B. Everett Jordan Reservoir, North Carolina Phase I Total Maximum Daily Load

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Cape Fear River Basin

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Executive summary

The B. Everett Jordan Reservoir (Jordan Reservoir) Total Maximum Daily Load was developed to satisfy state Nutrient Sensitive Water (NSW) requirements and a federally-mandated TMDL. Both the NSW and TMDL programs include the development of a calibrated nutrient response model to support a management strategy to control nutrients and meet the state chlorophyll *a* standard.

Jordan Reservoir is a multi-use impoundment operated by the U.S. Army Corps of Engineers. The reservoir was formed with the construction of a dam on the Haw River in the Cape Fear River Basin. The lake covers an area of 13,940 acres at elevation 216 feet msl, the normal operating level. The lake is operated for flood control, water quality (low flow augmentation), fish and wildlife conservation, recreation, and water supply. Jordan Reservoir consists of two distinct arms - the Haw River and New Hope Creek arms. The Haw River Arm of the lake has an average hydraulic retention time of five days and accounts for 70 to 90 percent of the annual flow through Jordan Reservoir. The New Hope Creek Arm of the lake has an average hydraulic retention time of 418 days. The Jordan Reservoir watershed encompasses 1,686 square miles and includes parts of Alamance, Caswell, Chatham, Durham, Forsyth, Guilford, Orange, Randolph, Rockingham, and Wake counties. It includes all or portions of the urban areas of Durham, Chapel Hill, Cary, Burlington, Greensboro, and several other small municipalities.

The Clean Water Responsibility Act of 1997 (often referred to as House Bill 515) included legislation to further address water quality problems in NSW waters (NC General Statute 143-215.1(c1) to (c5)). The act set total nitrogen (TN) and total phosphorus (TP) NPDES permit limits for facilities discharging greater than 0.5 MGD into the Jordan Reservoir/Haw River watershed. A 5-year compliance period for limits of 5.5 mg/L of TN and 2.0 mg/L of TP was established for qualifying wastewater facilities. The act also established that a calibrated nutrient response model may be developed by DWQ in conjunction with affected parties, and the model may indicate the required TN and TP concentration limits for dischargers greater than 0.5 MGD are different from those listed above. In 1998, Senate Bill 1366 allowed the Environmental Management Commission (EMC) to extend the compliance deadline for these dischargers if additional time was needed to develop a calibrated nutrient response model. The municipalities of Greensboro, Mebane, Reidsville, Graham, Pittsboro, and Burlington, and the Orange Water and Sewer Authority (OWASA) were granted a compliance extension in 1999. Facilities that did not seek compliance extensions were the City of Durham/Durham South WWTP and the Durham County/ Triangle WWTP. Conditions associated with the extended compliance period were achieved and the calibrated nutrient response model was accepted by the Water Quality Committee (WQC) of the EMC in July 2002.

The nutrient response model predicted a high frequency of violations of the chlorophyll *a* standard in the management area representing the Upper New Hope Arm of Jordan Reservoir. This management area corresponds to that portion of the lake upstream of SR 1008. As a result of this model prediction, the Upper New Hope Arm of Jordan Reservoir was placed on the 2002 303(d) List of impaired waters. The Lower New Hope Arm and the Haw River Arm were later placed on the 303(d) List of impaired waters in 2006 for chlorophyll *a* impairment. The Clean Water Act (CWA) requires that a Total Maximum Daily Load (TMDL) be developed for each of the waters appearing on the 303(d) list. The objective of a TMDL is to estimate the allowable pollutant loads

and allocate the loads to known sources so that the waterbody may be restored to its intended uses. All TMDLs must be approved by the US Environmental Protection Agency (EPA). This document represents Phase I of the Jordan Reservoir TMDL. The Haw River arm of the reservoir was listed as impaired for elevated pH on the 2006 303(d) list of impaired waters. Phase II of this TMDL will address the pH impairment of the Haw River arm. Like chlorophyll *a*, elevated pH is a symptom of excessive nutrient loading to the lake.

Jordan Reservoir has historically been one of the most eutrophic reservoirs in North Carolina. Excursions of the state water quality standard for chlorophyll *a* have been noted frequently, especially in the Upper New Hope Arm. Nutrients from a variety of point and nonpoint sources reach Jordan Reservoir. Point sources as a whole contributed an average of 1.5 million pounds of nitrogen and 140 thousand pounds of phosphorus to the reservoir each year. Nonpoint sources contributed an average of 2.5 million pounds of nitrogen and 350 thousand pounds of phosphorus per year.

Through the combined efforts of the facilities that were granted the compliance extension and the Division of Water Quality, multiple modeling tools were developed to evaluate conditions in the reservoir and potential management strategies for the reservoir. This includes the development of a calibrated hydrodynamic and nutrient response model for the years 1997 through 2001, an effluent nutrient delivery model, a nutrient fate and transport model, and a watershed loading model. The management strategies were determined through multiple runs of the nutrient response model with a variety of reduction strategies for both total nitrogen and total phosphorus. For each run of the nutrient response model, the frequency of violation of the chlorophyll *a* standard was evaluated for the entire modeled period (1997 - 2001) and for critical conditions during the summer months. Critical conditions were defined as May through September based on the model results and the measured data. The two distinct arms of the lake, the Haw River and New Hope Creek arms, were each evaluated separately. Further, the New Hope Creek arm was separated into the Upper New Hope Arm and the Lower New Hope Arm. The split between these two areas is SR 1008. Reduction targets were evaluated in terms of nitrogen and phosphorus loads. Multiple combinations of nitrogen and phosphorus loading scenarios that resulted in an 8% standard violation frequency were considered. Ultimately, three different targets were selected for Jordan Reservoir corresponding to the different areas of the reservoir.

Nutrient load reduction targets from 1997-2001 baseline		
Area	Total nitrogen (TN) percent reduction	Total phosphorus (TP) percent reduction
Upper New Hope Arm (above SR1008)	35%	5%
Lower New Hope Arm (from SR1008 to the narrows)	N/A (a)	N/A (a)
Haw River Arm	8%	5%
(a) Provides a loading cap equal to 1997-2001 baseline nutrient loads.		

Both point and nonpoint sources bear an equal burden for nutrient reductions. For example, point sources in the Upper New Hope Arm of Jordan Reservoir must reduce nitrogen loads by 35% and nonpoint sources in the Upper New Hope Arm of Jordan Reservoir must reduce nitrogen loads by

35%. In this manner, the burden for reductions resulting from the nutrient management strategy is equally borne by point and nonpoint sources.

Point Source Strategy.
Upper New Hope Arm of Jordan Reservoir. All of the available loading was allocated to the existing facilities. Therefore, there will be no new nitrogen or phosphorus bearing loads permitted in this watershed. There are four facilities discharging greater than 100,000 gallons per day in the watershed of the Upper New Hope Arm. These facilities account for 99.7% of the total permitted flow from point sources. The discharge allocations for these four facilities provide equivalent concentrations for each facility. For nitrogen, this equivalent concentration is 3.04 mg/L, and for phosphorus this equivalent is 0.23 mg/L.

Haw River Arm of Jordan Reservoir. All of the available loading was allocated to the existing facilities. Therefore, there will be no new nitrogen or phosphorus bearing loads permitted in this watershed. There are ten facilities discharging greater than 100,000 gallons per day in watershed of the Haw River Arm. These facilities account for 99.3% of the total permitted flow from point sources. The discharge allocations for these ten facilities provide equivalent treatment levels for each facility. For nitrogen, this equivalent treatment level is 5.3 mg/L, and for phosphorus this equivalent is 0.67 mg/L

Nonpoint Source Strategy
The NPS management strategy proposed by DWQ staff builds on concepts implemented in the Neuse and Tar-Pamlico River Basins. All of the following elements would apply in the subwatersheds of both the Upper New Hope and Haw River arms, while only the riparian buffer protection and new development controls - would apply in the Lower New Hope subwatershed. The proposed strategy would require that:

- All agricultural operations would collectively meet N and P export performance goals as implemented by local committees (EMC has no regulatory authority over this management area);
- Stormwater:
    - New development in unincorporated areas of all counties except Caswell and Rockingham are subject to the post-construction stormwater measure of the NPDES Phase II requirements and are permitted by DWQ beginning July 1, 2007
    - Seventeen of the twenty six municipalities in the watershed were issued permits by December 2005 to implement all six measures of the Phase II requirements, either alone or as part of another MS4's permit, and were required to begin implementing post-construction permitting under those permits by December 2007
    - All local governments would achieve stormwater N and P export performance goals from all new and existing development;
- DWQ would require local governments to protect riparian buffers;
- Persons who apply fertilizers to lands in the subwatershed would complete nutrient management training and a written plan for those lands. A tax on fertilizer would fund the implementation of this rule;
- DWQ would work with DEH to develop programs to reduce N and P loading from on-site wastewater (the EMC has no control over this management area);
- DWQ would refine existing wastewater land application permitting programs as needed;

- DWQ would establish a trading program between point and nonpoint sources and among nonpoint sources; and
- Local governments and agricultural committees would provide annual reports to the EMC. The EMC would reexamine the management strategy every five years.

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1 Introduction

This Total Maximum Daily Load (TMDL) was prepared by the NC Division of Water Quality to evaluate the protection and maintenance of the chlorophyll *a* standard within B. Everett Jordan Reservoir. This reservoir nutrient management strategy is unusual in that both a state-mandated nutrient management strategy and a federally-mandated TMDL were needed for the same waterbody. Although both programs have similar goals, the methodology for reaching those goals can be dissimilar. The strategy described herein was developed to meet the goals and methodology of both programs in order to provide non-conflicting recommendations for controlling nutrient-related issues.

The results of this strategy represent many years of work and collaboration between many parties. The first Request for Proposals for nutrient modeling and evaluation was issued in 1999 and technical work continued throughout 2004. Specifics of the NSW process are provided below in Section 2. Subsequent placement of the Upper New Hope Arm of B. Everett Jordan Reservoir on the North Carolina 2002 303(d) List and the Lower New Hope and Haw River Arms on the 2006 303(d) list required a TMDL to be developed for the lake. The NSW process, which preceded the TMDL process by several years, is described in Section 2. The TMDL process is described in Section 3.

This is a phased TMDL in that some of the wasteload allocations proposed in this document (i.e. phosphorus) will be implemented in the next permit cycle for facilities discharging in the Jordan reservoir. Wasteload allocations for nitrogen will be implemented in a second phase of the TMDL. Load allocations for nonpoint sources will be implemented as dictated by rules developed in the nutrient management strategy.

The Jordan Lake (Reservoir) Stakeholder Process began in 2003 in order to engage interested stakeholders in the development of a nutrient management strategy that could be presented to the North Carolina Environmental Management Commission. Through this process, approximately 113 stakeholder organizations, including the Division of Water Quality, developed recommendations for the nutrient management strategy and TMDL. A complete description of the meetings, discussion topics, and recommendations can be found at http://www.tjcog.dst.nc.us/jorlak/jlsp.htm.

All documentation supporting this nutrient management strategy can be found on the worldwide web at the following addresses:

- Triangle J Council of Governments, Jordan Lake Stakeholder Project
  - http://www.tjcog.dst.nc.us/jorlak/jlsp.htm
- Triangle J. Council of Governments, Jordan Lake Nutrient Response Modeling Project
  - http://www.tjcog.dst.nc.us/jorlak/index.htm
- NC Division of Water Quality, Special Studies, Jordan Lake
  - http://h2o.enr.state.nc.us/tmdl/SpecialStudies.htm#Jordan

2 Nutrient Sensitive Waters Management

In 1983, all waters in the Haw River watershed (subbasins 030601 to 030606), including B. Everett Jordan Reservoir (Jordan Reservoir) received a supplemental classification of nutrient sensitive water (NSW). This supplemental classification acknowledges that Jordan Reservoir could have water quality problems associated with excessive nutrient inputs from both wastewater discharges and runoff from the various land uses in the watershed. The supplemental classification requires that a NSW strategy be created and implemented to protect the reservoir from water quality problems associated with nutrient enrichment. As a result, total phosphorus (TP) limits of 2.0 mg/L were required for NPDES permitted wastewater facilities with permitted flows greater than 0.005 MGD. Due to special concerns in the Upper New Hope Arm of the reservoir, NPDES permitted wastewater facilities received TP limits of 0.5 mg/L during the months from April to October. However, nuisance algal blooms and chlorophyll *a* levels exceeding water quality standards continue to be observed.

The Clean Water Responsibility Act of 1997 (CWRA, often referred to as House Bill 515) included legislation to further address water quality problems in NSW waters (NC General Statute 143-215.1(c1) to (c5)). The act set total nitrogen (TN) and total phosphorus (TP) NPDES permit limits for facilities discharging greater than 0.5 MGD into the Jordan Reservoir/Haw River watershed. A 5-year compliance period for limits of 5.5 mg/L of TN and 2.0 mg/L of TP was established for qualifying wastewater facilities. The act also established that a calibrated nutrient response model may be developed by DWQ in conjunction with affected parties, and the model may indicate the required TN and TP concentration limits for dischargers greater than 0.5 MGD are different from those listed above. Amendments to the act approved in 1998 (referred to as Senate Bill 1366) provided a compliance extension to the nutrient limits, with conditions. Those wastewater facilities granted a compliance extension by the Environmental Management Commission were required to develop a calibrated nutrient response model, evaluate and optimize the operation of all facilities to reduce nutrient loading, and evaluate methods to reduce nutrient mass loading to NSW waters. The municipalities of Greensboro, Mebane, Reidsville, Graham, Pittsboro, and Burlington, and the Orange Water and Sewer Authority (OWASA) were granted the compliance extension by the Environmental Management Commission in April 1999. This collective group is referred to as the Project Partners in subsequent chapters. Facilities that did not seek compliance extensions are the City of Durham/ Durham South WWTP and Durham County/ Triangle WWTP.

The CWRA provided a timeline for progress towards a site-specific nutrient management strategy should facilities and/or municipalities choose to seek the compliance extension. This established timeline is as follows:

- Two years for the collection of data needed to prepare a calibrated nutrient response model;
- A maximum of one year to prepare the calibrated nutrient response model;
- The amount of time, if any, that is required for the Commission to develop a nutrient management strategy and to adopt rules or to modify discharge permits to establish maximum mass loads or concentration limits based on the calibrated nutrient response model; and
- A maximum of three years to plan, design, finance, and construct a facility that will comply with those maximum mass loads and concentration limits.

If the Commission finds that additional time is needed to complete the construction of a facility, the Commission may further extend the compliance date by a maximum of two additional years.

