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
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Adopted:	

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Contents

Figures

Tables

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.

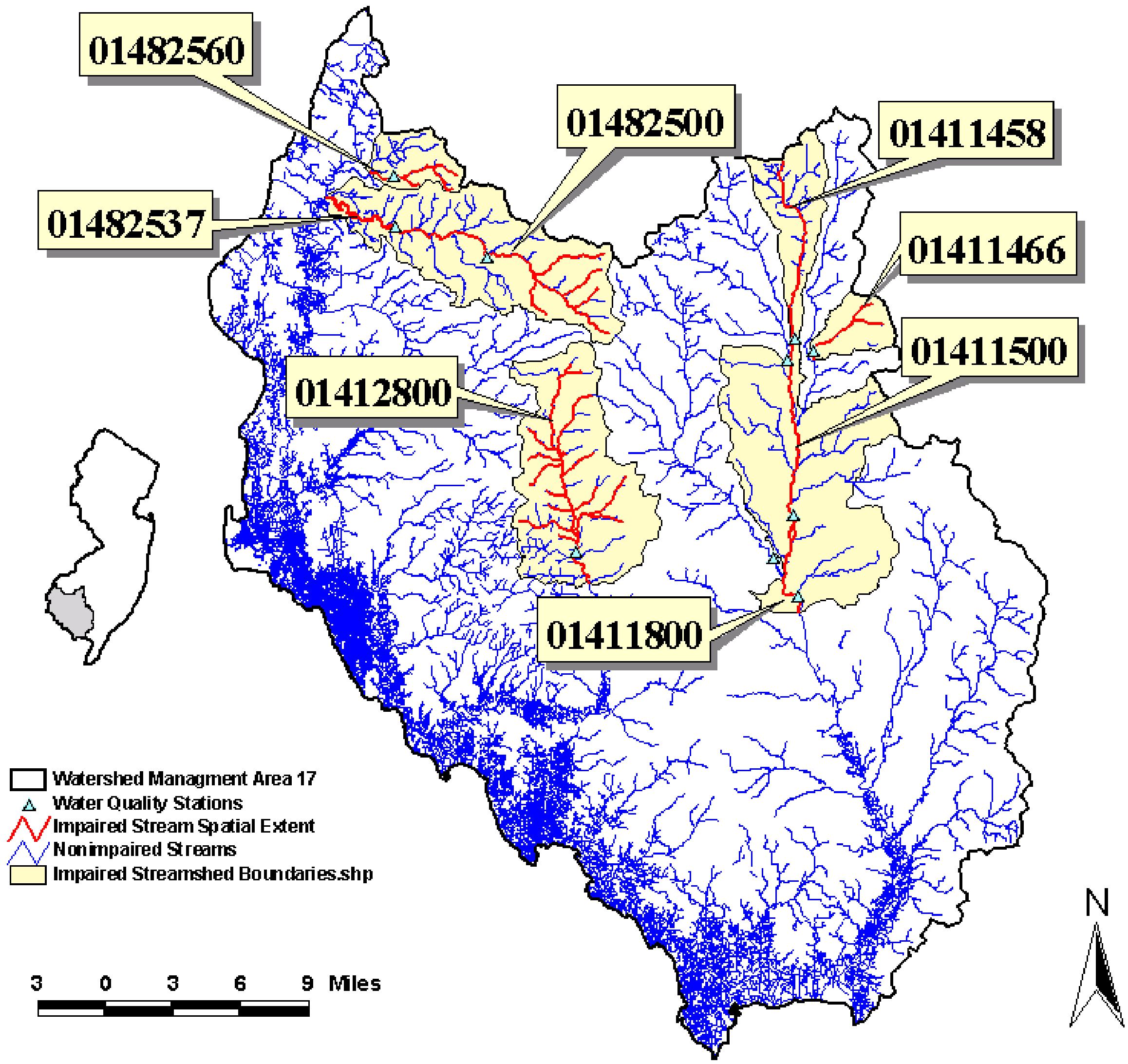


Table 3 **Description of the spatial extent for each Sublist 5 segment, listed for fecal coliform, in WMA 17.**

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
<u>Land Use/ Land Cover</u>					
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

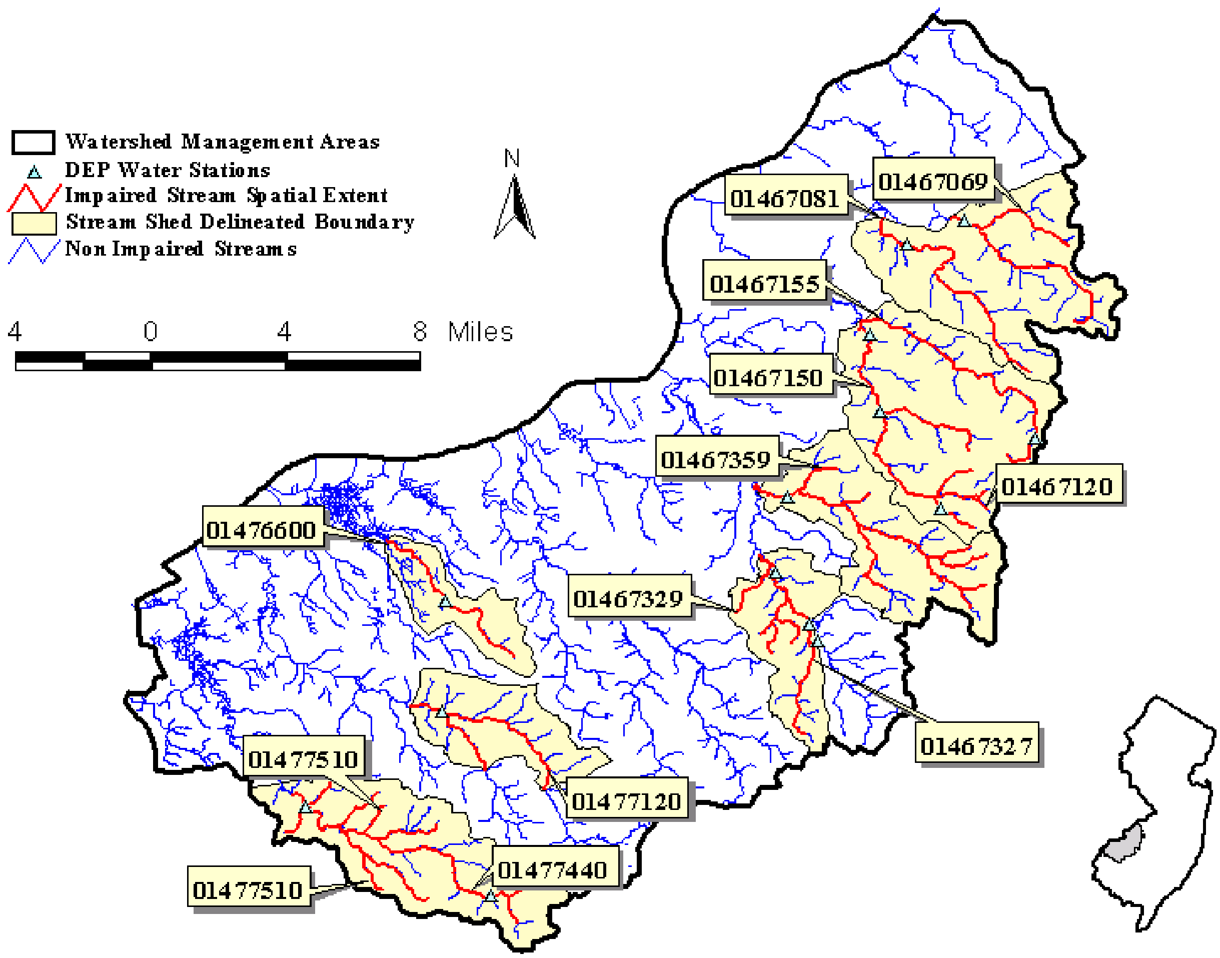


Table 5 Description of the spatial extent for each Sublist 5 segment, listed for fecal coliform, in WMA 18.

