Total Maximum Daily Load (TMDL)

for Phosphorus in Basic Creek Reservoir

Albany County, New York

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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" (USEPA 1991b). 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, or load, 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, and levels necessary to meet the applicable standards are specified. Due consideration is 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, 1991a).

1.2. Problem Statement

Basic Creek Reservoir (WI/PWL ID 1309-0001)(Water Index/Priority Waterbody List) is situated in the Town of Westerlo, within Albany County, New York. Over the past couple of decades, the reservoir has experienced degraded water quality that has reduced the reservoir's value as a secondary water supply to the City of Albany, as well as impacted the reservoir's recreational and aesthetic value. Basic Creek Reservoir was listed among the lakes on the Lower Hudson River Basin PWL in 2002.

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 reservoir from the surrounding drainage basin by way of streams, overland flow, and subsurface flow. Nutrients are then deposited and stored in the reservoir bottom sediments. Phosphorus is often the limiting nutrient in temperate lakes, ponds, and reservoirs and can be thought of as a fertilizer, a primary food for plants, including algae. When reservoirs receive excess phosphorus, it "fertilizes" the reservoir by feeding the algae. Too much phosphorus can result in algal blooms, which can damage the ecology/aesthetics of a reservoir, as well as the economic well-being of the surrounding drainage basin community. In 2002, Basic Creek Reservoir was added to the New York State Department of Environmental Conservation (NYS DEC) CWA Section 303(d) list of impaired waterbodies that do not meet water quality standards due to phosphorus impairments (NYS DEC, 2008). Based on this listing, a TMDL for phosphorus has been developed for the reservoir.

2.0 WATERSHED AND RESERVOIR CHARACTERIZATION

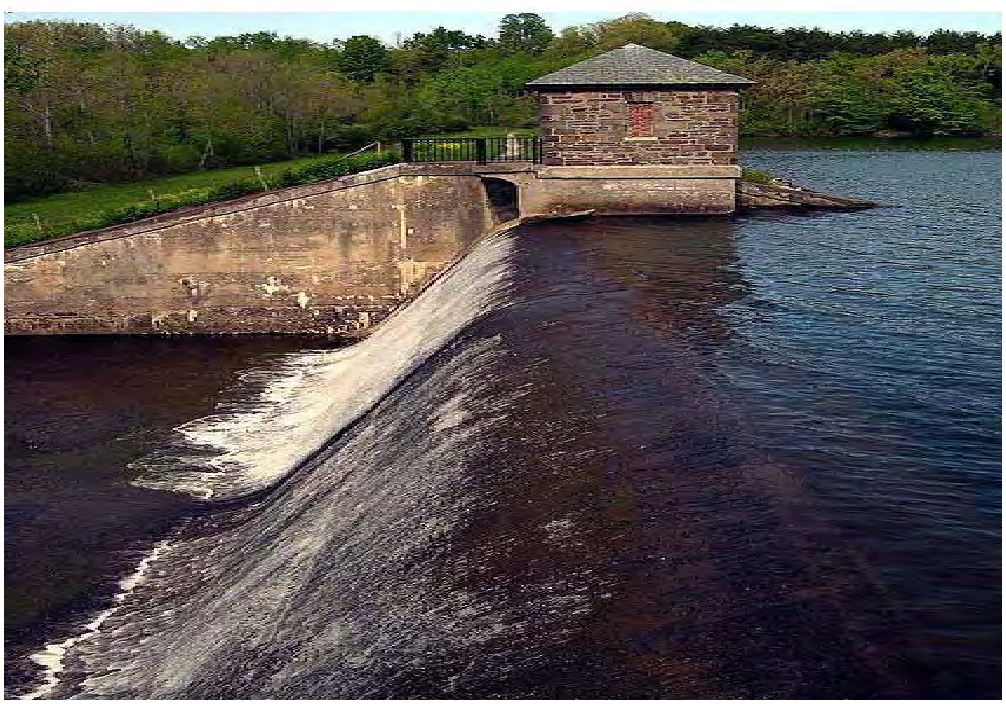
2.1. History of the Reservoir and Watershed

The **Basic Creek Reservoir** is located in Westerlo, N.Y. It was constructed in from 1928-1932 to serve as the back-up water supply to the Alcove Reservoir, which serves as the primary drinking water supply for the City of Albany, N.Y. The reservoir is approximately 265 acres and has a storage capacity of 716 million gallons. Accordingly, the Reservoir is rated as Class A, which is defined in 6NYCRR Part 701.6 as having a best usage as a "source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. The waters shall be suitable for fish, shellfish, and wildlife propagation and survival."

The reservoir is also identified as a high priority for nonpoint source pollution source pollution reduction in the Albany County Water Quality Coordinating Committee's (WQCC) Water Quality Strategy. The Committee has been involved with, and initiated, several projects over the years geared towards education about and reduction of nonpoint source pollutant and watershed protection. Efforts have focused mostly on residential sources, groundwater protection, and also outreach to the Albany and Westerlo school districts. Albany County SWCD, NRCS, and City of Albany Department of Water and Water Supply have made continuing efforts to work with agricultural landowners in the watershed to implement BMPs to reduce agricultural runoff.

Fishing is allowed in the Basic Creek Reservoir if a permit is bought. There are Smallmouth Bass, Largemouth Bass, Black Crappie, Walleye, Bluegill, Northern Pike, Chain Pickerel Brown Bullhead and Yellow Perch. Closed to visitors after September 11, 2001 for security reasons, it reopened for fishing and hiking on June 11, 2008.

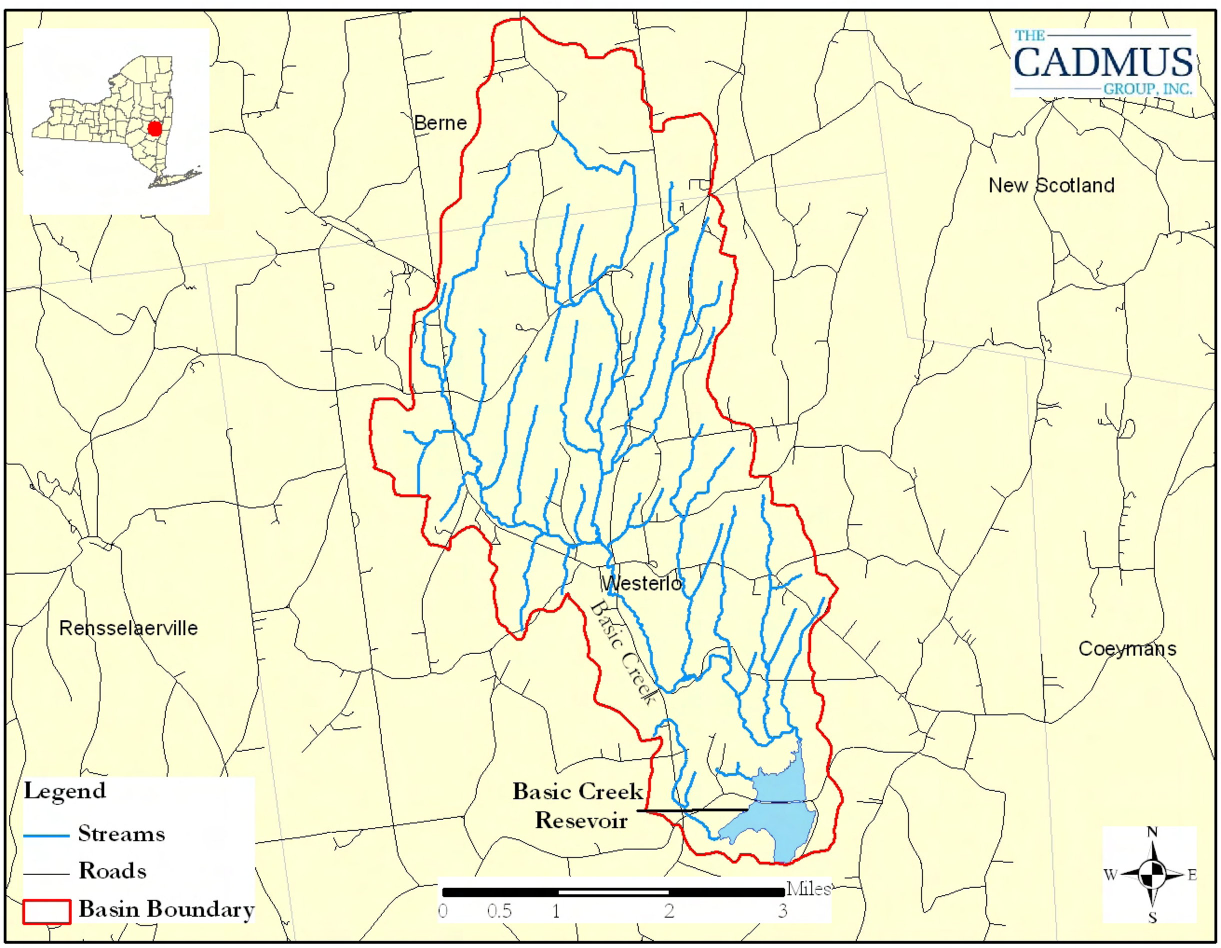
Basic Creek Reservoir Spillway



2.2. Watershed Characterization

Basic Creek Reservoir has a direct drainage basin area of 10,522 acres excluding the surface area of the reservoir (Figure 1). Elevations in the reservoir's basin range from approximately 1,801 feet above mean sea level (AMSL) to as low as 935 feet AMSL at the surface of Basic Creek Reservoir.

Figure 1. Basic Creek Reservoir Direct Drainage Basin



Existing land use and land cover in the Basic Creek Reservoir 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 (NLCD) (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 (Figure 2). Appendix A provides additional detail about the refinement of land use for the drainage basin. Land use categories (including individual category acres and percent of total) in Basic Creek Reservoir's drainage basin are listed in Table 1 and presented in Figures 3 and 4.

