Amendment to the Sussex County Water Quality Management Plan

Total Maximum Daily Load to Address Phosphorus in the Clove Acres Lake and Papakating Creek Northwest Water Region

Watershed Management Area 2
(Wallkill River, and Pochuck, Papakating, Rutgers Creeks)

Proposed:	April 19, 2004
Established:	
Approved (by EPA Region 2):	
Adopted:	

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1. Executive Summary

In accordance with Section 305(b) of the Federal Clean Water Act (CWA), the State of New Jersey developed the *2002 Integrated List of Waterbodies* (35 N.J.R. 470(a), January 21, 2003), addressing the overall water quality of the State's waters and identifying impaired waterbodies for which Total Maximum Daily Loads (TMDLs) may be necessary. The 2002 *Integrated List of Waterbodies* identified one stream segment and one lake in the Papakating Creek Watershed as being phosphorus impaired, as indicated by elevated total phosphorus (TP). These impairments were carried over to the proposed 2004 *Integrated List of Waterbodies* (36 N.J.R. 1238(b) March 1, 2004). This report, developed by the New Jersey Department of Environmental Protection (Department), establishes two total maximum daily loads (TMDLs) for total phosphorus (TP) in the Papakating Creek Watershed for the impaired segment and the impaired lake identified in Table 1.

Table 1: Phosphorus impaired stream segment and lake located in the Papakating Creek watershed, for which phosphorus TMDLs are being established, as identified in Sublist 5 of the 2002 Integrated List of Waterbodies.

TMDL Number	WMA	Station Name/Waterbody	Site ID	County	River Miles/Lake Area
1	2	Papakating Creek at Sussex	01367910	Sussex	2.5 miles
2	2	Clove Acres Lake	Clove Lake - 02	Sussex	Approx. 34 acres

A TMDL is developed to identify all the contributors of pollutants of concern and load reductions as necessary to meet Surface Water Quality Standards (SWQS). The pollutant of concern for these TMDLs is phosphorus, measured as TP.

In order to prevent excessive primary productivity[1] and consequent impairment of recreational, water supply and aquatic life designated uses, the SWQS define both numerical and narrative criteria for TP. The SWQS set forth a criterion for surface waters, as well as a more restrictive criterion for fresh water lakes and their tributaries at the point at which tributaries enter a lake. Phosphorus sources in the watershed were characterized on an annual scale (kg TP/yr) for both point and nonpoint sources. Runoff from land surfaces was found to comprise a substantial portion of the phosphorus load. To achieve the TMDLs, overall load reductions were calculated for 10-11 source categories. In order to track effectiveness of remediation measures (including TMDLs) and to develop baseline and trend information on lakes, the Department will augment its ambient monitoring program to

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

include lakes on a rotating schedule. The implementation plan also calls for a detailed characterization and assessment and the development of a Lake Restoration Plan for Clove Acres Lake. This plan will consider what specific measures are necessary to achieve, or possibly revise, the nutrient reductions required by the TMDL, as well as what in-lake measures need to be taken to supplement the nutrient reductions required by the TMDL. In addition to strategies to reduce nonpoint sources of phosphorus, a monitoring requirement and effluent limit for phosphorus will be included in the NJPDES permit for the High Point High School point source discharge to ensure the contribution from the facility is as assumed in the TMDL calculation. Each TMDL shall be proposed and adopted by the Department as an amendment to the appropriate areawide water quality management plan(s) in accordance with N.J.A.C. 7:15-3.4(g).

For Clove Acres Lake, an empirical model, developed by K.H. Reckhow, Ph.D. and described in *Modeling Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients*, (Reckhow, K.H., M.N. Beaulac and J.T. Simpson, 1980, EPA 440/5-80-011), was used to relate annual phosphorus load to steady-state in-lake concentration of total phosphorus. For the impaired stream segment, a stochastic model was used to define a loading and flow association. This method was adapted from *"TMDL Development Using Load Duration Curves"* as presented at an Association of State and Interstate Water Pollution Control Administrators (ASIWPCA) TMDL "Brown Bag" by Tom Stiles (Kansas Department of Health and Environment), Andrew Sullivan (Texas Natural Resource Conservation Commission), Charles Martin (Virginia Department of Environmental Quality), and Bruce Cleland (America's Clean Water Foundation), May 16, 2002. To achieve the goal of the TMDL, overall load reductions were calculated for each of the source categories.

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

2. Introduction

Sublist 5 (also known as the 303(d) List) of the State of New Jersey's *2002 Integrated List of Waterbodies* identifies Station #01367910, Papakating at Sussex, as being impaired for phosphorus, and monitoring location Clove Lake-02, known as Clove Acres Lake, as being eutrophic. This report establishes two TMDLs, which address phosphorus loads to the identified waterbodies. These TMDLs include strategies to reduce loadings of phosphorus from various sources in order to attain applicable surface water quality standards for phosphorus. The stream segment on the Papakating Creek is also listed in Sublist 5 for impairment caused by other pollutants, such as fecal coliform and arsenic. This TMDL addresses only the phosphorus impairment. A TMDL was established in 2003 to address the fecal coliform impairment at Station 01367910, Papakating at Sussex, and a separate TMDL evaluation will be developed to address arsenic. The waterbody will remain on Sublist 5 for arsenic until such time that a TMDL evaluation is completed, or it is determined that a TMDL is not the appropriate management response. As a result of establishing the fecal coliform

TMDL, this impairment will be moved to Sublist 4 in the *2004 Integrated List of Waterbodies*. With respect to the phosphorus impairment, the subject pollutant/waterbody combinations will be moved to Sublist 4 following approval of these TMDLs by the USEPA Region 2.

3. Background

In accordance with Section 305(b) of the Federal Clean Water Act (CWA) (33 U.S.C. 1315(B)), the State of New Jersey is required 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.

In accordance with Section 303(d) of the CWA, the State is also required biennially to prepare and submit to USEPA a report that identifies waters that do not meet or are not expected to meet surface water quality standards (SWQS) after implementation of technology-based effluent limitations or other required controls. This report is commonly referred to as the 303(d) List. In November 2001, USEPA issued guidance that encouraged states to integrate the 305(b) Report and the 303(d) List into one report. New Jersey's *2002 Integrated List of Waterbodies* uses the new format, as does the 2004 proposed *Integrated List of Waterbodies*. This integrated report assigns waterbodies to one of five categories. In general, Sublists 1 through 4 include waterbodies that are unimpaired, have limited assessment or data availability, are impaired due to pollution rather than pollutants or have had a TMDL prepared. Sublist 5 constitutes the traditional 303(d) List for waters impaired or threatened by one or more pollutants. In accordance with N.J.A.C. 7:15-6 and Section 303(d) of the Clean Water Act, water quality limited waters require TMDL evaluations.

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 applicable water quality standards and allocates that load capacity to known point sources in the form of wasteload allocations (WLAs), nonpoint sources in the form of load allocations (LAs), and includes a margin of safety and consideration of reserve capacity.

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

1. Identification of waterbody, 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 does not require and does not approve TMDL implementation plans).
11. Public Participation.

4. Pollutant of Concern and Area of Interest

Papakating Creek at Sussex, Station 01376910, was designated as impaired for phosphorus on Sublist 5 of the *2002 Integrated List of Waterbodies* as a result of monitoring conducted by the Department. This impairment was further confirmed by data submitted by the Sussex County Municipal Utilities Authority (SCMUA) and Wallkill River Watershed Management Group (WMG). Clove Acres Lake was also designated as being eutrophic on Sublist 5 of the *2002 Integrated List of Waterbodies* based on a report prepared by the Department, in association with Princeton Hydro-Science in January 1983, entitled *New Jersey Lakes Management Program, Case Study, Clove Acres Lake*. These impairments were carried over to the proposed *2004 Integrated List of Waterbodies* (36 N.J.R. 1238(b) March 1, 2004).

The mechanism by which phosphorus can cause use impairment is via excessive primary productivity. Phosphorus is an essential nutrient for plants and algae, but is considered a pollutant when it stimulates excessive growth (primary production). Phosphorus is most often the major nutrient in shortest supply relative to the nutritional requirements of primary producers in freshwater systems. Consequently, phosphorus is frequently a prime determinant of algal activity in a stream or lake. Furthermore, of the major nutrients, phosphorus is the most effectively controlled through engineering technology and land use management (Holdren et al, 2001). Eutrophication has been described as the acceleration of the natural aging process of surface waters. It is characterized by excessive loading of silt, organic matter, and nutrients, causing high biological production and decreased basin volume (Cooke et al, 1993). Symptoms of eutrophication (primary impacts) include oxygen super-saturation during the day, oxygen depletion during the night, and high sedimentation (filling in) rate. Algae and aquatic plants are the catalysts for these processes. Secondary biological impacts can include loss of biodiversity and structural changes to communities.

As reported in the *2002 Integrated List of Waterbodies*, the Department identified 2.5 miles of a stream segment on the Papakating Creek, in the Northwest Water Region (Table 2) as being impaired for phosphorus. Based on a detailed county hydrography stream coverage, a total of approximately 129 stream miles (including the Clove Brook tributary) in the Northwest Water Region are directly affected by the stream segment TMDL due to the fact that the implementation plan covers the entire Papakating Creek Watershed; not just the impaired waterbody segment. This phosphorus impairment is ranked as a High Priority in the proposed *2004 Integrated List of Waterbodies*.

Also as reported in the *2002 Integrated List of Waterbodies*, the Department identified the Clove Acres Lake in the Papakating Creek Watershed as being eutrophic. The Clove Acres Lake TMDL will address a 34 acre lake and its associated drainage, which includes approximately 48 stream miles of the Clove Brook and its tributaries due to the fact that the implementation plan covers the entire watershed, not just impaired portions of watersheds. (This 48 stream miles is included in the total of 129 stream miles for the entire Papakating Creek Watershed.) This eutrophic lake listing is ranked as a High Priority in the proposed *2004 Integrated List of Waterbodies.*

Table 2: Abridged Sublist 5 of the Proposed 2004 Integrated List of Waterbodies, Phosphorus impairments in the Papakating Creek Watershed.

TMDL No.	WMA	Station Name/Waterbody	Site ID	River Miles/Lake Area	Management Response
1	2	Papakating Creek at Sussex	1367910	2.5 miles	Establish TMDL
2	2	Clove Acres Lake	Clove Lake -02	Approx 34 acres	Establish TMDL

Description of the Papakating Creek Watershed and Sublist 5 Waterbodies

The Papakating Creek is located in Watershed Management Area 2 (WMA 2) in the northwestern portion of New Jersey (Figure 1). This 15 mile long creek runs through north-central Sussex County and flows into the Walkill River east of Sussex Borough. The Papakating Creek Watershed is approximately 60.6 square miles in area, and has three major tributaries, which include the West Branch Papakating Creek, the Neepaulakating Creek and the Clove Brook. The area is underlain by dark shale and limestone, and the soils are glacial in origin. The topography in this region ranges from gently rolling in the east to strongly sloping in the west. The Papakating Creek Watershed is comprised of seven United States Geological Survey (USGS) HUC 14 drainage units. "HUC", or Hydrologic Unit Code, refers to a system of geographic delineations developed by USGS to identify drainage basins on the watershed and sub-watershed basis throughout the country. The number of digits attached to a HUC gives reference to the level of detail in the delineation, with the larger numbers relating to a more detailed geographic area. For example, the entire Papakating Creek watershed is identified with one HUC 11, and is further broken down into seven sub-watersheds, or HUC 14 areas (see Figure 2).

Figure 1: Papakating Creek Watershed Location Map

Sussex County, New Jersey

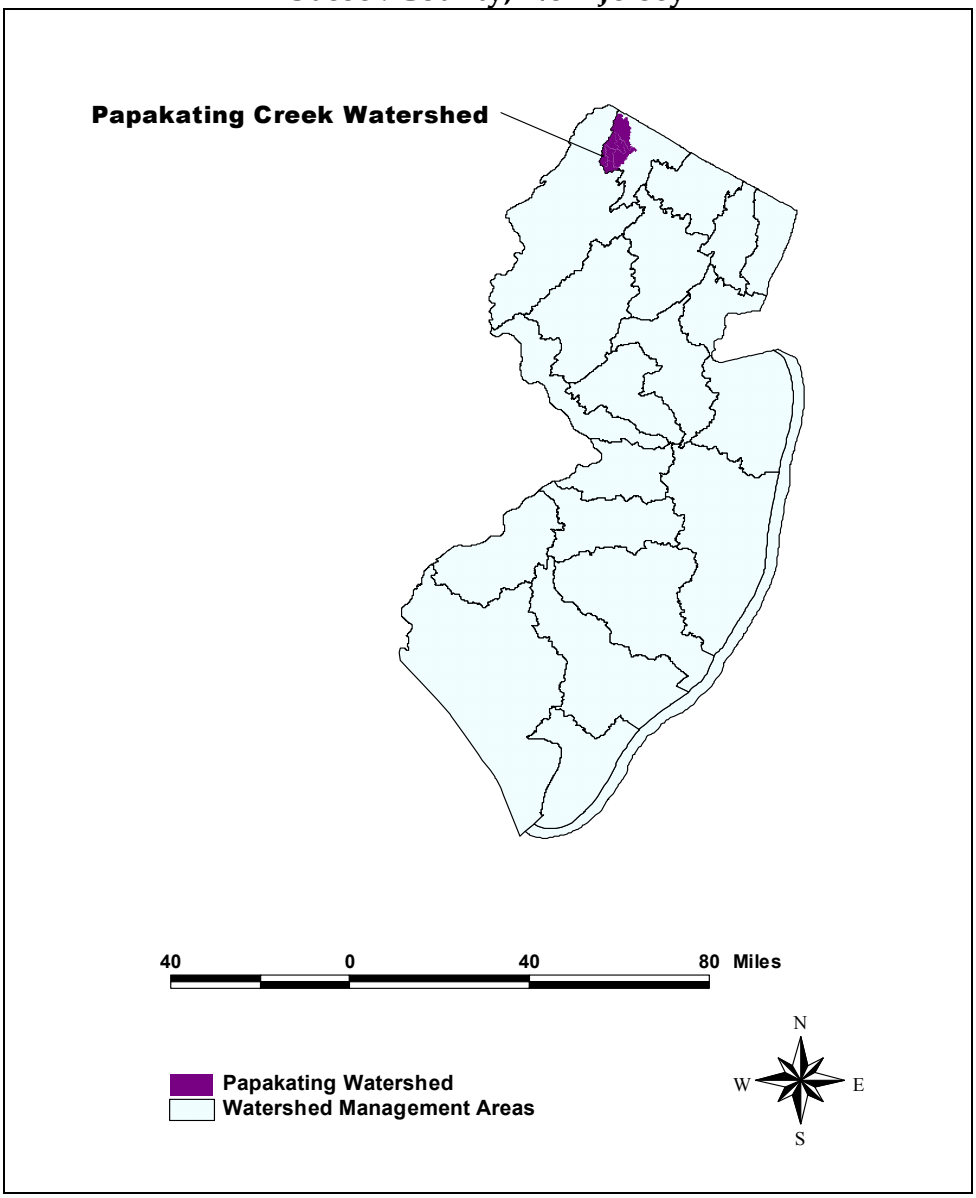
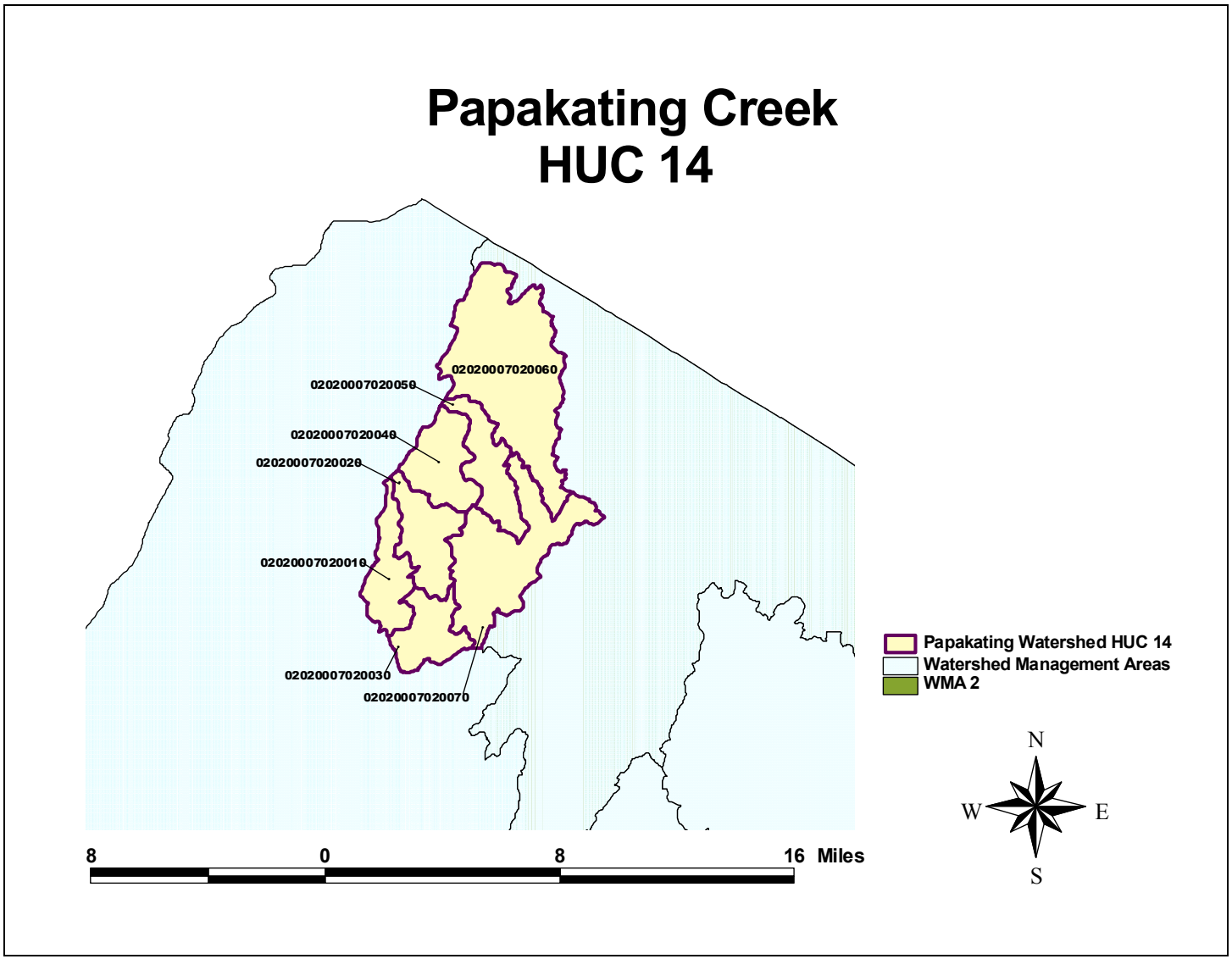


