Amendment to the
Monmouth County Water Quality Management Plan

Total Maximum Daily Loads for Total Phosphorus
To Address Two Streams Segments in the
Manasquan River Watershed, Monmouth County
Atlantic Coastal Water Region

Watershed Management Area 12
MANASQUAN RIVER AT SQUANKUM
LONG BROOK AT WYCKOFF MILLS

Proposed:	**May 16, 2005**
Established:	**August 31, 2005**
Approved (by EPA Region 2):	**September 23, 2005**
Adopted:	

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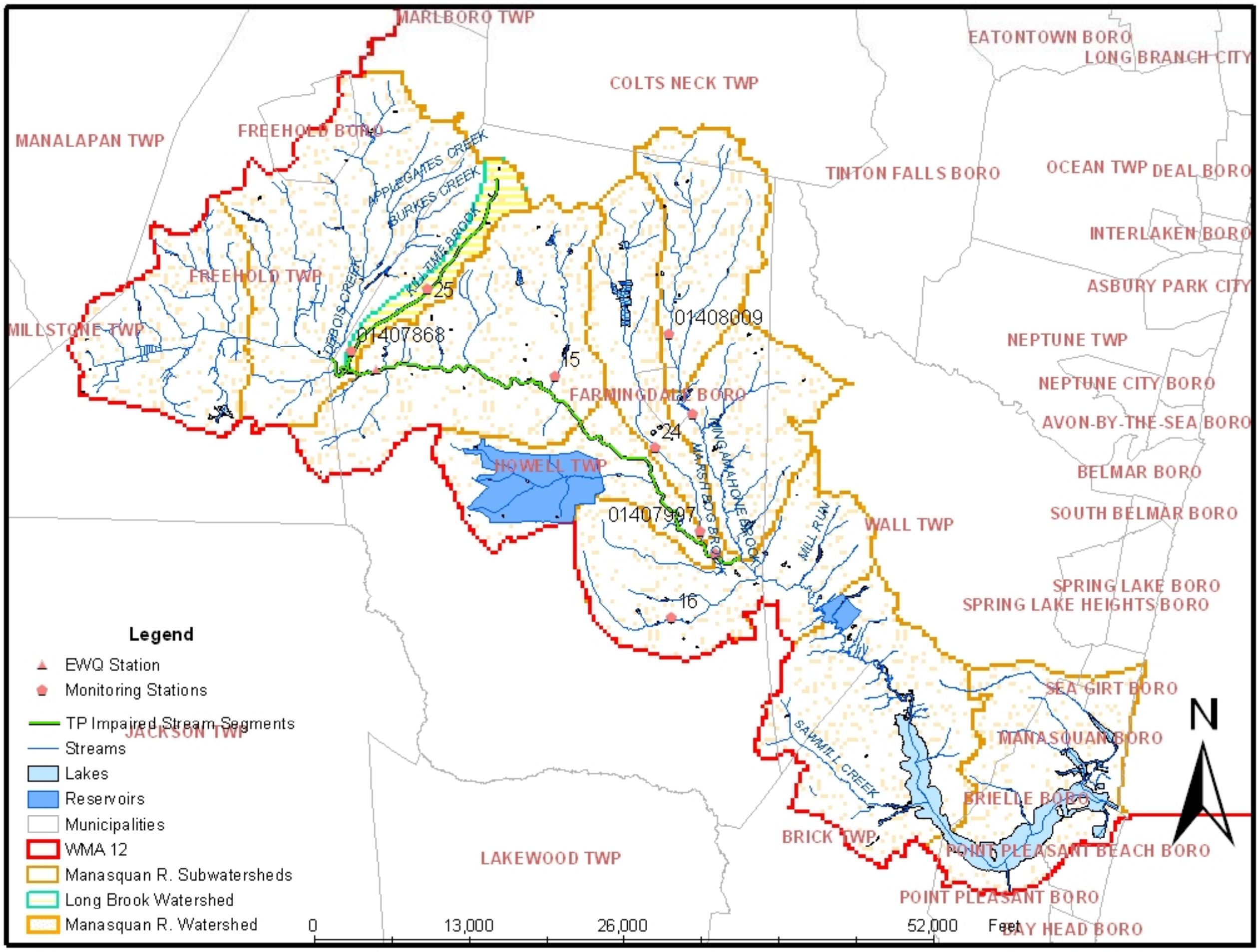
1.0 Executive Summary

In accordance with Sections 305(b) and 303(d) the Federal Clean Water Act (CWA) the State of New Jersey developed the *2004 Integrated List of Waterbodies,* which was adopted on October 4, 2004 (36 NJR 4543(a)). Two (2) stream segments in the Manasquan River Watershed were listed on Sublist 5 as being impaired for phosphorus, as indicated by elevated total phosphorus (TP) levels in the stream segments. A total maximum daily load (TMDL) is required to be developed for each impairment listed on Sublist 5. A TMDL is developed to identify all the contributors of a pollutant of concern and the load reductions necessary to meet the Surface Water Quality Standards (SWQS) relative to that pollutant. The pollutant of concern for this TMDL is TP. This document will establish two TMDLs for TP for the stream segments as identified in Table 1 and depicted in Figure 1.

Table 1 Phosphorus-impaired stream segments for which phosphorus TMDLs will be established

TMDL Number	WMA	Station Name/Waterbody	Site ID	County(s)	Length of Impaired Segment (miles)
1	12	Long Brook at Wyckoff Mills	25, 01407868	Monmouth	4.19
2	12	Manasquan River at Squankum	EWQ0489, MA-2, MA-3, 01408000	Monmouth	9.27
Total Length of Impaired Segments					13.46

Figure 1 Manasquan River Watershed, WMA 12



These two TMDLs identify sources of phosphorus and establish load reductions required in order to attain applicable surface water quality standards (SWQSs) and include an implementation plan. Phosphorus sources were characterized on an annual scale (kg TP/yr) for both point and nonpoint sources. Runoff from land surfaces comprises the most important source of phosphorus in these segments. For the impaired stream segments, a stochastic model was used to define a loading and flow association. This method was adapted from *"TMDL Development Using Load Duration Curves"* (Stiles 2002).

This TMDL Report is consistent with EPA's May 20, 2002 guidance document entitled, *Guidelines for Reviewing TMDLs under Existing Regulations Issued in 1992* (Sutfin, 2002), which describes the statutory and regulatory requirements for approvable TMDLs. This TMDL shall be proposed and, upon approval by EPA, adopted by the Department as an amendment to the Monmouth County Water Quality Management Plan (WQMP) in accordance with N.J.A.C. 7:15-3.4 (g).

2.0 Introduction

In accordance with Section 303(d) of the Federal Clean Water Act (CWA) (33 U.S.C. 1315(B)), the State of New Jersey is required biennially to prepare and submit to the USEPA a report that identifies waters that do not meet or are not expected to meet SWQS after implementation of technology-based effluent limitations or other required controls. This report is commonly referred to as the 303(d) List. In accordance with Section 305(b) of the CWA, the State of New Jersey is also required biennially to prepare and submit to the USEPA a report addressing the overall water quality of the State's waters. This report is commonly referred to as the 305(b) Report or the Water Quality Inventory Report. The *Integrated List of Waterbodies* combines these two assessments and assigns waterbodies to one of five sublists. Sublists 1 through 4 include waterbodies that are generally unimpaired (Sublist 1 and 2), have limited assessment or data availability (Sublist 3), are impaired due to pollution rather than pollutants or have had a TMDL or other enforceable management measure approved by EPA (Sublist 4). Sublist 5 constitutes the traditional 303(d) list for waters impaired or threatened by one or more pollutants, for which a TMDL may be required. Sublist 5 of the *2004 Integrated List of Waterbodies* identified two waterbodies in the Manasquan River watershed as being impaired for phosphorus, as evidenced by the presence of total phosphorus at concentrations in excess of the standards. Marsh Bog Brook, a tributary to the Manasquan, was listed on New Jersey's *2002 Integrated List of Waterbodies* as phosphorus impaired. This segment is no longer impaired, as indicated by more recent and/or more accurate data, which demonstrates that designated uses and the SWQS are being met for this waterbody.

A TMDL represents the assimilative or carrying capacity of a waterbody, taking into consideration point and nonpoint sources of pollutants of concern, natural background and surface water withdrawals. A TMDL quantifies the amount of a pollutant a water body can assimilate without violating a state's water quality standards and allocates that load capacity to known point and nonpoint sources in the form of waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and a margin of safety (MOS).

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

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

This report establishes two TMDLs, which address phosphorus loads to the identified waterbodies. This TMDL document includes management approaches or restoration plans to reduce loadings of total phosphorus from various sources in order to attain applicable surface water quality standards for total phosphorus. The segments addressed in this document are listed on Sublist 5 for impairment caused by other pollutants; these TMDLs address only total phosphorus impairments. Separate TMDL evaluations will be developed to address the other pollutants of concern. The waterbodies will remain on Sublist 5 with respect to other impairments until such time as TMDL evaluations for all pollutants have been completed and approved by EPA. With respect to the total phosphorus impairments, the waterbodies will be moved to Sublist 4 following approval of the TMDLs by USEPA.

3.0 Pollutant of Concern and Area of Interest

Pollutant of Concern and Applicable Surface Water Quality Standards

The pollutant of concern for this TMDL is phosphorus. The mechanism by which phosphorus can cause use impairment is via excessive primary productivity and consequent impairment of recreational, water supply and aquatic life designated uses. Phosphorus is an essential nutrient for plants and algae, but can be considered a pollutant because it can stimulate excessive growth (primary production). Phosphorus is most often the major nutrient in shortest supply relative to the nutritional requirements of primary producers in freshwater systems. Phosphorus is frequently a prime determinant of algal activity in a stream or lake as well as in estuarine and coastal environments. Eutrophication has been described as the acceleration of the natural aging process of surface waters.

As stated in N.J.A.C. 7:9B-1.14(c) of the SWQS for Fresh Water 2 (FW2) waters, the standards for phosphorus are as follows:

> Phosphorus, Total (mg/l):
>
> i. Lakes: Phosphorus as total P shall not exceed 0.05 in any lake, pond, reservoir, or in a tributary at the point where it enters such bodies of water, except where site-specific criteria are developed pursuant to N.J.A.C. 7:9B-1.5(g)3.
>
> ii. Streams: Except as necessary to satisfy the more stringent criteria in paragraph i. above or where site-specific criteria are developed pursuant to N.J.A.C. 7:9B1.5(g)3, phosphorus as total P shall not exceed 0.1 in any stream, unless it can be demonstrated that total P is not a limiting nutrient and will not otherwise render the waters unsuitable for the designated uses.

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

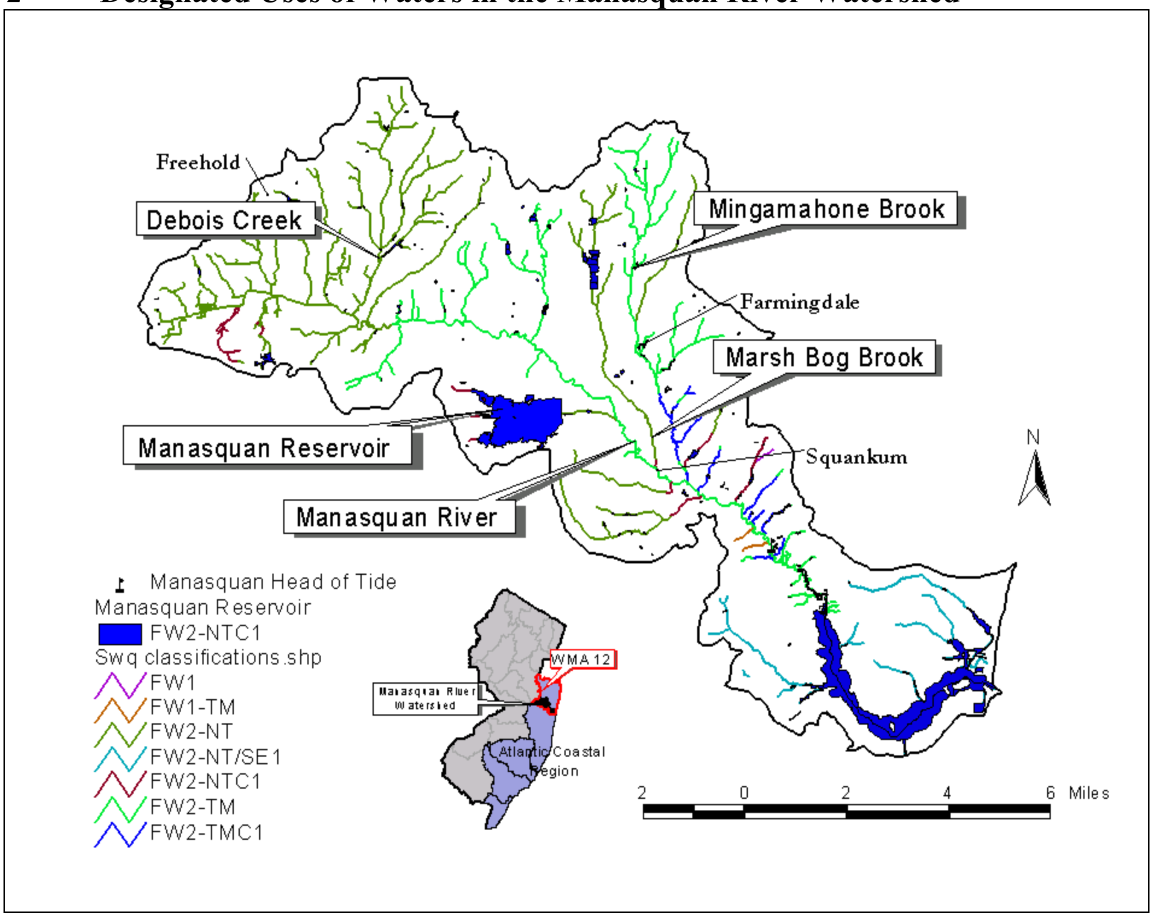
> Nutrient policies are as follows:
>
> Except as due to natural conditions, nutrients shall not be allowed in concentrations that cause objectionable algal densities, nuisance aquatic vegetation, abnormal diurnal fluctuations in dissolved oxygen or pH, changes to the composition of aquatic ecosystems, or otherwise render the waters unsuitable for the designated uses.

The following surface water classifications based on the designated uses are found in the phosphorus impaired part of the Manasquan River watershed: FW2-TM, FW2-TM(C1), FW2-NT, and FW2-NT(C1). Surface water quality designated classifications for the entire Manasquan River watershed are identified in Figure 2.

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

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

Figure 2 Designated Uses of Waters in the Manasquan River Watershed



As a result of monitoring conducted by the Department, TP concentrations were found to exceed New Jersey's SWQS for two stream segments in the Manasquan River Watershed, resulting in placement of these segments on Sublist 5, which requires development of a TMDL. Descriptions of the impaired segments and are provided in Table 2.

Table 2 Description of the spatial extent of the phosphorus impairments in the Manasquan River Watershed, WMA 12

Site Name	Station ID	River Miles	Description of the impaired segments
Long Brook at Wyckoff Mills	**25, 01407868**	4.2	Long Brook/Killtime Brook watershed covers 1.9 sq. miles area in Howell Twp. Station 01407868 is located 0.5 mile upstream from the confluence with the main stem of Manasquan River. Station 25 is located 1.7 mile upstream from station 01407868.
Manasquan River at Squankum	**EWQ0489, MA-2, MA-3, 01407900, 01408000**	9.3	Manasquan River at Squankum watershed covers an area of 44.1 sq. miles. The impaired segment of main stem goes from the confluence of DeBois Creek to the confluence of Mingamahone Brook. Station 01408000 is located on the main stem between Marsh Bog Brook and Mingamahone Brook. This TMDL covers entire watershed upstream from the station 01408000 with the exception of the Long Brook/Killtime Brook watershed for which TMDL was calculated separately.

These TMDLs will address a total of 13.5 river miles with a corresponding total of 28,195 acres of land within the affected watersheds. The implementation plans will address phosphorus reduction in the overall drainage area of the impaired segments. Both segments are identified as Medium Priority on the *2004 Integrated List of Waterbodies*.

Data Sources

The Department's Geographic Information System (GIS) was used extensively to describe the Manasquan River Watershed characteristics. In concert with the USEPA's November 2001 listing guidance, the Department is using Reach File 3 (RF3) from the 2004 Integrated Report to represent rivers, stream, lakes and lakesheds (watersheds of the lakes). The following is general information regarding the data used to describe the watershed management area:

- 1995/97 Land use/Land cover Update, published 12/01/2000 by NJDEP Bureau of Geographic Information and Analysis, delineated by watershed management area.
- Lakes 2003, Lakes Coverage, NJDEP - Bureau of Freshwater and Biological Monitoring, unpublished coverage, created March 2003.
- 2004 Assessed Rivers coverage, NJDEP, Watershed Assessment Group, unpublished coverage.
- NJPDES Surface Water Discharges in New Jersey, (1:12,000), published 02/02/2002 by Division of Water Quality (DWQ), Bureau of Point Source Permitting - Region 1 (PSP-R1) with the update from NJEMS (New Jersey Environmental Management System) on March 15, 2005.
- 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
- NJDEP Existing Water Quality Stations in New Jersey, published 5/12/2003, NJDEP, Division of Land Use Management (LUM), Water Monitoring & Standards, Bureau of Freshwater Biological Monitoring (BFBM) http://www.state.nj.us/dep/gis/digidownload/zips/statewide/ewqpoi.zip
- NJDEP Ambient Stream Quality Monitoring Sites, published 5/30/2001, NJDEP , Bureau of Freshwater Biological Monitoring (BFBM), http://www.state.nj.us/dep/gis/digidownload/zips/statewide/swpts01.zip

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

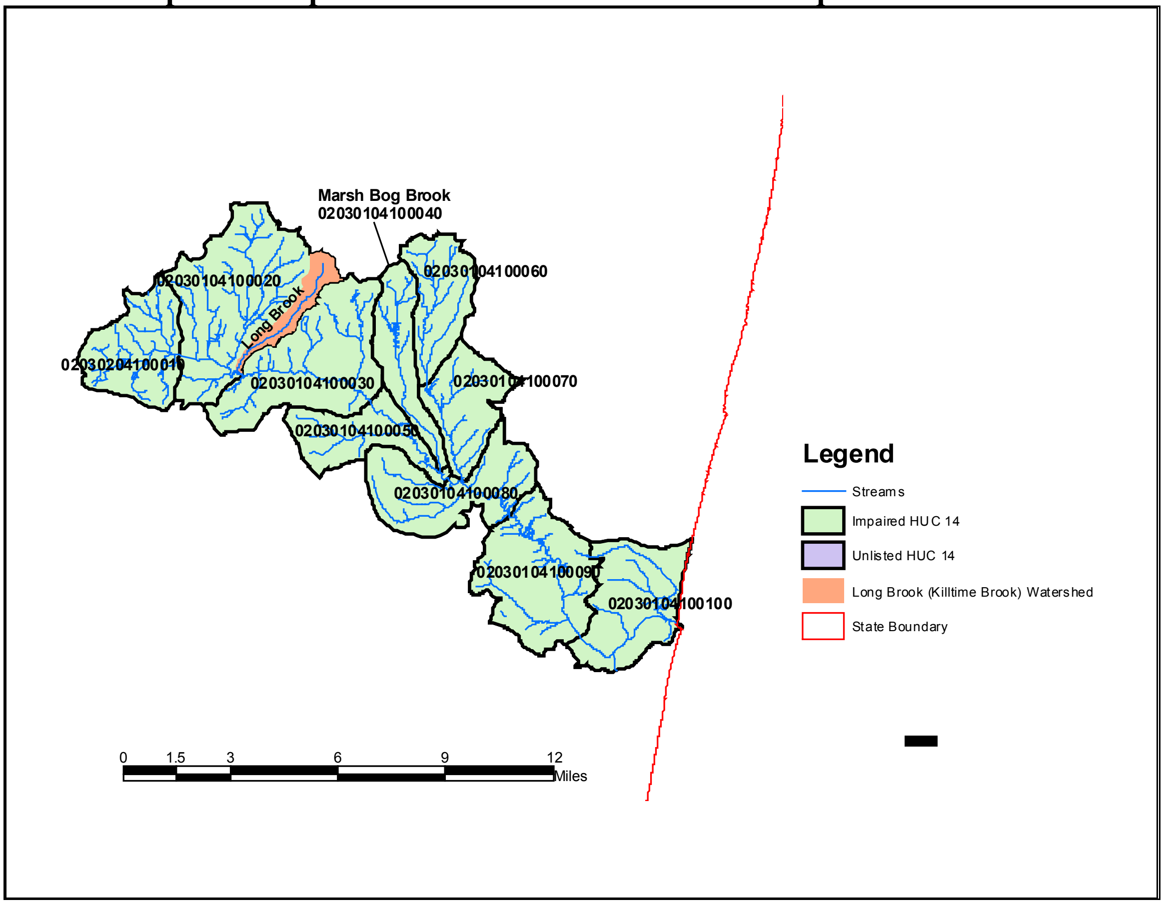
- NJDEP 14 Digit Hydrologic Unit Code delineation (DEPHUC14), published 4/5/2000 by New Jersey Geological Survey,
- http://www.state.nj.us/dep/gis/digidownload/zips/statewide/dephuc14.zip.
- NJDEP Hillshade Grid for New Jersey (100 meter), published 05/01/2002, Department of Environmental Protection (NJDEP), Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/nj100mhill.zip
- Statewide Elevation Contours (10 Foot Intervals), unpublished, auto-generated from: 7.5 minute Digital Elevation Models, published 7/1/1979 by U.S. Geological Survey.
- NJDEP Statewide Elevation Contours (20 Foot Intervals), published 1987 by Bureau of Geographic Information and Analysis (BGIA),
- http://www.state.nj.us/dep/gis/digidownload/zips/statewide/stcon.zip.
- The Killtime Brook sub-watershed was delineated based on NJ BASINS using its automatic delineation function based on NJDEP 10-meter Digital Elevation Grid for WMA 12. (http://www.nj.gov/dep/gis/wmalattice.html) The manual QC check was conducted on the boundaries automatically generated by NJ BASINS and necessary modifications were made to appropriately delineate the lakeshed and subbasins.

Description of the Manasquan River Watershed and Impaired Waterbodies

The Manasquan River watershed is part of the Watershed Management Area 12 (WMA 12). WMA 12 is the northern most WMA in the Atlantic Coastal Region (See Figure 2). The Manasquan River Watershed is located on the border between the easternmost portion of Ocean and Monmouth Counties. The river drains an area of 82 square miles and flows approximately 23 miles southeasterly from its western headwaters in Freehold and Manalapan Townships in Monmouth County. The lower 6.5 miles of the river forms an estuary that empties to the Atlantic Ocean at the Manasquan Inlet. The Manasquan River is tidally influenced up to a point approximately a half-mile west of the Garden State Parkway (east from the Hospital Road). Major tributaries include Debois Creek, Marsh Bog Brook, and Mingamahone Brook. Approximately 92% of the watershed is in Monmouth County and the remaining 8% is in Ocean County.

The Manasquan River Watershed (HUC11) is comprised of ten United States Geological Survey (USGS) HUC14 drainage units; "HUC", or Hydrologic Unit Code, refers to a system of geographic delineation developed by USGS to identify drainage basins on the watershed and sub-watershed basis throughout the country. Figure 2 illustrates the phosphorus-impaired part of the Manasquan River watershed which consists of five from ten HUC14's. The phosphorus impaired part of the watershed covers 44.1 mi^2 of 82 mi^2 or 54% of the entire watershed.

Figure 3 Phosphorus Impaired Sub-watersheds in the Manasquan River Watershed



The Manasquan River Watershed lies in the Coastal Plain physiographic province, which is characterized by low-lying topography (e.g., typically no greater than 100 feet above sea level). Sandy soils and coastal scrub/pine vegetation dominate the coastal plain physiographic province which strongly influences any hydrologic characteristics. There are a number of small lakes and ponds, most of which are used for recreational purposes. The Manasquan Reservoir is a pump-storage reservoir situated off the main stem Manasquan River and is used as a major potable water supply. It is fed by withdrawals from the Manasquan River taken from a point approximately 0.8 miles upstream of the head of tide.

