18	22	0.42
White Sucker	3	0.23	0	
Yellow Bullhead	33	0.23	32	0.63
Yellow Perch	27	0.36	28	0.51

An analysis of covariance model was used to estimate the length-adjusted concentrations of mercury in largemouth bass. Scatter plots indicated that a log transformation for mercury would approximately linearize the relationship between mercury and length, so the model used the log to the base 10 of mercury as the dependent variable. The independent variables were length and water body. Water bodies were considered to be fixed effects. The result of this analysis was to create a length-adjusted mercury concentration for each water body.

A model was also run in order to determine whether the length-adjusted concentrations changed over time. In order to do this, an independent variable defining the decade in which the sample was taken (1992 – 1999 vs. 2000 – 2007) was included in the model along with length and water body. This model was significant ($p < 0.001$) with an R-square of 82%. Mercury concentrations varied significantly ($p < 0.001$) with length, waterbody and the decade in which the samples were taken.

Because decade was a significant effect, the two decades were analyzed separately. The adjusted estimates were calculated at the mean length of 35.11cm for data collected from 1992-1999 and 39.78 cm for data collected from 2000-2007.

For the 1992-1999, the data set included 49 water bodies. The number of fish sampled from each water body ranged from 1 to 12. The independent variables included length and water body. This model run was significant ($p < 0.001$) with an R-square of 89%. Mercury concentration varied significantly ($p < 0.001$) with both length and waterbody. The 90th percentile of the length-adjusted mercury concentration is $10^{(0.0448)} = 1.109$ µg/g.

The 2000-2007 dataset included 46 water bodies. The number of fish sampled from each water body ranged from 3 to 5. The independent variables included length and water body. This model run was significant ($p < 0.001$) with an R-square of 85%. Mercury concentration varied significantly ($p < 0.001$) with both length and waterbody. The 90th percentile of the length adjusted mercury concentration is $10^{(0.0607)} = 1.150$ µg/g.

The statistical analyses were performed in SAS version 9.1.3.

Because the mercury concentration varies with the waterbody, the 90th percentile fish tissue concentration is used to calculate the reduction factor. This will be protective of all the waterbodies, even those with higher fish tissue mercury concentrations.

Table 6. Mercury Concentrations Related to Fish Length for 2000-2007 Data

Species	Standard Length (cm)	Mean Hg Concentration (ppm) at Standard Length	80th percentile Hg Concentration (ppm) at Standard Length	90th percentile Hg Concentration (ppm) at Standard Length
Largemouth bass	35.11	0.531	0.64	1.15
Chain pickerel	41.61	0.59	1.26	1.29

Figure 3 shows the distribution of methyl mercury concentrations in all species in the 2000–2007 data set and concentrations in the largemouth bass for the same period. The graph shows that targeting the 90th percentile concentration in largemouth bass corresponds to the 93rd percentile concentration for all fish species. Therefore, targeting the concentration of 90th percentile for largemouth bass, means that approximately 93% of all fish populations tested will comply with the TMDL target concentration. There is much environmental variability. Some lakes will show decreases in mercury more quickly, some more slowly. Both the Minnesota and the Northeast States regional TMDLs were based on the 90th percentile concentration. Therefore the 90th percentile target is in keeping with mercury TMDLs EPA has previously approved.

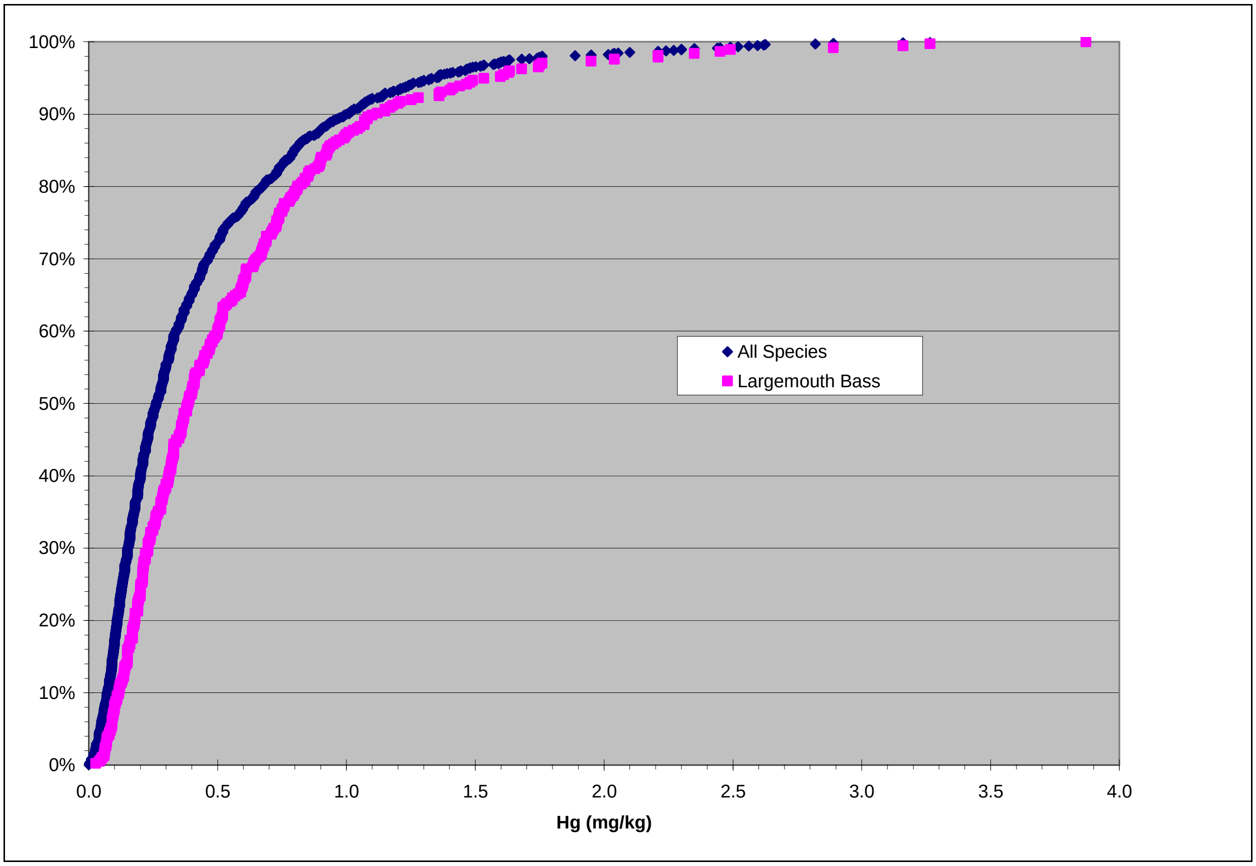


Figure 3. Cumulative Distribution of Mercury Concentrations in Fish Tissues

Based on the linear relationship premise, a Reduction Factor (RF) based on the existing and target fish tissue concentrations is calculated as follows:

RF= (EFMC-TFMC)/EFMC

where:
EFMC = the existing fish mercury concentration for the selected fish species.
TFMC = target fish mercury concentration

or:
$0.84 = (1.15\ \mu g/g - 0.18\ \mu g/g) / 1.15\ \mu g/g$

As discussed above, the EFCM for this study is 1.15 µg/g, which represents the 90th percentile concentration based on standard length for largemouth bass. The target fish tissue concentration is 0.18 µg/g, which will allow a consumption rate of 1 meal per week for the high risk population. For unlimited consumption of fish for the high risk population, the reduction factor would need to be 0.94. As discussed below, natural sources of mercury, which cannot be reduced, make this reduction factor unattainable. However, the TMDL calculation includes an implicit margin of safety based on a number of conservative assumptions. Therefore, it is possible that unlimited consumption for the high risk population may be attainable if the identified anthropogenic reductions are achieved. In any case, although this TMDL target will not allow unlimited consumption of top trophic level fish for high risk groups using the multiple conservative assumptions in this analysis, mercury will be reduced at all trophic levels, allowing greater options for safe consumption of fish at the lower trophic levels and one meal per week of the top trophic levels by the high risk population.

4.0. Source Assessment

In order to evaluate and characterize mercury loadings on a statewide basis source assessments are critical. Source assessments include identifying the types of sources and their relative contributions to mercury loadings and are necessary to develop proper management responses to reduce loadings and attain water quality targets.

Air deposition is the primary source of the mercury impairments addressed in this TMDL. A recent study was undertaken in partnership with the states and USEPA Regional Air and Water Offices to use atmospheric deposition modeling to quantify contributions of specific sources and source categories to mercury deposition within each of the lower 48 states (ICF, 2008). The annual simulation was performed based on data that represented late 90's emission profiles for most source categories. The primary modeling system used for this study is the Regional Modeling System for Aerosols and Deposition (REMSAD). REMSAD is a three-dimensional grid model designed to calculate the concentrations of pollutants by simulating the physical and chemical processes in the atmosphere that affect pollutant concentrations. REMSAD simulates both wet and dry deposition of mercury. REMSAD also includes algorithms for the reemission of previously deposited mercury (originating from anthropogenic and natural sources) into the atmosphere from land and water surfaces. The Particle and Precursor Tagging Methodology (PPTM) feature allows the user to tag or track emissions from selected sources or groups of sources, and quantify their contribution to mercury deposition throughout the modeling domain and simulation period. Results from the Community Multiscale Air Quality (CMAQ) modeling system were used to enhance the analysis of the effects of global background on mercury deposition. The outputs from three global models were used to specify the boundary conditions for both REMSAD and CMAQ and thus represent a plausible range of global background contributions based on current scientific understanding.

Preparation and quality assurance of the mercury emissions inventory were critical for the air deposition load modeling. Based on the emissions data utilized by USEPA in the Clean Air Mercury Rule (CAMR) modeling, detailed summaries of the top emitters in the CAMR mercury inventory for each state were prepared and provided to the appropriate EPA regional offices and state agencies for review. An effort was made to update emissions to the 2001 timeframe in addition to the general QA/QC that performed by the states and EPA regions. Then based on the state's input, any errors in the data were corrected. Table 7 lists New Jersey's emission inventory as it was used in the model. This inventory was developed based on the Department's 2001 mercury emission estimates (ICF, 2008). For the total of the three forms of mercury emission load, approximately 60% was due to air point sources and 40% from air nonpoint sources. Air point sources include fuel combustion-electric utilities, industrial facilities and other combustion facilities. Air nonpoint sources include human cremation, fluorescent lamp breakage, miscellaneous volatilization and other non-stationary sources.

Table 7. Summary of Emissions Inventory of New Jersey in Tons per Year (tpy) (ICF, 2008)

Facility Name	HG0* (tpy)	HG2* (tpy)	HGP* (tpy)	Total (tpy)
B.L. England	0.094	0.016	0.004	0.114
Hudson*	0.011	0.028	0.003	0.041
Mercer	0.030	0.015	0.011	0.057
Deepwater	0.002	0.004	0.000	0.006
Logan Generating Company - L.P.	0.001	0.000	0.000	0.002
Chambers Cogeneration - L.P.	0.010	0.006	0.004	0.021
Co Steel Raritan	0.090	0.011	0.011	0.112
Atlantics States Cast Iron Pipe	0.033	0.004	0.004	0.041
U.S. Pipe & Fndy. Co	0.019	0.011	0.000	0.030
Co Steel Sayreville*	0.178	0.022	0.022	0.222
Essex County RRF*	0.047	0.123	0.042	0.212
Camden RRF*	0.011	0.029	0.010	0.050
Union County RRF	0.003	0.008	0.003	0.014
Gloucester County	0.002	0.005	0.002	0.009
Warren Energy RF	0.001	0.001	0.001	0.003
Howarddown	0.002	0.001	0.001	0.004
Hoeganese	0.005	0.003	0.002	0.010
Camden County Muassi	0.005	0.003	0.002	0.010
Stony Brook Regional Sewerage Authority	0.011	0.007	0.005	0.023
Bayshore Regional Sewerage Authority	0.004	0.002	0.002	0.008
Somerset Raritan Valley Sewerage Authority	0.007	0.004	0.003	0.014
Northwest Bergen County Utilities Authority	0.005	0.003	0.002	0.010
Parsippany – Troy Hills Township WWTP	0.004	0.003	0.002	0.009
Atlantic County Utilities Authority	0.003	0.002	0.001	0.006
Gloucester County Utilities Authority	0.001	0.001	0.000	0.002
Point Source Total	0.579	0.312	0.137	1.030
Non-point Source	0.464	0.096	0.055	0.613
Total	1.043	0.408	0.192	1.643

*HG0 - elemental mercury vapor; HG2 - divalent mercury compounds in gas phase; HGP - divalent mercury compounds in particulate phase.

As summarized in Table 8 below, a total of 594 kg of annual mercury load due to air deposition was estimated for New Jersey. "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions, altogether, about 52% of the total load. Emissions from New Jersey are contributing 12.5% of the total load. The emissions from five surrounding states contribute 26% of the total load.

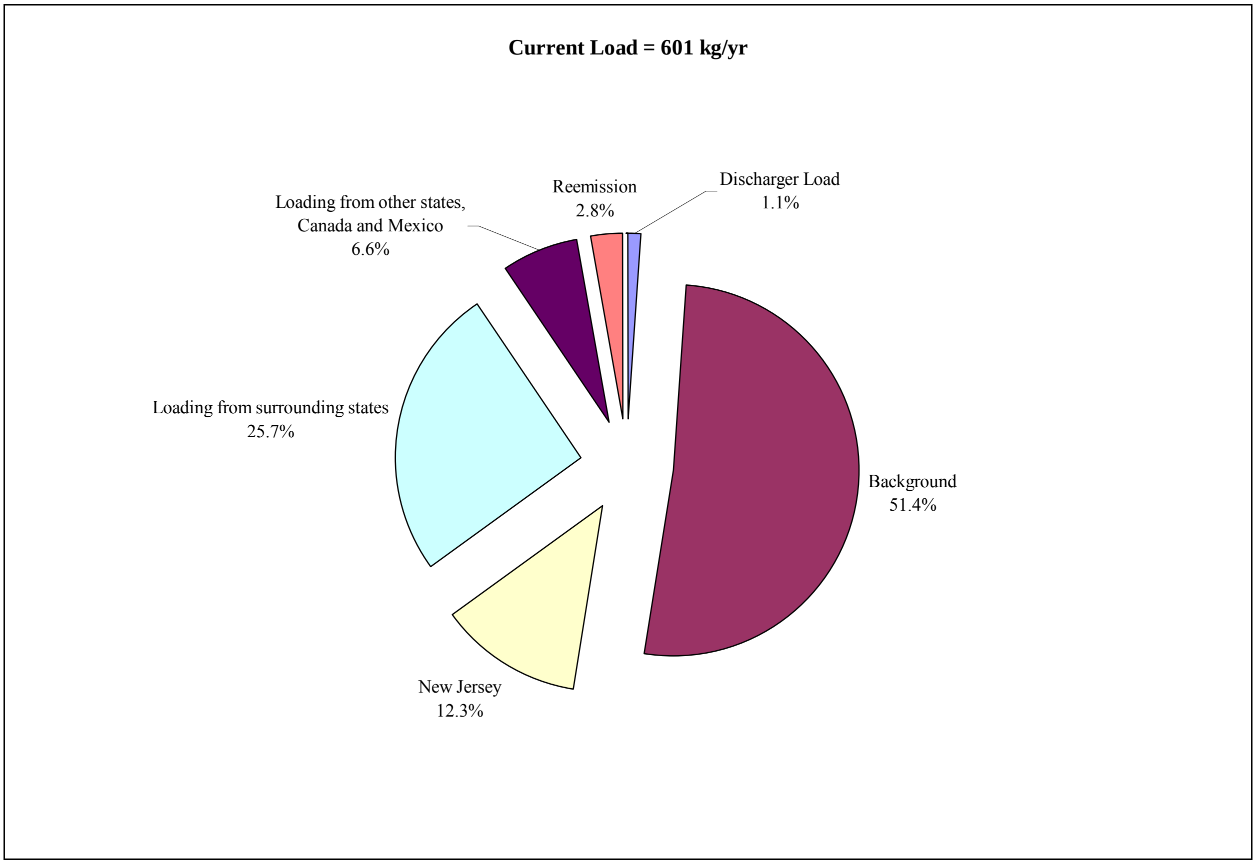
Table 8. Mercury Air Deposition Load for New Jersey (pers. com. D. Atkinson, March 26, 2009, see Appendix D)

Category	Load (kg/yr)	Percent of Total Load
Background	309.0	52.0%
Background-reemission	16.9	2.8%
New Jersey	74.1	12.5%
Loading from the surrounding state (Total)	154.6	26.0%
Pennsylvania	102.8	17.3%
Maryland	25.1	4.2%
New York	13.7	2.3%
Delaware	11.1	1.9%
Connecticut	1.8	0.3%
Loading from other states, Canada and Mexico	39.6	6.7%
Total	594.2	100%

Under the Clean Water Act (CWA), air deposition is a nonpoint source of mercury. Mercury deposited from air sources reaches the surface water as the result of direct deposition on the water surface and through stormwater runoff. Under the CWA, stormwater discharges subject to regulation under the National Pollutant Discharge Elimination System (NPDES) are a point source. In New Jersey, this includes facilities with individual or general industrial stormwater permits and Tier A municipalities and state and county facilities regulated under the New Jersey Pollutant Discharge Elimination System (NJPDES) municipal stormwater permitting program. Stormwater discharges that are not subject to regulation under NPDES, such as Tier B municipalities regulated under the NJPDES municipal stormwater permitting program, and direct stormwater runoff from land surfaces are nonpoint sources. Stormwater point sources derive their pollutant load from runoff from land surfaces and the necessary load reduction for this TMDL will be accomplished in the same way as for stormwater that is a nonpoint source, that is by reducing the air deposition load. The distinction is that, under the Clean Water Act stormwater point sources are assigned a WLA while nonpoint sources are assigned a LA. For this TMDL, the proportion of the air deposition loading attributed to stormwater point sources has been estimated by determining the amount of urban land located within Tier A municipalities. Based on NJDEP's 2002 land use coverage, the area of urban land use within the Tier A municipalities is about 25.6% of the entire state. Applying this percentage to the entire load due to air deposition is the best approximation of the air deposition load subject to stormwater regulation and this proportion of the air deposition load will be assigned a WLA.

Surface water discharges of sanitary and industrial wastewater that have the potential to discharge mercury are the other potential point source category which must be assigned a WLA. The Department reviewed over 240 existing major and minor municipal surface water discharge locations. Industrial surface water dischargers with mercury limits in their permits regulated under the New Jersey Pollutant Discharge Elimination System (NJPDES) were also included as the potential point sources for this TMDL. Since this TMDL is limited to non-tidal water, facilities discharging to coastal water were excluded. By examining the locations of the outfall pipes, approximately two-thirds of initially identified municipal and industrial surface water discharge facilities were used to estimate the point source loading from them.

Various sources of data were assessed in order to estimate an appropriate loading to attribute to discharge facilities. Due to the high detection limit of the standard method for analyzing the samples collected from the dischargers, mercury concentrations reported to date were generally listed as non-detected in the Monitoring Report Forms. Dental facilities are believed to be the largest source of mercury reaching wastewater treatment plants. Through the recently adopted New Jersey Pollutant Discharge Elimination System, Requirements for Indirect Users – Dental Facilities rules, N.J.A.C. 7:14A-21.12, dental facilities that generate amalgam waste are required to comply with best management practices and install amalgam separators. The amalgam separators will allow the mercury containing amalgam to be collected and recycled, thereby reducing the amount entering the environment through sludge incineration. The Department required major wastewater treatment facilities to carryout baseline monitoring of their effluent to determine mercury levels prior to implementation of the new dental requirements. However, the data from this monitoring effort are not yet available for use in this TMDL. As part of the New York-New Jersey Harbor TMDL development, in 2000 and 2001 a total of 30 samples were collected from 11 Publicly Owned Treatment Works (POTWs) in New Jersey which discharge to the Harbor (GLEC, 2008). Total recoverable mercury concentrations ranged from 8.32 to 74.9 ng/L, with a mean of 30.09 ng/L and a median of 19.75 ng/L. The Department believes that the mercury effluent concentrations found in these facilities will serve as an appropriate representation of effluent quality in the state. Therefore, the median concentration of 19.75 ng/L was used as a typical mercury concentration for treatment facilities. The total permitted flows for selected facilities is about 250 MGD. Using that flow and the selected median concentration, the total mercury load from these facilities is estimated to be 6.8 kg/year. This loading (6.8 kg/yr) is also a conservative assumption of the existing point source load since the permitted flow was used instead of the actual flow. The loading attributed to discharge facilities is insignificant at approximately 1% of the total load. Figure 4 shows the distribution of the current total load of mercury.



Note: Load from stormwater is not distinguished because it is derived from and is a subset of the air deposition load from the different air sources identified.

Figure 4. Distribution of the Current Mercury Load

5.0. TMDL Calculation

Methods similar to those used in the *Northeast Regional TMDL* (2007) are employed below to calculate the TMDL. A total source load (TSL), described in Section 4, and reduction factor (RF), as described in Section 3, are used to define the TMDL by applying the reduction factor to the total source load, as shown in Equation 1 below.

$$\text{TMDL} = \text{TSL} \times (1\text{-RF})$$

where:

- TMDL is the total maximum daily load (kg/yr) that is expected to result in attainment of the target fish tissue mercury concentration.
- TSL is the existing total source load (kg/yr), and is equal to the sum of the existing point source load and the existing nonpoint source load
- RF is the reduction factor required to achieve the target fish mercury concentration.

To allow a consumption rate for the high risk population of one meal per week, the required reduction is 84.3 % (1 - 0.18/1.15 = 84.3%). The total existing loading from air deposition and the treatment facilities discharging into non-tidal waters is 601.kg/yr. In this load, 6.8 kg/yr (about 1%) comes from NJPDES regulated facilities with discharges to surface water in non-tidal waters. Due to the insignificant percentage contribution from this source category, reductions from this source category are not required in this TMDL. Therefore, individual WLAs are not being assigned to the various facilities through this TMDL. Individual facilities have been and will continue to be assessed to determine if a water quality based effluent limit should be assigned to prevent localized exceedances of SWQS and to ensure that the aggregate WLA is not exceeded. As discussed above and in the Reasonable Assurance section below, the recently implemented dental amalgam rules are expected to significantly reduce the amounts of mercury entering wastewater treatment facilities. At this time, it is not known what effect this will have on effluent concentrations. The post-implementation monitoring will be assessed to determine the effect of best management practices (BMPs) for the handling of dental amalgam waste and installation and proper operation of amalgam separators and the need for adaptive management with regard to this source in air deposition impacted waterbodies. Waterbodies that may be impacted by NJPDES regulated facilities with discharges to surface water (those with water column exceedances of the SWQS) have been excluded from the TMDL and will be addressed individually at a later date.

Based on results of several paleolimnological studies (NEIWPCC, et.al. 2007) in the Northeast, the natural mercury deposition is estimated to range between 15 % and 25 % of deposition fluxes for circa 2000. Natural sources cannot be controlled and are expected to remain at the same long-term average. It is assumed, in this study, that 25% of the background and background reemission is due to natural sources and can not be reduced (Ruth Chemerys and John Graham Pers. Comm. April 28, 2009). Twenty-five percent of the background and background reemission load is about 81.5 kg/yr, which is 13.6% of the total existing load. Including the load of 6.8 kg/yr attributed to surface water dischargers, the portion of the existing load that is not expected to be reduced is about 14.7%. If 0.07 ug/g (the fish concentration for unlimited consumption by the high risk population) were used as the TMDL target, the required reduction would be 93.9% of the existing load, which is greater than the entire anthropogenic load of 85.3% (1-14.7%) and clearly unattainable. For this reason, the concentration level (0.18 ug/g) that allows the high risk population to consume fish once per week was used as the target for this TMDL and will also be used as the threshold in future assessments of impairment. In order to achieve the overall 84.3% reduction of the existing load to attain the target of 0.18 mg/kg in fish tissue, a reduction of 98.8% of the anthropogenic source load would be needed. An implicit margin of safety (MOS) is used in this study, therefore, the MOS term of the TMDL equation is set to zero. Figure 5 presents the distribution of the TMDL to achieve the target concentration that will allow one meal per week by the high risk population.

Table 9. Mercury TMDL for One Meal per Week by High Risk Population

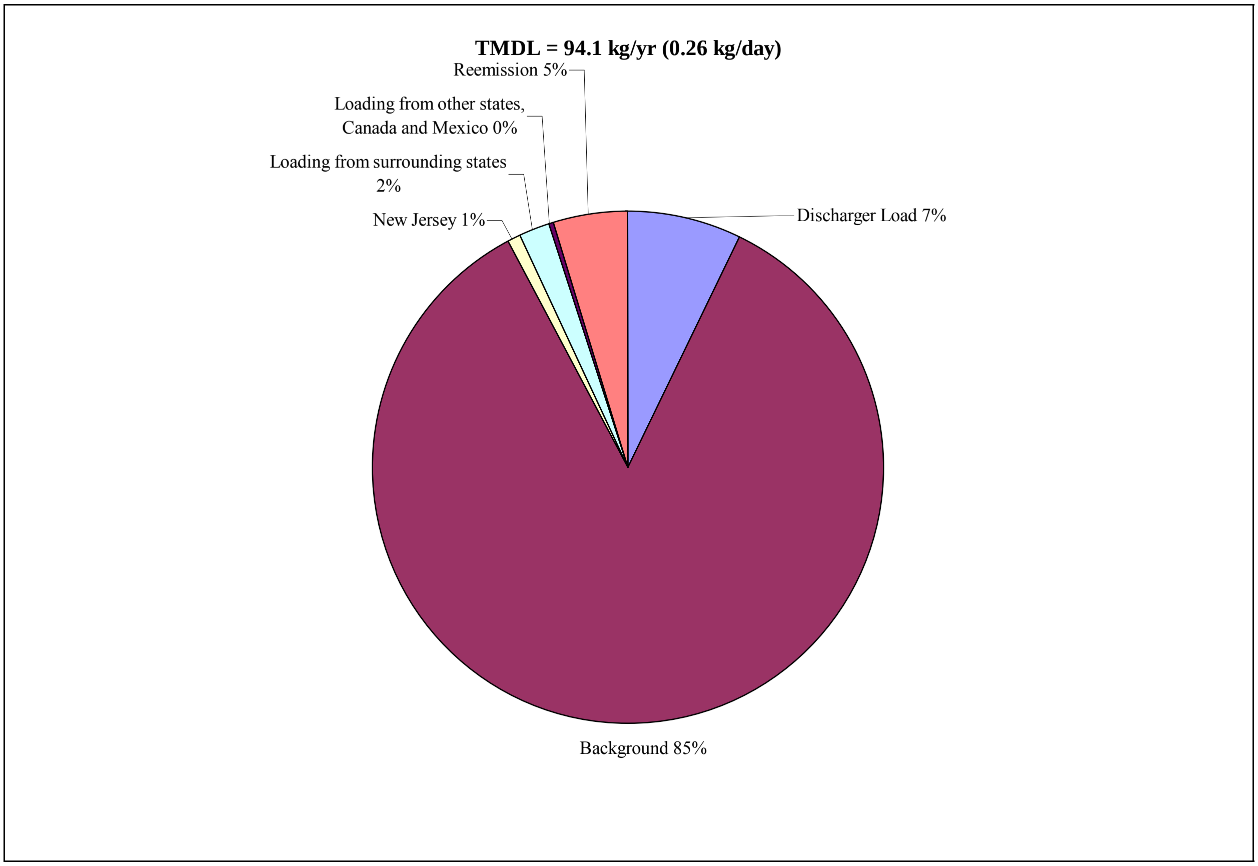
Category	Existing Load (kg/yr)	TMDL Load		Percent Reduction
		kg/yr	kg/day	
Total Annual Load	**601.0**	**94.1**	**0.26**	**84.3%**
Discharger Load (WLA)	6.8	6.8	0.02	-
Air Deposition Load (LA/WLA)	594.2	87.3	0.24	85.3%
Background due to natural source	77.3	77.3	0.21	-
Background due to anthropogenic sources	231.8	2.6	0.01	98.9%
New Jersey	74.1	0.8	0.002	98.9%
Loading from surrounding states	154.6	1.8	0.005	98.9%
Loading from other states, Canada and Mexico	39.6	0.4	0.001	98.9%
reemission due to natural source	4.2	4.2	0.01	-
Reemission due to anthropogenic source	12.7	0.1	0.0004	98.9%

Note: The TMDL loadings presented in the above table were rounded to 0.1 kg/yr. Percents of required reductions were calculated based on values with more significant digits. Using the values from the table to calculate the percent reduction may generate inaccurate results.