Figure 2: Papakating Creek Hydrologic Unit Codes (HUC) 14 Delineations



Sublist 5 Waterbodies in the Papakating Creek Watershed

The Papakating Creek Watershed contains one river segment and one lake for which phosphorus TMDLs are being developed. The Sublist 5 stream segment is identified as Papakating Creek at Sussex, Station #01367910, and the lake is identified as Clove Lake-02, Clove Acres Lake. The spatial extent of the impaired lake is identified in Figure 3 and described in Table 3. Likewise, the spatial extent of the impaired stream segment is identified in Figure 4 and described in Table 4. Land use broken down by type is presented in tabular and map form below under Land Use.

Table 3: Description of the Sublist 5 impaired lake, known as Clove Acres Lake, listed for Total Phosphorus, in the Papakating Creek Watershed in WMA 2.

Station ID	Watershed area associated with impaired lake
Clove Lake-02	Clove Lake lakeshed extends from the headwaters of the Clove Brook to the outlet of Clove Acres Lake, encompassing all tributaries feeding into Clove Brook.

Figure 3: Spatial extent of impaired lakeshed for Station Clove Lake - 02,Clove Acres Lake, for which a TMDL is being developed

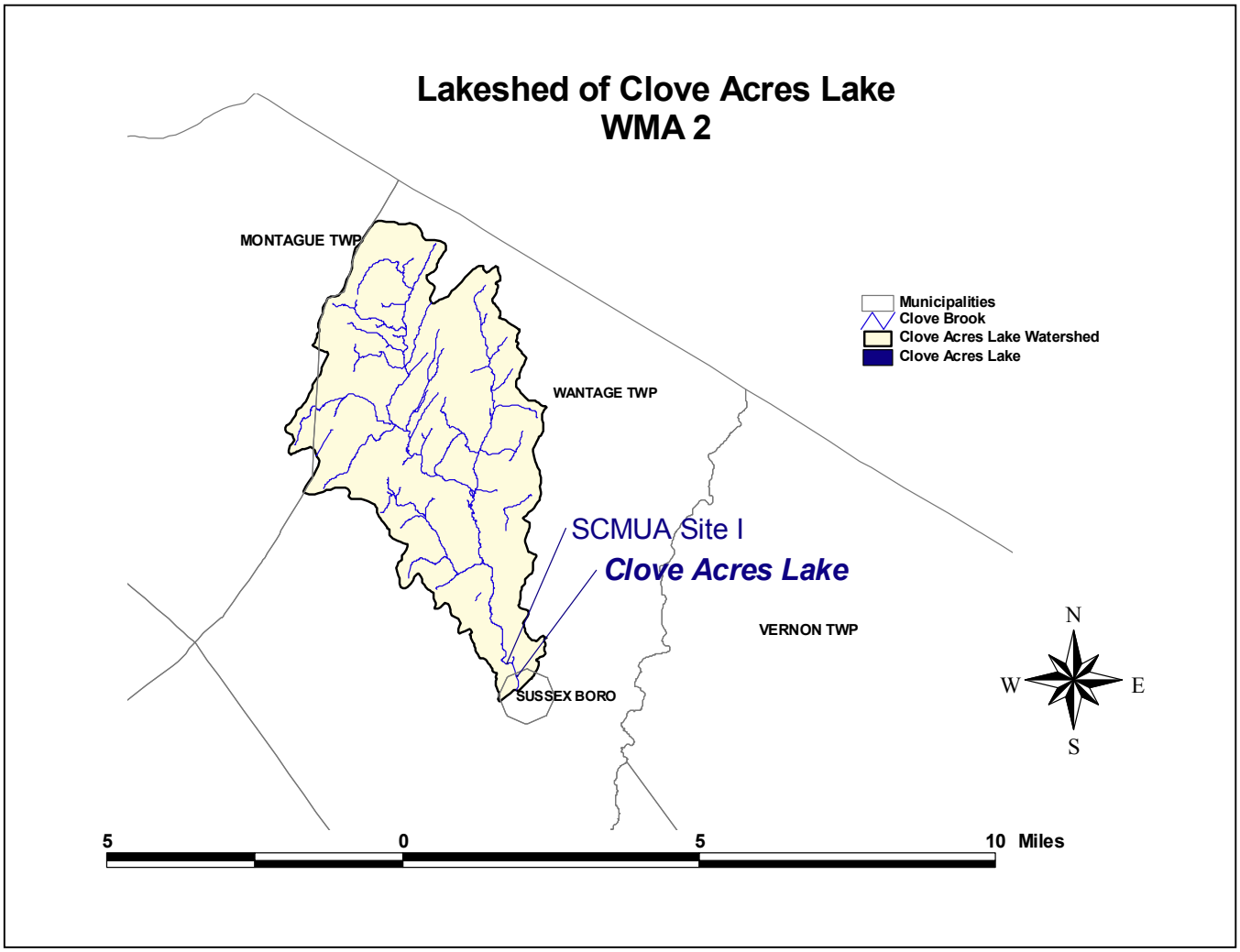
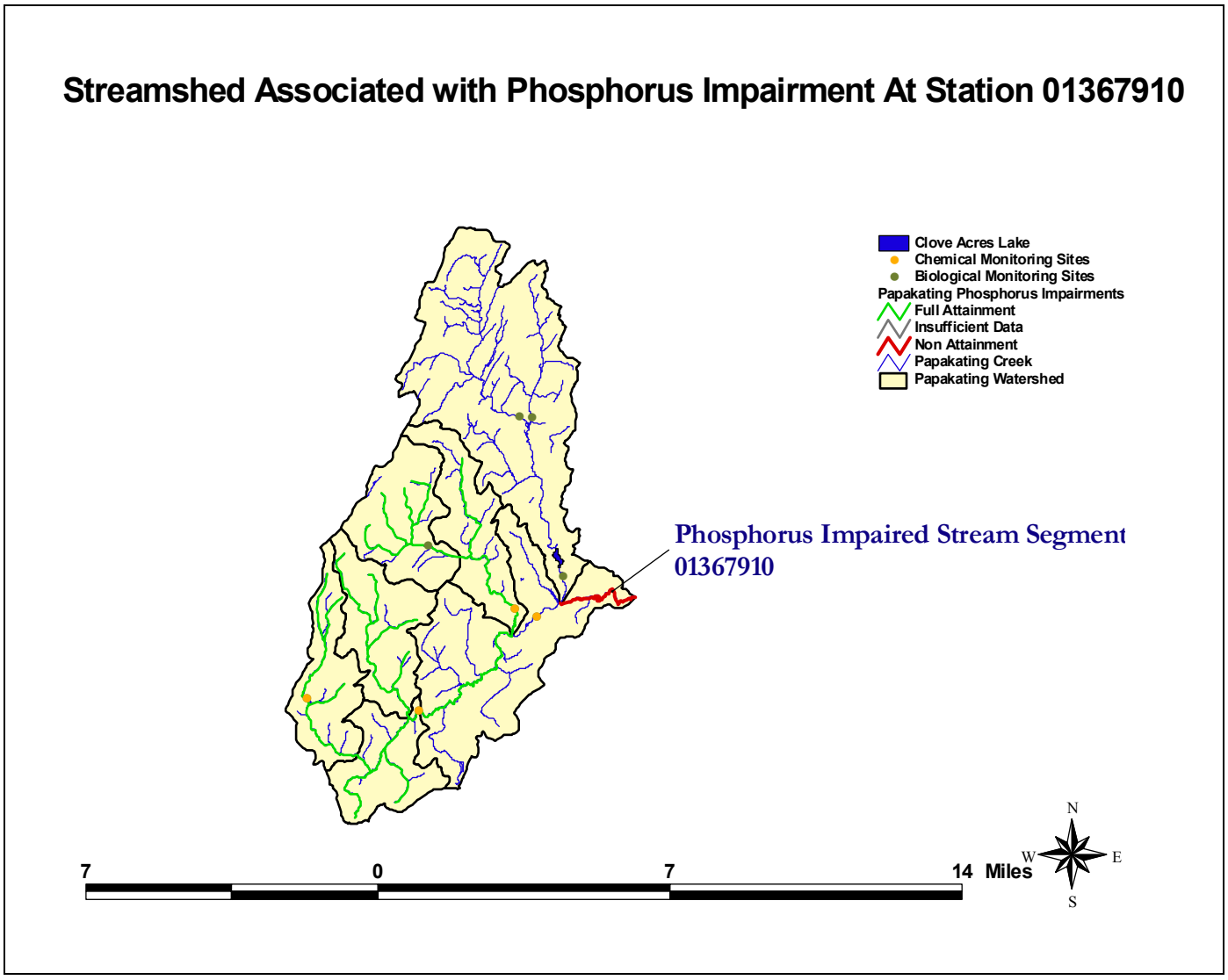


Table 4: Description of the spatial extent for the Sublist 5 segment, listed for Total Phosphorus, in the Papakating Creek Watershed, WMA 2.

Segment ID	Watershed area associated with impaired stream segments
01367910	Papakating Creek watershed that extends from the confluence of Papakating Creek with the West Branch Papakating Creek to the confluence of Papakating Creek with the Wallkill River

Figure 4: Spatial extent of impaired segment for Station 01367910, Papakating at Sussex



Land Use:

Clove Acres Lake Watershed

The Clove Acres lakeshed is predominately forested (49%), and agricultural land (22%). Urban developed land accounts for only 10% of the total land use in this lakeshed.

Figure 5: Clove Acres Lakeshed Land Use

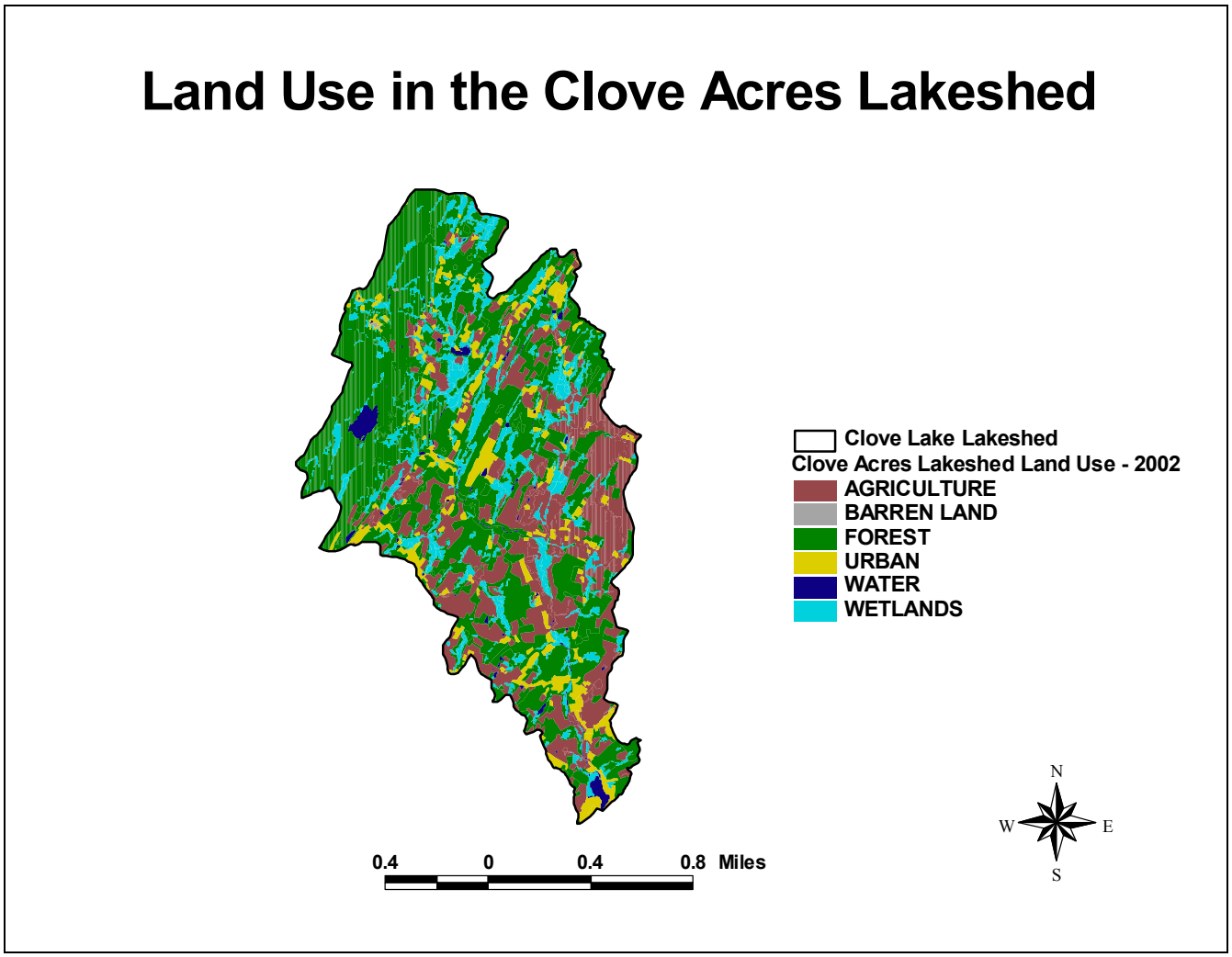


Table 5: Land Use Classification and Area summarized by Hydrologic Unit Code (HUC) 14 for the lakeshed associated with Station Clove Lake-02, Clove Acres Lake, in the Papakating Creek Watershed, WMA 2.

Land Use Type	Agriculture	Barren	Forest	Urban	Water	Wetlands	Total Acres
Totals Acres	2802.9	84.7	6122.2	1236.4	165.4	2122.4	**12,534.2**

Papakating Creek Watershed

The predominant land uses in the Papakating Creek Watershed include forest and woodland, agriculture and urban development. Of the 16,449 acres of forested land, 2850 acres, or 17.3%, of that land is dedicated federal or state open space, which essentially precludes this land from future development pressure.