The Manasquan River is currently experiencing moderate to severe erosion along several upstream stream segments and tributaries (Princeton Hydro, LLC. 2002), which results in sedimentation and in the vicinity of the Squankum Dam and noted at the location of USGS station #01408000, Manasquan River at Squankum, NJ. The erosion in the Manasquan River Watershed is considered to be substantially greater than expected under normal conditions given the lack of erosion evidenced in nearby streams within the same physiographic region of the State.

Long Brook at Wyckoff Mills

Long Brook is also known as Killtime Brook. Long Brook is 4.19 miles long with a very narrow drainage area of 1.9 mi^2. USGS station 01407868 on Long Brook was monitored from 1997 through 2000. In addition, the Monmouth County Health Department has monitored Station #25 from 1995 to present. From these stations, 28 TP samples were collected (to September 2003) and seven of them (21 percent) exceeded the SWQS of 0.1 mg/L TP. The Long Brook watershed is the most southeastern part of HUC14 (02030104100020) and empties directly to the main stem Manasquan River. DeBois Creek with its tributaries occupy the major portion of this HUC14.

Manasquan River at Squankum

The Manasquan River impaired segment, Manasquan River at Squankum, has Site ID 01408000. This segment extends for 9.3 miles from DeBois Creek to Mingamahone Brook. This TMDL considers loads from the entire 44.1 square mile drainage area, which consists of five sub-watersheds (HUC14s) above the USGS station 01408000. In the past twelve years, five stations were monitored on the Manasquan River impaired segment and a total of 14 stations throughout the impaired watershed. From 1991 to 2003, 74 total phosphorus samples were collected from the stations located throughout the Manasquan River at Squankum segment. From this number, 18 percent exceeded the SWQS of 0.1 mg/L.

Marsh Bog Brook, sub-watershed 02030104100040 (HUC14), discharges directly to the impaired segment, though total phosphorus results from stations located on this stream did not warrant placing it on Sublist 5 (only seven percent of TP results exceeded 0.1 mg/L). Phosphorus loadings from this sub-watershed contribute to TP loadings at station 01408000 and are included in calculating the TMDL and distributing load allocations for the impaired segment.

4.0 Source Assessment

In order to evaluate and characterize total phosphorus loadings in the two waterbodies of interest, Long/Killtime Brook and Manasquan River at Squankum, and thus propose proper management responses, source assessments are warranted. Source assessments include identifying the types of sources and their relative contributions to total phosphorus loadings, in both time and space variables. Phosphorus sources were characterized on an annual scale (kg TP/yr).

Assessment of Point Sources other than Stormwater

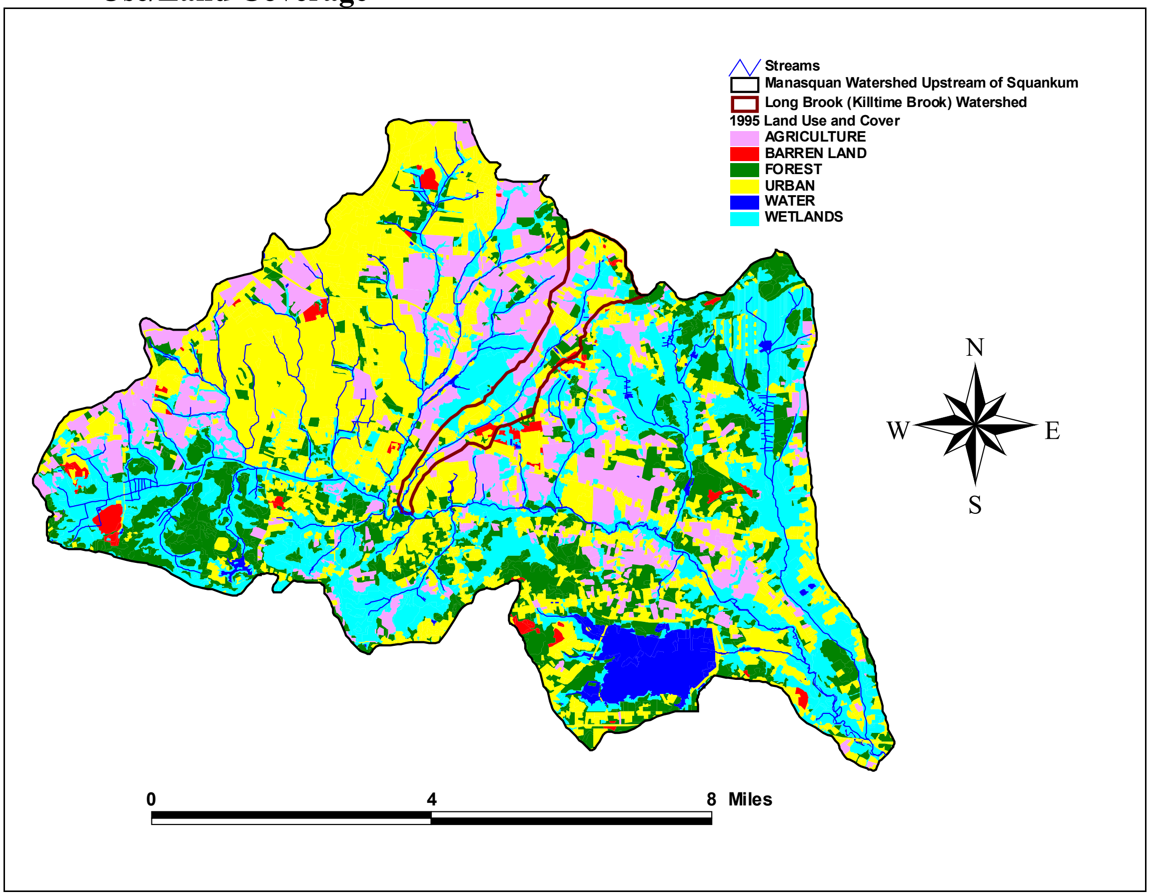
Historically the main stem of the Manasquan River, Marsh Bog Brook and Debois Creek experienced significant point source loadings. Nutrients, volatile organic compounds and metals were discharged by industrial facilities in the Freehold Borough area to Debois Creek and its tributaries. These loadings resulted in low dissolved oxygen levels in some segments. At this time, all major and minor point sources, other than stormwater, in the Manasquan River Watershed have been eliminated. As of 1994, all municipal wastewater facilities in the non-tidal portion of the Manasquan River Watershed were connected to the Ocean County Utilities Authority - Northern Treatment Plant for treatment and discharge to the Atlantic Ocean. Therefore, point sources other than stormwater are a de minimis source of phosphorus in the drainage area.

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 pollutants from sources such as farms and urban and suburban areas to the receiving water. Urban and suburban land uses are assumed to correspond to areas served by stormwater facilities regulated under NJPDES, including Phase II municipal stormwater, or MS4s. Nonpoint sources also include inputs from sources such as failing sewage conveyance systems, sanitary sewer overflows (SSOs), and failing or inappropriately located septic systems.

Watershed loads were estimated using the Unit Areal Load (UAL) methodology, which applies pollutant export coefficients obtained from literature sources to the land use patterns within the watershed, as described in EPA's Clean Lakes Program guidance manual (Reckhow, 1979b). Land use was determined using the Department's GIS system using the 1995/1997 land use coverage and is depicted in Figure 4.

Figure 4 Phosphorus Impaired part of the Manasquan River Watershed with 95/97 Land Use/Land Coverage



Phosphorus loadings were calculated based on the area covered by each land use and corresponding phosphorus export coefficients, or Unit Areal Loads. The UAL values used were those selected by the Department from an extensive database as most representative of loadings in New Jersey, see Appendix B. Areas covered by each land use and calculated runoff loading rates for each of the watersheds are presented in Table 3.

Table 3 Nonpoint and Stormwater Sources of Phosphorous Loads in the Long Brook and Manasquan River at Squankum Watersheds

Land Uses	Export Coefficients	Manasquan River at Squankum *		Long Brook/Killtime Brook	
	kg/acre/yr TP	acres	kg/yr	acres	kg/yr
medium / high density residential	0.6475	1635	1059	101.1	65.49
low density / rural residential	0.2833	4352	1233	207.4	58.75
commercial	0.8094	771.0	624.1	28.02	22.68
industrial	0.6880	534.0	367.4	27.88	19.18
mixed urban / other urban	0.4047	2009	812.9	65.75	26.61
agricultural	0.6071	4510	2738	280.4	170.2
forest, wetland, water	0.04047	14010	567.0	472.4	19.12
barren	0.2024	373.6	75.60	31.46	6.365
TOTAL		28,195	7,476	1,214	388.4

* Phosphorus Load from the Long Brook (Killtime Brook) is included in the Manasquan River watershed loads

Figures 5 and 6 show the existing phosphorus loading distributions calculated for both watersheds, as presented in Table 3.

Figure 5 Current Phosphorus Load Distribution in the Manasquan River at Squankum Watershed

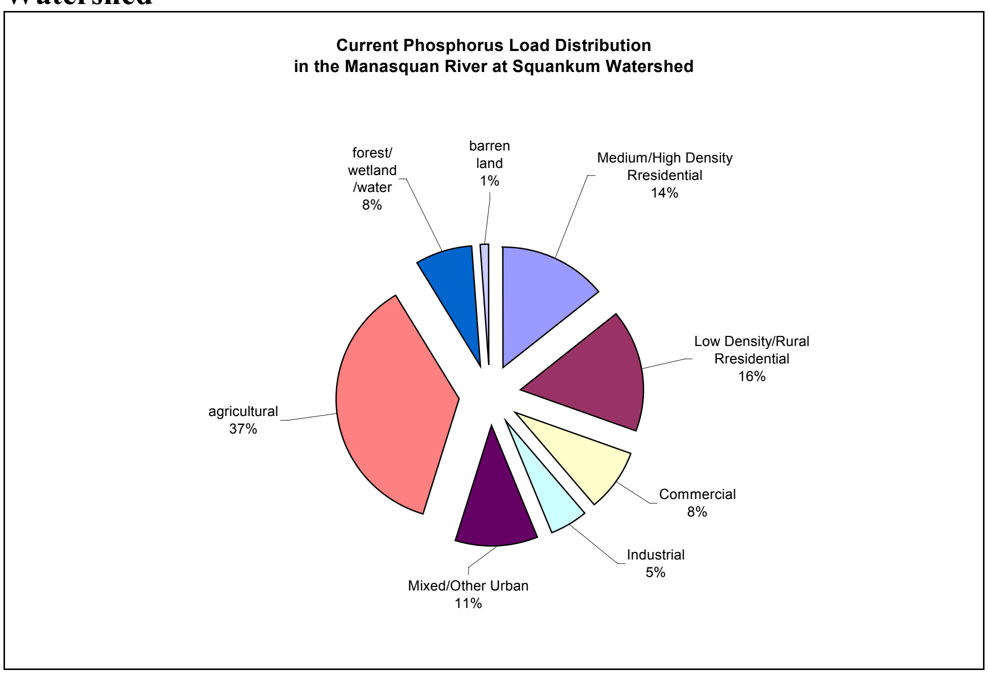
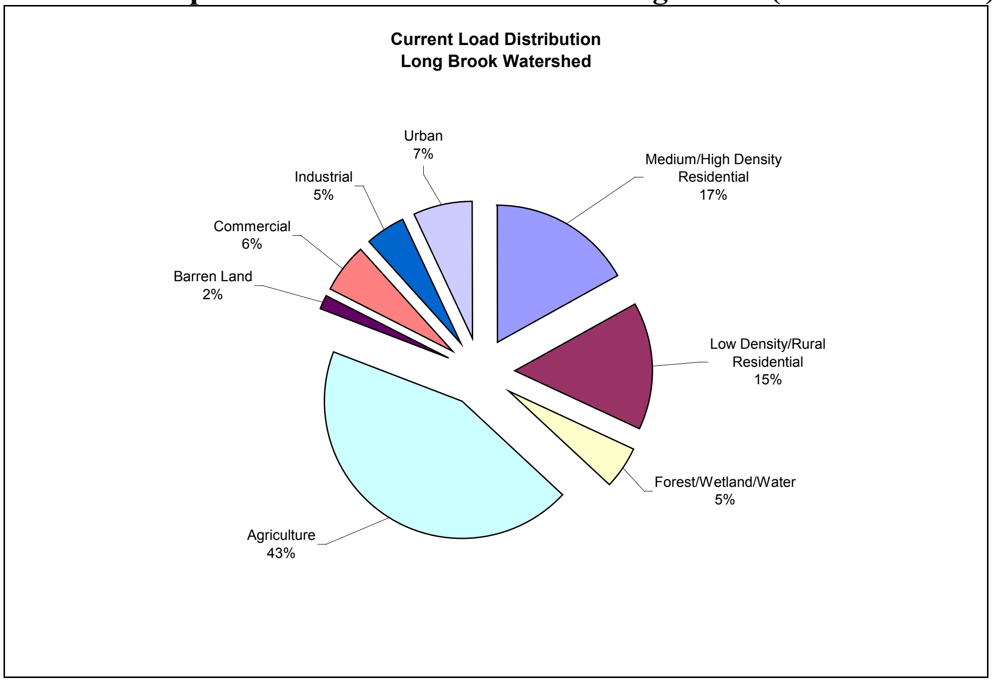


Figure 6 Current Phosphorus Load Distribution for Long Brook (Killtime Brook)



Phosphorus measurement in soils throughout the Manasquan River Watershed

The Department considered whether the elevated phosphorus levels were the result of naturally occurring conditions, given the phosphorus-rich local geology from which soil is derived. The total phosphorus concentration in water samples shows correlation with the total suspended solids concentration. The water sampling results evaluated and presented in next section of this report, Water Quality Analyses, have shown (see Figure 14) that the total phosphorus exceedances above the SWQS standards occurred during higher flows and also were accompanied by higher TSS concentrations. soil particles are rich in phosphorus. This fact was established by the Rutgers Cooperative Extension Soil Testing Laboratory at Cook College, New Brunswick. One of the services provided by this laboratory is soil analysis, a diagnostic service available to residents of the State of New Jersey. The laboratory was established in 1991 on the Cook College campus of Rutgers University. The Soil Testing Laboratory was consulted as part of the TMDL development process to identify phosphorus levels in soil samples throughout the Manasquan River Watershed. A database, primarily consisting of samples submitted by homeowners and, to a lesser extent, farmers, has been developed and summarized in Table 4. It should be noted that samples containing more than 137 pounds/acre of total phosphorus are generally considered to have “very high” levels of phosphorus. Samples containing 72-136 pounds/acre are considered “high/optimum”, samples containing 46-71 pounds/acres are considered to have “medium” levels, samples containing 25-45 are considered “low”, and samples containing 0-24 are considered “very low” (Murphy, personal communication). All soils in the area of interest exhibit above “very high” concentrations with most containing phosphorus levels 5-15 times higher than the “very high” concentration. This table is a summary of raw data located in Appendix G.

The "very high" phosphorus content in the watershed soils contributes to the phosphorus concentration in water column because soil particles are washed out by runoff to the waterbodies. It was not established to what extent the phosphorus levels are intrinsic to the soil and to what extent they are the result of application of phosphorus as a fertilizer. In any case, the existence of phosphorus-rich soil does not rise to the level of a naturally occurring condition because the unusually high level of erosion of the soil is related to anthropogenic activities.

Table 4 Average and maximum levels of phosphorus in soils throughout the Manasquan River Watershed.

Location	Zip Code	Number of Soil Samples	Phosphorus, Average concentration (lbs/acre)	Phosphorus, Maximum concentration (lbs/acre)	Phosphorus, Standard Deviation
Allaire/ Farmingdale	07727	26	205	1283	264
Freehold	07728	38	227	1429	255
Howell	07731	150	175	1997	186
Howell	07731-0364	36	264	948	229
Howell	07731-8832	2	156	267	157
Allenwood	08720	1	237	237	NA
Brielle	08730	25	753	1950	684
Manasquan	08736	7	264	609	161
Sea Girt	08750	2	343	522	254

5.0 Water Quality Analysis

As described in EPA guidance, a TMDL identifies the loading capacity of a waterbody for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a waterbody can receive without violating water quality standards (40 C.F.R. 130.2). The loadings are required to be expressed as either mass-per-time, toxicity, or other appropriate measures (40 C.F.R. 130.2(i)). TP loadings are expressed on an annual basis in these TMDLs because sediment trapping of particulate P and adsorption onto Fe(oxy)hydroxides during the entire year and the release of iron-bound P during summer after reduction of Fe(oxy)hydroxides are instrumental in sustaining high primary production, which could not be sustained if it depended only on phosphorus imported during the growing season.

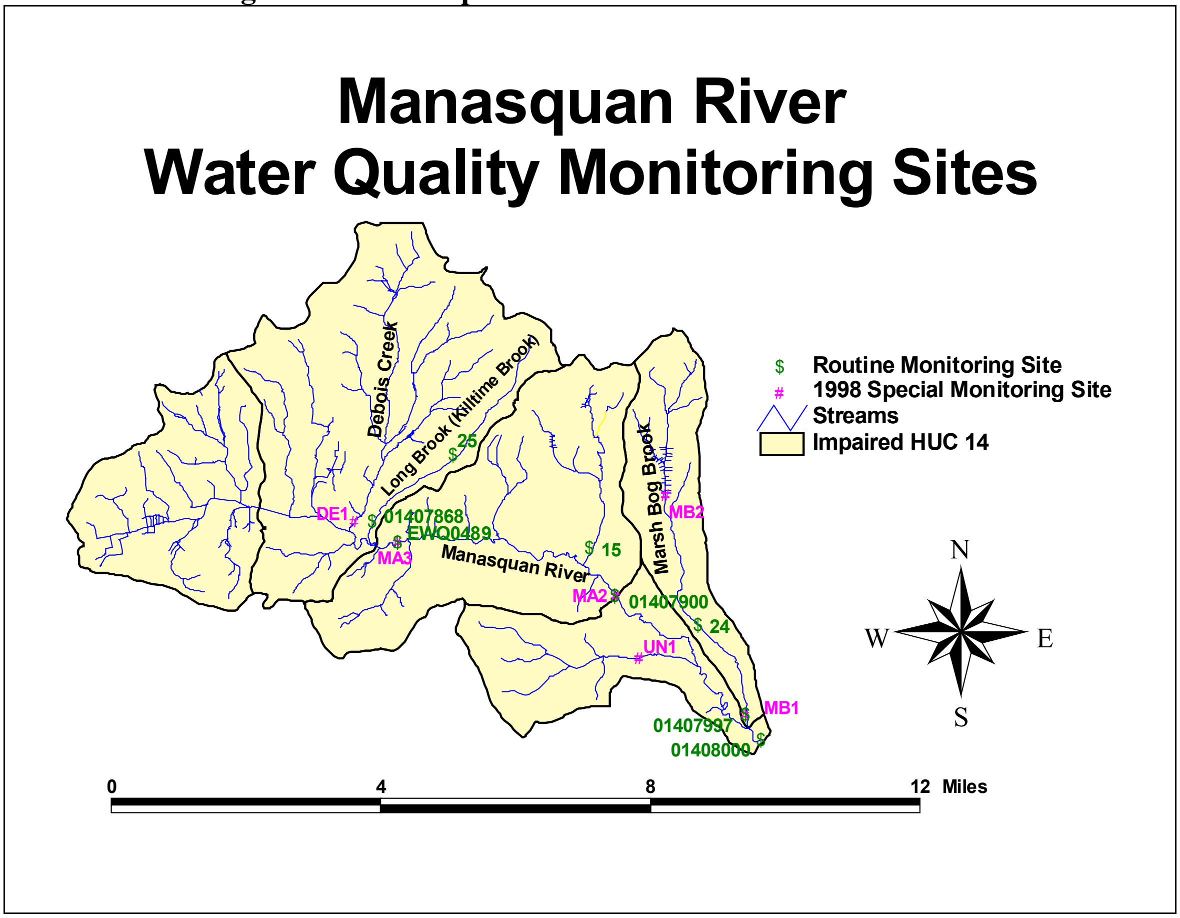
Historical Surface Water Quality Data Overview

The United States Geological Survey (USGS) in collaboration with NJDEP has collected monitoring data on the Manasquan River since 1959. Although the monitored stations and monitoring schedule have changed over the years, the historical data were reviewed to understand changes and trends in water quality. In addition to USGS/NJDEP monitoring sites, the Monmouth County Health Department (MCHD) has been collecting water samples from 1995. Also a special study in 1998 conducted by the Department as reconnaissance sampling for metals included phosphorus testing. The phosphorus results from the metal reconnaissance sampling event were reviewed but were not used in calculating loading reduction rates because some results give an approximate value due to the sample exceeding holding time. Table 5 lists all stations where water quality data were collected in the last twelve years and Figure 7 shows sampling locations.

Table 5 Summary of Total Phosphorus sampling data and percent exceedences above the surface water quality standard of 0.1mg/L for water years 1991-2003 in the Manasquan River Watershed

Water Quality Sample Locations	Site Number	# of samples	Average (mg/L)	% exceeding 0.1 mg/L
Manasquan R. at Squankum	01408000	56	0.067	14%
Manasquan River at West Farm Road	01407900, 12-MA-2	4 3	0.112 0.083	50% 33%
Manasquan River at Rt. 9, Howell Twp.	EWQ0489	8	0.034	12.5%
Manasquan River at Wyckoff Mills Rd	12-MA-3	3	0.097	33%
Total Manasquan River Segment		**74**	**0.067**	**18%**
Long Brook at Wyckoff Mills	01407868	12	0.074	8%
Long Brook at Howell Rd	25 (MCHD)	16	0.166	31%
Total Long Brook Segment		**28**	**0.127**	**21%**
DeBois Creek	DE-1	3	0.070	0%
Yellow Brook	15 (MCHD)	18	0.074	17%
Timber Swamp Brook	UN-1	3	0.150	33%
Marsh Bog Brook	MB-2	3	0.077	0%
Marsh Bog Brook	24 (MCHD)	18	0.061	6%
Marsh Bog Brook	MB-1 01407997	3 4	0.083 0.053	33% 0%
Marsh Bog Brook (not impaired) Total		28	0.064	7%

Figure 7 Monitoring Sites in the Impaired Watershed



The Manasquan River Impaired Segment

The Manasquan River impaired segment was sampled at three different locations during different periods of time. The most comprehensive data were collected at USGS station 01408000, Manasquan River at Squankum. At this station, water samples were collected 56 times for a period 1991-2003 and flow data were collected continuously from 1932 to present. Table 6 lists all TP exceedences with accompanying total suspended solids (TSS) and flows. From 1991 to 2003, thirteen TP results in the entire Manasquan River impaired segment exceeded the SWQS of 0.1 mg/L TP.

Station EWQ0489, located at the bridge on Rt. 9, had one exceedance, see Figure 8. The data analysis suggests that this TP result might be an outlier, because high TP concentrations were associated with wet weather. In this case, the corresponding TSS result is considerably below SWQS (40 mg/L (FW2-TN) and 25 mg/L (FW2-TM)). Because flow rates were not measured, the precipitation data from the weather station in Mount Holly, NJ, were used to determine that this high phosphorus result was detected during dry weather, see Figure 9. The Department concluded that this TP exceedence would not be used in the segment analysis.

Also at station USGS 01407900, West Farm Road, TP results exceeded SWQS in two of four samples. An on-site investigation (see photo-documentation presented in Appendix F) revealed extensive disturbance in the riverbed and unprotected construction sites with a wide area of barren land. Because of this transient interference, the data set of four TP results from this station were not used in the TMDL calculation.