Figure 2. Aerial Image of Basic Creek Reservoir

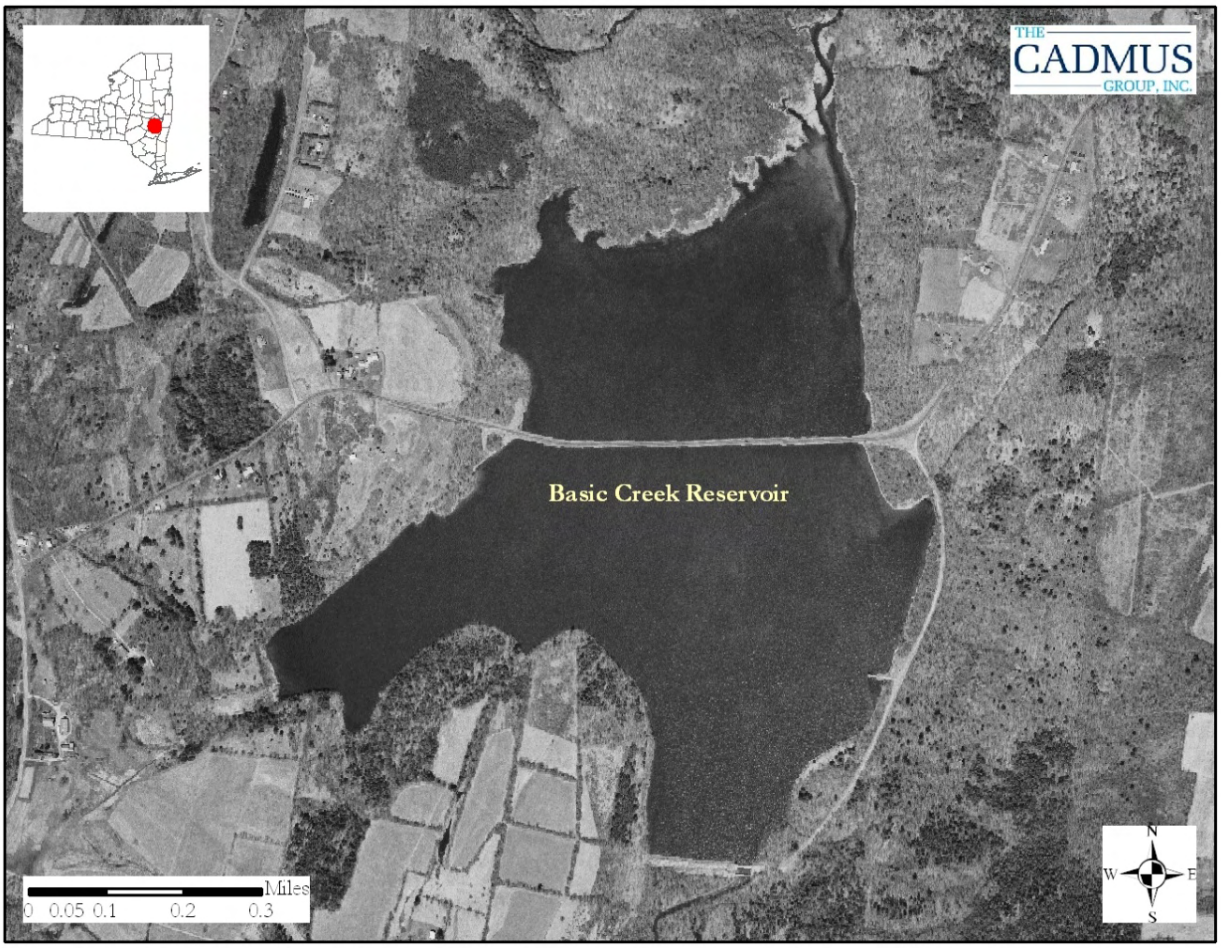


Table 1. Land Use Acres and Percent in Basic Creek Reservoir Drainage Basin

Land Use Category	Acres	% of Drainage Basin
Open Water	98	0.9%
Agriculture	3,072	29.2%
Hay & Pasture	2,798	26.6%
Cropland	274	2.6%
Developed Land	574	5.5%
Low Intensity	540	5.13%
High Intensity	34	0.32%
Forest	6,626	63.0%
Wetlands	152	1.4%
TOTAL	**10,522**	**100%**

Figure 3. Percent Land Use in Basic Creek Reservoir Drainage Basin

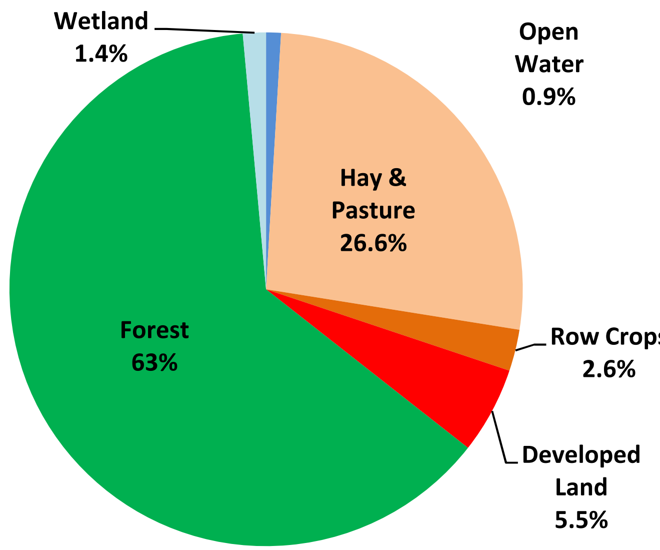
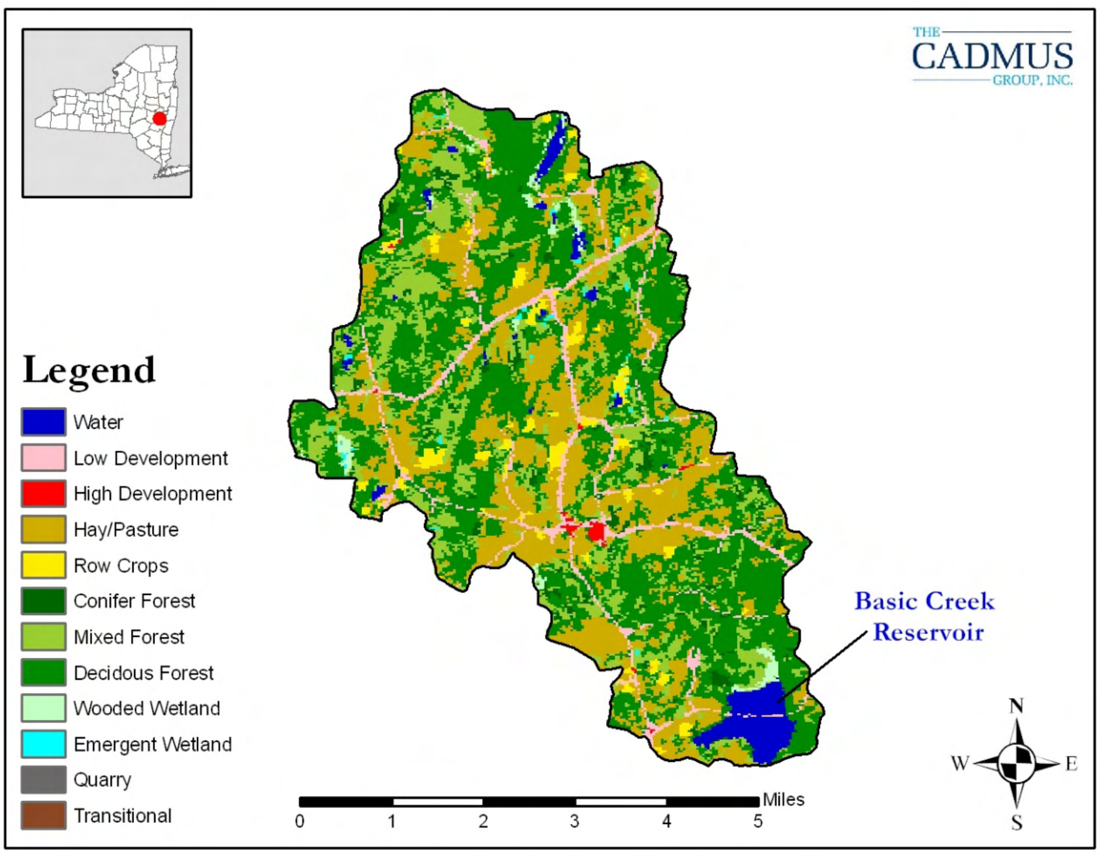


Figure 4. Land Use in Basic Creek Reservoir Drainage Basin



2.3. Reservoir Morphometry

Basic Creek Reservoir is a 237 acre waterbody at an elevation of about 935 feet AMSL. Figure 5 shows a bathymetric map for Basic Creek Reservoir based on reservoir contour maps developed by NYS DEC. Table 2 summarizes key morphometric characteristics for Basic Creek Reservoir.

Figure 5. Bathymetric Map of Basic Creek Reservoir

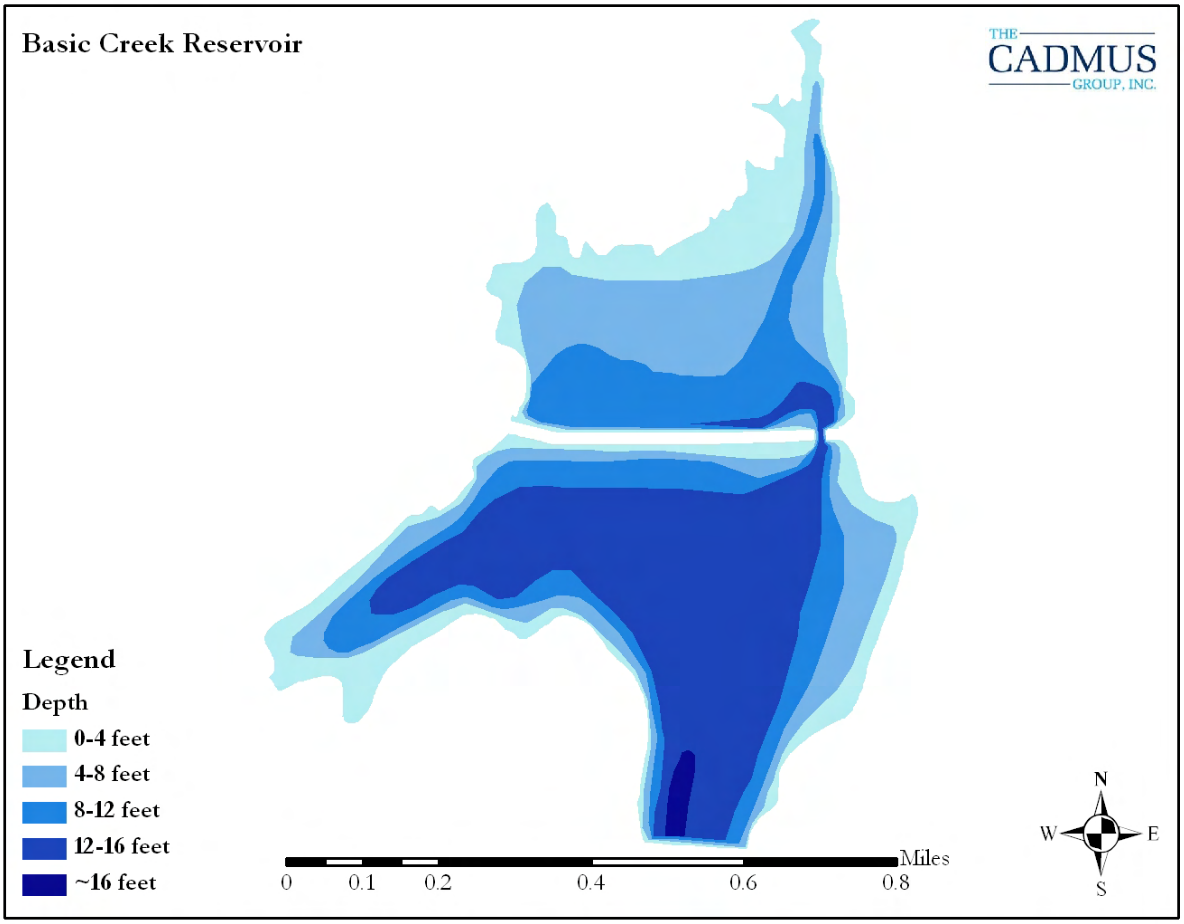


Table 2. Basic Creek Reservoir Characteristics

Surface Area (acres)	237
Elevation (ft AMSL)	935
Maximum Depth (ft)	16
Mean Depth (ft)	9
Length (ft)	4,852
Width at widest point (ft)	4,166
Shoreline perimeter (ft)	25,645
Direct Drainage Area (acres)	10,522
Watershed: Reservoir Ratio	44:1
Hydraulic Residence Time (years)	0.1

2.4. Water Quality

Observed water quality data for total phosphorus were not available for Basic Creek Reservoir when the TMDL's model was originally developed. The initial model was based entirely on simulated water quality data. Subsequent to this model development, two years of Basic Creek Reservoir monitoring data were collected and are included in Figure 7 for comparison. The data consisted of 5 samples during both 2004 and 2005, between April 1 and September 30 of each year. The annual medians of these 5 values are shown in Figure 7, and are 42 and 55 for the two years respectively.

Both of these values were higher than the average simulated values from 1990 to 2003. A review of the USGS weather gage for the Albany County Airport indicted that the actual rainfall for those two years (39.99" and 47.72") were higher than the average rainfall (38.90") that resulted in the simulated value of 31 ug/l. This appears to support the use of the AVGWLF model since the surface area loading factors use rainfall amounts determine the volume of water that transports Phosphorous. It stands to reason, then, that increased rainfall should increase the amount of Phosphorous transported to the Reservoir.

