

Total Maximum Daily Load (TMDL) for Phosphorus in Moon Lake

Jefferson County, New York

September 2007

Prepared for:

U.S. Environmental Protection Agency
Region 2
290 Broadway
New York, NY 10007



New York State Department of
Environmental Conservation
625 Broadway, 4th Floor
Albany, NY 12233



Prepared by:



TABLE OF CONTENTS

1.0	INTRODUCTION	3
1.1.	Background.....	3
1.2.	Description of Waterbody and Drainage Basin	3
1.3.	Water Quality Data.....	7
1.4.	Problem Definition	8
1.5.	Numeric Water Quality Target	9
2.0	SOURCE ASSESSMENT.....	9
2.1.	Estimating Phosphorus Loading Using AVGWLF.....	9
2.2.	Sources of Phosphorus Loading.....	10
3.0	DETERMINATION OF LOAD CAPACITY	13
3.1.	Lake Modeling Using the BATHTUB Model	13
3.2.	Linking Total Phosphorus Loading to the Numeric Water Quality Target.....	13
4.0	POLLUTANT LOAD ALLOCATIONS	15
4.1.	Wasteload Allocation (WLA).....	15
4.2.	Load Allocation (LA)	15
4.3.	Margin of Safety (MOS).....	17
4.4.	Critical Conditions.....	17
4.5.	Seasonal Variations.....	17
5.0	IMPLEMENTATION	17
5.1.	Reasonable Assurance for Implementation	18
5.2.	Follow-up Monitoring.....	20
6.0	PUBLIC PARTICIPATION	20
7.0	REFERENCES.....	20
	APPENDIX A. AVGWLF MODELING ANALYSIS.....	23
	APPENDIX B. BATHTUB MODELING ANALYSIS.....	37
	APPENDIX C. TOTAL EQUIVALENT DAILY PHOSPHORUS LOAD ALLOCATIONS..	42

1.0 INTRODUCTION

1.1. Background

In April of 1991, the United States Environmental Protection Agency (EPA) Office of Water's Assessment and Protection Division published "Guidance for Water Quality-based Decisions: The Total Maximum Daily Load (TMDL) Process." In July 1992, EPA published the final "Water Quality Planning and Management Regulation" (40 CFR Part 130). Together, these documents describe the roles and responsibilities of EPA and the states in meeting the requirements of Section 303(d) of the Federal Clean Water Act (CWA) as amended by the Water Quality Act of 1987, Public Law 100-4. Section 303(d) of the CWA requires each state to identify those waters within its boundaries not meeting water quality standards for any given pollutant applicable to the water's designated uses.

Further, Section 303(d) requires EPA and states to develop TMDLs for all pollutants violating or causing violation of applicable water quality standards for each impaired waterbody. A TMDL determines the maximum amount of pollutant that a waterbody is capable of assimilating while continuing to meet the existing water quality standards. Such loads are established for all the point and nonpoint sources of pollution that cause the impairment at levels necessary to meet the applicable standards with consideration given to seasonal variations and margin of safety. TMDLs provide the framework that allows states to establish and implement pollution control and management plans with the ultimate goal indicated in Section 101(a)(2) of the CWA: "water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water, wherever attainable" (USEPA, 1991).

1.2. Description of Waterbody and Drainage Basin

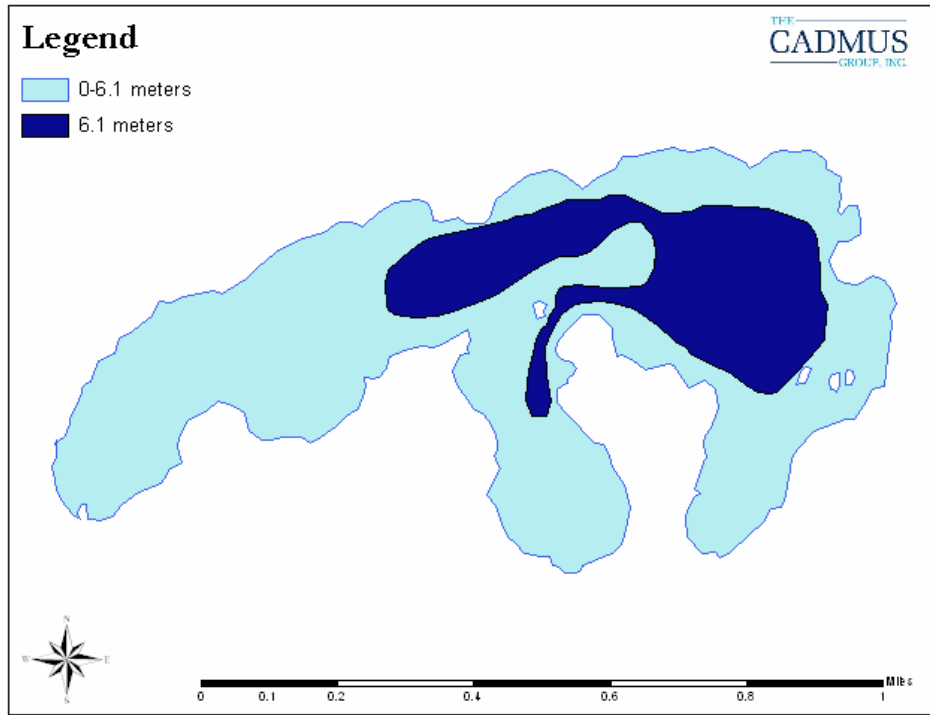
Moon Lake (WI/PWL ID 0905-0093) is a 230 acre (0.93 km²) waterbody situated in the Town of Theresa, within Jefferson County, New York at an elevation of about 309 feet (94 meters) above mean sea level (AMSL) (Figure 1). Moon Lake has a direct drainage area of 893 acres (3.6 km²) excluding the surface area of the lake.

Moon Lake is approximately 6,470 feet (1,972 meters) long, 3,146 feet (959 meters) wide at the widest point, and has a shoreline perimeter of approximately 26,988 feet (8,226 meters). Bathymetric map calculations suggest that the lake has an approximate mean depth of 12.6 feet (3.8 meters) and an estimated maximum depth of 20 feet (6.1 meters) (Figure 2). The topography of the Moon Lake drainage basin exhibits little relief and low drainage. Elevation ranges from a maximum of 525 feet (160 meters) AMSL on a southern bluff and a minimum elevation of 309 feet (94 meters) AMSL at the surface of Moon Lake. There are no major tributaries flowing into Moon Lake. Water exits the lake at the eastern-most end.

Figure 1. Maps of Moon Lake Direct Drainage Basin



Figure 2. Bathymetric Map of Moon Lake



Existing land use and land cover in the Moon Lake drainage basin was determined from digital aerial photography and geographic information system (GIS) datasets. Digital land use/land cover data were obtained from the 2001 National Land Cover Dataset (Homer, 2004). The NLCD is a consistent representation of land cover for the conterminous United States generated from classified 30-meter resolution Landsat thematic mapper satellite imagery data. High-resolution color orthophotos were used to manually update and refine land use categories for portions of the drainage basin to reflect current conditions in the drainage basin. Appendix A provides additional detail about the refinement of land use for the drainage basin. Land use categories in Moon Lake's drainage basin include: forest, agricultural, developed, wetlands and open water (excluding lake) (Table 1 and Figures 3 and 4).