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

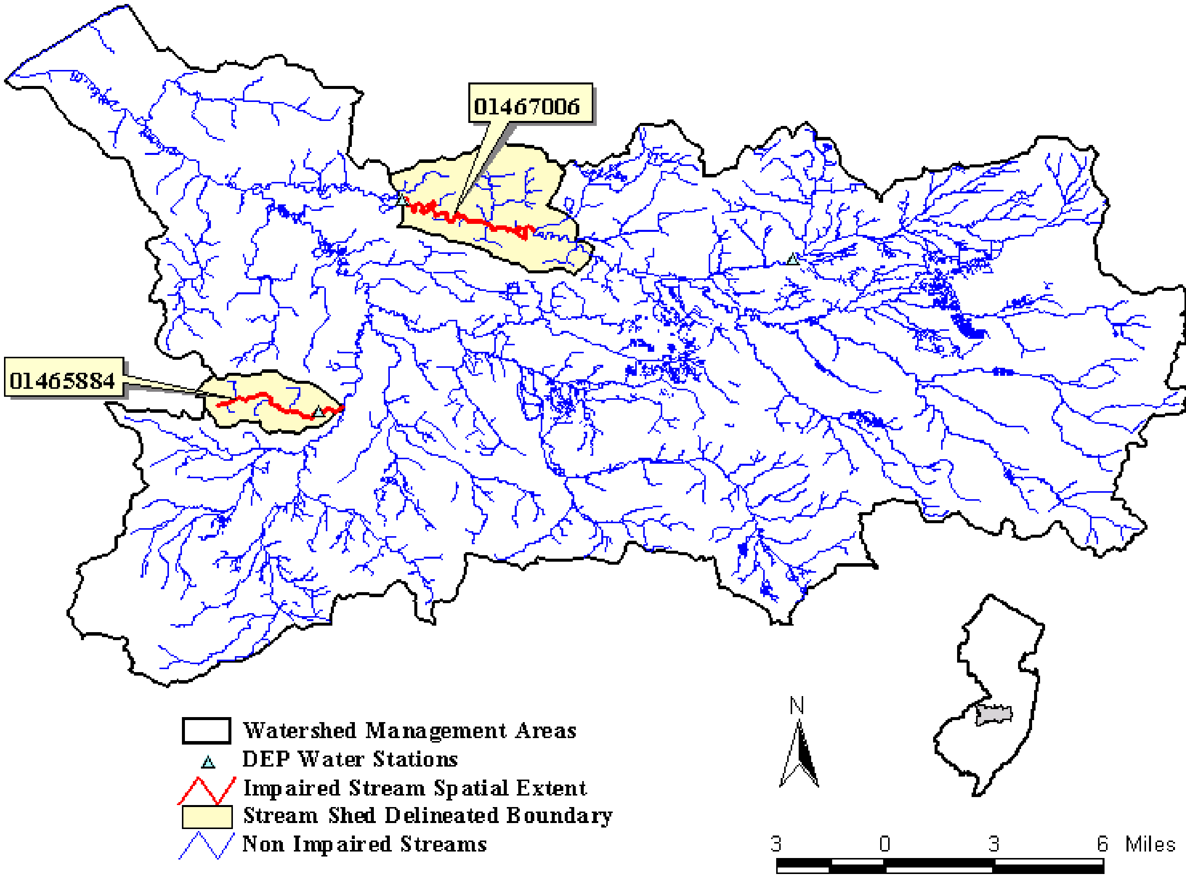


Table 7 Description of the spatial extent for each Sublist 5 segment, listed for fecal coliform, in WMA 19.

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**

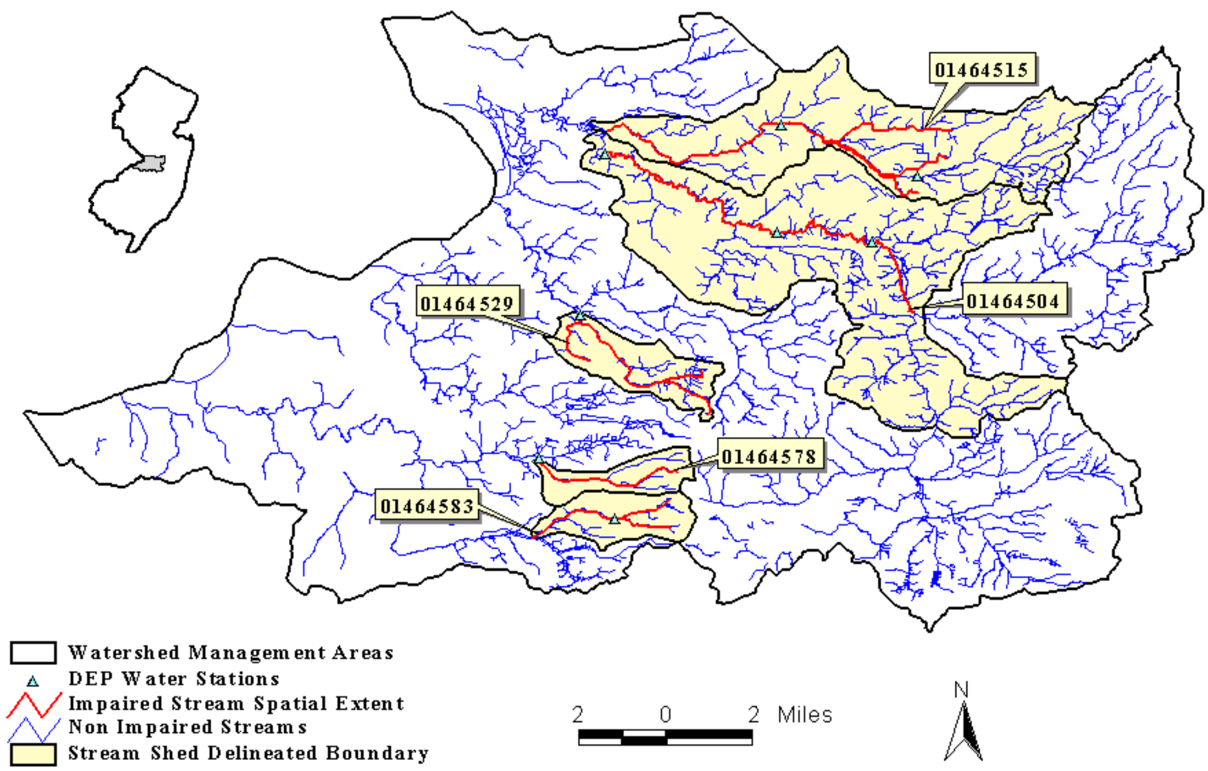


Table 9 **Description of the spatial extent for each Sublist 5 segment, listed for fecal coliform, in WMA 20.**

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 Asse ssment

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.