Table 10. Distribution of Air Deposition Load between LA and WLA under the TMDL Condition

Air Deposition Load	Annual Load (kg/yr)	Daily Load (kg/day)	Percent of Loading Capacity
Total	87.3	0.24	92.8%
WLA	22.3	0.06	23.7%
LA	65.0	0.18	69.1%

The urban storm water WLA portion of the air deposition load is derived by applying the percentage of urban land within Tier A municipalities (25.6%) to the overall air deposition load (87.3 kg/yr) based on the assumption that this load reaches the water bodies through regulated stormwater sources (see discussion in Section 4). Thus, under the TMDL conditions the WLA has been approximated to be 22.3 kg/yr (87.3 * 0.256), equivalent to 0.06 kg/day (Table 10). The air deposition rate under the TMDL condition is not available to conduct a more precise calculation of the stormwater WLA. More accuracy in developing this WLA is not necessary because the major source of mercury in stormwater is air deposition. Mercury in stormwater must be reduced by reducing air deposition and not through the usual stormwater measures. Therefore a WLA that represents an approximation of the total stormwater load is sufficient for the purposes of this TMDL. Individual stormwater WLAs would not change the response.



Note: Load from stormwater is not distinguished because it is derived from and is a subset of the air deposition load from the different air sources identified.

Figure 5. Distribution of TMDL for One Meal per Week by High Risk Population

As discussed in Section 5.2, multiple conservative assumptions have been made so that the calculated TMDL includes an implicit Margin of Safety (MOS). Therefore, the MOS term of the TMDL equation is set equal to zero. As explained above, a reduction of 85.3% (1-88.3/601) is the highest possible overall reduction that can be expected. The required reduction to achieve unlimited consumption for the high risk population is higher, (1 – 0.07/1.15 = 93.9%). Nevertheless, given the multiple conservative assumptions, this reduction may be achievable. Data gathered following implementation of the TMDL will be used to evaluate success in achieving goals.

5.1. Seasonal Variation/Critical Conditions

40 CFR 130.7(c)(1) requires that "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical WQS with seasonal variations". Calculated TMDLs shall take into account critical conditions for stream flow, loading, and water quality parameters."

The relative contribution of local, regional, and long-range sources of mercury to fish tissue levels in a waterbody are affected by the speciation of natural and anthropogenic emission sources. The amount of bioavailable methyl mercury in water and sediments is a function of the relative rates of mercury methylation and demethylation. Factors such as pH, length of the aquatic food chain, temperature and dissolved organic carbon can affect bioaccumulation. (EPA, 2009). These factors influence the extent to which mercury bioaccumulates in fish and may vary seasonally and spatially. However, mercury concentrations in fish tissue represent accumulation of the life span of a fish. Use of a fish tissue target integrates spatial and temporal variability, making seasonal variation and critical conditions less significant. In addition, the TMDL fish target value is human health-based, reflecting a longer- term exposure.

In New Jersey, data show levels of mercury in some species of fish in the Pinelands sampling region are generally higher compared to fish in other sampling regions of the state. The reductions called for in this TMDL will attain the target fish tissue concentration in the Pinelands, thereby ensuring that the target is met statewide, within the areas addressed by the TMDL.

5.2. Margin of Safety

A TMDL must include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality (CWA 303(d)(1)(C), 40C.F.R.130.7(c)(1)). EPA's 1991 TMDL Guidance explains that the MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. If the MOS is implicit, the conservative assumptions in the analysis that account for the MOS must be described.

The MOS included in this TMDL is implicit because of the following conservative assumptions:

- The 90th percentile fish mercury concentration based on the largemouth bass, *Micropterus salmoides*. This species of fish has the highest concentration of the species that are ubiquitous throughout the state
- The percent reduction does not account for additional reductions in methyl mercury that may occur as a result of the implementation of ongoing state and federal programs to reduce sulfur emissions. Reductions in sulfur deposition and sulfate-reducing bacterial activity will decrease the rate of mercury methylation. This TMDL does not account for potential mercury reductions associated with decreased sulfur deposition.

6.0. Monitoring

The Department has engaged in various monitoring efforts that have provided significant insight into mercury contamination issues, some of which are described below. In order to effectively assess progress toward achieving mercury reduction objectives, several monitoring programs are recommended, including:

- A primary monitoring strategy for measuring the levels of mercury and calculating trends is the previously mentioned Routine Fish Monitoring Program for Toxics in Fish. This comprehensive program divides the State's waters into five regions that are sampled on a rotating basis for contaminants in fish. Since mercury is persistent in the environment, accumulates in biological tissue, and biomagnifies in the food chain, adverse impacts to non-aquatic, piscivorous (fish eating) organisms may arise from very low surface water concentrations. Fish tissue sampling provides a cost-effective measure to understanding the effects of mercury in the food chain and the environment.

- A mercury water monitoring program is needed to understand the extent and magnitude of the State's mercury contamination and its effect on aquatic organisms. Such a program must have a comprehensive scope and long-term sampling period. Recent mercury studies from the United State Geological Survey (USGS) have suggested the use of screening tools to target areas where elevated concentrations of mercury may occur. These studies have suggested looking at the presence of wetlands within watersheds, dissolved organic carbon and suspended sediment concentrations, and stream flow. High dissolved oxygen content (DOC) and suspended sediment concentrations, increased stream flow, and larger wetland areas may point to elevated mercury concentrations. The sampling requirements would consist of total and methyl mercury in the water column as well as methyl mercury in fish tissue. The locations would extend to all regions of the state such as the Pinelands, Northern New Jersey, Delaware Estuary, and Atlantic Estuary. Each region would have at least five randomized sampling locations as well as a reference site, which are small undeveloped watersheds with no known sources of mercury contamination other than air deposition. This sampling is not needed on a yearly basis, but quarterly sampling once every 2-5 years is appropriate. An ongoing project, that is targeting local air source reduction by sampling for mercury in fish, water column, and leaves at four locations from 2007 to 2013, is expected to impact the development of the statewide mercury monitoring program by refining sampling frequencies, protocols, and objectives. In addition, an ongoing study in collaboration with USGS involves establishing a baseline for natural background levels for mercury in surface waters to discern the location of impairments that may have anthropogenic sources in addition to atmospheric deposition e.g. mercurial pesticides on orchard, crops and golf courses and which may have other natural sources, e.g. geologic. This evaluative monitoring has been completed in the Inner and Outer Coastal Plain, Raritan River Basin, Papakating and Wallkill River Watersheds. The investigation is ongoing in the Millstone River Basin, Crosswicks Creek Watershed and Passaic River Basin.

- One hundred POTWs in New Jersey submitted baseline data on mercury concentrations in their treatment plant effluent. These samples were analyzed using the most sensitive analytical method for mercury in wastewater, Method 1631E. This baseline data will be used to determine the effectiveness of the implementation of the dental BMPs and the installation of the amalgam separators. These POTWs are required to conduct additional mercury sampling and analyses, using the same analytical method, after amalgam separator installation.

- In-stream monitoring to evaluate effectiveness of the dental amalgam rule is required at target locations upstream and downstream of the POTW discharge. The monitoring sites will be sampled semi-annually to evaluate ambient water quality before and after the rule's implementation to observe the significance of the reductions. Currently, only one site has been targeted. This project needs to expand by selecting suitable locations based on reviewing the POTW effluent data.

- Air sampling under the National Mercury Monitoring Deposition Network is required to continue to monitor long-term loadings and trends from atmospheric deposition. This program currently has only one site in the New Brunswick area. Additional sites in southern and northern portions of the state this network are needed to improve knowledge of depositional rates for different regions of the state and assist in atmospheric deposition source track down.

Monitoring studies already carried out have provided the following information:

- The Department's Air Program has collected speciated ambient mercury concentration data from several Tekran units that can be used to estimate dry deposition. To date, over two years' data from units at two locations, Elizabeth and New Brunswick have been checked for quality and are in the process of being evaluated. Data on wet deposition is being collected in New Brunswick and is analyzed by the National Mercury Deposition Network.

- Water monitoring data collected by NJDEP/USGS in the Ambient and Supplemental Surface Water Networks show that of the 1,752 results since 1997, nearly 67% had concentrations less than the detection levels. None of the total mercury values exceeded the current acute freshwater aquatic life criterion for dissolved mercury of 1.4 microgram per liter (ug/l) or the chronic criterion of 0.77 ug/l, but 3% of the samples exceeded the human health criterion of 0.05 ug/l. Other mercury studies and projects by NJDEP and USGS over the years show similar results, the majority of mercury concentrations are below detection levels. Detection levels have improved since 1997 with detection levels between 0.04 and 0.1 ug/l to detection levels between 0.01 and 0.02 ug/l since 2004.

- In response to the need for detection of low levels of mercury, the Department initiated a preliminary study of low level mercury occurrence in surface waters. Using EPA's method 1631E, the project consisted of 33 filtered samples with accompanying field blanks at 23 unique stations across the state. The detection level at the Wisconsin laboratory being used was 0.04 ppt. Results did not exceed any of the existing surface water quality criteria. Mercury concentrations did not appear to be influenced by land use, but did appear to increase with stream flow. The findings suggest that air deposition is a major influence on in-stream mercury concentrations. In 2007, the Department conducted a follow-up study to determine seasonal variability in total and methyl mercury concentrations at 7 reference stations, small undeveloped watersheds with no known sources of mercury contamination other than air deposition. Although total mercury showed no seasonal patterns, methyl mercury had elevated levels during the summer due to higher methylation rates during the warmer months. In addition, the project verified new sampling protocols that allow one person to conduct low level mercury sampling, thereby reducing manpower requirements and allowing this sampling to be incorporated into an ambient or routine program.

- A 150 well, statewide, shallow Ground Water Quality Monitoring Network, which was stratified as a function of land use, has been established and is sampled on a 5 year cycle for mercury and other contaminants. During the first 5 year sampling cycle from 1999 to 2004, mercury concentrations were found to range from <0.01 to 1.7 ug/L in ground water from 148 wells and only 5 of those were detectable above the laboratory reporting limits. In addition, other ground water data has been collected under the Private Well Testing Act that required private wells in 9 Southern New Jersey counties to test for mercury. A total of 25,270 wells were tested with a concentration range of 114.2 ug/l to "not detected". Approximately 1% had concentrations above the drinking water maximum contaminate level (MCL) of 2 ug/l. An analysis of the data showed no obvious geographic or land use patterns for the elevated mercury results.

7.0. Reasonable Assurance

New Jersey has a long history of working toward the reduction of mercury contamination within the state and working with interstate organizations to reduce the mercury both coming into and leaving the state. Much progress has been made. Because of New Jersey's past successes in the reduction of mercury, the actions New Jersey has underway and its commitment to implementing further actions as necessary, including working with neighboring states to reduce sources originating from outside the state, there is reasonable assurance that the goals of the TMDL will be met.

New Jersey began working to reduce mercury releases to the environment in 1992 with the formation of a Mercury Task Force. That Task Force examined the many routes and sources of mercury exposure and found air emissions to be the number one source of mercury contamination in New Jersey. The Task Force identified the largest source of mercury air emissions in New Jersey as Municipal Solid Waste (MSW) Incinerators. The Task Force recommended a statewide mercury emission standard for MSW Incinerators, which was implemented in 1996. In addition to the MSW incinerator standards, New Jersey passed the "Dry Cell Battery Management Act" in 1992, banning the use of mercury in certain batteries. These two efforts reduced MSW incinerator mercury emissions by 97% between 1992 and 2006.

In 1998, New Jersey convened a second Mercury Task Force. The second Task Force consisted of representatives from government, emission sources, public interest groups, academia, and fishing organizations. This Task Force was charged with reviewing the current science on mercury impacts on human health and ecosystems, inventorying and assessing mercury sources, and developing a comprehensive mercury reduction plan for NJ. The "New Jersey Mercury Task Force Report" published in December 2001 established a goal of the virtual elimination of anthropogenic sources of mercury and provided recommendations and targets for further reducing mercury emissions in New Jersey. The Task Force Report is available at http://www.nj.gov/dep/dsr/mercury_task_force.htm

In 2007 the Department's Mercury Workgroup evaluated New Jersey's progress towards meeting the goals and recommendations of the Task Force and began putting together a Mercury Reduction Plan to identify the necessary additional actions to continue to reduce mercury emissions in New Jersey. The reduction plan will serve as the implementation plan for these TMDLs.

Below is a summary of actions that have been taken to reduce New Jersey's mercury loadings.

- To participate in and support regional, national, and global efforts to reduce mercury uses, releases, and exposures New Jersey is a member of the Interstate Mercury Education and Reduction Clearinghouse (IMERC), a member of the Northeast Waste Management Officials Association (NEWMOA), the Quicksilver Caucus, Northeast States for Consolidated Air Use Management (NESCAUM), Environmental Council of the States (ECOS), and Toxics in Packaging.

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- In conjunction with NEWMOA, informational brochures were developed for tanning salons and property managers concerning the management of mercury containing fluorescent lamps. The brochures were sent to every tanning salon and property management company in the state.

- New Jersey works with interstate organizations to assist in the development of federal legislation that minimizes the use of mercury in products. The Department is a member of and works with the Northeast Waste Management Officials Association (NEWMOA) on mercury issues. The Department will participate in any effort conducted by NEWMOA or other interstate organization to develop federal legislation to minimize the use of mercury in products.

- On December 6, 2004, New Jersey adopted regulations to establish new requirements for coal-fired boilers, in order to decrease emissions of mercury. These rules are located at http://www.state.nj.us/dep/aqm/Sub27-120604.pdf.

- On December 6, 2004, New Jersey adopted regulations to establish new requirements for iron or steel melters in order to decrease emissions of mercury. The Department provided three years to reduce mercury contamination of scrap through elimination and separation measures. If the source reduction measures do not achieve emission reduction, the rule requires the installation and operation of mercury air pollution control and requires achieving mercury standard starting 1/2010. These rules are located at http://www.state.nj.us/dep/aqm/Sub27-120604.pdf.

- On December 6, 2004, New Jersey adopted regulations to establish new requirements for Hospital/medical/infectious waste (HMIW) incinerators in order to prevent or decrease emissions of mercury by ensuring that the mercury emissions from HMIW incinerators will be maintained at low levels. These rules are located at http://www.state.nj.us/dep/aqm/Sub27-120604.pdf.

- The Department has closely monitored mercury sewage sludge levels and has taken action where existing authority would allow the imposition of a sewage sludge limit or a discharge limitation. For example, the POTW with the highest sewage sludge mercury concentrations was identified and the industry responsible voluntarily agreed to shut down all production of mercury-containing diagnostic kits. Increased focus on removing mercury from products, as well as the proposed dental rule noted above, should continue the decreasing trend of detectable concentrations of mercury found in sewage sludge.

- On December 6, 2004, New Jersey adopted revised regulations to establish new requirements for municipal solid waste (MSW) incinerators in order to prevent or decrease emissions of mercury by requiring MSW incinerators to further reduce their mercury emissions. These rules are located at http://www.state.nj.us/dep/aqm/Sub27-120604.pdf.

- The Department has included all mercury containing products in the Universal Waste Rule which allows generators of waste mercury containing products to manage the waste under less stringent regulations than the Hazardous Waste Regulations. In addition, every county in the state holds at least one household hazardous waste (HHW) collection per year. Most counties hold multiple collections and 3 counties (Burlington, Monmouth, and Morris) have permanent collection sites. Households generating mercury containing products can properly dispose of the items at their county's collection.

- Legislation banning the sale of mercury thermometers was passed in April 2005.

- The New Jersey Legislature passed the Mercury Switch Removal Act of 2005 requiring automobile recycling facilities to remove mercury auto switches from vehicles prior to sending the vehicles for recycling. Automobile recyclers located in New Jersey were required to begin removing the mercury auto switches in May 2006. Manufacturers have stopped using mercury switches in convenience lighting.

- The Department adopted new rules on October 1, 2007 to curtail the release of mercury from dental facilities into the environment. The new rules, under most circumstances, exempt a dental facility from the requirement to obtain an individual permit for its discharge to a POTW, if it implements best management practices (BMPs) for the handling of dental amalgam waste and installs and properly operates an amalgam separator. Dental facilities were required to implement the BMPs by October 1, 2008 and must install and operate an amalgam separator by October 1, 2009. These measures are expected to prevent at least 95 percent of the mercury wastes from being sent to the

POTW and result in approximately 2,550 pounds of mercury removed from the environment each year.

- The Department participated in the Quicksilver Caucus, which developed methods for the retirement and sequestering of mercury.

The out of state contributions to the depositional load of mercury are too great for New Jersey to eliminate mercury contamination of fish tissue by reducing sources originating within its borders alone. New Jersey will work with EPA and other states to eliminate mercury sources nationwide. EPAs efforts to issue MACT (Maximum Achievable Control Technology) standards for utilities to reduce the depositional load of mercury are supported by New Jersey. In October 2008, the New England Interstate Water Pollution Control Commission (NEIWPCC), on behalf of seven states, submitted a petition under the Clean Water Act Section 319(g) requesting EPA to convene an interstate conference to address mercury deposition to the Northeast from upwind states. The petition builds on the Northeast States' regional mercury TMDL (approved by EPA in 2007), which indicates that reductions in mercury deposition from outside the region are needed to meet water quality standards. New Jersey will participate actively in this conference when it is held.

8.0. Implementation Plan

The implementation actions below are the recommendations of the Department's Mercury Task Force (NJDEP, 2009) intended to reduce anthropogenic sources of mercury:

1) Consider developing legislation that reflects the provisions of the Mercury Education and Reduction Model Act prepared by the Northeast Waste Management Officials' Association (NEWMOA), as part of the New England Governors' Mercury Action Plan. This plan addresses mercury-containing products and limits the sale of mercury for approved purposes. Provisions of the model legislation have been adopted by 16 states, including all of the New England states.

2) Continue monitoring of mercury in environmental media. Needed follow-up monitoring is described in Section 6 and is essential for determining the effectiveness of the mercury Total Maximum Daily Load (TMDL).

3) New Jersey contributes only 12.5% to the state mercury deposition; 52% is background deposition (natural and anthropogenic) and the remaining percentage comes from surrounding states, Mexico, and Canada. Reductions required in this TMDL can not be achieved from the New Jersey anthropogenic air sources alone. Mercury reductions on the nationwide and global scales are necessary to meet the TMDL targets set up above.

4) The Department plans to update its mercury water quality criteria based upon the EPA recommended Clean Water Act Section 304(a) for methyl mercury in fish tissue. This criterion requires the development of regional bioaccumulation factors (BAFs) to address differences in the rate of methylation based on other water quality parameters such as pH and

dissolved organic carbon. While the EPA's recommended Clean Water Act Section 304(a) water quality criterion is based on a methyl mercury fish tissue concentration value of 0.3 mg/kg, New Jersey plans to develop criteria based upon a methyl mercury fish tissue concentration of 0.18 mg/kg which is based upon consumption of 1 meal per week by high risk individuals. Updating the mercury criteria based on EPA's recommendation will require calculating BAFs for New Jersey that involves additional surface water and fish tissue sampling. This information will also be used to reevaluate the previously proposed wildlife mercury criteria using updated regional BAFs. The revised mercury criteria will be used to develop TMDLs for areas of the State not covered by the Total Maximum Daily Load for Mercury Impairments Based on Concentration in Fish Tissue Caused Mainly by Air Deposition. In calculating an updated, revised mercury SWQS for human health and wildlife, the Department will divide the state into four regional waters: Pinelands, Non-Pinelands, Delaware Estuary tidal waters, and Atlantic tidal waters. Surface water and fish tissue data will be collected and used to develop new BAFs for each region of the state. The data results will then be applied in calculating the mercury criteria for each region. In 2009, the Department expects to begin data collection in the Pinelands region with plans to continue collection in non-Pinelands water the following year. The next action is to collect data for the Delaware Estuary and Atlantic tidal waters.

5) The existing regulations concerning mercury will continue to be implemented, enforced, and evaluated for effectiveness. This includes the regulations on mercury emissions from air sources, the removal of automobile mercury switches and the dental amalgam regulations.

9.0. Public Participation

There have been various efforts to inform and educate the general public as well as the regulated community about the effects of mercury and the need to reduce anthropogenic sources. The regulatory controls regarding mercury are described in Section 7 and some of the outreach to the general public are noted below.

Over the years the Department, in cooperation with the Department of Health and Senior Services has conducted a great deal of public outreach to the fishing community to inform them of the fish consumption advisories. Surveys were done to determine how best to reach the public. As a result the fish advisories are posted in both Spanish and English. Brochures have been developed and are distributed to doctors and WIC (the federal Women, Infants and Children nutrition program) centers. The Department of Health seafood inspectors distribute and check for postings as part of their inspections.

Currently the Department's Urban Fishing Program educates children from the Newark Bay Complex and throughout New Jersey about their local watershed. Children learn about how people's actions affect the water and human health, and what they can do to help. The NJDEP's Divisions of Watershed Management and Science, Research and Technology in conjunction with the Division of Fish and Wildlife, the Hackensack RiverKeeper, the City of Bayonne and the Municipal Utilities Authority of Bayonne have offered the program for over 10 years. The first several years of the Urban Watershed Program were conducted only in the Newark Bay

Complex. The program has now expanded to other urban areas around the state. Trenton and Camden have participated over the last three years, and we hope to add several more cities in the future.

In conjunction with NEWMOA, informational brochures were developed for tanning salons and property managers concerning the management of mercury containing fluorescent lamps. The brochures were sent to every tanning salon and property management company in the state.

There has been additional public outreach and opportunity for comment for the TMDL itself. In accordance with N.J.A.C. 7:15–7.2(g), this TMDL was proposed by the Department as an amendment to the Atlantic, Cape May, Lower Delaware, Lower Raritan-Middlesex, Mercer, Monmouth, Northeast, Ocean, Sussex, Tri-County, Upper Delaware and Upper Raritan Water Quality Management Plans.

Notice proposing this TMDL was published on June 15, 2009 in the New Jersey Register and in newspapers of general circulation in the affected area in order to notify the public of the opportunity to review the TMDL and submit comments. In addition, an informational presentation followed by a public hearing for the proposed TMDL was held on July 15, 2009. Notice of the proposal and the hearing was also provided to affected Designated Planning Agencies and dischargers in the affected watersheds. One member of the public attended the hearing and declined to comment. No comments were submitted during the public comment period. Various minor edits to the proposal document have been made for clarification.

10.0. Data Sources

Geographic Information System (GIS) data from the Department was used extensively to describe the areas addressed in this document.

- State Boundary of New Jersey, Published by New Jersey Office of Information Technology (NJOIT), Office of Geographic Information Systems (OGIS), May 20, 2008. On line at: https://njgin.state.nj.us/NJ_NJGINExplorer/jviewer.jsp?pg=DataDownloads

- Watersheds (Subwatersheds by name - DEPHUC14), Drainage basins are delineated from 1:24,000-scale (7.5-minute) USGS quadrangles. The delineations have been developed for general purpose use by USGS District staff over the past 20 years. Arc and polygon attributes have been included in the coverage with basin names and ranks of divides, and 14-digit hydrologic unit codes. *Originator:* U.S. Geological Survey, William H. Ellis, Jr. *Publication_Date:* 19991222 http://www.state.nj.us/dep/gis/digidownload/zips/statewide/dephuc14.zip

- NJDEP 2002 Waters of New Jersey (Lakes and Ponds), *Edition* 2008-05-01. The data was created by extracting water polygons which represented lakes and ponds from the 2002 land use/land cover (LU/LC) layer from NJ DEP's geographical information systems (GIS) database http://www.state.nj.us/dep/gis/digidownload/zips/statewide/njwaterbody.zip

- NJDEP 2002 Waters of New Jersey (Rivers, Bays and Oceans), *Version* 20080501; *Edition:* 20080501. The data was created by extracting water polygons which represented Rivers, Bays and Oceans from the 2002 land use/land cover (LU/LC) layer from NJ DEP's geographical information systems (GIS) database. *Online Linkage* http://www.state.nj.us/dep/gis/digidownload/zips/statewide/njarea.zip

- NJPDES Surface Water Discharges in New Jersey, (1:12,000), Version 20090126, *Edition:* 2009-01-26. This is a 2009 update of the 2002 data. New Jersey Pollutant Discharge Elimination System (NJPDES) surface water discharge pipe GIS point coverage compiled from GPSed locations, NJPDES databases, and permit applications. This coverage contains the surface water discharge points and the receiving waters coordinates for the active as well as terminated pipes. *Online Linkeage*: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/njpdesswd.zip

- NJDEP Surface Water Quality Standards of New Jersey *Edition:* 200812. This data is a digital representation of New Jersey's Surface Water Quality Standards in accordance with "Surface Water Quality Standards for New Jersey Waters" as designated in N.J.A.C. 7:9 B. The Surface Water Quality Standards (SWQS) establish the designated uses to be achieved and specify the water quality (criteria) necessary to protect the State's waters. Designated uses include potable water, propagation of fish and wildlife, recreation, agricultural and industrial supplies, and navigation. These are reflected in use classifications assigned to specific waters. When interpreting the stream classifications and anti-degradation designations, the descriptions specified in the SWQS at N.J.A.C. 7:9B-1.15 always take precedence. The GIS layer reflects the stream classifications and anti-degradation designations adopted as of June 16, 2008, and it is only supplemental to SWQS and is not legally binding. http://www.state.nj.us/dep/gis/digidownload/zips/statewide/swqs.zip

- “Water Management Areas”, created 03/2002 by NJDEP, Division of Watershed Management, the last update January, 2009. *Online Linkage*. http://www.state.nj.us/dep/gis/digidownload/zips/statewide/depwmas.zip

- NJDEP Known Contaminated Site List for New Jersey, 2005, *Edition:* 200602; The Known Contaminated Sites List for New Jersey 2005 are those sites and properties within the state where contamination of soil or ground water has been identified or where there has been, or there is suspected to have been, a discharge of contamination. This list of Known Contaminated Sites may include sites where remediation is either currently under way, required but not yet initiated or has been completed. http://www.state.nj.us/dep/gis/digidownload/zips/statewide/kcsl.zip

- Groundwater Contamination Areas (CKE); this data layer contains information about areas in the state which are specified as the Currently Known Extent (CKE) of ground water pollution. CKE areas are geographically defined areas within which the local ground water resources are known to be compromised because the water quality exceeds drinking water and ground water quality standards for specific contaminants. NJDEP Currently Known Extent of Groundwater Contamination (CKE) for New Jersey, 2007. *Edition:* 200703. *Online Linkage:* http://www.state.nj.us/dep/gis/digidownload/zips/statewide/cke.zip

11.0. References

Academy of Natural Sciences of Philadelphia (ANSP). 1994. Preliminary Assessment of Total Mercury Concentrations in fishes from rivers, lakes and reservoirs of New Jersey. Report 93-15F; Submitted to New Jersey Department of Environmental Protection and Energy, Division of Science and Research. Contract P-35272. 92 pp.

Academy of Natural Sciences of Philadelphia (ANSP). 1999. Phase II Assessment of total mercury concentrations in fishes from rivers, lakes and reservoirs of New Jersey. Report 99-7. Submitted to New Jersey Department of Environmental Protection and Energy, Division of Science and Research. 155 pp.