Table 1. Land Use Acres and Percent in Moon Lake Drainage Basin

Land Use Category	Acres	% of Basin
Open Water (excluding lake)	15	2%
Agriculture	52	6%
<i>Hay & Pasture</i>	52	6%
Developed Land	39	4%
<i>Low Intensity</i>	39	4%
Forest	740	83%
Wetlands	47	5%
TOTAL	893	100%

Figure 3. Distribution of Land Use in Moon Lake Drainage Basin

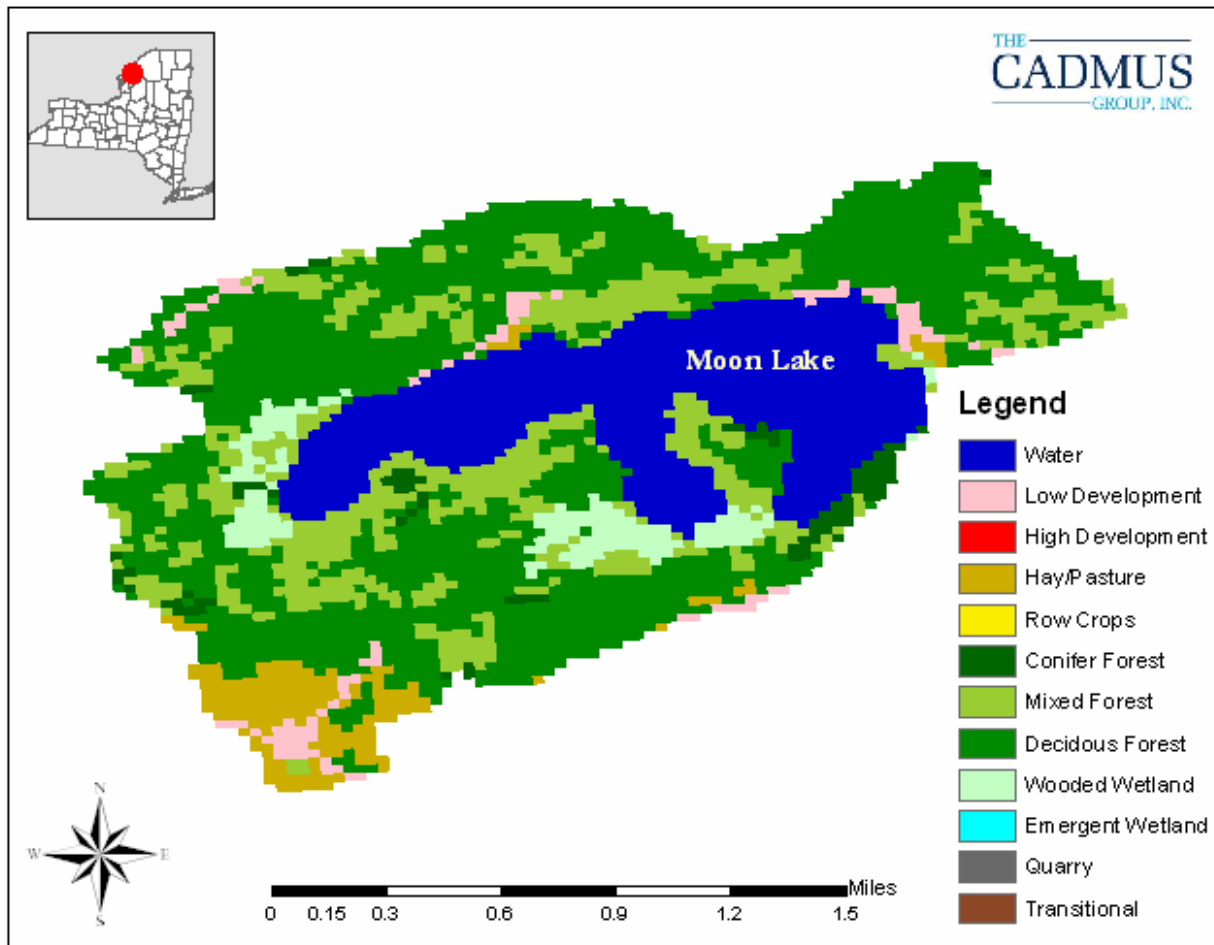
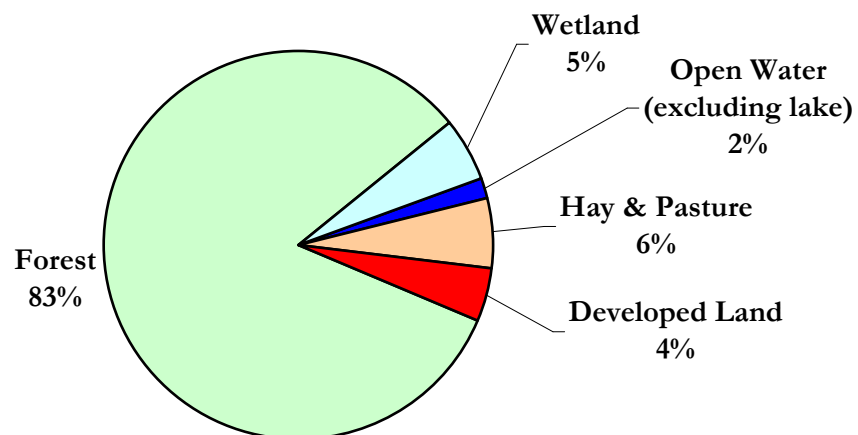


Figure 4. Percent Land Use in Moon Lake Drainage Basin



1.3. Water Quality Data

The New York State Department of Environmental Conservation's (NYS DEC) Citizens Statewide Lake Assessment Program (CSLAP) is a cooperative volunteer monitoring effort between NYS DEC and the New York Federation of Lake Association (FOLA). The goal of the program is to establish a volunteer lake monitoring program that provides data for a variety of purposes, including establishment of a long-term database for NYS lakes, identification of water quality problems on individual lakes, and geographic and ecological groupings of lakes, and education for data collectors and users. The data collected in CSLAP are fully integrated into the state database for lakes, have been used to assist in local lake management and evaluation of trophic status, spread of invasive species, and other problems seen in the state's lakes.