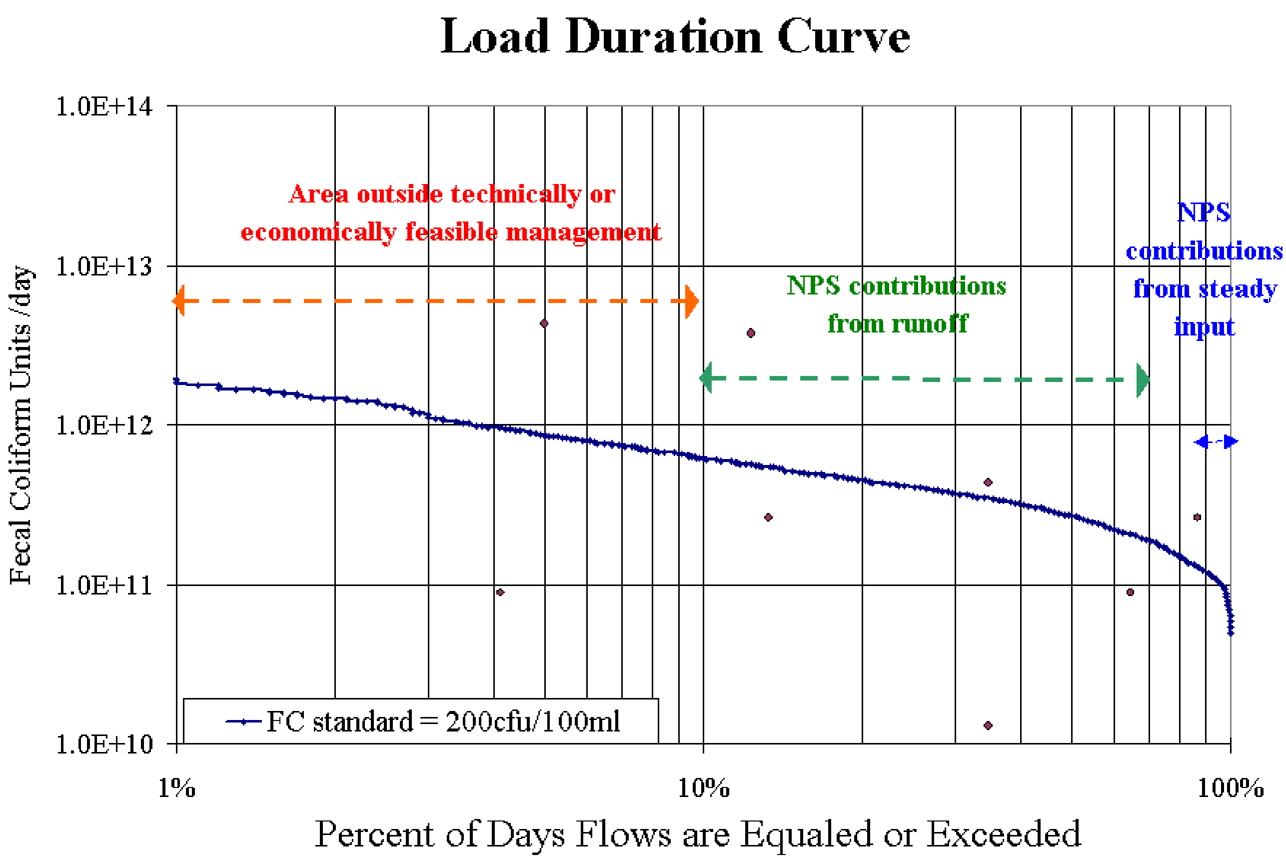
Since sewage treatment plants routinely achieve essentially complete disinfection (less than 20 CFU/100ml), the requirement to disinfect results in fecal coliform concentrations well below the criteria and permit limit. The percent of the total point source contribution is an insignificant fraction of 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.

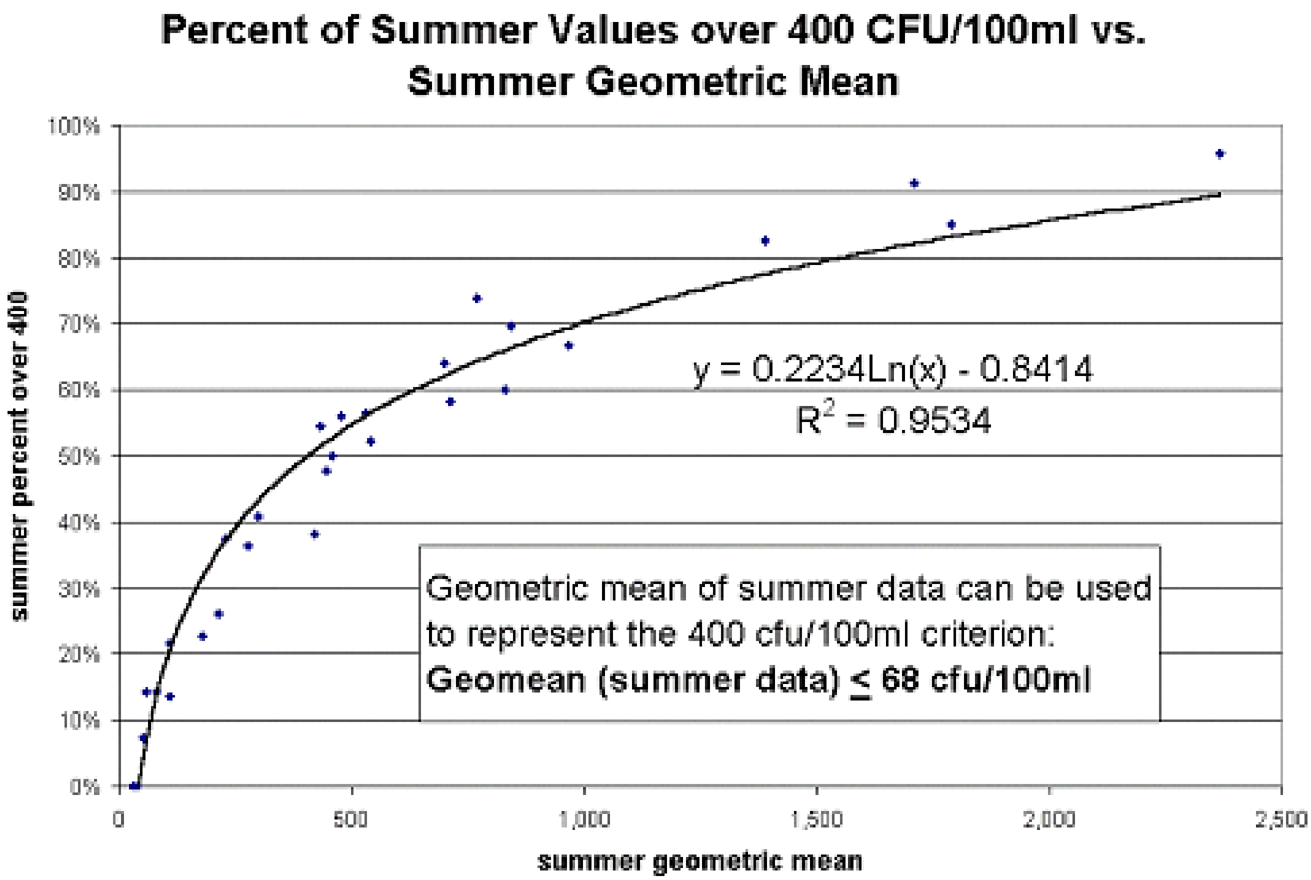
As described in EPA guidance, a TMDL identifies the loading capacity of a waterbody for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a waterbody can receive without violating water quality standards (40 C.F.R. 130.2). The loadings are required 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