Each municipality developed optimization plans and submitted summaries at the July 2000 Water Quality Committee meeting. Plans for the nutrient response model development began in 1999 when the Project Partners, through the local councils of governments, released a request for proposals for both a data review document and nutrient response model development. Screening level and detailed nutrient response models, and an effluent nutrient delivery model, were developed by consultants, Tetra Tech, Inc. and subcontractors. The total cost to the project partners for the development of the data review document and the models was $370,000. The combined hydrodynamic and water quality model was approved by the Water Quality Committee in July 2002.

The Upper New Hope Arm of B. Everett Jordan Reservoir was placed on the 2002 303(d) list of impaired waters based on results of the nutrient response model and the approval of the model by the Water Quality Committee. The listing of the Upper New Hope Arm is consistent with EPA rules that allow water quality models to be utilized as a basis for 303(d) listing. The Lower New Hope Arm and Haw River Arms were listed on the 2006 303(d) list. The 303(d) listing of the reservoir resulted in the need for a TMDL for the lake. Thus, the Jordan Reservoir nutrient management strategy was developed in order to meet requirements of both the Clean Water Responsibility Act and the federal rules and guidance regarding TMDLs.

3 TMDL Process

The B. Everett Jordan Reservoir (Jordan Reservoir) is currently on the 303(d) list of impaired waters in North Carolina (NC). The 303(d) list is developed biennially pursuant to 40CFR130.7. The NC Division of Water Quality (DWQ) has identified all management areas of Jordan Reservoir in the Cape Fear River Basin as impaired by chlorophyll *a*.

Section 303(d) of the Clean Water Act (CWA) requires states to develop a list of waters not meeting water quality standards or which have impaired uses. This list, referred to as the 303(d) list, is submitted biennially to the U.S. Environmental Protection Agency (EPA) for review.

The 303(d) process requires that a Total Maximum Daily Load (TMDL) be developed for each of the waters appearing on Part I of the 303(d) list. The objective of a TMDL is to estimate allowable pollutant loads and allocate the loads to known sources so that actions may be taken to restore the water to its intended uses (USEPA, 1991). Generally, the primary components of a TMDL, as identified by EPA (1991, 2000a) and the Federal Advisory Committee (FACA, 1998) are as follows:

Target identification or selection of pollutant(s) and end-point(s) for consideration. The pollutant and end-point are generally associated with measurable water quality related characteristics that indicate compliance with water quality standards. North Carolina indicates known pollutants on the 303(d) list.

Source assessment. All sources that contribute to the impairment should be identified and loads quantified, where sufficient data exist.

Reduction target. Estimation of the level of pollutant reduction needed to achieve water quality goal. The level of pollution should be characterized for the waterbody, highlighting how current conditions deviate from the target end-point. Generally, this component is identified through water quality modeling.

Allocation of pollutant loads. Allocating pollutant control responsibility to the sources of impairment. The wasteload allocation portion of the TMDL accounts for the loads associated with existing and future point sources including NPDES-permitted stormwater. Similarly, the load allocation portion of the TMDL accounts for the loads associated with existing and future non-point sources, non-NPDES stormwater, and natural background sources.

Margin of Safety. The margin of safety addresses uncertainties associated with pollutant loads, modeling techniques, and data collection. Per EPA (2000a), the margin of safety may be expressed explicitly as unallocated assimilative capacity or implicitly due to conservative assumptions.

Seasonal variation. The TMDL should consider seasonal variation in the pollutant loads and end-point. Variability can arise due to stream flows, temperatures, and exceptional events (e.g., droughts, hurricanes).

Critical Conditions. Critical conditions indicate the combination of environmental factors that result in just meeting the water quality criterion and have an acceptably low frequency of occurrence.

Section 303(d) of the CWA and the Water Quality Planning and Management regulation (USEPA, 2000a) require EPA to review all TMDLs for approval or disapproval. Once EPA approves a TMDL, then the waterbody may be moved to Category 4a of the Integrated Report. Waterbodies remain in Category 4a until compliance with water quality standards is achieved. Where conditions are not appropriate for the development of a TMDL, management strategies may still result in the restoration of water quality.

The goal of the TMDL program is to restore designated uses to water bodies. Thus, the implementation of source controls throughout the watershed will be necessary to restore uses in Jordan Reservoir. An implementation plan is included as part of the combined nutrient management strategy and TMDL document. Per TMDL program guidance, individual NPDES wasteload allocations are provided for continuously discharging facilities subject to this TMDL. NPDES stormwater wasteload allocations are not provided separately, but are included in the overall nonpoint source reduction target. The nutrient management strategy provided herein includes a majority of nonpoint sources, including NPDES stormwater, septic systems, and non-discharge systems.

3.1 Reservoir and Watershed Description

Jordan Reservoir is a multi-use impoundment operated by the U.S. Army Corps of Engineers and located on Haw River and New Hope Creek, Cape Fear River Basin, in the eastern Piedmont region of North Carolina (Figure 1). The length of the shoreline is approximately 200 miles. The lake covers an area of 13,940 acres at elevation 216 feet msl, which is at the top of the conservation pool and the normal operating level. The lake, impounded in 1982, is operated for flood control, water quality (low flow augmentation), fish and wildlife conservation, recreation, and water supply (PL 88-253). It has an estimated water supply yield of 100 million gallons per day, and currently serves as a regional source of drinking water supply.

Jordan Reservoir consists of two distinct arms - the Haw River arm and the New Hope arm. Major inflows are the Haw River and New Hope and Morgan Creeks. The Haw River arm of the lake has an average hydraulic retention time of five days and accounts for 70 to 90 percent of the annual flow through Jordan Reservoir. The New Hope Creek arm of the lake has an average hydraulic retention time of 418 days. Maximum depth of the lake is approximately 66 feet (20 meters) with a mean depth of five meters and a total volume of 265 million cubic meters.

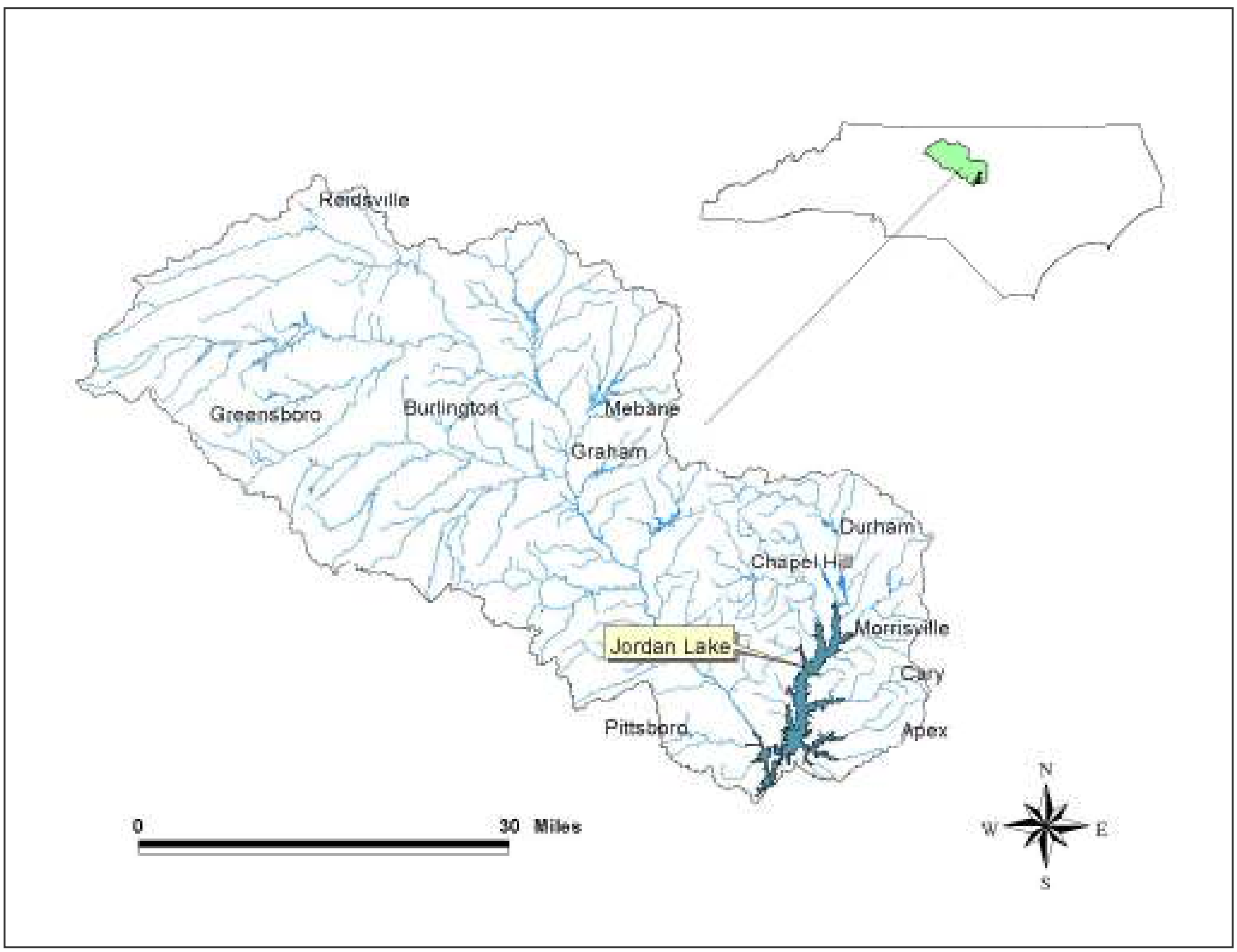

Figure 1. Location map for Jordan Reservoir.

Surface water classifications are designations applied to surface water bodies that define the best uses to be protected within these waters (e.g., swimming, fishing, and drinking water supply) and carry with them an associated set of water quality standards to protect those uses. The New Hope Creek Arm of Jordan Reservoir is classified as a WS-IV B NSW CA. The Haw River Arm of Jordan Reservoir is classified as WS-IV NSW CA. Combined, the waters of the reservoir are protected for water supply, primary and secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, agriculture and other uses suitable for Class C. Jordan Reservoir was designated as a Nutrient Sensitive Water (NSW) in 1983.

The Jordan Reservoir watershed encompasses 1,686 square miles (excluding the lake itself) and includes parts of Alamance, Caswell, Chatham, Durham, Forsyth, Guilford, Orange, Randolph, Rockingham, and Wake counties. It includes some or all of the urban areas of Durham, Chapel Hill, Cary, Burlington, Greensboro, and several other small municipalities. For the purposes of this TMDL, the reservoir was divided into management areas as shown in figure 2. The drainage areas for the three TMDL management areas are shown in Table 1.

Table 1. Total watershed areas for Jordan Reservoir by lake management area

Lake management area	Acres	Percent
Haw River Arm	859,442	79.65%
Upper New Hope (River) Arm	148,146	13.73%
Lower New Hope (River) Arm	71,437	6.62%
Total watershed area	1,079,026	100%

An improved land use database was created consisting of the 1992 National Land Cover Database (NLCD) from the Multi-Resolution Land Characterization (MRLC) Consortium, updated in Orange, Durham, Chatham, and Wake counties using current tax parcel information, and updated in all other areas for residential density using the 2000 Census (Tetra Tech, 2003b). This yields a near-current estimate of land use in the basin, with the primary exception that commercial/industrial development in the Haw River basin that occurred after the date of the NLCD. A summary provided in Figure 3 indicates approximately 18% urban, 20% agriculture, and 56% forest in the Jordan Reservoir watershed.

The Jordan Reservoir watershed lies primarily within the Carolina Slate Belt and Triassic Basins. The Carolina Slate Belt consists of heated and deformed volcanic and sedimentary rocks. Soils in the belt have high silt content and overlie thin saprolite. The major soils are Georgeville, Badin, and Tatum. Streams within the belt have narrow valleys and flood plains that widen abruptly upon entering the Triassic basin (Daniels et al., 1999). The Triassic basins are filled with sedimentary rocks that formed about 190-200 million years ago. Mayodan, Creedmor, and White Store soils occupy the largest area of the basin. Upper portions of the Haw River Arm are located in the Milton Belt and the Charlotte Belt.

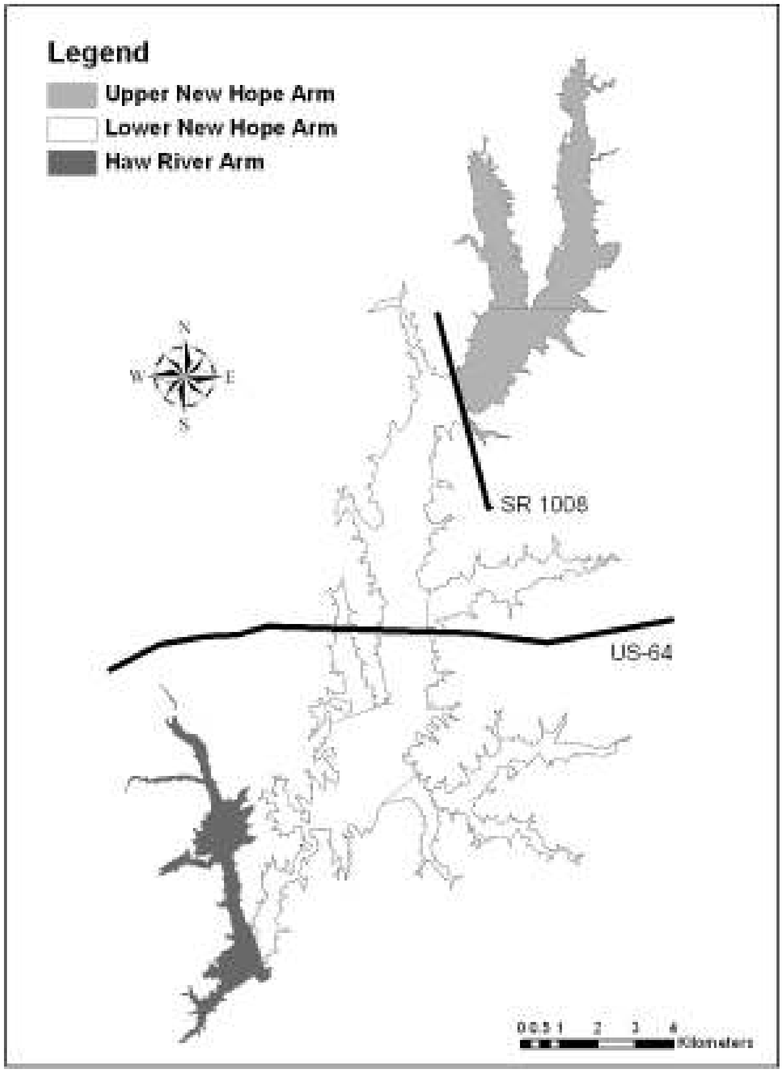

Figure 2. Jordan Reservoir management areas.