Figure 6: Land Use Distribution in the Papakating Creek Watershed,

Based on 2002 Land Use

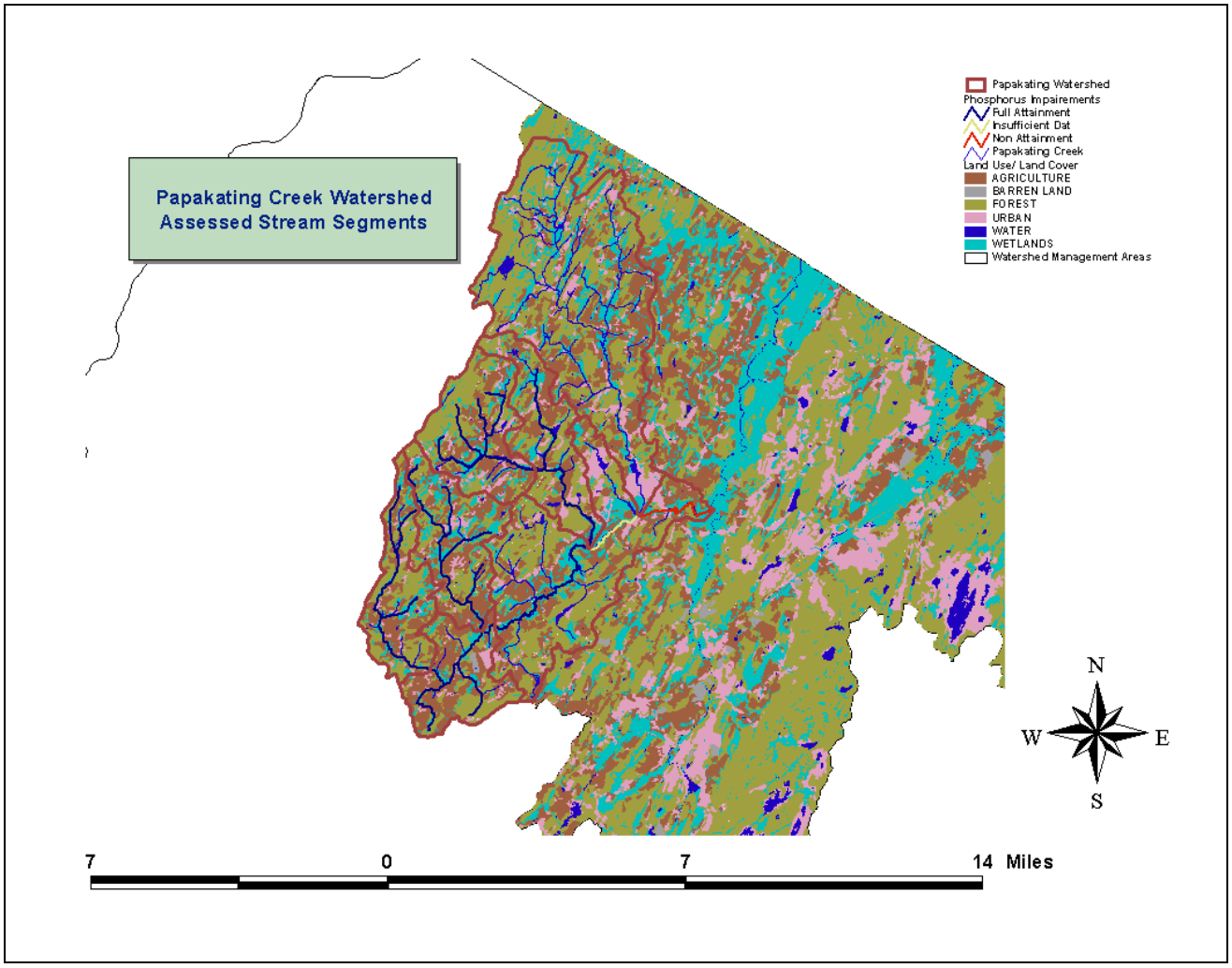


Figure 7: Federal and State Owned Open Space in the Papakating Creek Watershed

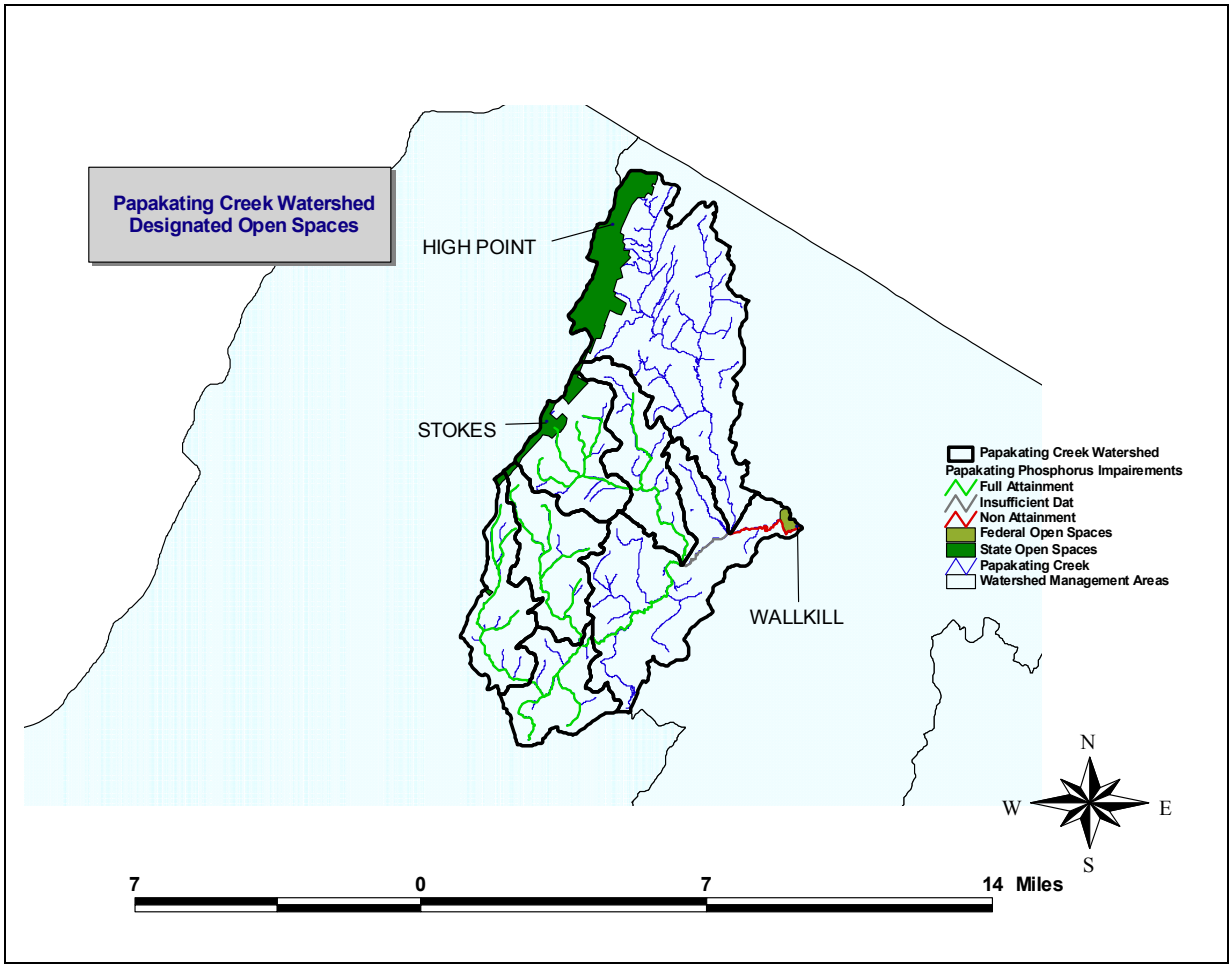


Table 6: Land Use Classification and Area summarized by Hydrologic Unit Code (HUC) 14 for the Watershed Associated with Station 01367910, Papakating at Sussex, on the Papakating Creek, in WMA 2.

HUC	Agriculture	Barren	Forest	Urban	Water	Wetlands	Total Acres
02020007020010	953.7	4.9	1512.7	332.4	14.9	442.8	3261.3
02020007020060	2815.9	87.8	6151.9	1440.7	168.6	2176.4	12841.3
02020007020020	1315.1	46.3	1301	467.4	29.7	654.4	3813.9
02020007020070	2316.6	85.4	3419.6	1087	165.5	1424.2	8498.3
02020007020040	1114.6	16.9	1668.2	462.2	23.8	534.2	3819.9
02020007020050	898.9	19.9	1453.4	645.6	78.1	445.4	3541.3
02020007020030	1345.2	36.4	941.8	384.4	10.2	304.8	3022.8
Totals	**10760**	**297.6**	**16448.6**	**4819.7**	**490.8**	**5982.2**	**38798.9**
	27.7%	0.8%	42.4%	12.4%	1.3%	15.4%	60.6 sq.mi.

Data Sources

The Department's Geographic Information System (GIS) was used extensively to describe Papakating Watershed characteristics. In concert with USEPA's November 2001 listing guidance, the Department is using Reach File 3 (RF3) in the 2002 Integrated List of Waterbodies to represent rivers and streams. The following is general information regarding the data used to describe the watershed management area:

- Land use/Land cover information was taken from the 1995/1997 Land Use/Land cover updated for New Jersey DEP, published 12/01/2000 by Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), delineated by watershed management area, and from updates received from the Sussex County Department of Planning.
- 2002 Assessed Rivers coverage, NJDEP, Watershed Assessment Group, unpublished coverage.
- County Boundaries: Published 11/01/1998 by the NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), "NJDEP County Boundaries for the State of New Jersey." Online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/stco.zip
- Detailed stream coverage (RF3) by County: Published 11/01/1998 by the NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA). "Hydrography of Sussex County, New Jersey (1:24000)." Online at: http://www.state.nj.us/dep/gis/digidownload/zips/strm/
- NJDEP 14 Digit Hydrologic Unit Code delineations (DEPHUC14), published 4/5/2000 by Department of Environmental Protection (NJDEP), New Jersey Geological Survey (NJGS) Online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/dephuc14.zip
- NJPDES Surface Water Discharges in New Jersey, (1:12,000), published 02/02/2002 by Division of Water Quality (DWQ), Bureau of Point Source Permitting - Region 1 (PSP-R1).
- NJDEP State Owned, Protected Open Space and Recreation Areas in New Jersey, New Jersey Department of Environmental Protection (NJDEP), Green Acres Program, published 1999. http://www.state.nj.us/dep/gis/digidownload/zips/statewide/newstate.zip NJDEP Municipality Boundaries for the State of New Jersey, NJ Department of Environmental Protection (NJDEP), Office of Information Resources Management (OIRM), Bureau of Geographic Information Systems (BGIS), published 01/23/2003, http://www.state.nj.us/dep/gis/digidownload/zips/statewide/stmun.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 Lakes (Shapefile) with Name Attributes (from 95/97 Land Use/Land Cover) in New Jersey, published 7/13/2001 by NJDEP - Bureau of Freshwater and Biological Monitoring, http://www.state.nj.us/dep/gis/digidownload/zips/statewide/njlakes.zip
- NJDEP Hillshade Grid for New Jersey (100 meter), NJ Department of Environmental Protection (NJDEP), Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), published 05/01/2002,

http://www.state.nj.us/dep/gis/digidownload/zips/statewide/nj100mhill.zip (used to delineate lakeshed).

5. Pollutant of Concern and Applicable Water Quality Standards

The pollutant of concern for these TMDLs is phosphorus. These TMDLs identify all the phosphorus contributions and establish WLAs and LAs expressed as maximum annual loads for phosphorus allowed in order to meet the SWQS. WLAs are established for point sources of phosphorus, namely wastewater discharges and regulated stormwater discharges of runoff from medium/high density residential, low density/rural residential, commercial, industrial and mixed urban/other urban land uses. LAs are established for the major categories of nonpoint sources of phosphorus: runoff from nonurban land uses and, for the lake, air deposition onto the lake surface.

In order to prevent excessive primary productivity and consequent impairment of recreational water supply and aquatic life designated uses, the Surface Water Quality Standards (SWQS, N.J.A.C. 7:9B) define both numerical and narrative criteria that address phosphorus concentrations in fresh waters. These TMDLs are designed to meet both numeric and narrative criteria of the SWQS.

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

Phosphorus, Total (mg/l):

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

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

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

Nutrient policies are as follows:

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

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

In all FW2 waters, the designated uses are (N.J.A.C. 7:9B-1.12):

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

Presently, no site-specific criteria apply to this stream segment and TP is the limiting nutrient, therefore the SWQS criterion of 0.1 mg/l will apply within the Papakating Creek watershed, except for Clove Brook as it enters Clove Acres Lake, and will be the measure to determine the effectiveness of the TMDL in the impaired segment associated with Station 01367910. The criterion of 0.05 mg/l will apply for Clove Acres Lake, which is the critical location for the Clove Brook and drives the load reduction requirements there.

6. Source Assessment

In order to evaluate and characterize phosphorus loadings in the waterbodies of interest in these TMDLs, and thus propose proper management responses, source assessments are warranted. Source assessments include identifying the types of sources and their relative contributions to phosphorus loadings, in both time and space variables.

Assessment of Point Sources

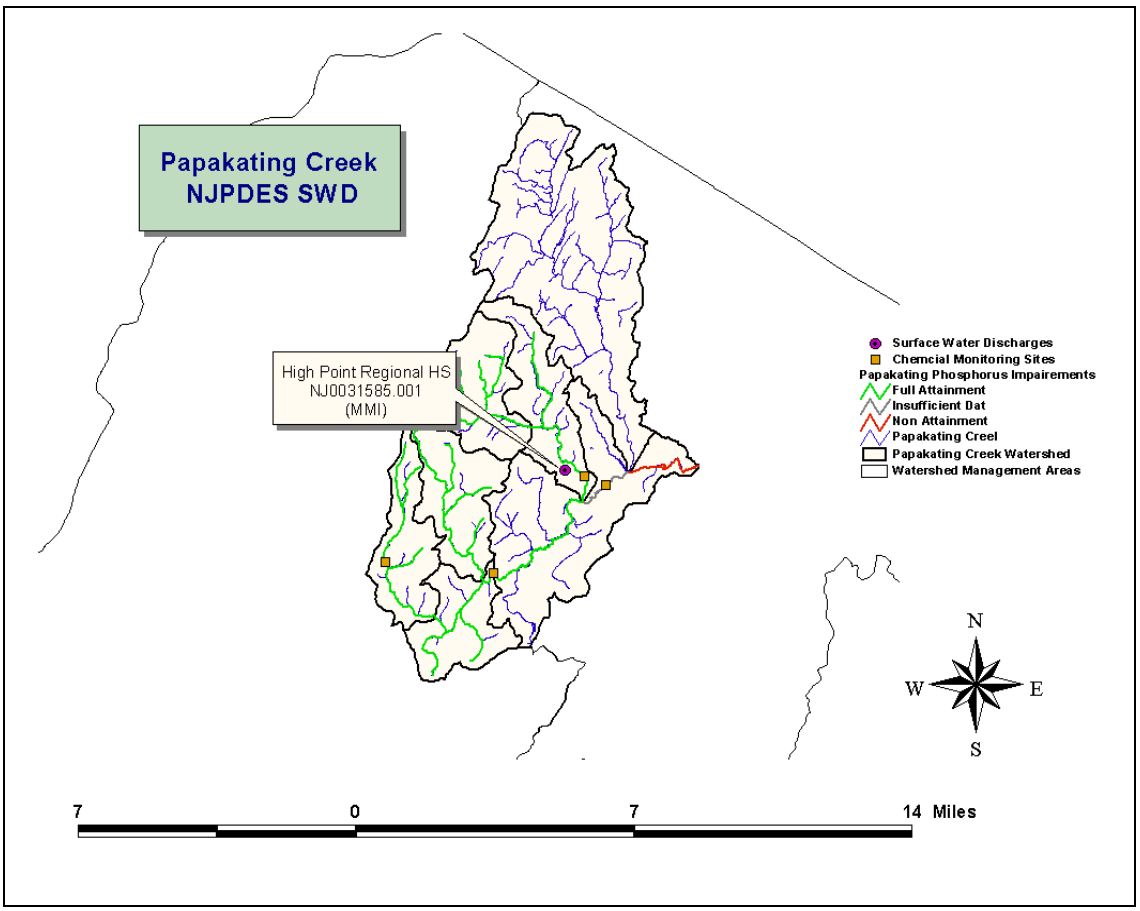
All NJPDES permits, other than Phase II municipal stormwater permits, within the Papakating Creek Watershed were evaluated for their possible contribution to phosphorus loading in the stream. Three active permits exist within this watershed, two of which are storm water discharges and one of which is a municipal minor discharge (MMI), identified in Table 7 and Figure 8. This discharge to surface water is the only one with the potential to contribute phosphorus and is located at the High Point High School, on the West Branch Papakating Creek. This facility operates under a New Jersey Pollution Discharge Elimination System (NJPDES) permitted discharge to surface water of 0.03 MGD, as a monthly average. They will receive an effluent limit commensurate with the WLA and will be required to monitor for TP upon renewal of their permit. Routine phosphorus monitoring is not currently included as part of the facility's permit requirements. There is currently no phosphorus effluent limit and no phosphorus monitoring requirement in the facility's permit.