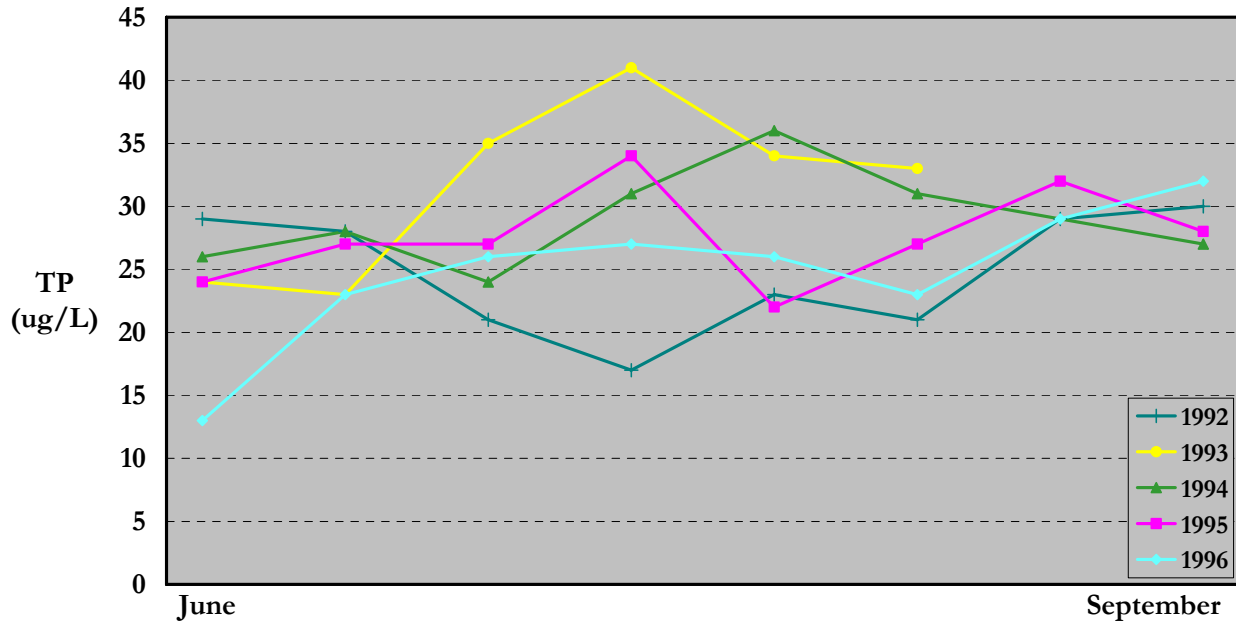
Volunteers undergo on-site initial training and follow-up quality assurance and quality control sessions are conducted by NYS DEC and trained NYS FOLA staff. After training, equipment, supplies, and preserved bottles are provided to the volunteers by NYS DEC for bi-weekly sampling for a 15 week period between May and October. Prior to 2002, water samples, field data, and observation forms were transported to the NYS Department of Health (NYS DOH) for analysis. Water samples are analyzed for standard lake water quality indicators, with a focus on evaluating eutrophication status-total phosphorus, nitrogen (nitrate, ammonia, and total), chlorophyll *a*, pH, conductivity, color, and calcium. Field measurements include water depth, water temperature, and Secchi disk transparency. Volunteers also evaluate use impairments through the use of field observation forms, utilizing a methodology developed in Minnesota and Vermont. Aquatic vegetation samples, deepwater samples, and occasional tributary samples are also collected by sampling volunteers at some lakes. Data are sent from the laboratory to NYS DEC and annual interpretive summary reports are developed and provided to the participating lake associations and other interested parties.

CSLAP monitors several parameters related to the trophic (extent of eutrophication) state of a lake, including phosphorus. Figure 5 shows the epilimnetic concentrations for phosphorus data collected during all sampling seasons and years in which Moon Lake was sampled as part of CSLAP. Table 2 provides the annual summer mean epilimnetic phosphorus concentrations for these data.

Table 2. Annual Summer Mean Epilimnetic Total Phosphorus Concentrations in Moon Lake

Year	Total Phosphorus (µg/L)
1992	25
1993	32
1994	29
1995	28
1996	25

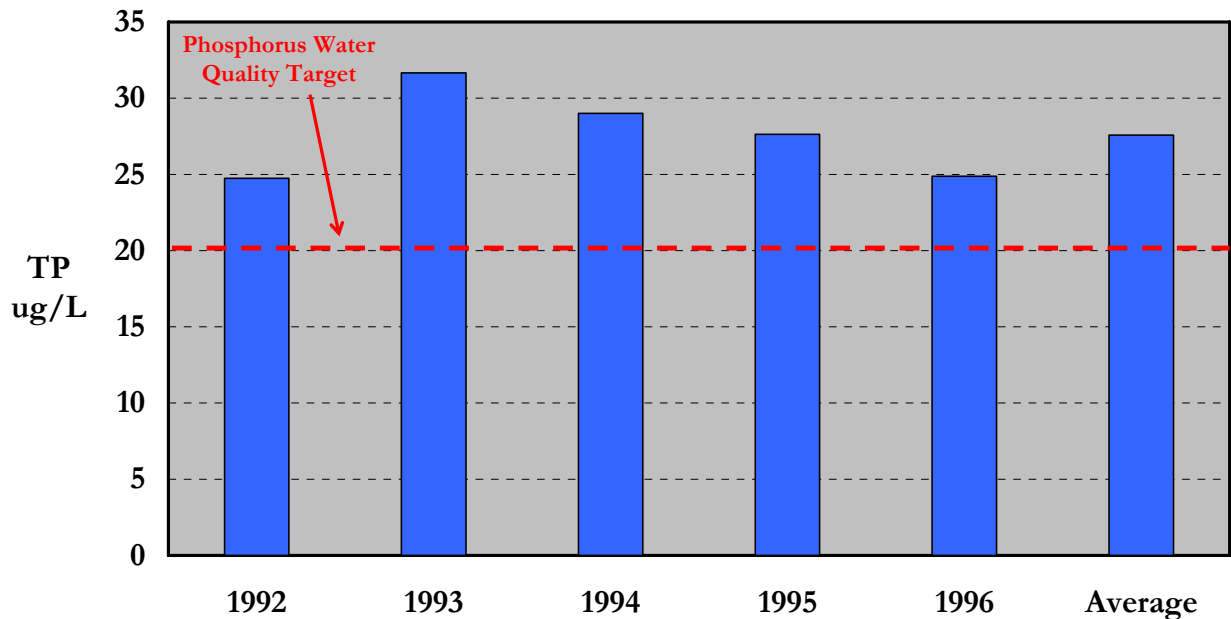
Figure 5. Epilimnetic Phosphorus Concentrations For Moon Lake



1.4. Problem Definition

As part of CSLAP, a limited number of water quality samples were collected in Moon Lake during the summers of 1992-1996. The results from these sampling efforts show eutrophic conditions in Moon Lake, with concentrations of phosphorus in the lake being higher than the state guidance value for phosphorus (20 $\mu\text{g/L}$ or 0.020 mg/L, applied as the mean summer, epilimnetic total phosphorus concentration), which increases the potential for nuisance summertime algae blooms (Figure 6).