In addition to these two years of data as model validation, the model itself had been initially calibrated for half of the 22 watersheds in the northeast for which the simulations were developed. The calibration for these other similar lakes and reservoirs in the region are discussed more fully in Appendix A. The remaining 11 watersheds were used to verify the statistical accuracy of the model. A map of the watersheds used for this calibration and verification is in Appendix A Figure 9.

The two years of subsequent monitoring data, and the calibration/verification protocol found in Appendix A, both indicate the model should provide a good approximation as to the probable water quality in Basic Creek Reservoir.

3.0 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. 6 NYCRR Part 863 lists Basic Creek Reservoir as a Class A waterbody, which means that the best usages of the reservoir are as a source of water supply for drinking, culinary or food processing purposes, primary and secondary contact recreation, and fishing. The reservoir must also be suitable for fish propagation and survival.

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 NYCRR 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 Basic Creek Reservoir.

4.0 SOURCE ASSESSMENT

4.1. Analysis of Phosphorus Contributions

The ArcView Generalized Watershed Loading Function (AVGWLF) watershed model was used in combination with the BATHTUB reservoir response model to develop the Basic Creek Reservoir TMDL. This approach consists of using AVGWLF to determine mean annual phosphorus loading to the reservoir, and 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 (one that transmits loading rates) 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 and reservoir TMDL assessments in New York.

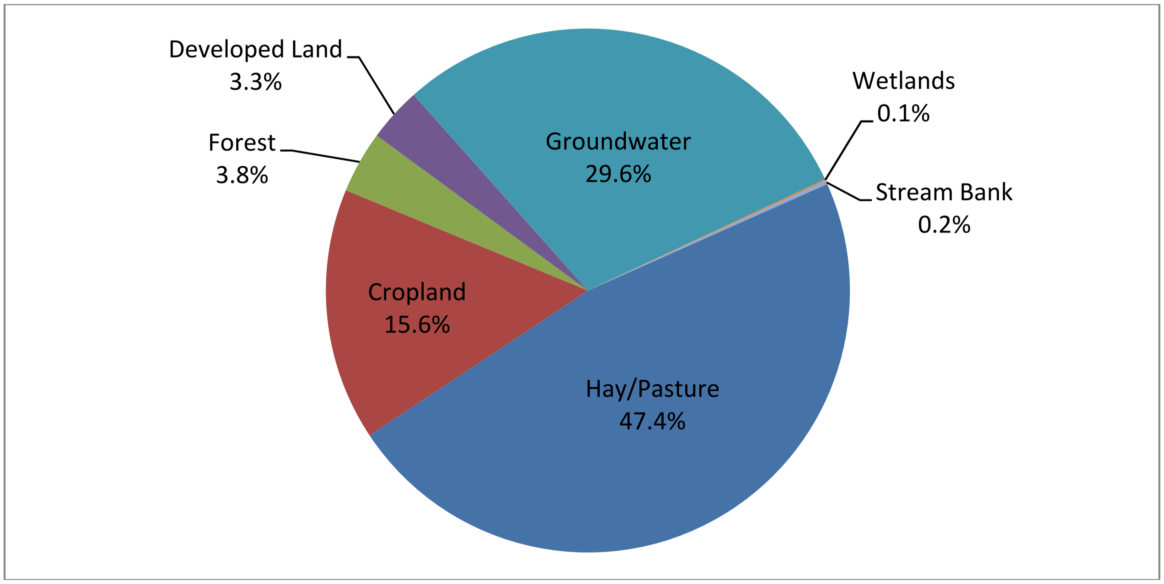
4.2. Sources of Phosphorus Loading

AVGWLF was used to estimate long-term (4/1990-3/2004) mean annual phosphorus (external) loading to Basic Creek Reservoir. The estimated mean annual external load of 2,082 lbs/yr of total phosphorus that enters Basic Creek Reservoir comes from the sources listed in Table 3 and shown in Figure 6. Appendix A provides the detailed simulation results from AVGWLF.

Table 3. Estimated Sources of Phosphorus Loading to Basic Creek Reservoir

Source	Total Phosphorus (lbs/yr)
Hay/Pasture	986
Cropland	324
Forest	79.7
Wetlands	2.2
Developed Land	69.6
Stream Bank	4.6
Groundwater	616
TOTAL	**2,082**

Figure 6. Estimated Sources of Total Phosphorus Loading to Basic Creek Reservoir



4.2.1. Agricultural Runoff

Agricultural land encompasses 3,072 acres (29.2%) of the reservoir drainage basin and includes hay and pasture land (26.6%) and row crops (2.6%). Overland runoff from agricultural land is estimated to contribute 1,310 lbs/yr of phosphorus loading to Basic Creek Reservoir, which is 63% of the total phosphorus loading to the reservoir.

In addition to the contribution of phosphorus to the reservoir from overland agriculture runoff, additional phosphorus originating from agricultural lands is leached in dissolved form from the surface and transported to the reservoir through subsurface movement via groundwater. The process for estimating subsurface delivery of phosphorus originating from agricultural land is discussed in the Groundwater Seepage 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.

4.2.2. Urban and Residential Development Runoff

Developed land comprises 574 acres (5.5%) of the reservoir drainage basins. Stormwater runoff from developed land contributes less than 70 lb/yr of phosphorus to Basic Creek Reservoir, which is 3% of the total phosphorus loading to the reservoir. In addition to the contribution of phosphorus to the reservoir from overland urban runoff, additional phosphorus originating from developed lands is leached from the surface and transported to the reservoir through subsurface movement via groundwater. The process for estimating subsurface delivery of phosphorus originating from developed land is discussed in the Groundwater Seepage 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.

4.2.3. Forest Land Runoff

Forested land comprises 6,626 acres (63%) of the reservoir drainage basin. Runoff from forested land is estimated to contribute less than 80 lbs/yr of phosphorus loading to Basic Creek Reservoir, which is about 4% of the total phosphorus loading to the reservoir. Phosphorus contribution from forested land is considered a component of background loading. Additional dissolved phosphorus originating from forest land is leached from the surface and transported to the lake though subsurface movement via groundwater. The process for estimating subsurface delivery of phosphorus originating from forest land is discussed in the Groundwater Seepage section (below).

4.2.4. Groundwater Seepage

In addition to nonpoint sources of phosphorus delivered to the reservoir by surface runoff, a portion of the phosphorus loading from nonpoint sources seeps into the ground and is transported to the reservoir via groundwater. Groundwater is estimated to transport 616 lbs/yr (30%) of the total phosphorus load to Basic Creek Reservoir. With respect to groundwater, there is typically a small "background" concentration owing to various natural sources. In the Basic Creek Reservoir drainage basin, the model-estimated groundwater phosphorus concentration is 0.02 mg/L. The GWLF manual provides estimated background groundwater phosphorus concentrations for ≥90% forested land in the eastern United States, which is 0.006 mg/L. Consequently, about 30% of the groundwater load (185 lbs/yr) can be attributed to natural sources, including forested land and soils.

The remaining amount of the groundwater phosphorus load (about 431 lbs/yr) likely originates from agricultural or developed land sources (i.e., leached in dissolved form from the surface). It is estimated that the remaining phosphorus transported to the reservoir through groundwater originates from developed land (22 lbs/yr) and agricultural land (409 lbs/yr), proportional to their respective surface runoff loads. Table 4 summarizes this information.

Table 4. Sources of Phosphorus Transported in the Subsurface via Groundwater

	Total Phosphorus (lbs/yr)	% of Total Groundwater Load
Natural Sources	185	30%
Developed Land	22	4%
Agricultural Land	409	66%
TOTAL	**616**	**100%**

4.2.5. Other Sources

Atmospheric deposition, wildlife, waterfowl, and domestic pets are also potential sources of phosphorus loading to the reservoir. All of these small sources of phosphorus are incorporated into the land use loadings as identified in the TMDL analysis (and therefore accounted for). Further, the deposition of phosphorus from the atmosphere over the surface of the reservoir is accounted for in the reservoir model, though it is small in comparison to the external loading to the reservoir.

5.0 DETERMINATION OF LOAD CAPACITY

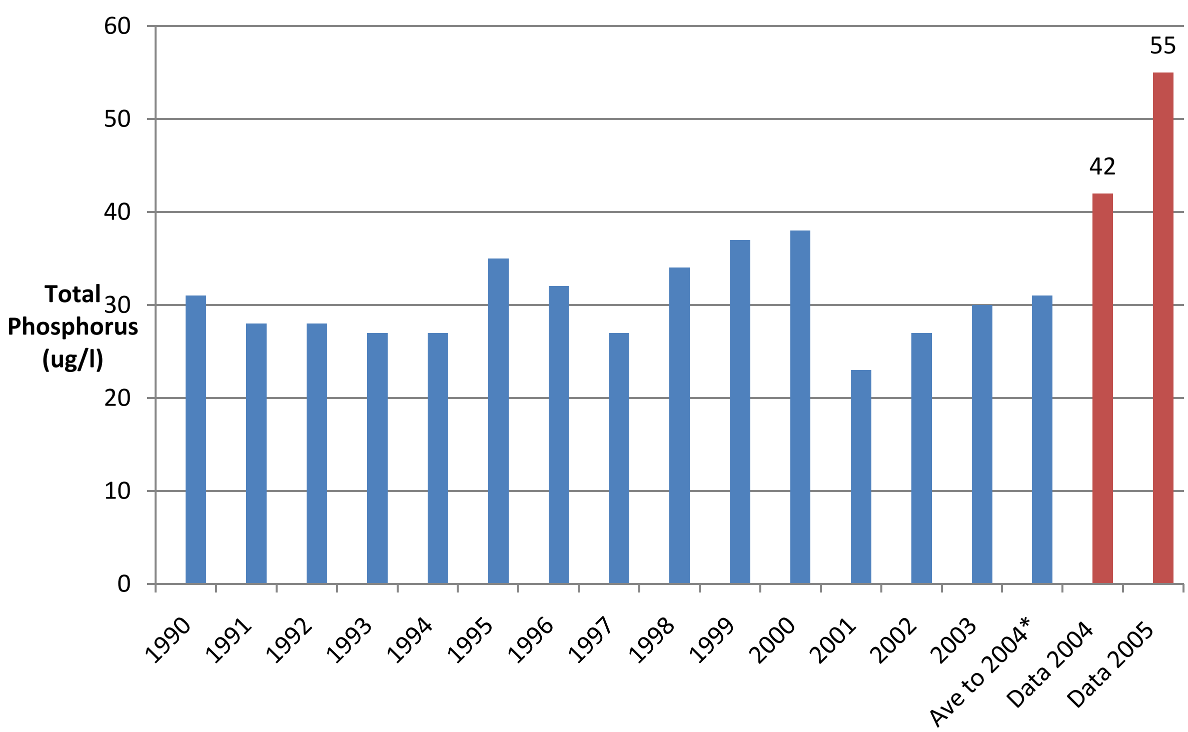
5.1. Reservoir Modeling Using the BATHTUB Model

BATHTUB was used to define the relationship between phosphorus loading to the reservoir and the resulting concentrations of total phosphorus in the reservoir. 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.

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

In order to estimate the loading capacity of the reservoir, simulated phosphorus loads from AVGWLF were used to drive the BATHTUB model to simulate water quality in Basic Creek Reservoir. AVGWLF was used to derive a mean annual phosphorus loading to the reservoir for the period 1990-2004. Using this load as input, BATHTUB was used to simulate water quality in the reservoir. (Figure 7).

Figure 7. Simulated Summer Mean Epilimnetic Total Phosphorus Concentrations (μg/l) in Basic Creek Reservoir



* Simulated average is for the period April 1, 1990 to March 31, 2004.