$y = 0.2234\text{Ln}(x) - 0.8414$ 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.

$$Geometric\ Mean\ for\ 200CFU\ criteria = \sqrt[n]{y_1 y_2 y_3 y_4 \ldots . y_n}$$ Equation 2

where:
y = sample measurement
n = total number of samples

$$200\ CFU\ criteria\ Percent\ \text{Re}duction = \frac{(Geometric\ mean - (200 - e))}{Geometric\ mean} \times 100\ \%$$ Equation 3

$$400\ CFU\ criteria\ Percent\ \text{Re}duction = \frac{(SummerGeometric\ mean - (68 - e))}{SummerGeometric\ mean} \times 100\ \%$$ Equation 4

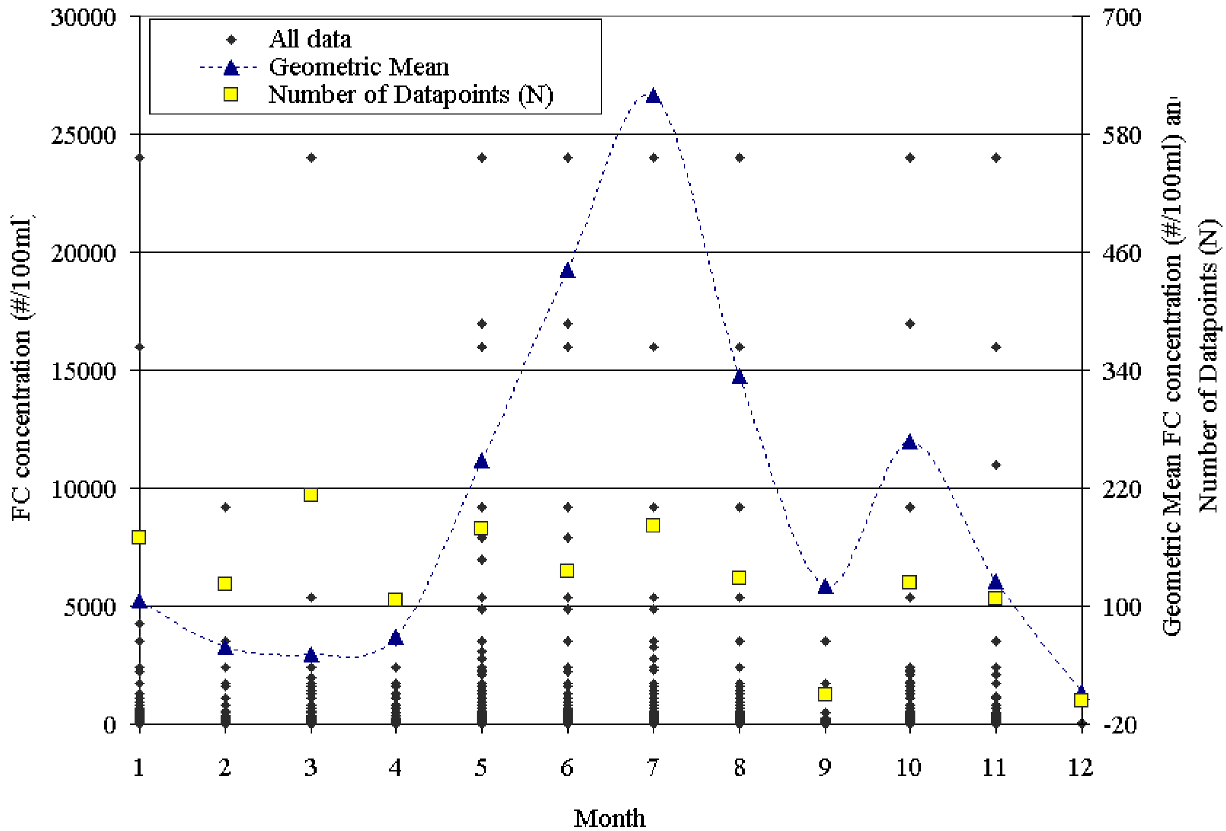
where:
e = (margin of safety)

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 ($x_{standard}$), $y_{standard}$ = 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_{target} = 2.301- n* $s_{\bar{y}}$
7- The target value for x, $x_{target} = 10^{y\ target}$
8- The margin of safety (e) therefore will be e = $x_{standard}$ - x_{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%

					Load Allocation (LA) and Margin of Safety (MOS)					
TMDL Number	**WMA**	**303(d) Category 5 Segments**	**Water Quality Stations**	**Station Names**	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)**
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

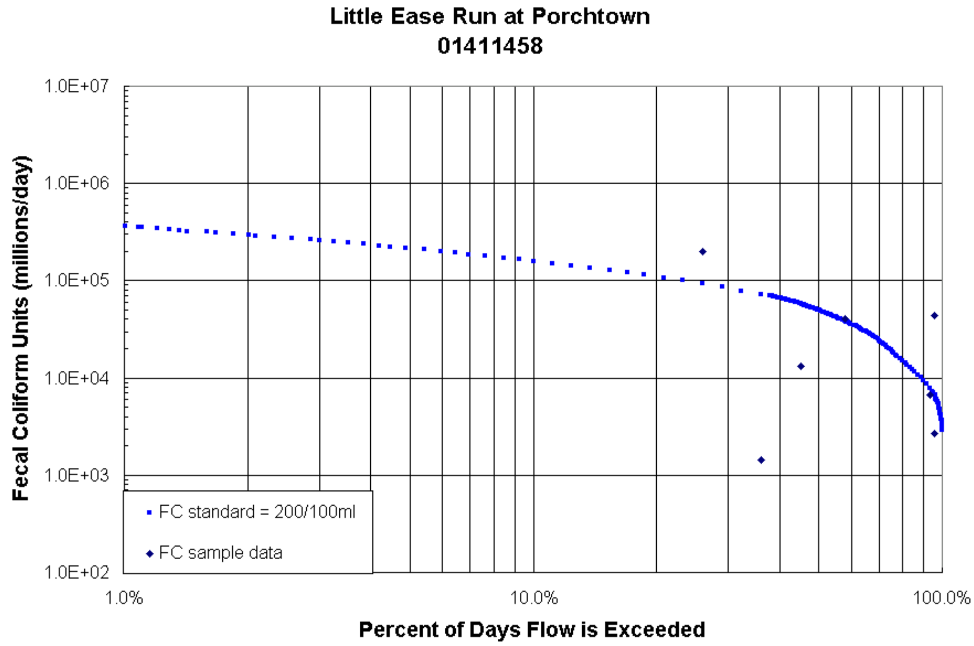
[a] "MMI" indicates a Municipal Minor discharge and "MMJ" indicates Municipal Major discharge.