Table 6 Total Phosphorus and Total Suspended Solids Results for the Impaired Segment of Manasquan River

Site #	Date	Flow (cfs)	TP (mg/L)	TSS (mg/L)
MA-3	10/20/1998	NM	0.13	NA
EWQ0489	7/29/2002	NM	0.134	3
MA-2	10/20/1998	NM	0.11	NA
01407900	12/12/2002	NM	0.25	54
01407900	3/4/2003	NM	0.102	22
01408000	5/26/1994	108	0.3	63
01408000	8/18/1994	32	0.18	29
01408000	5/13/1998	297	0.16	15
01408000	8/18/1998	70	0.14	1
01408000	5/23/2000	76	0.113	14
01408000	8/15/2000	83	0.168	28
01408000	5/22/2003	66	0.195	35
01408000	9/3/2003	60	0.105	8

NA - Not Analyzed

NM - Not Measured

Figure 8 Changes in Total Phosphorus and Total Suspended Solid at EWQ0489

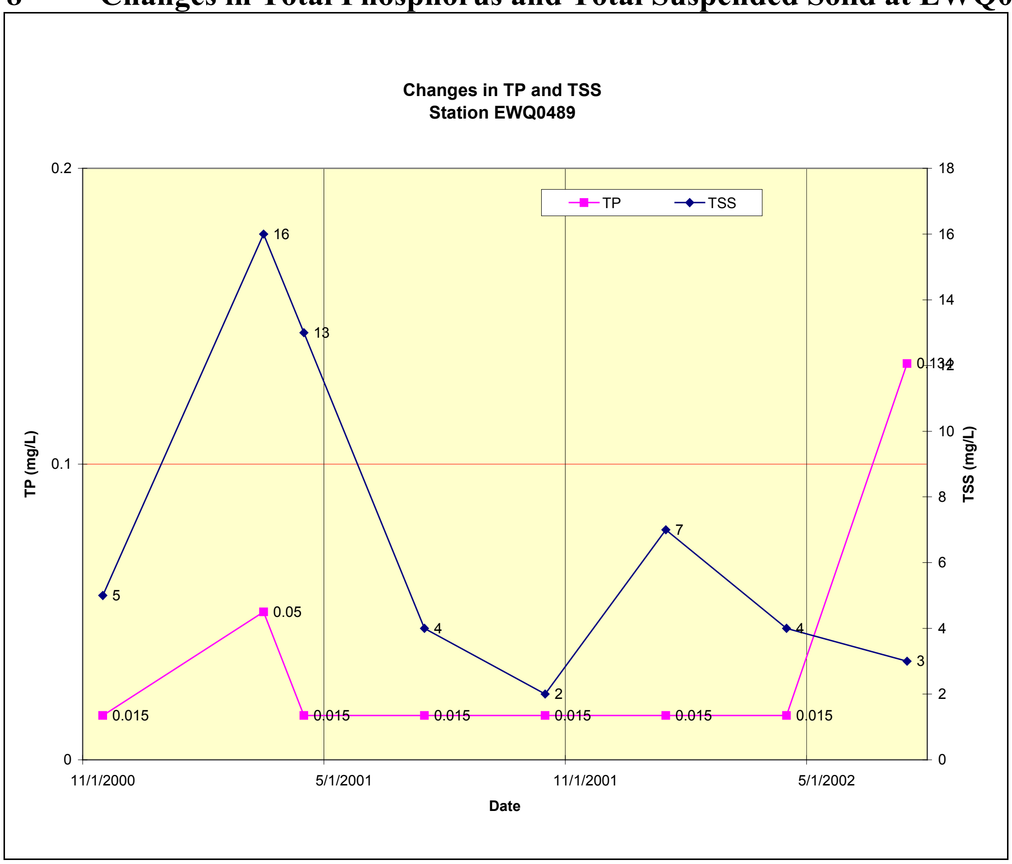


Figure 9 Precipitation data from the Mount Holly, NJ, Weather Station

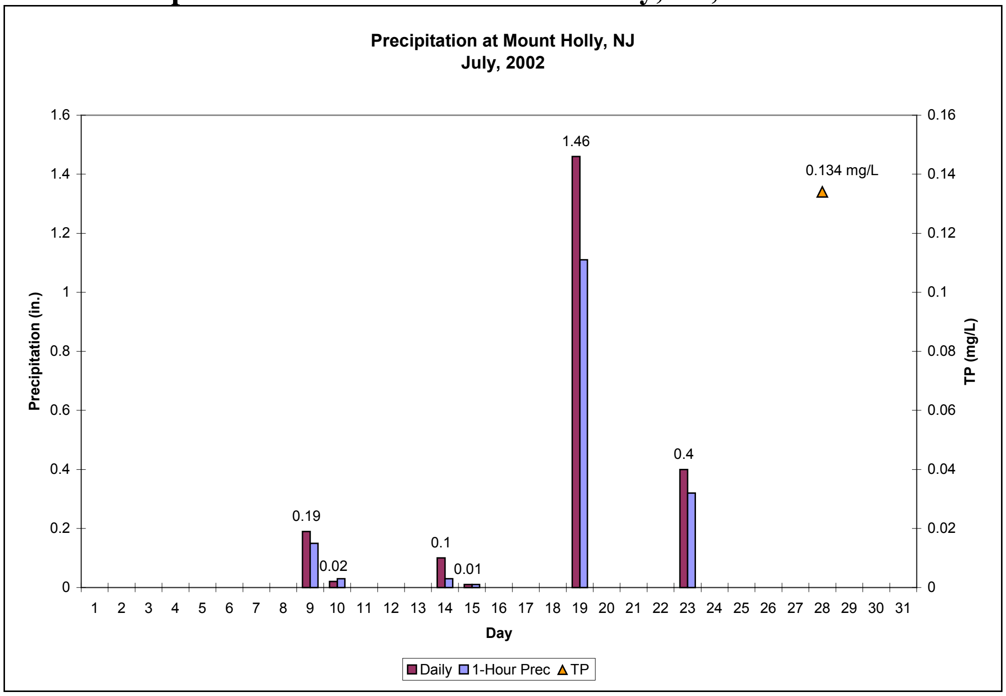


Figure 10 depicts all total phosphorus results obtained during the monitoring period of 1972-2003 at the USGS station 01408000, Manasquan River at Squankum. Total phosphorus data show that the water quality has improved substantially since 1991. From 1991 to 2003, 56 TP results were collected. The arithmetic mean of TP concentration for this period was 0.066 mg/L with the median result of 0.05 mg/L. The highest concentration was detected at 0.3 mg/L and the lowest 0.01 mg/L. The SWQS for total phosphorus was exceeded eight times. No data quality flaws were detected; therefore, this data set was used in the TMDL analysis. Figure 11 demonstrates TP results and flow rates changes during monitoring period 1991-2003. Figure 12 illustrates TP changes with the flow rate. The measured flow rates during sampling events ranged from 14 to 297 cubic feet per second (cfs) with an average flow 57.9cfs. Each sample with TP above the SWQS occurred when the sample was collected after rainfall or snow melting. Appendix H presents examples of hourly flows with the sampling time and TP concentration depicted on the graphs.

Figure 10 Total Phosphorus Changes at the Manasquan at Squankum Station

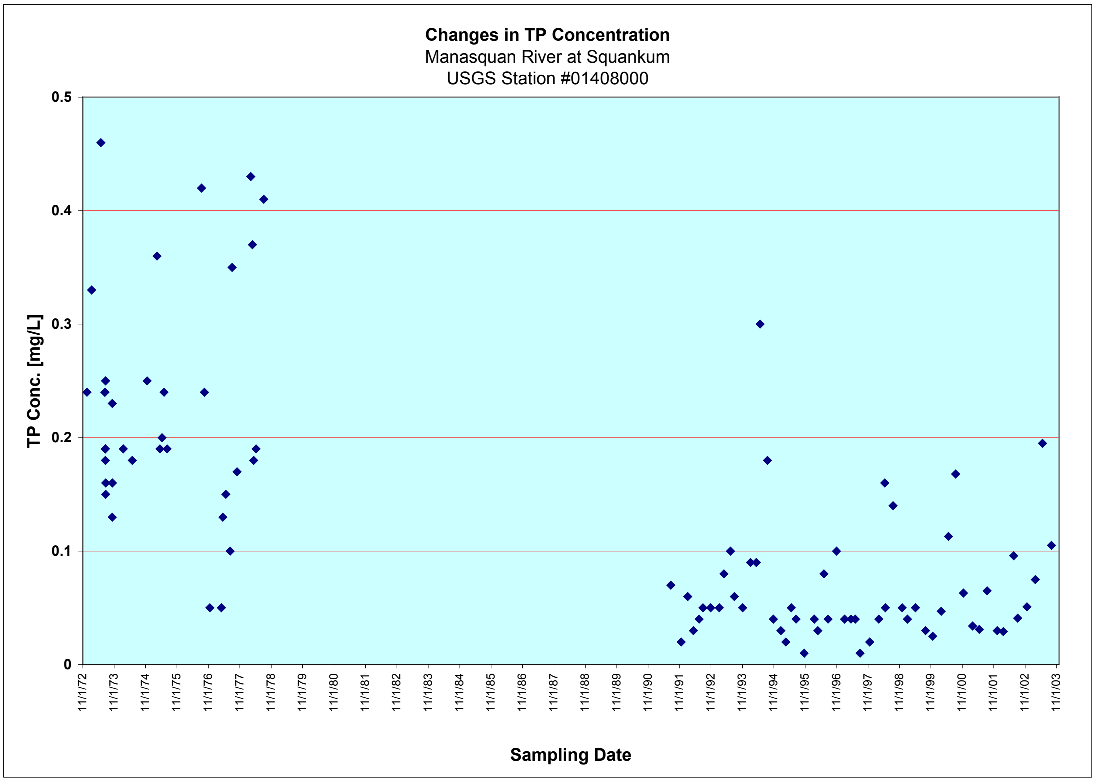


Figure 11 Changes in TP and Flow over the 1991-2003 period

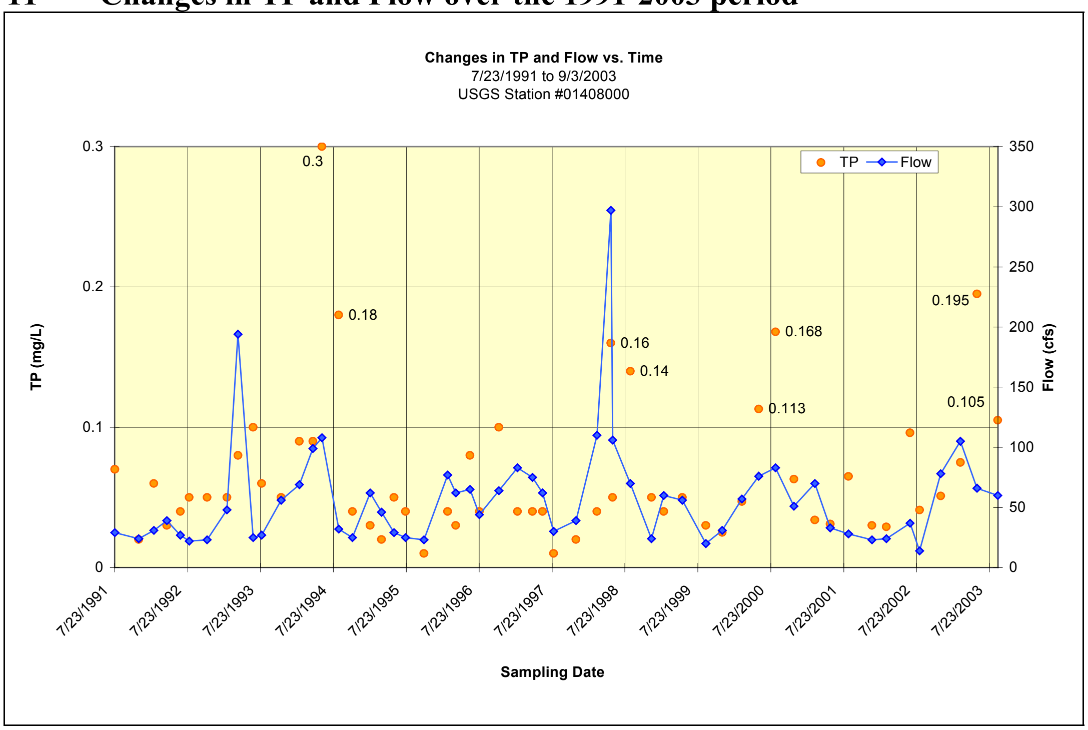
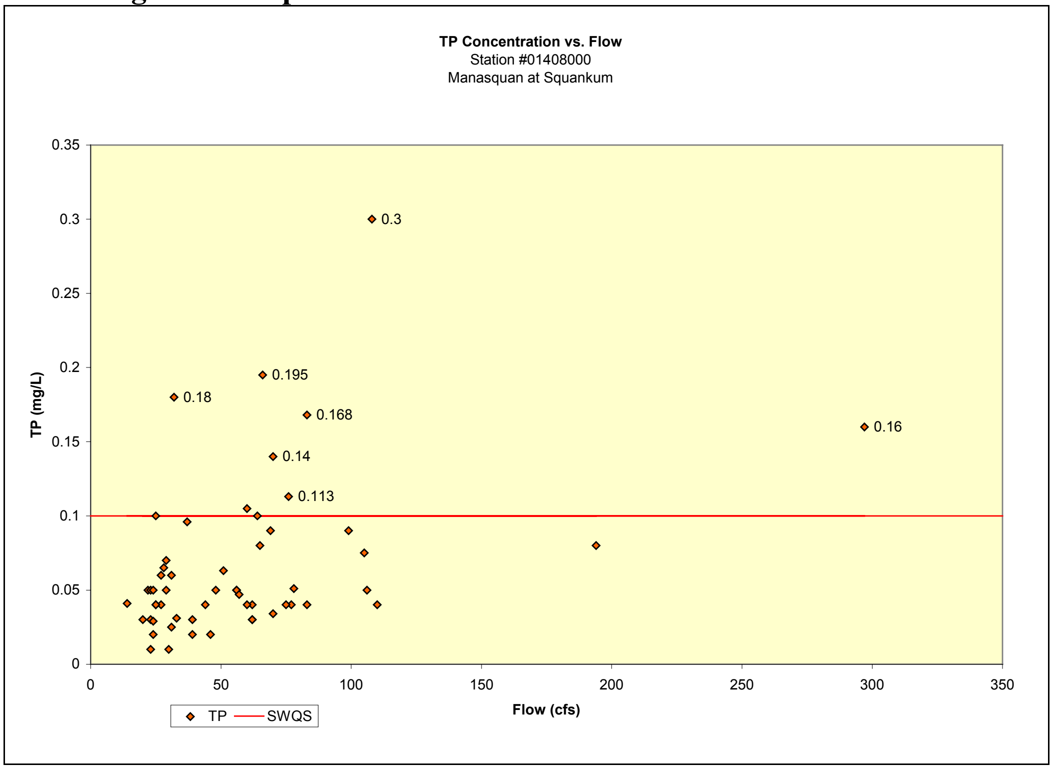
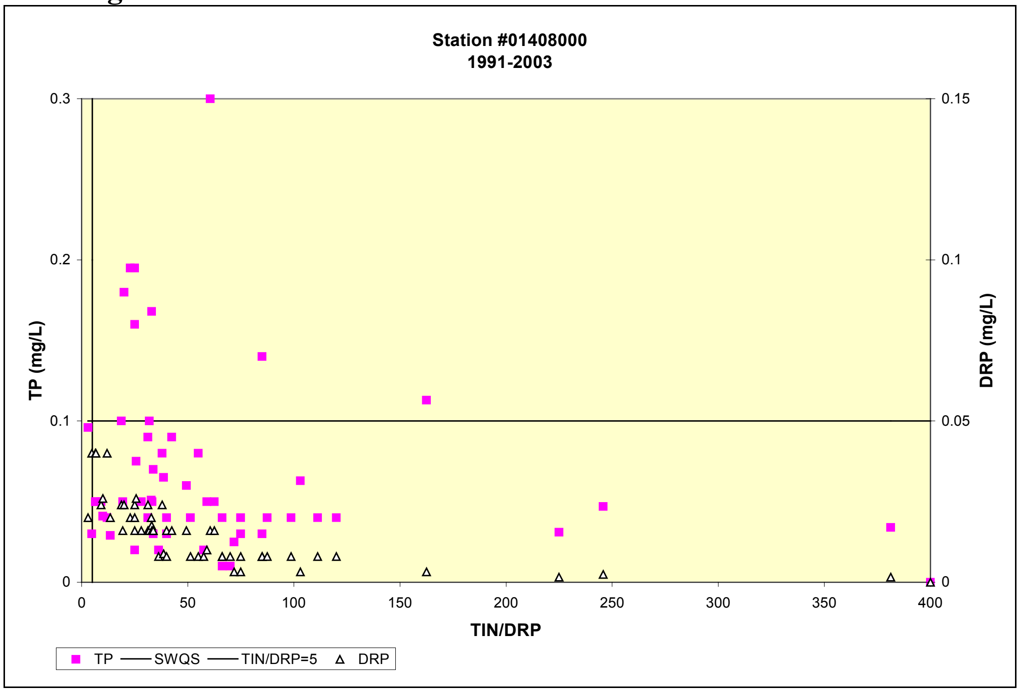


Figure 12 Changes in Phosphorus Concentration with Flow



The NJDEP Division of Water Quality's March 2003 guidance document, entitled *"Technical Manual for Phosphorus Evaluations (N.J.A.C. 7:9B-1.14(c)) for NJPDES Discharge to Surface Water Permits"*, recommends considering ratios of nitrogen and phosphorus as an indicator of a nutrient rich environment suitable for algal overgrowth. When the ratio of total inorganic nitrogen (TIN) to total orthophosphate (TOP) or dissolved reactive phosphorus (DRP) is smaller than or equal to 5, then phosphorus is not limiting the system. Figure 13 depicts the relationship of these two key nutrients at the Manasquan River at Squankum station. At this station, when the total phosphorus exceeded 0.1 mg/L and the DRP < 0.05 mg/L, the ratio TIN/DRP exceeded 5. This suggests that phosphorus is the limiting nutrient and the 0.1 mg/l criterion applies. A more detailed explanation of the nitrogen-phosphorus relationship is given in Appendix C.

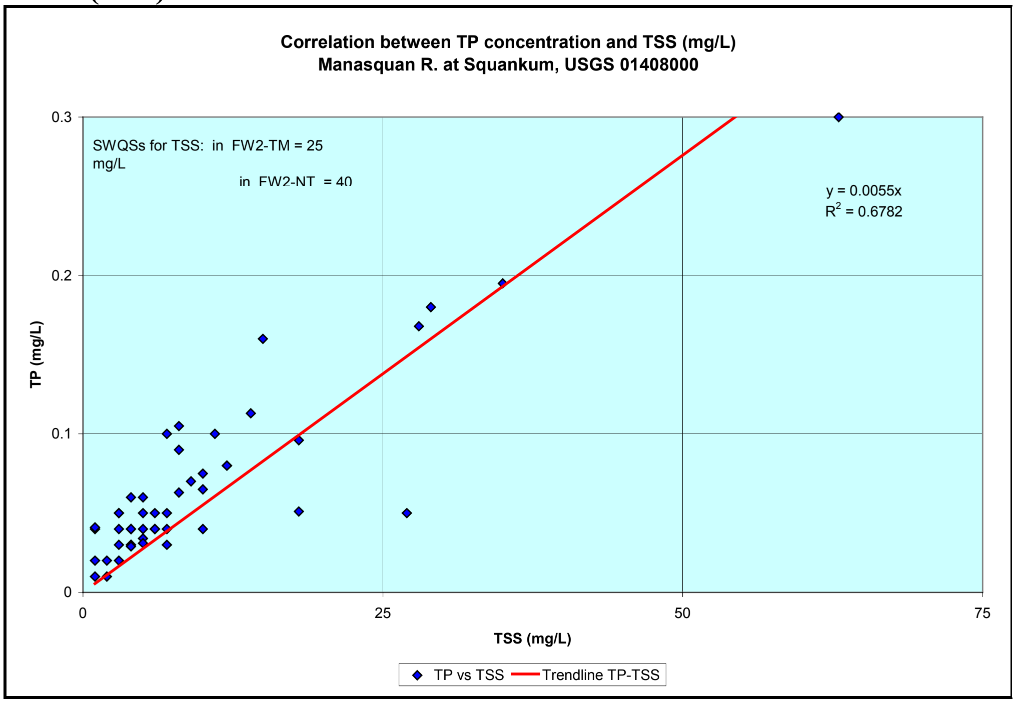
Figure 13 Limiting Nutrient



TIN = dissolved nitrite, nitrate and ammonia. TIN calculated as: a sum of dissolved ammonia (P00608) & dissolved nitrite and nitrate (P00631) or a sum of total ammonia (P00610) and total nitrite & nitrate (P00630)
DRP = dissolved reactive phosphorus: orthophosphorus (P00671) if available, or 80% dissolved phosphorus (P00666)

The TP and TSS results presented in Figure 14 show a strong correlation between TP and TSS. Elevated phosphorus results are accompanied by elevated suspended solid results. This fact suggests that total phosphorus is associated with particulate matter in the water column and that loads are contributed by runoff. When TP concentrations are elevated, the orthophosphorus or dissolved phosphorus concentrations did not change significantly. At this station orthophosphorus (0671) was tested only 8 times in the recent 12 years. Two results were 0.026 mg/L P and six times the results were below the method detection limit of 0.02 mg/L. Dissolved phosphorus was tested 57 times and 11 results were above 0.02 mg/L. For the samples that exceeded SWQS for TP, the calculated DRP was very low and ranged from 0.0032 mg/L to 0.024 mg/L.

Figure 14 Correlation between total phosphorus concentration (TP) and total suspended solids (TSS)



Long Brook (Station #01407868 and #25)

Long Brook at Wyckoff Mills has a drainage area of 1.9 square miles. The water quality samples were collected at two stations: USGS 01407868 from 1997 to 2000 and the Monmouth County Health Department (MCHD) station #25 from 1995 to 2003. The Department's Assessment Team included results from both stations in assessing water quality of Long/Killtime Brook.

At USGS station 01407868 a full range of tests was performed, including instantaneous flow measures during the sample collections. In the three-year sampling period, only one TP result exceeded SWQS of 0.1 mg/L. Sampling at this station was discontinued in 2000. Long Brook at Howell Road in Howell (#25) has been sampled by the Monmouth County Health Department (MCHD) from 1995 to present. The samples were collected twice a year, March and October, and so did not include the growing season. The flow was not measured at this site. All TP results exceeding SWQS are listed in Table 7, with TSS results, if available.

Table 7 Phosphorus Exceedences at the Long Brook Segment

Site #	Date	Flow (cfs)	TP (mg/L)	TSS (mg/L)
25	10/11/95	NM	0.66	NA
25	3/10/97	NM	0.11	NA
25	5/12/98	NM	0.21	NA
25	3/14/00	NM	0.13	NA
25	3/13/01	NM	0.26	24
25	10/9/01	NM	0.73	1205
1407868	2/24/98	40	0.30	54

NA - Not Analyzed
NM - Not Measured

Figure 15 shows the precipitation level on 2/24/98, when a sample was collected at USGS 01407868. This sample was collected immediately after heavy precipitation, and the TP concentration reached 0.3 mg/L TP. Nonpoint sources were clearly active during this event, which notably also shows that TSS exceeded SWQS of 40 mg/L (FW2-NT).