As a comparison calculation, CADMUS used a Mapshed method, rather than AVGWLF, to approximate a simulated Phosphorus level using rainfall data from 1990 to 2007 as well as slightly different area loading factors unique to Mapshed. The result was a simulated value of 35 ug/l of average Phosphorus from 1990 to 2007. This value seems to concur with the AVGWLF simulated values, and both values indicate a reduction is needed to achieve the target value of 20 ug/l.

The BATHTUB model was used as a "diagnostic" tool to derive the total phosphorus load reduction required to achieve the phosphorus target of 20 μg/l. The loading capacity of Basic Creek Reservoir 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 reservoir'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 water quality goal of 20 μg/l in Basic Creek Reservoir is a mean annual load of 1,210 lbs/yr. The daily TMDL of 3.3 lbs/day 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 reservoirs. 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, the annual loading target will be used to guide implementation efforts. 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 reservoirs than daily loads. Ultimate compliance with water quality standards for the TMDL will be determined by measuring the reservoir's water quality to determine when the phosphorus guidance value is attained.

6.0 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 sources) 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

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

6.1. Wasteload Allocation (WLA)

There are no permitted wastewater treatment plant dischargers in the Basic Creek basin. There are also no Municipal Separate Storm Sewer Systems (MS4s) 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.

6.2. Load Allocation (LA)

The LA is set at 1,089 lbs/yr. Nonpoint sources that contribute total phosphorus to Basic Creek Reservoir on an annual basis include loads from developed and agricultural land. Table 5 lists the current loading for each source and the load allocation needed to meet the TMDL; Figure 8 provides a graphical representation of this information. Phosphorus originating from natural sources (including forested land, wetlands, and stream banks) is assumed to be a minor source of loading that is unlikely to be reduced further and therefore the load allocation is set at current loading.

6.3. Margin of Safety (MOS)

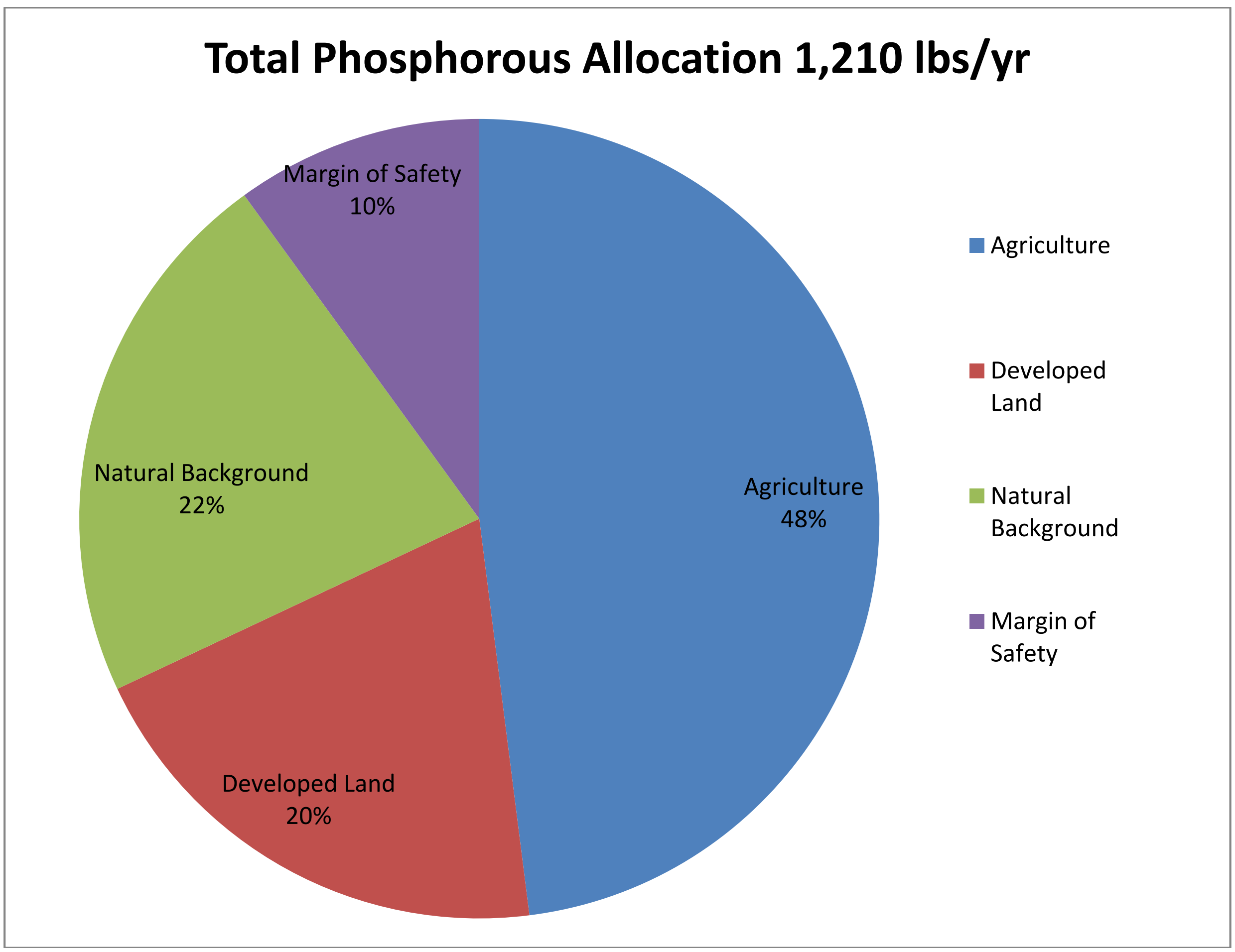
The margin of safety (MOS) can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a combination of both. For the Basic Creek Reservoir TMDL, the MOS is explicitly accounted for during the allocation of loadings. An implicit 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 errors in projecting the benefits of BMPs and in projecting reservoir 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 corresponding to 10% of the loading capacity, or 121.0 lbs/yr. The MOS can be reviewed in the future as new data become available.

Table 5. Total Annual Phosphorus Load Allocations for Basic Creek Reservoir*

Source	Total Phosphorus Load (lbs/yr)			% Reduction
	Current	Allocated	Reduction	
Agriculture**	**1,514**	**580**	**934**	**62%**
Developed Land**	**297**	**238**	**59**	**20%**
Forest, Wetland, Stream Bank, and Natural Background**	**271**	**271**	**0**	**0%**
LOAD ALLOCATION	**2,082**	**1,089**	**993**	**48%**
Point Sources	0	0	0	0%
WASTELOAD ALLOCATION	**0**	**0**	**0**	**0%**
LA + WLA	**2,082**	**1,089**	**993**	**48%**
Margin of Safety	---	**121**	---	---
TOTAL	**2,082**	**1,210**	**---**	**---**

* The values reported in Table 5 are annually integrated. Daily equivalent values are provided in Appendix C.
** Includes phosphorus transported through surface runoff and subsurface (groundwater)

Figure 8. Total Phosphorus Load Allocations for Basic Creek Reservoir (lbs/yr)



6.4. 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 reservoirs. However, the water quality ramifications of these nutrient loads are most severe during middle or late summer. Therefore, BATHTUB 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.

6.5. Seasonal Variations

Seasonal variation in nutrient load and response is captured within the models used for this TMDL. In BATHTUB, 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. This takes into account the seasonal effects the reservoir will undergo during a given year.

7.0 IMPLEMENTATION

One of the critical factors in the successful development and implementation of TMDLs is the identification of potential management alternatives, such as BMPs in collaboration with the involved stakeholders. NYSDEC, in coordination with these local interests, will address the sources of impairment, using regulatory and non-regulatory tools in that watershed, matching management strategies with sources, and aligning available resources to effect implementation.

7.1. Reasonable Assurance for Implementation

Meeting the loading limits specified in this TMDL will require reductions from nonpoint sources. Implementation will rely upon existing programs which have proven successful in reducing loads from the targeted source sectors. For the agricultural source sector, implementation relies upon voluntary installation of BMPs. Financial assistance and resource conservation provides incentives for participation.

7.1.1. Recommended Phosphorus Management Strategies for Agricultural Runoff

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, which is an important overall goal of this implementation plan.

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.

Albany County Soil and Water Conservation District should continue to implement the AEM program on farms in the watershed, focusing on identification of management practices that 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.

Tier 1 could be used to identify farmers that for economic or personal reasons may be changing or scaling back operations, or contemplating selling land. These farms would be candidates for conservation easements, or conversion of cropland to hay, as would farms identified in Tier 2 with highly-erodible soils and/or needing stream management. Ideally, Tier 3 would include a Comprehensive Nutrient Management Plan with phosphorus indexing at the appropriate stage in the planning process. Additional practices could be fully implemented in Tier 4 to reduce phosphorus loads, such as conservation tillage, stream fencing, rotational grazing and cover crops. Also, riparian buffers reduce losses from upland fields and stabilize stream banks in addition to reducing load by taking land out of production.

The Albany County AEM Strategic Plan has noted Basic Creek Watershed Suspected sources of nutrients and sediment as related to agriculture as including: Barnyards, Livestock, Manure/fertilizer spreading and storage, Silage storage and nutrient rich leachate, Cropland Erosion, and Streambank Erosion.

7.1.2. Recommended Phosphorus Management Strategies for Developed Lands.

NYSDEC issued SPDES general permits GP-0-10-001 for construction activities, and GP-0-10-002 for stormwater discharges from municipal separate stormwater sewer systems (MS4s) in response to the federal Phase II Stormwater rules. GP-0-10-002 applies to urbanized areas of New York State, so it does not cover the Basic Creek Reservoir watershed.

As a reasonable assurance measure DEC will evaluate the progress shown in phosphorus reduction, and if necessary to achieve the 20 ug/l target, will propose including the Basic Creek Reservoir

Watershed in the Construction Stormwater General Permit Appendix C listing of "Watersheds Where Enhanced Phosphorus Removal Standards are Required". Basic Creek Reservoir is already on the Appendix E list of 303(d) segments impaired by pollutants related to construction activity.

Developed lands represent a minor part of the total load delivered to the lake. However, minor reductions may still be realized through the present Nonpoint Source Management Program. There are several measures, which if implemented in the watershed, could directly or indirectly reduce phosphorus loads.

- Public education regarding:
  - Lawn care, specifically reducing fertilizer use or using phosphorus-free products now commercially available. The NYS Household Detergent and Nutrient Runoff Law restricts the sale and application of fertilizers containing phosphorus.
  - Cleaning up pet waste.
- Management practices to address any significant existing erosion sites.
- Construction site and post construction stormwater runoff control ordinance, inspection and enforcement programs.
- Pollution prevention practices for road and ditch maintenance.
- Management practices for the handling, storage and use of deicing products.

7.1.3. Additional Protection Measures

Measures to further protect water quality and limit the growth of phosphorus load that would otherwise offset load reduction efforts should be considered. The basic protections afforded by local zoning ordinances could be enhanced to promote smart growth, limit non-compatible development and preserve natural vegetation along shorelines and tributaries. Identification of wildlife habitats, sensitive environmental areas, and key open spaces within the watershed could lead to their preservation or protection by way of conservation easements or other voluntary controls.

7.2. Follow-up Monitoring

A targeted post-assessment monitoring effort will be initiated to determine the effectiveness of the implementation plan associated with this TMDL. Sampling will be coordinated with the existing Lake Classification and Inventory (LCI) program. Samples will be 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. The program is next scheduled to conduct sampling in the basin in 2013 and then every 5 years subsequent.

8.0 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 February 13, 2013. A 30-day public review period was established for soliciting written comments from stakeholders prior to the finalization and submission of the TMDL for USEPA approval.