Appendix C: TMDL Calculations

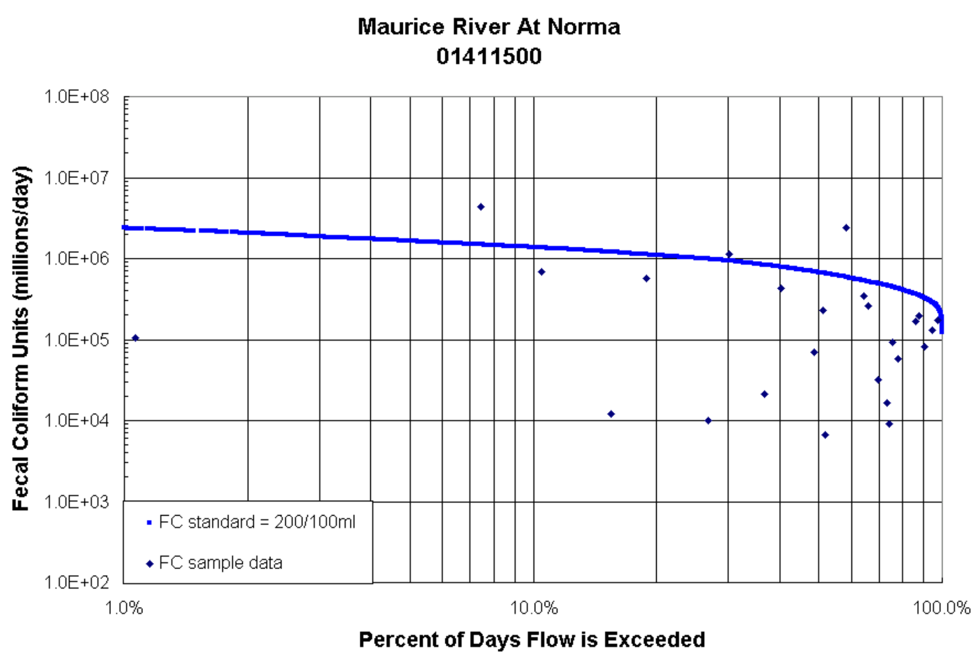
WMA	303(d) Category 5 Segments	Water Quality Stations	Station Names	Load Allocation (LA) and Margin of Safety (MOS)										Wasteload Allocation (WLA)	Period of record used in analysis
				200 FC/100ml Standard					400 FC/100ml Standard						
				N (# of values)	Geometric mean CFU/100ml	MOS as a percent 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

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		
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

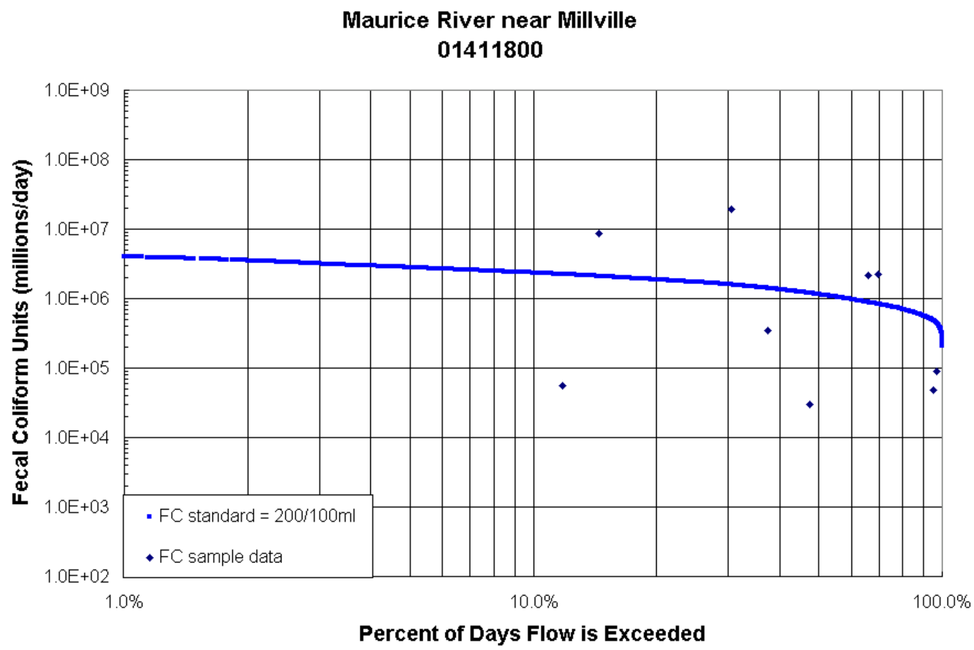
Appendix D: Load Duration Curves for selected listed waterbodies



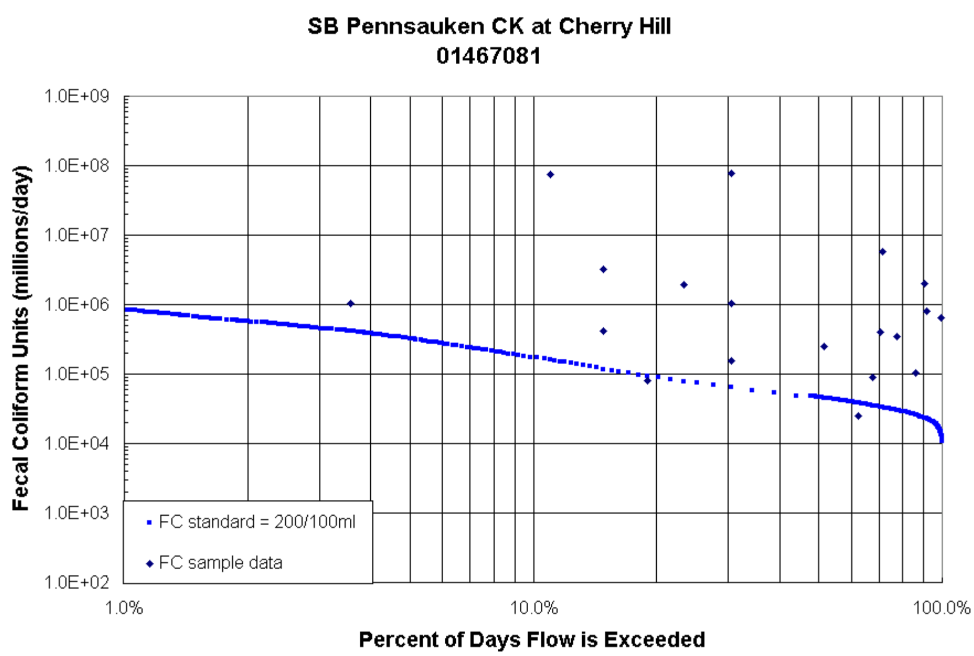
Load Duration Curve for Little Ease Run at Porchtown. Fecal coliform data from USGS station # 01411458 during the period 2/9/94 through 9/17/98. Water years 1970-2001 from USGS station # 01411456 (Little Ease Run near Clayton) were used in
generating the FC standard curve.



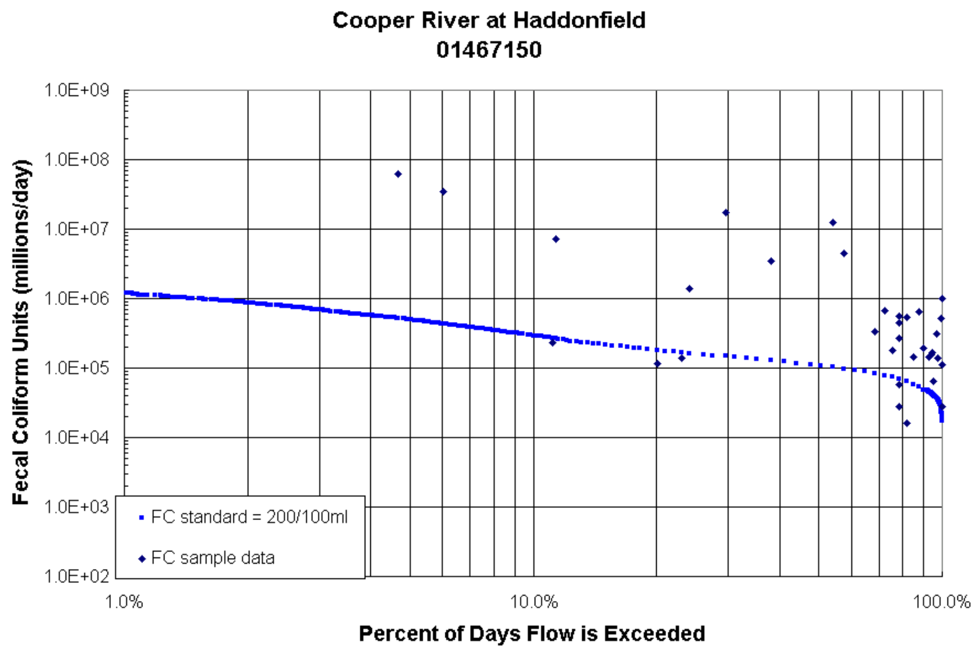
Load Duration Curve for Maurice River at Norma. Fecal coliform data from USGS station # 01411500 during the period 2/9/94 through 7/26/01. Water years 1970-2001 from USGS station # 01411500 were used in generating the FC standard curve.