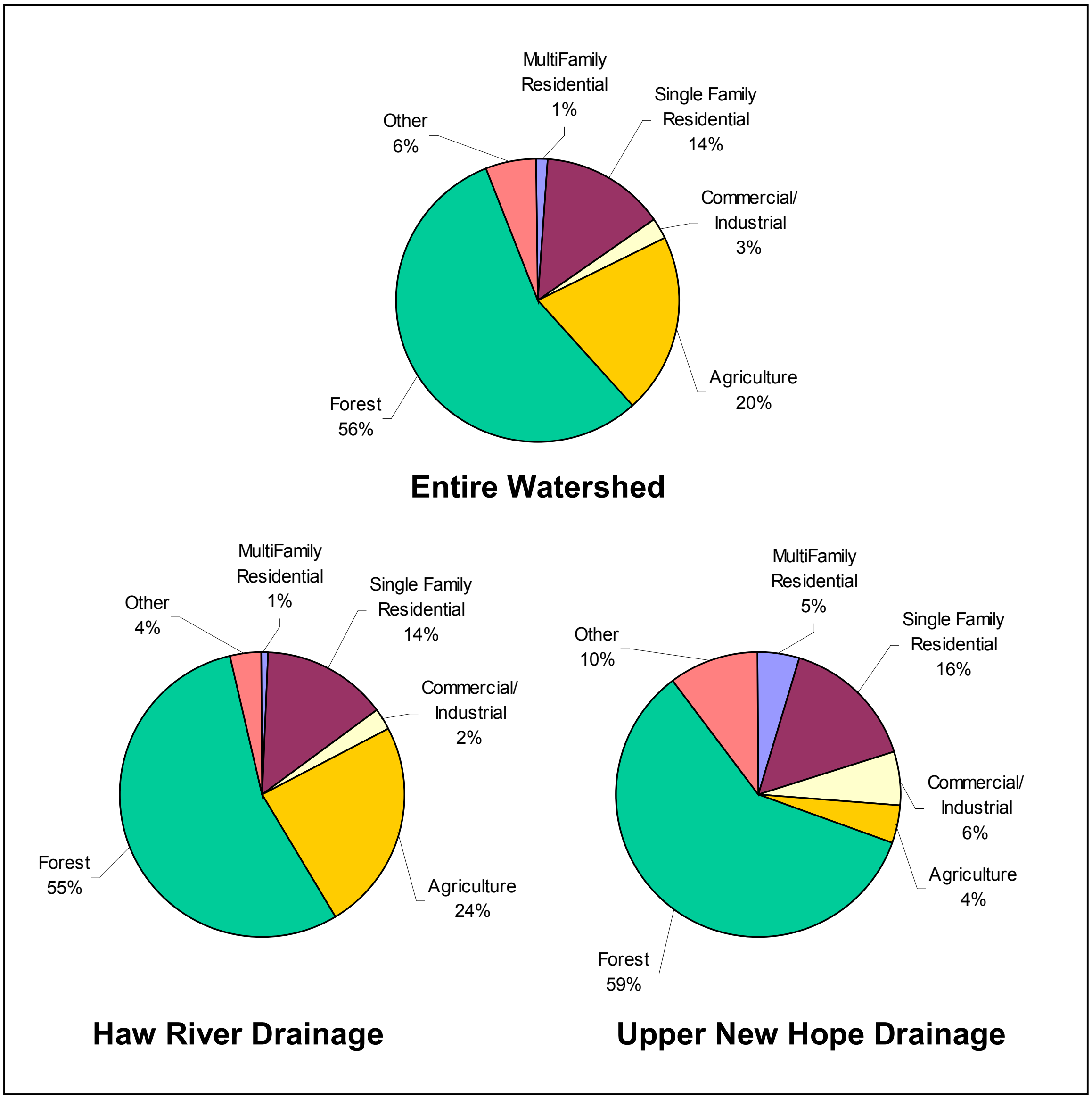

Figure 3. Distribution of land uses across the Jordan Reservoir watershed.

3.2 Water Quality Target

The North Carolina fresh water quality standard for chlorophyll *a* in Class C waters (T15A: 02B.0211) states the following: not greater than 40 µg/l for lakes, reservoirs, and other waters subject to growths of macroscopic or microscopic vegetation not designated as trout waters, and not greater than 15 µg/l for lakes, reservoirs, and other waters subject to growths of macroscopic or microscopic vegetation designated as trout waters (not applicable to lakes and reservoirs less than 10 acres in surface area).

Chlorophyll *a* is the endpoint for this nutrient management strategy and TMDL. The target is based on the chlorophyll *a* criterion of 40 µg/L: DWQ seeks to have less than a 10% violation frequency (excluding the margin of safety) of that criterion during the critical period where algal growth is highest, defined for this application as May through September. The application of the standard in this manner is supported by EPA Region 4 (Appendix II).

Algal growth is affected by numerous biotic and abiotic factors including light availability, flow and water velocity, nutrients (particularly nitrogen and phosphorus), grazing, and other influences. Nutrient controls are the most common focus of management schemes for reducing excessive algal growth and chlorophyll *a* concentrations. Therefore, the TMDL will be written for total nitrogen (TN) and total phosphorus (TP) loads to the lake.

The instream numeric target, or endpoint, is the restoration objective associated with implementing the specified nutrient load reductions in the TMDL. The target allows for the evaluation of progress towards the goal of reaching water quality standards for the impaired stream by comparing the instream data to the target.

3.3 Water Quality Assessment

Since the reservoir was impounded in 1982, it has been monitored extensively. Monitoring on the lake over the years has been performed by DWQ, Town of Cary, City of Durham, Orange Water and Sewer Authority, Town of Pittsboro, Durham County, the U.S. Geological Survey, and UNC-Chapel Hill.

In addition to historical sampling of the lake since July of 1982, the lake was sampled monthly by DWQ during the summer in 1996 through 1999. During 2000 and 2001, sampling was conducted twice per month during May through August, and monthly during cooler periods. The locations of sampling stations are provided in Figure 4.

Jordan Reservoir has historically been one of the most eutrophic reservoirs in North Carolina. Excursions of the state water quality standard for chlorophyll *a* have been noted frequently as evidenced in Figures 5, 6, and 7, especially in the Upper New Hope Arm. Nutrient concentrations in the lake are also high (Table 2). The elevated nutrient concentrations result from a combination of point and nonpoint source loads.

A detailed presentation and summary of historical data from 1982 through 1999 can be found in Tetra Tech (2001). The document also summarizes past research on the lake. Key results from the evaluation of existing data include the following:

- Jordan Reservoir is eutrophic, with high algal productivity, especially in the upstream ends of the New Hope and Haw River arms.
- Conditions in the lake appear to have improved somewhat from lake startup until the early 1990's, but have shown little change since that time.
- Excessive algal growth in the lake is supported by high levels of nutrient input and recycling.

- Several lines of evidence, including an initial BATHTUB scoping model, N:P ratio, and algal growth potential tests, suggest that algal response in the lake is sensitive to nitrogen loading, with less sensitivity to phosphorus loading.
- Nonalgal turbidity and consequent reduction in light penetration plays an important role in controlling algal growth in the lake.
- Nutrient cycling in the lake is complex, with strong feedback between algal populations and concentrations of nutrient species. Algal biomass is sufficiently high that dissolved inorganic forms of nutrients are rapidly scavenged from the water column during the summer months.
- Algal response to nutrient loads differs among taxonomic groups. In particular, blue green algae (Cyanophytes) have a high correlation with summer nuisance conditions, but show a negative correlation with nitrate-plus-nitrite nitrogen concentration.
- Because of the complex responses of different algal groups to nutrient loads, chlorophyll *a* concentrations provide only an approximate and rough indicator of responses that may degrade or impair uses of the lake.
- Mixing patterns in the lake are complex, and involve exchanges between the Haw River and New Hope arms. These two management areas have very different hydraulic characteristics and residence times, and may exhibit qualitatively different responses to changes in nutrient loads.

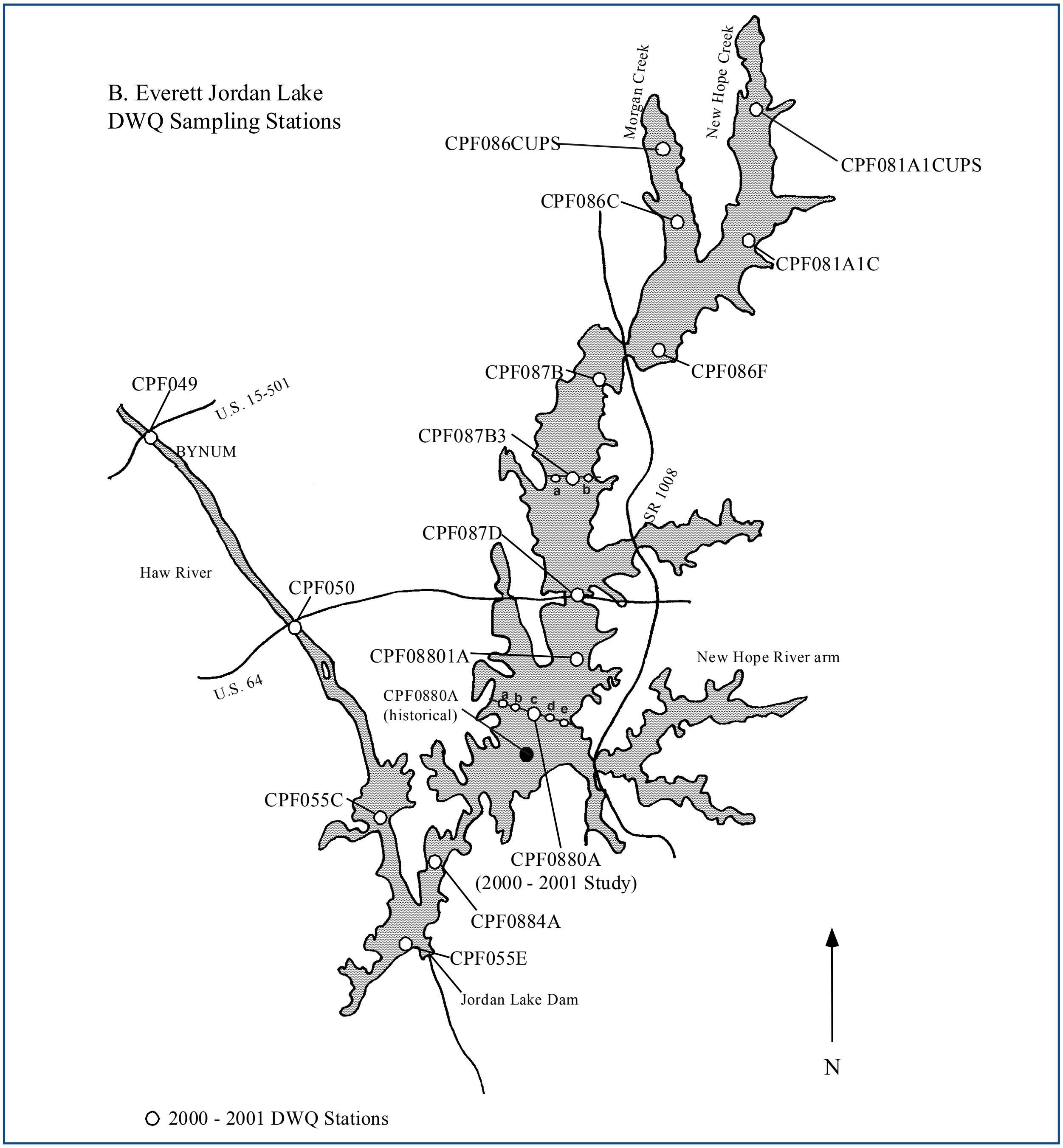

Figure 4. Jordan Reservoir sampling stations.

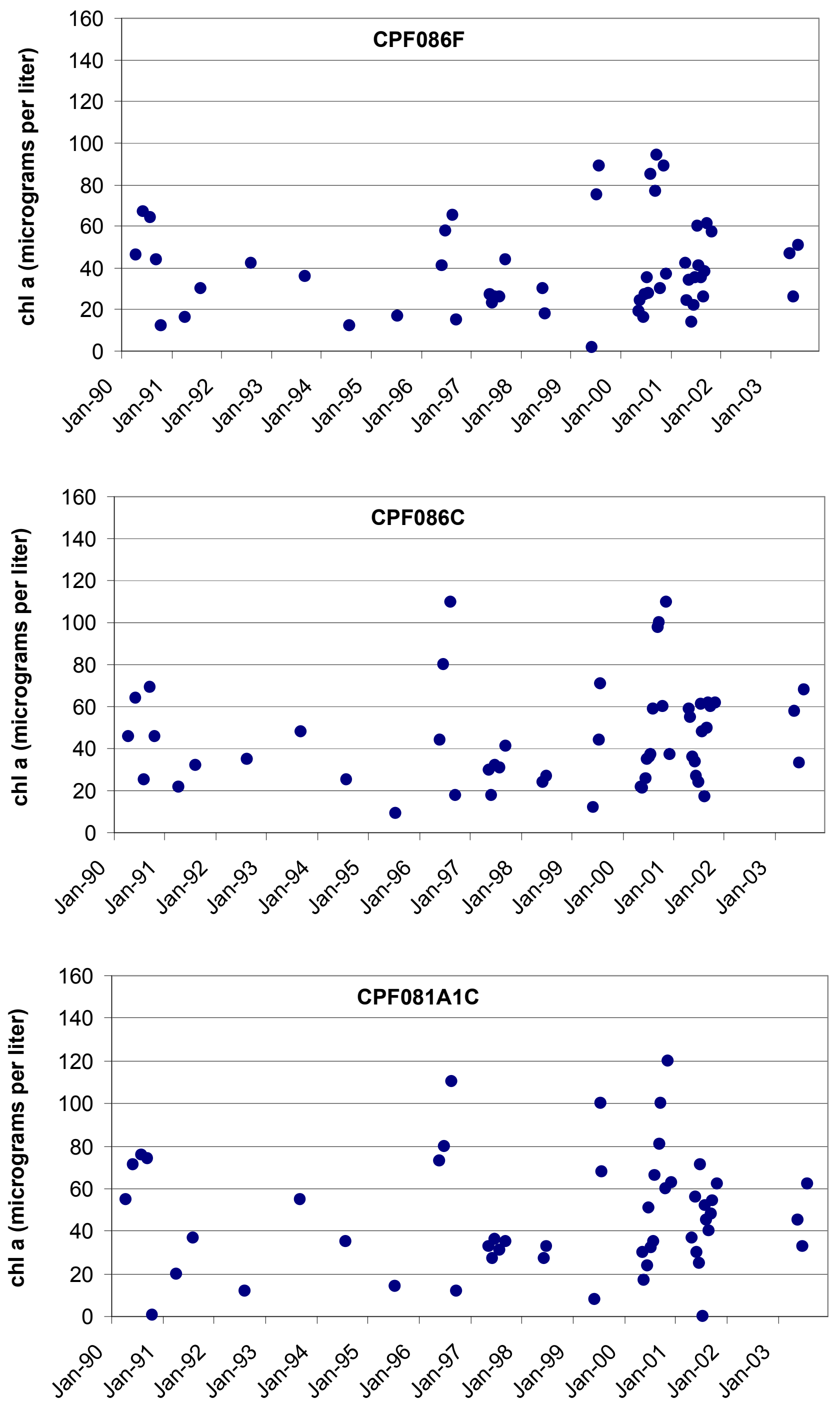

Figure 5: Chlorophyll *a* concentrations collected by DWQ for 1990 - 2003 at three stations, CPF086F, CPF086C, and CPF081A1C, in the Upper New Hope Arm of Jordan Reservoir. Data from 9/96 - 1/01 are uncorrected concentrations.