Figure 15 Precipitation at Freehold Weather Station

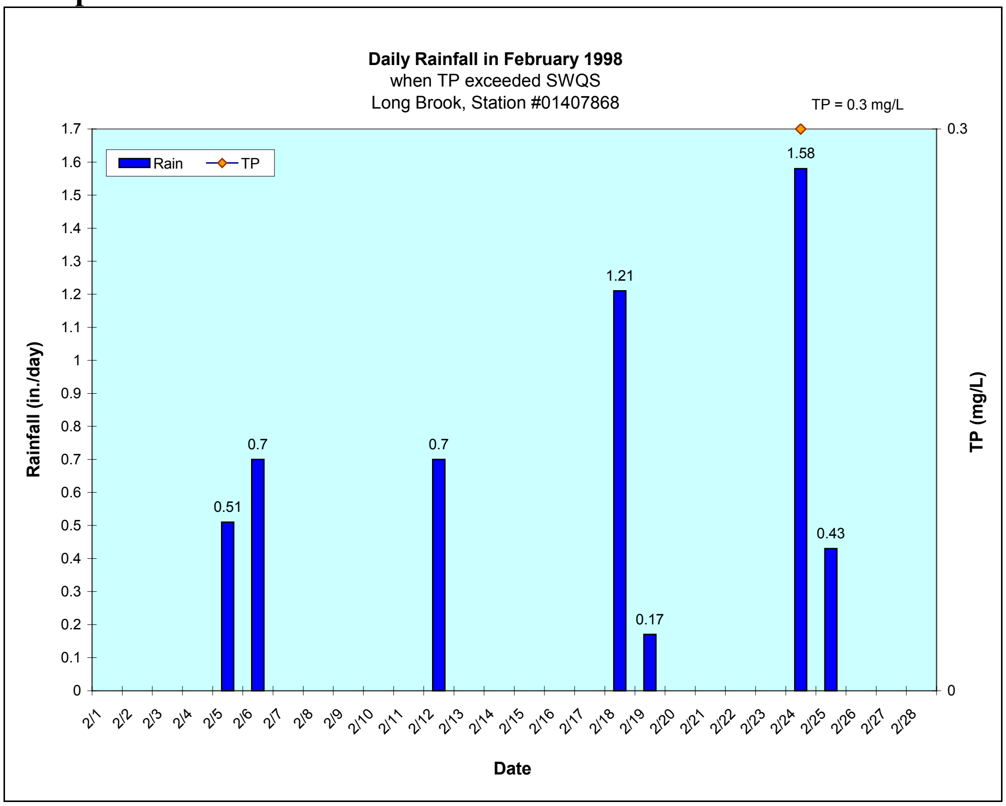
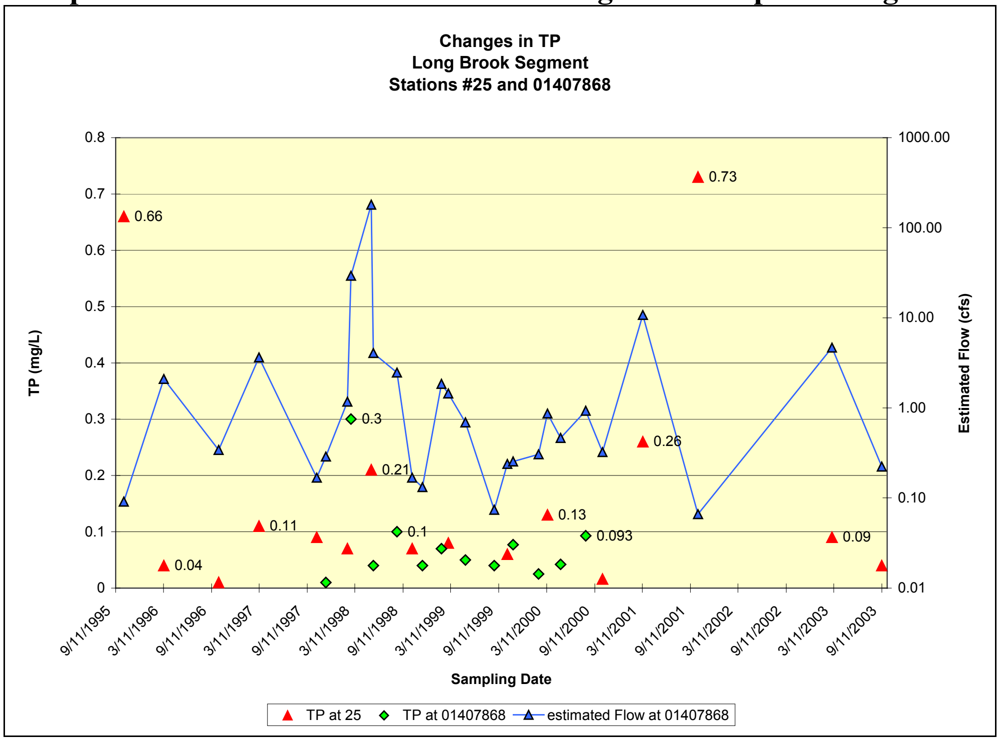


Figure 16 Phosphorus Results and Flow from the Long Brook Impaired Segment



At station #25, the TP results exceeded SWQS six times (37.5 percent). Each exceedance was analyzed to determine if there were any relationships to other water quality parameters or precipitation. Because of a very limited number of data points, it is difficult to draw any meaningful conclusions. However, based on a site investigation conducted on March 10th, 2005, it is noteworthy that the stream is very shallow, filled with sediments that appear to be regularly washed into the stream from the nearby cropland. Moreover, the highest noted TP concentration of 0.73 mg/L was accompanied by elevated TSS at 1205 mg/L. It is believed that the high phosphorus concentration is related to the high phosphorus content in soil; under favorable environmental conditions, this phosphorus load could be released to the water column from sediments.

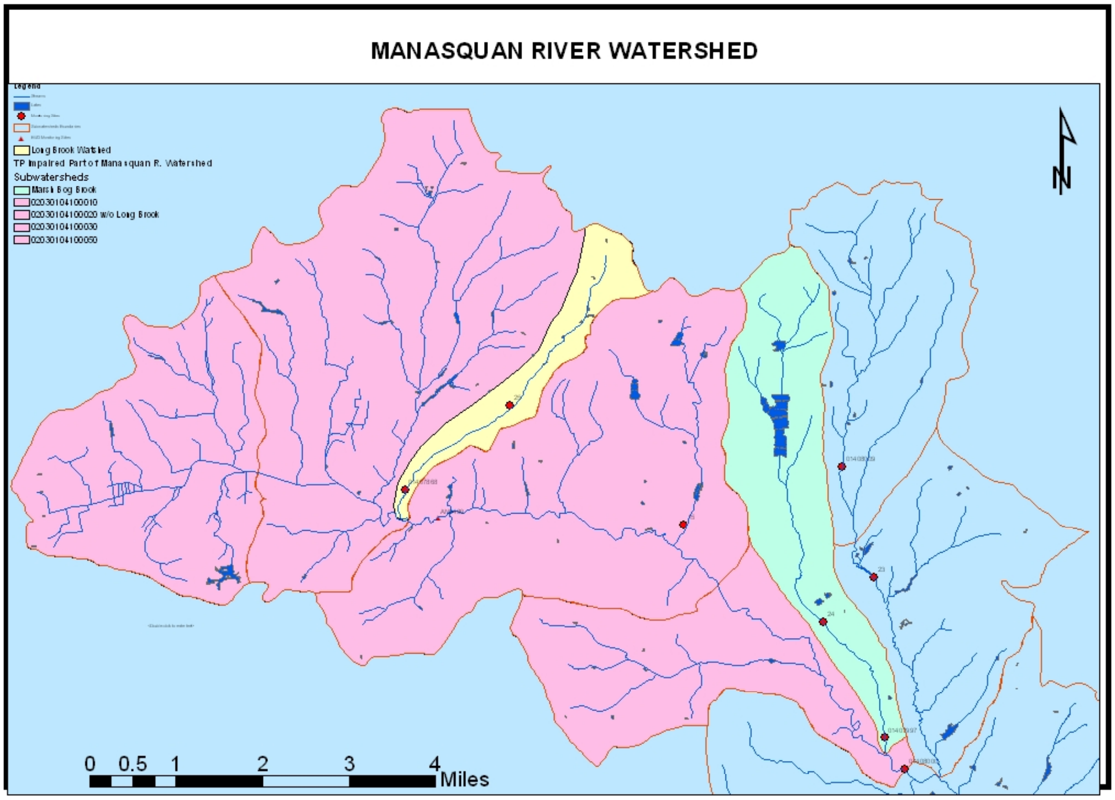
Because the flow rate is not measured at the station #25, estimated flows, based on instantaneous flow measurements at station 01407868 and continuous flows from station 01408000 (Long Brook at Wyckoff Mills and Manasquan at Squankum, respectively), were used in calculating phosphorus loadings. The methodology of estimating flows at this location is presented in Appendix E.

6.0 Analytical Approach and TMDL Calculations

TMDL Development Procedure

For the purpose of calculating load capacity and load allocations in the impaired watershed, the entire Manasquan River at Squankum watershed was geographically divided into three segments; Long/Killtime Brook watershed, Marsh Bog Brook watershed and the remaining part of the impaired Manasquan River watershed as shown in Figure 17.

Figure 17 Phosphorus Impaired Manasquan River Watershed



Where sufficient concentration and flow data are available, a method that determines the percent reduction based on the linear regression of daily total phosphorus loading (pound per day, lb/day) versus flow (cubic feet per second, cfs) can be used. The method applied was adapted from "TMDL Development Using Load Duration Curves" (Stiles 2002). In many cases, long-term continuous flow monitoring data are not available. When continuous flow data are not available, flows must be estimated using either continuous flow records from a flow measurement station in a nearby watershed, or by using a constant flow per unit drainage area. Both of these flow-estimating techniques introduce variability that is inherent to the use of data from other locations or from approximations of watershed characteristics. The adapted regression technique used here permits the use of fewer flow data while providing a site-specific analysis of loading exceedances over a range of measured flows.

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

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

For the Manasquan River at Squankum station (01408000), the actual phosphorus loadings are compared to the 0.1 mg/L total phosphorus target, presented as daily loadings on Figure 18. Exceedances are analyzed and load reductions are calculated. The upper 95 percent confidence limit for the regression of the exceedances is calculated and plotted. Finally, the percent reduction in total phosphorus loads (difference between the upper 95 percent confidence limit of the exceedence regression and the target load regression) is calculated to maintain compliance with the 0.1 mg/L TP SWQS.

Calculated phosphorus loads based on actual data are plotted against corresponding flows in Figure 18. The target load line corresponding with the TP concentration of 0.1 mg/L is plotted on the same graph along with a linear exceedance regression line and an upper 95% confidence line. The last two lines are derived from statistical analysis of exceedances (TP results above 0.1 mg/L) shown in Table 8. The percent reduction in total phosphorus loads (difference between the upper 95 percent confidence limit of the exceedance regression and the target load) is calculated to maintain compliance with a 0.1 mg/L TP standard for the stream.

Table 8 Manasquan River at Squankum (01408000)

SUMMARY OUTPUT FOR EXCEEDANCES AT MANASQUAN AT SQUANKUM

Regression Statistics	
Multiple R	0.917267749
R Square	0.841380124
Adjusted R Square	0.698522981
Standard Error	32.02885811
Observations	8

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	38090.40523	38090.41	37.13066	0.000889236
Residual	7	7180.934261	1025.848		
Total	8	45271.33949			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.917551803	0.090081788	10.18576	1.89E-05	0.704542375	1.1305612

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

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

Required TP Load Reduction based on the regression line:

$$(1-\frac{0.539}{0.9176})x100\% = 0.41259x100\% = 41.3\%$$

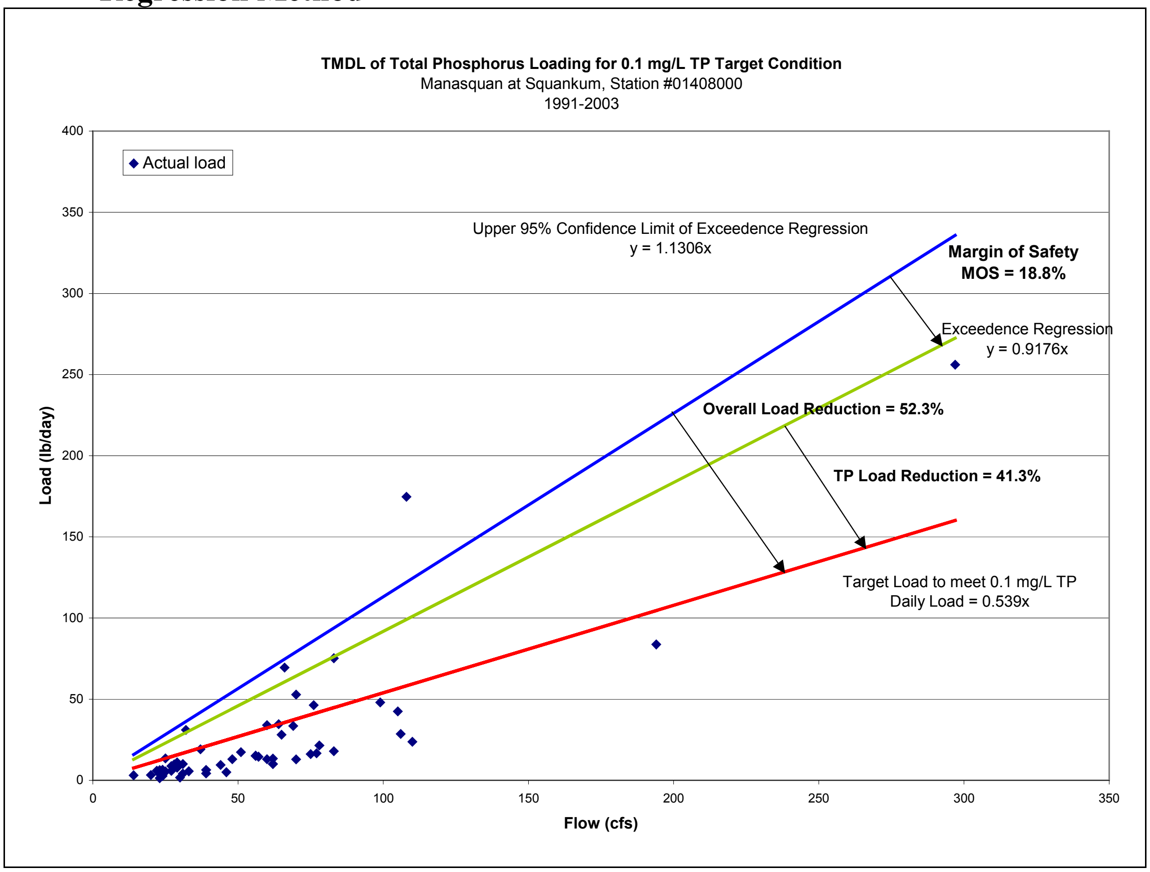
TP Load reduction required, based on the Upper 95% Confidence Limit of the regression line:

$$(1-\frac{0.539}{1.1306})x100\% = 0.5233x100\% = 52.3\%$$

MOS = $(1-\frac{0.9179}{1.1306})x100\% = 0.1881x100\% = 18.8\%$

The loading capacity **(LC)** for the Manasquan River at Squanqum station is determined by 41.3 percent reduction on the existing loading, of which 18.8 percent will be a margin of safety (MOS).

Figure 18 Estimated Percent Reduction for the Manasquan River at Squankum Using a Regression Method



The same method was used for the Long Brook (Killtime Brook) segment, the Monmouth County Health Department's station #25 (MCHD 25), located on the up-stream site of the Howell Road bridge in Howell Township. The data set consisted of 16 TP concentration data without the corresponding flows. Six TP results exceeded 0.1 mg/L SWQS. The flow rates corresponding to each TP result were derived in two steps from the continuous flow measurements at the USGS station 01408000 (Manasquan River at Squankum). The technique of obtaining flows corresponding to each sampling event and developing a flow equations are presented in Appendix E.

Table 9 Long Brook at Howell Rd in Howell Twp. (MCHD #25)

Summary output for exceedences TP > 0.1 mg/L

Regression Statistics	
Multiple R	0.999814103
R Square	0.99962824
Adjusted R Sq	0.79962824
Standard Error	1.106966165
Observations	6

ANOVA

	df	SS	MS	F	Significance F
Regression	1	16474.58	16474.58	13444.53	3.3178E-08
Residual	5	6.12687	1.225374		
Total	6	16480.71			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	1.132625535	0.008752	129.4176	5.22E-10	1.11012859	1.15512248

To achieve SWQS of 0.1 mg/L TP, the required reductions are as follows:

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

Required TP Load Reduction based on the regression line (from Figure 19):

$$(1-\frac{0.539}{1.1326})x100\% = 0.5241x100\% = 52.4\%$$

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

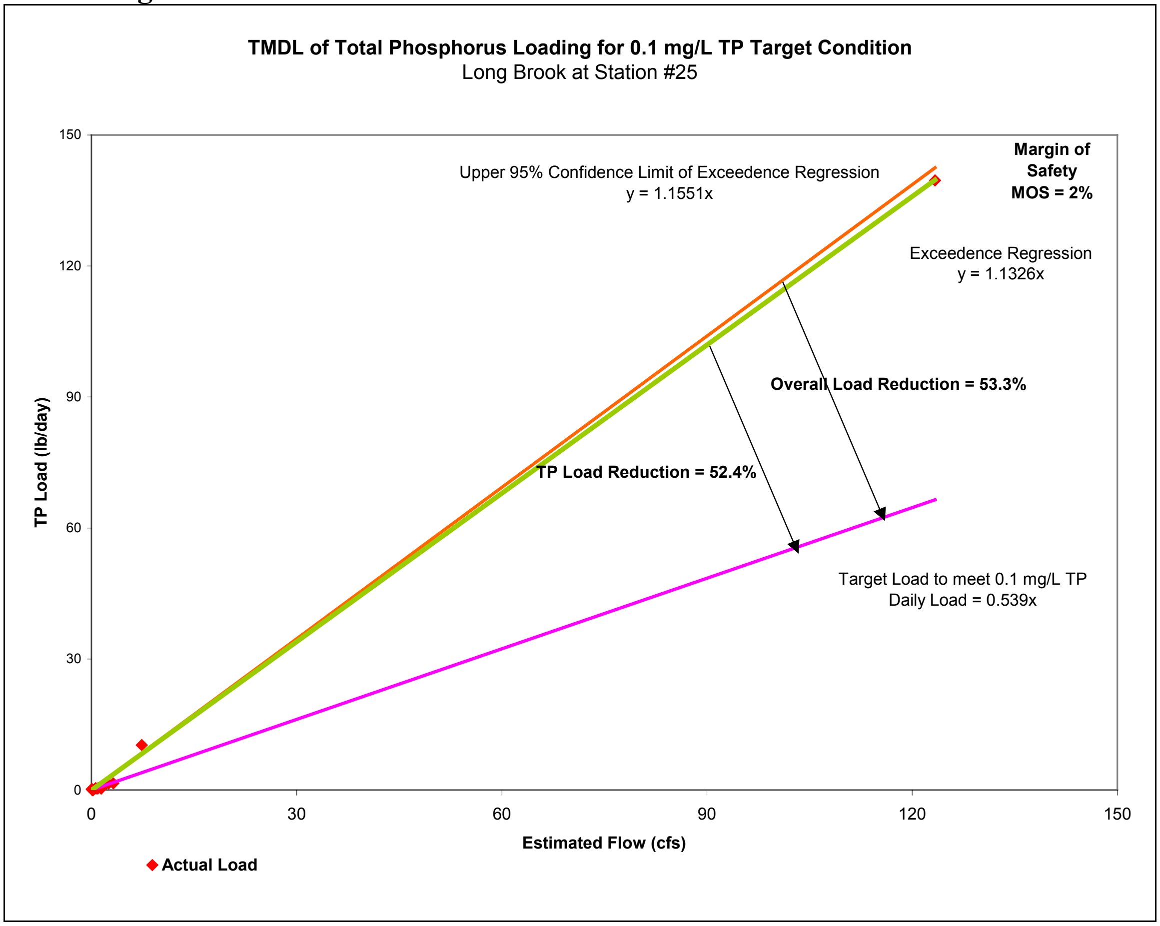
$$(1-\frac{0.539}{1.1551})x100\% = 0.5333x100\% = 53.3\%$$

The loading capacity (LC) is determined by 52.4% reduction on the existing loading, of which 1.9% will be a margin of safety (MOS):

$$\text{MOS} = (1-\frac{1.1326}{1.1551})x100\% = 0.01948x100\% = 1.9\%$$

The loading capacity **(LC)** for the Long/Killtime Brook is determined by 52.4 percent reduction on the existing loading, of which 1.9 percent will be a margin of safety (MOS).

Figure 19 Estimated Percent Reduction for the Long Brook (Killtime Brook) Using a Regression Method



Given the upper bound target concentration of 0.1 mg/l, the loading capacities were calculated for Long/Killtime Brook and Manasquan River at Squankum watersheds, which were 207.6 kg/year and 4392 kg/year, respectively; see Table 12 and 13.

Loading capacity for the Manasquan River at Squankum watershed includes the load from Long/Killtime Brook watershed and from Marsh Bog Brook watershed. Because phosphorus loadings from the Marsh Bog Brook watershed do not exceed target loading at 0.1 mg/L TP, SWQS for streams, the future load from Marsh Bog Brook is equal to the existing load from the land uses.

Table 10 Current condition, target condition and overall percent reduction

Segment	Current Condition [TP] (kg/day/cfs)	Target Condition [TP] (kg/day/cfs)	% overall TP load reduction
Long Brook Impaired Segment 25, 01407868	0.525	0.245	53.3
Manasquan River Watershed at Squankum 01408000	0.516	0.245	52.3

Critical Condition

The regression analysis represents the entire range of flows from which the total phosphorus data were collected. The loading reduction calculated to attain SWQS will do so under both low and high flow conditions, according to the data available. High flow conditions reflect critical conditions because sources are primarily nonpoint in nature. Therefore, the TMDL addresses critical conditions.

Allocation of Loading Capacity

USEPA regulations at 40 CFR § 130.2(i), state that "pollutant loadings may be expressed in terms of either mass per time, toxicity, or other appropriate measure." For the nutrient TMDLs, it is appropriate to express the TMDL on a annual basis. Long-term average pollutant loadings are typically more critical to overall water quality due to the storage and recycling mechanisms in the bottom sediments.

The TMDLs for total phosphorus are therefore calculated as follows:

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

Point sources by definition include domestic wastewater treatment plants, industrial wastewater treatment plants, industrial storm sewers and municipal stormwater facilities (MS4s) regulated under the Phase II stormwater permitting program. There are no wastewater treatment plants discharging within the impaired segments. A list of pertinent NJPDES permitted dischargers is provided in Appendix D. The permits for these facilities are general permits. These facilities do not generate phosphorus above levels normally associated with the land use category and the permits do not include phosphorus monitoring. Phosphorus loads to surface water associated with these facilities result from the land use as a category. To establish the WLA for regulated stormwater, the phosphorus loads attributed to land uses associated with regulated stormwater are assigned a reduction comparable to the phosphorus loads attributed to land uses associated with unregulated stormwater, which is expressed as a load allocation. This distribution of loading capacity between WLAs and LAs is consistent with recent EPA guidance that clarifies existing regulatory requirements for establishing WLAs for stormwater discharges (Wayland, November 2002). Stormwater discharges are captured within the runoff sources quantified according to land use, as described previously. Distinguishing between regulated and unregulated stormwater is necessary in order to express WLAs and LAs numerically; however, "EPA recognizes that these allocations might be fairly rudimentary because of data limitations and variability within the system" (Wayland, November 2002, p.1). Therefore allocations are established according to source categories as shown in Table 11. This demarcation between WLAs and LAs based on land use source categories is not perfect, but it represents the best estimate defined as narrowly as data allow. The Department acknowledges that there may be stormwater sources in the residential, commercial, industrial and mixed urban runoff source categories that are not NJPDES-regulated. Nothing in these TMDLs shall be construed to require the Department to regulate a stormwater source under NJPDES that would not already be regulated as such, nor shall anything in these TMDLs be construed to prevent the Department from regulating a stormwater source under NJPDES. WLAs are hereby established for all NJPDES-regulated point sources, including stormwater, according to their source category. Quantifying WLAs and LAs according to source categories provides the best estimation defined as narrowly as data allow. The WLAs and LAs in Tables 12-13 are not themselves "Additional Measures" under proposed N.J.A.C. 7:14A-25.6 or 25.8.

Table 11 Distribution of WLAs and LAs among source categories

Source category	TMDL allocation
Nonpoint and Stormwater Sources	
medium / high density residential	WLA
low density / rural residential	WLA
commercial	WLA
industrial	WLA
Mixed urban / other urban	WLA
agricultural	LA
forest, wetland, water	LA
barren land	LA

In order to attain the TMDLs, the overall load reductions shown in Table 10 must be achieved. Since loading rates have been defined for at least eight source categories, countless combinations of source reductions could be used to achieve the overall reduction target. The allocation of loading capacity includes a portion reserved for the Margin of Safety. In addition, the current loading is assumed to be unchangeable for certain types of land use, such as forest/wetland/water and barren land. Therefore, the reduction from other loading sources needs to be sufficient to achieve the necessary overall load reductions with no change from forest/wetland/water and barren land. Equal percent reduction is applied to all the loading sources that can be affected by BMP implementation. The reduction rate is calculated to be 53.3% for the Long Brook watershed and 57.1% for the remaining portion of the Manasquan River watershed excluding Marsh Bog Brook (not impaired) and Long/Killtime Brook (reduction rate already calculated) watersheds. The current loading from each type of land use is used to calculate the allocation based on the reduction rate.