Figure 6. Summer Mean Epilimnetic Total Phosphorus Levels in Moon Lake



A variety of nonpoint sources of phosphorus contribute to poor water quality in Moon Lake. The water quality of the lake is influenced by runoff events from the drainage basin, as well as loading from nearby residential septic tanks. In response to precipitation, nutrients, such as phosphorus – naturally found in New York soils – drain into the lake from the surrounding drainage basin by way of streams, overland flow, and subsurface flow. Nutrients are then deposited and stored in the lake bottom sediments. Phosphorus is often the limiting nutrient in temperate lakes, ponds, and bays and can be thought of as a fertilizer; a primary food for plants, including algae. When lakes receive excess phosphorus, it “fertilizes” the lake by feeding the algae. Too much phosphorus can result in algae blooms, which can damage the ecology/aesthetics of a lake, as well as the economic well-being of the surrounding drainage basin community. Moon Lake is listed on the New York State CWA Section 303(d) list of waterbodies that do not meet water quality standards due to phosphorus impairments (NYS DEC, 2004). Based on this listing, a TMDL for phosphorus is being developed for the lake.

1.5. Numeric Water Quality Target

The TMDL target is a numeric endpoint specified to represent the level of acceptable water quality that is to be achieved by implementing the TMDL. The water quality classification for Moon Lake is C, which means that the most appropriate usage is fishing. New York State has a narrative standard for nutrients -- none in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages (6 NYSCRR Part 703.2). As part of its Technical and Operational Guidance Series (TOGS 1.1.1 and accompanying fact sheet, NYS, 1993), NYS DEC has suggested that for waters classified as ponded (i.e., lakes, reservoirs and ponds, excluding Lakes Erie, Ontario and Champlain), the epilimnetic summer mean total phosphorus level shall not exceed 20 µg/L (or 0.02 mg/L), based on biweekly sampling, conducted from June 1 to September 30. This guidance value of 20 µg/L is the TMDL target for Moon Lake.

2.0 SOURCE ASSESSMENT

2.1. Estimating Phosphorus Loading Using AVGWLF

The ArcView Generalized Watershed Loading Function (AVGWLF) model was used in combination with BATHTUB to develop the Moon Lake TMDL. This approach consists of using AVGWLF to determine mean annual phosphorus loading to the lake, and then using BATHTUB to define the extent to which this load must be reduced to meet the water quality target. This approach required no additional data collection thereby expediting the modeling efforts.

The GWLF model was developed by Haith and Shoemaker (1987). GWLF simulates runoff and stream flow by a water-balance method based on measurements of daily precipitation and average temperature. The complexity of GWLF falls between that of a detailed, process-based simulation model and a simple export coefficient model that does not represent temporal variability. The GWLF model was determined to be appropriate for this TMDL analysis because it simulates the important processes of concern, but does not have onerous data requirements for calibration. AVGWLF was developed to facilitate the use of the GWLF model via an ArcView interface (Evans, 2002). Appendix A discusses the setup, calibration, and use of the AVGWLF model for lake TMDL assessments in New York.

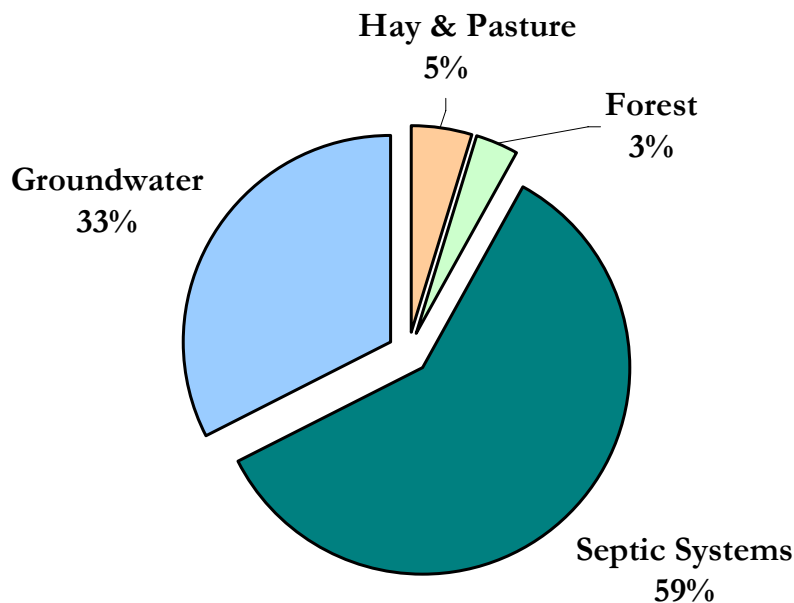
2.2. Sources of Phosphorus Loading

AVGWLF was used to estimate long-term (1990-2004) mean annual phosphorus loading to Moon Lake. Appendix A provides the detailed simulation results from AVGWLF. The estimated mean annual load of 170 lbs/yr of total phosphorus that enters the lake comes primarily from the sources listed in Table 3 and shown in Figure 7.

Table 3. Estimated Sources of Phosphorus Loading to Moon Lake

Source Category	Total Phosphorus (lbs/yr)
Hay/Pasture	8
Forest	6
Groundwater	55
Septic Systems	101
TOTAL	170

Figure 7. Estimated Sources of Total Phosphorus Loading to Moon Lake



Residential On-Site Septic Systems

Residential on-site septic systems contribute an estimated 101 lbs/yr of phosphorus to Moon Lake, which is about 59% of the total loading to the lake. Residential septic systems contribute dissolved phosphorus to nearby waterbodies due to system malfunctions. Septic systems treat human waste using a collection system that discharges liquid waste into the soil through a series of distribution lines that comprise the drain field. In properly functioning (normal) systems, phosphates are adsorbed and retained by the soil as the effluent percolates through the soil to the shallow saturated zone. Therefore, normal systems contribute very little phosphorus loads to nearby waterbodies. A

septic system (ponding) malfunction occurs when there is a discharge of waste to the soil surface (where it is available for runoff); as a result, malfunctioning septic systems can contribute high phosphorus loads to nearby waterbodies. Short-circuited systems (those systems in close proximity to surface waters where there is limited opportunity for phosphorus adsorption to take place) also contribute significant phosphorus loads.

GIS analysis of orthoimagery for the basin shows approximately 21 houses within 50 feet of the shoreline and 57 houses between 50 and 250 feet of the shoreline; all of the houses are assumed to have septic systems. To convert the estimated number of septic systems to population served, an average household size of 2.61 people per dwelling was used based on the circa 2000 USCB census estimate for number of persons per household in New York State. All of the septic systems within 50 feet of the shoreline and 75% of systems between 50 and 250 feet of the shoreline were categorized as short-circuiting systems. Approximately 10% of septic systems beyond 250 feet of the shoreline (up to the drainage basin boundary) were categorized as ponding systems. All remaining systems in the basin (including those beyond 250 feet of the shoreline) were categorized as normal. Correspondence between NYS DEC and Craig MacFarland (the contact for the Moon Lake Association) revealed that approximately 10 of the 80 dwellings along the lake are year-round. To account for seasonal variations in population, approximately 12% of the homes around the lake are assumed to be year-round residences, while 88% are seasonally occupied (i.e., June through August only). Additional details about the process for estimating the population served by normal and malfunctioning systems within the lake drainage basin is provided in Appendix A. The estimated population in the Moon Lake drainage basin served by normal and malfunctioning systems is summarized in Table 4.