Academy of Natural Sciences of Philadelphia (ANSP). 2007. Quality Assurance and Quality Control Plan: Routine Monitoring for Toxics in New Jersey Fish: Year 3, Raritan River Region. Contract # SR06-008. Academy Reference No. 464. Submitted to New Jersey Department of Environmental Protection, Division of Science, Research and Technology. http://www.state.nj.us/dep/dsr/njmainfish.htm

Ashley, J. And R. Horwitz. 2000. Assessment of PCBs, selected organic pesticides and mercury in fishes from New Jersey: 1998-1999 Monitoring Program, Academy of Natural Sciences; Report No. 00-20F. 112 pp.

Chemerys, R. and Graham, J. E-mail to Helen Pang dated April 28, 2009.

GLEC. 2008. New York-New Jersey Harbor Estuary Program, New Jersey Toxics Reduction Work Plan, Study I-G Project Report. Great Lakes Environment Center, Traverse City, MI. 350 pp. http://www.state.nj.us/dep/dsr/njtrwp/njtrwp-study-i-g.pdf

Hooks, Craig, Director, Office of Wetlands, Oceans and Watersheds, September 29, 2008."Elements of Mercury TMDLs Where Mercury Loadings are Predominantly from Air Deposition” http://www.epa.gov/owow/tmdl/pdf/cover_memo_mercury_tmdl_elements.pdf http://www.epa.gov/owow/tmdl/pdf/document_mercury_tmdl_elements.pdf

Horwitz, R.J., J. Ashley, P. Overbeck and D. Velinsky. 2005. Final Report: Routine Monitoring Program for Toxics in Fish. Contract SR02-064. ANS Report No. 04-06. April 12, 2005. 175 pp.

Horwitz, R. J., P. Overbeck, J. Ashley, D. Velinsky and L. Zadoudeh. 2006. Final Report: Monitoring Program for Chemical Contaminants in Fish from the State of New Jersey. Contract SR04-073. ANS Report No. 06-04F. August 17, 2006. 77pp.

ICF International San Rafael, CA 2008. Model-Based Analysis and Tracking of Airborne Mercury Emissions to Assist in Watershed Planning Revised Final Report, Prepared for U.S. EPA Office of Water Washington, D.C.

Korn, L. R., e-mail to Anne Witt, dated April 16, 2009.

New England Interstate Water Pollution Control Commission, New Hampshire Department of Environmental Services, New York State Department of Environmental Conservation, Rhode Island Department of Environmental Management, Vermont Department of Environmental Conservation, Connecticut Department of Environmental Protection, Maine Department of Environmental Protection, Massachusetts Department of Environmental Protection
October 24, 2007, Northeast Regional Mercury Total Maximum Daily Load.
http://www.neiwpcc.org/mercury/mercury-docs/FINAL Northeast Regional Mercury TMDL.pdf

NJDEP, 2001 New Jersey's Mercury Task Force Final Report Volume I: Executive Summary and Recommendations, Volume II: Exposure and Impacts, Volume III: Sources of Mercury to New Jersey's Environment. http://www.nj.gov/dep/dsr/mercury_task_force.htm

NJDEP, 2009 New Jersey Mercury Reduction Plan, Mercury Work Group, Unpublished

NJDEP 2008 NJ Integrated Water Quality Monitoring and Assessment Report (305(b) and 303(d)). Water Assessment Team. NJDEP.
www.state.nj.us/dep/wms/bwqsa/integratedlist2008Report.html.

Toxics in Biota Committee, 1994, Mercury Contamination in New Jersey Freshwater Fish,. NJDEP, NJDHOH, NJDA. 88 pp.

Sutfin, 2002, Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992" USEPA

USEPA. 1997. Mercury Study Report to Congress. Volume III: Fate and Transport of Mercury in the Environment. EPA 452/R-97-005. Washington, DC.
www.epa.gov/ttn/oarpg/t3/reports/volume3.pdf

Appendix A

Listed Assessment units that were excluded from the Statewide TMDL

Waterbody	Name	Reason for Exclusion from TMDL
02030103120070-01	Passaic River Lwr (Fair Lawn Ave to Goffle)	Mercury in surface water
02030103120080-01	Passaic River Lwr (Dundee Dam to F.L. Ave)	Mercury in surface water
02030103120090-01	Passaic River Lwr (Saddle R to Dundee Dam)	Mercury in surface water
02030103150030-01	Passaic River Lwr (Second R to Saddle R)	Mercury in surface water
02030103150040-01	Passaic River Lwr (4th St br to Second R)	Mercury in surface water
02030103150050-01	Passaic River Lwr (Nwk Bay to 4th St brdg)	Mercury in surface water
02030103170030-01	Hackensack River (above Old Tappan gage)	Mercury in surface water
02030103170060-01	Hackensack River (Oradell to Old Tappan gage)	Mercury in surface water
02030103180030-01	Hackensack River (Ft Lee Rd to Oradell gage)	Mercury in surface water
02030103180080-01	Hackensack River (Rt 3 to Bellmans Ck)	Mercury in surface water
02030103180090-01	Hackensack River (Amtrak bridge to Rt 3)	Mercury in surface water
02030103180100-01	Hackensack River (below Amtrak bridge)	Mercury in surface water
02030104010020-01	Kill Van Kull West	Mercury in surface water
02030104010020-02	Newark Bay / Kill Van Kull (74d 07m 30s)	Mercury in surface water
02030104010030-01	Kill Van Kull East	Mercury in surface water
02030104010030-02	Upper NY Bay / Kill Van Kull (74d07m30s)	Mercury in surface water
02030104020030-01	Arthur Kill North	Mercury in surface water
02030104030010-01	Arthur Kill South	Mercury in surface water
02030104050120-01	Arthur Kill waterfront (below Grasselli)	Mercury in surface water
02040105210060-01	Jacobs Creek (above Woolsey Brook)	Mercury in surface water
02040105230050-01	Assunpink Creek (Shipetaukin to Trenton Rd)	Mercury in surface water
02040201050040-01	Crosswicks Creek (Walnford to Lahaway Ck)	Mercury in surface water
02040201050050-01	Crosswicks Creek (Ellisdale trib - Walnford)	Mercury in surface water
02040201050070-01	Crosswicks Creek (Doctors Ck-Ellisdale trib)	Mercury in surface water
02040206140040-01	Blackwater Branch (above/incl Pine Br)	Mercury in surface water
02040206140050-01	Blackwater Branch (below Pine Branch)	Mercury in surface water
02040206200010-01	Middle Branch / Slab Branch	Mercury in surface water
02040206200020-01	Muskee Creek	Mercury in surface water
02040301020040-01	Muddy Ford Brook	Mercury in surface water
02040301070080-01	Manapaqua Brook	Mercury in surface water
02040301170010-01	Hammonton Creek (above 74d43m)	Mercury in surface water
02040301170020-01	Hammonton Creek (Columbia Rd to 74d43m)	Mercury in surface water
02040302020020-01	Absecon Creek SB	Mercury in surface water
02040302020030-01	Absecon Creek (AC Reserviors) (gage to SB)	Mercury in surface water
02030103010180-01	Passaic River Upr (Pine Bk br to Rockaway)	Mercury in surface water
02030103040010-01	Passaic River Upr (Pompton R to Pine Bk)	Mercury in surface water
02030103120100-01	Passaic River Lwr (Goffle Bk to Pompton R)	Mercury in surface water
02030103180060-01	Berrys Creek (above Paterson Ave)	Mercury in surface water
02030103180070-01	Berrys Creek (below Paterson Ave)	Mercury in surface water
02030105160070-01	South River (below Duhernal Lake)	Mercury in surface water
02040202020030-01	Rancocas Creek NB (incl Mirror Lk-Gaunts Bk)	Mercury in surface water
02040202020040-01	Rancocas Creek NB (NL dam to Mirror Lk)	Mercury in surface water
02040202100060-01	Pennsauken Creek (below NB / SB)	Mercury in surface water
02040301020050-01	Metedeconk River NB (confluence to Rt 9)	Mercury in surface water
02040301040020-01	Metedeconk River (Beaverdam Ck to confl)	Mercury in surface water
02040302050060-01	Great Egg Harbor River (Miry Run to Lake Lenape)	Mercury in surface water

02040302050130-01	Great Egg Harbor River (GEH Bay to Miry Run)	Mercury in surface water
Delaware River 1	Delaware River 1C2	Mercury in surface water
Delaware River 2	Delaware River 1C3	Mercury in surface water
Delaware River 3	Delaware River 1C4	Mercury in surface water
Delaware River 4	Delaware River 1D1	Mercury in surface water
Delaware River 5	Delaware River 1D2	Mercury in surface water
Delaware River 6	Delaware River 1D3	Mercury in surface water
Delaware River 7	Delaware River 1D4	Mercury in surface water
Delaware River 8	Delaware River 1D5	Mercury in surface water
Delaware River 9	Delaware River 1D6	Mercury in surface water
Delaware River 10	Delaware River 1E1	Mercury in surface water
Delaware River 11	Delaware River 1E2	Mercury in surface water
Delaware River 12	Delaware River 1E3	Mercury in surface water
Delaware River 13	Delaware River 1E4	Mercury in surface water
Delaware River 14	Delaware River 1E5	Mercury in surface water
Delaware River 15	Delaware River 2	Mercury in surface water
Delaware River 16	Delaware River 3	Mercury in surface water
Delaware River 17	Delaware River 4	DRBC
Delaware River 18	Delaware River 5A	DRBC
Delaware River 19	Delaware River 5B	DRBC
Delaware River 20	Delaware River 5C	DRBC
02040204910010-02	Delaware Bay (Cape May Pt to Dennis Ck) offshore	DRBC
02040204910010-01	Delaware Bay (CapeMay Pt to Dennis Ck) inshore	DRBC
02040204910040-01	Delaware Bay (Cohansey R to FishingCk)	DRBC
02040204910020-02	Delaware Bay (Dennis Ck to Egg Islnd Pt) offshore	DRBC
02040204910020-01	Delaware Bay (DennisCk to Egg Islnd Pt) inshore	DRBC
02040301200030-02	Wading River (below Rt 542)	Tidal
02040301200080-02	Mullica River (GSP bridge to Turtle Ck)	Tidal
02040301210010-02	Mullica River (below GSP bridge)	Tidal
02030104020030-02	Elizabeth River (below Elizabeth CORP BDY)	Tidal
02030104030010-02	Morses Creek / Piles Creek	Tidal
02030104080040-01	Shrewsbury River (above Navesink River)	Tidal
02030104090040-01	Shark River (above Remsen Mill gage)	Tidal
02030104090060-01	Shark River (below Remsen Mill gage)	Tidal
02030104910020-01	Sandy Hook Bay (east of Thorns Ck)	Tidal
02040201030010-01	Duck Creek and UDRV to Assunpink Ck	Tidal
02030104060010-01	Cheesequake Creek / Whale Creek	Tidal
02030104070110-01	Navesink River (below Rt 35) / Lower Shrewsbury	Tidal
02040301080060-01	Toms River Lwr (Rt 166 to Oak Ridge Pkwy)	Tidal
02030104070110-01	Navesink River (below Rt 35) / Lower Shrewsbury	Tidal
02030104060060-01	Pews Creek to Shrewsbury River	Tidal
02040301080060-01	Toms River Lwr (Rt 166 to Oak Ridge Pkwy)	Tidal
02040301200030-02	Wading River (below Rt 542)	Tidal
02030104080010-01	Little Silver Creek / Town Neck Creek	Tidal
02040301200080-02	Mullica River (GSP bridge to Turtle Ck)	Tidal
02040301210010-02	Mullica River (below GSP bridge)	Tidal
02040302020010-01	Absecon Creek NB	Tidal
02040302020040-01	Absecon Creek (below gage)	Tidal

02030104080010-01	Little Silver Creek / Town Neck Creek	Tidal
02030104080020-01	Parkers Creek / Oceanport Creek	Tidal
02030104080030-01	Branchport Creek	Tidal
02040201070030-01	Shady Brook / Spring Lake / Rowan Lake	Tidal
02040202120080-01	Big Timber Creek (below NB/SB confl)	Tidal
02040202130040-01	Mantua Creek (Edwards Run to rd to Sewell)	Tidal
02040202140040-01	Moss Branch / Little Timber Creek (Repaupo)	Tidal
02040202140050-01	Repaupo Creek (below Tomlin Sta Rd) / Cedar Swamp	Tidal
02040202160020-01	Oldmans Creek (Rt 45 to Commissioners Rd)	Tidal
02040206090080-01	Cohansey River (Greenwich to 75d17m50s)	Tidal
02040206090100-01	Cohansey River (below Greenwich)	Tidal
02030104010010-01	Newark Airport Peripheral Ditch	Tidal
02040206100040-01	Cedar Creek (above Rt 553)	Tidal
02040206160030-01	Maurice River (Union Lake to Sherman Ave)	Other sources of Hg
02030103030070-01	Rockaway River (74d 33m 30s to Stephens Bk)	Other sources of Hg
02030103100070-01	Ramapo River (below Crystal Lake bridge)	Other sources of Hg
02040201050060-01	Ellisdale Trib (Crosswicks Creek)	Other sources of Hg
02040201070020-01	Crosswicks Creek (below Doctors Creek)	Other sources of Hg
02030103100060-01	Crystal Lake / Pond Brook	Other sources of Hg
02030104060040-01	Chingarora Creek to Thorns Creek	Other sources of Hg
02030104060050-01	Waackaack Creek	Other sources of Hg
02030105160090-01	Red Root Creek / Crows Mill Creek	Hg in groundwater
02030105160100-01	Raritan River Lwr (below Lawrence Bk)	Hg in groundwater
02040105230020-01	Assunpink Creek (New Sharon Br to/incl Lake)	Hg in groundwater
02040105230030-01	New Sharon Branch (Assunpink Creek)	Hg in groundwater
02040105230040-01	Assunpink Creek (Trenton Rd to New Sharon Br)	Hg in groundwater
02040105240010-01	Shabakunk Creek	Hg in groundwater
02040105240050-01	Assunpink Creek (below Shipetaukin Ck)	Hg in groundwater
02040201030010-01	Duck Creek and UDRV to Assunpink Ck	Hg in groundwater
02040201040040-01	Jumping Brook (Monmouth Co)	Hg in groundwater
02040301160020-01	Mullica River (above Jackson Road)	Hg in groundwater
02040301170040-01	Mullica River (Batsto R to Pleasant Mills)	Hg in groundwater
02040301170060-01	Mullica River (Rt 563 to Batsto River)	Hg in groundwater
02040301170080-01	Mullica River (Lower Bank Rd to Rt 563)	Hg in groundwater
02040301170130-01	Mullica River (Turtle Ck to Lower Bank Rd)	Hg in groundwater
02040301190050-01	Wading River WB (Jenkins Rd to Rt 563)	Hg in groundwater
02040301200020-01	Wading River (Rt 542 to Oswego River)	Hg in groundwater
02030103180040-01	Overpeck Creek	HEP
02030103180050-01	Hackensack River (Bellmans Ck to Ft Lee Rd)	HEP
02030104050060-01	Rahway River (Robinsons Br to Kenilworth Blvd)	HEP
02030104050100-01	Rahway River (below Robinsons Branch)	HEP
02030105120170-01	Raritan River Lwr (Lawrence Bk to Mile Run)	HEP
02030105160100-01	Raritan River Lwr (below Lawrence Bk)	HEP
02040302940010-01	Atlantic Ocean (34th St to Corson Inl) inshore	Tidal
02040302940010-02	Atlantic Ocean (34th St to Corson Inl) offshore	Tidal
02040302920010-01	Atlantic Ocean (Absecon In to Ventnor) inshore	Tidal
02040302920010-02	Atlantic Ocean (Absecon In to Ventnor) offshore	Tidal
02040301920010-02	Atlantic Ocean (Barnegat to Surf City) offshore	Tidal
02040301920010-01	Atlantic Ocean (Barnegat to Surf City)inshore	Tidal

02040302940050-01	Atlantic Ocean (CM Inlet to Cape May Pt) inshore	Tidal
02040302940050-02	Atlantic Ocean (CM Inlet to Cape May Pt) offshore	Tidal
02030902940020-01	Atlantic Ocean (Corson to Townsends Inl) inshore	Tidal
02030902940020-02	Atlantic Ocean (Corson to Townsends Inl) offshore	Tidal
02040302930010-01	Atlantic Ocean (Great Egg to 34th St) inshore	Tidal
02040302930010-02	Atlantic Ocean (Great Egg to 34th St) offshore	Tidal
02040301920030-01	Atlantic Ocean (Haven Bch to Lit Egg) inshore	Tidal
02040301920030-02	Atlantic Ocean (Haven Bch to Lit Egg) offshore	Tidal
02040302940040-01	Atlantic Ocean (Hereford to Cape May In) inshore	Tidal
02040302940040-02	Atlantic Ocean (Hereford to Cape May In) offshore	Tidal
02040301910020-01	Atlantic Ocean (Herring Is to Rt 37) inshore	Tidal
02040301910020-02	Atlantic Ocean (Herring Is to Rt 37) offshore	Tidal
02040302910010-01	Atlantic Ocean (Ltl Egg to Absecon In) inshore	Tidal
02040302910010-02	Atlantic Ocean (Ltl Egg to Absecon In) offshore	Tidal
02040301910010-01	Atlantic Ocean (Manasquan/Herring Is) inshore	Tidal
02040301910010-02	Atlantic Ocean (Manasquan/Herring Is) offshore	Tidal
02030104920020-01	Atlantic Ocean (Navesink R to Whale Pond) inshore	Tidal
02030104920020-02	Atlantic Ocean (Navesink R to Whale Pond) offshore	Tidal
02040301910030-01	Atlantic Ocean (Rt 37 to Barnegat Inlet) inshore	Tidal
02040301910030-02	Atlantic Ocean (Rt 37 to Barnegat Inlet) offshore	Tidal
02030104920010-01	Atlantic Ocean (Sandy H to Navesink R) inshore	Tidal
02030104920010-02	Atlantic Ocean (Sandy H to Navesink R) offshore	Tidal
02030104930020-01	Atlantic Ocean (Shark R to Manasquan) inshore	Tidal
02030104930020-02	Atlantic Ocean (Shark R to Manasquan) offshore	Tidal
02040301920020-01	Atlantic Ocean (Surf City to Haven Be) inshore	Tidal
02040301920020-02	Atlantic Ocean (Surf City to Haven Be) offshore	Tidal
02030902940030-01	Atlantic Ocean (Townsends to Hereford In) inshore	Tidal
02030902940030-02	Atlantic Ocean (Townsends to Hereford In) offshore	Tidal
02040302920020-01	Atlantic Ocean (Ventnor to Great Egg) inshore	Tidal
02040302920020-02	Atlantic Ocean (Ventnor to Great Egg) offshore	Tidal
02030104930010-01	Atlantic Ocean (Whale Pond to Shark R) inshore	Tidal

Appendix B

Fish Tissue Data

Location	Species	Field (or lab) Total Length (cm)	Hg (mg/kg) ug/g wet wt	Year
Alcyon Lake	Largemouth Bass	28.6	0.67	1992
Alcyon Lake	Largemouth Bass	33.7	0.41	1992
Batsto Lake	Yellow Bullhead	23.7	0.23	1992
Batsto Lake	Brown Bullhead	26.5	0.18	1992
Batsto Lake	Chain Pickerel	57.3	1.06	1992
Batsto Lake	Largemouth Bass	27.1	0.76	1992
Batsto Lake	Largemouth Bass	35.4	1.20	1992
Batsto Lake	Largemouth Bass	37.5	1.28	1992
Big Timber Creek	Black Crappie	15.5	0.07	1992
Big Timber Creek	Brown Bullhead	29.4	0.05	1992
Big Timber Creek	Brown Bullhead	31	0.06	1992
Big Timber Creek	Channel Catfish	42.3	0.09	1992
Big Timber Creek	White Catfish	33.4	0.08	1992
Big Timber Creek	White Catfish	29.6	0.09	1992
Big Timber Creek	Largemouth Bass	33.0	0.10	1992
Big Timber Creek	Largemouth Bass	28.2	0.12	1992
Big Timber Creek	Largemouth Bass	25.5	0.06	1992
Clementon Lake	Chain Pickerel	35.5	0.14	1992
Clementon Lake	Chain Pickerel	33	0.16	1992
Clementon Lake	Chain Pickerel	40	0.16	1992
Clementon Lake	Chain Pickerel	50.5	0.32	1992
Clementon Lake	Chain Pickerel	48.6	0.37	1992
Clementon Lake	Chain Pickerel	47.6	0.38	1992
Clementon Lake	Largemouth Bass	35.9	0.28	1992
Clementon Lake	Largemouth Bass	38.7	0.49	1992
Clinton Reservoir	Largemouth Bass	28.2	0.39	1992
Clinton Reservoir	Largemouth Bass	34.3	0.60	1992
Clinton Reservoir	Largemouth Bass	34.6	0.73	1992
Clinton Reservoir	Largemouth Bass	44.1	0.83	1992
Clinton Reservoir	Largemouth Bass	36.0	0.84	1992
Clinton Reservoir	Largemouth Bass	37.1	0.85	1992
Cooper River Park Lake	Black Crappie	16.7	0.04	1992
Cooper River Park Lake	Black Crappie	18.1	0.10	1992
Cooper River Park Lake	Black Crappie	18.4	0.12	1992
Cooper River Park Lake	Largemouth Bass	19.5	0.12	1992
Cooper River Park Lake	Largemouth Bass	21.4	0.03	1992
Cooper River Park Lake	Largemouth Bass	21.7	0.04	1992
Cooper River Park Lake	Largemouth Bass	25.5	0.08	1992
Cooper River Park Lake	Largemouth Bass	28	0.07	1992
Cooper River Park Lake	Largemouth Bass	30.8	0.09	1992

Cooper River Park Lake	Largemouth Bass	32.2	0.10	1992
Cooper River Park Lake	Largemouth Bass	32.8	0.13	1992
Cooper River Park Lake	Largemouth Bass	35.5	0.14	1992
Cooper River Park Lake	Largemouth Bass	43.5	0.31	1992
Cooper River Park Lake	Largemouth Bass	44	0.56	1992
Cooper River Park Lake	Largemouth Bass	22.1	0.09	1992
Cooper River Park Lake	Largemouth Bass	25.5	0.08	1992
Cooper River Park Lake	Largemouth Bass	28	0.07	1992
Cooper River Park Lake	Largemouth Bass	30.8	0.09	1992
Cooper River Park Lake	Largemouth Bass	35.5	0.14	1992
Cooper River Park Lake	Largemouth Bass	43.5	0.31	1992
Cranberry Lake	Chain Pickerel	42.4	0.27	1992
Cranberry Lake	Chain Pickerel	56.9	0.37	1992
Cranberry Lake	Chain Pickerel	55.5	0.37	1992
Cranberry Lake	Hybrid Striped Bass	38.2	0.29	1992
Cranberry Lake	Hybrid Striped Bass	37	0.31	1992
Cranberry Lake	Hybrid Striped Bass	52	0.43	1992
Crystal Lake	Brown Bullhead	19.8	0.02	1992
Crystal Lake	Brown Bullhead	20	0.05	1992
Dundee Lake	Brown Bullhead	27.1	0.19	1992
Dundee Lake	Brown Bullhead	29.3	0.20	1992
East Creek Lake	Chain Pickerel	31.5	0.79	1992
East Creek Lake	Chain Pickerel	34..5	1.03	1992
East Creek Lake	Chain Pickerel	41.4	1.33	1992
East Creek Lake	Chain Pickerel	39	1.33	1992
East Creek Lake	Chain Pickerel	51	1.59	1992
East Creek Lake	Chain Pickerel	40	1.76	1992
East Creek Lake	Chain Pickerel	50	2.30	1992
East Creek Lake	Chain Pickerel	46.2	2.44	1992
East Creek Lake	Chain Pickerel	52.5	2.82	1992
East Creek Lake	Yellow Bullhead	26.8	1.29	1992
East Creek Lake	Yellow Bullhead	27.4	1.47	1992
Evans Lake	Largemouth Bass	27.8	0.15	1992
Evans Lake	Largemouth Bass	21.5	0.33	1992
Harrisville Lake	Chain Pickerel	40	0.99	1992
Harrisville Lake	Chain Pickerel	33.5	1.21	1992
Harrisville Lake	Chain Pickerel	28.3	1.71	1992
Harrisville Lake	Chain Pickerel	45.7	1.74	1992
Harrisville Lake	Chain Pickerel	51.4	2.10	1992
Harrisville Lake	Yellow Bullhead	27.5	1.36	1992
Lake Carasaljo	Chain Pickerel	34.9	0.28	1992
Lake Hopatcong	Chain Pickerel	35.1	0.19	1992
Lake Hopatcong	Chain Pickerel	48	0.22	1992
Lake Hopatcong	Chain Pickerel	47.3	0.35	1992
Lake Hopatcong	Chain Pickerel	45	0.37	1992
Lake Hopatcong	Chain Pickerel	53	0.64	1992
Lake Hopatcong	Largemouth Bass	39.9	0.27	1992
Lake Hopatcong	Largemouth Bass	41.4	0.28	1992
Lake Hopatcong	Largemouth Bass	29.5	0.30	1992

Lake Nummy	Chain Pickerel	35	1.36	1992
Lake Nummy	Yellow Bullhead	26.7	0.32	1992
Lake Nummy	Yellow Bullhead	27.8	0.32	1992
Lake Nummy	Yellow Bullhead	28.1	0.32	1992
Lenape Lake	Chain Pickerel	35.5	0.25	1992
Lenape Lake	Chain Pickerel	44.8	0.54	1992
Lenape Lake	Chain Pickerel	49.7	0.89	1992
Marlton Lake	Largemouth Bass	38	1.36	1992
Maskells Mill Lake	Chain Pickerel	28	0.37	1992
Merrill Creek	Rainbow Trout	25.3	0.04	1992
Merrill Creek	Rainbow Trout	24.7	0.08	1992
Merrill Creek Reservoir	Rainbow Trout	32.1	0.14	1992
Merrill Creek Reservoir	Rainbow Trout	37.5	0.14	1992
Merrill Creek Reservoir	Rainbow Trout	38.6	0.24	1992
Merrill Creek Reservoir	Lake Trout	51.3	0.44	1992
Merrill Creek Reservoir	Lake Trout	51.6	0.77	1992
Merrill Creek Reservoir	Lake Trout	53.2	0.79	1992
Merrill Creek Reservoir	Lake Trout	56.4	0.69	1992
Merrill Creek Reservoir	Largemouth Bass	30.9	0.29	1992
Merrill Creek Reservoir	Largemouth Bass	43.9	0.96	1992
Merrill Creek Reservoir	Largemouth Bass	41.0	1.21	1992
Monksville Reservoir	Chain Pickerel	39.3	0.21	1992
Monksville Reservoir	Chain Pickerel	42.4	0.36	1992
Monksville Reservoir	Chain Pickerel	64	1.14	1992
Monksville Reservoir	Largemouth Bass	28.7	0.45	1992
Monksville Reservoir	Largemouth Bass	33.9	0.52	1992
Monksville Reservoir	Largemouth Bass	38.4	1.00	1992
Mountain Lake	Largemouth Bass	31.8	0.22	1992
Mountain Lake	Largemouth Bass	37.4	0.37	1992
Mountain Lake	Largemouth Bass	47.0	0.90	1992
New Brooklyn Lake	Chain Pickerel	18.7	0.10	1992
New Brooklyn Lake	Chain Pickerel	37.7	0.23	1992
New Brooklyn Lake	Chain Pickerel	46.6	0.79	1992
Newton Creek, North	Brown Bullhead	29	0.02	1992
Newton Creek, North	Brown Bullhead	34.4	0.03	1992
Newton Creek, North	Brown Bullhead	32.3	0.03	1992
Newton Creek, North	Brown Bullhead	32.4	0.03	1992
Newton Creek, North	Channel Catfish	36.5	0.08	1992
Newton Creek, North	Channel Catfish	47.1	0.12	1992
Newton Creek, South	Brown Bullhead	25.9	0.04	1992
Newton Creek, South	Brown Bullhead	26.1	0.06	1992
Newton Creek, South	Brown Bullhead	29.5	0.18	1992
Newton Creek, South	Chain Pickerel	25.3	0.10	1992
Newton Creek, South	Largemouth Bass	37.1	0.23	1992
Newton Creek, South	Largemouth Bass	36.6	0.24	1992
Newton Creek, South	Largemouth Bass	30.7	1.15	1992
Newton Lake	Black Crappie	18.4	0.09	1992
Newton Lake	Black Crappie	19.4	0.11	1992
Newton Lake	Black Crappie	20.4	0.13	1992