The Stream Restoration Plans developed for each watershed as part of the TMDL implementation (Section 8) may revisit the distribution of reductions among the various sources in order to better reflect actual implementation projects. The resulting TMDLs are shown in Tables 12-13 and illustrated in Figures 20 and 21.

Table 12 TMDL calculations for the Long Brook watershed

	Long Brook/Killtime Brook		% reduction
	kg TP/yr	% of LC	
Loading capacity (LC)	207.6	100%	n/a
Load allocation			
Point Sources other than Stormwater	n/a		
Nonpoint and Stormwater Sources			
medium / high density residential	31.59	15.2	57.1%
low density / rural residential	28.34	13.6	57.1%
commercial	10.94	5.3	57.1%
industrial	9.254	4.5	57.1%
mixed urban / other urban	12.83	6.2	57.1%
agricultural	82.12	39.6	57.1%
forest, wetland, water	21.47	10.3	0%
barren land	7.150	3.4	0%
Margin of Safety	3.924	1.9	n/a

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

Figure 20 Phosphorus allocations for the Long Brook Watershed

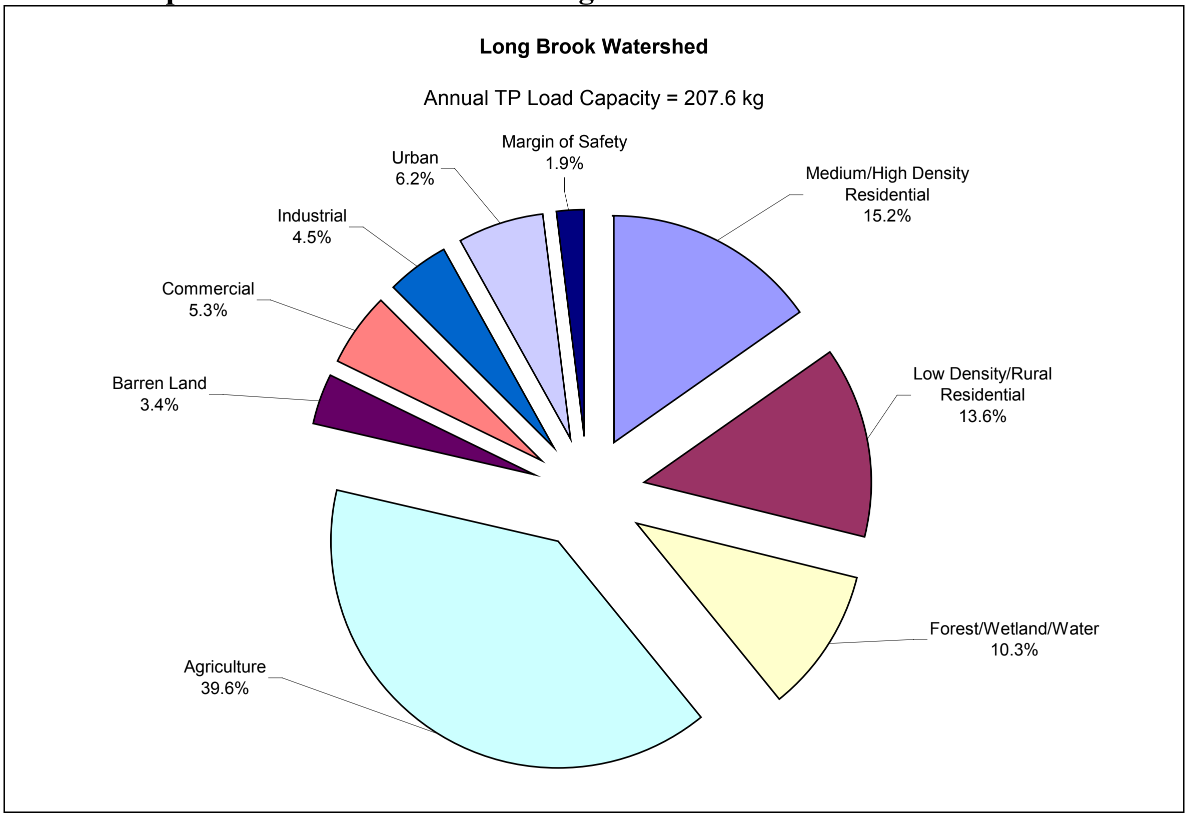
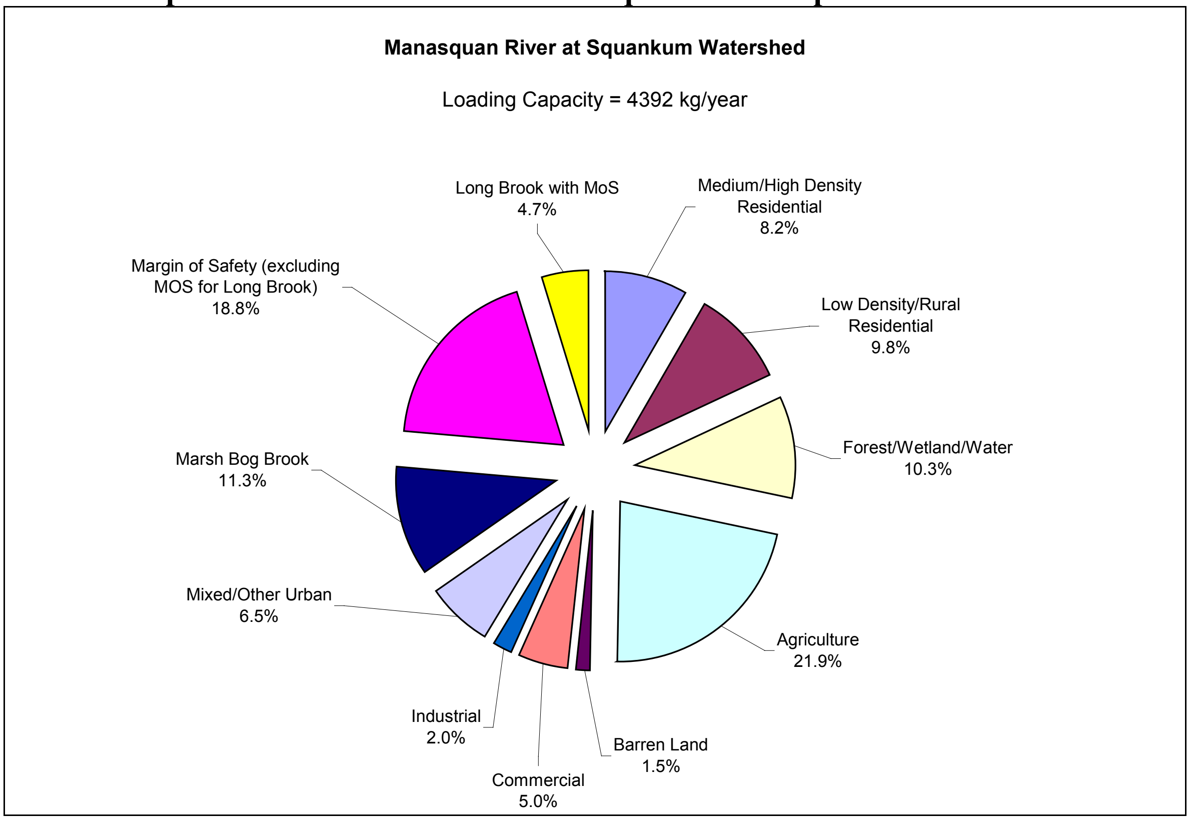


Table 13 TMDL calculations for the impaired Manasquan River at Squankum watershed

	Manasquan River at Squankum		% reduction
	kg TP/yr	% of LC	
Loading capacity (LC)	4392	100%	n/a
Load Allocation			
Point Sources other than Stormwater	n/a		
Nonpoint and Stormwater Sources			
medium / high density residential	361.6	8.2	61.3
low density / rural residential	432.0	9.8	61.3
commercial	219.2	5.0	61.3
industrial	87.23	2.0	61.3
Mixed urban / other urban	286.7	6.5	61.3
agricultural	961.7	21.9	61.3
forest, wetland, water	450.5	10.3	0
barren land	67.41	1.5	0
Long Brook (after reduction)	207.6	4.7	n/a
Marsh Bog Brook	494.4	11.3	0
Margin of Safety	1360	18.8	n/a

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

Figure 21 Phosphorus allocations for the Manasquan River impaired watershed



Margin of Safety

For these TMDL calculations, an implicit MOS is inherent in the estimates of current pollutant loadings and treating phosphorus as a conservative substance. For the Long Brook stream segment, the percent loading reduction is the difference in slopes between the upper 95 percent confidence limit of the exceedances regression line and the target loading regression line, i.e., (1 - 0.539/1.1551) x 100 = 53.3 percent. An explicit MOS is included within the upper 95 percent confidence interval about the slope of the regression line of the exceedances. The upper 95 percent confidence limit about the slope provides an estimate of the possible range where there is a 95 percent certainty that the slope will be located. Therefore, the confidence limit provides a margin of safety for the statistical certainty of the regression slope for the TMDL. The margin of safety is a difference between the upper 95 percent confidence limit of the exceedances regression line and the exceedance regression line; in this case the explicit MOS is approximately 2 percent: (1 - 1.1326/1.1551) x 100%.

For the Manasquan River at Squankum segment, the percent loading reduction is the difference in slopes between the upper 95 percent confidence limit of the exceedances regression line and the target loading regression line, i.e., (1 - 0.539/1.1306) x 100% = 52.3 percent. An explicit MOS is included within the upper 95 percent confidence interval about the slope of the regression line of the exceedances. The upper 95 percent confidence limit about the slope provides an estimate of the possible range where there is a 95 percent certainty that the slope will be located. Therefore, the confidence limit provides a margin of safety for the statistical certainty of the regression slope for the TMDL. The margin of safety is a difference between the upper 95 percent confidence limit of the exceedances regression line and the exceedance regression line; in this case the explicit MOS is approximately 18.8 percent: (1 - 0.9176/1.1306) x 100%. The detailed calculations of phosphorus reduction requirements with the recalculated margins of safety for both impaired segments are presented in the same section under TMDL Development Procedure.

Reserve Capacity

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

7.0 Follow-up Monitoring

The Water Resources Division of the U.S. Geological Survey and the Department have cooperatively operated the Ambient Stream Monitoring Network (ASMN) in New Jersey since the 1970s. The ASMN currently includes approximately 115 stations that are routinely monitored on a quarterly basis. A second ambient monitoring network, DEP's Supplemental Ambient Surface Water Network (100 stations), has improved spatial coverage for water quality monitoring in New Jersey. The data from this these networks have been used to assess the quality of freshwater streams and percent load reductions. The ambient networks, as well as targeted studies, will be the means to determine the effectiveness of TMDL implementation and the need for additional management strategies.

8.0 Implementation

The Department recognizes that TMDLs alone are not sufficient to restore impaired stream segments. The TMDL establishes the required nutrient reduction targets and provides the regulatory and non-regulatory tools, matching management strategies with sources, determining responsible entities and aligning available resources to assist with implementation activities. The Department's ongoing watershed management initiative will develop stream restoration plans for priority segments using available resources.

Point Sources

The NJPDES permitted stormwater facilities in this watershed must be assigned WLAs. The WLAs for these point sources are expressed in terms of the required percent reduction for nonpoint sources and is applied to the land use categories that correspond to the areas regulated under industrial and municipal stormwater programs. The BMPs required through these permits are expected to achieve the required load reduction, which will be assessed through follow up monitoring. As needed through adaptive management, additional measures may need to be identified and included in stormwater permits. A more detailed discussion of the municipal stormwater control measures follows.

Stormwater Regulation

On February 2, 2004 the Department promulgated two sets of stormwater rules: The Phase II New Jersey Pollutant Discharge Elimination System (NJPDES) Stormwater Rules, N.J.A.C. 7:14A and the Stormwater Management Rules, N.J.A.C. 7:8

The Phase II NJPDES Stormwater rules require municipalities, counties, highway systems, and large public complexes to develop stormwater management programs consistent with the NJPDES permit requirements. The stormwater discharged through "municipal separate storm sewer systems" (MS4s) is regulated under the Department's Phase II NJPDES stormwater rules. Under these rules and associated general permits, the municipalities (and various county, State, and other agencies) in the Manasquan River watershed are required to implement various control measures. These control measures include adoption and enforcement of pet waste disposal ordinances, prohibiting the feeding of unconfined wildlife on public property, cleaning catch basins, performing good housekeeping at maintenance yards, and providing related public education and employee training. Follow up monitoring may determine that additional measures are required, which would then be incorporated into Phase II permits. Additional measures that may be considered may include, where feasible, retrofit of stormwater management facilities to include water quality controls, conversion to bioretention facilities, or reconfiguring to allow non-erosive, distributed flow to be discharged through vegetated stream buffers, low phosphorus fertilizer ordinances and goose management plans. .

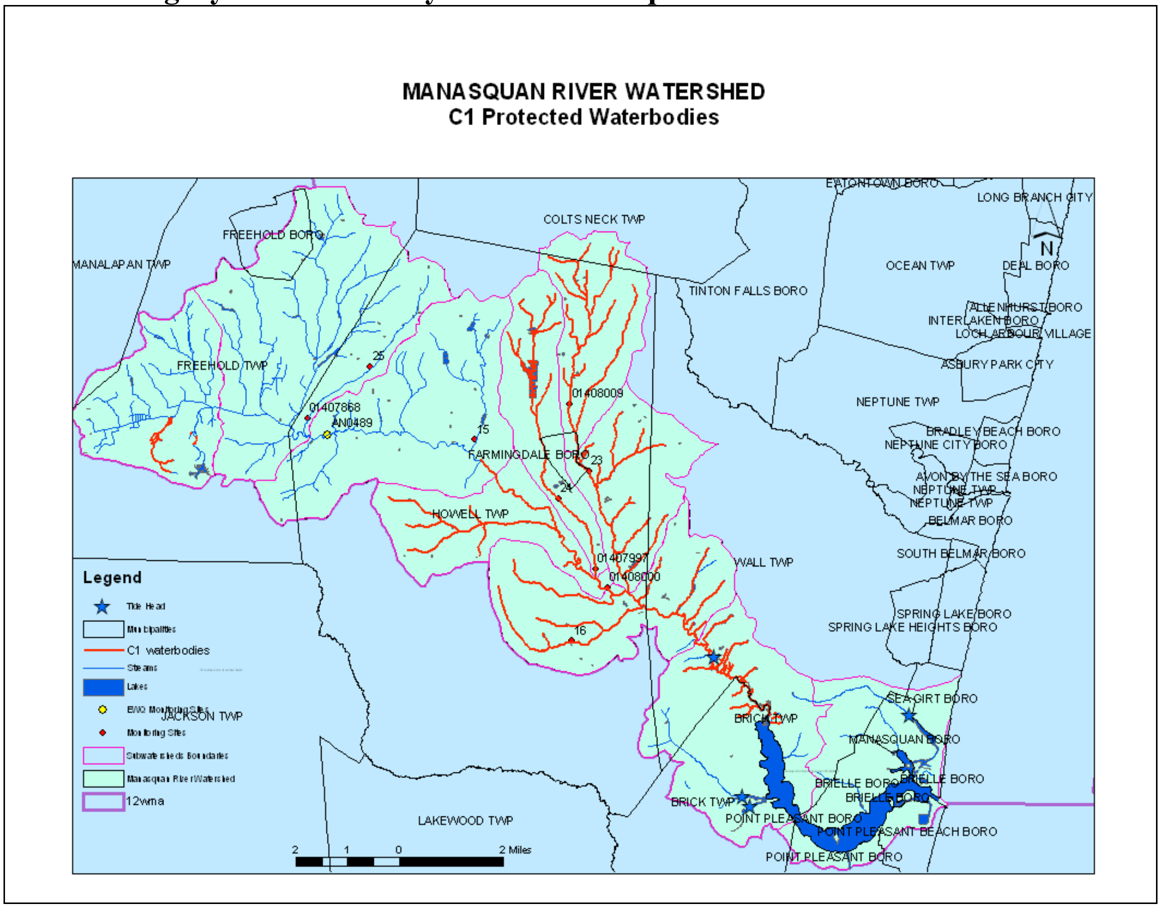
The Stormwater Management Rules have been updated for the first time since their original adoption in 1983. These rules establish statewide minimum standards for stormwater management in new development, and the ability to analyze and establish region-specific performance standards targeted to the impairments and other stormwater runoff related issues within a particular drainage basin through regional stormwater management plans. The Stormwater Management rules are currently implemented through the Residential Site Improvement Standards (RSIS) and the Department's Land Use Regulation Program (LURP) in the review of permits such as freshwater wetlands, stream encroachment, CAFRA, and Waterfront Development.

The Stormwater Management Rules focus on the prevention and minimization of stormwater runoff and pollutants in the management of stormwater. The rules require every project to evaluate methods to prevent pollutants from becoming available to stormwater runoff and to design the project to minimize runoff impacts from new development through better site design, also known as low impact development. Some of the issues that are required to be assessed for the site are the maintenance of existing vegetation, minimizing and disconnecting impervious surfaces, and pollution prevention techniques. In addition, performance standards are established to address existing groundwater that contributes to baseflow and aquifers, to prevent increases to flooding and erosion, and to provide water quality treatment through stormwater management measures for TSS and nutrients.

As part of the requirement under the NJPDES Phase II program, municipalities are required to adopt and implement municipal stormwater management plans and stormwater control ordinances consistent with the requirements of the stormwater management rules. As such, in addition to changes in the design of projects regulated through the RSIS and LURP, municipalities will also be updating their regulatory requirements to provide the additional protections in the stormwater management rules within approximately two years of the issuance of the NJPDES General Permit Authorization.

Furthermore, the New Jersey Stormwater Management rules establish a 300-foot special water resource protection area (SWRPA) around Category One (C1) waterbodies and their intermittent and perennial tributaries, within the HUC 14 subwatershed. In the SWRPA, new development is typically limited to existing disturbed areas to maintain the integrity of the C1 waterbody. C1 waters receive the highest form of water quality protection in the state, which prohibits any measurable deterioration in the existing water quality. Figure 22 shows the category one (C1) waterways in the Manasquan River watershed as amended on August 2, 2004. Definitions for surface water classifications, detailed segment description, and designated uses are provided in the August 2, 2004, Amendment to Surface Water Quality Standards at www.state.nj.us/dep/wmm/sgwqt/swqsdocs.html.

Figure 22 Category One Waterways at the Manasquan River Watershed



Non-point sources

For the purposes of a TMDL document, nonpoint sources include stormwater that is not regulated under NJPDES and all other nonpoint sources, such as effluent from septic tanks and direct inputs from domestic animals and wildlife that access water bodies.

Generic management strategies for various source categories, beyond those under the Phase II stormwater management program, and responses are summarized below, followed by specific planned and ongoing short-term and long-term management strategies.

Table 14 Non-point source management

Source Category	Responses	Potential Responsible Entity	Possible Funding options
Human Sources	Low phosphorus fertilizer ordinances, septic system management programs	Municipalities, residents, watershed stewards, property owner	319(h), State sources
Non-Human Sources	Goose management programs	Municipalities, residents, watershed stewards, property owner	319(h), State sources
Agricultural practices	Develop and implement conservation plans or resource management plans	Property owner	EQIP, CRP, CREP

Agricultural measures

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

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

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

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

Segment Specific Assessment and Management Measures

Short-Term Management Measures:

Short-term management measures include projects recently completed; underway or planned that will address sources of phosphorus load. Short-term management strategies include existing projects dubbed "Action Now" that are on the ground projects funded by the Department to address NPS impairments to an impaired waterbody. Funding sources include Clean Water Act 319(h) NPS funds and other state sources.

In FY 02, Friends of Monmouth County Park System received a $100,000 section 319(h) grant, entitled "Riparian Restoration in the Manasquan Watershed". It involved a streamside assessment of park system lands to identify damaged riparian areas and appropriate BMP's for their restoration. The priority sites will be targeted for restoration first and each site will be addressed as resources allow. The remaining restoration sites and cost estimates for improving water and habitat quality will also be provided to the Department and other partners for implementation. The NRCS Stream Assessment Protocol combined with elements of Rosgen Analysis will be used in the assessment.

In 2002, Princeton Hydro (Princeton Hydro, LLC, 2002) presented the results of the Rosgen based analysis of portions of the Manasquan River watershed. Rosgen analysis is a tool that characterizes stream channels by their natural geomorphology for the purpose of restoring the channel. This study developed a conceptual stabilization approach to address portions of the Manasquan River watershed experiencing high streambank erosion. The specific area of interest included the Manasquan River from its headwater areas in Freehold and Howell Townships, to a point upstream of the Squankum Dam, in Howell Township.

This study evaluated seven stream segments within the Manasquan River watershed using the Rosgen Level I, II, and III classification methods. The Rosgen Level II analysis resulted in classifying each of the stream segments, except the reference site (Cattail Brook) as F5. The reference site was classified as C5/E5 (Princeton Hydro, 2002). An F5 stream type is characterized as a sand dominated, entrenched, meandering channel, deeply incised in gentle terrain. The "top of banks" elevation for this stream type is much greater than the bankfull stage which is indicative of the deep entrenchment. An F5 stream type is also characterized as having a slope range of < 0.02, entrenchment ratio of < 1.4, a width/depth ratio of >12 and a sinuosity of >1.2. Stream bank erosion rates are very high due to side slope rejuvenation and mass-wasting processes which enhance the entrapment of eroded materials (Rosgen, 1996). Additional results from the Rosgen study are presented in Table 8 below.

Table 15 Results from the Assessment of the Manasquan River, Final Report (Princeton Hydro, LLC, 2002).

Stream Segment	Rosgen Level II Type	Streambank Erosion Potential	Stream Bank Stability
Unnamed Trib – Polo Club Drive	F5	moderate	fair
Applegates Creek	F5	low to moderate	fair
DeBois Creek	F5	moderate to high	fair
Manasquan R. – Bergerville	F5	very high	poor
Manasquan R. – Fishing Access	F5	high	poor
Manasquan R. – Squankum	F5	low	poor
Reference – Cattail Brook	C5/E5	low	good

Reasonable Assurance

Reasonable assurance for the implementation of these TMDLs has been considered for point and nonpoint sources for which phosphorus load reductions are necessary. Moreover, stormwater sources for which WLAs have been established will be regulated as NJPDES point sources.

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

Ambient monitoring will be evaluated to determine if additional strategies for source reduction are needed.

9.0 Public Participation

The Water Quality Management Planning Rules NJAC 7:15-7.2 require the Department to initiate a public process prior to the development of each TMDL and to allow public input to the development of the TMDL. Further, the Department shall propose each TMDL as an amendment to the appropriate areawide water quality management plan in accordance with procedures at N.J.A.C. 7:15-3.4(g). As part of the public participation process for the development and implementation of the TMDLs for phosphorus in the Atlantic Coastal Water Region, the Department worked collaboratively with stakeholders in WMA 12. Stakeholder meetings were held on April 6, 2005 to explain the TMDL document. The purpose of the informal meetings was for stakeholders to identify areas of concern based on their local knowledge. The stakeholders were encouraged to provide any additional source information through the formal comment period after advertisement of the TMDL proposal in the New Jersey Register.

Amendment Process

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

Notice proposing these TMDLs was published on May 16, 2005, 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 June 20, 2005. Notice of the proposal and the hearing was provided to applicable designated planning agencies and to affected municipalities.

Appendix A References

BASIN - New Jersey, Version 1.0. December 2004. Prepared by Tetra-Tech, Inc.

Kratzer, Todd W., Flow-Integrated Load Reduction Estimation Technique for TMDLs, Water Environment Federation, June 2005 (In Progress).