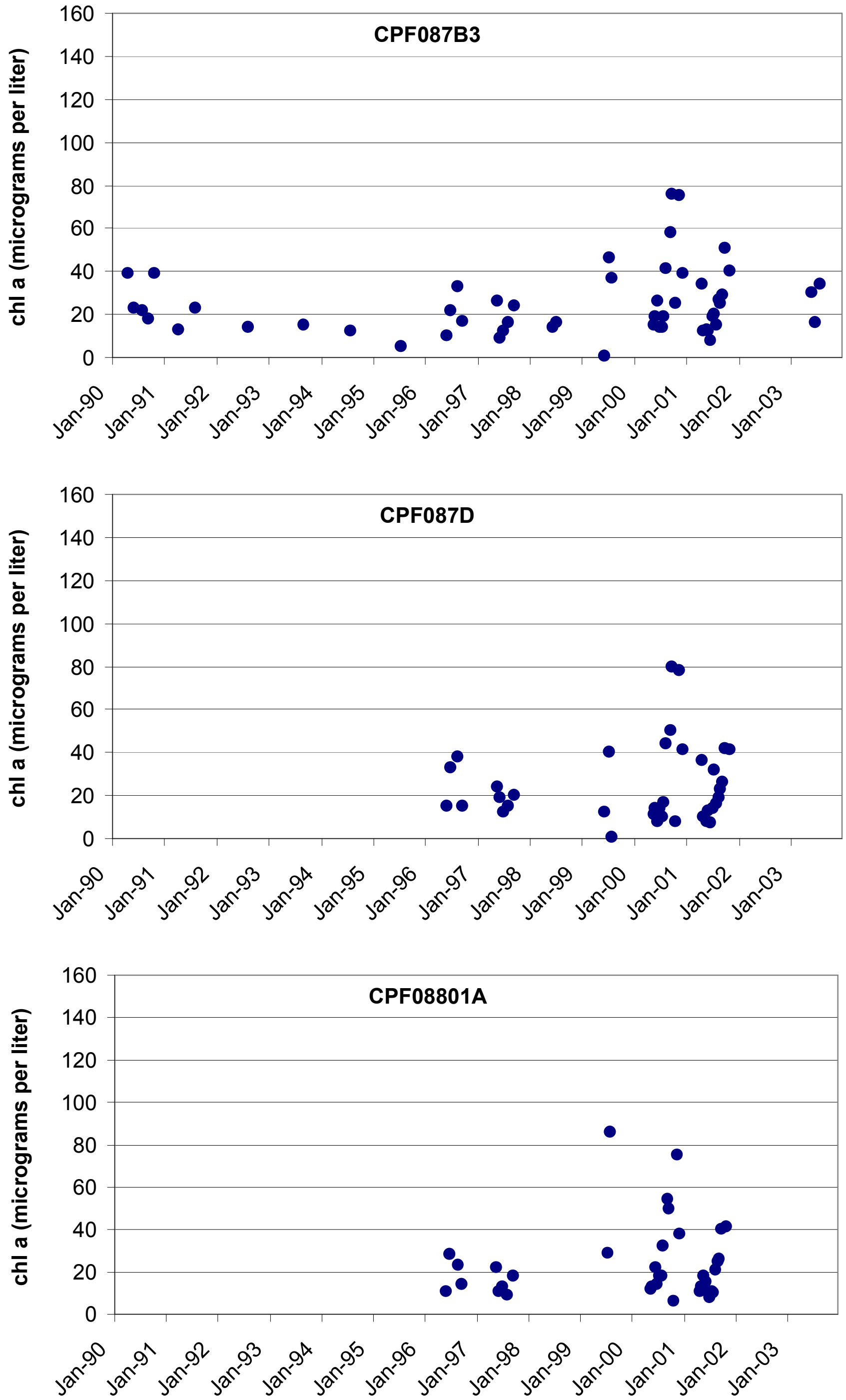

Figure 6: Chlorophyll *a* concentrations collected by DWQ for 1990 - 2003 at three stations, CPF087B3, CPF087D, and CPF08801A, in the Lower New Hope Arm of Jordan Reservoir. Data from 9/96 - 1/01 are uncorrected concentrations.

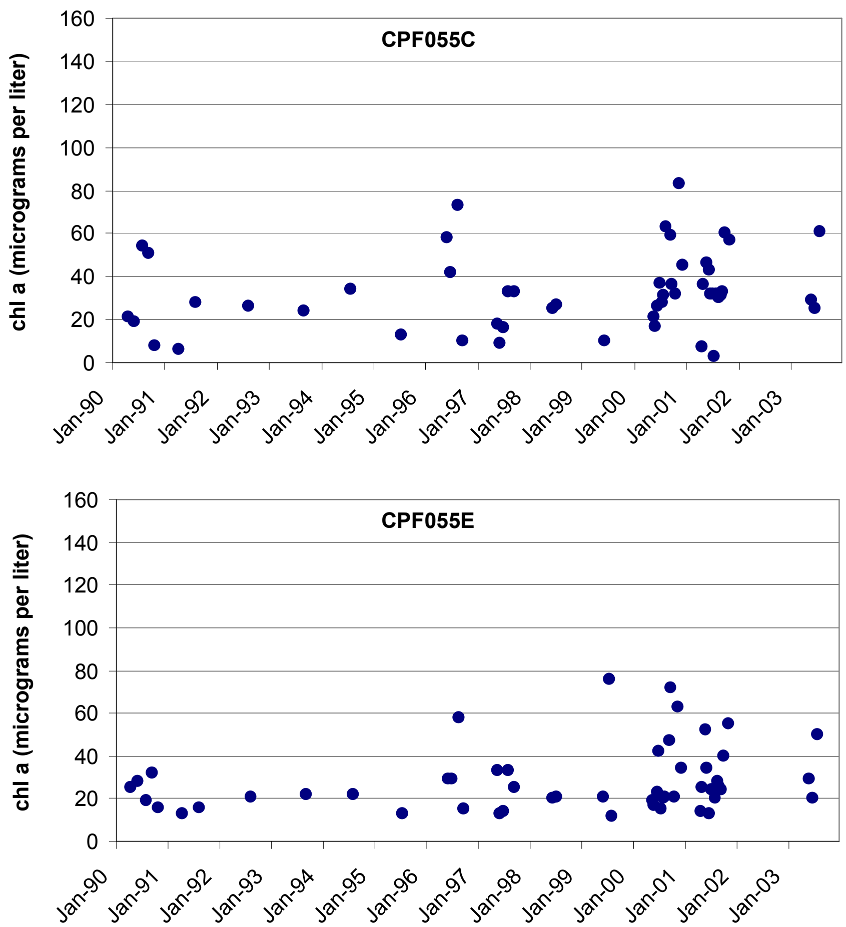

Figure 7: Chlorophyll *a* concentrations collected by DWQ for 1990 - 2003 at two stations, CPF055C and CPF055E, in the Haw River Arm of Jordan Reservoir. Data from 9/96 - 1/01 are uncorrected concentrations.

Table 2. Summary statistics for nutrients (mg/l) and chlorophyll *a* (µg/l) collected by DWQ at selected stations in the Jordan Reservoir (1990-2003). Data for Lower Hope Arm Stations CPF087D and CPF08801A are not shown because those stations were not monitored continuously during these time periods. Chlorophyll a data from 9/96 – 1/01 are uncorrected for phaeophytin concentrations.

		1990-1996			1997-2003		
		TP	**TN**	**chl a**	**TP**	**TN**	**chl a**
Upper New Hope Arm	**CPF081A1C**						
	Mean	0.11	0.66	48.3	0.09	0.77	48.3
	Median	0.11	0.64	55.0	0.10	0.71	42.5
	N	16	16	15	40	40	36
	Std. Dev.	0.04	0.16	32.4	0.03	0.37	24.4
	CPF086C						
	Mean	0.10	0.65	44.9	0.08	0.72	45.4
	Median	0.10	0.65	44.0	0.08	0.65	37.0
	N	16	16	15	40	40	38
	Std. Dev.	0.03	0.12	26.8	0.02	0.35	23.3
	CPF086F						
	Mean	0.08	0.64	37.7	0.07	0.69	40.4
	Median	0.08	0.70	41.0	0.07	0.61	34.5
	N	16	16	15	39	39	38
	Std. Dev.	0.03	0.15	20.1	0.02	0.27	23.2
Lower New Hope Arm	**CPF087B3**						
	Mean	0.04	0.55	20.33	0.04	0.55	26.49
	Median	0.04	0.51	18.00	0.04	0.59	22.00
	N	16	16	15	40	40	38
	Std. Dev.	0.02	0.10	10.10	0.02	0.20	17.23
Haw River Arm	**CPF055C**						
	Mean	0.09	0.78	31.13	0.11	0.87	38.27
	Median	0.08	0.75	26.00	0.08	0.85	32.00
	N	16	16	15	39	39	37
	Std. Dev.	0.04	0.17	20.35	0.14	0.33	33.66
	CPF055E						
	Mean	0.06	0.66	23.87	0.06	0.67	30.00
	Median	0.05	0.61	22.00	0.05	0.71	24.00
	N	16	16	15	40	40	38
	Std. Dev.	0.03	0.18	11.27	0.02	0.23	16.39

4 Source Assessment

Elevated nutrient concentrations in Jordan Reservoir result from a combination of point and nonpoint source loads. The point source loads include three major wastewater treatment plants at the headwaters of the New Hope arm and seven major wastewater treatment plants upstream on the Haw River. There are also several smaller dischargers. Nonpoint loading includes runoff from urban areas in Durham, Chapel Hill, Cary, Burlington, Greensboro, and several other small municipalities, as well as a variety of rural sources.

4.1 Point Source Assessment

All wastewater discharges to surface water in the State of North Carolina must receive a permit to control water pollution. The Clean Water Act of 1972 initiated strict control of wastewater discharges with responsibility of enforcement given to the Environmental Protection Agency (EPA). The EPA then created the National Pollutant Discharge Elimination System (NPDES) to track and control point sources of pollution. The primary method of control is by issuing permits to discharge with limitations on wastewater flow and constituents. The EPA delegated permitting authority to the State of North Carolina in 1975. Table 3 presents large and small dischargers in the Upper New Hope Arm watershed, and Table 4 presents those for the Haw River Arm watershed. Locations of dischargers in the Jordan Reservoir are shown in Figure 8.

NPDES wastewater permits are distinguished between individual and general. General permits are issued for a given statewide activity such as the discharge of wastewaters associated with sand dredging or non-contact cooling. Individual permits are permits developed and issued on a case-by-case basis for activities not covered by general permits. These permits can be readily identified by their prefix. Individual NPDES permits have the prefix NC while general NPDES permits have the prefix NCG. General wastewater permits currently exist for the following activities: Non-contact cooling water discharges; Petroleum-based groundwater remediation; Sand dredging; Seafood packaging; and Domestic discharges from single family residences. Tables 3 and 4 list the continuous wastewater discharges into the Upper New Hope and Haw River Arms of Jordan Reservoir. There is one permitted discharger in the Lower New Hope Management Area. Fearrington Utilities, Inc., Fearrington Utilities WWTP (NC0043559) has a permitted flow of 0.5 MGD with an average annual TN load of 8138 lb/yr and an average annual TP load of 566 lb/yr.

Table 3. Continuous point source dischargers in the Upper New Hope Watershed of Jordan Reservoir.

Permit	Owner	Type	Average Annual Flow (MGD) (1997-2001)	Average Annual TN Load (lbs) (1997-2001)	Average Annual TP Load (lbs) (1997-2001)
NC0047597	City of Durham/ South Durham WRF	Municipal , Large	10.23	199,126	13,977
NC0025241	Orange Water & Sewer Authority/ Mason Farm WWTP	Municipal , Large	8.13	313,155	10,395

Permit	Owner	Type	Average Annual Flow (MGD) (1997-2001)	Average Annual TN Load (lbs) (1997-2001)	Average Annual TP Load (lbs) (1997-2001)
NC0026051	Durham County/ Triangle WWTP	Municipal , Large	3.86	170,021	9,391
NC0056413	Whippoorwill LLC/ Carolina Meadows WWTP	100% Domestic < 1MGD	0.114	5,284	540
NC0051314	North Chatham Water & Sewer Company, LLC/ Cole Park Plaza	100% Domestic < 1MGD	0.013	700	55
NC0043257	Nature Trails Association, CLP/ Nature Trails Mobile Home Park WWTP	100% Domestic < 1MGD	0.032	2,795	525
NC0042803	Birchwood Mobile Home Park/ Birchwood Mobile Home Park	100% Domestic < 1MGD	0.011	831	225
NC0074446	Hilltop Mobile Home Park/ Hilltop Mobile Home Park	100% Domestic < 1MGD	0.003	414	49
NC0048429	Cedar Village Apartments/ Cedar Village Apartments	100% Domestic < 1MGD	0.002	161	33
NC0025305	UNC Chapel Hill/ UNC Cogeneration Facility	Industrial Process & Commercial	---	---	---
NC0081591	Town of Cary/ Cary & Apex WTP	Water Plants and Water Conditioning	---	---	---
NC0082210	Orange Water & Sewer Authority/ Jones Ferry Road WTP	Water Plants and Water Conditioning	---	---	---
NC0084093	County of Chatham/ Jordan Lake WTP	Water Plants and Water Conditioning	---	---	---
NC0086827	Brenntag/ Brenntag Southeast, Inc.	Groundwater Remediation	---	---	---
		Totals	22.40	692,488	35,210

Table 4. Continuous point source dischargers in the Haw River Arm watershed of Jordan Reservoir.