Newton Lake	Largemouth Bass	30	0.05	1992
Newton Lake	Largemouth Bass	30.6	0.05	1992
Newton Lake	Largemouth Bass	33.6	0.06	1992
Newton Lake	Largemouth Bass	33.1	0.06	1992
Newton Lake	Largemouth Bass	25.8	0.06	1992
Newton Lake	Largemouth Bass	25.0	0.06	1992
Newton Lake	Largemouth Bass	31.0	0.07	1992
Newton Lake	Largemouth Bass	31.0	0.07	1992
Newton Lake	Largemouth Bass	29.1	0.07	1992
Newton Lake	Largemouth Bass	45.2	0.18	1992
Newton Lake	Largemouth Bass	41.1	0.22	1992
Newton Lake	Largemouth Bass	45.6	0.40	1992
Rancocas Creek	Channel Catfish	45.6	0.11	1992
Rockaway River	Brown Bullhead	31	0.12	1992
Rockaway River	Chain Pickerel	34	0.15	1992
Rockaway River	Chain Pickerel	30.6	0.15	1992
Rockaway River	Chain Pickerel	38.8	0.25	1992
Rockaway River	Chain Pickerel	40.7	0.29	1992
Rockaway River	Chain Pickerel	44.7	0.31	1992
Rockaway River	Rainbow Trout	53.6	0.04	1992
Rockaway River	Yellow Bullhead	21.2	0.15	1992
Rockaway River near Whippany	Largemouth Bass	26.4	0.36	1992
Rockaway River near Whippany	Largemouth Bass	28.9	0.59	1992
Rockaway River near Whippany	Largemouth Bass	31.5	0.73	1992
Round Valley Reservoir	Lake Trout	40	0.06	1992
Round Valley Reservoir	Lake Trout	54.4	0.14	1992
Round Valley Reservoir	Lake Trout	75.5	0.14	1992
Saw Mill Lake	Brown Bullhead	36.5	0.05	1992
Saw Mill Lake	Brown Bullhead	33.1	0.06	1992
Saw Mill Lake	Brown Bullhead	39.5	0.07	1992
Saw Mill Lake	Brown Bullhead	37.9	0.07	1992
Saw Mill Lake	Northern Pike	53.4	0.27	1992
Shadow Lake	Largemouth Bass	29.1	0.12	1992
Shadow Lake	Largemouth Bass	30.4	0.15	1992
Shadow Lake	Largemouth Bass	36.7	0.18	1992
Shadow Lake	Largemouth Bass	31.2	0.26	1992
Spring Lake	Largemouth Bass	37.1	0.21	1992
Spring Lake	Largemouth Bass	49.9	0.75	1992
Spring Lake	Largemouth Bass	47.8	0.80	1992
Spruce Run Reservoir	Hybrid Striped Bass	33.1	0.17	1992
Spruce Run Reservoir	Hybrid Striped Bass	37.1	0.19	1992
Spruce Run Reservoir	Hybrid Striped Bass	38.2	0.22	1992
Spruce Run Reservoir	Largemouth Bass	25.2	0.10	1992
Spruce Run Reservoir	Largemouth Bass	28.4	0.19	1992
Spruce Run Reservoir	Largemouth Bass	41.2	0.41	1992
Spruce Run Reservoir	Largemouth Bass	43.8	0.64	1992
Stafford Forge Main Line	Chain Pickerel	26.6	0.59	1992
Stafford Forge Main Line	Chain Pickerel	27.7	0.63	1992
Stafford Forge Main Line	Chain Pickerel	29.9	0.85	1992

Strawbridge Lake	Black Crappie	15.3	0.13	1992
Strawbridge Lake	Black Crappie	14.8	0.24	1992
Strawbridge Lake	Black Crappie	14.3	0.24	1992
Swartswood Lake	Chain Pickerel	39.6	0.09	1992
Swartswood Lake	Chain Pickerel	43.3	0.10	1992
Swartswood Lake	Chain Pickerel	42.3	0.12	1992
Swartswood Lake	Smallmouth Bass	30.8	0.12	1992
Swartswood Lake	Smallmouth Bass	35.5	0.18	1992
Swartswood Lake	Smallmouth Bass	37.5	0.29	1992
Wading River	Chain Pickerel	39.4	0.66	1992
Wading River	Chain Pickerel	40.8	0.68	1992
Wading River	Chain Pickerel	34.3	0.82	1992
Wading River	Chain Pickerel	37.3	1.09	1992
Wading River	Chain Pickerel	43.6	1.23	1992
Wanaque Reservoir	Chain Pickerel	38.7	0.33	1992
Wanaque Reservoir	Chain Pickerel	55.5	0.93	1992
Wanaque Reservoir	Smallmouth Bass	27.5	0.34	1992
Wanaque Reservoir	Smallmouth Bass	37.9	0.51	1992
Wanaque Reservoir	Largemouth Bass	32.8	0.40	1992
Wanaque Reservoir	Largemouth Bass	37.8	0.61	1992
Wanaque Reservoir	Largemouth Bass	36.6	0.75	1992
Wanaque Reservoir	Largemouth Bass	40.5	1.01	1992
Wanaque Reservoir	Largemouth Bass	43.8	1.17	1992
Wanaque Reservoir	Largemouth Bass	46.4	1.18	1992
Wilson Lake	Chain Pickerel	37.8	0.24	1992
Wilson Lake	Chain Pickerel	36.3	0.38	1992
Wilson Lake	Chain Pickerel	50.6	1.06	1992
Wilson Lake	Chain Pickerel	34.4	1.53	1992
Woodstown Memorial Lake	Black Crappie	17.5	0.08	1992
Woodstown Memorial Lake	Largemouth Bass	24.5	0.11	1992
Woodstown Memorial Lake	Largemouth Bass	27.8	0.20	1992
Woodstown Memorial Lake	Largemouth Bass	27.6	0.23	1992
Woodstown Memorial Lake	Largemouth Bass	39.3	0.34	1992
Woodstown Memorial Lake	Largemouth Bass	45.1	0.50	1992
Big Timber Creek	Channel Catfish	42.3	0.09	1993
Budd Lake	White Catfish	33.8	0.17	1993
Budd Lake	Northern Pike	54.8	0.11	1993
Budd Lake	Northern Pike	64	0.11	1993
Budd Lake	Northern Pike	68.5	0.14	1993
Canistear Reservoir	Largemouth Bass	36	0.41	1993
Canistear Reservoir	Largemouth Bass	42.2	0.52	1993
Canistear Reservoir	Largemouth Bass	40	0.55	1993
Canistear Reservoir	Largemouth Bass	45.7	0.61	1993
Canistear Reservoir	Largemouth Bass	43.5	0.68	1993
Canistear Reservoir	Largemouth Bass	39.1	0.69	1993
Canistear Reservoir	Largemouth Bass	38.8	0.74	1993
Carnegie Lake	Largemouth Bass	39.1	0.20	1993
Carnegie Lake	Largemouth Bass	32.3	0.29	1993
Carnegie Lake	Largemouth Bass	35.1	0.37	1993

Carnegie Lake	Largemouth Bass	44.7	0.45	1993
Carnegie Lake	Largemouth Bass	35.1	0.58	1993
Carnegie Lake	Largemouth Bass	51.3	1.07	1993
Corbin City Impoundment #3	Brown Bullhead	26.7	0.07	1993
Crystal Lake	Black Crappie	19.1	0.04	1993
Crystal Lake	Black Crappie	20.7	0.18	1993
Crystal Lake	Largemouth Bass	23.5	0.09	1993
Crystal Lake	Largemouth Bass	30.0	0.14	1993
Crystal Lake	Largemouth Bass	42.6	0.28	1993
Manasquan Reservoir	Largemouth Bass	31	0.76	1993
Manasquan Reservoir	Largemouth Bass	38.9	2.35	1993
Manasquan Reservoir	Largemouth Bass	36.4	2.45	1993
Manasquan Reservoir	Largemouth Bass	40	2.49	1993
Manasquan Reservoir	Largemouth Bass	38	2.89	1993
Manasquan Reservoir	Largemouth Bass	41.1	3.16	1993
Manasquan Reservoir	Largemouth Bass	40.3	3.87	1993
Maskells Mill Lake	Black Crappie	20.8	0.20	1993
Maskells Mill Lake	Black Crappie	26.3	0.29	1993
Maskells Mill Lake	Brown Bullhead	25.4	0.23	1993
Maskells Mill Lake	Brown Bullhead	28.9	0.31	1993
Maskells Mill Lake	Brown Bullhead	28.9	0.47	1993
Maskells Mill Lake	Largemouth Bass	25.9	0.36	1993
Maskells Mill Lake	Largemouth Bass	32.4	0.48	1993
Mullica River	Chain Pickerel	40.7	1.21	1993
New Brooklyn Lake	Chain Pickerel	46.2	0.82	1993
New Brooklyn Lake	Chain Pickerel	59.7	1.30	1993
Round Valley Reservoir	Largemouth Bass	25.2	0.16	1993
Round Valley Reservoir	Largemouth Bass	37.1	0.24	1993
Round Valley Reservoir	Largemouth Bass	35.1	0.24	1993
Spruce Run Reservoir	Northern Pike	63.2	0.41	1993
Spruce Run Reservoir	Northern Pike	64.2	0.39	1993
Woodstown Memorial Lake	Black Crappie	19.5	0.10	1993
Woodstown Memorial Lake	Black Crappie	37.3	0.22	1993
Batsto Lake	Bluegill sunfish	18.5	0.31	1994
Batsto Lake	Bluegill sunfish	22	0.33	1994
Batsto Lake	Bluegill sunfish	20	0.56	1994
Batsto Lake	Brown bullhead	30.5	0.16	1994
Batsto Lake	Brown bullhead	30	0.16	1994
Batsto Lake	Brown bullhead	28	0.16	1994
Batsto Lake	Brown bullhead	30	0.21	1994
Batsto Lake	Brown bullhead	30	0.25	1994
Batsto Lake	Chain pickerel	29	0.38	1994
Batsto Lake	Chain pickerel	29.5	0.43	1994
Batsto Lake	Chain pickerel	28.5	0.44	1994
Batsto Lake	Chain pickerel	30	0.44	1994
Batsto Lake	Chain pickerel	38	0.79	1994
Batsto Lake	Largemouth bass	27	0.47	1994
Batsto Lake	Largemouth bass	26.5	0.60	1994
Batsto Lake	Largemouth bass	31.5	0.90	1994

Batsto Lake	Largemouth bass	32.5	0.92	1994
Batsto Lake	Largemouth bass	34	1.15	1994
Carnegie Lake	Bluegill sunfish	16.2	0.06	1994
Carnegie Lake	Bluegill sunfish	16.8	0.02	1994
Carnegie Lake	Bluegill sunfish	17.5	0.05	1994
Carnegie Lake	White perch	20	0.13	1994
Carnegie Lake	White perch	20.5	0.19	1994
Carnegie Lake	White perch	21.1	0.11	1994
Carnegie Lake	White perch	21.2	0.20	1994
Carnegie Lake	White perch	21.4	0.19	1994
Carnegie Lake	Largemouth bass	43.0	0.24	1994
Carnegie Lake	Largemouth bass	45.2	0.37	1994
Carnegie Lake	Largemouth bass	43.5	0.45	1994
Carnegie Lake	Largemouth bass	48.0	0.68	1994
Carnegie Lake	Largemouth bass	54.0	0.81	1994
Merrill Creek Reservoir	Largemouth bass	41.0	0.67	1994
Merrill Creek Reservoir	Largemouth bass	39.5	0.93	1994
Merrill Creek Reservoir	Largemouth bass	36.7	0.93	1994
Merrill Creek Reservoir	Largemouth bass	41.0	1.10	1994
Merrill Creek Reservoir	Largemouth bass	49.6	1.12	1994
Monksville Reservoir	Largemouth bass	31.3	0.20	1994
Monksville Reservoir	Largemouth bass	31.2	0.21	1994
Monksville Reservoir	Largemouth bass	28.5	0.51	1994
Monksville Reservoir	Largemouth bass	41.2	0.78	1994
Monksville Reservoir	Largemouth bass	39	1.00	1994
Wilson Lake	Pumpkinseed sunfish	20.4	0.26	1994
Wilson Lake	Pumpkinseed sunfish	18.5	0.60	1994
Wilson Lake	Pumpkinseed sunfish	18.2	1.52	1994
Wilson Lake	Yellow perch	22	0.48	1994
Wilson Lake	Yellow perch	24.5	0.65	1994
Wilson Lake	Yellow perch	26.1	0.72	1994
Wilson Lake	Yellow perch	30	1.08	1994
Wilson Lake	Yellow perch	2.95	1.23	1994
Wilson Lake	Largemouth bass	35.5	0.74	1994
Wilson Lake	Largemouth bass	40.0	0.88	1994
Wilson Lake	Largemouth bass	25.6	0.90	1994
Wilson Lake	Largemouth bass	34.5	0.90	1994
Wilson Lake	Largemouth bass	47.0	1.75	1994
Carnegie Lake	Brown bullhead	30.1	0.03	1995
Carnegie Lake	Brown bullhead	31.1	0.05	1995
Carnegie Lake	Brown bullhead	28.2	0.06	1995
Carnegie Lake	Brown bullhead	28.5	0.10	1995
Carnegie Lake	Brown bullhead	29.4	0.12	1995
Carnegie Lake	Channel catfish	56.6	0.12	1995
Carnegie Lake	Channel catfish	61.8	0.16	1995
Carnegie Lake	Channel catfish	56.2	0.18	1995

Carnegie Lake	Channel catfish	41.2	0.44	1995
East Creek Lake	Brown bullhead	33.2	2.62	1995
East Creek Lake	Chain pickerel	31.2	0.65	1995
East Creek Lake	Chain pickerel	33.5	0.78	1995
East Creek Lake	Chain pickerel	35	0.99	1995
East Creek Lake	Chain pickerel	33.3	1.14	1995
East Creek Lake	Chain pickerel	33.7	1.35	1995
East Creek Lake	Pumpkinseed sunfish	11.3	0.35	1995
East Creek Lake	Pumpkinseed sunfish	11.4	0.43	1995
East Creek Lake	Pumpkinseed sunfish	11.4	0.53	1995
East Creek Lake	Yellow bullhead	11.7	0.30	1995
East Creek Lake	Yellow bullhead	22.3	0.73	1995
East Creek Lake	Yellow perch	18	0.67	1995
East Creek Lake	Yellow perch	20	0.82	1995
East Creek Lake	Yellow perch	22	0.90	1995
East Creek Lake	Yellow perch	24	0.95	1995
East Creek Lake	Yellow perch	20.1	1.01	1995
East Creek Lake	Largemouth bass	33.1	1.07	1995
East Creek Lake	Largemouth bass	33.5	1.44	1995
East Creek Lake	Largemouth bass	34	1.95	1995
East Creek Lake	Largemouth bass	38	2.04	1995
East Creek Lake	Largemouth bass	42	2.21	1995
Harrisville Lake	Chain pickerel	27.5	0.90	1995
Harrisville Lake	Chain pickerel	24.5	0.94	1995
Harrisville Lake	Chain pickerel	25	1.20	1995
Harrisville Lake	Chain pickerel	33.5	1.48	1995
Harrisville Lake	Chain pickerel	45	2.27	1995
Harrisville Lake	mud sunfish	11.1	0.76	1995
Harrisville Lake	mud sunfish	17.5	0.95	1995
Harrisville Lake	mud sunfish	18.5	1.32	1995
Harrisville Lake	Yellow bullhead	15.5	0.96	1995
Harrisville Lake	Yellow bullhead	32.5	2.52	1995
Lake Nummy	Chain pickerel	33.3	0.47	1995
Lake Nummy	Chain pickerel	33.3	0.49	1995
Lake Nummy	Chain pickerel	33.6	0.60	1995
Lake Nummy	Chain pickerel	33.7	0.63	1995
Lake Nummy	Chain pickerel	33.2	0.64	1995
Lake Nummy	Yellow bullhead	25.7	0.21	1995
Lake Nummy	Yellow bullhead	11	0.23	1995
Lake Nummy	Yellow bullhead	25.5	0.31	1995
Lake Nummy	Yellow bullhead	25.1	0.34	1995
Lake Nummy	Yellow perch	22.3	0.52	1995
Lake Nummy	Yellow perch	20	0.53	1995
Lake Nummy	Yellow perch	22.3	0.53	1995
Lake Nummy	Yellow perch	22.3	0.54	1995
Lake Nummy	Yellow perch	22.1	0.59	1995

Manasquan Reservoir	Black crappie	17.5	0.35	1995
Manasquan Reservoir	Black crappie	16.5	0.51	1995
Manasquan Reservoir	Black crappie	16.5	0.53	1995
Manasquan Reservoir	Bluegill sunfish	15	0.16	1995
Manasquan Reservoir	Bluegill sunfish	15.5	0.22	1995
Manasquan Reservoir	Bluegill sunfish	16.8	0.22	1995
Manasquan Reservoir	Bluegill sunfish	16.5	0.31	1995
Manasquan Reservoir	Bluegill sunfish	16.5	0.37	1995
Manasquan Reservoir	Brown bullhead	24	0.06	1995
Manasquan Reservoir	Brown bullhead	21.5	0.11	1995
Manasquan Reservoir	Brown bullhead	22	0.12	1995
Manasquan Reservoir	Brown bullhead	26	0.15	1995
Manasquan Reservoir	Brown bullhead	24	0.16	1995
Manasquan Reservoir	Chain pickerel	21.6	0.08	1995
Manasquan Reservoir	Chain pickerel	20	0.13	1995
Manasquan Reservoir	Chain pickerel	24.1	0.15	1995
Manasquan Reservoir	Chain pickerel	39.8	0.48	1995
Manasquan Reservoir	Yellow perch	19.5	0.11	1995
Manasquan Reservoir	Yellow perch	18	0.12	1995
Manasquan Reservoir	Yellow perch	21	0.17	1995
Manasquan Reservoir	Largemouth bass	27	0.29	1995
Manasquan Reservoir	Largemouth bass	28	0.47	1995
Manasquan Reservoir	Largemouth bass	39.5	1.49	1995
Manasquan Reservoir	Largemouth bass	39.5	1.75	1995
Manasquan Reservoir	Largemouth bass	44.5	2.21	1995
Merrill Creek Reservoir	Black crappie	25.3	0.09	1995
Merrill Creek Reservoir	Black crappie	26.1	0.12	1995
Merrill Creek Reservoir	Bluegill sunfish	14.6	0.05	1995
Merrill Creek Reservoir	Bluegill sunfish	172	0.09	1995
Merrill Creek Reservoir	Bluegill sunfish	25.4	0.16	1995
Merrill Creek Reservoir	Brown bullhead	26	0.12	1995
Merrill Creek Reservoir	Brown bullhead	27.9	0.14	1995
Merrill Creek Reservoir	Brown bullhead	29.5	0.14	1995
Merrill Creek Reservoir	Brown bullhead	25.4	0.16	1995
Merrill Creek Reservoir	Brown bullhead	25.1	0.17	1995
Merrill Creek Reservoir	Lake trout	56.7	0.38	1995
Merrill Creek Reservoir	Lake trout	56.5	0.44	1995
Merrill Creek Reservoir	Lake trout	60	0.46	1995
Merrill Creek Reservoir	Lake trout	58.6	0.51	1995
Merrill Creek Reservoir	Lake trout	64	0.73	1995
Merrill Creek Reservoir	Smallmouth bass	38.5	0.44	1995
Merrill Creek Reservoir	Smallmouth bass	40.1	0.44	1995
Merrill Creek Reservoir	Smallmouth bass	42.5	0.49	1995
Merrill Creek Reservoir	Smallmouth bass	39.3	0.63	1995
Merrill Creek Reservoir	Smallmouth bass	43.3	0.68	1995
Merrill Creek Reservoir	Yellow perch	31.2	0.20	1995
Merrill Creek Reservoir	Yellow perch	30.1	0.22	1995
Merrill Creek Reservoir	Yellow perch	34	0.32	1995
Monksville Reservoir	Brown bullhead	31.8	0.04	1995

Monksville Reservoir	Brown bullhead	31	0.06	1995
Monksville Reservoir	Brown bullhead	29	0.06	1995
Monksville Reservoir	Brown bullhead	28.5	0.09	1995
Monksville Reservoir	Brown bullhead	29.2	0.13	1995
Monksville Reservoir	Brown trout	45	0.20	1995
Monksville Reservoir	Pumpkinseed sunfish	19.2	0.09	1995
Monksville Reservoir	Pumpkinseed sunfish	18.1	0.14	1995
Monksville Reservoir	Pumpkinseed sunfish	18	0.25	1995
Monksville Reservoir	Smallmouth bass	31.6	0.26	1995
Monksville Reservoir	Smallmouth bass	27	0.28	1995
Monksville Reservoir	Smallmouth bass	37	0.33	1995
Monksville Reservoir	Walleye	35.5	0.30	1995
Monksville Reservoir	Walleye	41.4	0.42	1995
Monksville Reservoir	Walleye	42	0.48	1995
Monksville Reservoir	Walleye	47.6	0.80	1995
Monksville Reservoir	Walleye	45.9	0.98	1995
Monksville Reservoir	Walleye	52.2	1.44	1995
Monksville Reservoir	White perch	24.5	0.19	1995
Monksville Reservoir	White perch	26.8	0.55	1995
Monksville Reservoir	White perch	27	0.58	1995
Monksville Reservoir	White perch	28.5	0.74	1995
Monksville Reservoir	White perch	32.1	0.79	1995
Mullica River	Brown bullhead	25.5	0.26	1995
Mullica River	Brown bullhead	24.5	0.28	1995
Mullica River	Brown bullhead	22	0.40	1995
Mullica River	Chain pickerel	23.5	0.25	1995
Mullica River	Chain pickerel	30	0.45	1995
Mullica River	Chain pickerel	33.2	0.49	1995
Mullica River	Chain pickerel	46	0.62	1995
Mullica River	Chain pickerel	50.5	0.92	1995
Mullica River	Pumpkinseed sunfish	13	0.12	1995
Mullica River	Pumpkinseed sunfish	13	0.21	1995
Mullica River	Pumpkinseed sunfish	17	0.52	1995
Mullica River	White catfish	29.6	0.23	1995
Mullica River	White catfish	29	0.25	1995
Mullica River	White catfish	29	0.35	1995
Mullica River	White perch	18.3	0.34	1995
Mullica River	White perch	17.4	0.35	1995
Mullica River	White perch	20	0.36	1995
Mullica River	White perch	19	0.36	1995
Mullica River	White perch	21	0.51	1995
New Brooklyn Lake	Black crappie	21	0.08	1995
New Brooklyn Lake	Black crappie	21.8	0.16	1995
New Brooklyn Lake	Black crappie	21.5	0.19	1995

New Brooklyn Lake	Chain pickerel	20.5	0.13	1995
New Brooklyn Lake	Chain pickerel	29.7	0.20	1995
New Brooklyn Lake	Chain pickerel	34	0.25	1995
New Brooklyn Lake	Chain pickerel	43.9	0.48	1995
New Brooklyn Lake	Chain pickerel	32.5	0.64	1995
New Brooklyn Lake	Pumpkinseed sunfish	15.4	0.22	1995
New Brooklyn Lake	Pumpkinseed sunfish	16	0.28	1995
New Brooklyn Lake	Pumpkinseed sunfish	16.5	0.30	1995
New Brooklyn Lake	Yellow bullhead	20	0.05	1995
New Brooklyn Lake	Yellow bullhead	24.1	0.06	1995
New Brooklyn Lake	Yellow bullhead	23,8	0.08	1995
New Brooklyn Lake	Yellow bullhead	25.9	0.09	1995
New Brooklyn Lake	Yellow bullhead	26.9	0.20	1995
New Brooklyn Lake	Largemouth bass	23.3	0.25	1995
New Brooklyn Lake	Largemouth bass	27.4	0.32	1995
New Brooklyn Lake	Largemouth bass	31.7	0.41	1995
Wading River	Brown bullhead	31.5	0.62	1995
Wading River	Chain pickerel	42.5	0.46	1995
Wading River	Chain pickerel	35.1	0.49	1995
Wading River	Chain pickerel	28.5	0.55	1995
Wading River	Chain pickerel	22.3	0.55	1995
Wading River	Chain pickerel	32	0.71	1995
Wading River	White catfish	30.3	0.49	1995
Wading River	White catfish	30	0.60	1995
Wading River	Yellow bullhead	20.2	1.01	1995
Wading River	Yellow bullhead	30.3	1.59	1995
Wanaque Reservoir	Bluegill sunfish	17.2	0.07	1995
Wanaque Reservoir	Brown bullhead	35.8	0.01	1995
Wanaque Reservoir	Brown bullhead	36.2	0.03	1995
Wanaque Reservoir	Brown bullhead	34	0.07	1995
Wanaque Reservoir	Chain pickerel	51	0.12	1995
Wanaque Reservoir	Chain pickerel	47.5	0.18	1995
Wanaque Reservoir	Chain pickerel	50.5	0.37	1995
Wanaque Reservoir	Chain pickerel	47	0.41	1995
Wanaque Reservoir	Chain pickerel	50.6	0.43	1995
Wanaque Reservoir	Chain pickerel	56	0.73	1995
Wanaque Reservoir	Smallmouth bass	38.5	0.27	1995
Wanaque Reservoir	Smallmouth bass	29.6	0.29	1995
Wanaque Reservoir	Smallmouth bass	46.2	0.36	1995
Wanaque Reservoir	White catfish	41.5	0.12	1995
Wanaque Reservoir	White catfish	40.5	0.17	1995
Wanaque Reservoir	White catfish	37.1	0.17	1995
Wanaque Reservoir	White catfish	37.7	0.28	1995
Wanaque Reservoir	White catfish	42.9	0.33	1995
Wanaque Reservoir	White perch	27.2	0.35	1995
Wanaque Reservoir	White perch	30.7	0.63	1995