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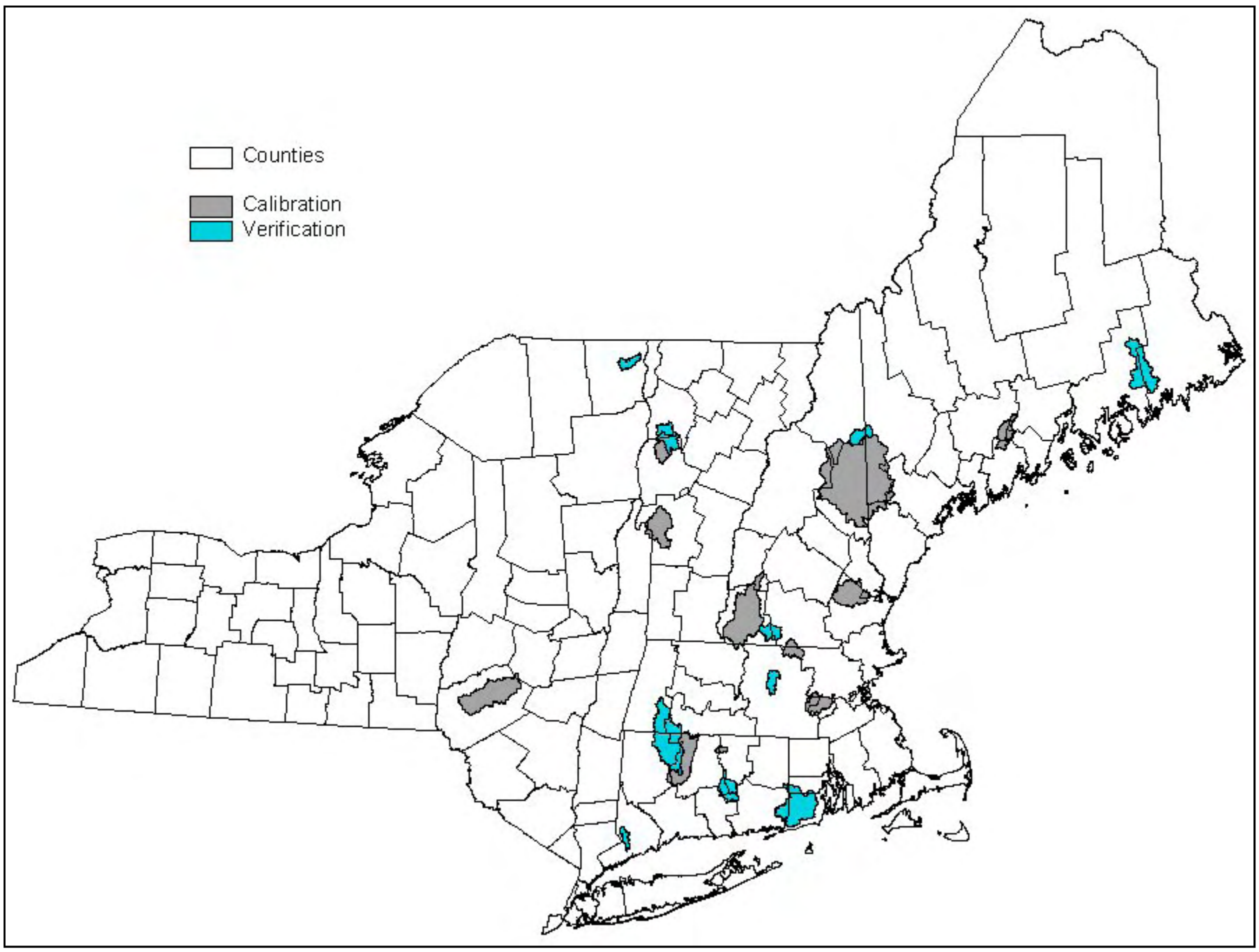
APPENDIX A. AVGWLF MODELING ANALYSIS

Northeast AVGWLF Model

The AVGWLF model was calibrated and validated for the northeast (Evans et al., 2007). AVGWLF requires that calibration watersheds have long-term flow and water quality data. For the northeast model, watershed simulations were performed for twenty-two (22) watersheds throughout New York and New England for the period 1997-2004 (Figure 9). Flow data were obtained directly from the water resource database maintained by the U.S. Geological Survey (USGS). Water quality data were obtained from the New York and New England State agencies. These data sets included in-stream concentrations of nitrogen, phosphorus, and sediment based on periodic sampling.

Figure 9. Location of Calibration and Verification Watersheds for the Northeast AVGWLF Model



Initial model calibration was performed on half of the 22 watersheds for the period 1997-2004. During this step, adjustments were iteratively made in various model parameters until a "best fit" was achieved between simulated and observed stream flow, and sediment and nutrient loads. Based on the calibration results, revisions were made in various AVGWLF routines to alter the manner in which model input parameters were estimated. To check the reliability of these revised routines, follow-up verification runs were made on the remaining eleven watersheds for the same time period. Finally, statistical evaluations of the accuracy of flow and load predictions were made.

To derive historical nutrient loads, standard mass balance techniques were used. First, the in-stream nutrient concentration data and corresponding flow rate data were used to develop load (mass) versus flow relationships for each watershed for the period in which historical water quality data were obtained. Using the daily stream flow data obtained from USGS, daily nutrient loads for the 1997-2004 time period were subsequently computed for each watershed using the appropriate load versus flow relationship (i.e., "rating curves"). Loads computed in this fashion were used as the "observed" loads against which model-simulated loads were compared.

During this process, adjustments were made to various model input parameters for the purpose of obtaining a "best fit" between the observed and simulated data. With respect to stream flow, adjustments were made that increased or decreased the amount of the calculated evapotranspiration and/or "lag time" (i.e., groundwater recession rate) for sub-surface flow. With respect to nutrient loads, changes were made to the estimates for sub-surface nitrogen and phosphorus concentrations. In regard to both sediment and nutrients, adjustments were made to the estimate for the "C" factor for cropland in the USLE equation, as well as to the sediment "a" factor used to calculate sediment loss due to stream bank erosion. Finally, revisions were also made to the default retention coefficients used by AVGWLF for estimating sediment and nutrient retention in lakes and wetlands.

Based upon an evaluation of the changes made to the input files for each of the calibration watersheds, revisions were made to routines within AVGWLF to modify the way in which selected model parameters were automatically estimated. The AVGWLF software application was originally developed for use in Pennsylvania, and based on the calibration results, it appeared that certain routines were calculating values for some model parameters that were either too high or too low. Consequently, it was necessary to make modifications to various algorithms in AVGWLF to better reflect conditions in the Northeast. A summary of the algorithm changes made to AVGWLF is provided below.

- **ET**: A revision was made to increase the amount of evapotranspiration calculated automatically by AVGWLF by a factor of 1.54 (in the "Pennsylvania" version of AVGWLF, the adjustment factor used is 1.16). This has the effect of decreasing simulated stream flow.

- **GWR:** The default value for the groundwater recession rate was changed from 0.1 (as used in Pennsylvania) to 0.03. This has the effect of "flattening" the hydrograph within a given area.

- **GWN:** The algorithm used to estimate "groundwater" (sub-surface) nitrogen concentration was changed to calculate a lower value than provided by the "Pennsylvania" version.

- **Sediment "a" Factor:** The current algorithm was changed to reduce estimated stream bank-derived sediment by a factor of 90%. The streambank routine in AVGWLF was originally developed using Pennsylvania data and was consistently producing sediment estimates that were too high based on the in-stream sample data for the calibration sites in the Northeast. While the exact reason for this is not known, it's likely that the glaciated terrain in the Northeast is less erodible than the highly erodible soils in Pennsylvania. Also, it is likely that the relative abundance of lakes, ponds and wetlands in the Northeast have an effect on flow velocities and sediment transport.

- **Lake/Wetland Retention Coefficients:** The default retention coefficients for sediment, nitrogen and phosphorus are set to 0.90, 0.12 and 0.25, respectively, and changed at the user's discretion.

To assess the correlation between observed and predicted values, two different statistical measures were utilized: 1) the Pearson product-moment correlation (R^2) coefficient and 2) the Nash-Sutcliffe coefficient. The R^2 value is a measure of the degree of linear association between two variables, and represents the amount of variability that is explained by another variable (in this case, the model-simulated values). Depending on the strength of the linear relationship, the R^2 can vary from 0 to 1, with 1 indicating a perfect fit between observed and predicted values. Like the R^2 measure, the Nash-Sutcliffe coefficient is an indicator of "goodness of fit," and has been recommended by the American Society of Civil Engineers for use in hydrological studies (ASCE, 1993). With this coefficient, values equal to 1 indicate a perfect fit between observed and predicted data, and values equal to 0 indicate that the model is predicting no better than using the average of the observed data. Therefore, any positive value above 0 suggests that the model has some utility, with higher values indicating better model performance. In practice, this coefficient tends to be lower than R^2 for the same data being evaluated.

Adjustments were made to the various input parameters for the purpose of obtaining a "best fit" between the observed and simulated data. One of the challenges in calibrating a model is to optimize the results across all model outputs (in the case of AVGWLF, stream flows, as well as sediment, nitrogen, and phosphorus loads). As with any watershed model like GWLF, it is possible to focus on a single output measure (e.g., sediment or nitrogen) in order to improve the fit between observed and simulated loads. Isolating on one model output, however, can sometimes lead to less acceptable results for other measures. Consequently, it is sometimes difficult to achieve very high correlations (e.g., R^2 above 0.90) across all model outputs. Given this limitation, it was felt that very good results were obtained for the calibration sites. In model calibration, initial emphasis is usually placed on getting the hydrology correct. Therefore, adjustments to flow-related model parameters are usually finalized prior to making adjustments to parameters specific to sediment and nutrient production. This typically results in better statistical fits between stream flows than the other model outputs.

For the monthly comparisons, mean R^2 values of 0.80, 0.48, 0.74, and 0.60 were obtained for the calibration watersheds for flow, sediment, nitrogen and phosphorus, respectively. When considering the inherent difficulty in achieving optimal results across all measures as discussed above (along with the potential sources of error), these results are quite good. The sediment load predictions were less satisfactory than those for the other outputs, and this is not entirely unexpected given that this constituent is usually more difficult to simulate than nitrogen or phosphorus. An improvement in sediment prediction could have been achieved by isolating on this particular output during the calibration process; but this would have resulted in poorer performance in estimating the nutrient loads for some of the watersheds. Phosphorus predictions were less accurate than those for nitrogen. This is not unusual given that a significant portion of the phosphorus load for a watershed is highly related to sediment transport processes. Nitrogen, on the other hand, is often linearly correlated to flow, which typically results in accurate predictions of nitrogen loads if stream flows are being accurately simulated.

As expected, the monthly Nash-Sutcliffe coefficients were somewhat lower due to the nature of this particular statistic. As described earlier, this statistic is used to iteratively compare simulated values against the mean of the observed values, and values above zero indicate that the model predictions are better than just using the mean of the observed data. In other words, any value above zero would indicate that the model has some utility beyond using the mean of historical data in estimating the flows or loads for any particular time period. As with R^2 values, higher Nash-Sutcliffe values reflect higher degrees of correlation than lower ones.

Improvements in model accuracy for the calibration sites were typically obtained when comparisons were made on a seasonal basis. This was expected since short-term variations in model output can oftentimes be reduced by accumulating the results over longer time periods. In particular, month-to-month discrepancies due to precipitation events that occur at the end of a month are often resolved by aggregating output in this manner (the same is usually true when going from daily output to weekly or monthly output). Similarly, further improvements were noted when comparisons were made on a mean annual basis. What these particular results imply is that AVGWLF, when calibrated, can provide very good estimates of mean annual sediment and nutrient loads.

Following the completion of the northeast AVGWLF model, there were a number of ideas on ways to improve model accuracy. One of the ideas relates to the basic assumption upon which the work undertaken in that project was based. This assumption is that a "regionalized" model can be developed that works equally well (without the need for resource-intensive calibration) across all watersheds within a large region in terms of producing reasonable estimates of sediment and nutrient loads for different time periods. Similar regional model calibrations were previously accomplished in earlier efforts undertaken in Pennsylvania (Evans et al., 2002) and later in southern Ontario (Watts et al., 2005). In both cases this task was fairly daunting given the size of the areas involved. In the northeast effort, this task was even more challenging given the fact that the geographic area covered by the northeast is about three times the size of Pennsylvania, and arguably is more diverse in terms of its physiographic and ecological composition.