Table 7: Point Source Discharger located in the Papakating Creek Watershed

WMA	Station #	NJPDES	Facility Name	Discharge Type[a]	Receiving waterbody
2	1367850	NJ0031585.001A	High Point Regional High School	MMI	Papakating Creek W B

[a] "MMI" indicates a Municipal Minor discharge

Figure 8: NJPDES Surface Water Discharge in the Papakating Creek Watershed



Assessment of Nonpoint and Municipal Stormwater Point Sources

Runoff from land surfaces comprises most of the nonpoint and stormwater point sources of phosphorus into the lake and stream segment. Watershed loads for total phosphorus were therefore estimated using the Unit Areal Load (UAL) methodology, which applies pollutant

export coefficients obtained from literature sources to the land use patterns within the watershed, as described in USEPA's Clean Lakes Program guidance manual (Reckhow, 1979b). Land use was determined using the Department's GIS system from the 1995/1997 land use coverage. The Department reviewed phosphorus export coefficients from an extensive database (Appendix B) and selected the land use categories and values shown in Table 8.

Table 8: Phosphorus export coefficients (Unit Areal Loads)

land use / land cover	**LU/LC codes[2]**	**UAL (kg TP/ha/yr)**
Mixed density residential	1100	1.2
medium / high density residential	1110, 1120, 1150	1.6
low density / rural residential	1130, 1140	0.7
Commercial	1200	2.0
Industrial	1300, 1500	1.7
mixed urban / other urban	other urban codes	1.0
Agricultural	2000	1.5
forest, wetland, water	1750, 1850, 2140, 2150, 4000, 6000, 5000, 8000	0.1
barren land	7000	0.5
Units:	1 hectare (ha) = 2.47 acres 1 kilogram (kg) = 2.2 pounds (lbs) 1 kg/ha/yr = 0.89 lbs/acre/yr	

Land uses and calculated runoff loading rates for both the impaired lake and the impaired streamshed are shown in Table 9. For Clove Acres Lake, estimates of loading from septic systems, waterfowl and from internal sources were not available for use in this TMDL, but will be assessed in the implementation stage through the Lake Characterization and Assessment. For the Clove Acres Lake TMDL, a UAL of 0.07 kg TP/ha/yr was used to estimate air deposition of phosphorus directly onto the lake surface. This value was developed from statewide mean concentrations of total phosphorus from the New Jersey Air Deposition Network (Eisenreich and Reinfelder, 2001). The load contribution from the High Point High School was based on effluent samples taken for the purpose of characterizing effluent concentration, multiplied by the permitted flow of 0.03 mgd.

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

Table 9: Sources of Phosphorus Loads

Source	Clove Acres Lake Lakeshed		Papakating Creek Impaired Streamshed *	
	acres	Kg/yr	acres	Kg/yr
land use loads		(estimates)		(estimates)
Mixed density residential	0.0	0.0	21.8	10.6
Medium / high density residential	54	34.9	364.6	236.5
low density / rural residential	887.7	252.0	2626.3	745.5
commercial	48.1	39.0	135	109.5
industrial	8.3	5.7	26.9	18.5
mixed urban / other urban	238.4	85.6	398.6	160.1
agricultural	2802.9	1705	8000.2	4866.5
forest, wetland, water	8410.1	546.2	14468.6	1006.1
barren land	84.7	6.8	212.9	33.9
other loads				
High Point High School				44.0
septic systems				
waterfowl				
tributary load				
air deposition	34	1		
groundwater				
Totals	12,534.2	2676.1	26,254.9	7231.3

*These values represent the phosphorus load generated from the Papakating Creek watershed excluding the Clove Acres Lake Lakeshed.

Wasteload Allocations and Load Allocations

WLAs are established for all NJPDES-regulated point sources, including stormwater point sources, while LAs are established for stormwater sources that are not subject to NJPDES regulation and for all other nonpoint sources. This distribution of loading capacity between WLAs and LAs is consistent with recent EPA guidance that clarifies existing regulatory requirements for establishing WLAs for stormwater discharges (Wayland, November 2002). Stormwater discharges are captured within the runoff sources quantified according to land use, as described previously. Distinguishing between regulated and unregulated stormwater is necessary in order to express WLAs and LAs numerically; however, "EPA recognizes that these allocations might be fairly rudimentary because of data limitations and variability within the system." (Wayland, November 2002, p.1) While the Department does not have the data to actually delineate drainage basins according to stormwater drainage areas subject to NJPDES regulation, the land use runoff categories previously defined can be used to estimate between them. Therefore allocations are established according to source categories as shown in Table 10. This demarcation between WLAs and LAs based on land use source categories is not perfect, but it represents the best estimate defined as narrowly as data allow. The Department acknowledges that there may be stormwater sources in the residential,

commercial, industrial and mixed urban runoff source categories that are not NJPDES-regulated. However, nothing in these TMDLs shall be construed to require the Department to regulate a stormwater source under NJPDES that would not already be regulated as such, nor shall anything in these TMDLs be construed to prevent the Department from regulating a stormwater source under NJPDES.

Table 10: Distribution of WLAs and LAs among source categories

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

7. Clove Acres Lake – Water Quality Analysis and TMDL Calculation

Water Quality Analysis

The SCMUA/Walkill River WMG monitoring program is being conducted as part of a grant provided by the Department. The data collection began in July 2003 and will continue until June 2004. Two of the sampling locations monitored by SCMUA are located on the Clove Brook tributary to Papakating Creek. The Clove Brook watershed is approximately 12,841.3 acres in area, and makes up the northwestern portion of the Papakating Creek Watershed. The actual drainage to the Clove Acres Lake is approximately 12,530 acres.

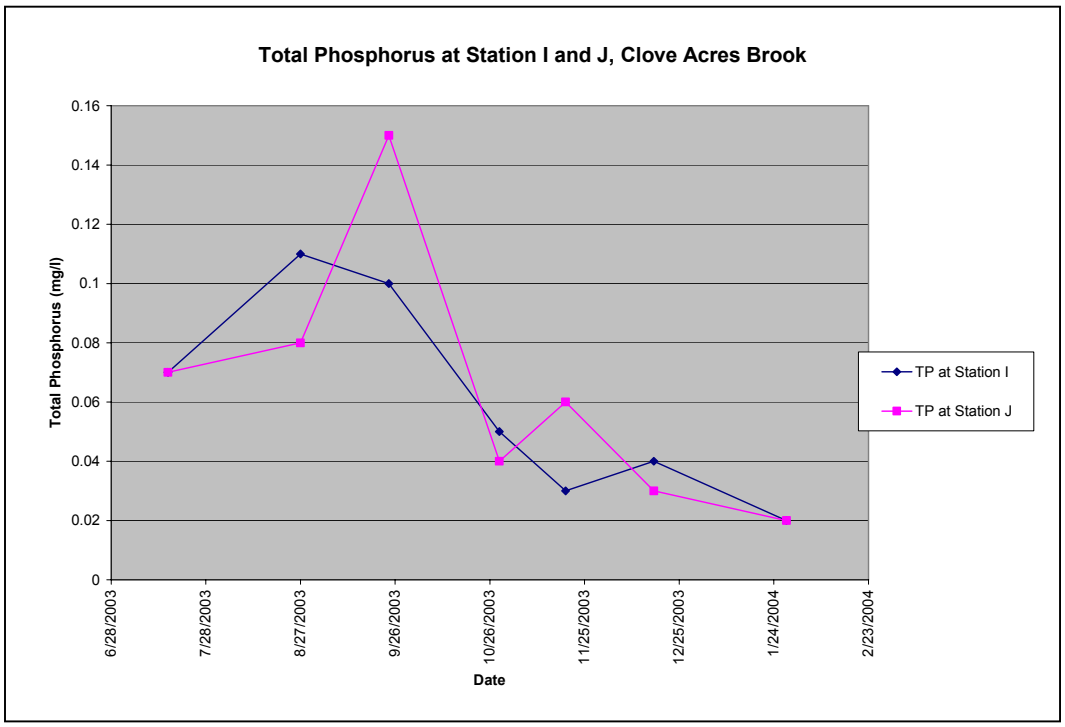
The timing of the data collection precluded this data from being incorporated into the proposed *2004 Integrated List of Waterbodies*. However, since a Quality Assurance Performance Plan (QAPP) has been approved by the Department, it is anticipated that this data set will be formally submitted by the SCMUA/Walkill River WMG for consideration in the development of the *2006 Integrated List of Waterbodies*. Until that time, the data collected and submitted by this group will be used to confirm the known impairments.

On the Clove Brook, Site I is located upstream of Clove Acres Lake, and Site J is located about 0.25 miles below the outlet of Clove Acres Lake. Four of the seven samples

collected between July 2003 and January 2004 at Station I, upstream of the lake, were either at, or in exceedance of, the 0.05 mg/l phosphorus criteria for lakes and streams upstream of lakes. (see Figure 9)

It should be noted that the Clove Acres Lake was drained approximately 15 years ago, and was reestablished as a lake recently. The effects of this on phosphorus dynamics in Clove Acres Lake have not yet been determined. However, even though the determination of impairment was based on data gathered prior to the lake draining, data from Site J, which was collected in 2003-2004, shows that 4 of the 7 samples are in exceedance of the 0.05mg/l criteria for lakes. Therefore, it is likely that the lake itself still exceeds the standards. In any case, the lake loadings and water quality will be further characterized in the implementation stage.

Figure 9: SCMUA Papakating Creek Data from Sites I and J



Model Approach

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

To achieve a TMDL for the impaired lake, phosphorus sources were characterized on an annual scale (kg TP/yr). Since no point source dischargers exist in the Clove Acres Lake lakeshed, phosphorus sources are comprised solely of runoff from land surfaces. An empirical model, developed by K.H. Reckhow, Ph.D. and described in *Modeling Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients*, (Reckhow, K.H., M.N. Beaulac and J.T. Simpson, 1980, EPA 440/5-80-011), was used to relate annual phosphorus load to steady-state in-lake concentration of total phosphorus. To achieve the goal of the TMDL, overall load reductions were calculated for each of the source categories.

Empirical models were used to relate annual phosphorus load and steady-state in-lake concentration of total phosphorus. These empirical models consist of equations derived from simplified mass balances that have been fitted to large datasets of actual lake measurements. The resulting regressions can be applied to lakes that fit within the range of hydrology, morphology and loading of the lakes in the model database. The Department surveyed the commonly used models in Table 11.

Table 11: Empirical models considered by the Department

reference	steady-state TP concentration in lake (mg/l)	Secondary term	Application
Rast, Jones and Lee, 1983	$1.81 \times NPL^{0.81}$	$NPL = \left(\frac{P_a \times DT/D_m}{1+\sqrt{DT}} \right)$	expanded database of mostly large lakes
Vollenweider and Kerekes, 1982	$1.22 \times NPL^{0.87}$	$NPL = \left(\frac{P_a \times DT/D_m}{1+\sqrt{DT}} \right)$	mostly large natural lakes
Reckhow, 1980	$\frac{P_a}{13.2}$	none	Upper bound for closed lake
Reckhow, 1979a	$\frac{P_a}{(11.6+1.2\times Q_a)}$	$Q_a = \frac{Q_i}{A_l}$	General north temperate lakes, wide range of loading concentration, areal loading, and water load
Walker, 1977	$\frac{P_a \times DT/D_m}{(1+0.824\times DT^{0.454})}$	none	oxic lakes with $D_m/DT < 50$ m/yr
Jones and Bachmann, 1976	$\frac{0.84\times P_a}{(D_m \times (0.65+DT^{-1}))}$	none	may overestimate P in shallow lakes with high D_m/DT
Vollenweider, 1975	$\frac{P_a}{(D_m \times (DT^{-1}+S))}$	$S = 10/D_m$	Overestimate P lakes with high D_m/DT

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

where:
NPL = normalized phosphorus loading
P_a = areal phosphorus loading ($g/m^2/yr$)
DT = detention time (yr)
D_m = mean depth (m)
Qa = areal water load (m/yr) [3]
Q_i = total inflow (m^3/yr)
A_l = area of lake (m^2)
S = settling rate (per year)

Reckhow (1979a) model was selected because it has the broadest range of hydrologic, morphological and loading characteristics in its database. Also, the model includes an uncertainty estimate that was used to calculate a Margin of Safety. The Reckhow (1979a) model is described in USEPA Clean Lakes guidance documents: *Quantitative Techniques for the Assessment of Lake Quality* (Reckhow, 1979b) and *Modeling Phosphorus Loading and Lake Response Under Uncertainty* (Reckhow *et al*, 1980). The derivation of the model is summarized in Appendix C. The model relates TP load to steady state TP concentration, and is generally applicable to north temperate lakes, which exhibit the following ranges of characteristics (see Symbol definitions after Table 11):

phosphorus concentration: $0.004 < P < 0.135$ mg/l
average influent phosphorus concentration: $P_a*DT/D_m < 0.298$ mg/l
areal water load: $0.75 < Q_a < 187$ m/yr
areal phosphorus load: $0.07 < P_a < 31.4$ $g/m^2/yr$

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

For comparison, Table 12 below summarizes the characteristics for Clove Acres Lake based on the current and target conditions, which fall within the specified ranges. It should be noted that no attempt was made to recalibrate the Reckhow (1979a) model for lakes in New Jersey or in this Water Region, since sufficient lake data was not available to make comparisons with model predictions of steady-state in-lake concentration of total phosphorus. The model was already calibrated to the dataset on which it is based, and is generally applicable to north temperate lakes that exhibit the range of characteristics listed previously.

Table 12. Clove Acres Lake input data for the Reckhow model and the resultant total phosphorus load reduction.

Lake Area[1] (m^2)	Total Annual Inflow[2] (m^3/yr)	Areal Water Load[3] (m/yr)	Average Annual Phosphorus Concentration[4] (mg/l)
137,592	**24,370,000**	**177.12**	**0.0866**

[1] Lake area = 34 acres (Communication with Ernest Hofer, P.E., Watershed Specialist, Watershed Management Area 02) = 137,592 m^2
[2] Total annual inflow = 24,370,000 m^3/yr (New Jersey Lakes Management Program, Lakes Classification Study, Clove Lake – Sussex, Sussex County, NJDEP – Division of Water Resources, Bureau of Monitoring and Data Management, January 1983)
[3] Areal water load = 24,370,000 m^3/yr / 137,592 m^2 = 177.12 m/yr
[4] Steady-state average annual lake concentration (from Reckhow, 1979) = 19.409 g/m^2/yr / (11.6 + (1.2 x 177.118 m/yr)) = 0.0866 mg/l (based on an average annual loading of 2,676.1 kg/yr)

Table 12 (Continued).

Current Avg Influent[5] TP (mg/l)	Target Avg Influent TP (mg/l)	Current Areal TP load[6] (g/m^2/yr)	Target Areal TP load[7] (g/m^2/yr)	Load Reduction from Model Results[8] (%)
0.1087	**0.03**	**19.409**	**6.724**	**65**

[5] Equivalent to: Current Areal TP load (g/m^2/yr) x Total Lake Volume (m^3)/Total Annual Inflow (m^3/yr) x Avg Depth (m)
[6] Areal phosphorus loading = 5,887 lb/yr, or 2,676.1 kg/yr (estimated from land-use export coefficients, using 2002 land use/land cover data from Sussex County) / 34 acres = 5887 lb/yr / 34 acres = 19.409 g/m^2/yr
7 Equivalent to: Target Avg Influent x (11.2 + (1.2 x Areal Water Load))

8 Annual load reduction from model results required for a total phosphorus target of 0.03 mg/l = [0.0866 mg/l – 0.03 mg/l)/0.0866 mg/l] x 100 = 65 percent

TMDL Calculations

Figures 10 and 11 illustrate the percent of estimated loadings from land use types and the percent areal coverage of each land use, respectively.

An "internal load" for the lake was not calculated from the difference in total phosphorus loading between the inflow to and the outflow from the lake. Although there exists water

quality data from the Sussex County Municipal Utilities Authority, these data have not been verified for appropriate QA/QC for use by the Department.