Wanaque Reservoir	White perch	36.8	0.65	1995
Wanaque Reservoir	White perch	32.1	0.75	1995
Wanaque Reservoir	White perch	33.9	1.18	1995
Wanaque Reservoir	Yellow bullhead	23.9	0.03	1995
Wanaque Reservoir	Largemouth bass	37.9	0.36	1995
Wanaque Reservoir	Largemouth bass	34.6	0.45	1995
Wanaque Reservoir	Largemouth bass	39.5	0.51	1995
Wanaque Reservoir	Largemouth bass	41.4	0.71	1995
Wanaque Reservoir	Largemouth bass	41.4	0.85	1995
Wilson Lake	Chain pickerel	29.5	0.66	1995
Wilson Lake	Chain pickerel	30.5	0.88	1995
Wilson Lake	Chain pickerel	25.7	0.91	1995
Wilson Lake	Chain pickerel	47	1.14	1995
Wilson Lake	Chain pickerel	47	1.30	1995
Boonton Reservoir	Brown Bullhead	30.5	0.01	1996
Boonton Reservoir	Brown Bullhead	32.8	0.02	1996
Boonton Reservoir	White Catfish	40	0.54	1996
Boonton Reservoir	Largemouth Bass	35	0.33	1996
Boonton Reservoir	Largemouth Bass	45.1	0.60	1996
Boonton Reservoir	Largemouth Bass	41.6	0.81	1996
Butterfly Bogs	Brown Bullhead	30.6	0.08	1996
Butterfly Bogs	Chain Pickerel	33.9	0.78	1996
Cedar Lake	Brown Bullhead	31.5	0.06	1996
Cedar Lake	Chain Pickerel	47.9	0.24	1996
Cedar Lake	Chain Pickerel	49.6	0.31	1996
Cedar Lake	Chain Pickerel	64.7	0.76	1996
Cedar Lake	Largemouth Bass	39	0.25	1996
Cedar Lake	Largemouth Bass	41.5	0.59	1996
Cedar Lake	Largemouth Bass	43.8	0.61	1996
Crater Lake	Brown Bullhead	30	0.39	1996
Crater Lake	Yellow Perch	21.6	0.29	1996
Crater Lake	Yellow Perch	19.9	0.43	1996
Crater Lake	Yellow Perch	27.9	0.58	1996
DeVoe Lake	Brown Bullhead	27	0.09	1996
DeVoe Lake	Chain Pickerel	41.5	0.14	1996
DeVoe Lake	Chain Pickerel	43	0.25	1996
DeVoe Lake	Chain Pickerel	48.5	0.27	1996
DeVoe Lake	Largemouth Bass	31.7	0.07	1996
DeVoe Lake	Largemouth Bass	34.1	0.21	1996
DeVoe Lake	Largemouth Bass	36.5	0.26	1996
Double Trouble Lake	Chain Pickerel	18.1	0.74	1996
Double Trouble Lake	Chain Pickerel	37.7	1.24	1996
Double Trouble Lake	Chain Pickerel	46.7	1.60	1996
Double Trouble Lake	Chain Pickerel	52.4	2.24	1996
Double Trouble Lake	Chain Pickerel	57.6	2.30	1996
Double Trouble Lake	Yellow Bullhead	26.1	0.82	1996
Double Trouble Lake	Yellow Bullhead	28.3	1.09	1996
Double Trouble Lake	Yellow Bullhead	26.6	1.18	1996
Echo Lake Reservoir	Largemouth Bass	30.4	0.12	1996

Echo Lake Reservoir	Largemouth Bass	34.4	0.15	1996
Echo Lake Reservoir	Largemouth Bass	29	0.16	1996
Echo Lake Reservoir	Largemouth Bass	35	0.17	1996
Green Turtle Lake	Chain Pickerel	28.1	0.11	1996
Green Turtle Lake	Chain Pickerel	44.7	0.14	1996
Green Turtle Lake	Chain Pickerel	44.6	0.15	1996
Green Turtle Lake	Yellow Perch	20.8	0.09	1996
Green Turtle Lake	Yellow Perch	24.6	0.10	1996
Green Turtle Lake	Largemouth Bass	23.6	0.17	1996
Green Turtle Lake	Largemouth Bass	26.1	0.22	1996
Green Turtle Lake	Largemouth Bass	34.7	0.32	1996
Greenwood Lake	White perch	18.3	0.00	1996
Greenwood Lake	White perch	19.2	0.02	1996
Greenwood Lake	Largemouth Bass	36.2	0.15	1996
Greenwood Lake	Largemouth Bass	34.3	0.18	1996
Greenwood Lake	Largemouth Bass	31.4	0.21	1996
Greenwood Lake	Largemouth Bass	36.3	0.24	1996
Greenwood Lake	Largemouth Bass	40	0.40	1996
Grovers Mill Pond	Brown Bullhead	33	0.08	1996
Grovers Mill Pond	Brown Bullhead	32.2	0.40	1996
Grovers Mill Pond	Chain Pickerel	35.3	0.12	1996
Grovers Mill Pond	Chain Pickerel	35.2	0.16	1996
Grovers Mill Pond	Chain Pickerel	37.2	0.16	1996
Grovers Mill Pond	Chain Pickerel	36.5	0.18	1996
Grovers Mill Pond	Largemouth Bass	31.3	0.25	1996
Grovers Mill Pond	Largemouth Bass	35.8	0.30	1996
Grovers Mill Pond	Largemouth Bass	35	0.36	1996
Grovers Mill Pond	Largemouth Bass	41.5	0.39	1996
Grovers Mill Pond	Largemouth Bass	28	0.47	1996
Hainesville Pond	Chain Pickerel	39.3	0.14	1996
Hainesville Pond	Chain Pickerel	36.6	0.14	1996
Hainesville Pond	Chain Pickerel	36.5	0.15	1996
Hainesville Pond	Largemouth Bass	30.3	0.13	1996
Hainesville Pond	Largemouth Bass	31.0	0.21	1996
Hainesville Pond	Largemouth Bass	31.3	0.23	1996
Malaga Lake	Chain Pickerel	32	0.73	1996
Malaga Lake	Chain Pickerel	29.3	0.88	1996
Malaga Lake	Chain Pickerel	36.2	0.97	1996
Malaga Lake	Chain Pickerel	31	0.99	1996
Malaga Lake	Chain Pickerel	34	1.38	1996
Malaga Lake	Largemouth Bass	32.4	0.95	1996
Passaic River at Hatfield Swamp	Pumpkinseed Sunfish	12.4	0.08	1996
Passaic River at Hatfield Swamp	Pumpkinseed Sunfish	12.6	0.09	1996
Passaic River at Hatfield Swamp	Black Crappie	18.1	0.30	1996
Passaic River at Hatfield Swamp	Black Crappie	18.9	0.32	1996
Passaic River at Hatfield Swamp	Bluegill Sunfish	18.9	0.19	1996
Passaic River at Hatfield Swamp	Black Crappie	20	0.21	1996

Passaic River at Hatfield Swamp	Black Crappie	20	0.22	1996
Passaic River at Hatfield Swamp	Yellow Bullhead	21.4	0.11	1996
Passaic River at Hatfield Swamp	Largemouth Bass	23	0.17	1996
Passaic River at Hatfield Swamp	Largemouth Bass	23.5	0.21	1996
Passaic River at Hatfield Swamp	Largemouth Bass	36	0.53	1996
Pompton River at Lincoln Park	Pike	27.8	0.17	1996
Pompton River at Lincoln Park	Pike	42	0.41	1996
Pompton River at Lincoln Park	Pike	66.6	0.59	1996
Pompton River at Lincoln Park	Yellow Perch	21	0.21	1996
Pompton River at Lincoln Park	Yellow Perch	24	0.26	1996
Pompton River at Lincoln Park	Largemouth Bass	35.4	0.50	1996
Pompton River at Lincoln Park	Largemouth Bass	35.5	0.68	1996
Raritan River at Millstone River	Brown Bullhead	25.4	0.06	1996
Raritan River at Millstone River	Brown Bullhead	27.5	0.07	1996
Raritan River at Millstone River	Channel Catfish	39.8	0.15	1996
Raritan River at Millstone River	Largemouth Bass	32.5	0.33	1996
Raritan River at Millstone River	Largemouth Bass	36.3	0.33	1996
Raritan River at Millstone River	Largemouth Bass	44.9	0.37	1996
Raritan River at Millstone River	Largemouth Bass	37	0.46	1996
Ridgeway Branch of Tom's River	Brown Bullhead	26.4	0.17	1996
Ridgeway Branch of Tom's River	Brown Bullhead	27	0.44	1996
Ridgeway Branch of Tom's River	Brown Bullhead	22.8	1.15	1996
Ridgeway Branch of Tom's River	Brown Bullhead	25.6	1.57	1996
Ridgeway Branch of Tom's River	Chain Pickerel	36	1.22	1996
Rockaway River near Whippany	Black Crappie	17.9	0.21	1996
Rockaway River near Whippany	Bluegill Sunfish	14.5	0.12	1996
Rockaway River near Whippany	Largemouth Bass	39.8	0.92	1996
South Branch Raritan River at Neshanic Station	Brown Bullhead	17.2	0.08	1996
South Branch Raritan River at Neshanic Station	Redbreast Sunfish	15.7	0.09	1996
South Branch Raritan River at Neshanic Station	Redbreast Sunfish	15.9	0.15	1996
South Branch Raritan River at Neshanic Station	Rock Bass	15	0.09	1996
South Branch Raritan River at Neshanic Station	Smallmouth Bass	20.7	0.18	1996
South Branch Raritan River at Neshanic Station	Largemouth Bass	18.2	0.11	1996
Speedwell Lake	Bluegill Sunfish	18.3	0.12	1996
Speedwell Lake	Bluegill Sunfish	19.7	0.13	1996
Speedwell Lake	Brown Bullhead	21	0.01	1996
Speedwell Lake	Largemouth Bass	27.5	0.10	1996
Speedwell Lake	Largemouth Bass	32.5	0.34	1996
Speedwell Lake	Largemouth Bass	36.1	0.38	1996
Steenykill Lake	Largemouth Bass	26.5	0.16	1996
Steenykill Lake	Largemouth Bass	27.5	0.19	1996
Steenykill Lake	Largemouth Bass	27.7	0.19	1996
Steenykill Lake	Largemouth Bass	27.8	0.15	1996
Steenykill Lake	Largemouth Bass	28.3	0.22	1996

Steenykill Lake	Largemouth Bass	29.6	0.15	1996
Sunset Lake	Bluegill Sunfish	11.2	0.05	1996
Sunset Lake	Chain Pickerel	30.7	0.09	1996
Sunset Lake	Largemouth Bass	22.5	0.10	1996
Sunset Lake	Largemouth Bass	33.8	0.17	1996
Sunset Lake	Largemouth Bass	38.2	0.21	1996
Sunset Lake	Largemouth Bass	38.5	0.35	1996
Sunset Lake	Largemouth Bass	53	0.69	1996
Wawayanda Lake	Chain Pickerel	35	0.25	1996
Wawayanda Lake	Chain Pickerel	39.5	0.28	1996
Wawayanda Lake	Chain Pickerel	40.5	0.29	1996
Wawayanda Lake	Chain Pickerel	37.9	0.31	1996
Wawayanda Lake	Chain Pickerel	42	0.34	1996
Wawayanda Lake	Chain Pickerel	42.4	0.44	1996
Oak Ridge Reservoir	Yellow Bullhead	24.5	0.25	1997
Oak Ridge Reservoir	Chain Pickerel	25	0.24	1997
Oak Ridge Reservoir	Chain Pickerel	28	0.29	1997
Oak Ridge Reservoir	Chain Pickerel	30.6	0.30	1997
Oak Ridge Reservoir	Brown Bullhead	33	0.02	1997
Oak Ridge Reservoir	Brown Bullhead	34.5	0.02	1997
Oak Ridge Reservoir	Smallmouth Bass	40.2	0.49	1997
Oak Ridge Reservoir	Chain Pickerel	58	0.30	1997
Oak Ridge Reservoir	Largemouth Bass	36.8	0.38	1997
Oak Ridge Reservoir	Largemouth Bass	42.5	0.64	1997
Oak Ridge Reservoir	Largemouth Bass	48	0.71	1997
Oak Ridge Reservoir	Largemouth Bass	48	0.89	1997
Pompton River at Pequannock River	Black Crappie	19.3	0.24	1997
Pompton River at Pequannock River	Pumpkinseed Sunfish	14.5	0.35	1997
Pompton River at Pequannock River	Pumpkinseed Sunfish	14.1	0.78	1997
Pompton River at Pequannock River	Redbreast Sunfish	13.7	0.32	1997
Pompton River at Pequannock River	Redbreast Sunfish	15.8	0.41	1997
Pompton River at Pequannock River	Rock Bass	19.2	0.54	1997
Pompton River at Pequannock River	Rock Bass	21.1	0.54	1997
Pompton River at Pequannock River	Rock Bass	22	0.68	1997
Pompton River at Pequannock River	Smallmouth Bass	29.6	0.57	1997
Pompton River at Pequannock River	Smallmouth Bass	36.8	1.02	1997
Pompton River at Pequannock River	Smallmouth Bass	25.4	1.10	1997
Pompton River at Pequannock River	Smallmouth Bass	27.8	1.14	1997
Pompton River at Pequannock River	Yellow Bullhead	26.2	0.80	1997
Pompton River at Pequannock River	Largemouth Bass	39	0.99	1997
Pompton River at Pequannock River	Largemouth Bass	39.8	1.36	1997
Whitesbog Pond	Chain Pickerel	23	0.43	1997
Whitesbog Pond	Chain Pickerel	31.5	0.58	1997
Whitesbog Pond	Chain Pickerel	34.3	0.74	1997
Whitesbog Pond	Chain Pickerel	32.5	0.76	1997
Whitesbog Pond	Chain Pickerel	39.6	1.02	1997
Willow Grove Lake	Brown Bullhead	33	0.23	1997

Willow Grove Lake	Brown Bullhead	32.4	0.28	1997
Willow Grove Lake	Chain Pickerel	31	0.76	1997
Willow Grove Lake	Chain Pickerel	48.1	1.03	1997
Willow Grove Lake	Chain Pickerel	36.5	1.13	1997
Willow Grove Lake	Chain Pickerel	45.2	1.26	1997
Willow Grove Lake	Chain Pickerel	53	1.29	1997
Willow Grove Lake	White Catfish	43	0.17	1997
Willow Grove Lake	Yellow Bullhead	28	0.82	1997
Willow Grove Lake	Yellow Bullhead	30.5	0.91	1997
Willow Grove Lake	Largemouth Bass	33.2	1.68	1997
Mullica River @ Green Bank	American Eel	45.7	0.51	1999
Mullica River @ Green Bank	American Eel	69	0.49	1999
Mullica River @ New Gretna	American Eel	42.5	0.3	1999
Mullica River, below dam @ Batsto Village	American Eel	29.7	0.65	1999
Mullica River, below dam @ Batsto Village	American Eel	39.5	0.04	1999
Mullica River, below dam @ Batsto Village	American Eel	46.3	0.8	1999
Stewart Lake (Woodbury)	Bluegill	15.9	0.03	1999
Stewart Lake (Woodbury)	Bluegill	16.4	0.03	1999
Stewart Lake (Woodbury)	Black Crappie	18.3	0.1	1999
Stewart Lake (Woodbury)	Brown Bullhead	25.4	0.01	1999
Stewart Lake (Woodbury)	Brown Bullhead	27.3	0.01	1999
Stewart Lake (Woodbury)	Brown Bullhead	31.1	0.04	1999
Stewart Lake (Woodbury)	Common Carp	43.8	0.01	1999
Stewart Lake (Woodbury)	Common Carp	49.3	0.04	1999
Stewart Lake (Woodbury)	Common Carp	54.5	0.08	1999
Stewart Lake (Woodbury)	Common Carp	59.8	0.03	1999
Stewart Lake (Woodbury)	Common Carp	65.8	0.03	1999
Stewart Lake (Woodbury)	Largemouth Bass	35.9	0.2	1999
Stewart Lake (Woodbury)	Largemouth Bass	38.9	0.15	1999
Stewart Lake (Woodbury)	Largemouth Bass	43.5	0.19	1999
Boonton Reservoir	rock bass	20.7	0.13	2002
Boonton Reservoir	rock bass	22.2	0.27	2002
Boonton Reservoir	rock bass	22.3	0.22	2002
Boonton Reservoir	rock bass	22.3	0.26	2002
Boonton Reservoir	smallmouth bass	38.9	0.39	2002
Boonton Reservoir	smallmouth bass	41.0	0.39	2002
Boonton Reservoir	smallmouth bass	43.4	0.52	2002
Boonton Reservoir	smallmouth bass	48.4	0.75	2002
Boonton Reservoir	largemouth bass	41.6	0.36	2002
Boonton Reservoir	largemouth bass	45.0	0.59	2002
Boonton Reservoir	largemouth bass	48.3	1.08	2002
Boonton Reservoir	largemouth bass	48.7	0.73	2002
Boonton Reservoir	largemouth bass	52.2	0.80	2002
Branch Brook Park	bluegill	14.5	0.16	2002
Branch Brook Park	bluegill	15.3	0.15	2002
Branch Brook Park	bluegill	15.5	0.24	2002

Branch Brook Park	common carp	60.5	0.10	2002
Branch Brook Park	common carp	69.0	0.19	2002
Branch Brook Park	common carp	69.5	0.19	2002
Branch Brook Park	common carp	72.5	0.07	2002
Canistear Reservoir	bluegill	18.5	0.11	2002
Canistear Reservoir	yellow perch	20.5	0.29	2002
Canistear Reservoir	bluegill	21.0	0.10	2002
Canistear Reservoir	bluegill	21.8	0.11	2002
Canistear Reservoir	yellow bullhead	24.5	0.12	2002
Canistear Reservoir	yellow bullhead	25.1	0.17	2002
Canistear Reservoir	yellow perch	25.3	0.18	2002
Canistear Reservoir	yellow perch	27.5	0.22	2002
Canistear Reservoir	yellow bullhead	27.6	0.16	2002
Canistear Reservoir	yellow bullhead	28.6	0.19	2002
Canistear Reservoir	chain pickerel	41.5	0.19	2002
Canistear Reservoir	chain pickerel	41.8	0.25	2002
Canistear Reservoir	chain pickerel	44.0	0.14	2002
Canistear Reservoir	chain pickerel	47.2	0.16	2002
Canistear Reservoir	bluegill	21.2	0.23	2002
Canistear Reservoir	largemouth bass	41.7	0.38	2002
Canistear Reservoir	largemouth bass	43.8	0.29	2002
Canistear Reservoir	largemouth bass	44.5	0.51	2002
Canistear Reservoir	largemouth bass	51.4	0.67	2002
Clinton Reservoir	redbreast sunfish	12.7	0.25	2002
Clinton Reservoir	redbreast sunfish	13.2	0.19	2002
Clinton Reservoir	redbreast sunfish	13.8	0.16	2002
Clinton Reservoir	redbreast sunfish	14.1	0.16	2002
Clinton Reservoir	rock bass	15.8	0.18	2002
Clinton Reservoir	rock bass	15.9	0.19	2002
Clinton Reservoir	rock bass	18.2	0.65	2002
Clinton Reservoir	yellow bullhead	28.2	0.43	2002
Clinton Reservoir	yellow bullhead	28.3	0.74	2002
Clinton Reservoir	yellow bullhead	28.4	0.44	2002
Clinton Reservoir	yellow bullhead	29.7	0.45	2002
Clinton Reservoir	white sucker	44.5	0.25	2002
Clinton Reservoir	chain pickerel	45.2	0.61	2002
Clinton Reservoir	white sucker	45.5	0.19	2002
Clinton Reservoir	white sucker	46.8	0.24	2002
Clinton Reservoir	chain pickerel	53.0	0.43	2002
Echo Lake Reservoir	bluegill	16.4	0.10	2002
Echo Lake Reservoir	bluegill	17.9	0.06	2002
Echo Lake Reservoir	bluegill	18.5	0.11	2002
Echo Lake Reservoir	bluegill	19.0	0.11	2002
Echo Lake Reservoir	yellow bullhead	22.4	0.09	2002
Echo Lake Reservoir	yellow bullhead	22.9	0.14	2002
Echo Lake Reservoir	yellow bullhead	26.4	0.16	2002
Echo Lake Reservoir	yellow bullhead	28.6	0.07	2002
Echo Lake Reservoir	chain pickerel	43.5	0.20	2002
Echo Lake Reservoir	chain pickerel	45.6	0.27	2002

Echo Lake Reservoir	chain pickerel	62.8	0.37	2002
Echo Lake Reservoir	largemouth bass	45.6	0.43	2002
Echo Lake Reservoir	largemouth bass	48.1	0.61	2002
Echo Lake Reservoir	largemouth bass	49.4	0.72	2002
Echo Lake Reservoir	largemouth bass	50.5	0.79	2002
Green Turtle Lake	bluegill	17.7	0.07	2002
Green Turtle Lake	bluegill	17.9	0.09	2002
Green Turtle Lake	bluegill	18.6	0.14	2002
Green Turtle Lake	bluegill	19.9	0.58	2002
Green Turtle Lake	largemouth bass	31.7	0.20	2002
Green Turtle Lake	largemouth bass	32.5	0.26	2002
Green Turtle Lake	largemouth bass	38.9	0.32	2002
Green Turtle Lake	largemouth bass	40.0	0.36	2002
Green Turtle Lake	largemouth bass	49.4	0.74	2002
Greenwood Lake	bluegill	19.0	0.08	2002
Greenwood Lake	bluegill	19.1	0.13	2002
Greenwood Lake	bluegill	19.2	0.07	2002
Greenwood Lake	bluegill	20.1	0.09	2002
Greenwood Lake	yellow bullhead	21.4	0.06	2002
Greenwood Lake	yellow bullhead	23.6	0.09	2002
Greenwood Lake	yellow bullhead	23.7	0.07	2002
Greenwood Lake	yellow bullhead	23.8	0.11	2002
Greenwood Lake	walleye		0.18	2002
Greenwood Lake	walleye		0.28	2002
Greenwood Lake	walleye		0.28	2002
Greenwood Lake	walleye		0.30	2002
Greenwood Lake	walleye		0.47	2002
Greenwood Lake	largemouth bass	39.9	0.31	2002
Greenwood Lake	largemouth bass	42.0	0.31	2002
Greenwood Lake	largemouth bass	42.6	0.31	2002
Greenwood Lake	largemouth bass	42.7	0.21	2002
Greenwood Lake	largemouth bass	44.4	0.29	2002
Monksville reservoir	bluegill	17.8	0.11	2002
Monksville reservoir	bluegill	18.5	0.08	2002
Monksville reservoir	yellow bullhead	19.4	0.11	2002
Monksville reservoir	bluegill	19.8	0.17	2002
Monksville reservoir	bluegill	19.9	0.13	2002
Monksville reservoir	yellow bullhead	23.0	0.13	2002
Monksville reservoir	yellow perch	27.6	0.17	2002
Monksville reservoir	yellow perch	34.9	0.17	2002
Monksville reservoir	chain pickerel	35.5	0.15	2002
Monksville reservoir	chain pickerel	38.4	0.19	2002
Monksville reservoir	walleye	44.4	0.44	2002
Monksville reservoir	walleye	47.8	0.55	2002
Monksville reservoir	chain pickerel	51.1	0.31	2002
Monksville reservoir	walleye	51.6	0.42	2002
Monksville reservoir	walleye	54.0	0.35	2002
Monksville reservoir	walleye	59.8	0.78	2002
Monksville Reservoir	Largemouth bass	26.5	0.20	2002

Monksville Reservoir	Largemouth bass	28.0	0.18	2002
Monksville Reservoir	Largemouth bass	31.5	0.13	2002
Monksville Reservoir	Largemouth bass	36.9	0.32	2002
Monksville Reservoir	Largemouth bass	44.0	0.39	2002
Oak Ridge Reservoir	bluegill	17.5	0.15	2002
Oak Ridge Reservoir	bluegill	18.1	0.11	2002
Oak Ridge Reservoir	bluegill	19.9	0.24	2002
Oak Ridge Reservoir	bluegill	20.0	0.28	2002
Oak Ridge Reservoir	yellow bullhead	23.8	0.10	2002
Oak Ridge Reservoir	yellow bullhead	28.5	0.23	2002
Oak Ridge Reservoir	largemouth bass	41.3	0.90	2002
Oak Ridge Reservoir	largemouth bass	41.6	0.65	2002
Oak Ridge Reservoir	largemouth bass	42.2	0.81	2002
Oak Ridge Reservoir	largemouth bass	45.1	0.82	2002
Pompton River at Lincoln Park	black crappie	17.5	0.19	2002
Pompton River at Lincoln Park	black crappie	20.3	0.29	2002
Pompton River at Lincoln Park	rock bass	20.8	0.64	2002
Pompton River at Lincoln Park	black crappie	21.4	0.15	2002
Pompton River at Lincoln Park	rock bass	21.5	0.60	2002
Pompton River at Lincoln Park	rock bass	23.7	0.83	2002
Pompton River at Lincoln Park	common carp	49.5	0.22	2002
Pompton River at Lincoln Park	common carp	49.9	0.47	2002
Pompton River at Lincoln Park	common carp	57.5	0.28	2002
Pompton River at Lincoln Park	common carp	58.7	0.39	2002
Pompton River at Lincoln Park	largemouth bass	34.6	0.35	2002
Pompton River at Lincoln Park	largemouth bass	35.2	0.50	2002
Pompton River at Lincoln Park	largemouth bass	39.2	0.74	2002
Rockaway River at Powerville	bluegill	15.8	0.11	2002
Rockaway River at Powerville	bluegill	16.0	0.11	2002
Rockaway River at Powerville	bluegill	16.1	0.13	2002
Rockaway River at Powerville	yellow bullhead	16.6	0.10	2002
Rockaway River at Powerville	yellow bullhead	22.5	0.28	2002
Rockaway River at Powerville	rock bass	23.3	0.29	2002
Rockaway River at Powerville	yellow bullhead	23.5	0.14	2002
Rockaway River at Powerville	rock bass	23.9	0.41	2002
Rockaway River at Powerville	rock bass	24.1	0.34	2002
Rockaway River at Powerville	rock bass	24.5	0.32	2002
Shepherds lake	redbreast sunfish	14.6	0.19	2002
Shepherds lake	rock bass	15.3	0.20	2002
Shepherds lake	redbreast sunfish	15.6	0.18	2002
Shepherds lake	redbreast sunfish	15.9	0.20	2002
Shepherds lake	rock bass	20.9	0.15	2002
Shepherds lake	brown bullhead	28.9	0.06	2002
Shepherds lake	brown bullhead	29.5	0.13	2002
Shepherds lake	brown bullhead	36.1	0.07	2002
Shepherds lake	largemouth bass	39.0	0.76	2002
Shepherds Lake	largemouth bass	39.2	0.71	2002
Shepherds Lake	largemouth bass	39.7	0.56	2002
Shepherds Lake	largemouth bass	40.4	0.67	2002

Shepherds Lake	largemouth bass	41.1	0.60	2002
Speedwell Lake	bluegill	15.4	0.10	2002
Speedwell Lake	bluegill	15.8	0.10	2002
Speedwell Lake	bluegill	18.6	0.13	2002
Speedwell Lake	bluegill	20.5	0.16	2002
Speedwell Lake	chain pickerel	25.9	0.09	2002
Speedwell Lake	chain pickerel	31.8	0.11	2002
Speedwell Lake	common carp	57.7	0.13	2002
Speedwell Lake	chain pickerel	59.6	0.26	2002
Speedwell Lake	common carp	61.7	0.10	2002
Speedwell Lake	common carp	62.5	0.14	2002
Speedwell Lake	common carp	63.6	0.05	2002
Split Rock Reservoir	bluegill	21.2	0.13	2002
Split Rock Reservoir	bluegill	21.4	0.21	2002
Split Rock Reservoir	bluegill	22.0	0.10	2002
Split Rock Reservoir	bluegill	22.6	0.12	2002
Split Rock Reservoir	yellow perch	26.2	0.10	2002
Split Rock Reservoir	yellow perch	29.5	0.15	2002
Split Rock Reservoir	yellow perch	30.0	0.13	2002
Split Rock Reservoir	yellow perch	30.0	0.34	2002
Split Rock Reservoir	brown bullhead	30.7	0.04	2002
Split Rock Reservoir	brown bullhead	39.0	0.04	2002
Split Rock Reservoir	chain pickerel	46.8	0.30	2002
Split Rock Reservoir	chain pickerel	49.0	0.32	2002
Split Rock Reservoir	chain pickerel	54.5	0.30	2002
Split Rock Reservoir	chain pickerel	57.0	0.32	2002
Split Rock Reservoir	chain pickerel	61.0	0.26	2002
Split Rock Reservoir	largemouth bass	35.5	0.32	2002
Split Rock Reservoir	largemouth bass	35.9	0.38	2002
Split Rock Reservoir	largemouth bass	38.0	0.32	2002
Split Rock Reservoir	largemouth bass	39.4	0.48	2002
Split Rock Reservoir	largemouth bass	40.5	0.52	2002
Wanaque Reservoir	yellow bullhead	18.8	0.10	2002
Wanaque Reservoir	yellow bullhead	19.9	0.08	2002
Wanaque Reservoir	bluegill	20.2	0.22	2002
Wanaque Reservoir	bluegill	20.4	0.23	2002
Wanaque Reservoir	bluegill	20.6	0.27	2002
Wanaque Reservoir	bluegill	21.2	0.41	2002
Wanaque Reservoir	yellow bullhead	22.2	0.16	2002
Wanaque Reservoir	yellow bullhead	22.9	0.17	2002
Wanaque Reservoir	largemouth bass	30.7	0.28	2002
Wanaque Reservoir	largemouth bass	34.2	0.23	2002
Wanaque Reservoir	largemouth bass	45.2	1.03	2002
Wanaque Reservoir	largemouth bass	48.0	1.47	2002
Wawayanda Lake	bluegill	17.9	0.14	2002
Wawayanda Lake	bluegill	18.2	0.21	2002
Wawayanda Lake	bluegill	18.3	0.21	2002
Wawayanda Lake	chain pickerel	26.4	0.23	2002
Wawayanda Lake	chain pickerel	27.1	0.23	2002
Wawayanda Lake	yellow bullhead	27.1	0.30	2002