Permit	Owner	Type	Average Annual Flow (MGD) (1997-2001)	Average Annual TN Load (lbs) (1997-2001)	Average Annual TP Load (lbs) (1997-2001)
NC0047384	City of Greensboro/ T.Z. Osborne WWTP	Municipal, Large	18.606	552,397	75,871
NC0024325	City of Greensboro/ North Buffalo WWTP	Municipal, Large	13.058	510,119	63,382
NC0023868	City of Burlington/ Eastside WWTP	Municipal, Large	6.65	311,609	27,217
NC0023876	City of Burlington/ Southside WWTP	Municipal, Large	7.762	184,015	21,571
NC0024881	City of Reidsville/ Reidsville WWTP	Municipal, Large	3.14	56,151	8,113

Permit	Owner	Type	Average Annual Flow (MGD) (1997-2001)	Average Annual TN Load (lbs) (1997-2001)	Average Annual TP Load (lbs) (1997-2001)
NC0021211	City of Graham/ Graham WWTP	Municipal, Large	1.826	51,328	10,294
NC0021474	City of Mebane/ Mebane WWTP	Municipal, Large	0.984	25,509	3,928
NC0020354	Town of Pittsboro/ Pittsboro WWTP	Municipal, < 1MGD	0.314	15,613	1,759
NC0066966	Quarterstone Farm Homeowners Association/ Quarterstone Farm WWTP	100% Domestic < 1MGD	0.054	3,250	341
NC0022691	Chateau Communities, Inc./ Autumn Forest Mfr. Home	100% Domestic < 1MGD	0.061	3,427	329
NC0022675	Country Club Communities LLC/ Birmingham Place	100% Domestic < 1MGD	0.033	1,237	136
NC0042285	Trails Property Owners Assoc./ Trails WWTP	100% Domestic < 1MGD	0.011	488	193
NC0046043	Oak Ridge Military Academy/ Oak Ridge Military Academy	100% Domestic < 1MGD	0.011	838	209
NC0077968	Horners Mobile Home Park/ Horners Mobile Home Park	100% Domestic < 1MGD	0.008	358	30
NC0042528	B Everett Jordan & Son – 1927 LLC	100% Domestic < 1MGD	0.002	184	26
NC0038156	Guilford County Schools/ Northeast Middle & Senior High WWTP	100% Domestic < 1MGD	0.009	1,565	156
NC0073571	Mervyn R. King/ Countryside Manor WWTP	100% Domestic < 1MGD	0.006	228	39
NC0035866	County of Chatham/ Bynum WWTP	Municipal, < 1MGD	0.012	1,025	146
NC0029726	NC Department of Correction/ Guilford Correctional Center	100% Domestic < 1MGD	0.016	772	57
NC0065412	REA Enterprises, LLC/ Pleasant Ridge WWTP	100% Domestic < 1MGD	0.014	417	44
NC0046809	Pentecostal Holiness Church/ Pentecostal Holiness Church	100% Domestic < 1MGD	0.001	51	5
NC0060259	Willow Oak Mobile Home Park/ Willow Oak Mobile Home Park	100% Domestic < 1MGD	0.009	894	122
NC0031607	Alamance-Burlington School System/ Western Alamance Middle School	100% Domestic < 1MGD	0.005	681	61
NC0046019	Episcopal Diocese of North Carolina/ The Summit WWTP	100% Domestic < 1MGD	0.002	44	5
NC0045161	Alamance-Burlington School System/ Altamahaw/ Ossipee Elementary	100% Domestic < 1MGD	0.003	383	39

Permit	Owner	Type	Average Annual Flow (MGD) (1997-2001)	Average Annual TN Load (lbs) (1997-2001)	Average Annual TP Load (lbs) (1997-2001)
NC0045144	Alamance-Burlington School System/ Western Alamance High School	100% Domestic < 1MGD	0.005	743	77
NC0038172	Guilford County Schools/ McLeansville Middle School	100% Domestic < 1MGD	0.001	2,044	123
NC0022098	Cedar Valley Communities LLC/ Cedar Valley WWTP	100% Domestic < 1MGD	0.007	367	88
NC0045152	Alamance-Burlington School System/ Jordan Elementary	100% Domestic < 1MGD	0.002	232	37
NC0055271	Shields Mobile Home Park/ Shields Mobile Home Park	100% Domestic < 1MGD	0.002	150	17
NC0038164	Guilford County Schools/ Nathanael Greene Elementary	100% Domestic < 1MGD	0.003	469	40
NC0036994	Rockingham County Board of Education/ Monroeton Elementary School	100% Domestic < 1MGD	0.002	71	61
NC0066010	Rockingham County Board of Education/ Williamsburg Elementary School	100% Domestic < 1MGD	0.002	51	65
NC0045128	Alamance-Burlington School System/ Sylvan Elementary School	100% Domestic < 1MGD	0.002	232	32
NC0003671	Amoco Oil Company/ Amoco Greensboro Terminal	Industrial Process & Commercial	---	---	---
NC0071463	Apex Oil Company/ Apex Oil Company	Industrial Process & Commercial	---	---	---
NC0003913	Glen Raven Inc/ Altamahaw Division plant	Industrial Process & Commercial	0.021	251	48
NC0001210	Monarch Hosiery Mills Inc./ Monarch Hosiery Mills, Inc.	Industrial Process & Commercial	0.024	2,609	124
NC0001384	Burlington Industries, Inc./ Williamsburg plant	Industrial Process & Commercial	0.007	943	88
NC0048241	Staley Hosiery Mills/ Staley Hosiery Mills	Industrial Process & Commercial	0.005	21	324
		Totals	52.68	1,730,765	215,195

Certain types of stormwater runoff are covered under the NPDES permit program (Figures 8 and 9). Regulated discharges are those associated with large and small municipalities with municipal separate storm sewer systems (MS4s). Phase I of this permitting program, established in 1990, includes large municipalities serving populations greater than 100,000. In North Carolina, there are six permitted local governments that have municipal separate storm sewer systems (MS4s) serving populations of 100,000 or more (Raleigh, Durham, Fayetteville and Cumberland County, Charlotte, Winston-Salem, Greensboro). Durham (NCS000249) and Greensboro (NCS000248) are the Phase I municipalities draining to Jordan Reservoir. Stormwater from Durham discharges to the Upper New Hope Arm of the reservoir, while stormwater from Greensboro discharges to the Haw River Arm of the reservoir.

Industrial facilities that fall into one of the subject ten categories are required obtain permit coverage under a general permit or an individual permit for stormwater.

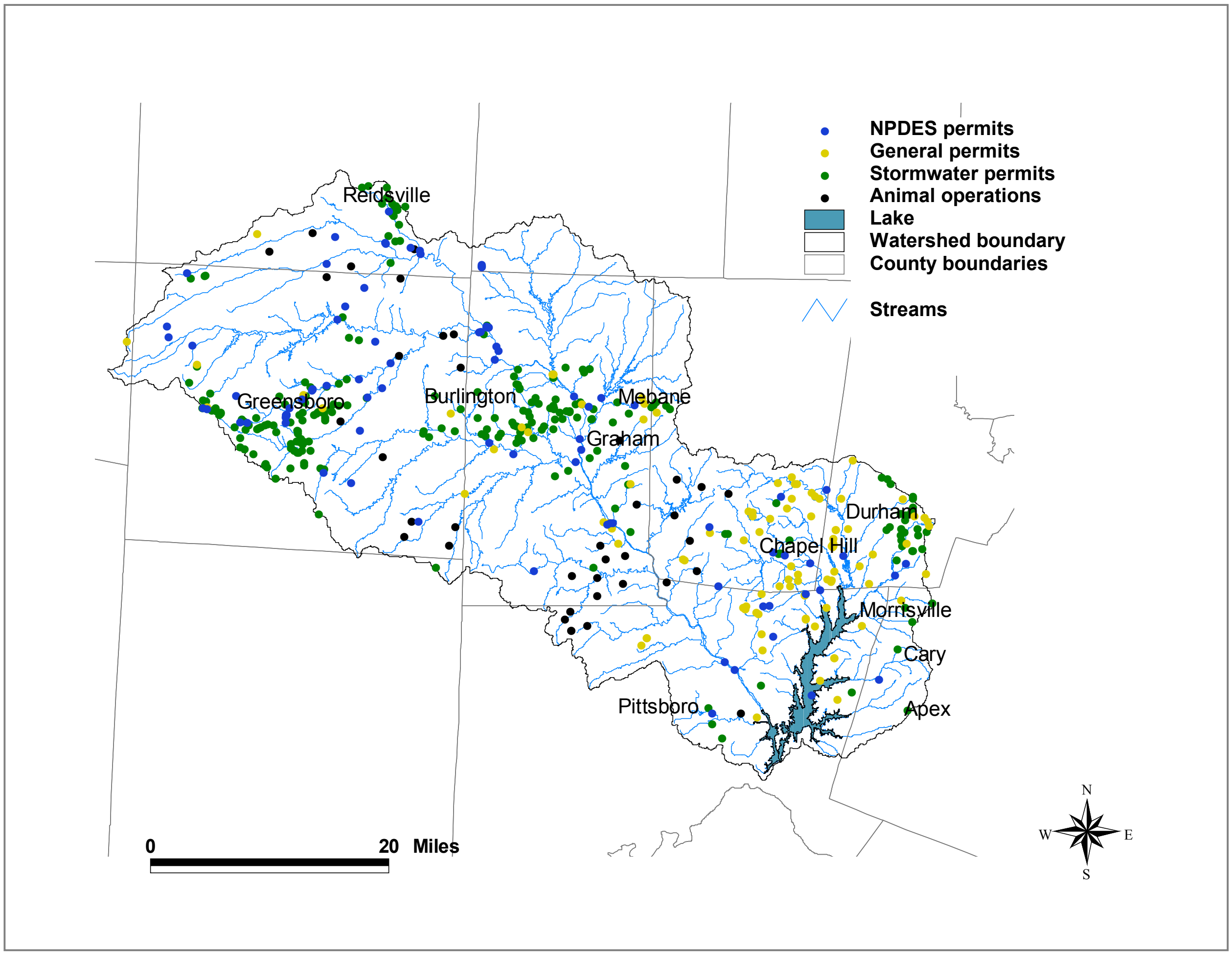

Figure 8. Locations of NPDES wastewater permits, NPDES stormwater permits, and certified confined animal operations in the Jordan Reservoir watershed.

Phase II of the NPDES Stormwater program was signed into law in December 1999. Regulated small MS4s were required to apply for permit coverage by March 2003. Additional activities or jurisdictions may be designated for coverage under the program based upon the potential for significant water quality impacts. Phase I and II MS4 permits are listed in Table 5. EPA requires that loads allocated to NPDES permitted stormwater be placed in the wasteload allocation (WLA), which had previously been reserved for continuous point source loads (Wayland, 2002). The NC Department of Transportation also has a NPDES stormwater permit in this watershed (statewide).

Table 5. Stormwater MS4 permits in the watershed of Jordan Reservoir.

Permit number	Entity	Reservoir management area
NCS000248	City of Greensboro	Haw River Arm
NCS000401 (a)	Guilford County	Haw River Arm
NCS000402	City of Mebane	Haw River Arm
NCS000403	Town of Elon	Haw River Arm
NCS000404	Town of Haw River	Haw River Arm
NCS000405	Town of Gibsonville	Haw River Arm
NCS000408	City of Graham	Haw River Arm
NCS000428	City of Burlington	Haw River Arm
NCS000463	Town of Green Level	Haw River Arm
NCS000477	Town of Swepsonville	Haw River Arm
NCS000483	Town of Kernersville	Haw River Arm
NCS000508	Piedmont Triad Airport Authority	Haw River Arm
NCS000446	Town of Apex	Lower New Hope Arm
NCS000250	NC Department of Transportation	Statewide
NCS000427	City of Cary	Upper and Lower New Hope Arm
NCS000433 (a)	Wake County	Upper and Lower New Hope Arm
NCS000249	City of Durham	Upper New Hope Arm
NCS000414	City of Chapel Hill	Upper New Hope Arm
NCS000450	City of Carrboro	Upper New Hope Arm
NCS000465	Town of Morrisville	Upper New Hope Arm
(a) Application in process		

Land application systems for animal waste contribute nutrients to the hydrologic system. Animal operations that are designed for, and actually serve, greater than or equal to the following number of animals must be have a certified animal waste management plan under 15A NCAC 02H .0201: 100 head of cattle, 75 horses, 250 swine, 1,000 sheep, 30,000 birds with a liquid waste system. There are 38 such facilities in the Jordan Reservoir watershed (31 dairy; 7 swine; Figure 7). Any farm that has animal numbers meeting the federal threshold numbers or any farm that has had a recent discharge violation must obtain a federal NPDES Permit. Federal Threshold Numbers are: 2500 Swine greater than 55 pounds in weight, 700 Mature Dairy Cattle, 1,000 Beef Cattle in confinement, and 30,000 Poultry with liquid waste management system. General permits for animal operations have been approved for swine, poultry, and cattle.

4.2 Non-Point Source Assessment

Non-point sources are diffuse sources that typically cannot be identified as entering a water body at a single location. These sources of nutrients are typically runoff constituents from surfaces during storm events. However, some sources may allow nutrients to be leached to shallow groundwater and subsequently transported to surface waters.

Agricultural and urban land uses can contribute considerable amounts of nutrients due to fertilizer use. In the Upper New Hope Management Area, agriculture makes up only approximately 4% of land use (Figure 3). The Upper New Hope Arm is developed more intensely than the Haw River Arm, which has 24% agriculture land use. Impervious surfaces associated with developed areas increase the quantity and velocity of runoff and associated contaminants.

Septic systems are a potential source of nutrients to water bodies. Septic systems are designed to pre-treat the sewage before it is applied to the soil via a drain field. The soil matrix provides biological, chemical, and physical treatment for nutrients. However, the extent of treatment depends on factors such as soil type, hydrology, and weather conditions of the site.

Lack of maintenance and improper use can cause septic systems to fail, creating the potential for increased transport of nutrients to water bodies. A study by the NC Office of Budget and Management suggested that 11% of systems surveyed had malfunctions or failures (NC DEH, 2000). Based on the CDM (1989) study for Little River Reservoir and Lake Michie subwatersheds, a 10-15 percent steady-state rate of septic system failure was assumed, 20 percent of which is sufficiently close to waterbodies to cause direct loading of nutrients. These septic failures are illicit discharges and there are programs in place to detect and deter illicit discharges.

No comprehensive, up-to-date coverage of sewer service areas is available for the entire watershed. Data from the 1990 census indicate the following sewer usage proportions (NC DEH, 1999). :

- Alamance County, 62% of population,
- Chatham County, 33% of population,
- Durham County, 91% of population, and
- Orange County, 68% of population.

The reporting conditions for Guilford County are incorrect and not presented in this document. The 2000 census did not collect information on sewage and septic. Sanitary sewer overflows (SSO) and sewer pipe leaks may also contribute to nutrient loading of Jordan Reservoir.

According to the NC Division of Forest Resources, managed forest activity (cut and reforestation) totaled approximately 15,423 acres in Chatham, Durham, Alamance, Orange and Guilford Counties between 1997 and 2001 (Raval, 2004). Assuming all of the activity occurred within the Jordan Reservoir watershed (activities are not tracked by watershed), it would represent approximately 1% of the total area and 3% of the total forested land use. In addition, managed forest in the Jordan Reservoir watershed generally does not receive fertilization (Raval, 2004).