Figure 10: Current Distribution of Phosphorus Loading by Land use/Land cover Within the Lakeshed of Clove Acres Lake

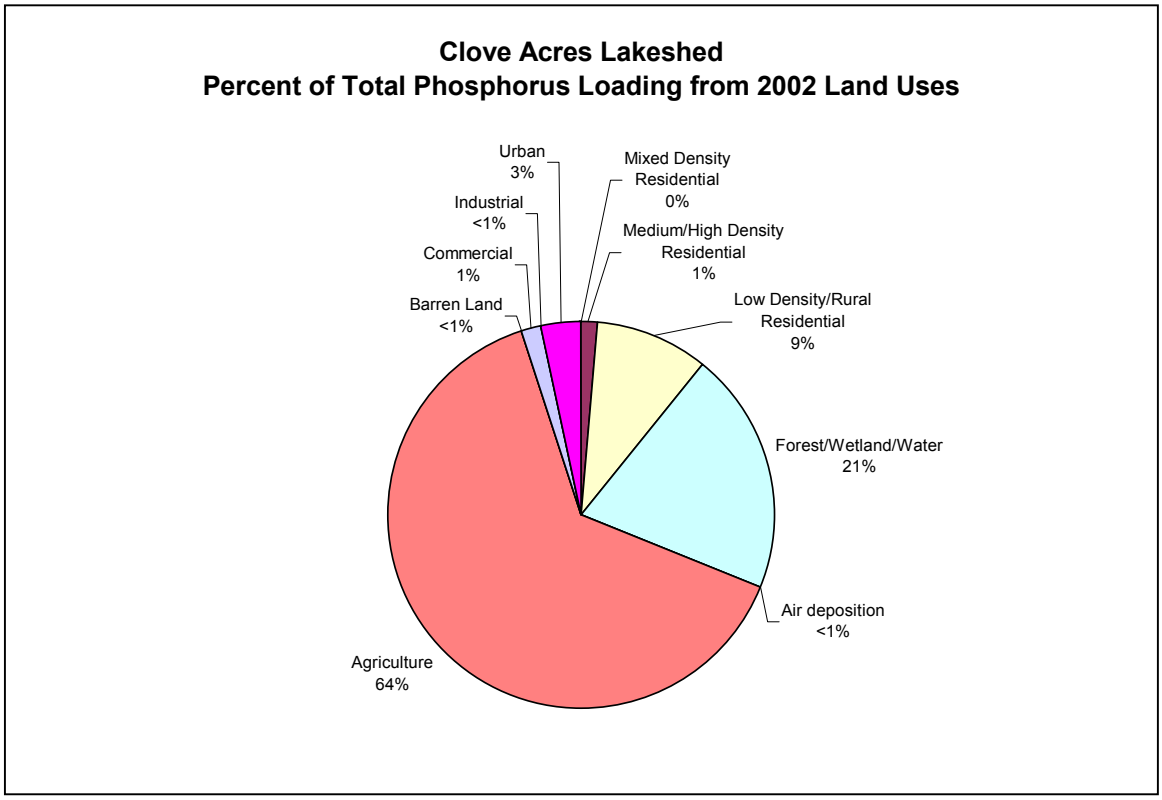
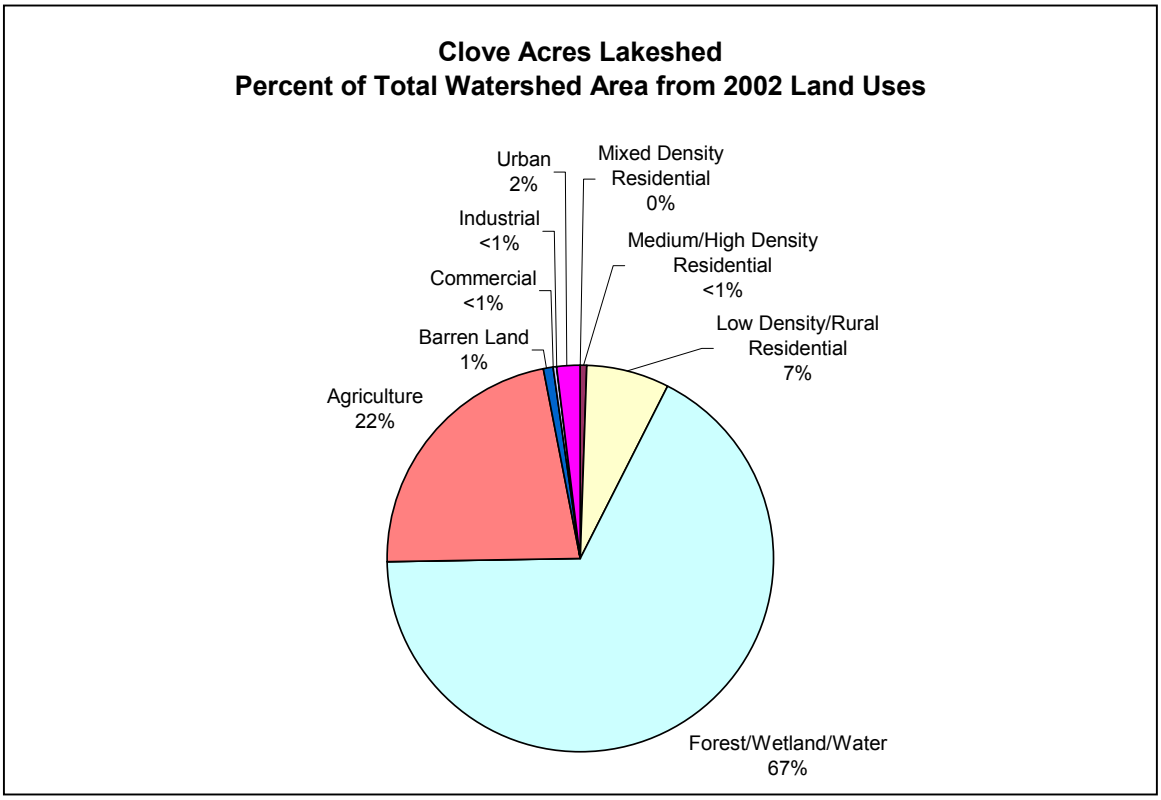


Figure 11: Percent of Total Watershed Area for Land use/Land Cover Within the Clove Acres Lake Watershed



Reference Condition

A reference condition for the lake was estimated using the Reckhow (1979a) formulation by calculating external loads as if the land use throughout the lakeshed were completely forest and wetlands. The estimate of air deposition was included in the reference condition for the lake. The reference steady-state condition TP concentration is 0.016 mg/l. Because the reference condition demonstrates the standard would be attained under natural conditions, the standard applies.

Seasonal Variation/Critical Condition

The Reckhow model predicts steady-state phosphorus concentration. To account for data variability, the Department generally interprets threshold criteria as greater than 10% exceedance for the purpose of defining impaired waterbodies. Data from two lakes in New Jersey (Strawbridge Lake, NJDEP 2000a; Sylvan Lake, NJDEP 2000b) exhibit peak (based on the 90th percentile) to mean ratios of 1.56 and 1.48, resulting in target phosphorus concentrations of 0.032 and 0.034 mg TP/l, respectively. Since the peak to mean ratios were

close and the target concentration not very sensitive to differences in peak to mean ratios, the Department determined that a target phosphorus concentration of 0.03 mg TP/l is reasonably conservative. The seasonal variation was therefore assumed to be 67%, resulting in a target phosphorus concentration of 0.03 mg TP/l. Since it is the annual pollutant load rather than the load at any particular time that determines overall water quality in the lake, the target phosphorus concentration of 0.03 mg TP/l accounts for critical conditions in the lake.

Margin of Safety

A Margin of Safety (MOS) is provided to account for "lack of knowledge concerning the relationship between effluent limitations and water quality" (40 CFR 130.7(c)). A MOS is needed in order to account for uncertainty in the loading estimates, physical parameters and the model itself. The MOS, as described in USEPA guidance (Sutfin, 2002), can be either explicit or implicit (i.e., addressed through conservative assumptions used in establishing the TMDL). For this TMDL calculation, both an implicit and explicit MOS have been incorporated. The implicit MOS is achieved by using conservative critical conditions, over-estimating loads, and using total phosphorus as the measure. Each conservative assumption is further explained below.

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

In addition to the multiple conservative assumptions built in to the calculation, an additional explicit MOS was included to account for the uncertainty in the model itself. As described in Reckhow *et al* (1980), the Reckhow (1979a) model has an associated standard error of 0.128, calculated on log-transformed predictions of phosphorus concentrations.

Transforming the terms in the model error analysis from Reckhow *et al* (1980) yields the following (Appendix C):

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

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

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

Setting the probability to 90% yields a margin of safety (MOS) of 51% when expressed as a percentage over predicted phosphorus concentration or estimated external load. The external load for each lake was therefore multiplied by 1.51 to calculate an "upper bound" estimate of steady-state phosphorus concentration. An additional explicit margin of safety was included in the analyses by setting the upper bound calculations equal to the target phosphorus concentration of 0.03 mg TP/l and the MOS target condition to 0.02 mg TP/l, as described in the next section and shown in Table 13. Note that the explicit MOS is equal to 51% when expressed as a percentage over the predicted phosphorus concentration; when expressed as a percentage of total loading capacity, the MOS is equal to 34%:

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

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

MoS_{lc} = margin of safety as a percentage of total loading capacity;

P = predicted phosphorus concentration (or external load).

Target Conditions

As discussed above, the current steady state concentration of phosphorus in Clove Acres Lake must be reduced to a steady state concentration of 0.03 mg/l to avoid exceeding the 0.05 mg/l phosphorus criterion. Using the Reckhow (1979a) formulation, the target conditions were calculated by reducing the loads as necessary to make the upper bound predictions (which incorporate the Margin of Safety, (0.03 ÷ 1.51) = 0.02) equal to the target phosphorus concentration of 0.03 mg TP/l. The target condition was set equal to the current condition, if the upper bound prediction assuming current loads was already less than the target phosphorus concentration of 0.03 mg TP/l. Overall reductions necessary to attain the target steady state concentration of total phosphorus in the lake were calculated by comparing the current condition to the reduced target condition of 0.02 mg TP/l (Table 14).

The load reduction target with the margin of safety included for the Clove Acres Lakeshed is 77 percent and was derived as follows:

The target condition and upper bound condition are both set equal to 0.03 mg TP/l (or an equivalent 925.2 kg/yr). Using the explicit MOS, the target condition is further reduced to 0.02 mg TP/l (or an equivalent 616.8 kg/yr). Therefore, the difference between the current

condition (Reckhow estimated concentration) and 0.02 mg TP/l is the required load reduction for the Lake, or [(0.0866 – 0.02)/0.0866] x 100 = 77 percent reduction.

The forest, wetland, water; barren land; and air deposition loadings are not reduced. These adjustments were compensated by those land use classifications that can be reduced. The compensated load reduction was an additional 546.2 kg/yr +6.8 kg/yr + 1 kg/yr = 554 kg/yr. This equates to a reduction of (1-((925.2 – 554 – 314.6)/2676.1)) x 100 = 20.9 percent for a total reduction of 77 + 20.9 = 98 percent. Table 14 presents the total phosphorus load reduction targets for land uses within the Clove Acres Lakeshed.

Table 13: Current condition, reference condition, target condition and overall percent reduction for Clove Acres Lake

Lake	current condition [TP] (mg/l)	reference condition [TP] (mg/l)	upper bound target condition [TP] (mg/l)	target condition [TP] (mg/l)	% overall TP load reduction	Estimated TP annual loading (kg/yr)
Clove Acres Lake	0.087	0.016	0.030	0.020	77%	2676

Note: Upper bound target condition is equal to the current condition multiplied by 1.51 with a maximum allowable upper bound limit of 0.030 mg/l.

In order to attain the TMDL, the overall load reductions shown in Table 14 must be achieved. Since loading rates have been defined for at least eight source categories, countless combinations of source reductions could be used to achieve the overall reduction target. The selected scenarios focus on land uses that can be affected by BMP implementation or NJPDES regulation, requiring equal percent reductions from each in order to achieve the necessary overall load reduction. The lake characterization and Lake Restoration Plan developed as part of the TMDL implementation (Section 9) may revisit the extent and distribution of reductions among the various sources in order to better reflect actual relative load contributions, as well as sources that were not quantified, such as septic tanks, due to lack of data.

Table 14: TMDL Calculations for Clove Acres Lake (annual loads and percent reductions)

Lake	Clove Acres Lake Estimated kg TP/yr	% of LC	% reduction
Loading capacity (LC)	925.2	100%	n/a
Point Sources other than Stormwater	n/a		
Stormwater Point Sources			
medium / high density residential	0.7	0.1%	98%
low density / rural residential	5.0	0.5%	98%
commercial	0.8	0.1%	98%
industrial	0.1	0.01%	98%
Mixed urban / other urban	1.7	0.2%	98%
Nonpoint Sources			
agricultural	34.1	3.7%	98%
forest, wetland, water	546.2	59.0%	0%
barren land	6.8	0.7%	0%
air deposition onto lake surface	1.0	0.1%	0%
Margin of Safety	315	34%	

Figure 12 illustrates the load allocation for the Clove Acres Lakeshed TMDL.

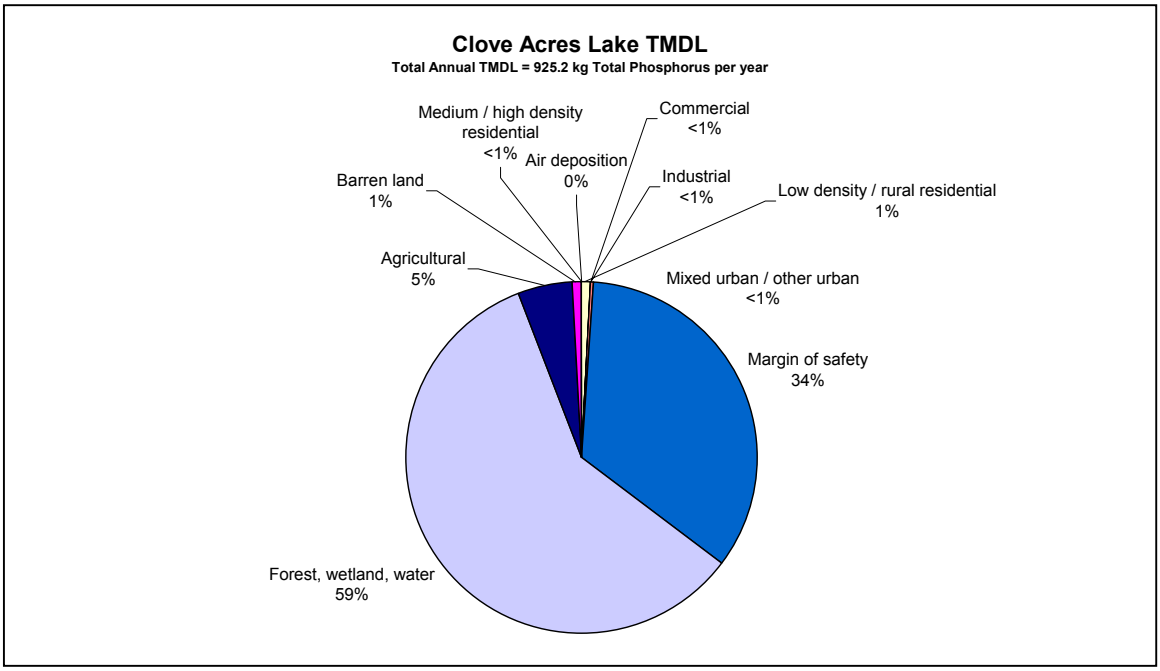


Figure 12. Percent of TMDL allocation for Clove Acres Lake land uses, including a margin of safety.

8. Papakating Creek Watershed Stream Segment: Water Quality Analysis and TMDL Calculations

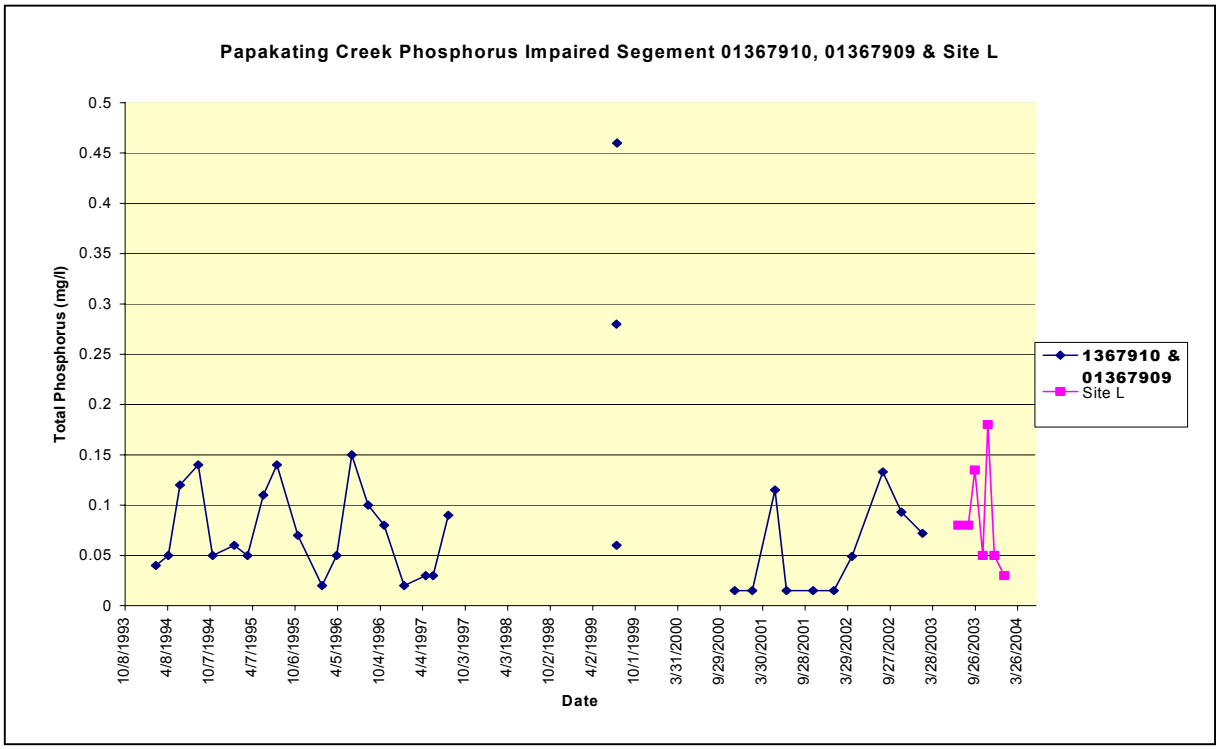
Water Quality Analysis

Phosphorus monitoring in the Papakating Creek watershed is conducted at seven Department chemical water quality stations, and four additional sites that are monitored by the SCMUA and the Wallkill River Watershed Management Group (WMG). Based on the Department monitoring, Station 01367910, Papakating Creek at Sussex, has been classified as impaired for the water quality parameter of phosphorus. This site was originally listed in 1998 on the NJDEP 303(d) List of Impaired Waterbodies for phosphorus, was carried over onto the *2002 Integrated List of Waterbodies* and continues to be listed on the *Proposed 2004 Integrated List of Waterbodies*.