As discussed, AVGWLF performed very well when calibrated for numerous watersheds throughout the region. The regionalized version of AVGWLF, however, performed less well for the verification watersheds for which additional adjustments were not made subsequent to the initial model runs. This decline in model performance may be a result of the regionally-adapted model algorithms not being rigorous enough to simulate spatially-varying landscape processes across such a vast geographic region at a consistently high degree of accuracy. It is likely that un-calibrated model performance can be enhanced by adapting the algorithms to reflect processes in smaller geographic regions such as those depicted in the physiographic province map in Figure 10.

Fine-tuning & Re-Calibrating the Northeast AVGWLF for New York State

For the TMDL development work undertaken in New York, the original northeast AVGWLF model was further refined by The Cadmus Group, Inc. and Dr. Barry Evans to reflect the physiographic regions that exist in New York. Using data from some of the original northeast model calibration and verification sites, as well as data for additional calibration sites in New York, three new versions of AVGWLF were created for use in developing TMDLs in New York State. Information on the fourteen (14) sites is summarized in Table 6. Two models were developed based on the following two physiographic regions: Eastern Great Lakes/Hudson Lowlands area and the Northeastern Highlands area. The model was calibrated for each of these regions to better reflect local conditions, as well as ecological and hydrologic processes. In addition to developing the above mentioned physiographic-based model calibrations, a third model calibration was also developed. This model calibration represents a composite of the two physiographic regions and is suitable for use in other areas of upstate New York.

Figure 10. Location of Physiographic Provinces in New York and New England

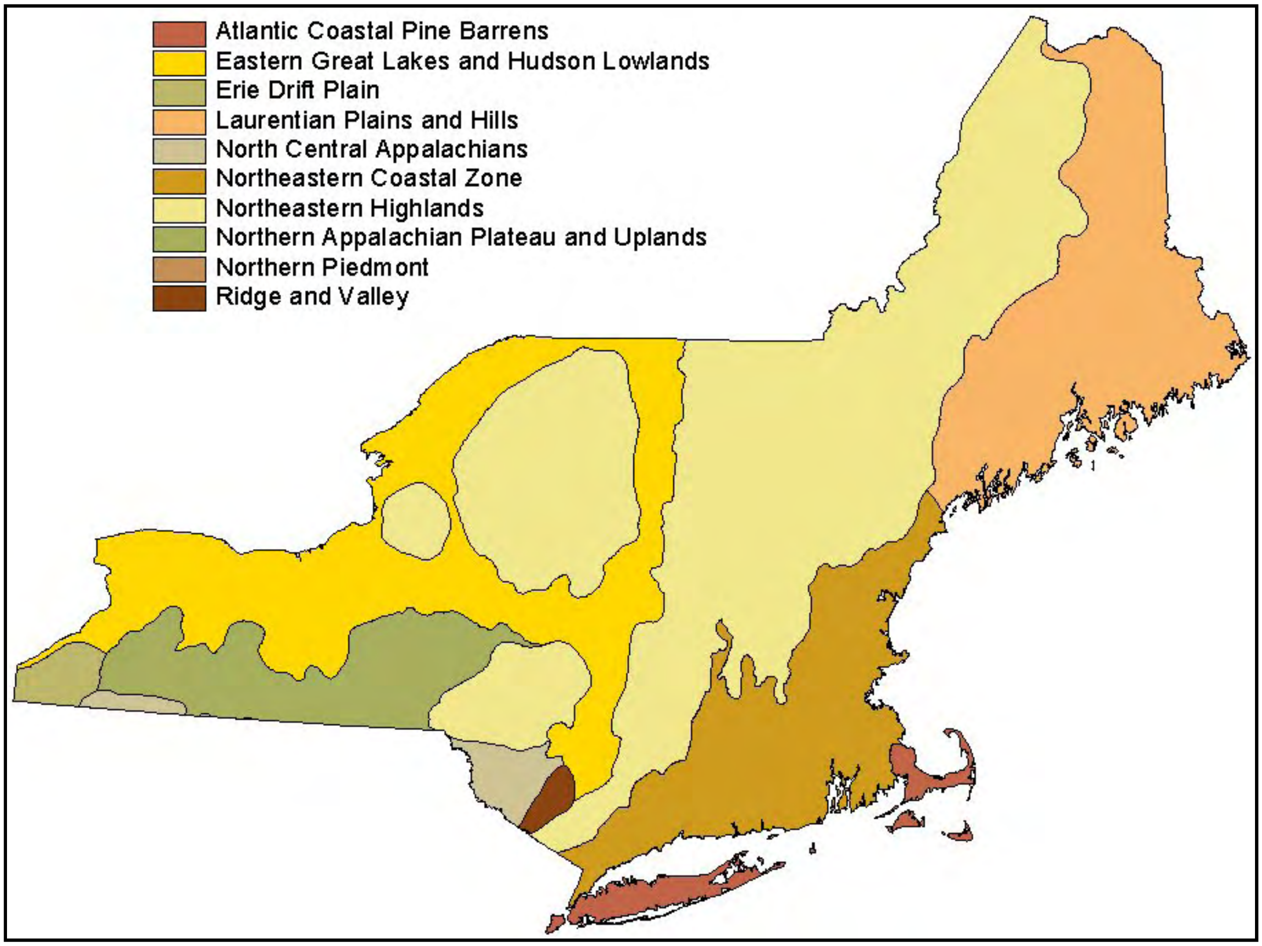


Table 6. AVGWLF Calibration Sites for use in the New York TMDL Assessments

Site	Location	Physiographic Region
Owasco Lake	NY	Eastern Great Lakes/Hudson Lowlands
West Branch	NY	Northeastern Highlands
Little Chazy River	NY	Eastern Great Lakes/Hudson Lowlands
Little Otter Creek	VT	Eastern Great Lakes/Hudson Lowlands
Poultney River	VT/NY	Eastern Great Lakes/Hudson Lowlands & Northeastern Highlands
Farmington River	CT	Northeastern Highlands
Saco River	ME/NH	Northeastern Highlands
Squannacook River	MA	Northeastern Highlands
Ashuelot River	NH	Northeastern Highlands
Laplatte River	VT	Eastern Great Lakes/Hudson Lowlands
Wild River	ME	Northeastern Highlands
Salmon River	CT	Northeastern Coastal Zone
Norwalk River	CT	Northeastern Coastal Zone
Lewis Creek	VT	Eastern Great Lakes/Hudson Lowlands

Set-up of the "New York State" AVGWLF Model

Using data for the time period 1990-2004, the calibrated AVGWLF model was used to estimate mean annual phosphorus loading to the reservoir. Table 7 provides the sources of data used for the AVGWLF modeling analysis. The various data preparation steps taken prior to running the final calibrated AVGWLF Model for New York are discussed below the table.

Table 7. Information Sources for AVGWLF Model Parameterization

WEATHER.DAT file	
Data	**Source or Value**
	Historical weather data from Albany Int. Airport, NY and Cairo, NY National Weather Services Stations
TRANSPORT.DAT file	
Data	**Source or Value**
Basin size	GIS/derived from basin boundaries
Land use/cover distribution	GIS/derived from land use/cover map
Curve numbers by source area	GIS/derived from land cover and soil maps
USLE (KLSCP) factors by source area	GIS/derived from soil, DEM, & land cover
ET cover coefficients	GIS/derived from land cover
Erosivity coefficients	GIS/ derived from physiographic map
Daylight hrs. by month	Computed automatically for state
Growing season months	Input by user
Initial saturated storage	Default value of 10 cm
Initial unsaturated storage	Default value of 0 cm
Recession coefficient	Default value of 0.1
Seepage coefficient	Default value of 0
Initial snow amount (cm water)	Default value of 0
Sediment delivery ratio	GIS/based on basin size
Soil water (available water capacity)	GIS/derived from soil map
NUTRIENT.DAT file	
Data	**Source or Value**
Dissolved N in runoff by land cover type	Default values/adjusted using GWLF Manual
Dissolved P in runoff by land cover type	Default values/adjusted using GWLF Manual
N/P concentrations in manure runoff	Default values/adjusted using AEU density
N/P buildup in urban areas	Default values (from GWLF Manual)
N and P point source loads	Derived from SPDES point coverage
Background N/P concentrations in GW	Derived from new background N map
Background P concentrations in soil	Derived from soil P loading map/adjusted using GWLF Manual
Background N concentrations in soil	Based on map in GWLF Manual
Months of manure spreading	Input by user
Population on septic systems	Derived from census tract maps for 2000 and house counts
Per capita septic system loads (N/P)	Default values/adjusted using AEU density

Land Use

The 2001 NLCD land use coverage was obtained, recoded, and formatted specifically for use in AVGWLF. The New York State High Resolution Digital Orthoimagery (for the time period 2000 – 2004) was used to perform updates and corrections to the 2001 NLCD land use coverage to more accurately reflect current conditions. Each basin was reviewed independently for the potential need for land use corrections; however individual raster errors associated with inherent imperfections in the satellite imagery have a far greater impact on overall basin land use percentages when evaluating smaller scale basins. As a result, for large basins, NLCD 2001 is generally considered adequate, while in smaller basins, errors were more closely assessed and corrected. The following were the most common types of corrections applied generally to smaller basins:

1) Areas of low intensity development that were coded in the 2001 NLCD as other land use types were the most commonly corrected land use data in this analysis. Discretion was used when applying corrections, as some overlap of land use pixels on the reservoir boundary are inevitable due to the inherent variability in the aerial position of the sensor creating the image. If significant new development was apparent (i.e., on the orthoimagery), but was not coded as such in the 2001 NLCD, than these areas were re-coded to low intensity development.

2) Areas of water that were coded as land (and vice-versa) were also corrected. Discretion was used for reservoirs where water level fluctuation could account for errors between orthoimagery and land use.

3) Forested areas that were coded as row crops/pasture areas (and vice-versa) were also corrected. For this correction, 100% error in the pixel must exist (e.g., the supposed forest must be completely pastured to make a change); otherwise, making changes would be too subjective. Conversions between forest types (e.g., conifer to deciduous) are too subjective and therefore not attempted; conversions between row crops and pasture are also too subjective due to the practice of crop rotation. Correction of row crops to hay and pasture based on orthoimagery were therefore not undertaken in this analysis.

Phosphorus retention in wetlands and open waters in the basin can be accounted for in AVGWLF. AVGWLF recommends the following coefficients for wetlands and pond retention in the northeast: nitrogen (0.12), phosphorus (0.25), and sediment (0.90). Wetland retention coefficients for large, naturally occurring wetlands vary greatly in the available literature. Depending on the type, size and quantity of wetland observed, the overall impact of the wetland retention routine on the original watershed loading estimates, and local information regarding the impact of wetlands on watershed loads, wetland retention coefficients defaults were adjusted accordingly. The percentage of the drainage basin area that drains through a wetland area was calculated and used in conjunction with nutrient retention coefficients in AVGWLF. To determine the percent wetland area, the total basin land use area was derived using ArcView. Of this total basin area, the area that drains through emergent and woody wetlands were delineated to yield an estimate of total watershed area draining through wetland areas. If a basin displays large areas of surface water (ponds) aside from the water body being modeled, then this open water area is calculated by subtracting the water body area from the total surface water area.

On-site Wastewater Treatment Systems (“septic tanks”)

GWLF simulates nutrient loads from septic systems as a function of the percentage of the unsewered population served by normally functioning vs. three types of malfunctioning systems: ponded, short-circuited, and direct discharge (Haith et al., 1992).