Table 4. Population Served by Septic Systems in the Moon Lake Drainage Basin

	Normally Functioning	Malfunctioning		Total
		Short-Circuit	Ponded	
September - May	55	21	2	78
June - August (Summer)	55	167	2	225

Agriculture

Agricultural land encompasses 52 acres (6%) of the lake drainage basin and includes only hay and pasture land. Overland runoff from agricultural land is estimated to contribute 8 lbs/yr of phosphorus loading to Moon Lake, which is 5% of the total phosphorus loading to the lake.

In addition to the contribution of phosphorus to the lake from overland agriculture runoff, additional phosphorus originating from agricultural lands is leached in dissolved form from the surface and transported to the lake through subsurface movement via groundwater. The process for estimating subsurface delivery of phosphorus originating from agricultural land is discussed in the Groundwater section (below). Phosphorus loading from agricultural land originates primarily from soil erosion and the application of manure and fertilizers. Implementation plans for agricultural sources will require voluntary controls applied on an incremental basis.

Forests

Forested land comprises 740 acres (83%) of the lake drainage basin. Runoff from forested land is estimated to contribute 69 lbs/yr of phosphorus loading to Moon Lake, which is less than 1% of the total phosphorus loading to the lake. Phosphorus contribution from forested land is considered a component of background loading.

Urban and Residential Development

Developed land comprises 39 acres of the lake drainage basin and contributes less than 1 lb/yr of phosphorus to Moon Lake. This load does not account for contributions from malfunctioning septic systems.

In addition to the contribution of phosphorus to the bay from overland urban runoff, additional phosphorus originating from developed lands is leached in dissolved form from the surface and transported to the bay through subsurface movement via groundwater. The process for estimating subsurface delivery of phosphorus originating from developed land is discussed in the Groundwater section (below).

Phosphorus runoff from developed areas originates primarily from human activities, such as fertilizer applications to lawns. Shoreline development, in particular, can have a large phosphorus loading impact to nearby waterbodies in comparison to its relatively small percentage of the total land area in the drainage basin.

Groundwater

In addition to nonpoint sources of phosphorus delivered to the lake by surface runoff, a portion of the phosphorus loading from nonpoint sources seeps into the ground and is transported to the lake via groundwater. Groundwater is estimated to transport 55 lbs/yr (32%) of the total phosphorus load to Moon Lake. With respect to groundwater, there is typically a small “background” concentration owing to various natural sources. In the Moon Lake drainage basin, the estimated groundwater phosphorus concentration is 0.019 mg/L. The GWLF manual provides estimated background groundwater phosphorus concentrations for $\geq 90\%$ forested land in the eastern United States, which is 0.006 mg/L. Consequently, about 32% of the groundwater load (17 lbs/yr) can be attributed to natural sources, including forested land and soils.

The remaining amount of the groundwater phosphorus load (about 38 lbs/yr) likely originates from agricultural and developed land sources (i.e., leached in dissolved form from the surface). The portion originating from developed land was estimated using the following equation from the final report for the Lake George Nationwide Urban Runoff Program (NURP) Study (Sutherland 1983):

$L_{AP} = -0.149 + 0.241 * \ln(\%D)$, where L_{AP} is the areal phosphorus loading from developed land and % D is the percent developed land in the basin

Based on the NURP study, the estimated phosphorus loading from urban land is approximately 16 lbs/yr. AVGWL estimates that less than 1 lb/yr of phosphorus is delivered from surface urban runoff. Therefore, it is assumed that the remaining phosphorus originating from developed land is

transported via groundwater. Using the NURP study, it is estimated that approximately 16 lbs/yr of phosphorus loading from developed land is transported to the lake via groundwater. The remaining amount of the groundwater phosphorus load (22 lbs/yr) is estimated to originate from agricultural sources. Table 5 summarizes this information.

Table 5. Sources of Phosphorus Transported in the Subsurface via Groundwater

	Total Phosphorus (lbs/yr)	% of Total Groundwater Load
Natural Sources	17	32%
Agriculture	22	40%
Developed Land	16	29%
Total	55	100%

Other Sources

Wildlife, waterfowl, and domestic pets may also be a potential source of phosphorus loading to the lake. Atmospheric deposition, while a small contributor, is also another source of phosphorus. All of these small sources of phosphorus are incorporated into the land use loadings as identified in the TMDL analysis (and therefore accounted for).

3.0 DETERMINATION OF LOAD CAPACITY

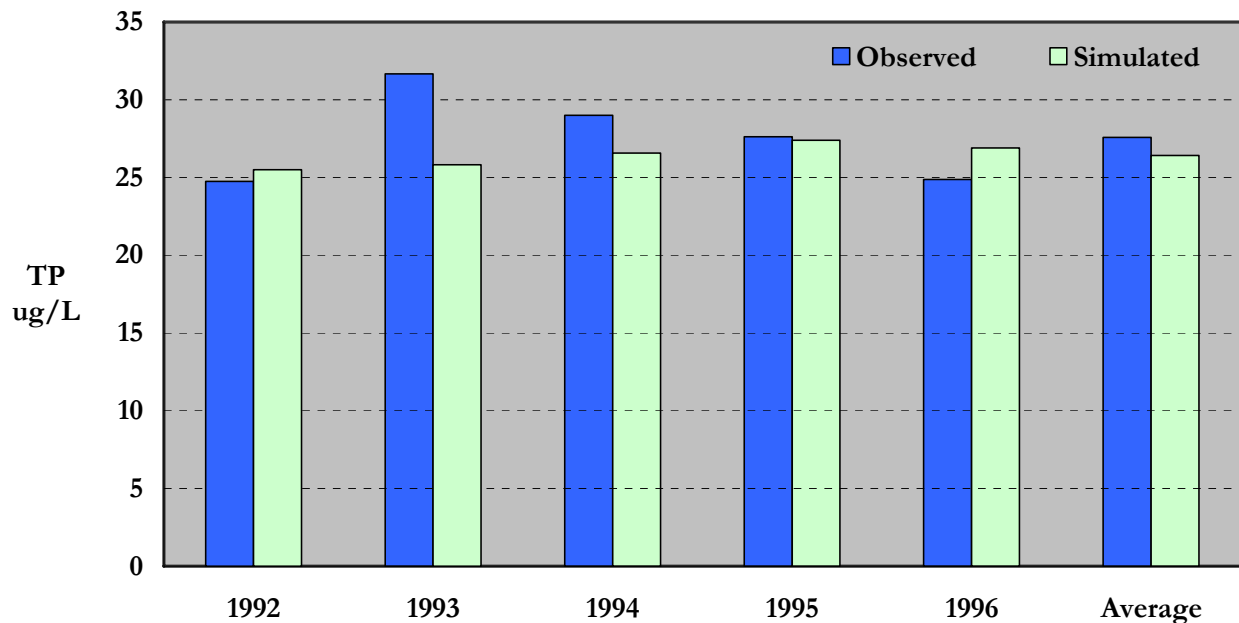
3.1. Lake Modeling Using the BATHTUB Model

BATHTUB was used to define the relationship between phosphorus loading to the lake and the resulting concentrations of total phosphorus in the lake. The U.S. Army Corps of Engineers' BATHTUB model predicts eutrophication-related water quality conditions (e.g., phosphorus, nitrogen, chlorophyll a, and transparency) using empirical relationships previously developed and tested for reservoir applications (Walker, 1987). BATHTUB performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network. Appendix B discusses the setup, calibration, and use of the BATHTUB model.