The impaired segment of the Papakating Creek begins in the area of Station 01367910, Papakating at Sussex. This monitoring site, located at the downstream end of the watershed, serves as an integrator site for this drainage area. As such, it not only represents the water quality of this particular stream segment, but can also be viewed as an indicator of the additive effects of the water received from each tributary upstream of the impaired segment along the Papakating Creek.

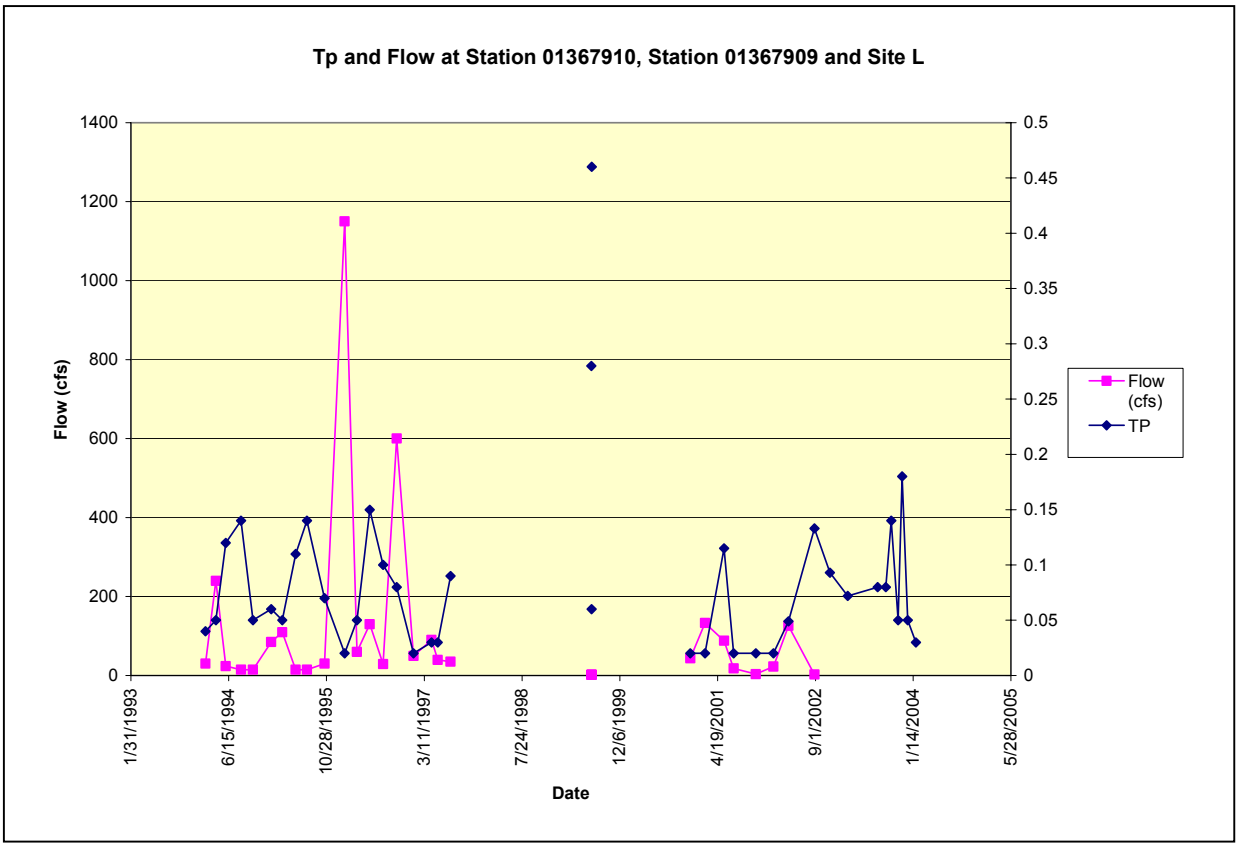
Papakating at Sussex (01367910 and 016709) is located along the mainstem of the Papakating Creek after the confluence with the Clove Brook. At this location, phosphorus levels have been at 0.1 mg/l or higher 10 times out of the 32 sampling occurrences between 1994 and 2003, resulting in a 31% exceedance rate. In addition, the SCMUA / Walkill River WMG data collected at Site L, Papakating Creek at Route 23, further confirms the impairment with 2 of the 7 samples (28.5%) collected between July 2003 and January 2004 being at or above 0.1mg/l (Figure 13).

Figure 13: Total Phosphorus at Stations 01367910, 01367909 and Site L



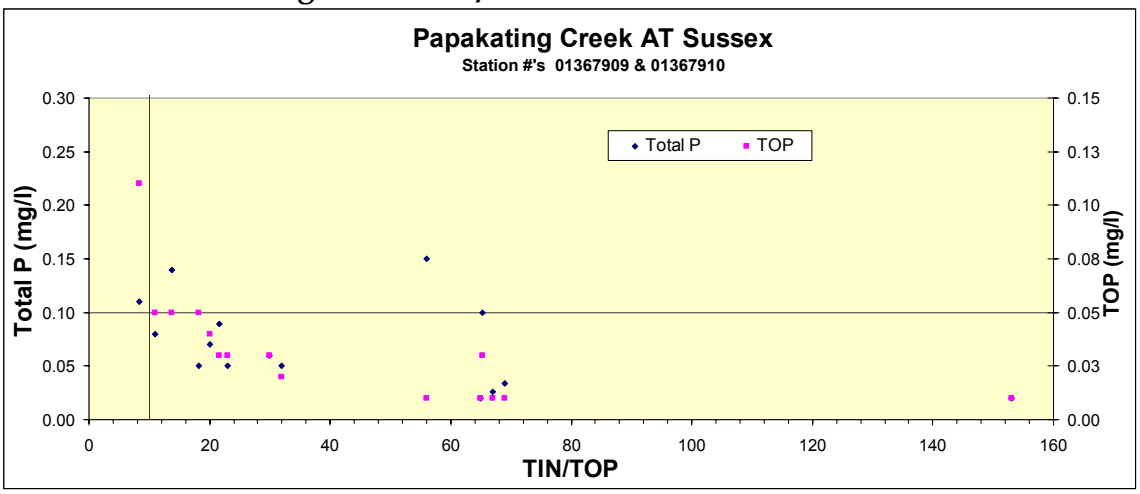
Phosphorus, as Total P, for Stations 01367910, 01367909, and Site L was plotted against flow at this site. The results, shown in Figure 14, show a correlation between increased flow and elevated phosphorus levels, indicating that the source of the phosphorus loading may be attributed primarily to nonpoint sources of pollution entering the Papakating Creek as runoff.

Figure 14: Total Phosphorus vs Flow at Stations 01367910, 01367909, and Site L



Existing data was assessed to determine if phosphorus is a limiting nutrient in the Papakating Creek. Total phosphorus (TP), total orthophosphorus (TOP) and the ratio of total inorganic nitrogen (TIN) to total orthophosphorus were plotted in Figure 15. Where the ratio of TIN/TOP is greater than 5 and TOP is generally less than 0.05 mg/l, it suggests that phosphorus is the limiting nutrient. This is discussed further in Appendix D. The available data for Papakating Creek suggest that phosphorus is limiting; therefore, the 0.01 mg/l criterion applies.

Figure 15: TIN/TOP for Stations 01367910



Model Approach

The stochastic approach that was selected by the Department for the Papakating Creek total phosphorus TMDL uses an adapted version of *"TMDL Development Using Load Duration Curves"* as presented at an ASIWPCA TMDL "Brown Bag" by Tom Stiles (Kansas Department of Health and Environment), Andrew Sullivan (Texas Natural Resource Conservation Commission), Charles Martin (Virginia Department of Environmental Quality), and Bruce Cleland (America's Clean Water Foundation), May 16, 2002. The referenced approach requires enough historical flow and concentration data to define a representative flow duration curve and the associated loading duration curve. The concept of this approach is to determine the average of the loading exceedances (derived from the measured data loadings) that exist between the probability curve (duration curve) of the associated regulatory loading target and a selected upper confidence limit of a regression through the exceedances. The regulatory loading target and measured pollutant loadings are plotted against flow duration. Half of the difference between the regulatory loading target curve and the selected upper confidence limit of the exceedance regression line is selected as the required TMDL loading reduction.

Although this method provides a good estimate of the loading reduction that is required to maintain ambient water quality conditions within the regulatory target(s), the number of water quality data required to satisfy a Department assessment of TP impairment may be as few as eight. Therefore, flow and loading duration curves developed with a small data set may not provide a good representation of the actual data distribution. This may impart additional error in the results of a load duration method. The Department has adapted this technique to use only those flows that were measured concurrently with water quality samples.

TMDL Calculation

Annual total phosphorus loading for the Papakating Creek Watershed, including Clove Brook, by land use/land cover categories are presented in Figure 16. Annual total phosphorus loading was estimated using the PLOAD model (*An AcrView GIS Tool to Calculate Nonpoint Sources of Pollution in Watershed and Stormwater Projects, Version 3.0, User's Manual, U.S. Environmental Protection Agency, January 2001*). The model calculates pollution loading from a stochastic relationship between pollution loading and land use/land cover. Loading estimates for land uses (Anderson classification system) are known as export coefficients or Unit Areal Loads (units of mass per land area per year). Figures 16 and 17 depict the percent of land use types within the Papakating watershed and the percent of TP loading per land use.

Total phosphorus export coefficients for land use/land cover characteristics were presented in Table 8. These coefficients represent average annual loadings of total phosphorus per land use and land cover.

Figure 16: Percent of TP Loading from LU/LC Cover Within Papakating Creek Watershed

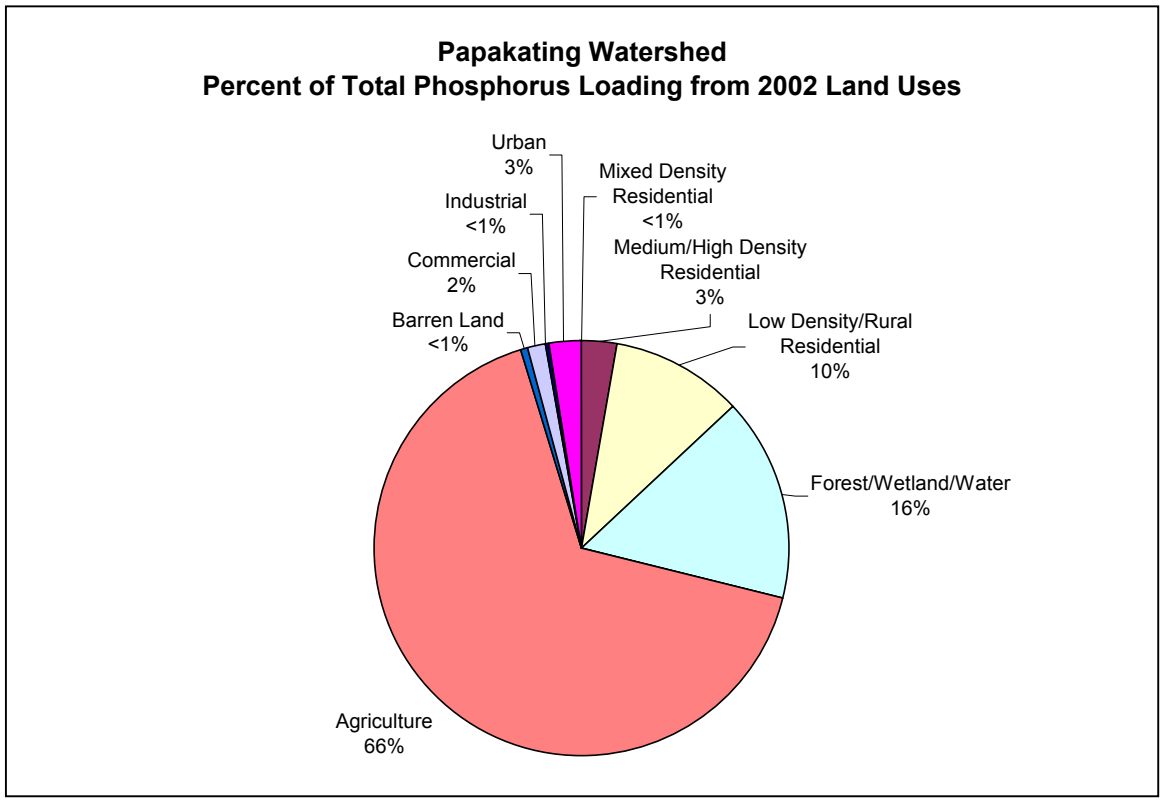


Figure 17: Papakating Creek Watershed Land Use Distribution

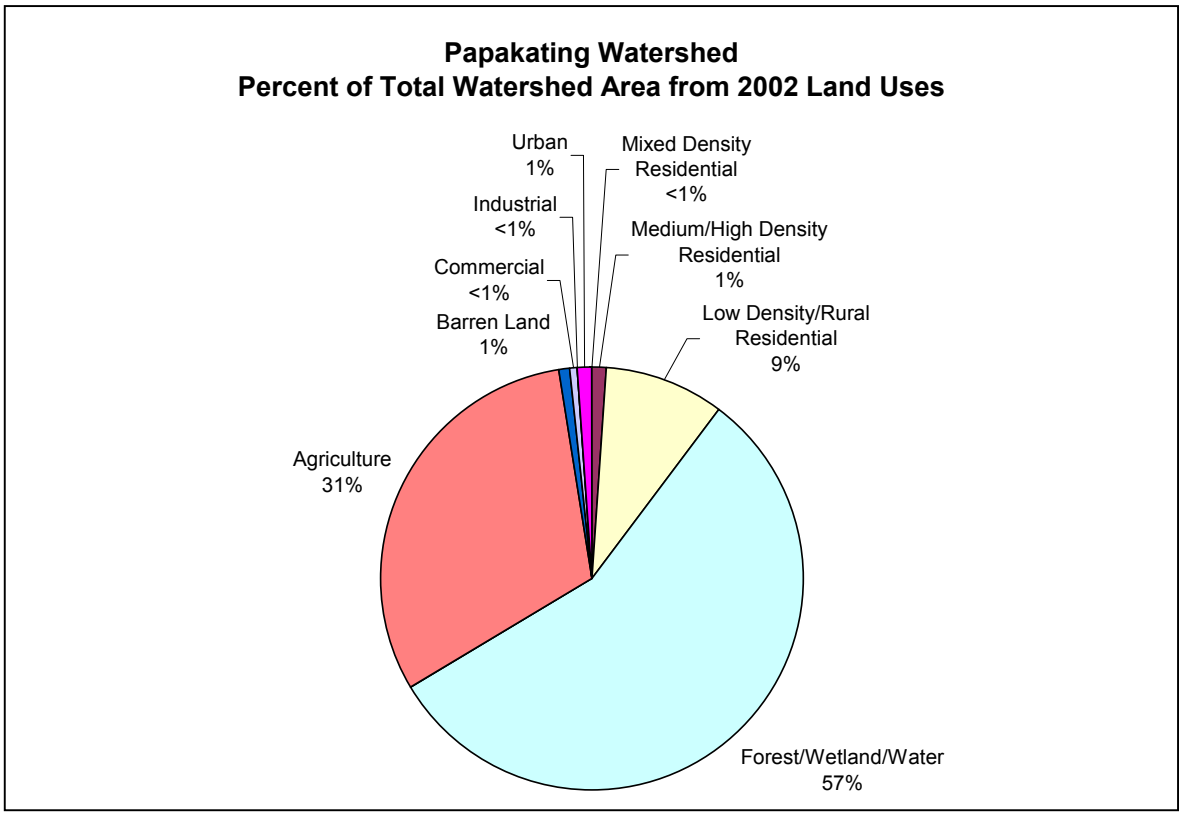


Figure 18: Estimated Percent Reduction, Using Regression of Daily Total Phosphorus Exceedances.