Jablonski CF. 1989, Soil Survey of Monmouth County, New Jersey, ILL Number: 563976. Soil Survey of Monmouth County New Jersey, April 1989, United States Department of Agriculture, Soil Conservation Service.

Manasquan Watershed Management Group. 1999. Manasquan River Watershed, Initial Characterization and Assessment Report.

Monmouth County Health Department. 1999. The Manasquan River Watershed, A Trend Analysis focusing on impact to water quality, prepared for The Manasquan Watershed Management Group.

Monmouth County Department of Health. 2003. Ambient Stream Monitoring Program, Ambient Monitoring Data for the years 2001, 2002.

National Research Council, Assessing the TMDL Approach to Water Quality Management. National Academy Press, Washington, D.C. 2001

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

New Jersey Department of Environmental Protection, Water Assessment Team. 1999. Initial Surface Water Quality Characterization and Assessment Report (Based on DEP Data) for Watershed Management Area 12.

New Jersey Department of Environmental Protection. 2002. Draft Technical Approaches to Restore Impaired Waterbodies in the Non-tidal Manasquan River Watershed. Presented to Watershed Management Area 12 TMDL/303(d) Committee and New Jersey EcoComplex.

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

New Jersey Department of Environmental Protection. 2003b. Integrated Water Quality Monitoring and Assessment Methods.

New Jersey Department of Environmental Protection. 2004a. Surface Water Quality Standards. N.J.A.C. 7:9B.

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

New Jersey Geological Survey, Technical Memorandum 98-1. 1998. Comprehensive Chemistry of Selected Greensand from the New Jersey Coastal Plain., Dooley, N.J. Department of Environmental Protection-Division of Science and Research

Princeton Hydro, LLC. 2002. Final Report Assessment of the Manasquan River, Monmouth County, New Jersey. Prepared for Watershed Management Area 12 Executive Committee Monmouth County Board of Health. Project No. 257.01.

Princeton Hydro, LLC. 2001. Interim Report, Assessment of the Manasquan River, Monmouth County, New Jersey. Prepared for Monmouth County Board of Health.

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

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

Tedrow, J.C.F. 1986. Soils of New Jersey, Published: Robert E. Krieger Publishing Company, Malabar, Florida

Tedrow, J.C.F. 2002. Greensand and Greensand Soils of New Jersey: A Review.

Thomas, T.A. 1999. Manasquan River Watershed, Land Development Capacity Analysis. Prepared for: The Manasquan River Watershed Management Group.

Tiedemann, John A. 1999. Manasquan River Watershed Initial Characterization and Assessment Report. Prepared for: The Manasquan Watershed Management Group.

U.S. Department of Agriculture, Soil Conservation Services, April 1989. Soil Survey of Monmouth County, New Jersey.

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

U.S.E.P.A., 2003. Guidance for 2004 Assessment, Listing and Reporting Requirements Pursuant to Section 303(d) and 305(b) of the Clean Water Act.

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

Appendix B: Database of Phosphorus Export Coefficients

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

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

Export Coefficient Database Reference List:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Appendix C: Phosphorus Criterion Applicability Determination

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

Is Phosphorus Limiting?

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

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

Figures 1 and 2 show examples of how to plot pairs of TP and DRP data along a TIN/DRP axis to visually evaluate the phosphorus limitation thresholds at a particular location. By making the TP range twice the DRP range, the thresholds of 0.1 mg/l TP and 0.05 mg/l DRP coincide, simplifying the interpretation. Episodes when TP > 0.1 mg/l AND DRP $\leq$ 0.05 mg/l and TIN/DRP $\geq$ 5 can be identified by seeing TP in the upper right quadrant while DRP is in the lower right quadrant. If phosphorus cannot be excluded as the limiting nutrient for more than 10% of the samples that exceed the 0.1 mg/l threshold (a minimum of 2 samples), then the 0.1 mg/l criterion is applicable.

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

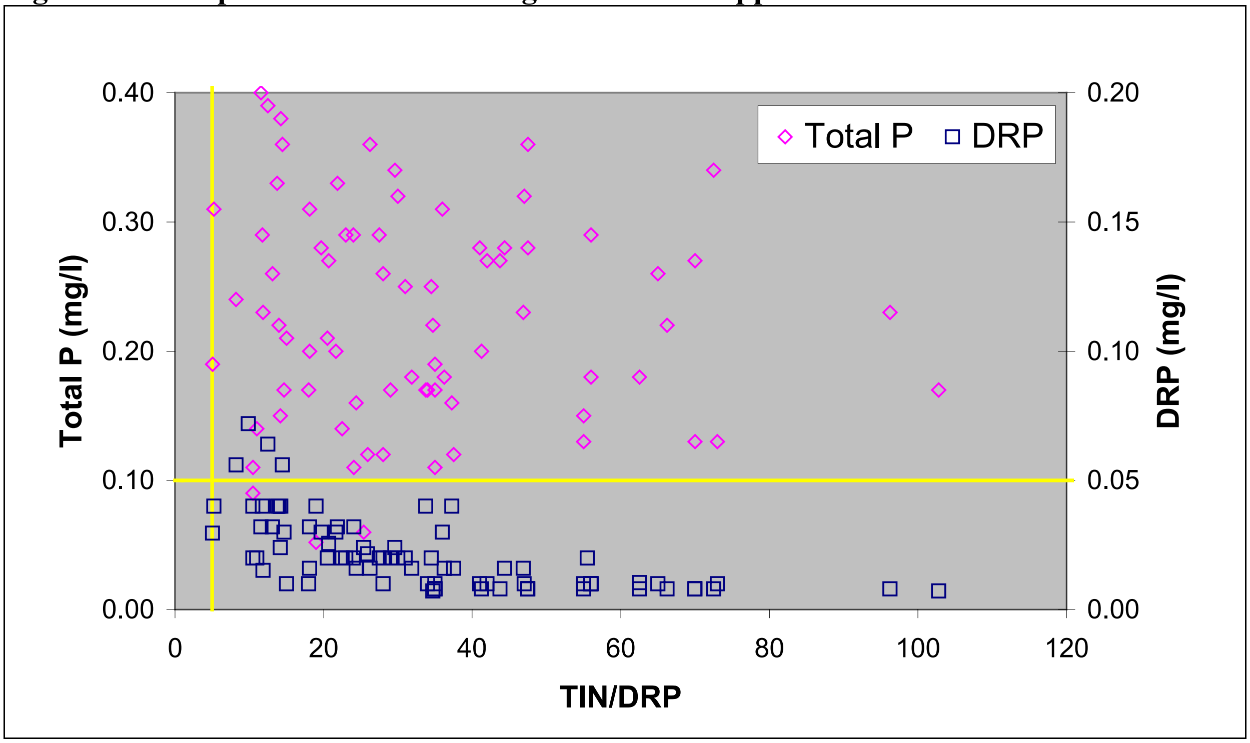
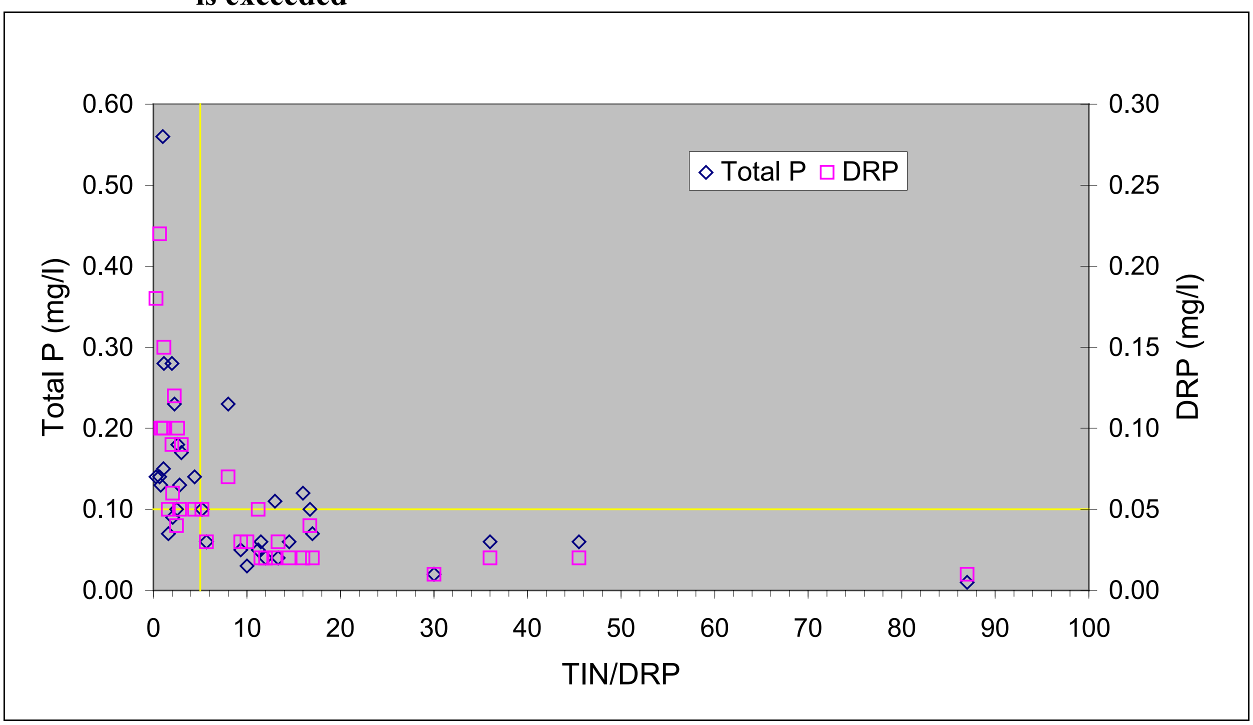


Figure 2: Example of site where phosphorus is not limiting algal growth when 0.1 mg/l threshold is exceeded



Appendix D: Active NJPDES Permitted Discharges in the Manasquan River Watershed

NJPDES ID	PI	Facility Name	Municipality	Street Address	Receiving Waters/HUC14	Category Code
NJG0117617 (NJ0068837)	46976	American Vitamin Company (Cooper Develop.)	Freehold Twp	505 Halls Mill Rd	Applegates Creek (02030104100020)	5G2
NJG0142719	190139	Anchor Concrete Products Inc	Howell Twp	103 Yellowbrook Rd	Marsh Bog Brook (02030104100040)	CPM
NJ0061824	46395	Angle Inn Mobile Home Park	Howell Twp	1235 Rt 33	(02030104100030)	GW
NJG0089630	46395	Angle Inn Mobile Home Park	Howell Twp	1235 Rt 33	(02030104100030)	T1
NJG0139521	96226	Arnold Steele Compant, Inc.	Howell Twp	79 Randolph Rd	DeBois Creek (02030104100020)	5G2
NJG0115339	48239	Asbury Park Press	Freehold Twp	235 Willowbrook Rd	DeBois Creek (02030104100020)	5G2
NJG0140864	142181	Briar Hill School	Freehold Borough	2 Harding Rd	DeBois Creek (02030104100020)	T1
NJG0140481	133031	Cabin Restaurant	Howell Twp	984 Rt 33	(02030104100030)	T1
NJG0117803	48433	Central Concrete Corp	Howell Twp	86 Yellowbrook Rd & Cranbury Rd	Marsh Bog Brook (02030104100040)	CPM
NJG0087696	47375	Chapter House Restaurant	Howell Twp	1454 Rt 9 S	(02030104100030)	T1
NJG0134295	49756	Edge of Town Restaurant	Farmingdale Boro	72 Adelphia Rd	(02030104100040)	T1
NJ0034771	46304	Emil A Schroth Inc	Howell Twp	Yellowbrook Rd & Copper Ave	Yellow Brook (02030104100030)	RF
NJG0072681	46610	Five Points Square	Howell Twp	919 Rt 33	(02030104100030)	T1
NJG0116165	48308	Freehold Cartage Inc	Freehold Borough	825 Rt 33	Yellow Brook (02030104100030)	5G2
NJG0136948	53985	Freehold Fire Company, Inc.	Freehold Borough	191 Dutch Ln Rd	DeBois Creek (02030104100020)	B4B
NJG0084271	47228	Green Acres Manor	Howell Twp	1 Snyder Rd & West Farm Rd	Bannen Meadow Brook (02030104100030)	T1
NJG0107964	87900	Kerr Concrete Pipe	Howell Twp	89 Yellowbrook Rd	Marsh Bog Brook (02030104100040)	CPM
NJ0053511	47034	Military Sealift Command	Freehold Borough	1029 Rt 33	Yellow Brook (02030104100030)	B
NJG0131806	46666	Nestle USA Inc	Freehold Borough	61 Jerseyville Ave	DeBois Creek (02030104100020)	EG
NJ0105856	46666	Nestle USA Inc	Freehold Borough	61 Jerseyville Ave	DeBois Creek (02030104100020)	GW
NJ0005606	46666	Nestle USA Inc	Freehold Borough	61 Jerseyville Ave	DeBois Creek (02030104100020)	RF
NJG0115533	48256	NJ Transit, Bus Garage	Howell Twp	1251 Rt 9	Bannen Meadow Brook (02030104100030)	5G2
NJG0085162	47296	Pine Cone Campground	Freehold Twp	340 Geargia Rd	(02030104100010)	T1
NJG0117650	46346	Prestone Products Corporation	Freehold Twp	250 Halls Mill Rd	Applegate Creek (02030104100020)	5G2
NJ0101486	46346	Prestone Products Corporation	Freehold Twp	250 Halls Mill Rd	Applegate Creek (02030104100020)	GW
NJG0117765	48429	Ralph Clayton & Sons - Freehold	Freehold Twp	62 Institute St	DeBois Creek (02030104100020)	CPM
NJG0129755	49394	Stavola Asphalt Co - Howell Twp	Howell Twp	Yellowbrook Rd	Marsh Bog Brook (02030104100040)	R4
NJG0142344	169740	YMCA of Western Monmouth County	Freehold Borough	470 E Freehold Rd	(02030104100020)	T1

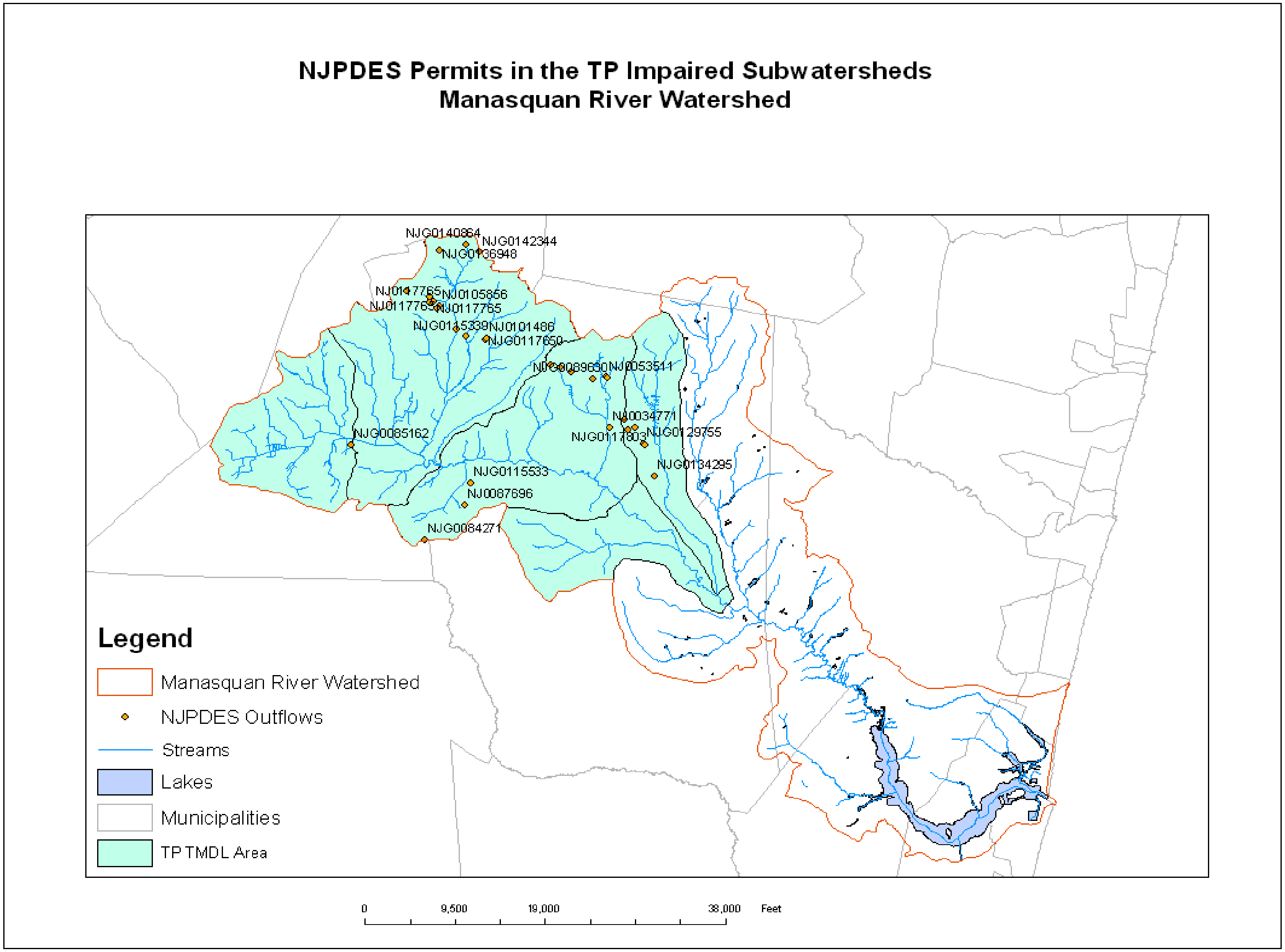
Stormwater Dischargers

SM	Scrap Metal Proc/Auto Recycling (GP)
RF	Stormwater
5G2	Stormwater Round 2 (GP)
CPM	Concrete Products Mgt. (GP)

Other Dischargers

T1	Sanitary Disposal, Permit-By-Rule
GW	Infiltration to GW
R4	Hot Mix Asphalt Production
B	Industrial/Commercial Wastwater (GP)
B4B	Petro Prod. Clean-Up of Groundwater
EG	Land App. Food Process. Residual

Figure 1 Outflows Location for Permitted Discharges in the Manasquan River Watershed



Appendix E Flow Assessment for Long Brook at Howell Road at Howell Township

Long Brook at Howell Road in Howell (site #25) was sampled by the Monmouth County Health Department (MCHD) sixteen times for total phosphorus in a period from 1995 through 2003. Six of sixteen (37.5 percent) samples exceeded the 0.1 mg/l TP of SWQS, therefore placing this site on list 5 of the Integrated List of Impaired Waters. The flow was not measured at this site during the water quality sample collection.

Flow values for Long Brook at Howell Road in Howell were derived in a two-step-calculation. In the first step, the correlation between continuous flow measurements for the Manasquan River at Squankum (USGS 01408000) and instantaneous flow measurements at Long Brook at Wyckoff Mills (USGS 01407868) derived an equation for calculating flows at the Long Brook site at any desired time. In the next step, a drainage area ratio for the lower and upper part of the Long Brook watershed was used to estimate the flows on Long Brook at Howell Road. Figure 1 illustrates a relationship between the instantaneous flow measurements at Long Brook at Wyckoff Mills and continuous flow measurements for the Manasquan River at Squankum. A drainage area ratio of 0.684, representing 1.3 mi^2 for Long Brook at Howell Road and 1.9 mi^2 for Long Brook at Wyckoff Mills, was used to estimate the flow of Long Brook at Howell Road. The resulting formulas for estimating a flow at Long Brook at Howell Road from the USGS Manasquan River gage at Squankum are presented below.

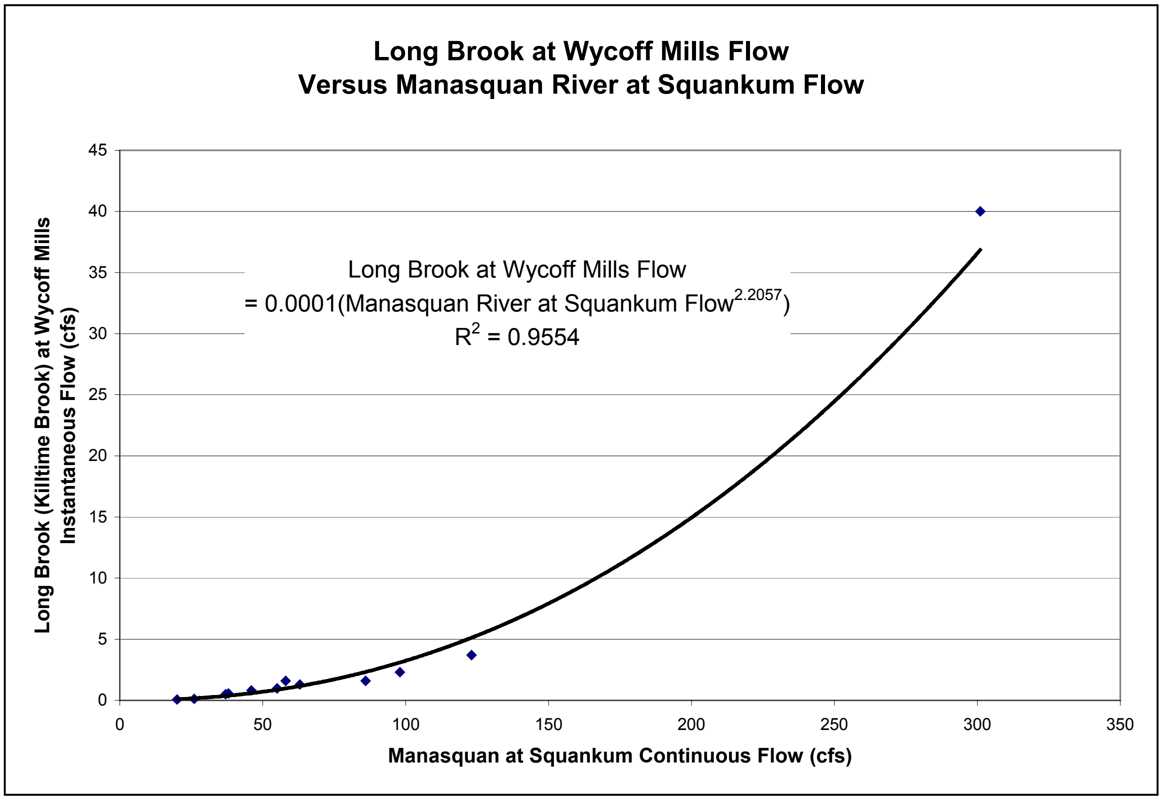
$$Q_{\text{Long Brook at Wyckoff Mills}} = 0.0001 \text{ x } Q_{\text{Manasquan}}^{2.2057}$$

Drainage area ratio between Long Brook at Wyckoff Mills and Long Brook at Howell Road equals 1.3 mi^2/1.9 mi^2 = 0.684

$$Q_{\text{Long Brook at Howell}} = (0.0001 \text{ x } Q_{\text{Manasquan}}^{2.2057}) \text{ x } 0.684$$

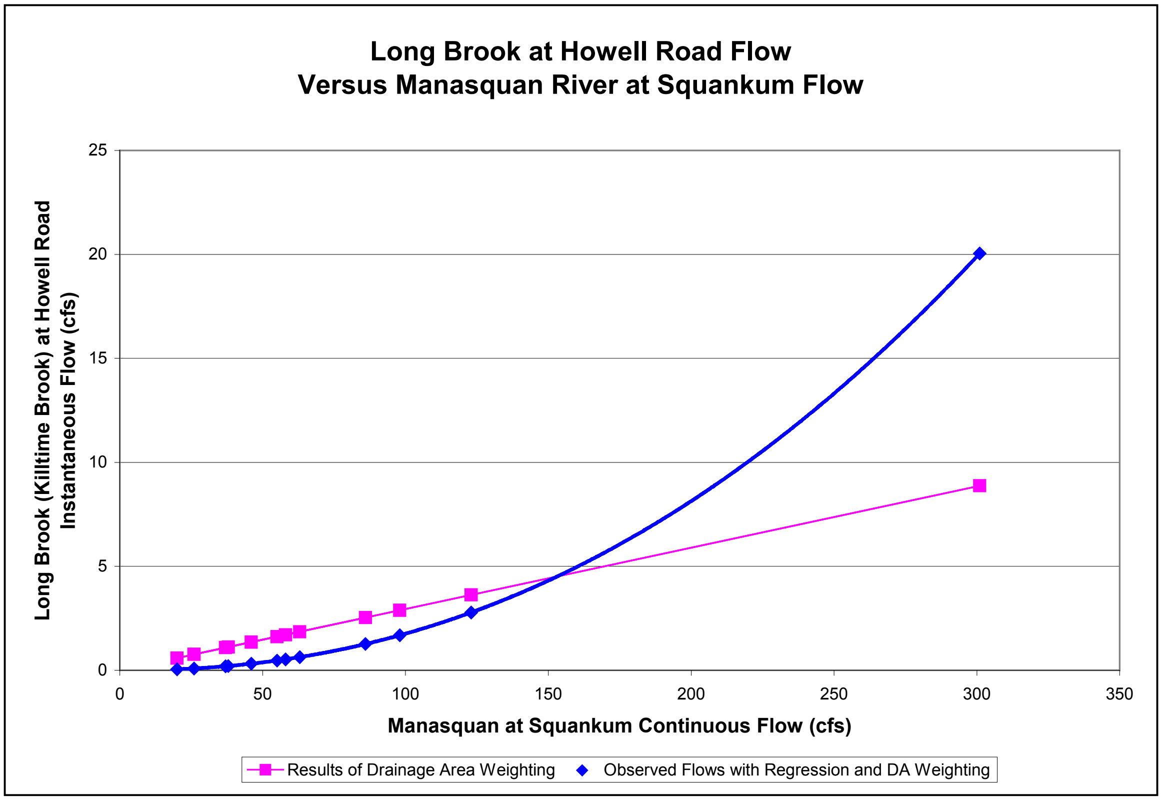
Where:
$Q_{\text{Long Brook at Wyckoff Mills}}$ = Estimated flow for Long Brook at Wyckoff Mills;
$Q_{\text{Long Brook at Howell}}$ = Estimated flow for Long Brook at Howell Road; and
$Q_{\text{Manasquan}}$ = Daily average flow for USGS gage on the Manasquan River at Squankum.