3.2. Linking Total Phosphorus Loading to the Numeric Water Quality Target

In order to estimate the loading capacity of the lake, simulated phosphorus loads from AVGWLf were used to drive the BATHTUB model to simulate water quality in Moon Lake. AVGWLf was used to derive a mean annual phosphorus loading to the lake for the period 1990-2004. Using this load as input, BATHTUB was used to simulate water quality in the lake. The results of the BATHTUB simulation were compared against the average of the lake's observed summer mean phosphorus concentrations for the years 1992-1996. Year-specific loading was also simulated with AVGWLf, run through BATHTUB, and compared against the observed summer mean phosphorus concentration for that particular year. The combined use of AVGWLf and BATHTUB provided a good fit to the observed data for Moon Lake (Figure 8).

Figure 8. Observed vs. Simulated Summer Mean Epilimnetic Total Phosphorus Concentrations ($\mu\text{g/L}$) in Moon Lake



The BATHTUB model was used as a “diagnostic” tool to derive the total phosphorus load reduction required to achieve the phosphorus target of $20 \mu\text{g/L}$. The loading capacity of Moon Lake was determined by running BATHTUB iteratively, reducing the concentration of the drainage basin phosphorus load until model results demonstrated attainment of the water quality target. The maximum concentration that results in compliance with the TMDL target for phosphorus is used as the basis for determining the lake’s loading capacity. This concentration is converted into a loading rate using simulated flow from AVGWLF.

The maximum annual phosphorus load (i.e., the annual TMDL) that will maintain compliance with the phosphorus TMDL water quality goal of $20 \mu\text{g/L}$ in Moon Lake is a mean annual load of 114 lbs/yr. The daily TMDL of 0.3 lbs/d was calculated by dividing the annual load by the number of days in a year. Lakes and reservoirs store phosphorus in the water column and sediment, therefore water quality responses are generally related to the total nutrient loading occurring over a year or season. For this reason, phosphorus TMDLs for lakes and reservoirs are generally calculated on an annual or seasonal basis. The use of annual loads, versus daily loads, is an accepted method for expressing nutrient loads in lakes and reservoir. This is supported by EPA guidance such as *The Lake Restoration Guidance Manual* (USEPA 1990) and *Technical Guidance Manual for Performing Waste Load Allocations, Book Iv, lakes and Impoundments, Chapter 2 Eutrophication* (USEPA 1986). While a daily load has been calculated, it is recommended that the annual loading target be used to guide implementation efforts since the annual load of total phosphorus as a TMDL target is more easily aligned with the design of best management practices (BMPs) used to implement nonpoint source and stormwater controls for lakes than daily loads. Ultimate compliance with water quality standards for the TMDL will be determined by measuring the lake’s water quality to determine when the phosphorus guidance value is attained.

4.0 POLLUTANT LOAD ALLOCATIONS

The objective of a TMDL is to provide a basis for allocating acceptable loads among all of the known pollutant sources so that appropriate control measures can be implemented and water quality standards achieved. Individual waste load allocations (WLAs) are assigned to discharges regulated by State Pollutant Discharge Elimination System (SPDES) permits (commonly called point sources) and unregulated loads (commonly called nonpoint source) are contained in load allocations (LAs). A TMDL is expressed as the sum of all individual WLAs for point source loads, LAs for nonpoint source loads, and an appropriate margin of safety (MOS), which takes into account uncertainty (Equation 1).

Equation 1. Calculation of the TMDL

$$TMDL = \sum WLA + \sum LA + MOS$$

4.1. Wasteload Allocation (WLA)

There are no point source discharges of treated wastewater effluent in the Moon Lake drainage basin. There are also no Municipal Separate Storm Sewer Systems in the basin. Therefore, the WLA is set at 0 (zero), and all of the loading capacity is allocated as a gross allotment to the load allocation.

4.2. Load Allocation (LA)

The LA is set at 103 lbs/yr. Nonpoint sources that contribute total phosphorus to Moon Lake on an annual basis include loads from developed land, agricultural land, and malfunctioning septic systems. Table 6 lists the current loading for each source and the load allocation needed to meet the TMDL; Figure 9 provides a graphical representation of this information. Phosphorus originating from forested land is assumed to be a minor source of loading that is unlikely to be further reduced and therefore the load allocation is set at the current loading level. Loads from developed and agricultural land were each assigned a twenty percent reduction, which is believed to be reasonable and practical. The bulk of the reductions need to come from septic systems, which account for most of the estimated load in the watershed, as is further discussed in Section 5, Implementation.

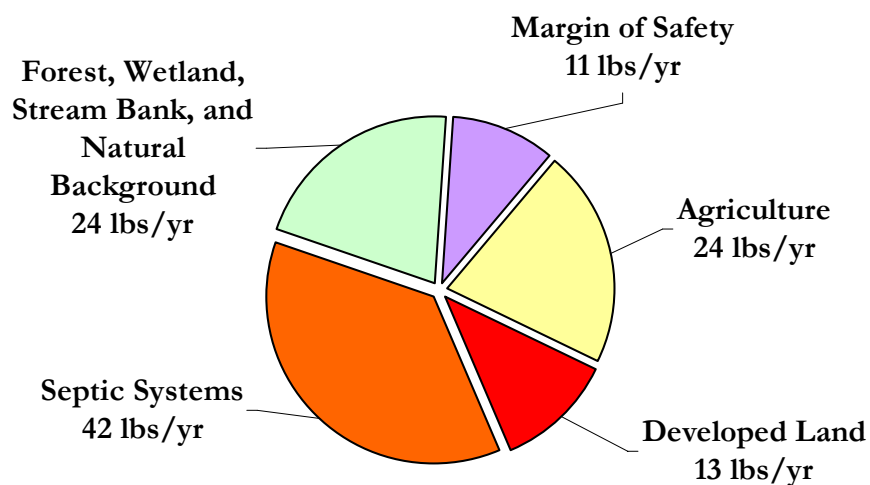
Table 6. Total Annual Phosphorus Load Allocations for Moon Lake¹

Source	Total Phosphorus Load (lbs/yr)			%
	Current	Allocated	Reduction	Reduction
Agriculture*	30	24	6	20%
Developed Land*	16	13	3	19%
Septic Systems	100	42	58	58%
Forest, Wetland, Stream Bank, and Natural Background	24	24	0	0%
LOAD ALLOCATION (subtotal)	170	103	67	39%
Point Sources	0	0	0	0%
WASTELOAD ALLOCATION (subtotal)	0	0	0	0%
LA + WLA	170	103	67	39%
Margin of Safety	---	11	---	---
TOTAL	170	114	n/a	n/a

1 - Note: The values reported in Table 6 are the annually integrated values. The daily equivalent values are provided in Appendix C.