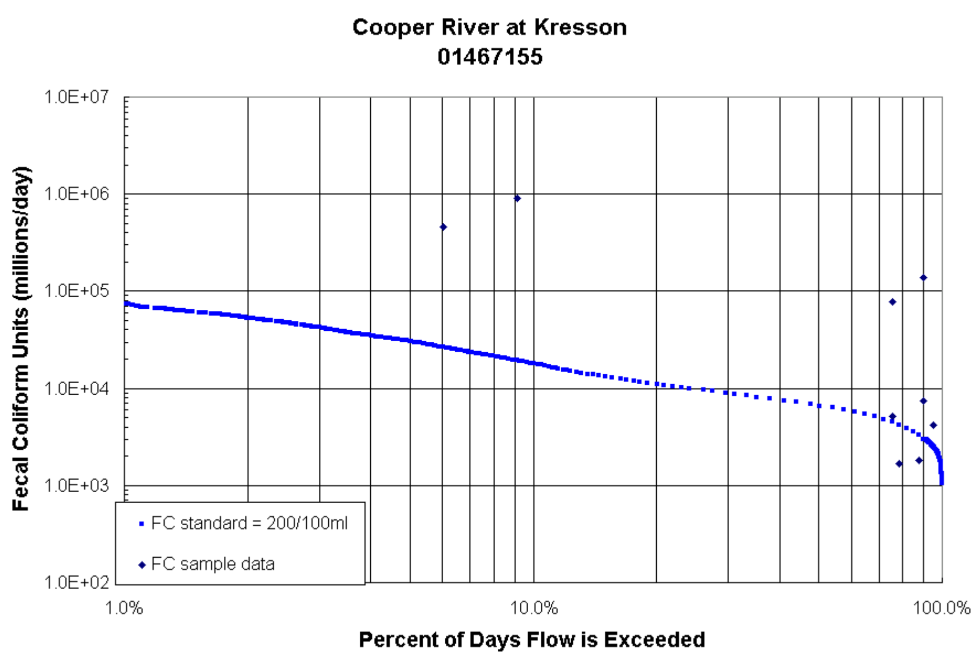
Load Duration Curve for Maurice River near Millville. Fecal coliform data from USGS station # 01411800 during the period 2/16/94 through 9/17/98. Water years 1970-2001 from USGS gaging station # 01411500 (Maurice River at Norma) were used in generating the FC standard curve.



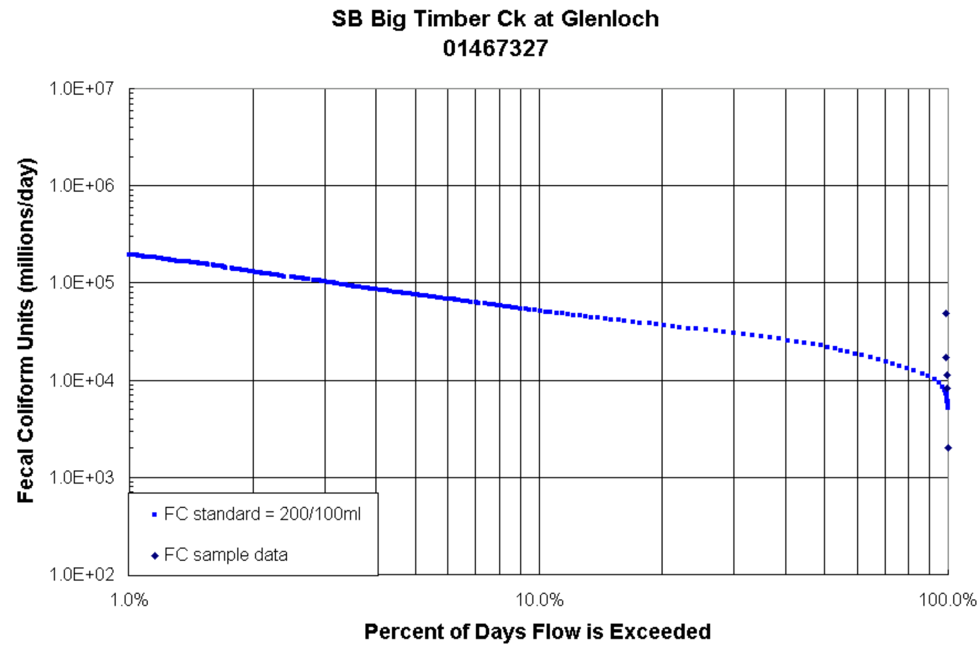
Load Duration Curve for SB Pennsauken CK at Cherry Hill. Fecal coliform data from USGS station # 01467081 during the period 2/17/94 through 7/23/97. Water years 1970-2001 from USGS gaging station # 01467081 were used in generating the FC standard curve



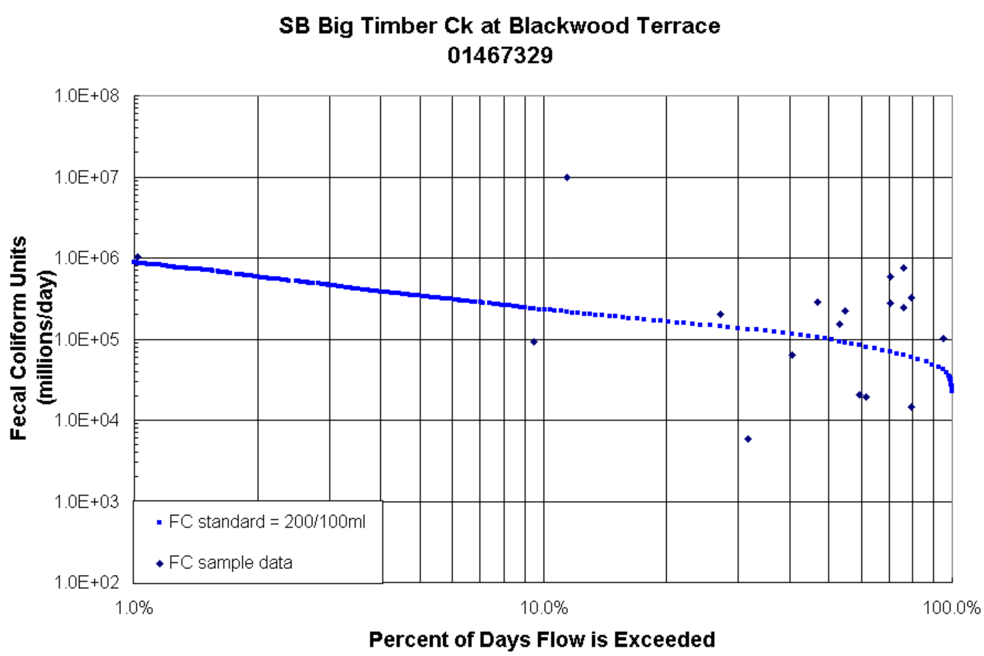
Load Duration Curve for Cooper River At Haddonfield. Fecal coliform data from USGS station # 01467150 during the period 2/15/94 through 7/53/01. Water years 1970-2001 from USGS gaging station # 01467150 were used in generating the FC standard curve