Wawayanda Lake	chain pickerel	28.0	0.23	2002
Wawayanda Lake	yellow bullhead	28.3	0.45	2002
Wawayanda Lake	yellow bullhead	29.9	0.36	2002
Wawayanda Lake	chain pickerel	33.9	0.50	2002
Wawayanda Lake	chain pickerel	44.5	0.44	2002
Wawayanda Lake	largemouth bass	33.0	0.29	2002
Wawayanda Lake	largemouth bass	33.4	0.33	2002
Wawayanda Lake	largemouth bass	42.9	0.78	2002
Wawayanda Lake	largemouth bass	44.1	0.66	2002
Wawayanda Lake	largemouth bass	45.3	0.73	2002
Weequachic Lake	bluegill	16.4	0.12	2002
Weequachic Lake	bluegill	17.3	0.15	2002
Weequachic Lake	bluegill	17.4	0.09	2002
Weequachic Lake	white perch	17.7	0.10	2002
Weequachic Lake	white perch	17.9	0.08	2002
Weequachic Lake	white perch	18.0	0.09	2002
Weequachic Lake	brown bullhead	27.2	0.03	2002
Weequachic Lake	brown bullhead	30.0	0.03	2002
Weequachic Lake	brown bullhead	31.0	0.03	2002
Weequachic Lake	common carp	50.5	0.04	2002
Weequachic Lake	common carp	56.2	0.08	2002
Weequachic Lake	common carp	71.0	0.10	2002
Weequachic Lake	largemouth bass	34.0	0.21	2002
Weequachic Lake	largemouth bass	35.1	0.20	2002
Weequachic Lake	largemouth bass	45.9	0.31	2002
Weequachic Lake	largemouth bass	47.5	0.39	2002
Mullica River	American Eel	49.5	0.29	2004
Mullica River	American Eel	63.5	0.33	2004
Mullica River	American Eel	64.9	0.18	2004
Mullica River	American Eel	73.2	0.2	2004
Mullica River	American Eel	77	0.2	2004
Below New Market Pond Dam	American eel	68.2	0.08673	2006
Below New Market Pond Dam	American eel	69.9	0.11418	2006
Bound Brook @ Shepard Rd.	American eel	51.3	0.08569	2006
Bound Brook @ Shepard Rd.	American eel	54.3	0.08921	2006
Bound Brook @ Shepard Rd.	American eel	61.3	0.20208	2006
Budd Lake	bluegill	17.8	0.09949	2006
Budd Lake	bluegill	18.2	0.1561	2006
Budd Lake	bluegill	18.8	0.12716	2006
Budd Lake	brown bullhead	25.6	0.02337	2006
Budd Lake	brown bullhead	27.2	0.0193	2006
Budd Lake	brown bullhead	31.5	0.01034	2006
Budd Lake	white catfish	34.3	0.18067	2006
Budd Lake	white catfish	35.6	0.21846	2006
Budd Lake	white catfish	42.1	0.27947	2006
Budd Lake	northern pike	74.1	0.30651	2006
Budd Lake	northern pike	78.4	0.45883	2006
Budd Lake	northern pike	81	0.19917	2006
Budd Lake	largemouth bass	35.7	0.16964	2006
Budd Lake	largemouth bass	36.4	0.43134	2006

Budd Lake	largemouth bass	36.9	0.53606	2006
Budd Lake	largemouth bass	43.1	0.48615	2006
Budd Lake	largemouth bass	47.6	0.41803	2006
Carnegie Lake	Bluegill sunfish	16.7	0.06306	2006
Carnegie Lake	Bluegill sunfish	17.9	0.05655	2006
Carnegie Lake	Bluegill sunfish	19	0.10097	2006
Carnegie Lake	white perch	20.8	0.23403	2006
Carnegie Lake	white perch	20.8	0.14171	2006
Carnegie Lake	white perch	21	0.16152	2006
Carnegie Lake	largemouth bass	34.3	0.15636	2006
Carnegie Lake	largemouth bass	38.3	0.11614	2006
Carnegie Lake	largemouth bass	43.3	0.40243	2006
Carnegie Lake	largemouth bass	44.3	0.36529	2006
Carnegie Lake	largemouth bass	49.6	0.51996	2006
Davidson Mill Pond	bluegill	18.1	0.18292	2006
Davidson Mill Pond	bluegill	19	0.0504	2006
Davidson Mill Pond	bluegill	20.3	0.14941	2006
Davidson Mill Pond	chain pickerel	43.5	0.27161	2006
Davidson Mill Pond	chain pickerel	43.9	0.24405	2006
Davidson Mill Pond	chain pickerel	48.3	0.35285	2006
Davidson Mill Pond	American eel	75.2	0.20145	2006
Davidson Mill Pond	American eel	79	0.20049	2006
Davidson Mill Pond	largemouth bass	37.7	0.5091	2006
Davidson Mill Pond	largemouth bass	40.4	0.50194	2006
Davidson Mill Pond	largemouth bass	41.3	0.56886	2006
DeVoe Lake	brown bullhead	30.9	0.07703	2006
DeVoe Lake	brown bullhead	32.5	0.12689	2006
DeVoe Lake	brown bullhead	35.7	0.16058	2006
DeVoe Lake	chain pickerel	45.8	0.26277	2006
DeVoe Lake	chain pickerel	50	0.38873	2006
DeVoe Lake	chain pickerel	50.5	0.50737	2006
Duhernal Lake	bluegill	18.4	0.04042	2006
Duhernal Lake	bluegill	20.2	0.07774	2006
Duhernal Lake	bluegill	22.3	0.16006	2006
Duhernal Lake	brown bullhead	31.6	0.03663	2006
Duhernal Lake	brown bullhead	33.5	0.02588	2006
Duhernal Lake	brown bullhead	34.5	0.05482	2006
Duhernal Lake	largemouth bass	36.4	0.19646	2006
Duhernal Lake	largemouth bass	36.5	0.1712	2006
Duhernal Lake	largemouth bass	39.2	0.2798	2006
Farrington Lake	bluegill	17.2	0.09828	2006
Farrington Lake	bluegill	17.8	0.1512	2006
Farrington Lake	bluegill	18.7	0.11982	2006
Farrington Lake	yellow perch	20.6	0.17985	2006
Farrington Lake	yellow perch	20.7	0.22166	2006
Farrington Lake	yellow perch	25.7	0.41141	2006
Farrington Lake	brown bullhead	29.8	0.03402	2006
Farrington Lake	brown bullhead	34.7	0.04048	2006
Farrington Lake	brown bullhead	36.5	0.01656	2006
Farrington Lake	chain pickerel	43.2	0.19105	2006

Farrington Lake	chain pickerel	45.8	0.20378	2006
Farrington Lake	chain pickerel	48.8	0.48139	2006
Farrington Lake	largemouth bass	39.8	0.51737	2006
Farrington Lake	largemouth bass	41	0.50762	2006
Farrington Lake	largemouth bass	42.3	0.93764	2006
Farrington Lake	largemouth bass	46.3	1.41272	2006
Farrington Lake	largemouth bass	49	0.97277	2006
Lamington River @ Lamington	redbreast sunfish	15.8	0.12666	2006
Lamington River @ Lamington	redbreast sunfish	16.1	0.16744	2006
Lamington River @ Lamington	redbreast sunfish	16.6	0.14858	2006
Lamington River @ Lamington	smallmouth bass	18.6	0.13566	2006
Lamington River @ Lamington	smallmouth bass	20.6	0.18452	2006
Lamington River @ Lamington	smallmouth bass	22	0.12535	2006
Lamington River @ Lamington	brown trout	23.7	0.07503	2006
Lamington River @ Lamington	brown trout	26.1	0.08884	2006
Lamington River @ Lamington	American eel	53.7	0.18808	2006
Lamington River @ Lamington	American eel	60.2	0.39376	2006
Lamington River @ Lamington	American eel	63.2	0.24738	2006
Manalapan Lake	bluegill	18.4	0.04791	2006
Manalapan Lake	bluegill	18.4	0.07113	2006
Manalapan Lake	bluegill	18.6	0.04947	2006
Manalapan Lake	black crappie	21	0.09823	2006
Manalapan Lake	black crappie	21.4	0.10733	2006
Manalapan Lake	black crappie	22.8	0.14389	2006
Manalapan Lake	American eel	49.5	0.07662	2006
Manalapan Lake	American eel	53.4	0.12536	2006
Manalapan Lake	American eel	59.7	0.17554	2006
Manalapan Lake	largemouth bass	38	0.23315	2006
Manalapan Lake	largemouth bass	39.1	0.32996	2006
Manalapan Lake	largemouth bass	40.8	0.40945	2006
New Market Pond	bluegill	16.5	0.06683	2006
New Market Pond	bluegill	17	0.06511	2006
New Market Pond	bluegill	17.3	0.0888	2006
New Market Pond	black crappie	20.6	0.05647	2006
New Market Pond	black crappie	22.5	0.08984	2006
New Market Pond	black crappie	24.1	0.05213	2006
New Market Pond	brown bullhead	33.3	0.02354	2006
New Market Pond	brown bullhead	33.5	0.00063	2006
New Market Pond	American eel	34	0.02819	2006
New Market Pond	brown bullhead	34.5	0.00419	2006
New Market Pond	American eel	46.6	0.04004	2006
New Market Pond	American eel	48.5	0.10651	2006
New Market Pond	common carp	50.7	0.04819	2006
New Market Pond	common carp	52.7	0.05352	2006
New Market Pond	common carp	53	0.03293	2006
New Market Pond	largemouth bass	35.9	0.13736	2006
New Market Pond	largemouth bass	36.8	0.10944	2006
New Market Pond	largemouth bass	41.4	0.26315	2006
Raritan River @ Millstone River	redbreast sunfish	18.2	0.13396	2006
Raritan River @ Millstone River	redbreast sunfish	18.2	0.16323	2006

Raritan River @ Millstone River	redbreast sunfish	19.3	0.10685	2006
Raritan River @ Millstone River	smallmouth bass	30.9	0.29331	2006
Raritan River @ Millstone River	smallmouth bass	31	0.33445	2006
Raritan River @ Millstone River	white catfish	32.6	0.20333	2006
Raritan River @ Millstone River	white catfish	35.7	0.21395	2006
Raritan River @ Millstone River	smallmouth bass	37.3	0.26906	2006
Raritan River @ Millstone River	white catfish	40.1	0.23869	2006
Raritan River @ Millstone River	channel catfish	48.7	0.35862	2006
Raritan River @ Millstone River	channel catfish	53	0.17138	2006
Raritan River @ Millstone River	American eel	57.6	0.10876	2006
Raritan River @ Millstone River	common carp	57.9	0.12682	2006
Raritan River @ Millstone River	common carp	59.7	0.15017	2006
Raritan River @ Millstone River	channel catfish	63.7	0.16402	2006
Raritan River @ Millstone River	common carp	65.9	0.00431	2006
Raritan River @ Millstone River	American eel	70.6	0.24336	2006
Raritan River @ Millstone River	American eel	71	0.29174	2006
Raritan River at Millstone River	largemouth bass	32.4	0.25569	2006
Raritan River at Millstone River	largemouth bass	37.2	0.32619	2006
Raritan River at Millstone River	largemouth bass	43	0.6896	2006
Rosedale Lake in Pennington	bluegill	18.4	0.05062	2006
Rosedale Lake in Pennington	bluegill	18.7	0.06377	2006
Rosedale Lake in Pennington	bluegill	20.2	0.10783	2006
Rosedale Lake in Pennington	black crappie	24.1	0.10195	2006
Rosedale Lake in Pennington	black crappie	25.7	0.11855	2006
Rosedale Lake in Pennington	black crappie	30.8	0.12335	2006
Rosedale Lake in Pennington	common carp	62.2	0.11683	2006
Rosedale Lake in Pennington	common carp	64.1	0.10668	2006
Rosedale Lake in Pennington	common carp	66.8	0.10278	2006
Rosedale Lake in Pennington	largemouth bass	40	0.22114	2006
Rosedale Lake in Pennington	largemouth bass	47.6	0.22991	2006
Rosedale Lake in Pennington	largemouth bass	47.7	0.3298	2006
Round Valley Reservoir	bluegill	21.5	0.11044	2006
Round Valley Reservoir	bluegill	21.9	0.11996	2006
Round Valley Reservoir	bluegill	22	0.09508	2006
Round Valley Reservoir	white catfish	36.8	0.08206	2006
Round Valley Reservoir	white catfish	40	0.0991	2006
Round Valley Reservoir	lake trout	43.9	0.08773	2006
Round Valley Reservoir	channel catfish	50.2	0.11492	2006
Round Valley Reservoir	lake trout	52.2	0.10409	2006
Round Valley Reservoir	lake trout	53.7	0.2057	2006
Round Valley Reservoir	lake trout	54.9	0.12745	2006
Round Valley Reservoir	channel catfish	58.7	0.4599	2006
Round Valley Reservoir	channel catfish	61.8	0.06823	2006
Round Valley Reservoir	lake trout	66.5	0.18896	2006
Round Valley Reservoir	largemouth bass	30.6	0.19463	2006
Round Valley Reservoir	largemouth bass	41.8	0.2981	2006
Round Valley Reservoir	largemouth bass	45.1	0.38514	2006
South Branch Raritan River at Neshanic Station	redbreast sunfish	16.9	0.10381	2006

South Branch Raritan River at Neshanic Station	redbreast sunfish	17.7	0.09302	2006
South Branch Raritan River at Neshanic Station	redbreast sunfish	17.9	0.12138	2006
South Branch Raritan River at Neshanic Station	rock bass	20.4	0.24498	2006
South Branch Raritan River at Neshanic Station	rock bass	20.6	0.16647	2006
South Branch Raritan River at Neshanic Station	rock bass	21.1	0.2056	2006
South Branch Raritan River at Neshanic Station	smallmouth bass	34.9	0.31523	2006
South Branch Raritan River at Neshanic Station	common carp	37.2	0.05298	2006
South Branch Raritan River at Neshanic Station	smallmouth bass	41.1	0.38035	2006
South Branch Raritan River at Neshanic Station	common carp	42.7	0.05706	2006
South Branch Raritan River at Neshanic Station	common carp	46.1	0.04491	2006
South Branch Raritan River at Neshanic Station	smallmouth bass	49.9	0.39461	2006
South Branch Raritan River at Neshanic Station	American eel	63	0.29096	2006
South Branch Raritan River at Neshanic Station	American eel	69.9	0.22739	2006
South Branch Raritan River at Neshanic Station	American eel	72.5	0.25548	2006
South Branch Raritan River at Neshanic Station	largemouth bass	20	0.18969	2006
South Branch Raritan River at Neshanic Station	largemouth bass	21.3	0.17653	2006
South Branch Raritan River at Neshanic Station	largemouth bass	26.9	0.1382	2006
Spring Lake	common carp	48.3	0.04448	2006
Spring Lake	common carp	54.5	0.00202	2006
Spring Lake	common carp	64.6	0.0799	2006
Spruce Run Reservoir	channel catfish	41	0.06091	2006
Spruce Run Reservoir	striped x white bass hybrid	42.4	0.14346	2006
Spruce Run Reservoir	striped x white bass hybrid	48	0.18523	2006
Spruce Run Reservoir	striped x white bass hybrid	49.2	0.22875	2006
Spruce Run Reservoir	striped x white bass hybrid	53.6	0.39913	2006
Spruce Run Reservoir	striped x white bass hybrid	54.3	0.51704	2006
Spruce Run Reservoir	channel catfish	55.6	0.22611	2006
Spruce Run Reservoir	channel catfish	56.3	0.32477	2006
Spruce Run Reservoir	common carp	57.8	0.12598	2006
Spruce Run Reservoir	common carp	58.1	0.12418	2006
Spruce Run Reservoir	common carp	58.3	0.13401	2006
Spruce Run Reservoir	northern pike	65.5	0.31375	2006

Spruce Run Reservoir	northern pike	68.5	0.24939	2006
Spruce Run Reservoir	northern pike	76.8	0.20958	2006
Spruce Run Reservoir	largemouth bass	28.7	0.17957	2006
Spruce Run Reservoir	largemouth bass	35.8	0.17422	2006
Spruce Run Reservoir	largemouth bass	39.8	0.43026	2006
Spruce Run Reservoir	largemouth bass	42.9	0.44294	2006
Spruce Run Reservoir	largemouth bass	47.3	0.60489	2006
Weston Mill Pond	bluegill	17.7	0.06793	2006
Weston Mill Pond	bluegill	18.6	0.11264	2006
Weston Mill Pond	bluegill	18.9	0.2196	2006
Weston Mill Pond	yellow perch	25.3	0.27386	2006
Weston Mill Pond	black crappie	25.8	0.19928	2006
Weston Mill Pond	yellow perch	26.3	0.14497	2006
Weston Mill Pond	black crappie	26.9	0.28312	2006
Weston Mill Pond	black crappie	26.9	0.22769	2006
Weston Mill Pond	brown bullhead	27.1	0.01612	2006
Weston Mill Pond	brown bullhead	28.2	0.05252	2006
Weston Mill Pond	yellow perch	29.3	0.39874	2006
Weston Mill Pond	brown bullhead	35.7	0.0256	2006
Weston Mill Pond	chain pickerel	38.9	0.16182	2006
Weston Mill Pond	chain pickerel	45.9	0.28877	2006
Weston Mill Pond	chain pickerel	48	0.48049	2006
Weston Mill Pond	American eel	49.8	0.10278	2006
Weston Mill Pond	American eel	50.2	0.11332	2006
Weston Mill Pond	American eel	55.1	0.13674	2006
Weston Mill Pond	largemouth bass	38	0.52104	2006
Weston Mill Pond	largemouth bass	38.1	0.41189	2006
Weston Mill Pond	largemouth bass	39.5	0.46808	2006
Atsion Lake	American eel	31.2	0.33	2007
Atsion Lake	American eel	32.1	0.27	2007
Atsion Lake	American eel	51.7	0.52	2007
Atsion Lake	chain pickerel	33.2	0.47	2007
Atsion Lake	chain pickerel	39.6	0.69	2007
Atsion Lake	chain pickerel	44.7	0.82	2007
Batsto Lake	brown bullhead	32.9	0.29	2007
Batsto Lake	brown bullhead	33.4	0.22	2007
Batsto Lake	brown bullhead	36.18	0.16	2007
Batsto Lake	chain pickerel	23.7	0.30	2007
Batsto Lake	chain pickerel	35	0.78	2007
Batsto Lake	chain pickerel	35.5	0.85	2007
Batsto Lake	chain pickerel	35.9	0.44	2007
Batsto Lake	largemouth bass	35.5	1.25	2007
Batsto Lake	largemouth bass	35.6	1.07	2007
Batsto Lake	largemouth bass	36.7	0.85	2007
Batsto Lake	largemouth bass	37.2	0.10	2007
Cedar Lake	American eel	48.7	0.16	2007
Cedar Lake	American eel	54.2	0.18	2007
Cedar Lake	American eel	63.9	0.22	2007
Cedar Lake	largemouth bass	32.8	0.18	2007
Cedar Lake	largemouth bass	38.8	0.31	2007

Cedar Lake	largemouth bass	47	1.63	2007
Cedar Lake	white perch	30.7	0.33	2007
Cedar Lake	white perch	31.8	0.22	2007
Cedar Lake	white perch	37.4	0.51	2007
Cedarville Ponds	chain pickerel	30.6	0.65	2007
Cedarville Ponds	chain pickerel	32.5	0.46	2007
Cedarville Ponds	chain pickerel	34.4	0.53	2007
Cedarville Ponds	chain pickerel	35.4	0.54	2007
Cedarville Ponds	chain pickerel	43.1	0.69	2007
Cedarville Ponds	yellow perch	28	0.31	2007
Cedarville Ponds	yellow perch	28.8	0.33	2007
Cedarville Ponds	yellow perch	29.8	0.35	2007
Deal Lake	American eel	31	0.30	2007
Deal Lake	American eel	60	0.05	2007
Deal Lake	largemouth bass	38	0.09	2007
Deal Lake	largemouth bass	39.8	0.12	2007
Deal Lake	largemouth bass	40.2	0.14	2007
Deal Lake	white perch	16.3	0.02	2007
Deal Lake	white perch	18.1	0.04	2007
Deal Lake	white perch	20.2	0.18	2007
East Creek Lake	American eel	43.2	1.05	2007
East Creek Lake	American eel	51.8	1.02	2007
East Creek Lake	American eel	53.9	1.24	2007
East Creek Lake	chain pickerel	33.6	1.14	2007
East Creek Lake	chain pickerel	41.1	1.46	2007
East Creek Lake	chain pickerel	42.9	1.05	2007
East Creek Lake	largemouth bass	30.5	1.05	2007
East Creek Lake	largemouth bass	39.4	1.40	2007
East Creek Lake	largemouth bass	44.6	1.37	2007
Harrisville Lake	American eel	27.4	0.47	2007
Harrisville Lake	American eel	40.5	0.58	2007
Harrisville Lake	American eel	54.1	0.73	2007
Harrisville Lake	chain pickerel	27.6	1.05	2007
Harrisville Lake	chain pickerel	29.4	0.61	2007
Harrisville Lake	chain pickerel	30.4	0.91	2007
Harrisville Lake	chain pickerel	31.3	1.05	2007
Lake Absegami	American eel	31.6	0.36	2007
Lake Absegami	American eel	32.7	0.29	2007
Lake Absegami	American eel	47.5	0.80	2007
Lake Absegami	chain pickerel	35.3	1.32	2007
Lake Absegami	chain pickerel	35.4	1.26	2007
Lake Absegami	chain pickerel	43.5	1.24	2007
Lake Absegami	chain pickerel	47.6	1.62	2007
Lake Absegami	chain pickerel	58.7	1.39	2007
Lake Manahawkin	American eel	46.3	1.50	2007
Lake Manahawkin	American eel	56.1	1.43	2007
Lake Manahawkin	American eel	79.6	1.89	2007
Lake Manahawkin	largemouth bass	33.6	1.08	2007
Lake Manahawkin	largemouth bass	35.2	0.93	2007

Lake Manahawkin	largemouth bass	45.1	1.76	2007
Lake Nummy	yellow bullhead	29.2	0.44	2007
Lake Nummy	yellow bullhead	29.7	0.26	2007
Lake Nummy	yellow bullhead	33.4	0.79	2007
Lake Nummy	chain pickerel	46.2	1.07	2007
Lake Nummy	chain pickerel	56	2.56	2007
Lake Oswego	American eel	49.6	0.70	2007
Lake Oswego	American eel	60.5	0.46	2007
Lake Oswego	chain pickerel	26.6	0.82	2007
Lake Oswego	chain pickerel	27.7	0.76	2007
Lake Oswego	chain pickerel	42.1	0.42	2007
Lake Oswego	chain pickerel	46.8	2.05	2007
Lefferts Lake	brown bullhead	27.8	0.07	2007
Lefferts Lake	brown bullhead	28.8	0.10	2007
Lefferts Lake	brown bullhead	29.1	0.10	2007
Lefferts Lake	chain pickerel	43.9	0.11	2007
Lefferts Lake	chain pickerel	44.7	0.19	2007
Lefferts Lake	chain pickerel	46.7	0.21	2007
Lefferts Lake	yellow perch	23.8	0.10	2007
Lefferts Lake	yellow perch	24.4	0.12	2007
Lefferts Lake	yellow perch	25.3	0.09	2007
Lenape Lake	American eel	53	0.42	2007
Lenape Lake	American eel	58.7	1.06	2007
Lenape Lake	American eel	62.4	0.89	2007
Lenape Lake	largemouth bass	40	1.60	2007
Lenape Lake	largemouth bass	44.6	1.04	2007
Lenape Lake	largemouth bass	45.9	1.61	2007
Manasquan Reservoir	American eel	54.2	0.08	2007
Manasquan Reservoir	American eel	58	0.05	2007
Manasquan Reservoir	American eel	82.4	0.17	2007
Manasquan Reservoir	largemouth bass	40.1	0.10	2007
Manasquan Reservoir	largemouth bass	44.5	0.21	2007
Manasquan Reservoir	largemouth bass	49.2	0.40	2007
Maple Lake	American eel	44.1	0.81	2007
Maple Lake	American eel	48.6	0.81	2007
Maple Lake	American eel	53.6	1.02	2007
Maple Lake	largemouth bass	33.1	0.43	2007
Maple Lake	largemouth bass	33.7	0.84	2007
Maple Lake	largemouth bass	34.7	0.86	2007
Maple Lake	largemouth bass	38	1.48	2007
Marlu Lake	common carp	64.4	0.04	2007
Marlu Lake	common carp	66.6	0.04	2007
Marlu Lake	common carp	67.9	0.04	2007
Marlu Lake	largemouth bass	34.5	0.08	2007
Marlu Lake	largemouth bass	41.4	0.09	2007
Marlu Lake	largemouth bass	44.2	0.14	2007
Parvin Lake	American eel	63.1	0.12	2007
Parvin Lake	American eel	64.9	0.12	2007
Parvin Lake	chain pickerel	45.7	0.24	2007
Parvin Lake	chain pickerel	47.7	0.21	2007