* Includes phosphorus transported through surface runoff and subsurface (groundwater)

Figure 9. Total Phosphorus Load Allocations for Moon Lake (lbs/yr)



4.3. Margin of Safety (MOS)

The margin of safety (MOS) can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a combination of both. For the Moon Lake TMDL, the MOS is explicitly accounted for during the allocation of loadings. An implicit MOS (MOS) could have been provided by making conservative assumptions at various steps in the TMDL development process (e.g., by selecting conservative model input parameters or a conservative TMDL target). However, making conservative assumptions in the modeling analysis can lead to serious errors in projecting the benefits of BMPs and in projecting lake responses. Therefore, the recommended method is to formulate the mass balance using the best scientific estimates of the model input values and keep the margin of safety in the “MOS” term.

The TMDL contains an explicit margin of safety (MOS) corresponding to 10% of the loading capacity, or 11 lbs/yr. The 10% MOS is appropriate based on the generally good agreement between the AVGWLF loading model and the observed loading and flow data and good agreement between the BATHUB water quality model and the observed lake water quality data. Since these models reasonably reflect the conditions in the drainage basin, a 10% MOS is considered to be adequate to address the uncertainty in the TMDL. The MOS can be reviewed in the future as new data become available.

4.4. Critical Conditions

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Critical conditions were taken into account in the development of this TMDL. In terms of loading, spring runoff periods are considered critical because wet weather events transport significant quantities of nonpoint source loads to lake. However, the water quality ramifications of these nutrient loads are most severe during middle or late summer. Therefore, BATHUB model simulations were compared against observed data for the summer period only. Furthermore, AVGWLF takes into account loadings from all periods throughout the year, including spring loads.

4.5. Seasonal Variations

Seasonal variation in nutrient load and response is captured within the models used for this TMDL. In BATHUB, seasonality is incorporated in terms of seasonal averages for summer. Seasonal variation is also represented in the TMDL by taking 14 years of daily precipitation data when calculating runoff through AVGWLF, as well as by estimating septic system loading inputs based on residency (i.e., seasonal or year-round). This takes into account the seasonal effects the lake will undergo during a given year.

5.0 IMPLEMENTATION

One of the critical factors in the successful development and implementation of TMDLs is the identification of potential management alternatives, such as best management practices (BMPs) and screening and selection of final alternatives in collaboration with the involved stakeholders. The ongoing watershed protection efforts (e.g., watershed characterization, restoration, and volunteer monitoring) have already been outlined in the 1999 Moon Lake Management Plan. Coordination

with state agencies, federal agencies, local governments, and stakeholders such as Moon Lake Preservation Council, the general public, environmental interest groups, and representatives from the point and nonpoint pollution sources will ensure that the proposed management alternatives are technically and financially feasible. NYS DEC, in coordination with these local interests, will address the sources of impairment, using primarily non-regulatory tools in this watershed, matching management strategies with sources, and aligning available resources to effect implementation.

NYS DEC recognizes that TMDL designated load reductions alone may not be sufficient to restore eutrophic lakes. The TMDL establishes the required nutrient reduction targets and provides some regulatory framework to effect those reductions. However, the nutrient load only affects the eutrophication potential of a lake. The implementation plan therefore calls for the collection of additional monitoring data, as discussed in Section 5.2, and consideration of the Moon Lake Management Plan, which discusses in-lake measures that need to be taken to supplement the nutrient reduction measures required by the TMDL. For example, the shallow portion of the lake supports macrophytes that, at some density levels, are a natural component of a healthy, clear-water lake ecology. However, because of density or location, these macrophytes ultimately interfere with boating. Phosphorus reductions alone may not address this issue and biological controls of macrophytes or other measures may be a long-term maintenance measure needed in certain areas to facilitate the boating use.

5.1. Reasonable Assurance for Implementation

Measures for Septic Systems

Because septic systems are the primary source of loading in the Moon Lake watershed, restoration depends on significant reductions from that source. A systematic approach, such as the formation of a management district, will be essential to achieving the load reductions specified above. A study should be undertaken to evaluate alternatives, such as clustered treatment and on-site upgrades to outline the most cost-effective plan. New York State has begun to offer funding for the abatement of inadequate onsite wastewater systems through the development and implementation of a septic system management program by a responsible management entity.

In the interim, the ongoing testing program should be expanded, and failing systems must be upgraded in accordance with the State Sanitary Code. State funding is also available for a voluntary septic system inspection and maintenance program or a septic system local law requiring inspection and repair. Property owners should be educated on proper maintenance of their septic systems and encouraged to make preventative repairs.

To further assist municipalities, NYS DEC is involved in the development of a statewide training program for onsite wastewater treatment system professionals. A largely volunteer industry group called the Onsite Wastewater Treatment Training Network (OTN) has been formed. NYS DEC has provided financial and staff support to the OTN during the last five years.

Measures for Agriculture

The New York State Agricultural Environmental Management (AEM) Program was codified into law in 2000. Its goal is to support farmers in their efforts to protect water quality and conserve natural resources, while enhancing farm viability. AEM provides a forum to showcase the soil and

water conservation stewardship farmers provide. It also provides information to farmers about Concentrated Animal Feeding Operation (CAFO) regulatory requirements, which helps to assure compliance. Details of the AEM program can be found at the New York State Soil and Water Conservation Committee (SWCC) website, <http://www.nys-soilandwater.org/aem/index.html>.

Using a voluntary approach to meet local, state and national water quality objectives, AEM has become the primary program for agricultural conservation in New York. It also has become the umbrella program for integrating/coordinating all local, state and federal agricultural programs. For instance, farm eligibility for cost sharing under the SWCC Agricultural Non-point Source Abatement and Control Grants Program is contingent upon AEM participation.

AEM core concepts include a voluntary and incentive-based approach, attending to specific farm needs and reducing farmer liability by providing approved protocols to follow. AEM provides a locally led, coordinated and confidential planning and assessment method that addresses watershed needs. The assessment process increases farmer awareness of the impact farm activities have on the environment and by design, it encourages farmer participation.

The AEM Program relies on a five-tiered process:

Tier 1 – Survey current activities, future plans and potential environmental concerns.

Tier 2 – Document current land stewardship; identify and prioritize areas of concern.

Tier 3 – Develop a conservation plan, by certified planners, addressing areas of concern tailored to farm economic and environmental goals.

Tier 4 – Implement the plan using available financial, educational and technical assistance.

Tier 5 – Conduct evaluations to ensure the protection of the environment and farm viability.

Jefferson County Soil and Water Conservation District has begun the AEM program on farms in the Moon Lake Watershed with the Tier 1 survey that will lead to identification of management practices to reduce phosphorus loads. These practices would be eligible for state or federal funding and because they address a water quality impairment associated with this TMDL, should score well.

Measures for Stormwater

In March 2002, NYS DEC issued SPDES general permits GP-02-01 for construction activities, and GP-02-02 for stormwater discharges from municipal separate stormwater sewer system (MS4s) in response to the federal Phase II Stormwater rules. GP-02-02 applies to urbanized areas of New York State, so it does not cover the Moon Lake watershed.