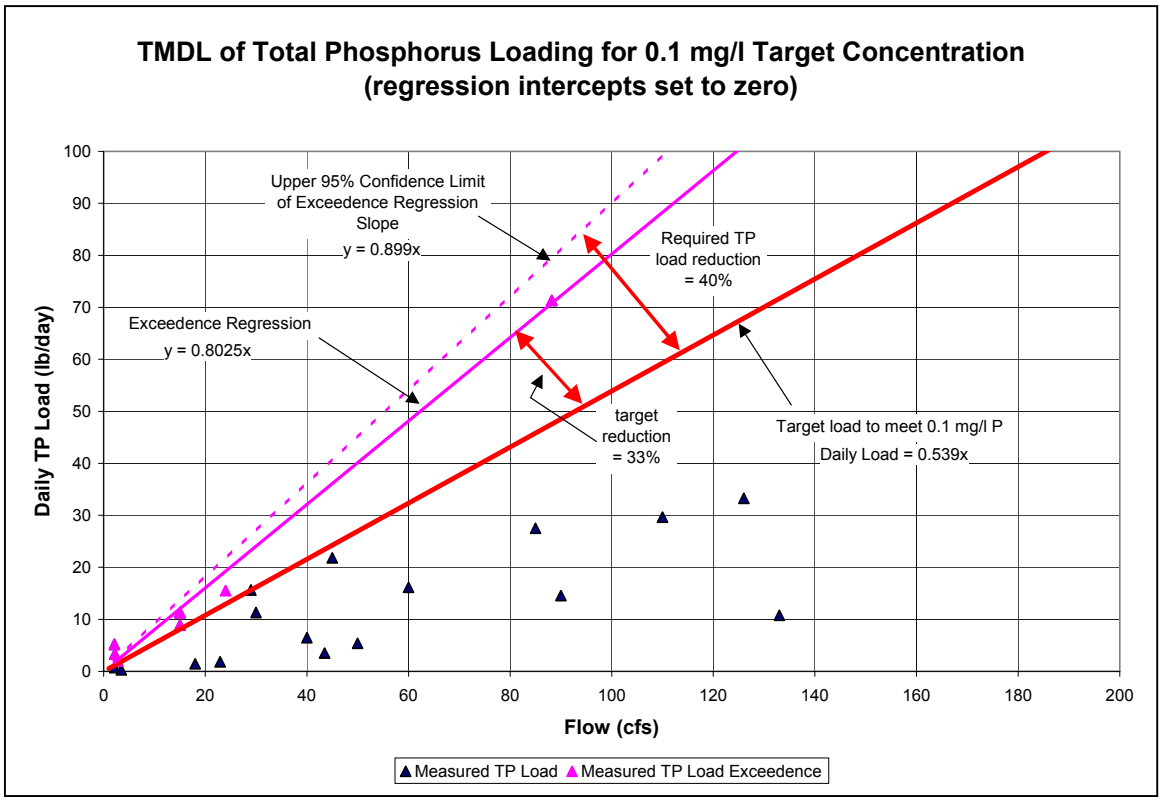


Figure 18 illustrates that a forty percent loading reduction of total phosphorus is required for the Papakating Creek Watershed as a whole, including Clove Brook, to attain the standard of 0.1 milligrams per liter (mg/l) at the integrator monitoring location near the mouth of Papakating Creek (site #1367910). The percent reduction was based on the linear regression of daily total phosphorus loading (pound per day, lb/day) versus flow (cubic feet per second, cfs).

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

Percent loading reduction is the difference between the upper 95 percent confidence limit of the slope of the regression for the loadings exceeding the target loading line and the slope of the target loading, i.e., [(0.899 – 0.539)/0.899] x 100 = 40 percent. 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 kiligrams per day or per year.

Margin of Safety

For this TMDL calculation, an implicit MOS is inherent in the estimates of current pollutant loadings and treating phosphorus as a conservative substance. For the Papakating Creek stream segment, the percent loading reduction is the difference in slopes between the upper 95 percent confidence limit of the exceedance regression line and the target loading regression line, i.e., [(0.899 – 0.539)/0.899] x 100 = 40 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. In this case, the margin of safety is approximately 11 percent of the required 40 percent load reduction. This MOS is in addition to the MOS that is included in the load reduction requirement for the Clove Acres Lake described in Section 7.

For the Papakating Creek stream segment, the percent loading reduction is the difference in slopes between the upper 95 percent confidence limit of the exceedence regression line and the target loading regresson line, i.e., [(0.899 – 0.539)/0.899] x 100 = 40 percent. A margin of safety is included within the upper 95 percent confidence interval about the slope of the regression line of the exceedences. 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. In this case, the margin of safety is approximately 11 percent of the required 40 percent load reduction.

Table 15: Current condition, reference condition, target condition and overall percent reduction for Papakating Creek Segment 01367910

Segment	current condition [TP] (kg/day/cfs)	target condition [TP] (kg/day/cfs)	% overall TP load reduction
Papakating Creek Impaired Segment 01367910	0.408	0.245	40

Reserve Capacity

Reserve capacity is an optional means of reserving a portion of the loading capacity to allow for future growth. Reserve capacities are not included at this time. Therefore, the loading capacities and accompanying WLAs and LAs must be attained in consideration of any new sources that may accompany future development. The primary means by which future growth could increase phosphorus load is through the development of forest land within the watershed. The implementation plan includes the development of Priority Stream Segment Plans that require the collection of more detailed information about each streamshed. If the development of forest with the watershed of a particular impaired stream segment is planned, the issue of reserve capacity to account for the additional runoff load of phosphorus may be revisited.

Load Reduction for the Papakating Creek Watershed, Excluding Clove Brook

The determination of required load reduction for the Papakating Creek watershed excluding the Clove Acres Lake watershed must be calculated, considering the load reduction that will occur from implementation of the Clove Acres Lake watershed TMDL. The load reduction target for the entire Papakating watershed is 40 percent. The load reduction target within the Clove Acres Lake watershed is 77 percent.

The area of the Papakating watershed that is not within the Clove Acres Lake watershed will realize a load reduction benefit from the Clove Acres Lake watershed TMDL target. The load reduction target for the entire Papakating watershed is 40 percent (or 9863.4 kg/yr). The TMDL target represents 67 percent of the total reduction target (or 6608.5 kg/yr).

The target load for the portion of the Papakating watershed, excluding the Clove Acres Lakeshed is: 6608.5 – 2060.6 (Clove Acres Lakeshed target) = 4547.9 kg/yr. The margin of safety is equivalent to the difference between the total load reduction target (40 percent) and the watershed loading target (67 percent), or 3945.4 - 3254.9 = 690.5 kg/yr, or 690.5/9863.4 x x 100 = 7 percent.
Table 16 presents the annual total phosphorus load reduction and the target load for obtaining the TMDL target concentration of 0.05 mg/l and 0.10 mg/l for Clove Acres Lake and the Papakating Creek, respectively.

Table 16: Estimated Loading Reductions in the Papakating Creek Watershed

Watershed	Estimated TP annual loading (kg/yr)	TP annual loading reduction (%)
Clove Acres Lake	2675.9	77
Adjoining Papakating Watershed Area	7190.9	31

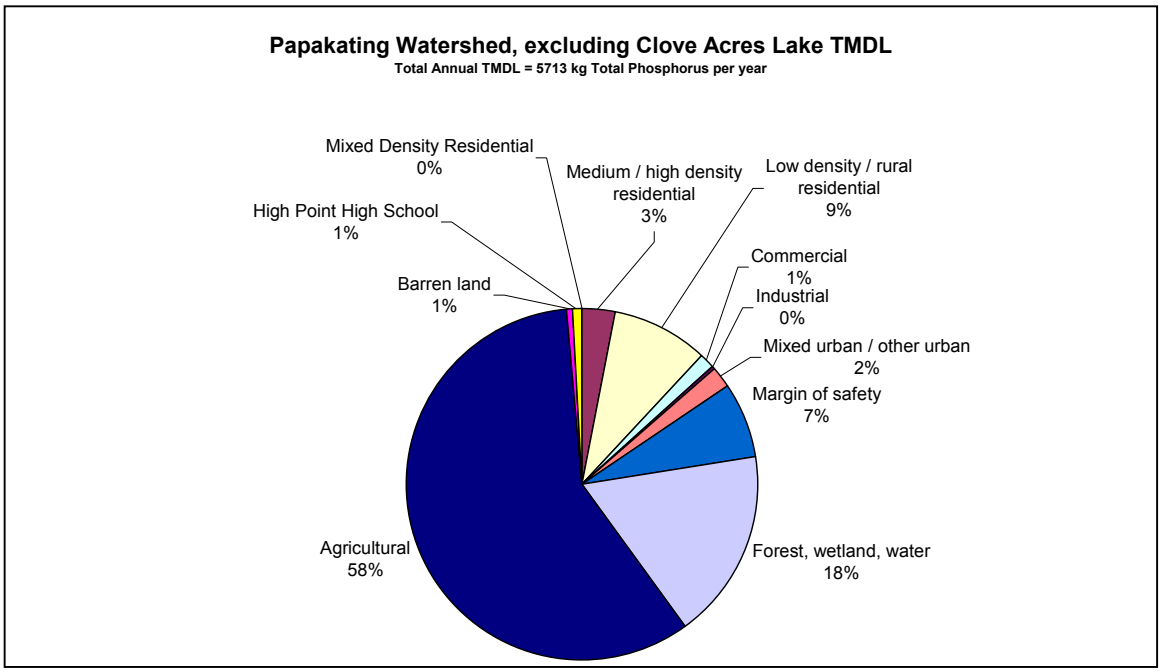
(excluding Clove Acres Lake)		
Total Papakating Watershed	**9866.8**	**40**

Table 17 presents the annual total phosphorus load reduction and the existing load for obtaining the TMDL target concentration of 0.05 mg/l and 0.10 mg/l for Clove Acres Lake and the Papakating Creek, respectively.

Table 17. TMDL calculations for the portion of Papakating watershed, excluding the Clove Acres Lakeshed

Papakating Excluding Clove Acres Lake	Estimated kg TP/yr	% of LC	% reduction
Loading capacity (LC)	5713	100%	n/a
Stormwater Point Sources			
Mixed density residential	7.3	0.1%	31%
medium / high density residential	162.8	2.9%	31%
low density / rural residential	513.1	9.0%	31%
commercial	75.4	1.3%	31%
industrial	12.7	0.2%	31%
Mixed urban / other urban	110.2	1.9%	31%
agricultural	3,349.3	58.6%	31%
Nonpoint Sources			
forest, wetland, water	1,006.1	17.6%	0%
barren land	33.9	0.6%	0%
air deposition onto lake surface	-	0.0%	0%
High Point High School	44.0	0.8%	0%
Margin of Safety	398	7.0%	

Figure 19: Percent of TMDL Allocation for Papakating Creek Watershed, Excluding Clove Acres Lake Watershed, Land Uses and Margin of Safety.



9. Implementation Plan

The Department will address the sources of impairment, using regulatory and non-regulatory tools, through systematic source assessment, matching management strategies with sources, selecting responsible entities and aligning available resources to effect implementation. Management measures are "economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint and stormwater sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint and stormwater source pollution control practices, technologies, processes, citing criteria, operating methods, or other alternatives" (USEPA, 1993).

In addition to chemical monitoring data analysis, through the watershed management process and the New Jersey Watershed Ambassador Program, river assessments and visual surveys of the impaired segment watersheds were conducted to identify potential sources of phosphorus. Watershed partners, who are intimately familiar with local land use practices, were able to share information relative to potential phosphorus sources. The New Jersey Watershed Ambassadors Program is a community-oriented AmeriCorps environmental program designed to raise awareness about watershed issues in New Jersey. Through this program, AmeriCorps members are placed in watershed management areas across the state to serve their local communities. Watershed Ambassadors monitor the rivers of New Jersey through visual and biological assessment volunteer monitoring programs. Supplemental training was provided through the fall/winter of 2002 to prepare the members to perform river assessments on the impaired segments. Each member was provided with detailed maps of the impaired segments within their watershed management area. The Department worked with and through watershed partners and AmeriCorps members to conduct visual assessments in fall of 2002.

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

Generic management strategies for various source categories and responses are summarized below:

Source Category	Responses	Potential Responsible Entity	Possible Funding options
Human Sources	Low phosphorus fertilizer ordinances, NPS public education, septic tank management to address failing systems	Municipalities, residents, watershed stewards	319(h), State sources
Non-Human Sources	Waterfowl ordinances, pet waste ordinances, goose management programs	Municipalities, residents, watershed stewards	319(h), State sources
Agricultural practices	Install BMPs, Prioritize for conservation programs	Property owner	EQIP, CRP, CREP

On February 2, 2004 the Department promulgated two sets of stormwater rules. The first set, N.J.A.C. 7: 8 update the state's Stormwater Management Rules for the first time since their

original adoption in 1983. The rules establish new statewide minimum standards for stormwater management. These standards will also become requirements of several state-issued permits such as freshwater wetlands and stream encroachment permits. The second set of adopted stormwater rules are the Phase II New Jersey Pollutant Discharge Elimination System Stormwater Regulation Program Rules N.J.A.C. 7:12A, which require municipalities, large public complexes such as hospitals, and highway systems to develop stormwater management programs consistent with Tier A or B requirements through the NJPDES permit program.

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

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

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

The stormwater discharged to the impaired segments through "municipal separate storm sewer systems" (MS4s) will be regulated under the Department's Phase II NJPDES stormwater rules, or the Municipal Stormwater Regulation Program. Under these rules and associated general permits, many municipalities (and various county, State, and other agencies) in the Papakating Creek Watershed will be required to implement various control measures that should substantially reduce phosphorus loadings. These 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. An additional measure that may be appropriate is the adoption and enforcement of a low phosphorus fertilizer ordinance in developed areas.

Agricultural activities are another example of potential sources of phosphorus. Implementation of conservation management plans and best management practices are the best means of controlling agricultural sources of phosphorus. Several programs are available to assist farmers in the development and implementation of conservation management plans and best management practices. The Natural Resource Conservation Service is the primary

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

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

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

- **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

Papakating Creek At Sussex (Site ID #01367910)

This section of the Papakating is very wide, slow moving and has very heavy bank erosion. Possible sources of phosphorus loading could be from fertilizer application on agricultural lands and to a lesser extent, from residential lawns. Just before this location on the Papakating both the Lake Neepaulakating Tributary as well as the Clove Brook empty in the Creek. Both come from densely developed lake communities, both of which also have large geese populations. The Clove Brook originates and travels through highly agricultural lands before emptying into the Clove Brook. Along these stream reaches, phosphorus input from agricultural lands could be significant. Monitoring: Continued monitoring in the Papakating Creek Watershed is recommended. Clove Lake should be prioritized for inclusion in the

upcoming Ambient Lake Monitoring Network. Strategies: prioritize for EQIP funds to install agricultural BMPs; organize local community based nutrient nonpoint source outreach programs.

Stream Segment Management Plan for Phosphorus in Clove Brook Tributary of Papakating Creek Through the WMA 2, Wallkill Watershed, Scope of Work entitled, *Phase III – Watershed Management Implementation Grant* (pending funding approval through the Department) a stream segment management plan will be developed. The purpose of this project is to develop a TMDL implementation workplan for phosphorous, in addition to other pollutants, in the Clove Brook Tributary of the Papakating Creek. This task will include coordination with municipalities and other authorities with responsibilities for implementing the TMDLs to assure buy-in, through promotion of outreach to continue to develop and maintain the stakeholder community involvement and commitment. An assessment will be conducted to determine data gaps and recommendations for additional monitoring. The main goal of this project will be to identify potential sources causing the impairment, determine the best management strategy for reducing the pollutant source, and identify potential funding sources to mitigate the impairments.