Parvin Lake	chain pickerel	51.4	0.19	2007
Parvin Lake	largemouth bass	35.9	0.16	2007
Parvin Lake	largemouth bass	39.5	0.21	2007
Parvin Lake	largemouth bass	43.3	0.26	2007
Parvin Lake	largemouth bass	44.6	0.19	2007
Parvin Lake	largemouth bass	49	0.27	2007
Pohatcong Lake	American eel	44.3	0.44	2007
Pohatcong Lake	American eel	45.3	0.95	2007
Pohatcong Lake	American eel	66.2	0.72	2007
Pohatcong Lake	largemouth bass	41.7	0.78	2007
Pohatcong Lake	largemouth bass	41.7	0.69	2007
Pohatcong Lake	largemouth bass	42.7	0.61	2007
Pohatcong Lake	largemouth bass	43	0.64	2007
Pohatcong Lake	yellow perch	26.5	0.14	2007
Pohatcong Lake	yellow perch	31.2	0.36	2007
Pohatcong Lake	yellow perch	34.6	0.83	2007
Shenandoah Lake	American eel	46.8	0.42	2007
Shenandoah Lake	American eel	47.9	0.24	2007
Shenandoah Lake	American eel	75.5	0.42	2007
Shenandoah Lake	chain pickerel	35.3	0.34	2007
Shenandoah Lake	chain pickerel	41.2	0.23	2007
Shenandoah Lake	chain pickerel	41.4	0.32	2007
Shenandoah Lake	largemouth bass	40.5	0.37	2007
Shenandoah Lake	largemouth bass	41.6	0.46	2007
Shenandoah Lake	largemouth bass	43.2	0.65	2007
Swimming River Reservoir	American eel	42.2	0.04	2007
Swimming River Reservoir	American eel	66.1	0.07	2007
Swimming River Reservoir	American eel	68.9	0.08	2007
Swimming River Reservoir	largemouth bass	40	0.09	2007
Swimming River Reservoir	largemouth bass	42.7	0.09	2007
Swimming River Reservoir	largemouth bass	50.1	0.15	2007
Wading River	chain pickerel	36.3	2.60	2007
Wading River	chain pickerel	37.5	2.63	2007
Wading River	chain pickerel	40.7	2.03	2007
Wilson Lake	chain pickerel	34.7	1.58	2007
Wilson Lake	chain pickerel	37	1.36	2007
Wilson Lake	chain pickerel	54.7	2.02	2007
Wilson Lake	largemouth bass	35.4	1.53	2007
Wilson Lake	largemouth bass	38.9	1.63	2007
Wilson Lake	largemouth bass	40.9	3.27	2007
Wilson Lake	yellow perch	28	1.25	2007
Wilson Lake	yellow perch	28	1.46	2007
Wilson Lake	yellow perch	30	0.87	2007

Appendix C

Non-Tidal Surface Water NJPDES Facility List to Quantify Potential Hg Load

NJPDES Permit Number	Facility Name	Permitted Flow	Description
NJ0000876	HERCULES INC - KENVIL	0.7	Industrial
NJ0020036	DEPT OF VETERANS AFFAIRS	0.08	Municipal minor
NJ0020184	NEWTOWN WASTEWATER TREATMENT PLANT	1.4	Municipal major
NJ0020206	ALLENTOWN BORO WWTP	0.238	Municipal minor
NJ0020281	CHATHAM HILL STP	0.03	Municipal minor
NJ0020290	CHATHAM TWP MAIN STP	1	Municipal minor
NJ0020354	BRANCHBURG NESHANIC STP	0.055	Municipal minor
NJ0020389	CLINTON TOWN WWTP	2.03	Municipal major
NJ0020419	LONG POND SCHOOL WTP	0.01	Municipal minor
NJ0020427	CALDWELL WASTEWATER TREATMENT PLANT	4.5	Municipal major
NJ0020532	HARRISON TOWNSHIP TREATMENT PLANT	0.8	Municipal minor
NJ0020605	ALLAMUCHY SEWERAGE TREATMENT PLANT	0.6	Municipal minor
NJ0020711	WARREN CO TECHNICAL SCHOOL STP	0.012	Municipal minor
NJ0021083	VETERANS AFFAIRS NJ HEALTH CARE SYSTEM-LYONS	0.4	Municipal minor
NJ0021091	JEFFERSON TWP HIGH-MIDDLE SCHOOL	0.0275	Municipal minor
NJ0021105	ARTHUR STANLICK SCHOOL	0.013	Municipal minor
NJ0021113	WASHINGTON BORO WWTP	1.5	Municipal major
NJ0021253	INDIAN HILLS HIGH SCHOOL	0.0336	Municipal minor
NJ0021326	MEDFORD LAKES BOROUGH STP	0.55	Municipal minor
NJ0021334	MENDHAM BORO	0.45	Municipal minor
NJ0021342	SKYVIEW/HIBROOK WTP	0.023	Municipal minor
NJ0021369	HACKETTSTOWN MUA	3.48	Municipal major
NJ0021571	SPRINGFIELD TWP ELEM SCH STP	0.0075	Municipal minor
NJ0021636	NEW PROVIDENCE WWTP	1.5	Municipal major
NJ0021717	BUENA BOROUGH MUA	0.4	Municipal major
NJ0021865	FIDDLER'S ELBOW CTRY CLUB WWTP	0.03	Municipal minor
NJ0021890	MILFORD SEWER UTILITY	0.4	Municipal minor
NJ0021954	CLOVERHILL STP	0.5	Municipal minor
NJ0022047	RARITAN TOWNSHIP MUA STP	3.8	Municipal major
NJ0022063	SUSSEX COUNTY HOMESTEAD WTP	0.05	Municipal minor
NJ0022101	BLAIR ACADEMY	0.05	Municipal minor
NJ0022110	EDUCATIONAL TESTING SERVICE	0.08	Municipal minor
NJ0022144	HAGEDORN PSYCHIATRIC HOSPITAL	0.052	Municipal minor
NJ0022250	WOODSTOWN WASTEWATER TREATMENT PLANT	0.53	Municipal minor
NJ0022276	STONYBROOK SCHOOL	0.01	Municipal minor
NJ0022349	ROCKAWAY VALLEY REG SA	12	Municipal major
NJ0022381	NORTHERN BURLINGTON COUNTY	0.0135	Municipal minor
NJ0022390	NPDC SEWAGE TREATMENT PLANT	0.5	Municipal minor
NJ0022438	HELEN A FORT MIDDLE SCHOOL	0.05	Municipal minor

NJ0022489	WARREN TWP SEWERAGE AUTH STAGE I-II STP	0.47	Municipal minor
NJ0022497	WARREN STAGE IV STP	0.8	Municipal minor
NJ0022586	MARLBORO PSYCHIATRIC HOSP STP	1	Municipal major
NJ0022675	ROXBURY TOWNSHIP	2	Municipal major
NJ0022764	RIVER ROAD STP	0.1172	Municipal minor
NJ0022781	POTTERSVILLE STP	0.048	Municipal minor
NJ0022845	HARRISON BROOK STP	2.5	Municipal major
NJ0022918	ROOSEVELT BORO WTP	0.25	Municipal minor
NJ0022985	WRIGHTSTOWN BOROUGH STP	0.337	Municipal minor
NJ0023001	SALVATION ARMY CAMP TECUMSEH	0.018	Municipal minor
NJ0023124	MONTGOMERY HIGH SCHOOL STP	0.035	Municipal minor
NJ0023175	ROUND VALLEY MIDDLE SCHOOL	0.009	Municipal minor
NJ0023311	KINGWOOD TWP SCHOOL	0.0048	Municipal minor
NJ0023493	WASHINGTON TOWNSHIP MUA WTP	0.5	Municipal minor
NJ0023540	NAVAL WEAPONS STATION EARLE	0.37	Municipal minor
NJ0023663	CARRIER FOUNDATION WTP	0.04	Municipal minor
NJ0023698	POMPTON LAKES BORO MUA	1.2	Municipal major
NJ0023728	PINE BROOK STP	8.8	Municipal major
NJ0023736	PINELANDS WASTEWATER COMPANY	0.5	Municipal minor
NJ0023787	EAST WINDSOR WATER POLLUTION CONTROL PLANT	4.5	Municipal major
NJ0023841	LOUNSBERRY HOLLOW MIDDLE SCH STP	0.032	Municipal minor
NJ0023949	LEGENDS RESORT & COUNTRY CLUB	0.35	Municipal minor
NJ0024031	ELMWOOD WTP	2.978	Municipal major
NJ0024040	WOODSTREAM STP	1.7	Municipal major
NJ0024091	UNION TWP ELEMENTARY SCHOOL	0.011	Municipal minor
NJ0024104	UNITED WATER PRINCETON MEADOWS	1.64	Municipal major
NJ0024163	BIG `N` SHOPPING CENTER STP	0.02	Municipal minor
NJ0024414	WEST MILFORD SHOPPING CENTER STP	0.02	Municipal minor
NJ0024457	OUR LADY OF THE MAGNIFICAT	0.0012	Municipal minor
NJ0024465	LONG HILL TOWNSHIP OF STP	0.9	Municipal minor
NJ0024490	VERONA TWP WTP	4.1	Municipal major
NJ0024511	LIVINGSTON WATER POLLUTION CONTROL FACILITY	4.6	Municipal major
NJ0024716	PHILLIPSBURG TOWN STP	3.5	Municipal major
NJ0024759	EWING-LAWRENCE SA WTP	16	Municipal major
NJ0024791	RIDGEWOOD VILLAGE WPC FACILITY	5	Municipal major
NJ0024813	NORTHWEST BERGEN CNTY UA	16.8	Municipal major
NJ0024821	PEMBERTON TOWNSHIP MUA STP	2.5	Municipal major
NJ0024864	SOMERSET RARITAN VALLEY SA	21.3	Municipal major
NJ0024902	HANOVER SEWERAGE AUTHORITY	4.61	Municipal major
NJ0024911	BUTTERWORTH WATER POLLUTION CONTROL UTILITY	3.3	Municipal major
NJ0024929	WOODLAND WATER POLLUTION CONTROL UTILITY(WPCU	2	Municipal major
NJ0024937	MOLITOR WATER POLLUTION CONTROL FACILITY	5	Municipal major
NJ0024970	PARSIPPANY TROY HILLS	16	Municipal major
NJ0025160	HAMMONTON WTPF	1.6	Municipal major
NJ0025330	CEDAR GROVE STP	2	Municipal major

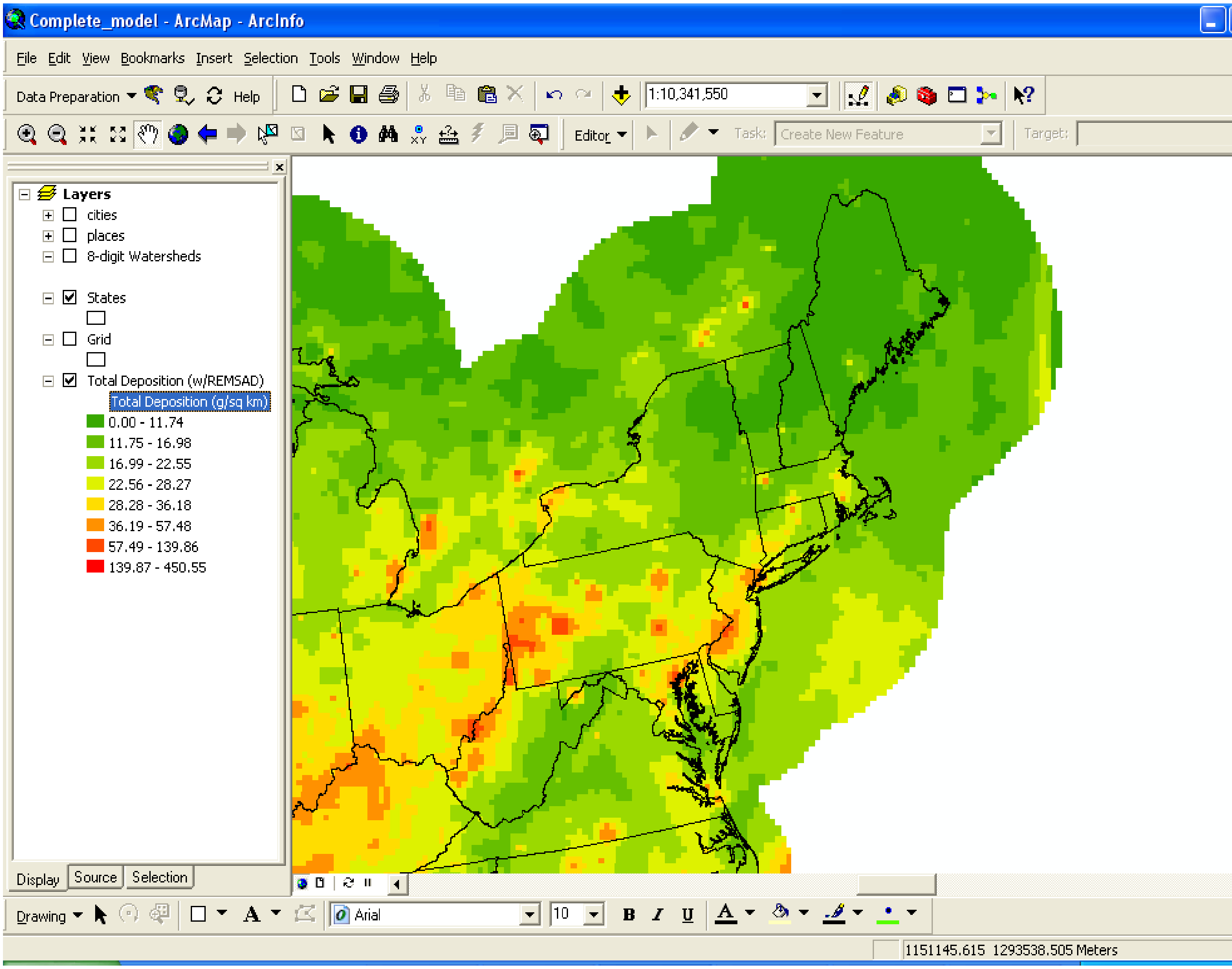
NJ0025496	MORRISTOWN SEWER UTILITY	6.3	Municipal major
NJ0025518	FLORHAM PARK SEWERAGE AUTH	1.4	Municipal major
NJ0026174	CRESCENT PARK STP	0.064	Municipal minor
NJ0026387	BERNARDSVILLE STP	0.8	Municipal minor
NJ0026689	GREYSTONE PARK PSYCH HOSPITAL	0.4	Municipal minor
NJ0026697	READINGTON TWP PUBLIC SCHOOL	0.017	Municipal minor
NJ0026719	ALBERT C WAGNER YOUTH CORRECTIONAL FACILITY	1.3	Municipal minor
NJ0026727	COLORADO CAFE WTP	0.0175	Municipal minor
NJ0026824	CHESTER SHOPPING CENTER	0.011	Municipal minor
NJ0026832	MEDFORD TWP WASTEWATER TREATMENT PLANT	1.75	Municipal major
NJ0026867	WHITE ROCK STP	0.1295	Municipal minor
NJ0026891	BURNT HILL TREATMENT PLANT #1	0.0153	Municipal minor
NJ0026905	STAGE II TREATMENT PLANT	0.48	Municipal minor
NJ0027006	RINGWOOD ACRES TREATMENT PLANT	0.036	Municipal minor
NJ0027031	HOLMDEL BD OF ED VILLAGE SCHOOL STP	0.01	Municipal minor
NJ0027049	POPE JOHN XXIII HIGH SCH WTP	0.022	Municipal minor
NJ0027057	SPARTA PLAZA WTP	0.05	Municipal minor
NJ0027065	SPARTA ALPINE SCHOOL	0.025	Municipal minor
NJ0027227	TRUMP NATIONAL GOLF COURSE	0.0005	Municipal minor
NJ0027464	HANOVER MOBILE VILLAGE ASSOC	0.02	Municipal minor
NJ0027511	CALIFORNIA VILLAGE SEWER PLANT	0.032	Municipal minor
NJ0027529	CAREONE @HOLMDEL	0.025	Municipal minor
NJ0027553	LESTER D. WILSON ELEM SCHOOL	0.0075	Municipal minor
NJ0027561	DELAWARE TOWNSHIP MUA	0.065	Municipal minor
NJ0027596	SPARTAN VILLAGE MOBILE HOME PK	0.038	Municipal minor
NJ0027669	AWOSTING STP	0.045	Municipal minor
NJ0027677	OLDE MILFORD ESTATES STP	0.172	Municipal minor
NJ0027685	HIGHVIEW ACRES STP	0.2	Municipal minor
NJ0027715	MERCER CO CORRECTION CTR STP	0.09	Municipal minor
NJ0027731	PRINCETON HEALTHCARE SYSTEM	0.296	Industrial
NJ0027774	OAKWOOD KNOLLS WWTP	0.035	Municipal minor
NJ0027821	MUSCONETCONG SEWERAGE AUTHORITY	5.79	Municipal major
NJ0027961	BERKELEY HEIGHTS WPCF	3.1	Municipal major
NJ0028002	MOUNTAIN VIEW STP	13.5	Municipal major
NJ0028304	QUALITY INN OF LEDGEWOOD	0.04	Municipal minor
NJ0028436	RARITAN TWP MUA-FLEMINGTON	2.35	Municipal major
NJ0028479	NJ TRAINING SCHOOL FOR BOYS	0.15	Municipal minor
NJ0028487	MOUNTAINVIEW CORRECTIONAL INSTITUTION	0.26	Municipal minor
NJ0028541	BIRCH HILL PARK STP	0.02	Municipal minor
NJ0028665	MOBILE ESTATES OF SOUTHAMPTON INC	0.06	Municipal minor
NJ0028894	KITTATINNY REG HS BD OF ED	0.045	Municipal minor
NJ0029041	REGENCY @ SUSSEX APT	0.08	Municipal minor
NJ0029386	TWO BRIDGES WASTEWATER TREATMENT PLANT	10	Municipal major
NJ0029432	ROBERT ERSKINE SCHOOL STP	0.008	Municipal minor
NJ0029475	HIGHTSTOWN BORO AWWTP	1	Municipal major

NJ0029831	FRENCHTOWN WASTEWATER TREATMENT PLANT	0.15	Municipal minor
NJ0029858	OAKLAND CARE CENTER INC	0.03	Municipal minor
NJ0031046	NORTH WARREN REG SCH DIST WTF	0.02	Municipal minor
NJ0031119	STONY BROOK RSA- RIVER ROAD STP	13.06	Municipal major
NJ0031585	HIGH POINT REGIONAL HS	0.03	Municipal minor
NJ0031615	CAMDEN COUNTY VOC & TECH SCHOOL	0.058	Municipal minor
NJ0031674	REMINGTON'S RESTAURANT	0.028	Municipal minor
NJ0031771	COLTS NECK INN HOTEL	0.006	Municipal minor
NJ0032395	RINGWOOD PLAZA STP	0.01168	Municipal minor
NJ0033995	ENVIRONMENTAL DISPOSAL CORP	2.1	Municipal major
NJ0035084	EXXONMOBIL RESEARCH & ENGINEERING CO	0.22	Industrial
NJ0035114	BELVIDERE AREA WWTF	0.5	Municipal minor
NJ0035301	STONY BROOK RGNL SEWERAGE AUTH	0.3	Municipal minor
NJ0035319	STONY BROOK RSA	0.3	Municipal minor
NJ0035483	OXFORD AREA WTF	0.5	Municipal minor
NJ0035670	ALEXANDRIA MIDDLE SCHOOL	0.011	Municipal minor
NJ0035718	HOLMDEL WASTEWATER TREATMENT FACILITY	0.04	Municipal minor
NJ0050130	RIVERSIDE FARMS STP	0.145	Municipal minor
NJ0050369	WARREN STAGE V STP	0.38	Municipal minor
NJ0050580	HAMPTON COMMONS WASTEWATER FACILITY	0.05	Municipal minor
NJ0052256	CHATHAM GLEN STP	0.155	Municipal minor
NJ0053112	CHAPEL HILL ESTATES STP	0.01	Municipal minor
NJ0053350	SUSSEX CNTY MUA UPPER WALLKILL FACILITY	3	Municipal major
NJ0053759	WANAQUE VALLEY REGIONAL SEWERAGE AUTHORITY	1.25	Municipal major
NJ0055395	BURLINGTON CNTY RESOURCE RECOVERY COMPLEX	2.075	Industrial
NJ0060038	PIKE BROOK STP	0.67	Municipal minor
NJ0067733	OXBRIDGE WASTEWATER TREATMENT PLANT	0.16	Municipal minor
NJ0069523	CHERRY VALLEY STP	0.286	Municipal minor
NJ0080811	RAMAPO RIVER RESERVE WWTP	0.1137	Municipal minor
NJ0098663	HOMESTEAD TREATMENT UTILITY	0.25	Municipal minor
NJ0098922	READINGTON-LEBANON SA	0.8	Municipal minor
NJ0100528	GLEN MEADOWS/TWIN OAKS STP	0.025	Municipal minor
NJ0102270	EVOINK DEGUSSA CORP	0.015	Industrial
NJ0102563	ROUTE 78 OFFICE AREA WWTF	0.09653	Municipal minor
NJ0109061	LONG VALLEY VILLAGE WTP	0.244	Municipal minor
NJ0136603	MORRIS LAKE WTP	0.2	Municipal minor
NJG0005134	HERCULES GROUNDWATER TREATMT AT GEO SPEC CHEM	0.432	Industrial

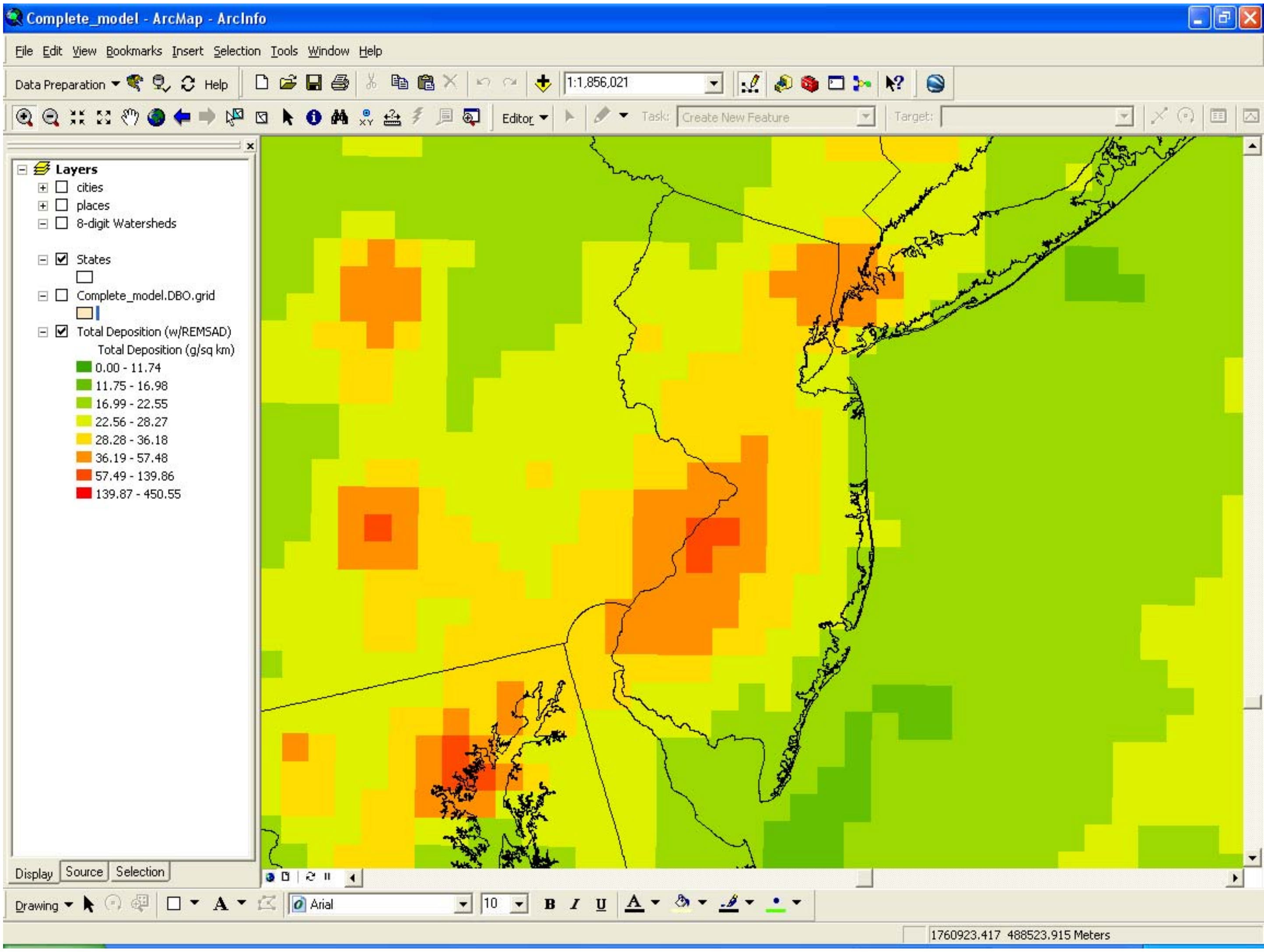
Footnote: TMDL Section 4.0 - Source Assessment describes list construction.