- **Normal Systems** are septic systems whose construction and operation conforms to recommended procedures, such as those suggested by the EPA design manual for on-site wastewater disposal systems. Effluent from normal systems infiltrates into the soil and enters the shallow saturated zone. Phosphates in the effluent are adsorbed and retained by the soil and hence normal systems provide no phosphorus loads to nearby waters.
- **Short-Circuited Systems** are located close enough to surface water (~15 meters) so that negligible adsorption of phosphorus takes place. The only nutrient removal mechanism is plant uptake. Therefore, these systems are always contributing to nearby waters.
- **Ponded Systems** exhibit hydraulic malfunctioning of the tank’s absorption field and resulting surfacing of the effluent. Unless the surfaced effluent freezes, ponding systems deliver their nutrient loads to surface waters in the same month that they are generated through overland flow. If the temperature is below freezing, the surfacing is assumed to freeze in a thin layer at the ground surface. The accumulated frozen effluent melts when the snowpack disappears and the temperature is above freezing.
- **Direct Discharge Systems** illegally discharge septic tank effluent directly into surface waters.

GWLF requires an estimation of population served by septic systems to generate septic system phosphorus loadings. In reviewing the orthoimagery for the reservoir, it became apparent that septic system estimates from the 1990 census were not reflective of actual population in close proximity to the shore. Shoreline dwellings immediately surrounding the reservoir account for a substantial portion of the nutrient loading to the reservoir. Therefore, the estimated number of septic systems in the drainage basin was refined using a combination of 1990 and 2000 census data and GIS analysis of orthoimagery to account for the proximity of septic systems immediately surrounding the reservoir. If available, local information about the number of houses within 250 feet of the reservoirs was obtained and applied. Great attention was given to estimating septic systems within 250 feet of the reservoir (those most likely to have an impact on the reservoir). 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.

GWLF also requires an estimate of the number of normal and malfunctioning septic systems. This information was not readily available for the reservoir. Therefore, several assumptions were made to categorize the systems according to their performance. These assumptions are based on data from local and national studies (Day, 2001; USEPA, 2002) in combination with best professional judgment. To account for seasonal variations in population, data from the 2000 census were used to estimate the percentage of seasonal homes for the town(s) surrounding the reservoir. The failure rate for septic systems closer to the reservoir (i.e., within 250 feet) were adjusted to account for increased loads due to greater occupancy during the summer months. If available, local information about seasonal occupancy was obtained and applied. For the purposes of this analysis, seasonal homes are considered those occupied only during the month of June, July, and August.

Groundwater Phosphorus

Phosphorus concentrations in groundwater discharge are derived by AVGWLF. Watersheds with a high percentage of forested land will have low groundwater phosphorus concentrations while watersheds with a high percentage of agricultural land will have high concentrations. The GWLF manual provides estimated groundwater phosphorus concentrations according to land use for the eastern United States. Completely forested watersheds have values of 0.006 mg/L. Primarily agricultural watersheds have values of 0.104 mg/L. Intermediate values are also reported. The AVGWLF-generated groundwater phosphorus concentration was evaluated to ensure groundwater phosphorus values reasonably reflect the actual land use composition of the drainage basin and modifications were made if deemed unnecessary.

Point Sources

If permitted point sources exist in the drainage basin, their location was identified and verified by NYS DEC and an estimated monthly total phosphorus load and flow was determined using either actual reported data (e.g., from discharge monitoring reports) or estimated based on expected discharge/flow for the facility type.

Concentrated Animal Feeding Operations (CAFOs)

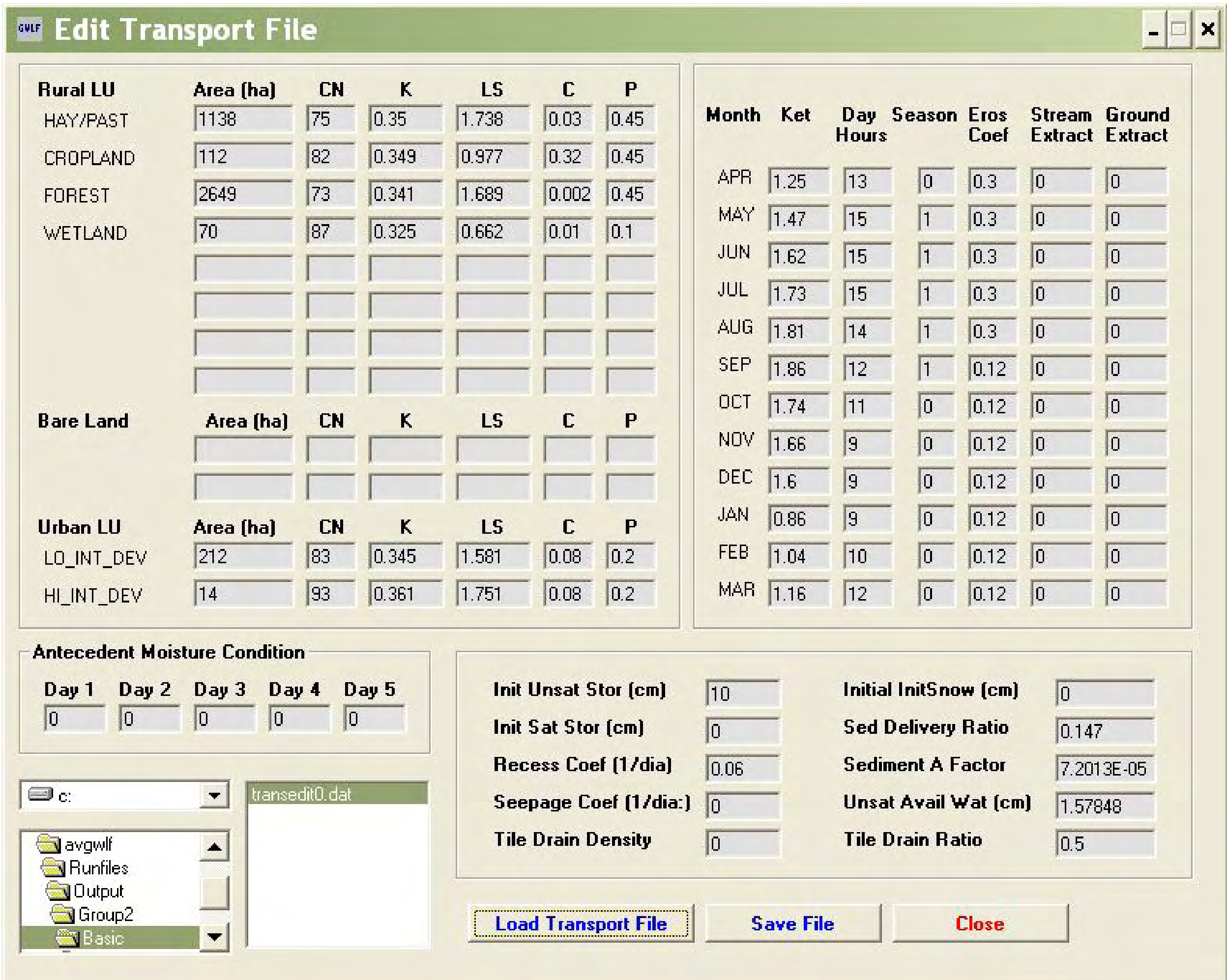
A state-wide Concentrated Animal Feeding Operation (CAFO) shapefile was provided by NYS DEC. CAFOs are categorized as either large or medium. The CAFO point can represent either the centroid of the farm or the entrance of the farm, therefore the CAFO point is more of a general gauge as to where further information should be obtained regarding permitted information for the CAFO. If a CAFO point is located in or around a basin, orthos and permit data were evaluated to determine the part of the farm with the highest potential contribution of nutrient load. In ArcView, the CAFO shapefile was positioned over the basin and clipped with a 2.5 mile buffer to preserve those CAFOS that may have associated cropland in the basin. If a CAFO point is found to be located within the boundaries of the drainage basin, every effort was made to obtain permit information regarding nutrient management or other best management practices (BMPs) that may be in place within the property boundary of a given CAFO. These data can be used to update the nutrient file in AVGWLF and ultimately account for agricultural BMPs that may currently be in place in the drainage basin.

Municipal Separate Storm Sewer Systems (MS4s)

Stormwater runoff within Phase II permitted Municipal Separate Storm Sewer Systems (MS4s) is considered a point source of pollutants. Stormwater runoff outside of the MS4 is non-permitted stormwater runoff and, therefore, considered nonpoint sources of pollutants. Permitted stormwater runoff is accounted for in the wasteload allocation of a TMDL, while non-permitted runoff is accounted for in the load allocation of a TMDL.

AVGWLF Model Simulation Results

Input Transport File



Edit Transport File

Rural LU	Area (ha)	CN	K	LS	C	P
HAY/PAST	1138	75	0.35	1.738	0.03	0.45
CROPLAND	112	82	0.349	0.977	0.32	0.45
FOREST	2649	73	0.341	1.689	0.002	0.45
WETLAND	70	87	0.325	0.662	0.01	0.1

Bare Land	Area (ha)	CN	K	LS	C	P

Urban LU	Area (ha)	CN	K	LS	C	P
LO_INT_DEV	212	83	0.345	1.581	0.08	0.2
HI_INT_DEV	14	93	0.361	1.751	0.08	0.2

Month	Ket	Day Hours	Season	Eros Coef	Stream Extract	Ground Extract
APR	1.25	13	0	0.3	0	0
MAY	1.47	15	1	0.3	0	0
JUN	1.62	15	1	0.3	0	0
JUL	1.73	15	1	0.3	0	0
AUG	1.81	14	1	0.3	0	0
SEP	1.86	12	1	0.12	0	0
OCT	1.74	11	0	0.12	0	0
NOV	1.66	9	0	0.12	0	0
DEC	1.6	9	0	0.12	0	0
JAN	0.86	9	0	0.12	0	0
FEB	1.04	10	0	0.12	0	0
MAR	1.16	12	0	0.12	0	0

Antecedent Moisture Condition

Day 1	Day 2	Day 3	Day 4	Day 5
0	0	0	0	0

Init Unsat Stor (cm)	10	Initial InitSnow (cm)	0
Init Sat Stor (cm)	0	Sed Delivery Ratio	0.147
Recess Coef (1/dia)	0.06	Sediment A Factor	7.2013E-05
Seepage Coef (1/dia:)	0	Unsat Avail Wat (cm)	1.57848
Tile Drain Density	0	Tile Drain Ratio	0.5