5 Modeling Approach

The existing data memorandum (Tetra Tech 2001) documents the application of a scoping-level, steady-state model of average annual lake response. This model does an adequate job of explaining the spatial gradients in average chlorophyll *a* concentrations in the lake in a given year. A single set of model parameters did not appear to fully capture the year-to-year variability in lake response. This likely reflects: (1) variability in nutrient loss to sedimentation associated with differing hydraulic patterns, (2) the complex, time-dependent interaction between the New Hope and Haw River management areas, and (3) the inability of the model to fully distinguish between algal responses in the short residence time Haw River arm versus the longer residence time New Hope arm.

Accordingly, it appeared that a more sophisticated modeling approach would be required to meet the needs for a calibrated nutrient response model. Specifically, an appropriate deterministic modeling tool should be able to: address dynamic changes in response on an intra-seasonal scale; represent the actual pattern of mixing between lake management areas; and include a representation of nutrient cycling that can represent nutrient-algal and water column-sediment interactions at a more sophisticated, process-based level.

In April 1999, the EMC approved a joint proposal from seven local governments to develop the Jordan Reservoir Nutrient Response Model. The original "Project Partners" included Burlington, Graham, Greensboro, Mebane, Orange Water and Sewer Authority, Pittsboro, and Reidsville. Subsequently, the cities of Apex and Cary joined as Project Partners.

In July 2002, the Jordan Reservoir Nutrient Response Model, developed for the Jordan Reservoir Project Partners by Tetra Tech, Inc., was delivered to the NC Environmental Management Commission. The model was developed under a requirement of the NC Clean Water Responsibility Act (HB 515). The model is a linked system that relies on Environmental Fluid Dynamics Code (EFDC) and Water Analysis Simulation Program (WASP) model simulations.

Later in 2002, DWQ placed the upper New Hope Arm of Jordan Reservoir on the 303(d) list of impaired waters requiring estimation of a Total Maximum Daily Load (TMDL) to meet the water quality criterion for chlorophyll *a*. DWQ selected the Jordan Reservoir Nutrient Response Model as a tool to develop the nutrient TMDL required by EPA.

Tetra Tech assisted DWQ in enhancing the Jordan Reservoir model for use in TMDL development and lake management, and developing additional watershed nutrient loading analysis tools. Additional data from an extensive monitoring study conducted by DWQ from late 2000 through 2001 was used for additional validation testing and calibration of the Jordan Reservoir Nutrient Response Model. Also, a spreadsheet-based model was developed that combines Generalized Watershed Loading Function (GWLF) model simulation of seasonal nutrient loads coupled with a stream transport and delivery model that can estimate both the point and nonpoint source component nutrient delivery to the lake.

5.1 Jordan Reservoir Response Model Enhancement - Summary

What follows is a summary of the lake nutrient response modeling. Detailed documentation is contained within two volumes: Tetra Tech (2002) and Tetra Tech (2003a).

The model is a linked system: hydrodynamic output and temperature simulation generated by EFDC (Hamrick, 1996) are input to the WASP water quality model (Ambrose et al., 1993) to account for the dynamic processes of lake mixing, seasonal changes, and nutrient cycling. A model representation of the lake and associated segmentation is shown in Figure 9. The EFDC and WASP input files require extensive amounts of data to predict nutrient cycling in Jordan Reservoir. Meteorology, hydrology, and nutrient loading must be considered simultaneously to predict impacts on the algal community. FLUX (Walker, 1987) is used to integrate observed concentration data and continuous flow series to create time series of loads, which are used to establish the tributary boundary loads for the Jordan Reservoir Nutrient Response Model.

The original nutrient response model was developed and calibrated based primarily on data collected from 1997 to 2000 (Tetra Tech, 2002). The subsequent application of the lake response model to 2001 was originally intended solely as a validation test of the previous calibration. The initial 2001 validation, however, was only partially successful, necessitating a constrained recalibration of the entire model.

Initial results for the recalibrated model showed that the simulation for 2001 did not meet the pre-specified criteria for average absolute prediction error at all monitoring stations, and tended to under-predict nutrient and algal concentrations during portions of the year. Changes in analytical laboratories and procedures as well as changes for in-lake and tributary monitoring for 2001 are some suspected sources of uncertainty. A final recalibration was undertaken with the intention of obtaining the best fit to both the 1997-1999 and 2001 results. Despite some inaccuracies in the simulation, the recalibrated model continues to provide a good representation of nutrient response in Jordan Reservoir.

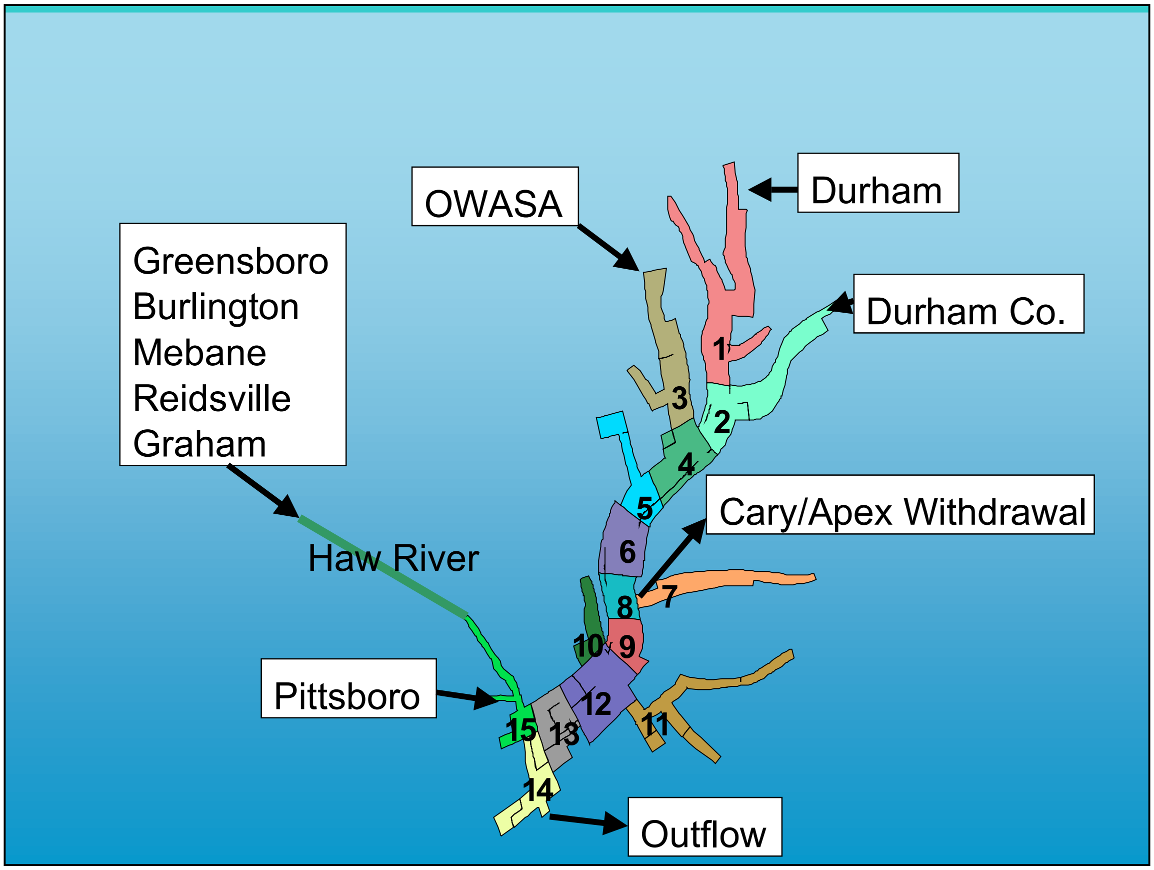

Figure 9. WASP model surface segments for Jordan Reservoir (outline at flood pool elevation). Major discharges and withdrawals are identified.

Highlights of the recalibrated model and validation:

- During the final recalibration, a compromise was made between fit for the 1997-1999 and 2001 periods. This results in a small degradation in the quality of fit. The resulting average absolute errors are often greater than the desired maxima of 0.25 for total nitrogen and 0.025 for total phosphorus. However, the errors for 1997-1999 and 2001 are generally of opposite sign and compensating.
- The model provides a good representation of summer algal concentrations for 1997-2001, represented as chlorophyll *a*, throughout the lake. The model, however, appears to under-predict chlorophyll *a* concentrations reported by NC DWQ during the fall of 2000 and 2001. For 2000, the fall chlorophyll *a* data are uncorrected for pheophytin. These issues were, however, resolved for the 2001 sampling. Thus, apparent under-estimation of chlorophyll *a* in fall 2001 should be considered in model interpretation and application.
- The 2000 lake data were not used in the recalibration process, and are therefore available for model validation. Unfortunately, only a limited amount of tributary data is available for 2000, so a relatively high degree of uncertainty in estimation of tributary loads is expected for this year. This fit yields some noticeable improvements over the results for 2000

presented for the previous model calibration (Tetra Tech, 2002). The only major discrepancies in the 2000 results are for fall chlorophyll *a* concentrations.
- Figure 10 provides a color ramp of simulated chlorophyll *a* concentrations (average) and frequency of concentrations greater than 40 µg/L for Jordan Reservoir, 1997-2001.

5.1.1 Special Issue: Carbon to Chlorophyll a Ratio

The water quality modeling tool is based on the EPA WASP5/EUTRO model. This model does not simulate chlorophyll *a* directly. Rather, it simulates phytoplankton carbon and converts this carbon concentration to a chlorophyll *a* concentration for reporting purposes based on a carbon:chlorophyll ratio. In addition, the model simulates algae as a single group.

This formulation limits the ability of the model to represent the effects of seasonal changes in algal species composition on chlorophyll *a* concentrations. Two major factors may influence the apparent difference in chlorophyll response during the fall season: First, there is a shift in species composition from summer dominance by cyanophytes to a mixed assemblage with a large proportion of diatoms. Second, available light for photosynthesis declines during the fall, causing algae to adjust their internal carbon:chlorophyll ratio.

The model is calibrated primarily to summer conditions, and thus reflects growth kinetic coefficients and a carbon: chlorophyll ratio typical of cyanophyte dominance in high light conditions (a ratio of 50 is used for calibration to observed chlorophyll *a*). Algae present in the fall typically have a lower ratio under good light conditions (more chlorophyll *a* per unit of carbon), and this ratio is likely to further decrease as available light declines.

The use of a theoretical calculation of carbon: chlorophyll ratios was explored for portions of the year not dominated by cyanophytes to improve the apparent fit between model predictions and observations. Note that interpretation with an alternate ratio does not affect the internal simulation, which uses algal carbon as a state variable. That this approach is an appropriate one is suggested by the fact that nutrient concentrations appear to fit reasonably well in the fall, suggesting that the discrepancies in chlorophyll *a* do not represent an actual change in algal density and algal activity that would alter the nutrient balance.

The results indicated that a fall chlorophyll *a* prediction calculated with the theoretical carbon: chlorophyll ratio (varied by month according to environmental conditions) does tend to provide a better fit to the observed fall values. It does not, however, provide a precise fit, and appears to underestimate November observations in the lower portion of the reservoir. One possibility is that some of the apparent deviation between model and observations in the fall could also be due to different algal kinetic coefficients (e.g., growth rates, cell nutrient content, Michaelis-Menton coefficients, etc.) for the algal assemblage present in the fall. Representation of different algal groups is not readily feasible within the existing model. Therefore, no adjustment to the model was made based on this analysis.

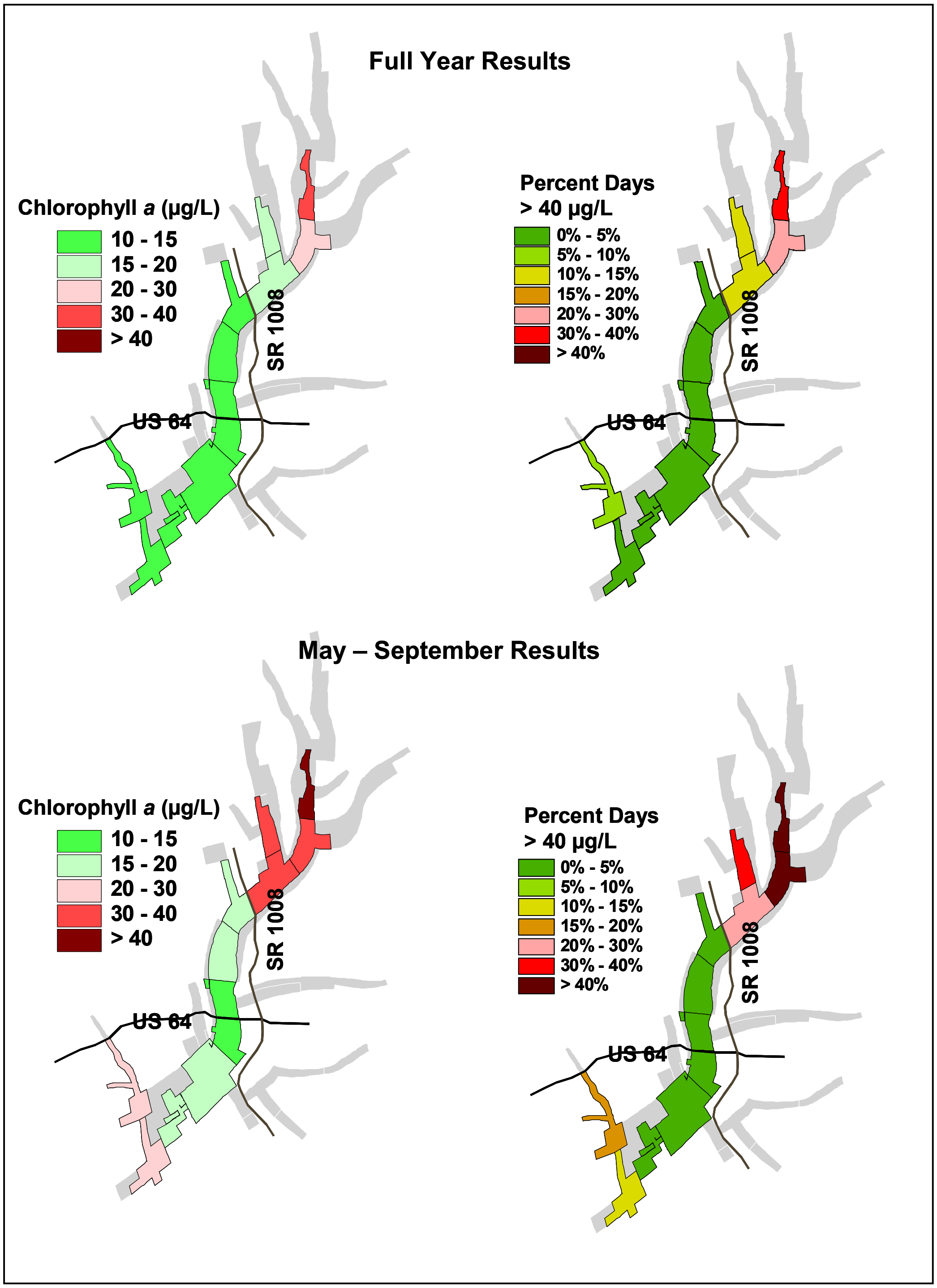

Figure 10. Simulated chlorophyll *a* concentrations (average) and frequency of concentrations greater than 40 µg/L for Jordan Reservoir, 1997-2001. Graphs indicate normal pool overlaid on flood elevation.