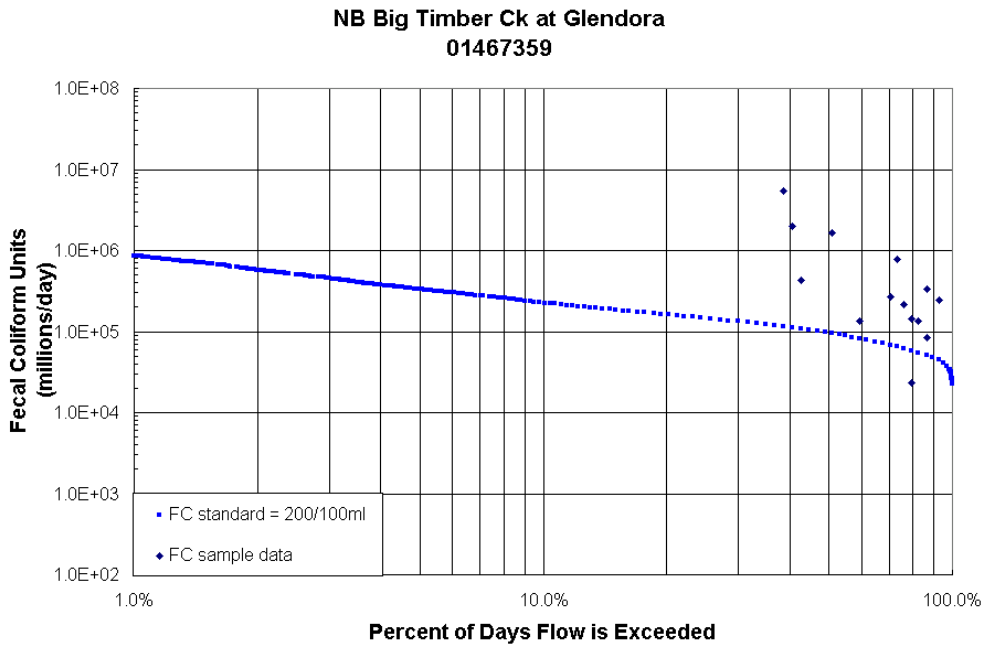
Load Duration Curve for Cooper River At Kresson. Fecal coliform data from USGS station # 01467155 during the period 6/1/98 through 7/5/01. Water years 1970-2001 from USGS gaging station # 01467150 (Cooper River at Haddonfield) were used in generating the FC standard curve



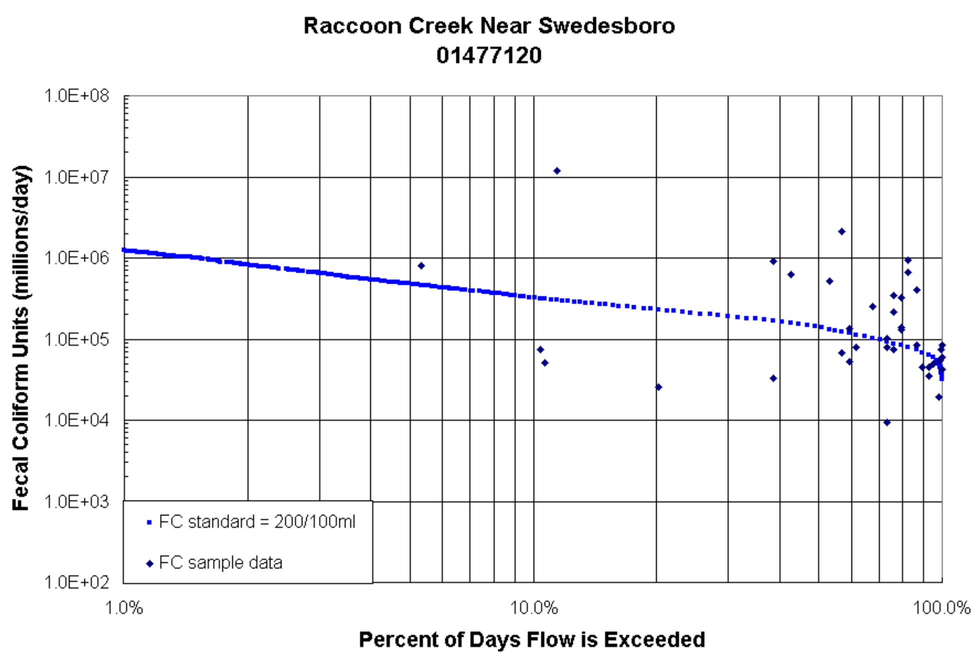
Load Duration Curve for SB Big Timber CK at Glenloch. Fecal coliform data from USGS station # 01467327 during the period 8/1/99 through 8/31/99. Water years 1970-2001 from USGS gaging station # 01477120 (Raccoon CK at Swedesboro) were used in generating the FC standard curve



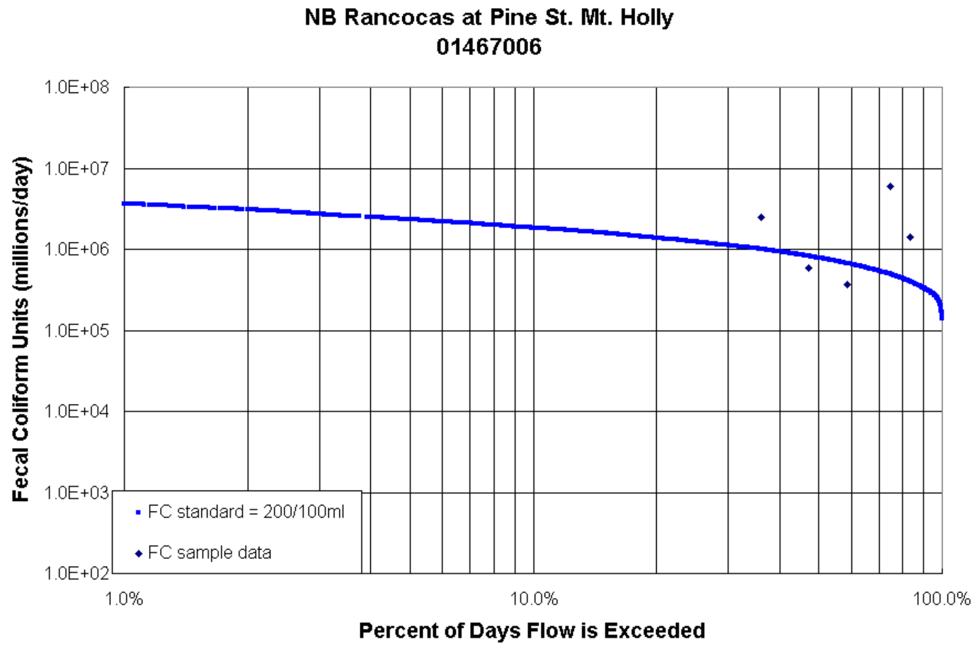
Load Duration Curve for SB Big Timber CK at Blachwood Terrace. Fecal coliform data from USGS station # 01467329 during the period 2/15/94 through 8/4/97. Water years 1970-2001 from USGS gaging station # 01477120 (Raccoon CK at Swedesboro) were used in generating the FC standard curve