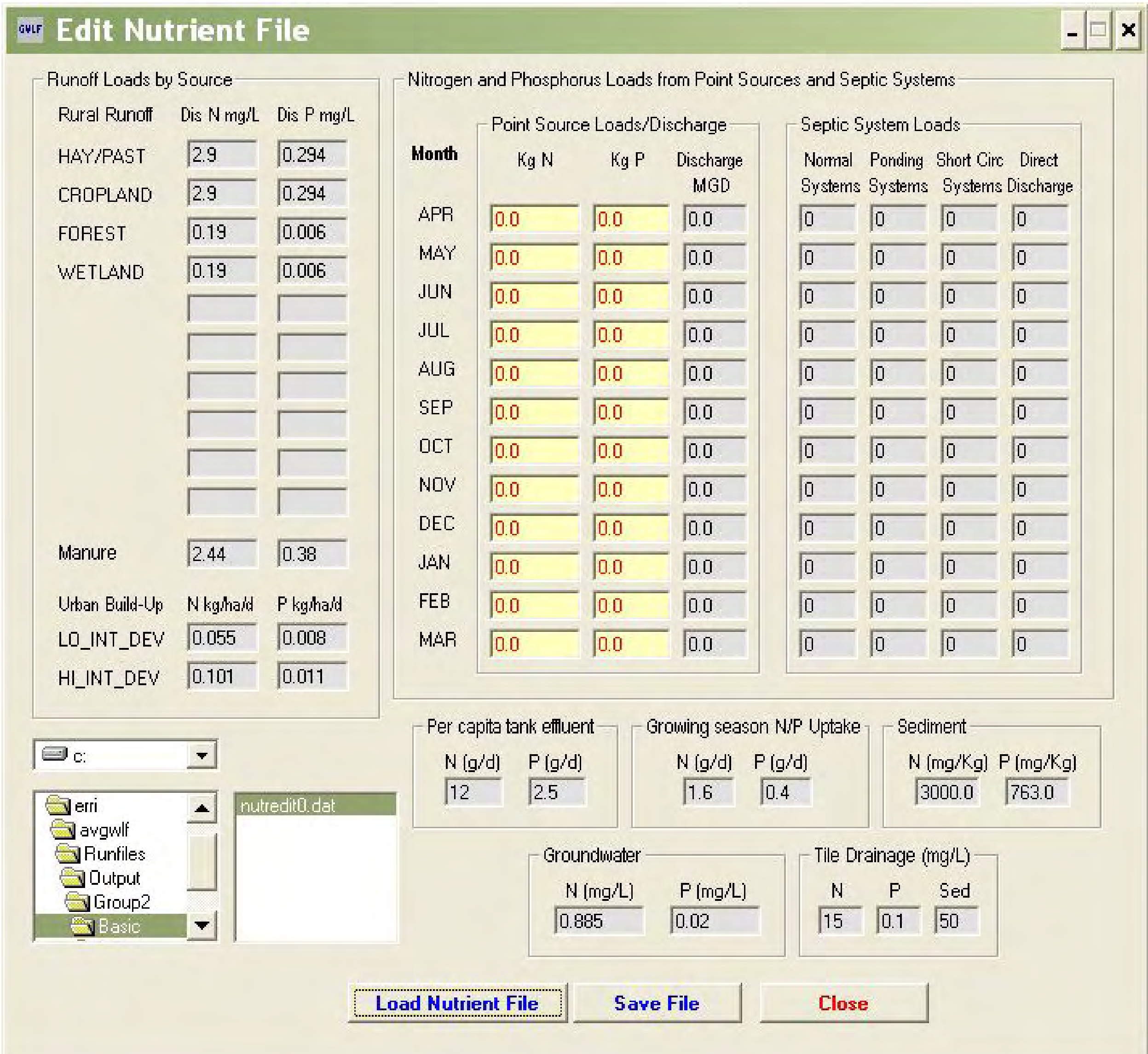
c:

avgwlf
Runfiles
Output
Group2
Basic

transedit0.dat

Load Transport File | Save File | Close

Input Nutrient File



APPENDIX B. BATHTUB MODELING ANALYSIS

Model Overview

BATHTUB is a steady-state (Windows-based) water quality model developed by the U. S. Army Corps of Engineers (USACOE) Waterways Experimental Station. BATHTUB performs steady-state water and nutrient balance calculations for spatially segmented hydraulic networks in order to simulate eutrophication-related water quality conditions in lakes and reservoirs. BATHTUB's nutrient balance procedure assumes that the net accumulation of nutrients in a reservoir is the difference between nutrient loadings into the reservoir (from various sources) and the nutrients carried out through outflow and the losses of nutrients through whatever decay process occurs inside the reservoir. The net accumulation (of phosphorus) in the reservoir is calculated using the following equation:

Net accumulation = Inflow – Outflow – Decay

The pollutant dynamics in the reservoir are assumed to be at a steady state, therefore, the net accumulation of phosphorus in the reservoir equals zero. BATHTUB accounts for advective and diffusive transport, as well as nutrient sedimentation. BATHTUB predicts eutrophication-related water quality conditions (total phosphorus, total nitrogen, chlorophyll-a, transparency, and hypolimnetic oxygen depletion) using empirical relationships derived from assessments of reservoir data. Applications of BATHTUB are limited to steady-state evaluations of relations between nutrient loading, transparency and hydrology, and eutrophication responses. Short-term responses and effects related to structural modifications or responses to variables other than nutrients cannot be explicitly evaluated.

Input data requirements for BATHTUB include: physical characteristics of the watershed reservoir morphology (e.g., surface area, mean depth, length, mixed layer depth), flow and nutrient loading from various pollutant sources, precipitation (from nearby weather station) and phosphorus concentrations in precipitation (measured or estimated), and measured reservoir water quality data (e.g., total phosphorus concentrations).

The empirical models implemented in BATHTUB are mathematical generalizations about reservoir behavior. When applied to data from a particular reservoir, actual observed reservoir water quality data may differ from BATHTUB predictions by a factor of two or more. Such differences reflect data limitations (measurement or estimation errors in the average inflow and outflow concentrations) or the unique features of a particular reservoir (no two reservoirs are the same). BATHTUB's "calibration factor" provides model users with a method to calibrate the magnitude of predicted reservoir response. The model calibrated to current conditions (against measured data from the reservoirs) can be applied to predict changes in reservoir conditions likely to result from specific management scenarios, under the condition that the calibration factor remains constant for all prediction scenarios.

Model Set-up

Using descriptive information about Basic Creek Reservoir and its surrounding drainage area, as well as output from AVGWLF, a BATHTUB model was set up for Basic Creek Reservoir. Mean annual phosphorus loading to the reservoir was simulated using AVGWLF for the period 1990-2004.

BATHTUB was the used to derive the total phosphorus load reduction needed in order to achieve the TMDL target.

Sources of input data for BATHTUB include:

- Physical characteristics of the watershed and reservoir morphology (e.g., surface area, mean depth, length, mixed layer depth) - Obtained from bathymetric maps provided by NYS DEC or created by the Cadmus Group, Inc.
- Flow and nutrient loading from various pollutant sources - Obtained from AVGWLF output.
- Precipitation – Obtained from nearby National Weather Services Stations.
- Phosphorus concentrations in precipitation (measured or estimated) – Obtained from NYS DEC.

Tables 8 – 11 summarize the primary model inputs for Basic Creek Reservoir, including the coefficient of variation (CV), which reflects uncertainty in the input value. Default model choices are utilized unless otherwise noted. Spatial variations (i.e., longitudinal dispersion) in phosphorus concentrations are not a factor in the development of the TMDL for Basic Creek Reservoir. Therefore, division of the reservoir into multiple segments was not necessary for this modeling effort. Modeling the entire reservoir with one segment provides predictions of area-weighted mean concentrations, which are adequate to support management decisions. Water inflow and nutrient loads from the reservoir's drainage basin were treated as though they originated from one "tributary" (i.e., source) in BATHTUB and derived from AVGWLF.

BATHTUB is a steady state model, whose predictions represent concentrations averaged over a period of time. A key decision in the application of BATHTUB is the selection of the length of time over which water and mass balance calculations are modeled (the "averaging period"). The length of the appropriate averaging period for BATHTUB application depends upon what is called the nutrient residence time, which is the average length of time that phosphorus spends in the water column before settling or flushing out of the reservoir. Guidance for BATHTUB recommends that the averaging period used for the analysis be at least twice as large as nutrient residence time for the reservoir. The appropriate averaging period for water and mass balance calculations would be 1 year for reservoirs with relatively long nutrient residence times or seasonal (6 months) for reservoirs with relatively short nutrient residence times (e.g., on the order of 1 to 3 months). The turnover ratio can be used as a guide for selecting the appropriate averaging period. A seasonal averaging period (April/May through September) is usually appropriate if it results in a turnover ratio exceeding 2.0. An annual averaging period may be used otherwise. Other considerations (such as comparisons of observed and predicted nutrient levels) can also be used as a basis for selecting an appropriate averaging period, particularly if the turnover ratio is near 2.0.

Precipitation inputs were taken from the observed long term mean daily total precipitation values from the Albany Int. Airport, NY and Cairo, NY National Weather Services Stations for the 1990-2004 period. Evapotranspiration was derived from AVGWLF using daily weather data (1990-2004) and a cover factor dependent upon land use/cover type. The values selected for precipitation and change in reservoir storage have very little influence on model predictions. Atmospheric phosphorus loads were specified using data collected by NYS DEC from the Cedar Lane Atmospheric Deposition Station located in Lake George Village, in Warren County. Atmospheric deposition is not a major source of phosphorus loading to Basic Creek Reservoir and has little impact on simulations.

Reservoir surface area, mean depth, and length were derived using GIS analysis of bathymetric data. Depth of the mixed layer was estimated using a multivariate regression equation developed by Walker (1999). The concentration of phosphorus loading to the reservoir was calculated using the average annual flow and phosphorus loads simulated by AVGWLF. To obtain flow in units of volume per time, the depth of flow was multiplied by the drainage area and divided by one year. To obtain phosphorus concentrations, the nutrient mass was divided by the volume of flow.

Internal loading rates reflect nutrient recycling from bottom sediments. Internal loading rates are normally set to zero in BATHTUB since the pre-calibrated nutrient retention models already account for nutrient recycling that would normally occur (Walker, 1999). Walker warns that nonzero values should be specified with caution and only if independent estimates or measurements are available. In some studies, internal loading rates have been estimated from measured phosphorus accumulation in the hypolimnion during the stratified period. Results from this procedure should not be used for estimation of internal loading in BATHTUB unless there is evidence the accumulated phosphorus is transported to the mixed layer during the growing season. Specification of a fixed internal loading rate may be unrealistic for evaluating response to changes in external load. Because they reflect recycling of phosphorus that originally entered the reservoir from the watershed, internal loading rates would be expected to vary with external load. In situations where monitoring data indicate relatively high internal recycling rates to the mixed layer during the growing season, a preferred approach would generally be to calibrate the phosphorus sedimentation rate (i.e., specify calibration factors < 1). However, there still remains some risk that apparent internal loads actually reflect under-estimation of external loads.

Table 8. BATHTUB Model Input Variables: Model Selections

Water Quality Indicator	Option	Description
Total Phosphorus	01	2^{nd} Order Available Phosphorus*
Phosphorus Calibration	01	Decay Rate*
Error Analysis	01	Model and Data*
Availability Factors	00	Ignore*
Mass Balance Tables	01	Use Estimated Concentrations*

* Default model choice

Table 9. BATHTUB Model Input: Global Variables

Model Input	Mean	CV
Averaging Period (years)	1	NA
Precipitation (meters)	1.016	0.2*
Evaporation (meters)	0.501	0.3*
Atmospheric Load (mg/m^2-yr)- Total P	4.829	0.5*
Atmospheric Load (mg/m^2-yr)- Ortho P	2.907	0.5*

* Default model choice

Table 10. BATHTUB Model Input: Reservoir Variables

Morphometry	Mean	CV
Surface Area (km^2)	0.96	NA
Mean Depth (m)	2.599	NA
Length (km)	1.475	NA
Estimated Mixed Depth (m)	2.6	0.12
Observed Water Quality	**Mean**	**CV**
Total Phosphorus (ppb)	NA	0.5

* Default model choice

Table 11. BATHTUB Model Input: Watershed "Tributary" Loading

Monitored Inputs	Mean	CV
Total Watershed Area (km^2)	41.95	NA
Flow Rate (hm^3/yr)	21.78	0.1
Total P (ppb)	43.35	0.2
Organic P (ppb)	27.60	0.2

APPENDIX C. TOTAL EQUIVALENT DAILY PHOSPHORUS LOAD ALLOCATIONS

Source	Total Phosphorus Load (lbs/d)			% Reduction
	Current	Allocated	Reduction	
Agriculture*	**4.15**	**1.59**	**2.55**	**62%**
Developed Land*	**0.814**	**0.65**	**0.17**	**20%**
Forest, Wetland, Stream Bank, and Natural Background*	**0.743**	**0.743**	**0.0**	**0%**
LOAD ALLOCATION	**5.70**	**2.98**	**2.72**	**48%**
Point Sources	0.0	0.0	0.0	0%
WASTELOAD ALLOCATION	**0.0**	**0.0**	**0.0**	**0%**
LA + WLA	**5.70**	**2.98**	**2.72**	**48%**
Margin of Safety	---	0.331	---	---
TOTAL	**5.70**	**3.31**	**---**	**---**

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