5.1.2 Nutrient Limitation

After recalibration, the conclusions regarding the important role of light limitation remain unchanged, but some refinements of the conclusions regarding nutrient limitation are required. Over the course of the simulation period, the most significant nutrient limitation alternates between nitrogen and phosphorus, with neither nutrient exerting strong limitation during the cold season. During the warm season (May-September) nitrogen is estimated to remain the most limiting nutrient - although it was less limiting during 2001, when there were higher inorganic nitrogen loads relative to phosphorus loads than in earlier years.

For the Upper New Hope Arm, nitrogen is the predominant limiting nutrient, because most of the nitrogen is tied up in organic forms. Within the remainder of the lake, nutrient limitation alternates between nitrogen and phosphorus, indicating an approximate balance between the available inorganic fractions of nitrogen and phosphorus.

5.1.3 Existing Nutrient Loads to Jordan Reservoir

Nutrient loads to Jordan Reservoir were calculated based on the input loads to the nutrient response model. Since these loads do not consider the source of the load, point or nonpoint, an additional calculation was made to determine the potential point and nonpoint source contributions to the loading at the lake. Two different methods of determining these contributions were utilized during this project. The first method, described in this section, utilizes the end-of-pipe effluent data reported on discharge monitoring reports (DMRs)and the effluent nutrient delivery model (RTI 2002a). The second method utilizes the watershed loading model described in Section 6.2.

These loads due to continuous point sources were calculated in two steps, as follows:

- First, the load generated at the effluent pipe was calculated. This generated load is also referred to as the end-of-pipe load or simply the point source load. To correspond with the nutrient response model, effluent loads were calculated for each year of the entire modeled period, 1997-2001. An average annual load from those five years, as shown in Tables 6 and 7, was carried forward through the analysis
- Second, the generated load was mathematically transported down-river to Jordan Reservoir. The load that is transported down-river is referred to as the delivered load. The delivered load is calculated using the generated load and transport factors obtained from the RTI Jordan Reservoir Nutrient Delivery Model. (RTI 2002a).

All loads are rounded to the nearest pound. The calculation of point source loads based on DMR data is not without uncertainty. While flow is measured daily, TN and TP concentrations are measured monthly or weekly depending upon the facility. The exception to this is OWASA, which collects daily TP. A simple calculation of annual load based on monthly averages is usually unreliable. Fill-in techniques must be used to generate daily time series that is then used to calculate the annual load values. Annual loads were calculated using methods described in RTI (2002a). Fill-in techniques allow a more reliable and less biased estimation of annual load.
In order to be consistent with lake hydrology, point source loads are summarized based on the area of the lake that received the delivered load. There are three different areas considered for this exercise based on the hydrology, subsequent nutrient response model segmentation (Figure 9), and

nutrient response model results (Figure 10). The three areas are the Upper New Hope Arm, which corresponds to model segments 1 through 4 in Figure 8, the Lower New Hope Arm, which corresponds to model segments 5 through 13, and the Haw River Arm, which corresponds to model segments 14 and 15. Summaries of generated and delivered loads are presented in Tables 6 and 7 for the Upper New Hope and Haw River Arms of Jordan Reservoir, respectively. The Fearrington Utilities, Inc., Fearrington Utilities WWTP (NC0043559) in the Lower New Hope Arm has an average annual TN load of 8138 lb/yr and an average annual TP load of 566 lb/yr. Transport factors of 84% and 88% for TN and TP, respectively, result in average annual delivered loads of 6836 lb/yr TN and 498 lb/yr TP for this facility.

Table 6. Nutrient Load Delivered to the Upper New Hope Arm of Jordan Reservoir by continuous NPDES dischargers

		Average Annual Generated Load, 1997-2001 (lbs)		Transport Factors (a)		Average Annual Delivered Load, 1997-2001 (lbs)	
Permit	Owner	TN	TP	TN	TP	TN	TP
NC0047597	City of Durham/ South Durham WRF	199,126	13,977	75%	67%	149,345	9,378
NC0025241	Orange Water & Sewer Authority/ Mason Farm WWTP	313,155	10,395	63%	47%	197,288	4,886
NC0026051	Durham County/ Triangle WWTP	170,021	9,391	96%	97%	163,220	9,110
NC0056413	Whippoorwill LLC/ Carolina Meadows WWTP	5,284	540	63%	47%	3,329	254
NC0051314	North Chatham Water & Sewer Company, LLC/ Cole Park Plaza	700	55	81%	84%	567	47
NC0043257	Nature Trails Association, CLP/ Nature Trails Mobile Home Park WWTP	2,795	525	81%	84%	2,264	441
NC0042803	Birchwood Mobile Home Park/ Birchwood Mobile Home Park	831	225	70%	64%	582	144
NC0074446	Hilltop Mobile Home Park/ Hilltop Mobile Home Park	414	49	70%	64%	290	31
NC0048429	Cedar Village Apartments/ Cedar Village Apartments	161	33	100%	100%	161	33
	Totals	692,488	35,210			517,045	24,324

(a) Obtained from the Jordan Reservoir Nutrient Delivery Model (RTI 2002a).
(b) Calculated by multiplying the facility generated load by the facility transport factor.

Table 7. Nutrient Load Delivered to the Haw River Arm of Jordan Reservoir by continuous NPDES dischargers

		Average Annual Generated Load, 1997-2001 (lbs)		Transport Factors (a)		Average Annual Delivered Load, 1997-2001 (lbs)	
Permit	Owner	TN	TP	TN	TP	TN	TP
NC0047384	City of Greensboro/ T.Z. Osborne WWTP	552,397	75,871	45%	44%	248,579	33,383
NC0024325	City of Greensboro/ North Buffalo WWTP	510,119	63,382	43%	42%	219,351	26,620
NC0023868	City of Burlington/ Eastside WWTP	311,609	27,217	77%	69%	239,939	18,779
NC0023876	City of Burlington/ Southside WWTP	184,015	21,571	80%	73%	147,212	15,747
NC0024881	City of Reidsville/ Reidsville WWTP	56,151	8,113	66%	56%	37,060	3,543
NC0021211	City of Graham/ Graham WWTP	51,328	10,294	81%	71%	41,576	7,309
NC0021474	City of Mebane/ Mebane WWTP	25,509	3,928	56%	55%	14,285	2,161
NC0020354	Town of Pittsboro/ Pittsboro WWTP	15,613	1,759	76%	82%	111,866	1,442
NC0066966	Quarterstone Farm Homeowners Association/ Quarterstone Farm WWTP	3,520	341	50%	43%	1,625	147
NC0022691	Chateau Communities, Inc./ Autumn Forest Mfr. Home	3,427	329	52%	46%	1,782	151
NC0022675	Country Club Communities LLC/ Birmingham Place	1,237	136	55%	52%	680	71
NC0042285	Trails Property Owners Assoc./ Trails WWTP	488	193	84%	76%	410	147
NC0046043	Oak Ridge Military Academy/ Oak Ridge Military Academy	838	209	46%	41%	386	86
NC0077968	Horners Mobile Home Park/ Horners Mobile Home Park	358	30	58%	49%	208	15
NC0042528	B Everett Jordan & Son – 1927 LLC	184	26	84%	76%	155	19
NC0038156	Guilford County Schools/ Northeast Middle & Senior High WWTP	1,565	156	52%	46%	814	72
NC0073571	Mervyn R. King/ Countryside Manor WWTP	228	39	42%	38%	96	15

		Average Annual Generated Load, 1997-2001 (lbs)		Transport Factors (a)		Average Annual Delivered Load, 1997-2001 (lbs)	
Permit	Owner	TN	TP	TN	TP	TN	TP
NC0035866	County of Chatham/ Bynum WWTP	1,025	146	84%	76%	861	111
NC0029726	NC Department of Correction/ Guilford Correctional Center	772	57	36%	34%	278	19
NC0065412	REA Enterprises, LLC/ Pleasant Ridge WWTP	417	44	51%	45%	213	20
NC0046809	Pentecostal Holiness Church/ Pentecostal Holiness Church	51	5	46%	41%	24	2
NC0060259	Willow Oak Mobile Home Park/ Willow Oak Mobile Home Park	894	122	51%	45%	456	55
NC0031607	Alamance-Burlington School System/ Western Alamance Middle School	681	61	64%	58%	436	36
NC0046019	Episcopal Diocese of North Carolina/ The Summit WWTP	44	5	46%	41%	20	2
NC0045161	Alamance-Burlington School System/ Altamahaw/ Ossipee Elementary	383	39	58%	49%	222	19
NC0045144	Alamance-Burlington School System/ Western Alamance High School	743	77	64%	58%	476	45
NC0038172	Guilford County Schools/ McLeansville Middle School	2,044	123	36%	34%	736	42
NC0022098	Cedar Valley Communities LLC/ Cedar Valley WWTP	367	88	55%	52%	202	46
NC0045152	Alamance-Burlington School System/ Jordan Elementary	232	37	84%	76%	195	28
NC0055271	Shields Mobile Home Park/ Shields Mobile Home Park	150	17	64%	58%	96	10
NC0038164	Guilford County Schools/ Nathanael Greene Elementary	469	40	75%	66%	352	27
NC0036994	Rockingham County Board of Education/ Monroeton Elementary School	71	61	42%	38%	30	23

		Average Annual Generated Load, 1997-2001 (lbs)		Transport Factors (a)		Average Annual Delivered Load, 1997-2001 (lbs)	
Permit	Owner	TN	TP	TN	TP	TN	TP
NC0066010	Rockingham County Board of Education/ Williamsburg Elementary School	51	65	51%	45%	26	29
NC0045128	Alamance-Burlington School System/ Sylvan Elementary School	232	32	84%	76%	195	24
NC0003671	Amoco Oil Company/ Amoco Greensboro Terminal	---	---	---	---	---	---
NC0071463	Apex Oil Company/ Apex Oil Company	---	---	---	---	---	---
NC0003913	Glen Raven Inc/ Altamahaw Division plant	251	48	58%	49%	146	23
NC0001210	Monarch Hosiery Mills Inc./ Monarch Hosiery Mills, Inc.	2,609	124	58%	49%	2,513	61
NC0001384	Burlington Industries, Inc./ Williamsburg plant	943	88	48%	47%	453	41
NC0048241	Staley Hosiery Mills/ Staley Hosiery Mills	21	324	74%	65%	16	211
	Totals	1,730,765	215,195			972,964	111,580

(a) Obtained from the Jordan Reservoir Nutrient Delivery Model (RTI 2002a).
(b) Calculated by multiplying the facility generated load by the facility transport factor.

Using the above delivered loading for point sources and the loading utilized for the calibrated reservoir model, the total nutrient loading for the baseline period (1997 through 2001) is presented in Table 8. Nonpoint source loads for each management area of the reservoir were calculated by difference.

Table 8. Existing nutrient loads to Jordan Reservoir (1997-2001 average in lb/yr).

	Total Load	Point Sources	% Point Sources	Nonpoint Sources	% Nonpoint Sources
Total Nitrogen					
Haw	2,790,217	972,964	35%	1,817,253	65%
Upper New Hope	986,186	517,045	52%	469,141	48%
Lower New Hope	221,929	6,836	3%	215,093	97%
Total Phosphorus					
Haw	378,569	111,580	29%	266,989	71%
Upper New Hope	87,245	24,324	28%	62,921	72%
Lower New Hope	26,574	498	2%	26,076	98%

The nonpoint source loads shown in Table 8 include those from traditional nonpoint sources as well as loads from stormwater.

5.2 Watershed Model Development - Summary

The lake model is driven by observations of flow and nutrient loads in tributaries to the lake, calculated using the FLUX model. This reliance on observations meant that it was not necessary to develop a full watershed model to implement the lake model. However, as part of the analyses performed for that work, RTI developed a point source nutrient delivery tool to estimate the fractions of discharged point source nutrient loads that are delivered to the lake. This work was based on national parameters for an instream loss model, and not calibrated to site-specific observations. In addition, the existing suite of tools did not explicitly represent the sources of nonpoint nutrient loads within the Jordan Reservoir watershed. The Jordan Reservoir nutrient response model provides an ideal platform with which to evaluate the impacts of a range of nutrient reduction scenarios. However, additional watershed nutrient loading analysis tools were desired to provide a foundation for attributing and evaluating nutrient load sources, delivery, and management opportunities within the watershed. A summary of the watershed modeling for Jordan Reservoir is provided below. Detailed documentation is provided in Tetra Tech (2003b).

Nonpoint loading of water and nutrients is simulated in the Jordan Reservoir watershed using the Generalized Watershed Loading Function (GWLF) model (Haith et al., 1992). The complexity of this loading function model falls between that of detailed simulation models and simple export coefficient models. GWLF provides a mechanistic, simplified simulation of precipitation-driven runoff and sediment delivery. Solids load, runoff, and groundwater seepage can then be used to estimate particulate and dissolved-phase nutrient delivery to a stream, based on concentrations in soil, runoff, and groundwater.

The GWLF model provides a well-accepted tool for generating seasonal loads at the small watershed scale. However, GWLF is limited in its ability to simulate large watersheds (such as the Haw River drainage) as it does not explicitly represent nutrient transformations and losses during transport through the stream network and upstream impoundments. Therefore, a spreadsheet-based model was developed that combines GWLF simulation of seasonal loads at the 14-digit HUC scale coupled with a stream transport/delivery model that can estimate both the point and nonpoint source component nutrient delivery to the lake. Such a tool provides a basis to estimate nutrient load allocations by addressing over-land runoff, septic system input, groundwater discharge into streams, and nutrient delivery to Jordan Reservoir.

The spreadsheet model incorporates a nonpoint loading series that ties nutrient load generation to land use and meteorology. The loading series are developed for the major land use, geology and soil areas in the watershed, drawing to a large extent upon existing GWLF calibrations local to the area, including the Cane Creek Reservoir watershed and the Falls Lake watershed. Quarterly and annual loads are generated based on variations in hydrology using the example GWLF models to calibrate the loading factors for the entire watershed. Point source loads are input to the spreadsheet according to outfall location in the stream network. The stream network and delivery component of the spreadsheet are based on an enhanced and refined version of the RTI Jordan Reservoir Nutrient Delivery Model (JLNDM).