Stormwater management in rural areas can be addressed through the Nonpoint Source Management Program. There are several measures, which, if implemented in the watershed, could directly or indirectly reduce phosphorus loads in stormwater discharges to the Lake or watershed:

- Public education regarding:
 - Lawn care, specifically reducing fertilizer use or using phosphorus-free products, now commercially available,
 - Cleaning up pet waste, and

- Discouraging waterfowl congregation by restoring natural shoreline vegetation.
- Management practices to address any significant existing erosion sites.
- Construction site and post construction stormwater runoff control ordinance and inspection and enforcement programs.
- Pollution prevention practices for road and ditch maintenance.

Protection Measures

The 1999 Moon Lake Management Plan outlined several goals and objectives, which if implemented, will serve to further protect water quality in Moon Lake and limit the growth of phosphorus load that would otherwise offset load reduction efforts. The basic protections afforded by Town of Theresa zoning ordinance could be enhanced to limit non-compatible development and preserve natural vegetation along shorelines. Identification of wildlife habitats, sensitive environmental areas, and key open spaces within the shoreline area could lead to their preservation or protection by way of conservation easements or other voluntary controls, which would supplement the regulated wetlands that border the lake.

5.2. Follow-up Monitoring

A targeted post-assessment monitoring effort will be initiated to determine the effectiveness of the implementation plan associated with the TMDL. Moon Lake will be sampled in 2008 at its deepest location (approx. 5-6 meters), during the warmer part of the year (May through September) on 8 sampling dates. Dissolved oxygen and temperature profiles will be done at 1 meter intervals at the “deep hole.” Grab samples will be collected at 1.5 meter and in the hypolimnion, if thermal stratification is present (but this is not expected). The samples will be analyzed for the phosphorus series (total phosphorus, total soluble phosphorus, and soluble reactive phosphorus), the nitrogen series (nitrate, ammonia and total nitrogen), and chloride. The epilimnetic samples will be analyzed for chlorophyll a and the Secchi disk depth will be measured. A simple macrophyte survey will also be conducted one time during mid summer.

Depending on the speed and extent of implementation, the sampling will be repeated at a regular interval. The initial plan will be to set the interval at 5 years. In addition, as the information on the DEC GIS system is updated (land use, BMPs, etc.), these updates will be applied to the input data for the models BATHTUB and AVGWLF. The information will be incorporated into the NY 305(b) report as needed.

6.0 PUBLIC PARTICIPATION

Notice of availability of the Draft TMDL was made to local government representatives and interested parties. This Draft TMDL was public noticed in the Environmental Notice Bulletin on July 11, 2007. A 30-day public review period was established for soliciting written comments from stakeholders prior to the finalization and submission to the TMDL for USEPA approval. No comments were received.

7.0 REFERENCES

ASCE Task Committee on Definition of Criteria for Evaluation of Watershed Models of the Watershed Management Committee, Irrigation and Drainage Division, 1993. Criteria for evaluation of watershed models. *Journal of Irrigation and Drainage Engineering*, Vol. 199, No. 3.

Chapra, S.C. and Martin, J.L. 2004. LAKE2K: A Modeling Framework for Simulating Lake Water Quality (Version 1.2): Documentation and Users Manual. Civil and Environmental Engineering Dept., Tufts University, Medford, MA.

Day, L.D., 2001. Phosphorus Impacts from Onsite Septic Systems to Surface Waters in the Cannonsville Reservoir Basin, NY. Delaware County Soil and Water Conservation District, Walton, NY, June, 2001.

Evans, B.M., D.W. Lehning, K.J. Corradini, *Summary of Work Undertaken Related to Adaptation of AVGWLF for Use in New England and New York*. 2007.

Evans, B.M., D.W. Lehning, K.J. Corradini, G.W. Petersen, E. Nizeyimana, J.M. Hamlett, P.D. Robillard, and R.L. Day, 2002. A Comprehensive GIS-Based Modeling Approach for Predicting Nutrient Loads in Watersheds. *Journal of Spatial Hydrology*, Vol. 2, No. 2.

Haith, D.A. and L.L. Shoemaker, 1987. Generalized Watershed Loading Functions for Stream Flow Nutrients. *Water Resources Bulletin*, 23(3), pp. 471-478.

Homer, C. C. Huang, L. Yang, B. Wylie and M. Coan. 2004. *Development of a 2001 National Landcover Database for the United States. Photogrammetric Engineering and Remote Sensing*, Vol. 70, No. 7, July 2004, pp. 829

National Atmospheric Deposition Program (NRSP-3). 2007. NADP Program Office, Illinois State Water Survey, 2204 Griffith Dr., Champaign, IL 61820

New York State, 2004. New York State Water Quality Report 2004. NYS Department of Environmental Conservation, Division of Water, Bureau of Watershed Assessment and Management.

New York State, 1998. 6 NYS Codes Rules and Regulations, Part 703.2, Narrative Water Quality Standards.

New York State, 1993. New York State Fact Sheet, Ambient Water Quality Value for Protection of Recreational Uses, Substance: Phosphorus, Bureau of Technical Services and Research. NYS Department of Environmental Conservation.

Sutherland, J.W., J.A. Bloomfield and J.M. Swart. 1983. Final report for the Lake George urban runoff study, nationwide urban runoff program. Bureau of Water Research, New York State Dept. of Environmental Conservation. Albany, NY. 79 p.

United States Army Corps of Engineers, Engineer Research and Development Center., 2004. Flux, Profile, and BATHTUB: Simplified Procedures for Eutrophication Assessment and Prediction. <<http://el.erdc.usace.army.mil/elmodels/emiinfo.html>>.

USEPA. 2002. *Onsite Wastewater Treatment Systems Manual*. EPA/625/R-00/008. February 2002.

USEPA, 1999. Protocol for Developing Sediment TMDLs (First Edition). EPA 841-B-99-004. Office of Water (4503F), United States Environmental Protection Agency, Washington, DC.

USEPA. 1990. *The Lake and Reservoir Restoration Guidance Manual*. 2nd Ed. and *Monitoring Lake and Reservoir Restoration (Technical Supplement)*. Prepared by North American Lake Management Society. EPA 440/4-90-006 and EPA 440/4-90-007.

USEPA. 1986. Technical Guidance Manual for Performing Wasteload Allocations, Book IV: Lakes, Reservoirs and Impoundments, Chapter 2: Eutrophication. EPA 440/4-84-019, p. 3-8.

United States Census Bureau, Census 2000 Summary File 3 (SF 3) - Sample Data. H18. *AVERAGE HOUSEHOLD SIZE OF OCCUPIED HOUSING UNITS BY TENURE Average Household Size of Occupied housing Units by Tenure*. 2007, <http://factfinder.census.gov/>

Watts, S., B. Gharabaghi, R.P. Rudra, M. Palmer, T. Boston, B. Evans, and M. Walters, 2005. Evaluation of the GIS-Based Nutrient Management Model CANWET in Ontario. In: Proc. 58th Natl. Conf. Canadian Water Resources Assoc., June 2005, Banff, Canada.