Figure 1 **Power (Log-Log) Regression of relationship between the flows of Long Brook at Wyckoff Mills and Manasquan River at Squankum**



From this set of relationships, a flow estimate can be developed for the Long Brook at Wyckoff Mills using only the sampling date for determining the average daily flow on the Manasquan River at Squankum for input to the equation. A comparison was performed to determine the difference in the resulting flow estimates if only drainage area weighting was used for deriving the flow estimate. Figure 2 shows the resulting flows for Long Brook at Howell Rd. (drainage area 1.3 mi^2) versus the average daily Manasquan River flows at Squankum (drainage area 44.1 mi^2). Clearly, using actual flow data to estimate a flow on an ungaged site from that at a gaged site more accurately represents the existing flows of the ungaged site. In this case the flow relationship between the two monitoring sites is not linear as a drainage area weighting relationship would suggest. Caution must be used when flow data are derived for a watershed that has obvious differences in geology, topography, elevation, or a combination of these in comparison to the continuous-measurement flow monitoring site.

Figure 2 **Comparison of using observed data for a combined regression and drainage area weighting relationship versus using only drainage area weighting for estimating flows for the Long Brook at Howell Rd**



Appendix F Photo-documentation from the Manasquan River Watershed

Manasquan River at Squankum, USGS continuous flow monitoring station, 01408000

Stream access below Squankum Dam

Run-off to Manasquan River at USGS Station 01408000 (Manasquan River at Squankum). Unconsolidated soil covers an unprotected slope and is washed down by runoff to a pool formed by a Squankum dam. The water quality sampling site 01408000 is approximately 60 feet from this site.

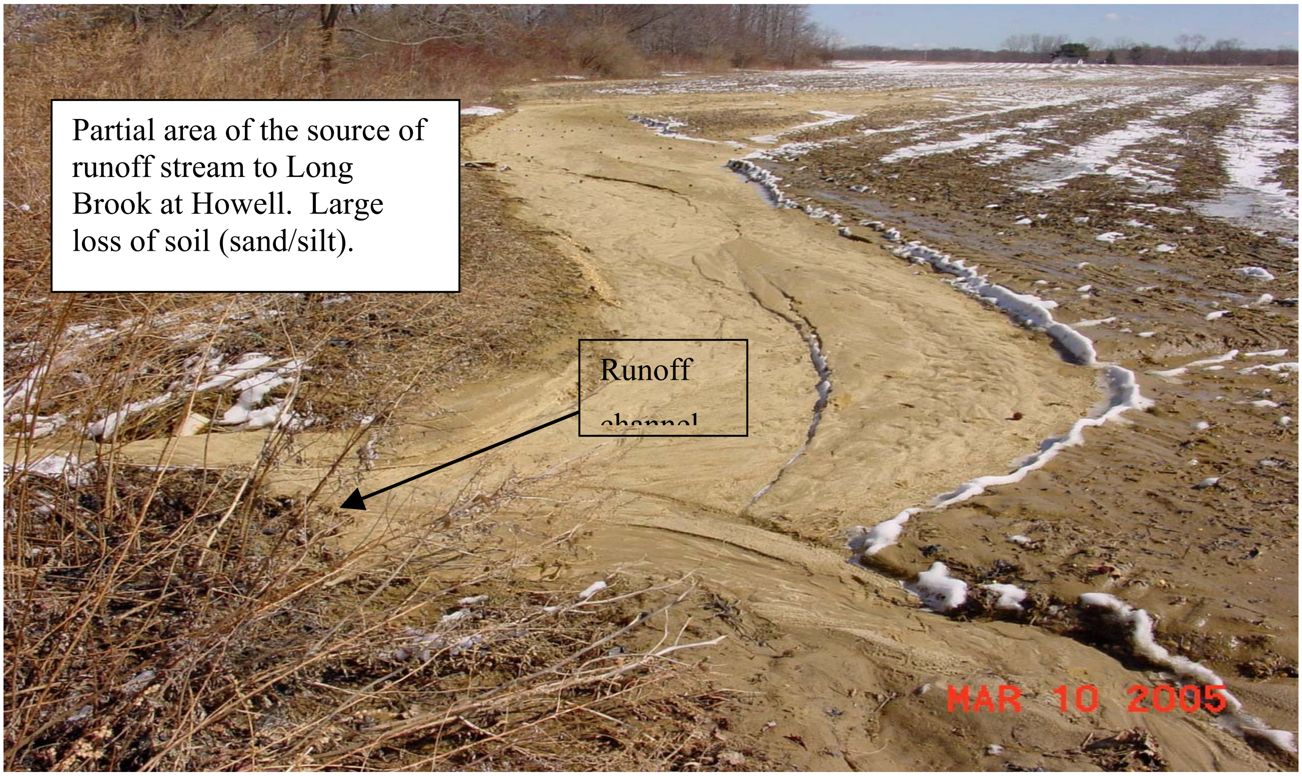
Example of banks erosion (upstream from USGS Station 01408000, Manasquan River at the Fishing Access

MCHD water quality sampling site #25, Long Brook (Killtime Brook), the upstream side of the bridge. Howell Road at Howell Township

Long Brook at MCHD sampling

Long Brook at Howell. Fine sand and silty material is deposited into the stream bed by the runoff water. Sitly deposit fills approximately ¾ of the total channel width.

Runoff from agricultural land into Long Brook at the Howell sampling site.



Upstream end of runoff stream, draining large agricultural field into Long Brook at Howell.

Runoff swale and channel from agricultural fields into Long Brook at Howell.

Local source of nonpoint phosphorus sources, runoff from agriculture to the stream. Fine particulate material is washed to the stream bed (Picture shows approximately ½ of entire field.

Appendix G Soil characteristics by zip code in the Manasquan River Watershed. Obtained through the Rutgers Cooperative Extension Soil Testing Laboratory at Cook College, New Brunswick (Stephanie Murphy)

CropID	Zip	pH	P	K	Mg	Ca	Cu	Mn	Zn	B
57	08750	5	522	261	229	2328	2	10.1	9.8	0.3
57	08750	5.9	163	253	122	1065	1.6	15	5	0.6
62	08736	6.5	609	273	248	2438	5.6	13.2	35.6	1.2
77	08736	7	268	290	282	2266	2.9	33.1	5.7	1.3
93	08736	8.4	228	499	687	20203	5.4	25.6	19.5	9.6
77	08736	8.3	220	449	448	12540	4.5	29.7	13.5	1.2
94	08736	6.5	216	1178	639	3770	2	15.8	13.6	3.8
57	08736	6	211	305	290	1639	2	14.3	6	1.1
57	08736	6	98	84	218	1821	3.3	6	7.6	0.3
62	08730	7.1	1950	657	434	6183	4.3	13.5	38.6	1.4
62	08730	7	1910	635	507	6329	4.1	16	37.2	1.9
62	08730	6.8	1879	952	468	5802	3.8	13.8	37.5	1.3
62	08730	6.8	1841	1664	463	6179	5.1	15.1	40	1.6
62	08730	7.1	1725	1124	479	5846	4.6	17.3	34.8	1.8
62	08730	6.9	1706	927	479	5299	7.8	14.6	38.8	1.3
62	08730	7.2	1430	1935	598	6379	3.9	18.1	36.3	2.6
62	08730	7.1	1146	354	424	5227	8.1	14.9	29.3	1.3
57	08730	5.5	479	273	333	1486	2.2	13.3	7.6	0.7
57	08730	6.2	452	189	298	2016	1.8	7.7	11.1	0.8
62	08730	6.9	442	38	363	3056	2.8	8	20.2	1
77	08730	7	380	132	314	4459	4.3	12.1	12.2	1.3
59	08730	6.6	368	108	352	1716	3.2	34	16	0.6
77	08730	6.7	349	119	205	3948	17	13	24.4	1.4
59	08730	5.5	344	391	426	3839	1.9	84.6	8.7	1
57	08730	6.9	339	204	358	1287	2.1	8.1	6.6	0.4
59	08730	6.8	333	90	297	2369	2.3	16.8	6.7	0.9
41	08730	6.4	323	253	261	2614	2.7	9	6.4	1
59	08730	6.6	273	78	179	1994	1.8	9.6	5	0.8
57	08730	4.5	245	209	109	701	5.5	22.5	13.7	0.5
57	08730	6.3	243	75	217	1013	3.6	15.1	7.1	0.3
57	08730	4.6	223	172	109	783	9.5	22.1	12.2	1
57	08730	7.7	160	409	466	7204	1.6	25.6	13.7	14.6
57	08730	6.9	156	365	293	2055	1.2	8.7	7.2	1.8
80	08730	6.2	117	529	301	1739	9.9	16.1	7.8	0.2
42	08720	5.5	237	108	176	1255	13.4	6.8	16.5	0.3
62	07731-8832	6.75	267	235	237	2040	2.4	7.9	6.1	0.2
103	07731-8832	5.65	45	105	87	446	1	6.4	1.8	0
59	07731-0364	7.15	948	263	625	7754	4.8	27.9	33.4	0.9
59	07731-0364	6.9	671	52	122	3438	5.4	8.4	6.3	0.9
59	07731-0364	7.3	669	272	275	3040	2.5	11.8	12.6	0.5
59	07731-0364	6.2	650	400	213	957	7.2	25	4.8	0.4
57	07731-0364	5.1	640	308	165	734	6.8	13.8	4.1	0.6
57	07731-0364	6.75	477	315	443	2917	1.7	10.9	7.5	0.2
59	07731-0364	6	470	210	612	5418	8.5	75.8	33.2	0.4
59	07731-0364	6.5	422	59	213	2253	2.8	7.7	3.9	0.1
59	07731-0364	6	399	276	234	1155	4.4	15.5	3.5	0.4
59	07731-0364	6.1	396	207	245	2328	3.9	14.1	72.1	0.7
59	07731-0364	6.95	360	151	344	4007	3.2	18.8	25.8	1.1
59	07731-0364	6.65	340	269	327	2341	3	17.8	8.1	0
103	07731-0364	5.9	294	86	81	254	2.7	5.5	4.1	1.1

CropID	Zip	pH	P	K	Mg	Ca	Cu	Mn	Zn	B
59	07731-0364	6	287	148	199	1841	2.2	5	3.4	0.2
62	07731-0364	5.7	235	255	332	1496	5.3	26	7.5	0.1
59	07731-0364	6.4	221	614	329	2376	2.2	9.5	11.5	0.3
59	07731-0364	6.6	207	270	225	1899	3.4	7.9	11.5	0
80	07731-0364	7.6	164	196	246	3693	11.3	25.1	14.2	0.1
59	07731-0364	6.9	159	83	350	1378	6.3	3.8	6.7	0.7
59	07731-0364	5.2	158	37	51	93	0.6	3.8	2	0.7
59	07731-0364	6.4	155	269	506	2262	0.6	5.4	11.2	0.6
59	07731-0364	5.4	144	96	126	1123	2.1	5.9	11.8	0.2
59	07731-0364	5	142	29	36	54	0.9	1.9	1.4	0.7
59	07731-0364	6.8	123	162	194	3216	1.6	5.7	4.6	0.2
59	07731-0364	7	122	83	157	1120	7.7	14	24.7	1
59	07731-0364	7.45	102	353	313	2727	1.6	16.4	5.2	1.1
59	07731-0364	5.3	88	156	235	1127	1.9	14.7	3.4	0.5
59	07731-0364	5.2	82	130	180	875	0.5	2.9	1.7	0.1
59	07731-0364	7	64	363	772	3560	3.6	18.4	23.1	1.5
59	07731-0364	5.1	62	242	236	1646	1	5.3	5	0.2
59	07731-0364	7.6	59	52	327	1946	1	5.6	2.8	0.5
59	07731-0364	6.9	58	72	258	1892	0.5	4.9	2.3	0.1
59	07731-0364	5.3	40	73	108	260	0.6	2.6	1	0
59	07731-0364	5.1	39	247	220	1217	2.3	15.5	6.4	0.1
59	07731-0364	5.3	38	148	321	2280	7.9	4.5	51.1	0.4
57	07731-0364	5.05	24	231	195	822	0.3	26.4	8.7	0.2
80	07731	7.6	1997	62	123	5665	4.1	17.3	47.3	1
61	07731	6.9	685	894	478	2658	9.8	64.6	12.3	2.7
57	07731	5.9	534	90	168	2053	1.8	7.4	7.3	0.9
46	07731	5.5	497	124	154	1905	1.7	8.9	10.9	1
59	07731	4.8	475	304	303	1908	9.5	11.7	38	0.5
57	07731	6.3	442	131	219	2483	4.1	10.8	18.4	0.9
57	07731	6.5	404	43	175	1020	1.4	2.7	5.1	0.6
62	07731	6.75	360	339	579	5190	2.3	37.1	21.5	2.2
57	07731	5.9	321	164	112	490	2.3	12.2	3.3	0.4
57	07731	6.8	313	102	138	1478	0.8	5	3.3	0.9
57	07731	6.5	311	282	316	1913	2.8	3.1	4.1	1.4
57	07731	6.9	310	179	298	2920	15	9.4	47.9	1.4
57	07731	6.1	310	376	196	948	4.9	9	2.6	1
59	07731	6.2	301	93	360	2252	1.8	4.7	4.4	0.6
59	07731	5.7	299	186	273	1323	1.8	7.6	3.5	0.2
59	07731	5.8	291	403	247	1319	4.4	15.9	3.2	0.8
57	07731	5.4	285	126	120	1221	1.2	6	16.5	0.6
57	07731	6.9	284	124	177	1809	1	9.8	12.4	0.4
77	07731	4.9	281	327	210	1211	1.8	14.7	24.7	0.2
59	07731	6.2	272	244	252	1432	3.3	39.7	3.6	0.6
57	07731	6.1	270	282	191	1144	1.5	5.1	8.1	0.6
57	07731	6	267	260	189	1511	0.9	8.9	7.4	0.9
59	07731	5.9	266	207	371	2032	1.4	19.3	5.9	0.5
77	07731	6.6	264	236	215	1732	3.8	10.2	12.2	1
59	07731	5.1	263	59	97	863	2	8.7	8.5	1.1
57	07731	5.6	263	148	186	597	1.7	4.1	4.7	1
57	07731	5.9	255	269	730	2868	1.5	12.7	14.5	1
57	07731	6.15	250	99	281	1869	1.5	18	7.2	0.5
59	07731	5.3	249	306	315	1306	3.8	24.8	2.8	0.6
57	07731	5.6	248	283	232	1384	3	7.3	5.7	0.3
94	07731	6.7	247	1424	488	2054	2.2	11.8	22.4	6.7
59	07731	7.15	246	247	475	6143	1.8	21.9	32.8	1.9

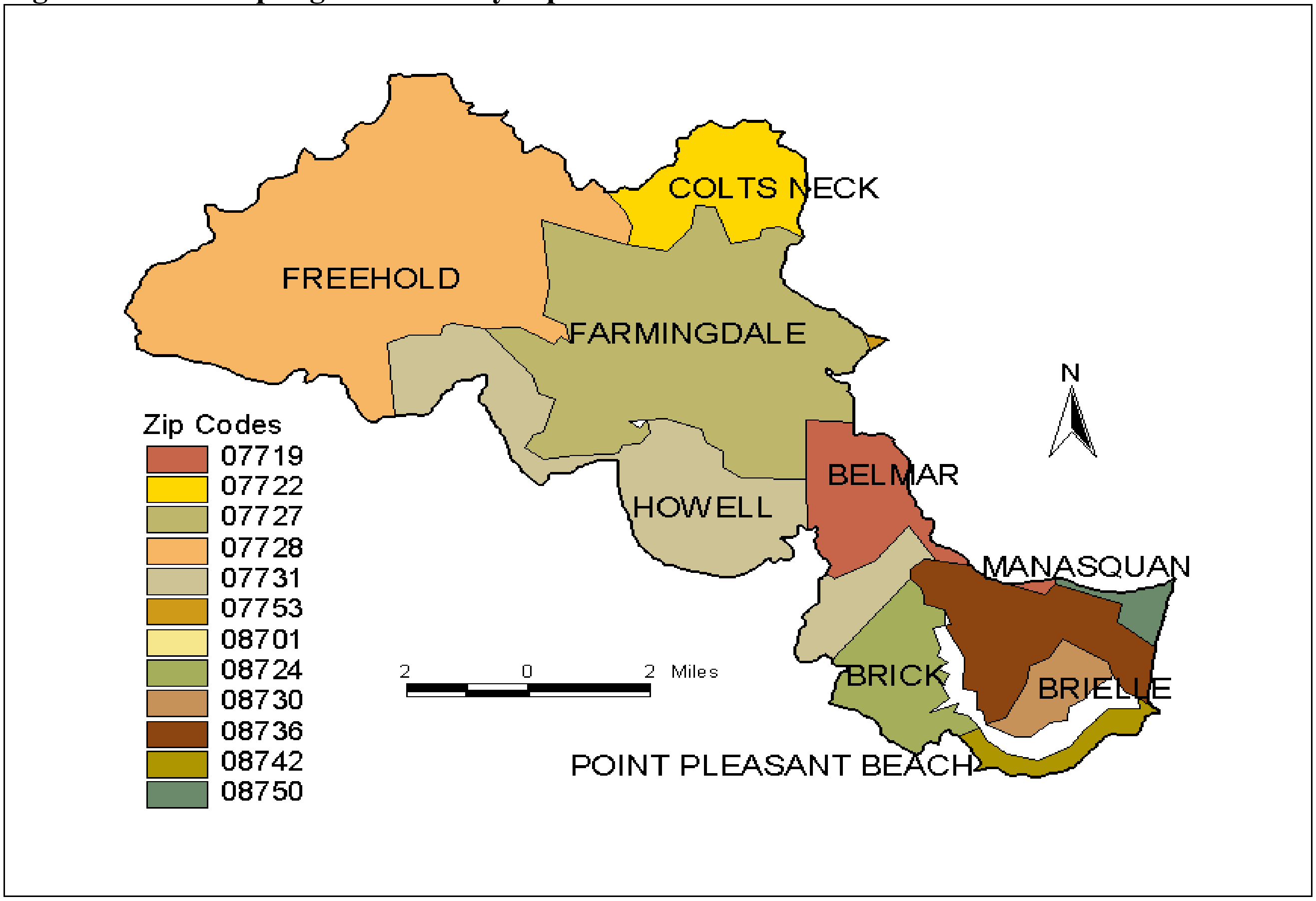
CropID	Zip	pH	P	K	Mg	Ca	Cu	Mn	Zn	B
59	07731	5.9	242	191	231	1382	2.7	7.3	7.3	0.7
57	07731	6.8	241	419	519	2403	1.6	10.7	11.8	1.3
57	07731	6	233	391	361	1632	1	6.1	5.1	1.1
59	07731	5.6	230	610	251	1013	3.8	11.7	3.8	0.6
57	07731	6.7	229	376	300	1639	2.4	14.6	2.2	1
94	07731	4.6	228	28	86	702	1.4	1.4	7.2	0.8
57	07731	5.7	227	36	43	717	1	5.8	3.6	0.8
57	07731	6	222	86	149	880	0.8	7.4	7.4	0.5
59	07731	6.3	221	108	290	1850	1.7	4.1	3	0.8
57	07731	7.6	217	46	389	4461	1.5	12	8.9	1.1
57	07731	6.2	216	68	202	1641	10.4	5.9	15.3	0.8
59	07731	5.3	216	322	284	1215	3.4	21.6	2.1	0.5
57	07731	5.9	214	108	511	2076	1.3	7	8.8	0.8
57	07731	6.7	214	114	237	1276	1.3	3.1	4	0.6
59	07731	5.5	214	258	247	1705	2.5	10.1	5.6	0.5
57	07731	6.5	206	115	348	2687	2.2	10.7	14.2	1.2
57	07731	5.6	204	311	158	1001	0.9	4.3	8.3	0.8
57	07731	5.5	204	63	123	1002	1.2	3.1	5.2	0.7
57	07731	5.6	204	58	116	677	0.8	11.4	6.1	0.3
59	07731	5.85	199	292	290	2323	4.1	17.1	11.4	0.6
59	07731	6	197	158	103	795	2.1	55.3	2.7	0
57	07731	5.3	194	173	169	1297	3.3	14.7	28.1	1.2
57	07731	7.1	193	202	167	2015	2.8	6.1	14.2	1.1
57	07731	5.7	190	474	326	1482	2.3	13.5	5	0.8
59	07731	6.4	190	122	271	1674	1.7	7.4	3.8	0.3
57	07731	4.9	189	211	172	1438	3.2	7.2	25.9	1.3
57	07731	6.5	188	210	265	2344	0.9	3	2.9	1.4
57	07731	5.7	185	481	123	742	1.9	12.3	3.4	1
57	07731	6.7	180	495	106	987	1.4	8.5	3.1	0.7
18	07731	5.4	179	61	139	967	1.6	3.5	6.9	0.4
59	07731	6.3	177	68	210	1957	1.4	6.2	5.5	0.9
57	07731	5.1	176	222	427	2219	0.8	5	5.2	0.9
59	07731	6.3	176	183	347	1763	3.2	31.4	2.7	0.7
59	07731	5.1	175	172	138	691	2.2	7.5	4.5	0.9
59	07731	5.2	173	229	202	1256	0.6	2.5	4.1	0.5
80	07731	5.1	170	27	32	223	1.2	2.8	3	0.5
57	07731	6.5	158	186	189	1823	4.1	11.2	9.5	1.3
80	07731	4.5	154	16	26	141	1.4	0.6	1.4	0.4
59	07731	6.1	151	96	121	793	1.8	5.7	3	0.7
57	07731	5.7	144	269	304	1500	3.4	14	3.3	0.7
57	07731	6	142	468	309	1342	2.2	7	2.7	0.7
59	07731	6.3	138	117	164	863	1.6	11.6	2.1	0.8
59	07731	6.1	138	77	102	753	2.2	8.3	3.5	0.5
57	07731	5.4	137	69	154	1333	4	5.3	12.6	1.4
59	07731	6	137	171	316	1528	1.7	4.1	3.5	0.5
57	07731	7.2	135	577	245	1291	1.4	12.3	2.3	0.6
57	07731	6.6	134	175	282	1780	0.1	2.1	2.4	0.8
57	07731	7.8	131	332	258	4399	2.9	25.4	9.2	1
57	07731	5.1	129	154	151	755	6.2	6.5	7.8	0.2
57	07731	5.4	127	165	144	1250	2.5	7.4	7	1.3
57	07731	5.9	125	273	330	976	4.8	6.8	2	0.1
59	07731	6.1	124	148	321	2190	2	6.6	17	0.9
57	07731	5.6	121	67	147	1272	0.6	5.7	5.4	1.1
57	07731	5.5	118	64	153	1018	1.1	4.9	3.7	0.7
57	07731	6.8	116	308	245	2599	3.1	5.3	6.8	1