Appendix D

Mercury Air Deposition Load for New Jersey (provided by Mr. Dwight Atkinson of EPA)



Layers
☐ cities
☐ places
☐ 8-digit Watersheds
☑ States
☐ Grid
☑ Total Deposition (w/REMSAD)
Total Deposition (g/sq km)
🟩 0.00 - 11.74
🟩 11.75 - 16.98
🟩 16.99 - 22.55
🟨 22.56 - 28.27
🟨 28.28 - 36.18
🟧 36.19 - 57.48
🟥 57.49 - 139.86
🟥 139.87 - 450.55

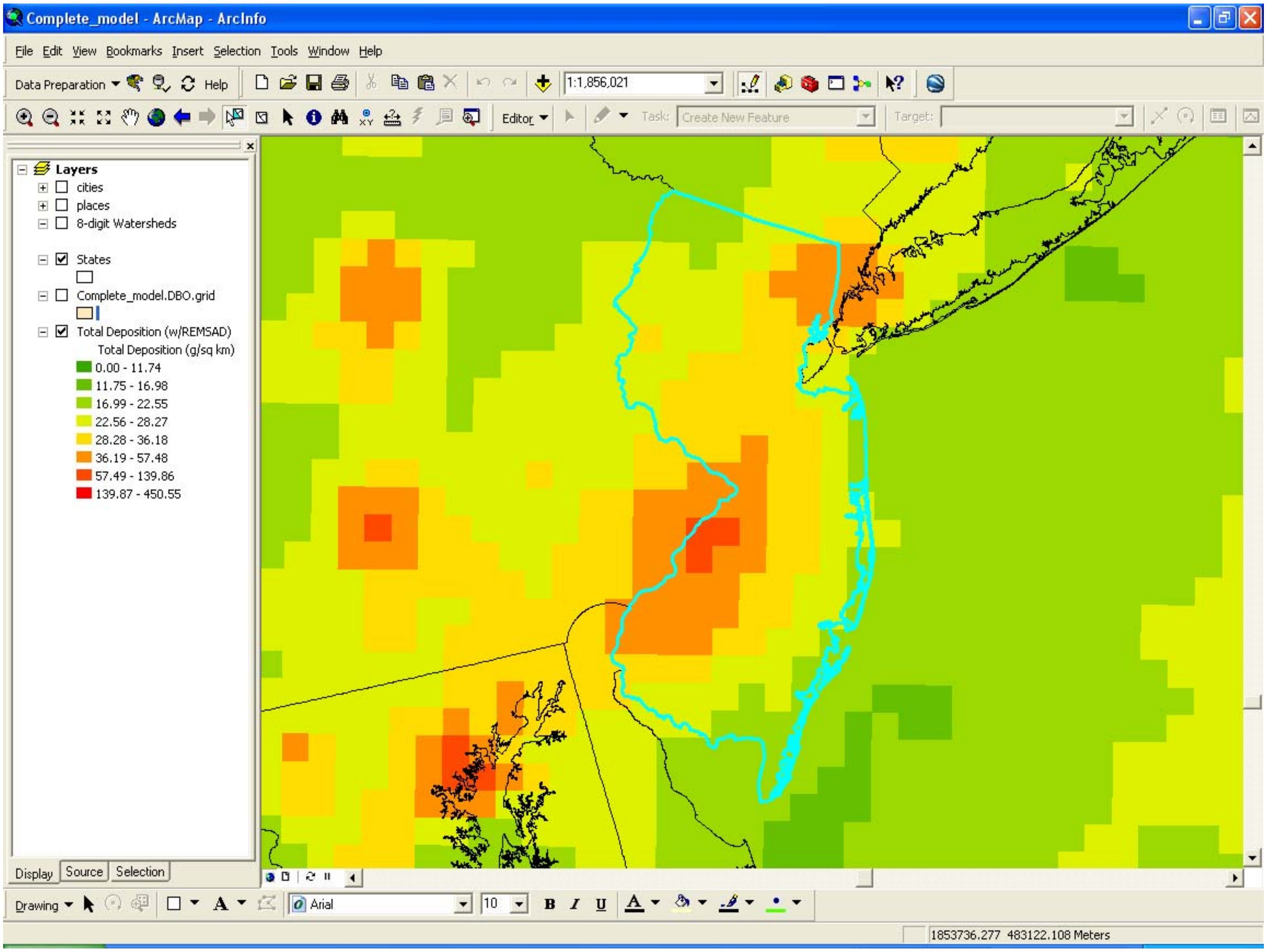


Layers
- ☐ cities
- ☐ places
- ☐ 8-digit Watersheds
- ☑ States
- ☐ Complete_model.DBO.grid
- ☑ Total Deposition (w/REMSAD)

Total Deposition (g/sq km)

🟩	0.00 - 11.74
🟩	11.75 - 16.98
🟩	16.99 - 22.55
🟨	22.56 - 28.27
🟨	28.28 - 36.18
🟧	36.19 - 57.48
🟥	57.49 - 139.86
🟥	139.87 - 450.55

1760923.417 488523.915 Meters



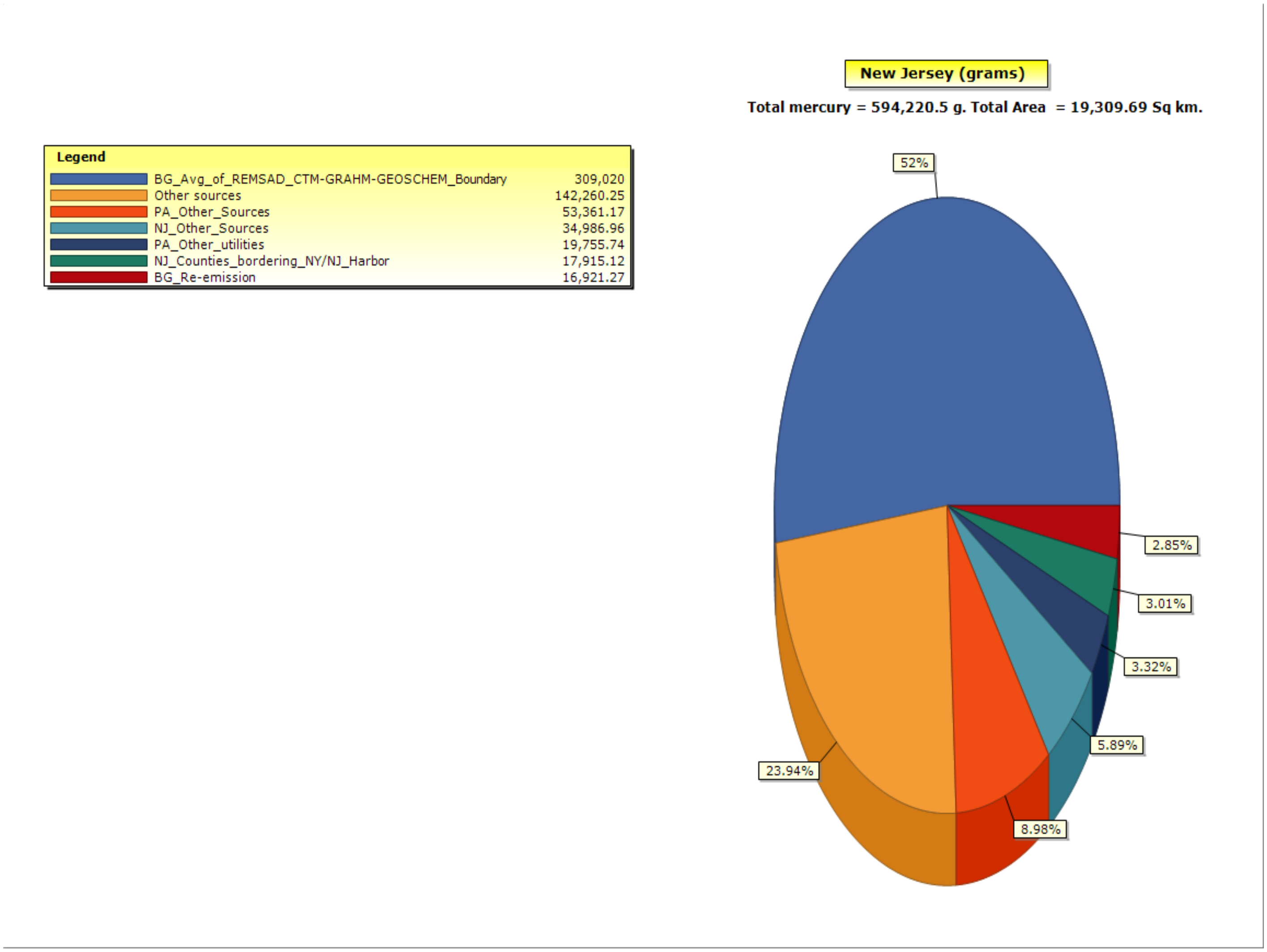
1:1,856,021

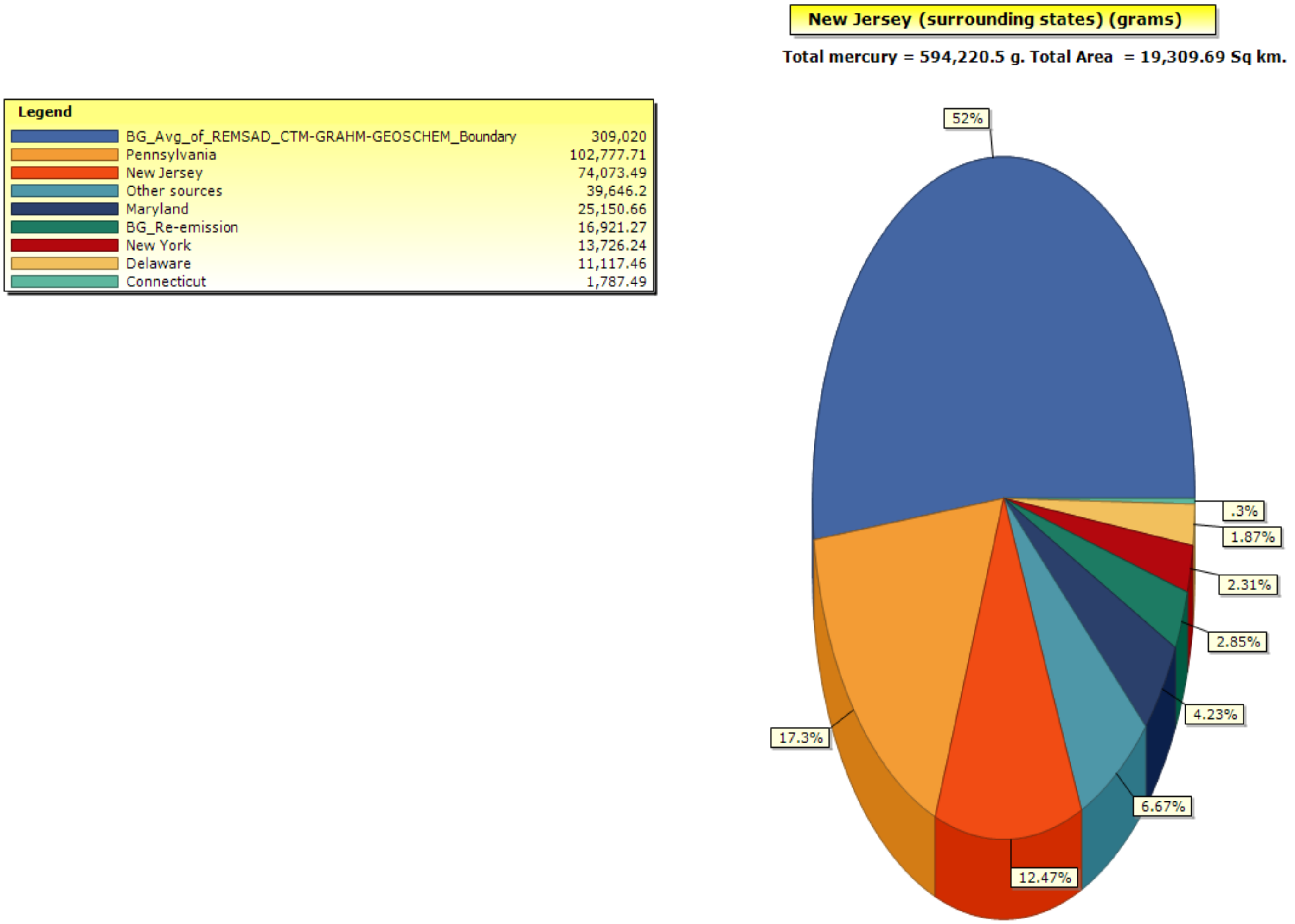
Layers
- ☐ cities
- ☐ places
- ☐ 8-digit Watersheds
- ☑ States
- ☐ Complete_model.DBO.grid
- ☑ Total Deposition (w/REMSAD)

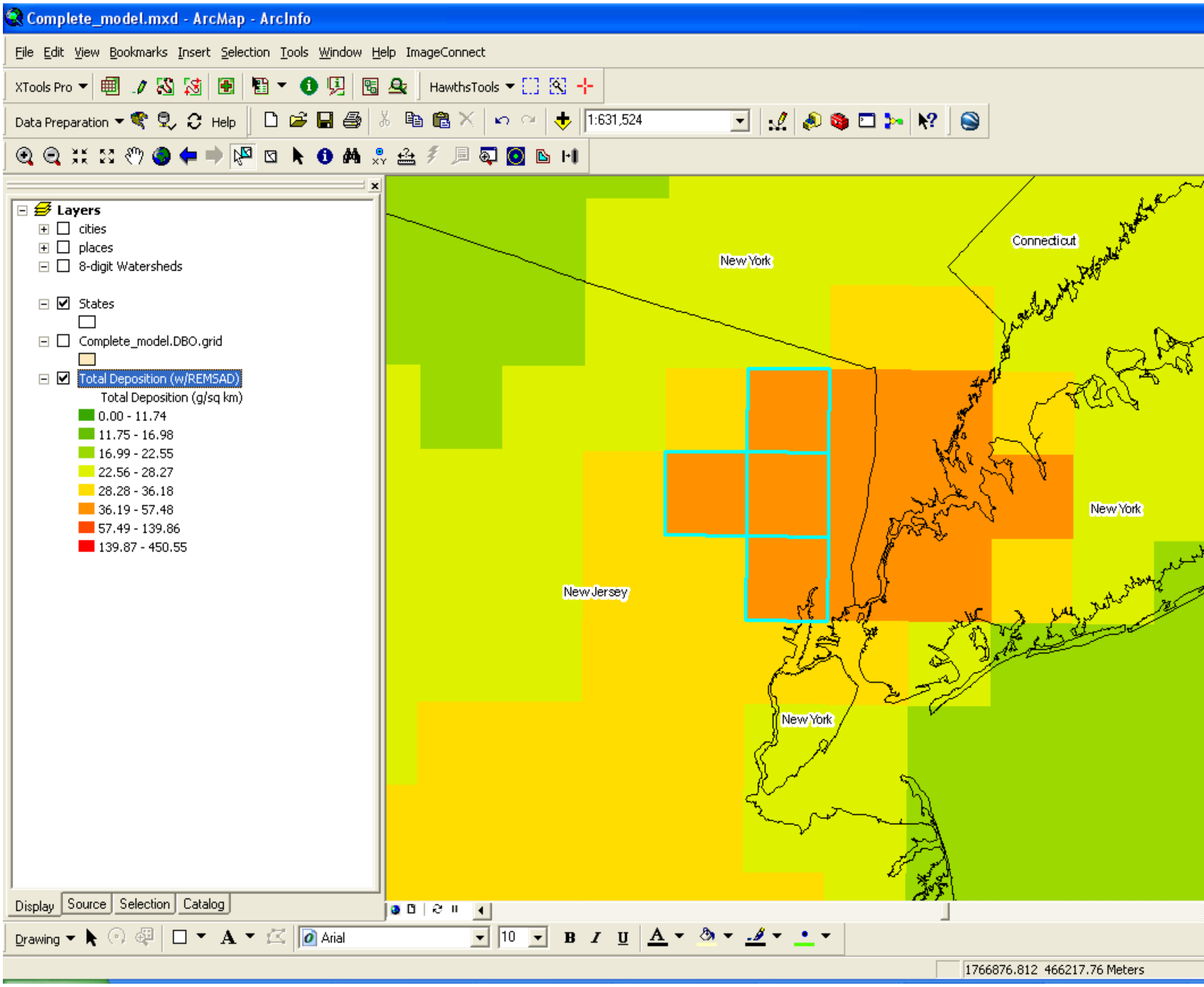
Total Deposition (g/sq km)

🟩	0.00 - 11.74
🟩	11.75 - 16.98
🟩	16.99 - 22.55
🟨	22.56 - 28.27
🟨	28.28 - 36.18
🟧	36.19 - 57.48
🟧	57.49 - 139.86
🟥	139.87 - 450.55

1853736.277 483122.108 Meters


New Jersey (grams)
Total mercury = 594,220.5 g. Total Area = 19,309.69 Sq km.
Legend
BG_Avg_of_REMSAD_CTM-GRAHM-GEOSCHEM_Boundary 309,020
Other sources 142,260.25
PA_Other_Sources 53,361.17
NJ_Other_Sources 34,986.96
PA_Other_utilities 19,755.74
NJ_Counties_bordering_NY/NJ_Harbor 17,915.12
BG_Re-emission 16,921.27
52%
2.85%
3.01%
3.32%
5.89%
8.98%
23.94%

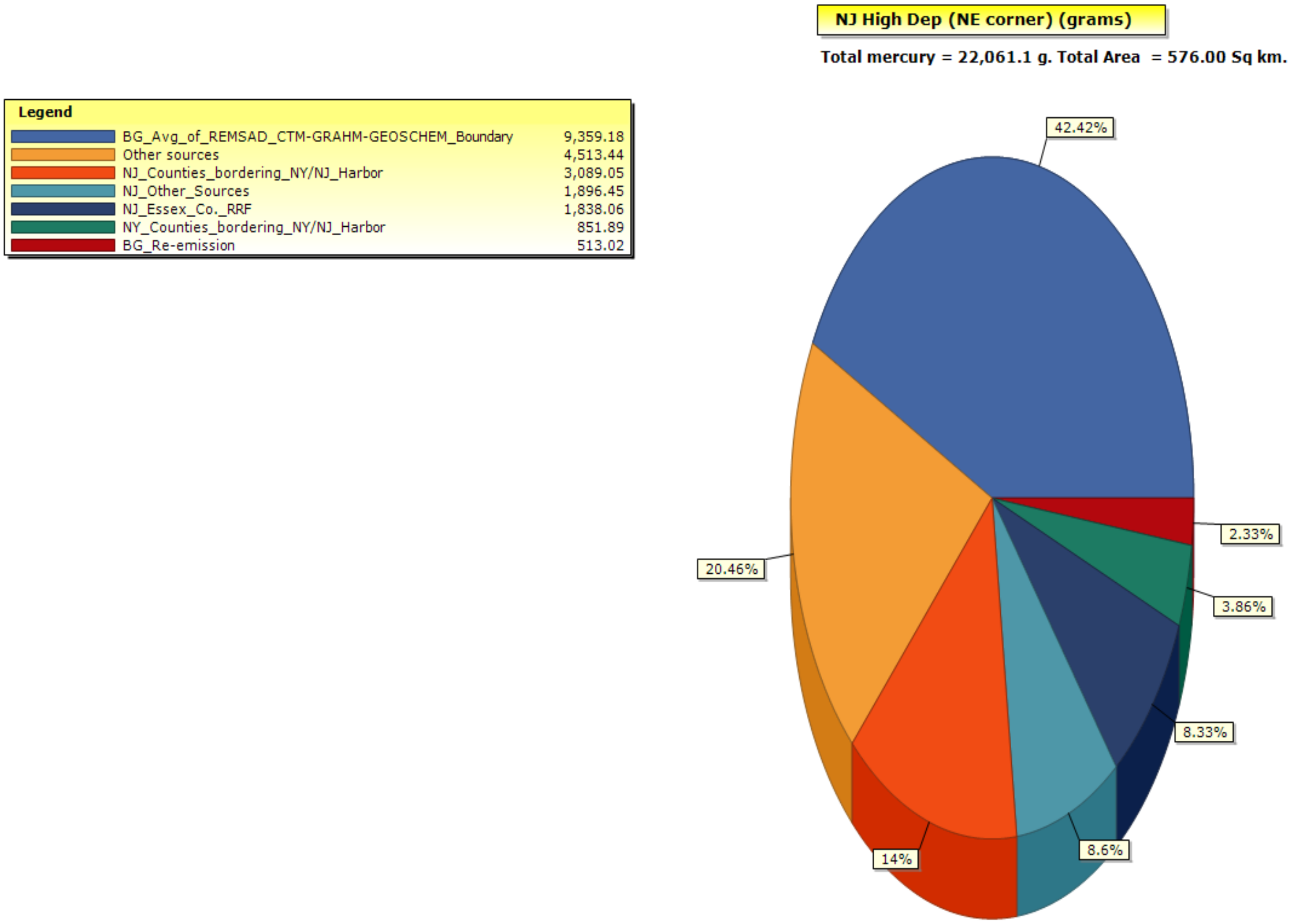

New Jersey (surrounding states) (grams)
Total mercury = 594,220.5 g. Total Area = 19,309.69 Sq km.
Legend
BG_Avg_of_REMSAD_CTM-GRAHM-GEOSCHEM_Boundary 309,020
Pennsylvania 102,777.71
New Jersey 74,073.49
Other sources 39,646.2
Maryland 25,150.66
BG_Re-emission 16,921.27
New York 13,726.24
Delaware 11,117.46
Connecticut 1,787.49
52%
.3%
1.87%
2.31%
2.85%
4.23%
6.67%
12.47%
17.3%

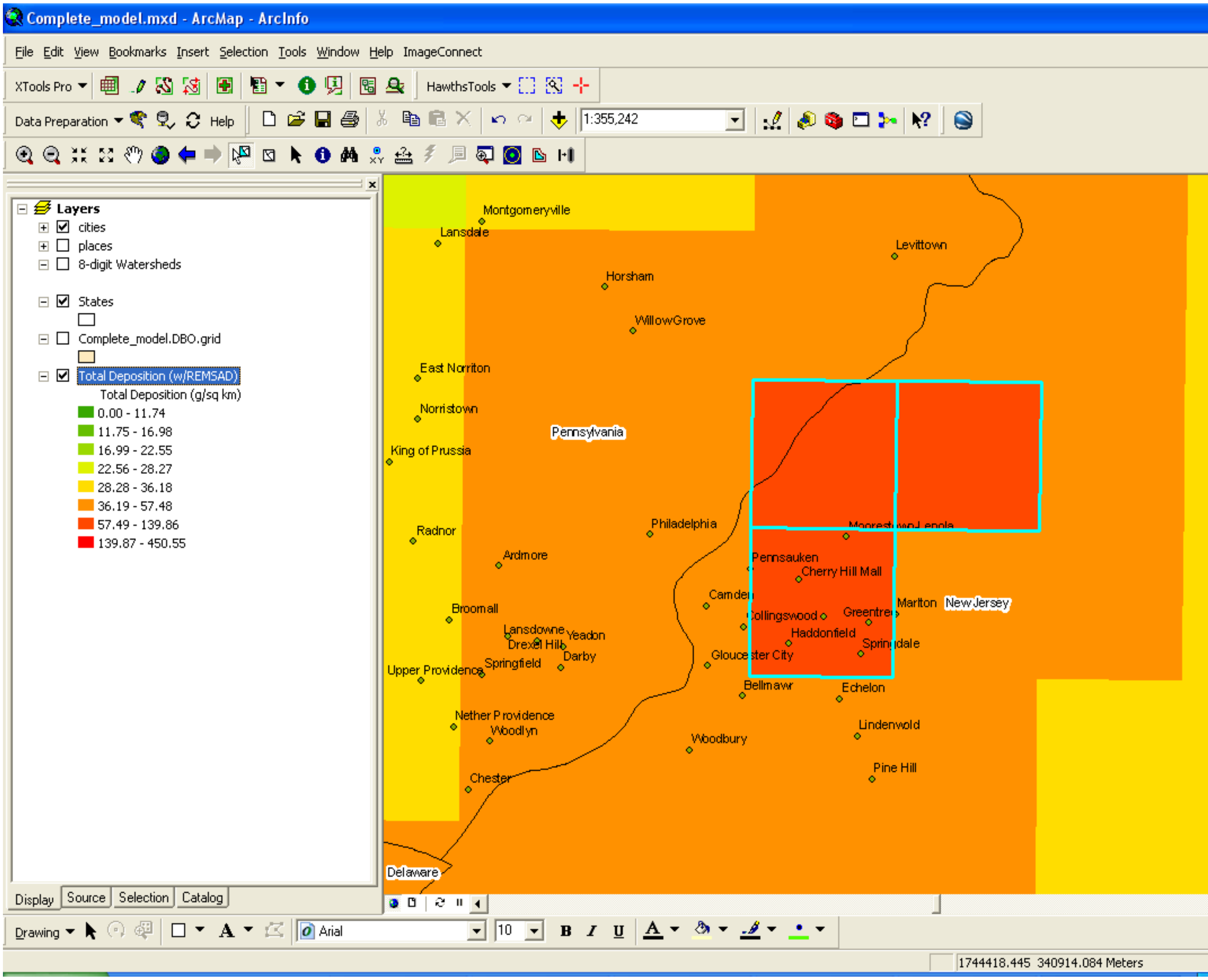


1:631,524

- Layers
  - ☐ cities
  - ☐ places
  - ☐ 8-digit Watersheds
  - ☑ States
  - ☐ Complete_model.DBO.grid
  - ☑ Total Deposition (w/REMSAD)
    - Total Deposition (g/sq km)
    - 🟩 0.00 - 11.74
    - 🟩 11.75 - 16.98
    - 🟩 16.99 - 22.55
    - 🟨 22.56 - 28.27
    - 🟨 28.28 - 36.18
    - 🟧 36.19 - 57.48
    - 🟥 57.49 - 139.86
    - 🟥 139.87 - 450.55

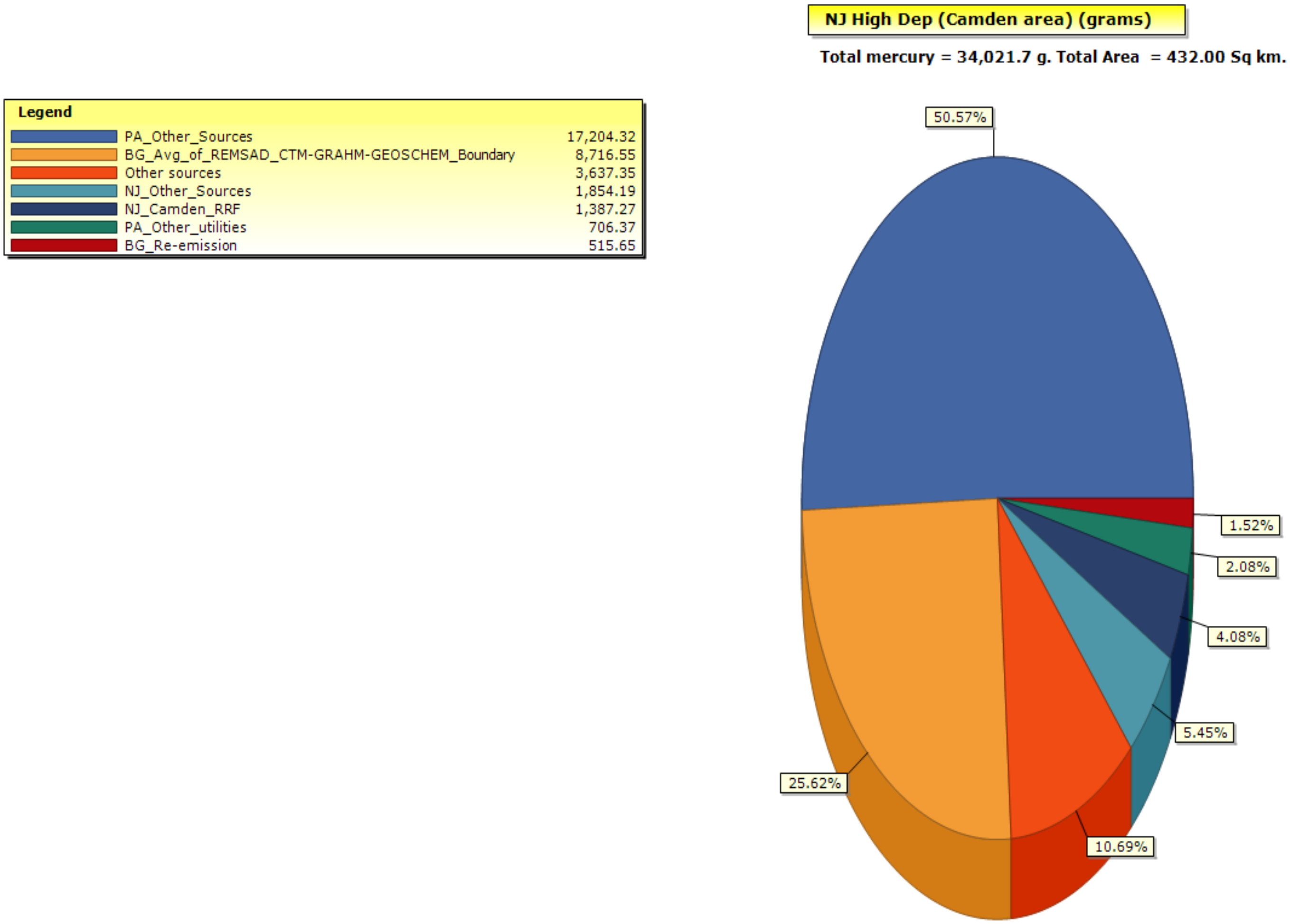
1766876.812 466217.76 Meters


NJ High Dep (NE corner) (grams)
Total mercury = 22,061.1 g. Total Area = 576.00 Sq km.
Legend
BG_Avg_of_REMSAD_CTM-GRAHM-GEOSCHEM_Boundary 9,359.18
Other sources 4,513.44
NJ_Counties_bordering_NY/NJ_Harbor 3,089.05
NJ_Other_Sources 1,896.45
NJ_Essex_Co._RRF 1,838.06
NY_Counties_bordering_NY/NJ_Harbor 851.89
BG_Re-emission 513.02
42.42%
20.46%
2.33%
3.86%
8.33%
8.6%
14%



Layers
- ☑ cities
- ☐ places
- ☐ 8-digit Watersheds
- ☑ States
- ☐ Complete_model.DBO.grid
- ☑ Total Deposition (w/REMSAD)
  - Total Deposition (g/sq km)
  - 🟩 0.00 - 11.74
  - 🟩 11.75 - 16.98
  - 🟩 16.99 - 22.55
  - 🟨 22.56 - 28.27
  - 🟨 28.28 - 36.18
  - 🟧 36.19 - 57.48
  - 🟧 57.49 - 139.86
  - 🟥 139.87 - 450.55

1744418.445 340914.084 Meters


Legend
PA_Other_Sources 17,204.32
BG_Avg_of_REMSAD_CTM-GRAHM-GEOSCHEM_Boundary 8,716.55
Other sources 3,637.35
NJ_Other_Sources 1,854.19
NJ_Camden_RRF 1,387.27
PA_Other_utilities 706.37
BG_Re-emission 515.65
NJ High Dep (Camden area) (grams)
Total mercury = 34,021.7 g. Total Area = 432.00 Sq km.
50.57%
1.52%
2.08%
4.08%
5.45%
10.69%
25.62%