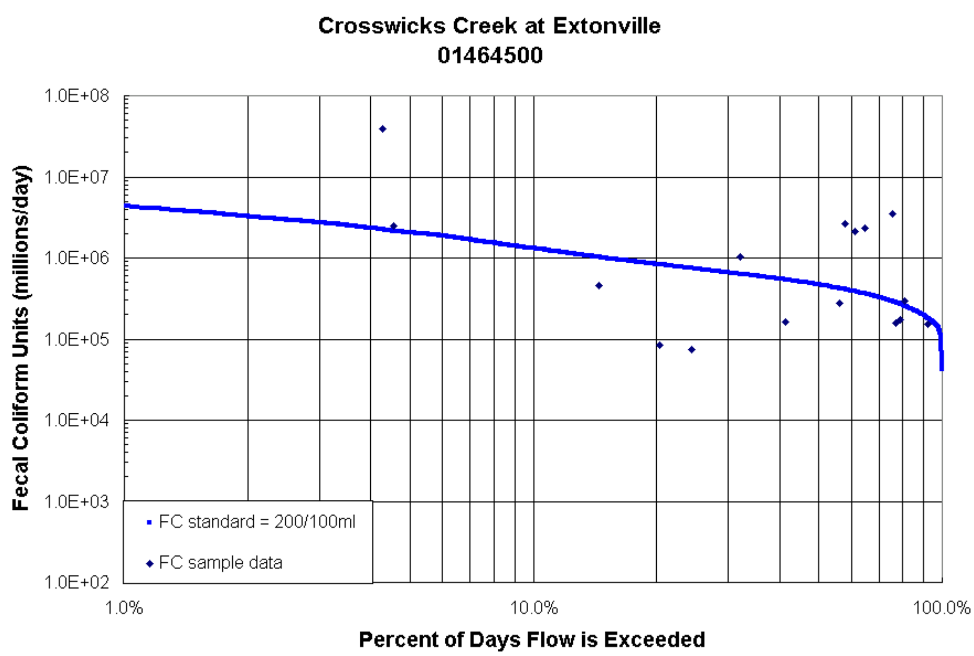
Load Duration Curve for NB Big Timber CK at Glendora. Fecal coliform data from USGS station # 01467359 during the period 6/9/98 through 7/5/01. Water years 1970-2001 from USGS gaging station # 01477120 (Raccoon CK near Swedesboro) were used in generating the FC standard curve



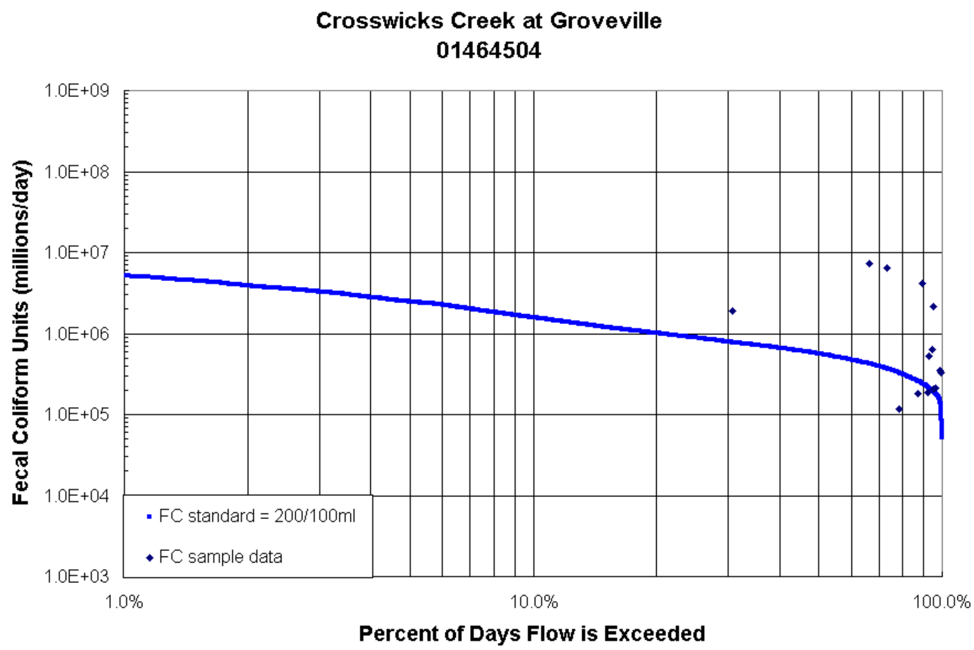
Load Duration Curve for Raccoon CK near Swedesboro. Fecal coliform data from USGS station # 01477120 during the period 2/17/94 through 8/7/01. Water years 1970-2001 from USGS gaging station # 01477120 (Raccoon CK near Swedesboro) were used in generating the FC standard curve



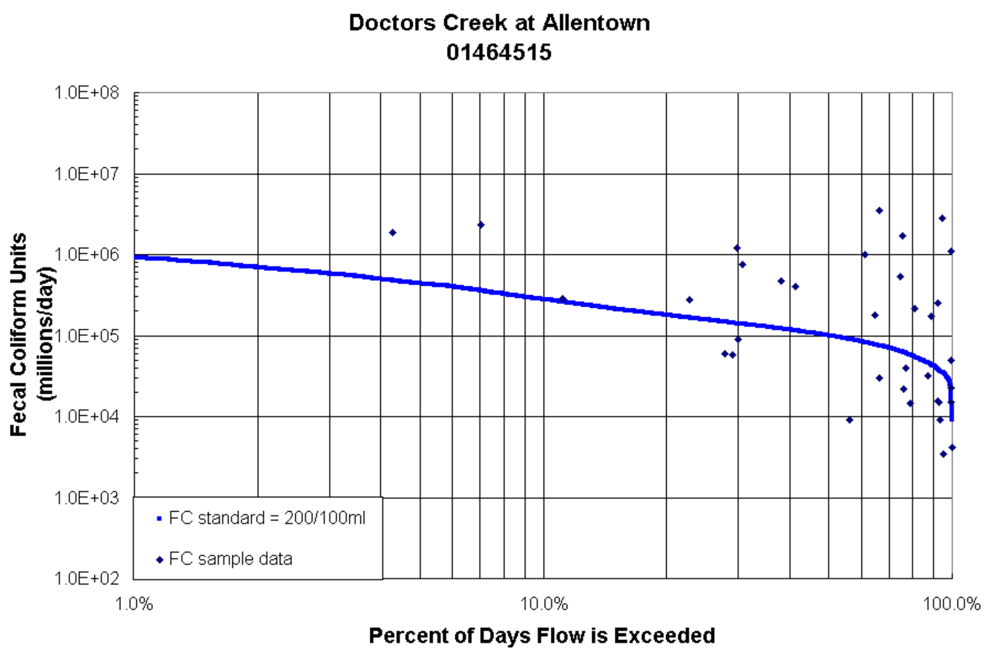
Load Duration Curve for NB Rancocas at Pine St. Mt. Holly. Fecal coliform data from USGS station # 01467006 during the period 6/9/98 through 7/22/98. Water years 1970-2001 from USGS gaging station # 01467000 (NB Rancocas CK at Pemberton) were used in generating the FC standard curve



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