CropID	Zip	pH	P	K	Mg	Ca	Cu	Mn	Zn	B
62	07731	5.9	116	37	165	1351	0.9	4.3	2.7	0.6
80	07731	4.8	110	17	55	297	0.9	0.9	3	1.4
59	07731	6.7	107	59	328	2403	1.1	6.2	3	1
59	07731	6.3	107	207	264	1767	0.9	8.1	5.7	0.8
57	07731	5.4	106	989	302	1387	3.3	14.7	6.8	0.3
59	07731	5.5	103	151	223	1344	0.9	7	2.8	0.9
59	07731	5.4	101	110	253	1234	1.1	6.7	4.1	1.7
57	07731	5.6	101	49	149	1256	4	4.5	38.6	1.1
59	07731	7	101	140	152	1449	3.5	12.7	6.6	0.5
59	07731	7	100	163	131	3040	1.5	6.7	6.9	0.3
57	07731	6.4	99	215	185	1588	2.1	17	2.3	1
57	07731	5.8	98	122	147	2156	6.2	5.5	12.3	1.3
57	07731	6.4	98	209	189	2399	1	5	3.6	0.6
59	07731	4.9	94	245	344	2070	2.2	6.2	3.3	0.8
57	07731	6.7	93	104	325	1555	9.5	10.9	9.9	0.8
95	07731	5.25	88	402	249	922	4.4	13.4	6.4	0.7
57	07731	4.8	85	306	131	923	5.8	20.5	18.6	1.1
59	07731	5.7	85	112	193	1194	2.4	7.4	3	0.5
57	07731	7.4	84	1147	249	1862	0.8	21	2.9	0.9
57	07731	6.7	81	100	240	1723	1.8	20	2.3	0.9
57	07731	6.8	80	78	185	1089	1.2	4.1	10.6	1.3
57	07731	6.3	78	357	227	1705	1.9	31.1	3.4	0.6
59	07731	4.6	77	80	49	286	0	2.8	2.6	2.9
59	07731	7.3	77	88	94	2682	1.2	3.9	3	0.7
57	07731	5.4	75	64	95	687	1	4.8	1.9	0.7
95	07731	5.2	74	293	203	846	4.1	10.9	6	0.3
57	07731	6.2	73	95	119	988	1	3.7	3.9	0.7
57	07731	6.05	70	39	68	496	0.5	2.6	2.2	0.9
57	07731	6.4	70	166	234	1945	3.4	3.3	18.6	0.8
59	07731	6.5	69	70	159	1012	2.1	5.1	4.3	1.3
57	07731	6.1	69	61	158	1060	0.5	2.6	1.8	0.6
59	07731	6.55	69	213	350	2184	2.6	21.8	2.8	0.6
59	07731	7.3	68	21	169	1223	1.5	4.4	2.6	1.3
57	07731	5.6	68	103	123	1416	6.4	4	6.2	1.3
57	07731	6.1	67	302	582	2879	2.5	3.6	5.4	0.6
59	07731	5.5	67	146	302	1412	1.5	16.5	3	0.4
57	07731	6.4	66	61	224	1224	0.6	5.1	2.4	0.8
59	07731	6.05	65	27	98	597	3.1	10.1	21.9	1.4
59	07731	4.7	65	134	23	129	0.8	1.1	1.6	1.3
57	07731	5.2	65	297	752	2979	0.9	5	3.3	0.8
59	07731	5.8	60	151	333	1445	3.6	8.9	7.7	0.7
57	07731	6	58	136	101	915	1	5.4	2.8	0.8
57	07731	6.5	57	442	346	1524	0.5	4.8	3.2	0.9
59	07731	4.4	56	22	45	293	0.9	1.2	1.9	2.4
59	07731	6.3	55	41	93	643	1	3.8	1.9	2.3
57	07731	5.4	55	69	114	852	1.2	3.6	2.5	0.6
57	07731	6.7	50	160	209	2476	2.8	10	7.9	1.1
57	07731	6.3	48	81	88	998	0.8	25.6	2.5	0.9
57	07731	5.3	45	29	41	432	0.9	1.5	3.6	0.8
57	07731	6.7	43	44	142	1223	0.4	2.9	1.8	0.8
59	07731	5.4	43	258	370	2428	2.2	4.1	8.3	0.7
59	07731	6.3	41	47	125	817	1.8	2.6	2.3	1.6
57	07731	5.6	41	45	122	1120	0.6	3.2	3.2	1.1
57	07731	6.7	41	199	145	1306	0.6	4.6	5	1.1
57	07731	5.5	41	318	364	1594	1	8.9	1.9	0.5

CropID	Zip	pH	P	K	Mg	Ca	Cu	Mn	Zn	B
59	07731	6.3	38	137	272	1528	1.4	8.5	2.3	0.6
59	07731	5.3	35	92	267	1567	1.5	3.1	1.9	0.5
59	07731	5.8	31	34	72	999	1.2	1.8	1.3	0.5
59	07731	5.1	26	184	99	590	0.5	5.6	2.3	0.2
57	07731	6.15	25	28	112	789	0.3	3.7	1.5	0.4
59	07731	5	23	39	96	483	0.9	2.8	2	0.5
59	07731	6	17	445	461	1873	2.7	26.2	1.8	0.6
57	07731	6.2	15	36	146	1163	0.6	4.3	2.8	0.8
41	07728	5.3	1429	0	1411	3944	3.1	30.7	42.2	0.8
55	07728	5.95	594	621	418	1535	3.2	40.5	2.4	0.3
47	07728	4.8	567	188	115	812	13.1	12.9	9.2	0.5
44	07728	4.4	485	158	87	530	13.5	8.9	4.7	0.5
62	07728	5.8	417	550	247	1691	6.8	11	5	0.5
62	07728	5.9	413	1406	435	2510	1.7	12.2	10.5	0.8
59	07728	6.9	379	954	452	4075	2.8	20.7	11.9	0.9
62	07728	6	373	453	380	3108	4.5	15.9	18.8	1.5
94	07728	7	339	274	421	5687	8.2	30.6	39.2	1.3
59	07728	7.2	319	209	324	3303	20.5	7.5	5.1	1.2
94	07728	6.9	301	300	355	3507	3	10.3	12.2	1
62	07728	7.4	293	4608	751	5951	3	39.7	9.4	2.6
85	07728	6.1	285	143	430	1488	51.8	9.3	3.9	0.5
95	07728	6.3	218	168	126	1208	0.9	5.5	1.9	0.2
95	07728	6.2	188	173	86	832	0.6	4	1.5	0.2
80	07728	5.8	181	364	354	2088	2.1	28.6	9.8	0.7
57	07728	5	176	37	149	788	2.8	12.2	4.5	0.4
62	07728	6.7	165	149	186	1896	3.9	11.5	20.5	1.3
41	07728	7.4	150	150	331	3138	1.6	24.1	4.4	0.8
70	07728	5.9	123	986	520	2642	1.6	10.7	5.4	0.8
42	07728	5.4	118	109	164	1009	0.9	18.8	6.6	1
57	07728	4.8	116	156	174	1119	3	17.3	7	0.2
70	07728	5.9	105	616	444	2303	1.4	9.4	4.6	0.7
57	07728	5	101	569	821	2948	1.9	42.3	4.8	0.7
57	07728	6.7	87	669	717	3694	0.9	10.7	5	0.6
94	07728	5.6	83	189	302	1644	0.8	17.9	4.6	0.5
57	07728	5.4	75	871	574	2324	1.2	10.7	7.4	0.6
85	07728	5.9	70	202	336	1837	8.9	16.3	2.4	0.6
57	07728	4.8	61	83	110	582	1.3	12	4.8	0.3
57	07728	6.6	56	137	323	1704	1.4	35.4	4	0.9
57	07728	4.9	56	407	555	2180	1.2	25.2	5.2	0
94	07728	4.6	53	57	49	198	2.4	2.7	1.9	0.2
94	07728	6.7	50	136	233	1662	0.9	21.1	5.8	0.5
57	07728	6.3	45	340	293	1526	0.9	16.6	3.6	2.3
41	07728	5.6	43	673	536	2172	1.4	11.3	5.1	0.4
47	07728	6.3	40	304	383	2173	16.8	19.9	3.2	0.8
57	07728	5.9	39	357	385	1947	0.9	17.2	4.8	2.2
57	07728	5.9	32	194	477	1632	0.5	13.8	2.9	2.3
47	07727	7.8	1283	93	387	5685	3.3	15	16.2	1
57	07727	6.9	499	278	488	3394	2.1	7.8	9.6	0.4
97	07727	6.9	421	350	392	1654	1.3	3.1	3.4	0.5
97	07727	7	396	22	321	1380	1.3	1.1	0.2	0.5
94	07727	5.5	373	134	140	933	2.5	4.5	11.5	0
94	07727	6.3	302	65	213	2170	2.5	15.4	17.8	0.5
108	07727	7.85	295	716	680	15296	5.7	46.9	13.9	0.9
59	07727	6.9	288	80	306	1836	1.3	9.6	6.9	1.1
97	07727	6.9	266	29	254	1295	1.9	1.7	12	0.7

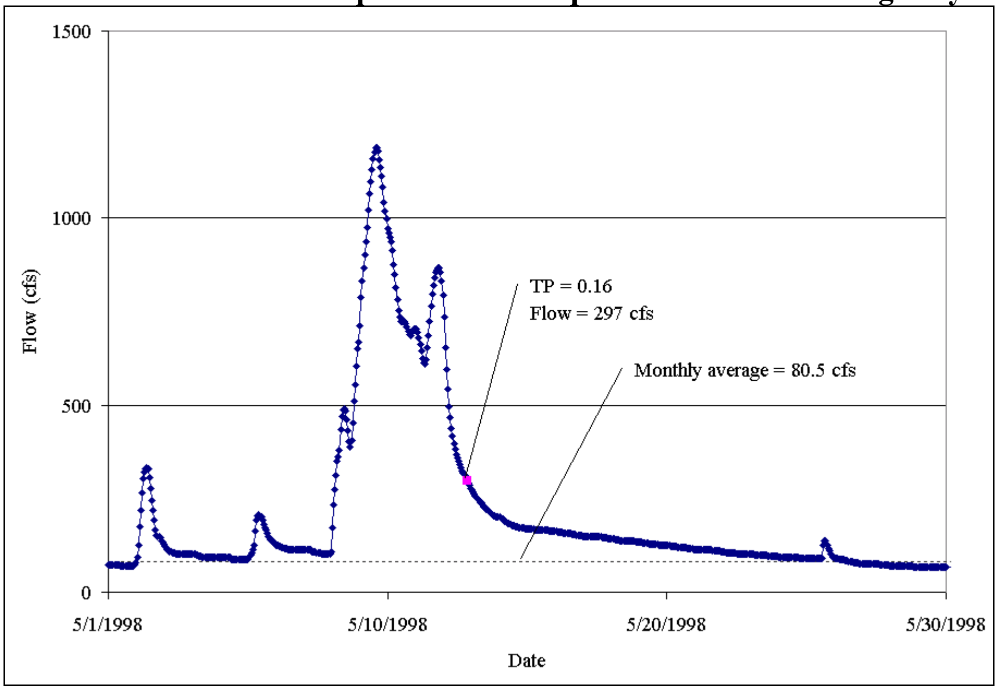
CropID	Zip	pH	P	K	Mg	Ca	Cu	Mn	Zn	B
108	07727	6.55	189	597	529	4995	0.4	44.3	4.7	0.3
77	07727	5.2	179	54	79	390	3.2	7.4	6.1	0.6
97	07727	6.8	136	123	261	1378	1.1	2.2	1.9	1.4
59	07727	6	118	75	138	950	2.3	12.9	3.8	0
57	07727	5.3	94	166	80	705	1.8	10.3	11.7	0.3
57	07727	5.2	84	112	82	723	1.2	8.2	6.6	0.3
57	07727	5.4	76	142	96	823	1.5	7.2	6.9	0.2
57	07727	5.6	61	300	76	752	1.1	8.6	3.7	0.4
42	07727	5.4	52	138	277	1258	0.3	3.1	2.9	0.1
57	07727	5.4	41	95	65	507	2.4	5	3.5	0.7
57	07727	4.6	38	120	72	592	8.1	5.2	5.1	1
57	07727	4.7	38	179	134	726	4.8	16.7	7.7	0.7
57	07727	5.9	34	111	125	1091	2.6	10.2	7.7	0.2
57	07727	5.4	33	247	228	1092	4.6	41.2	6.4	0.2
57	07727	4.5	13	121	53	287	0.6	4.1	2.3	0.1
57	07727	4.9	10	238	339	1317	3.1	48.6	5.7	0.3
57	07727	4.7	7	98	46	306	0.5	3.4	1.8	0

Figure 1 Sampling Locations by Zip Codes



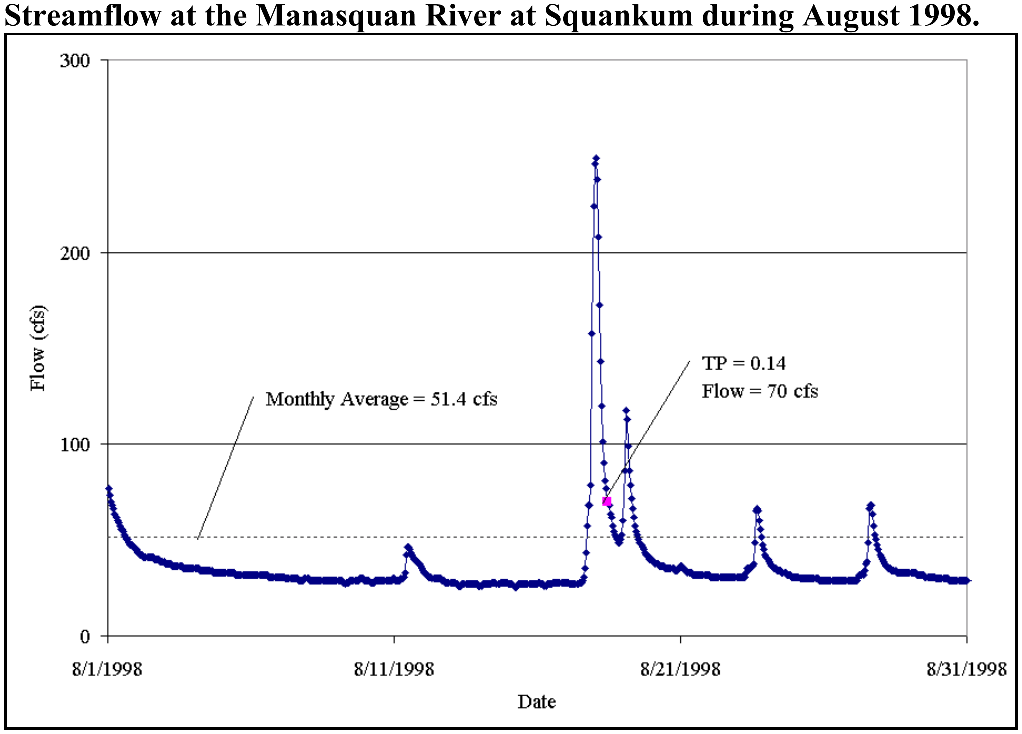
Appendix H Examples of Stream flows before, during and after Sampling Events for TP results which exceeded SWQS of 0.1 mg/L TP

Figure 1 Streamflow at the Manasquan River at Squankum station during May 1998.



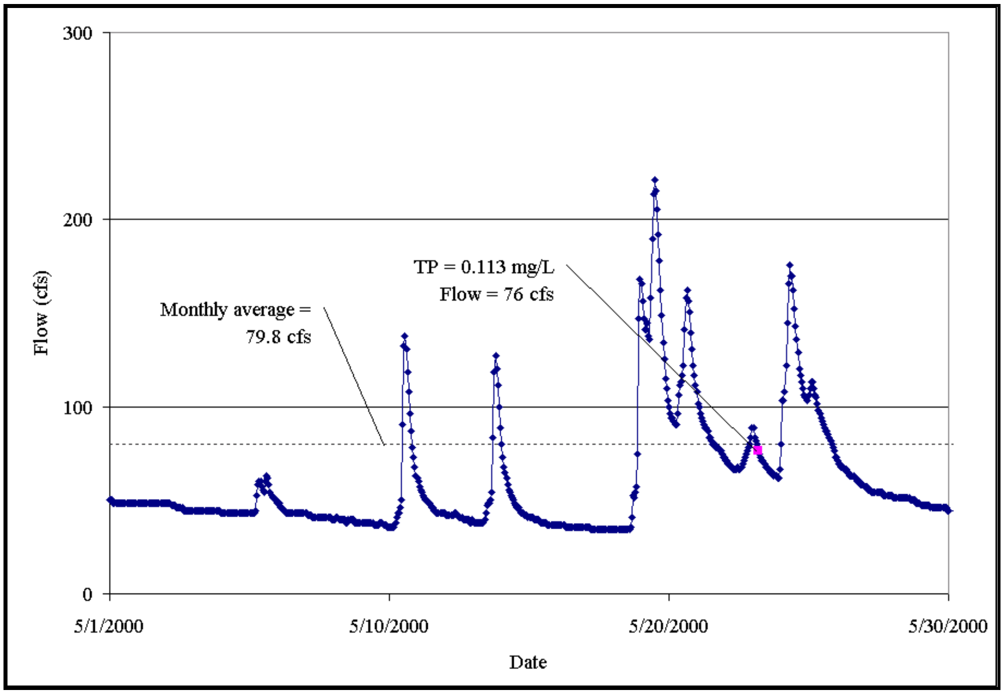
Note: Monthly average determined using water years 1932-1998 (USGS, 1998).

Figure 2 Streamflow at the Manasquan River at Squankum during August 1998.



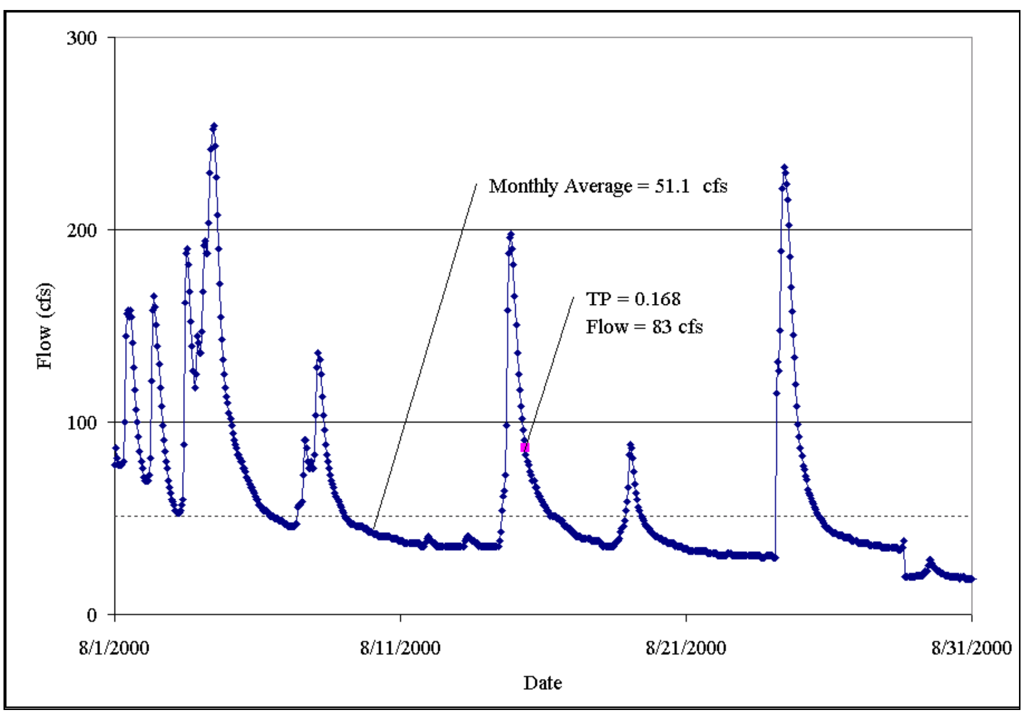
Note: Monthly average determined using water years 1932-2000 (USGS, 2000).

Figure 3 Streamflow at the Manasquan River at Squankum during May 2000.



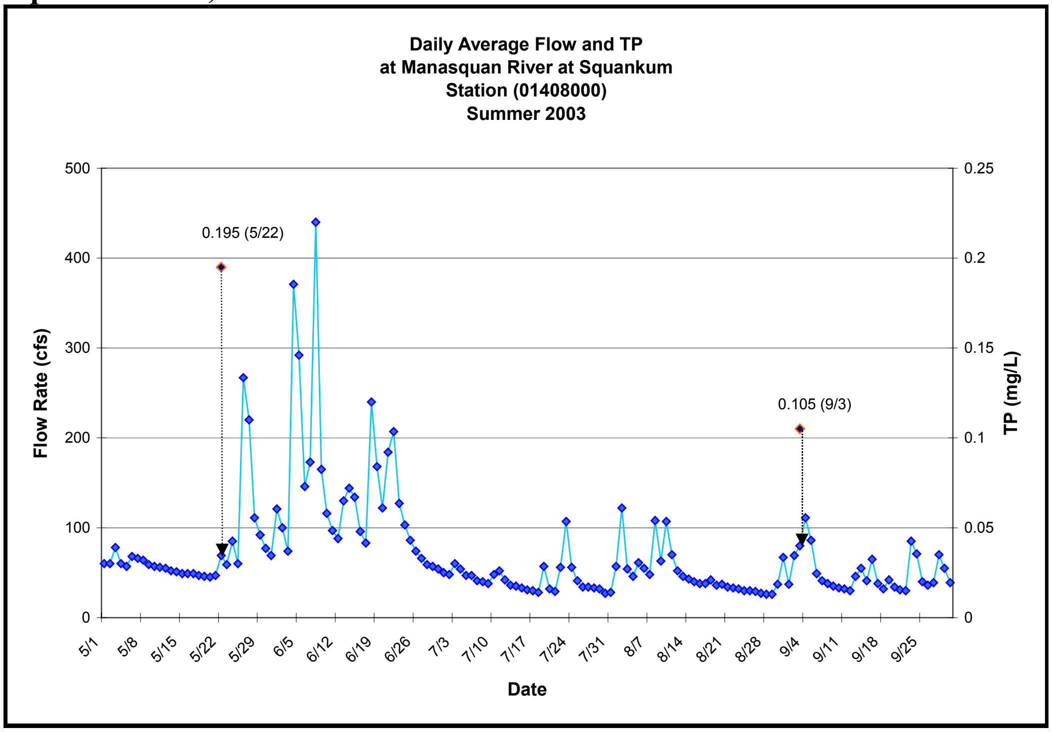
Note: Monthly average determined using water years 1932-2000 (USGS, 2000).

Figure 4 Streamflow at the Manasquan River at Squankum during August 2000.



Note: Monthly average determined using water years 1932-2000 (USGS, 2000).

Figure 5 **Total Phosphorus and Daily Average Streamflow at the Manasquan River at Squankum site, Summer 2003**



Note: Monthly average determined using water years 1932-2000 (USGS, 2000).

Figure 6 **Total Phosphorus and Daily Average Streamflow at the Manasquan River at Squankum site**