The North Jersey RC&D Council in partnership with Rutgers Cooperative Extension, New Jersey Farm Bureau and the North East Organic Farming Association, is undertaking a nonpoint source project that will provide targeted education and implementation to the agricultural community in the Walkill River Watershed. The project will work with farmers to protect water quality through the adoption of sustainable farming practices. Work will focus on grazing practices, nutrient and pest management and supporting organic and transition to organic operations. At the completion of the project it is anticipated that between 2,500 and 3,000 acres of farmland will be enrolled in Integrated Crop Management. It is anticipated that fertilizer chemical reductions will range as follows: Nitrogen reduction of 5-8 lbs/acre; Phosphorus reduction of 7-25 lbs/acre; and Potassium reduction of 27-29 lbs/acre of farmland.

Clove Acres Lake Watershed

The Department recognizes that TMDLs alone are not sufficient to restore eutrophic lakes. The TMDL establishes the required nutrient reduction targets and provides the regulatory framework to effect those reductions. In addition to nutrient reductions, therefore the next step towards implementation calls for the preparation of a lake characterization and the development of a Lake Restoration Plan for Clove Acre Lake. As appropriate, WLAs or additional measures to be applied to traditional or stormwater point sources through NJPDES permits will be adopted by the Department as amendments to the applicable areawide Water Quality Management Plan. The plans will consider in-lake measures that need to be taken to supplement the nutrient reduction measures required by the TMDL. In addition, the plans will consider the ecology of the lake and adjust the eutrophication indicator target as necessary to protect the designated uses.

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

The Department recognizes that lake restoration requires a watershed approach. Lake Restoration Plans will be used as a basis to address overfertilization and sedimentation issues in watersheds that drain to these sensitive lakes. Public education efforts will focus on the benefits of aquatic plants in shallow lakes and the balance of aquatic life uses with recreational uses of the lake. With the combination of New Jersey's strong commitment to the collection and use of high quality data to support environmental decisions and regulatory programs, including TMDLs, the Department is reasonably assured compliance with the total phosphorus criteria applicable to the lake.

Lake Characterization and Restoration Plans

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

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

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

The schedule for developing the lake characterization is summer 2006, and for the development of a Lake Restoration Plan spring 2007 to implement the Clove Acre Lake TMDL .

10. 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. The data from this network has been used to assess the quality of freshwater streams and percent load reductions. Although other units also perform monitoring functions, the ASMN will remain a principal source of phosphorus monitoring.

In addition, a targeted post-assessment monitoring effort should be initiated to determine the effectiveness of the implementation plan associated with these TMDLs.

11. Reasonable Assurance

With the implementation of follow-up monitoring, source identification and source reduction as described for the impaired segment and eutrophic lake, the Department has reasonable assurance that New Jersey's Surface Water Quality Standards will be attained for phosphorus. As a generalized strategy, the Department proposes the following with regard to categorical sources: 1) To address storm water point sources, the Phase II stormwater permitting program will require control measures to be phased in from the effective date of authorization to 60 months from that date; 2) The locations of impaired segments with significant agricultural land uses will be provided to the State Technical Committee for consideration in the FFY 2004 round of EQIP project selection; 3) Through continuing engagement of watershed partners, measures to identify and address other sources will be pursued, including encouragement and support of low phosphorus fertilizer ordinances and community based goose management programs, where appropriate. For FY 03, base 319(h) funds were dedicated to assist municipalities in implementing the requirements of the Phase II municipal stormwater permitting program.

The phosphorus reductions proposed in these TMDLs assume that the existing NJPDES permitted facility on the West Branch Papakating will receive an effluent limit commensurate with the WLA and will be required to monitor for phosphorus upon renewal of their permit.

The Department's ambient monitoring network will be the means to determine if the strategies identified have been effective. Ambient monitoring will be evaluated to determine if additional strategies for source reduction are needed.

12. Public Participation

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

The Department's watershed management process includes a comprehensive stakeholder process that includes of members from major stakeholder groups, (agricultural, business and industry, academia, county and municipal officials, commerce and industry, purveyors and dischargers, and environmental groups). As part of this watershed management planning process, Public Advisory Committees (PACs) and Technical Advisory Committees (TACs) were created in all 20 WMAs. The PACs serve in an advisory capacity to the Department, examining and commenting on a myriad of issues in the watersheds. The TACs are focused on scientific, ecological, and engineering issues relevant to the issues of the watershed, including water quality impairments and management responses to address them.

The Department shared the Department's TMDL process through a series of presentations and discussions with the WMA 2 PAC and TAC members. Various presentations on TMDL development for the Wallkill River Watershed were made to the WMA 2 TAC. Presentations included: Introduction to TMDLs, February 28, 2002; Assessment and Technical Approach Paper for the Wallkill River Watershed, March 28, 2002; and 2002 Integrated List and Methodology, June 27, 2002; Technical Approach for Phosphorus in the Papakating Creek, February 26, 2004. In addition to the presentations, the TAC has been instrumental in providing comments and suggestions to the Department during this process.

Additional input was received through the NJ EcoComplex (NJEC). The Department contracted with NJEC in August 2001. The NJEC consists of a review panel of New Jersey University professors whose role is to provide comments on the Department's technical approaches for development of TMDLs and management strategies. The strategies for applying nutrient criteria in streams were presented to NJEC in January 2002. Comments from the panel were received in April 2002 and subsequently incorporated into Technical Manual for Phosphorus Evaluation (N.J.A.C. 7:9B-1.14(c)). In addition, the technical approach for the Papakating Creek TMDLs was presented to the EcoComplex on December 12, 2003. The approach was modified with the input of the EcoComplex panel.

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 Sussex County Water Quality Management Plan.

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

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Appendices

Appendix A: Database of Phosphorus Export Coefficients

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

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Appendix B: Summary of Reckhow (1979a) Model Derivation

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

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

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

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

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

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

where:
- v_s = effective settling velocity (m/yr)
- A = area of lake (10^3 m^2)
- Q = annual outflow (10^3 m^3/yr).

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

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

where:
- P_a = areal phosphorus loading rate (g/m^2/yr)
- z = mean depth (m)
- T = hydraulic detention time (yr)
- Q_a = Q/A = areal water load (m/yr).

Using least squares regression on a database of 47 north temperate lakes, Reckhow fit the effective settling velocity using a function of areal water load: $P = \frac{P_a}{11.6 + 1.2 \cdot Q_a}$. **Equation 4**

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

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

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

where:

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

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

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

Substituting for ρ as a function of h:

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

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

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

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

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

Substituting the equation for P_U:

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

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

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

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

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

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

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

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

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

$$\log\left(\frac{MoS_p}{h} + 1\right) = 0.128$$

$$\frac{MoS_p}{h} + 1 = 10^{0.128}$$

$$\frac{MoS_p}{h} = 10^{0.128} - 1$$

$$MoS_p = h\left(10^{0.128} - 1\right)$$

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

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

Appendix D: Phosphorus Criterion Applicability Determination

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

Is Phosphorus Limiting?

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

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

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

Figure 2: Example of site where 0.1 mg/l criterion is applicable and exceeded

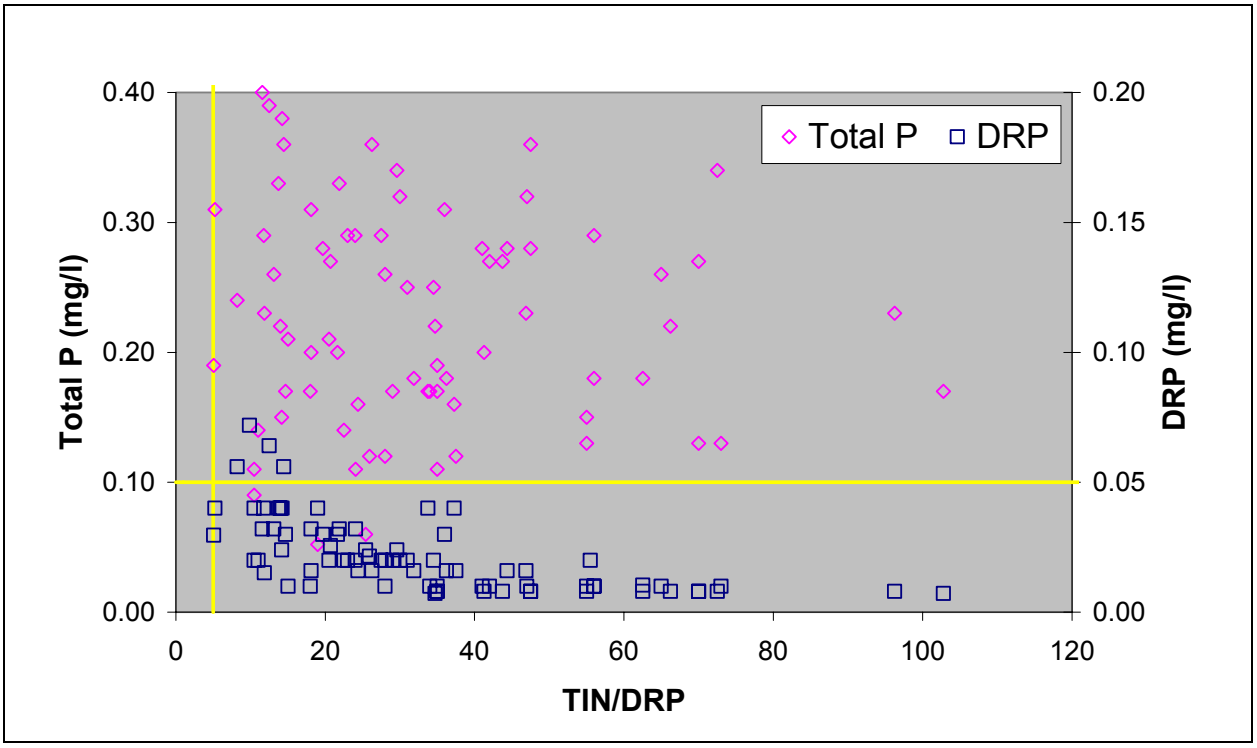
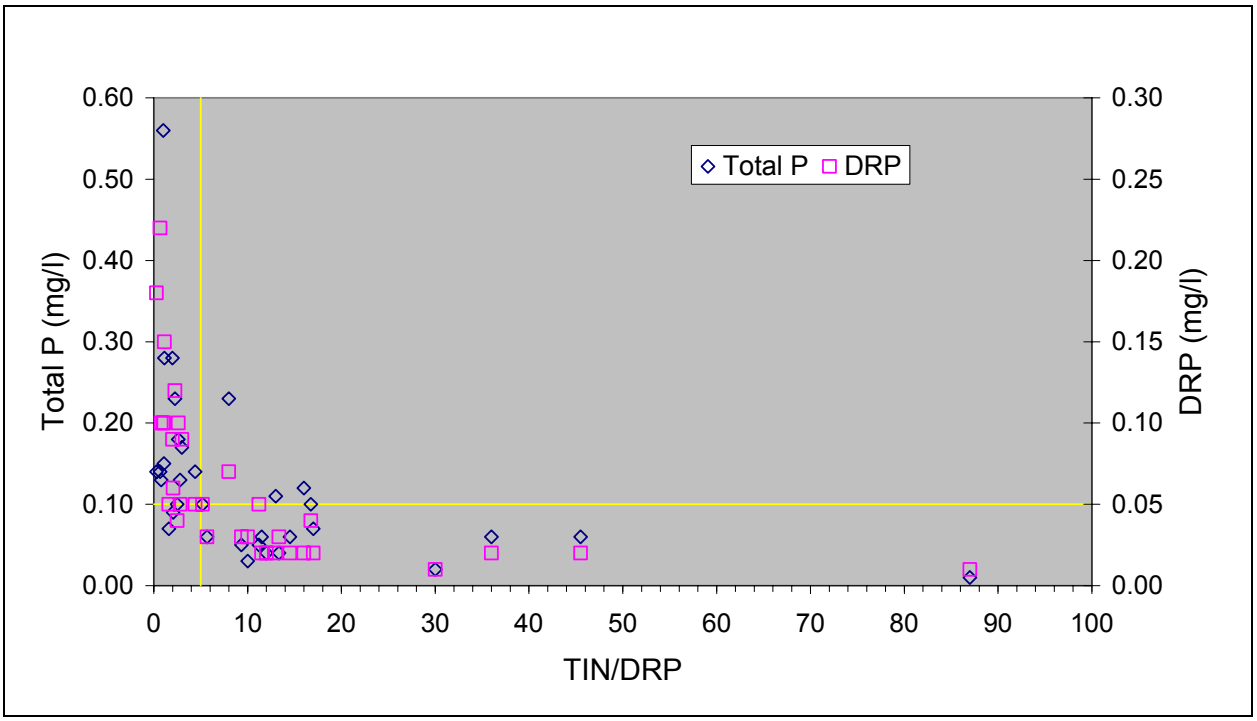
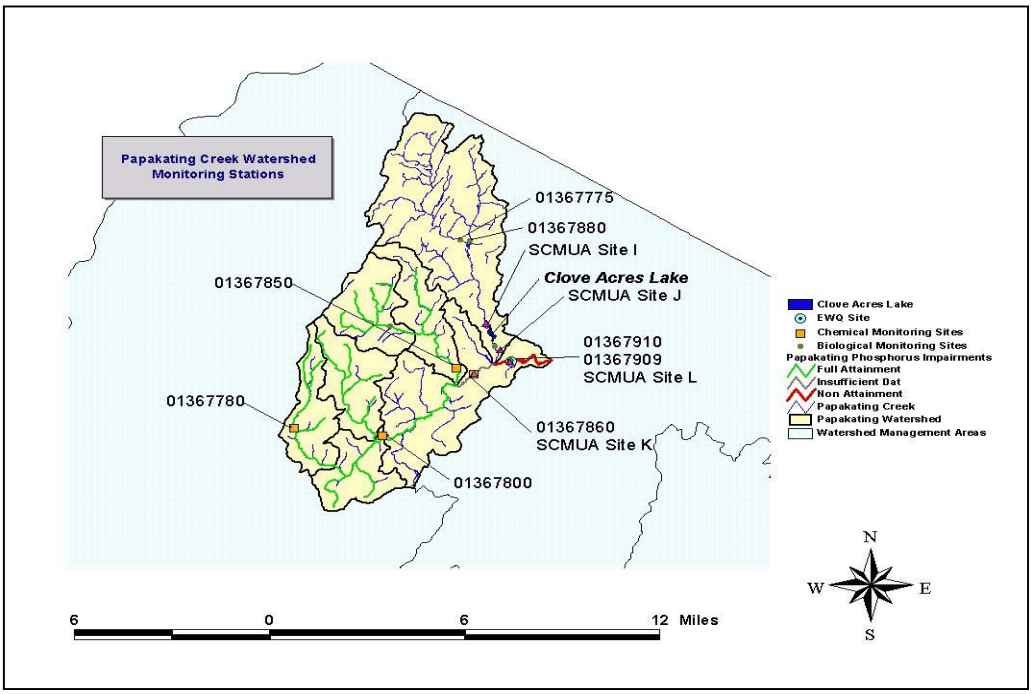


Figure 3: Example of site where phosphorus is not limiting algal growth when 0.1 mg/l threshold is exceeded



Please note that the use of the acronym DRP has been replaced with the acronym TOP for Figure 14. TOP stands for total ortho-phosphorus.

Appendix E: Map of monitoring locations within the Papakating Creek Watershed



Appendix F: Phosphorus and Flow Data for Stations 01367910, 01367909 and Site L

site	date	TP	Flow (cfs)
01367910	2/16/1994	0.04	30
01367910	4/11/1994	0.05	240
01367910	5/31/1994	0.12	24
01367910	8/17/1994	0.14	15
01367910	10/17/1994	0.05	15
01367910	1/18/1995	0.06	85
01367910	3/16/1995	0.05	110
01367910	5/23/1995	0.11	15
01367910	7/20/1995	0.14	15
01367910	10/18/1995	0.07	30
01367910	1/29/1996	0.02	1150
01367910	4/1/1996	0.05	60
01367910	6/5/1996	0.15	130
01367910	8/13/1996	0.1	29
01367910	10/21/1996	0.08	600
01367910	1/15/1997	0.02	50
01367910	4/17/1997	0.03	90
01367910	5/19/1997	0.03	40
01367910	7/23/1997	0.09	35
01367909	7/13/99	0.28	2.2
01367909	7/14/99	0.06	2.2
01367909	7/15/99	0.46	2.1
01367909	11/30/00	0.02	43.5
01367909	2/13/01	0.02	133
01367909	5/22/01	0.115	88.2
01367909	7/10/01	0.02	18
01367909	11/1/01	0.02	3.46
01367909	1/29/02	0.02	22.9
01367909	4/16/02	0.049	126
01367909	8/27/02	0.133	2.76
01367909	11/14/02	0.093	
01367909	2/13/03	0.072	
Site L	7/16/2003	0.08	
Site L	8/27/2003	0.08	
Site L	9/24/2003	0.14	
Site L	10/29/2003	0.05	
Site L	11/19/2003	0.18	
Site L	12/17/2003	0.05	
Site L	1/28/2004	0.03	