5.2.1 Land Use

An improved land use database was created consisting of the 1992 National Land Cover Database (NLCD) from the Multi-Resolution Land Characterization (MRLC) Consortium, updated in Orange, Durham, Chatham, and Wake counties using current tax parcel information, and updated in all other areas for residential density using the 2000 Census. This yields a near-current estimate of land use in the basin, with the primary exception that commercial/industrial development in the Haw River basin that occurred after the date of the NLCD.

5.2.2 Hydrologic Response Units

The U.S Department of Agriculture - Natural Resources Conservation Service (USDA-NRCS) delineated the Jordan Reservoir watershed into 58 hydrologic units (HUCs), averaging 29 square miles. For analytical and planning purposes, these units were categorized into one of 14 nutrient response zones based on soil erodibility, geographic region, and rainfall-runoff response.

For model development, unit (per-acre) watershed loads are combined with estimates of delivery to the lake. Different unit loads are appropriate for different areas of the watershed, due to differences in precipitation patterns and soil characteristics. Those areas with similar characteristics can be combined for the analysis of unit loads. Such areas of similar characteristics are termed hydrologic response units or HRUs.

5.2.3 GWLF Development

The GWLF application requires information on land use distribution, meteorology, and parameters that govern runoff, erosion, and nutrient load generation. In addition to the land use database, four primary data input classes are used to develop the model parameters for the watershed simulations: 1) soil and hydrologic properties, 2) nutrient concentration, buildup, and runoff assumptions, 3) onsite wastewater disposal information, and 4) meteorological data. The land use, watershed delineations, population, septic numbers, and meteorology data were collected and processed to generate a multi-year time series (April 1991 - March 2000 meteorology), which was used to derive seasonal and annual loading rates by land use type for each model HRU.

Nutrient loading from different land uses is based on the volume of flow and its pathways (overland or seepage), the amount of soil eroded, and coefficients that express the amount of nutrient load per unit volume of flow or erosion from a given land use.

GWLF is used to generate unit-loading rates for Jordan Reservoir watershed land uses within 14 nutrient response zones that encompass each of the 58 hydrologic units within the basin. Average loading rates by land use are summarized in Table 9.

5.2.4 Stream Delivery Model

The stream network delivery model relates the field scale loading estimates by land use and measured point source loads to the delivered or exerted load at Jordan Reservoir. Three types of factors are assessed: major stream delivery rates, representing the fraction delivered from point source discharges or the pour points of 14-digit HUCs during stream/river transport, trapping within impoundments, and local-scale trapping within 14-digit HUCs. All three factors serve to reduce the delivered nutrient load.

Table 9. Summary of Average Annual Field-Scale Loading Rates by Land Use Across all HRUs (lb/ac/yr).

Code	Land use description	TN	TP
BAR	Barren	45.96	29.92
CIT	Commercial/Heavy Industrial	24.05	3.70
FOR	Forest	1.59	0.33
OFF	Office/Light Industrial	16.47	2.63
PAS	Pasture	5.69	1.08
RVH	Residential <0.25 ac per du (sewered)	15.03	2.47
RHH	Residential – 0.25-0.5 ac per du (sewered)	11.86	2.00
RMH	Residential – 0.5-1.0 ac per du (sewered)	11.72	1.94
S-RMH	Residential – 0.5-1.0 ac per du (unsewered)	41.42	2.03
RML	Residential – 1.0-1.5 ac per du (sewered)	10.89	1.81
S-RML	Residential – 1.0-1.5 ac per du (unsewered)	28.71	1.86
RLL	Residential – 1.5-2.0 ac per du (sewered)	9.37	1.71
S-RLL	Residential – 1.5-2.0 ac per du (unsewered)	22.09	1.74
RVL	Residential – 2.0+ ac per du (sewered)	2.49	0.60
S-RVL	Residential – 2.0+ ac per du (unsewered)	11.40	0.63
ROW	Row Crop	13.37	5.32
UGR	Urban Green Space	3.57	0.61
WAT	Water	0.00	0.00
WET	Wetland	2.20	0.40

Delivery through the major stream network is represented using a methodology similar to the transport component of the USGS SPARROW approach (Smith et al., 1997). SPARROW refers to spatially referenced regressions of contaminant transport on watershed attributes, and was developed based on nationwide USGS NASQAN monitoring of 414 stations. The model empirically estimates the origin and fate of contaminants in streams, and quantifies uncertainties in these estimates based on model coefficient error and unexplained variability in the observed data.

The SPARROW tool actually contains two portions, one to generate loads and one to account for mass transport through stream reaches. The approach used for the Jordan Reservoir watershed is to use GWLF to generate the loads at the 14-digit HUC scale and then apply the portion of SPARROW that estimates instream transport losses.

Initial estimates of rates of nutrient transmission within the stream network were developed by RTI. The major stream delivery rates in the spreadsheet model were initially adjusted and then modified during calibration to achieve qualitative agreement with loads calculated by FLUX. Nutrient removal in these lakes was approximated using the same second order sedimentation rate equations employed in the BATHTUB model (Walker, 1987).

The nonpoint load is subject to three types of removal: retention in the local HUC, removal by lakes, and removal during instream transport. In contrast, the point source loads are subject only to removal during instream transport (none of the point sources are upstream of major impoundments). As a result, the delivered fraction for point sources is on average much higher than the delivered fraction for nonpoint sources, even though point and nonpoint sources are subject to the same instream removal processes.

5.2.5 Watershed Model Results

Sources of the nonpoint nitrogen and phosphorus load in the Upper New Hope Management Area are summarized in Figure 11. The Jordan Reservoir watershed contains a complex overlay of municipal and county jurisdictions with responsibility for the management of point and nonpoint sources. These jurisdictional boundaries typically do not correspond with subwatershed boundaries, which complicates any analysis of loads from individual jurisdictions to specific management areas of the lake. A useful summary is provided by analyzing exerted loads (loads delivered to the lake) by county. This is obtained by overlaying county and HUC boundaries, and weighting the exerted load from each HUC by area in a given county. Results are shown in Table 10.

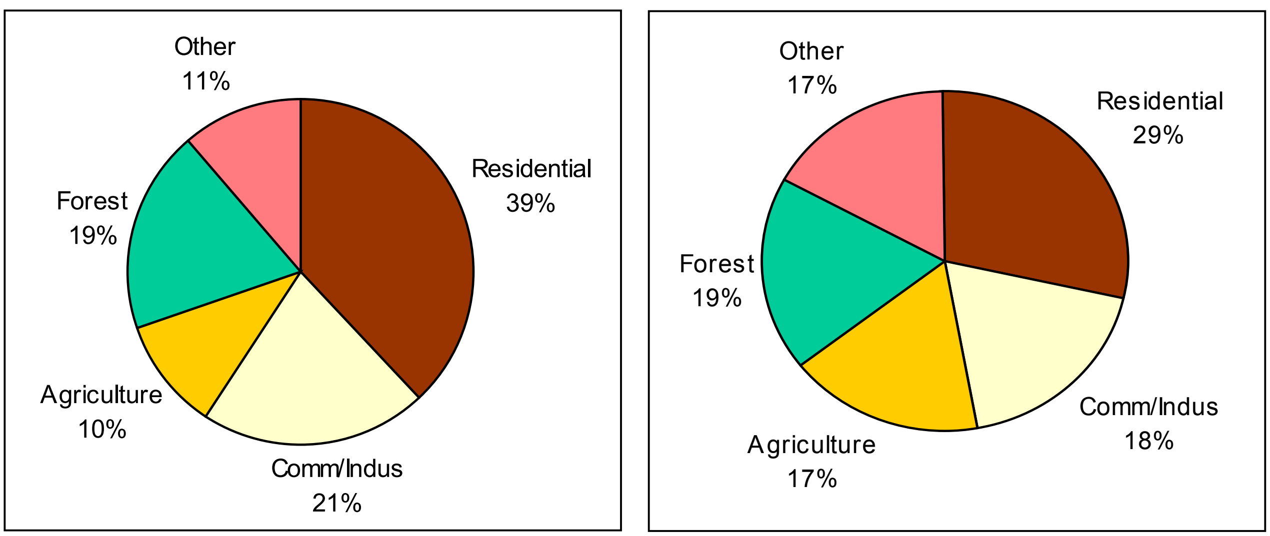

Figure 11. Sources of nitrogen (left panel) and phosphorus (right panel) nonpoint source loading to Jordan Reservoir in the Upper New Hope Arm.

Table 11 shows the percentage breakdown between point and nonpoint load sources delivered to Jordan Reservoir on a long term average basis. During the baseline period for the TMDL, the proportions will be different due to a drier hydrological condition. The nonpoint loads represent the long-term average derived from a 9-year simulation with the watershed model, while the point source loads represent the average delivered load for 1996-1998, the period for which RTI conducted a detailed analysis. The percentage contribution of point sources to nitrogen loads is similar to previous estimates (e.g., Tetra Tech, 2002) made without a calibrated watershed model. However, the point source contribution of phosphorus is less than was previously estimated, due to changes in the rates of instream trapping made during calibration of the delivery model.

Table 10. Distribution of Point and Nonpoint Source Nutrient Load Delivered to Jordan Reservoir by County.

County	Nonpoint load	Point source load	Total delivered	Percent of total
Total nitrogen				
Alamance	1,057,181	551,935	1,609,117	32.1%
Caswell	39,540	0	39,540	0.8%
Chatham	648,685	13,902	662,586	13.2%
Durham	251,321	298,027	549,348	11.0%
Forsyth	3,089	0	3,089	0.1%
Guilford	698,739	556,505	1,255,244	25.0%
Orange	395,160	156,728	551,888	11.0%
Randolph	8,686	0	8,686	0.2%
Rockingham	140,240	41,799	182,039	3.6%
Wake	151,527	0	151,527	3.0%
Total	3,394,168	1,618,896	5,013,064	
Total phosphorus				
Alamance	244,814	45,679	290,493	34.1%
Caswell	5,505	0	5,505	0.6%
Chatham	160,706	2,383	163,089	19.2%
Durham	42,691	15,445	58,136	6.8%
Forsyth	566	0	566	0.1%
Guilford	132,043	60,986	193,029	22.7%
Orange	72,930	4,702	77,631	9.1%
Randolph	2,062	0	2,062	0.2%
Rockingham	32,384	3,987	36,371	4.3%
Wake	24,520	0	24,520	2.9%
Total	718,221	133,182	851,403	

Table 11. Long-term average proportions of point and nonpoint source loads in the Jordan Reservoir watershed.

Watershed area	Point sources	Nonpoint sources
Total nitrogen		
Haw River Arm	32%	68%
Upper New Hope Arm	45%	55%
Lower New Hope Arm	4%	96%
Total phosphorus		
Haw River Arm	18%	82%
Upper New Hope Arm	17%	83%
Lower New Hope Arm	2%	98%

6 Reduction Targets

Reductions targets were evaluated for each area of the reservoir, as presented in Section 5. Thus, three different sets of reduction targets were calculated for Jordan Reservoir. All targets were derived consistent with methodology for TMDLs, regardless of current listing status. This was performed in order to avoid inconsistencies that could occur as a result of overlapping state programs for nutrient sensitive waters and federal programs for impaired waters.

6.1 Total Maximum Daily Load (TMDL)

A Total Maximum Daily Load is the maximum amount of a pollutant that a water body can receive and still meet water quality standards, partitioned among point and nonpoint sources. A TMDL is comprised of the sum of wasteload allocations (WLA) for point sources, load allocations (LA) for nonpoint sources, and a margin of safety (MOS), expressed by the equation:

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

The objectives of the TMDL are to estimate allowable pollutant loads, and to allocate them among the general pollutant sources in the watershed. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time (e.g. pounds per day), toxicity, or other appropriate measures. This TMDL will be expressed in terms of percent load reduction and allowable load of TN and TP. Further analysis was required to determine the breakdown between point source (WLA) and nonpoint source (LA) loadings that meet the TMDL objectives.

6.2 Model Scenarios

A 10 percent or less frequency of predicted (daily average) chlorophyll *a* concentrations greater than 40 µg/L is taken as the frequency target for management. The use of a 10 percent frequency as a target for completion of a chlorophyll *a* TMDL in North Carolina is supported by EPA. This TMDL is expected to reduce the nutrient inputs to Jordan Reservoir that contribute to algal blooms as indicated by chlorophyll *a* excursions. Nutrient load reductions developed using the water quality model must insure that the state chlorophyll *a* standard of 40 µg/L or less will be met 90 percent of the time during critical conditions (i.e. summer months).

For spatial applicability, results could be analyzed for individual model segments, or as an aggregate frequency across some or all of the model segments. Temporal applicability is also subject to interpretation. Four potential options were evaluated for the each area of Jordan Reservoir:

1. Long-term (five-year) frequency of excursions over all seasons,
2. Long-term (five-year) frequency of excursions for summer season (May-September) only,
3. Worst-case (individual 12-month window) annual frequency of excursions, and

4. Worst-case (individual year) frequency of excursions for summer season only.

Options 3 and 4 (the worst-case analyses) were subsequently dropped as overly restrictive and unreliable. A finding of non-compliance from the model using a worst-case approach runs a distinct risk of being caused by anomalies in the model forcing data, such as anomalies in the estimates of tributary load, rather than reflecting actual conditions.

The two long-term analyses (options 1 and 2) were both carried forward for further analyses. Option 1 (frequency over the entire simulation period) is consistent with the approach taken in the Neuse Estuary TMDL, and is likely to be less restrictive than requiring a 10 percent or less frequency during the summer season (because lower algal concentrations are expected in winter and early spring). However, this option has a drawback in that the model appears to underestimate chlorophyll *a* concentrations during the fall. Application of the 10 percent frequency target to a summer season (Option 2) is consistent with the TMDLs for the Roberson Creek Cove of Jordan Reservoir and Lake Wylie. Use of this option has the advantage of focusing on the period for which the model performs best, while avoiding the fall period in which the model may under-predict chlorophyll *a* concentrations.

The general strategy for scenarios was to run the calibrated water quality model for the full simulation period (1997-2001) with modifications to external loading and analyze the resulting predictions of chlorophyll *a* concentration in relation to magnitude and frequency targets. This procedure yields an estimate of total loading reductions necessary to meet the target. At this stage, the analysis does not distinguish between point and nonpoint loading components.

While algal growth in the Upper New Hope Arm of Jordan Reservoir is most strongly limited by inorganic nitrogen, algae can be expected to respond to loads of both nitrogen and phosphorus. This means that a loading target is potentially bivariate, consisting of a paired target loading rate for both nitrogen and phosphorus.

The recalibrated model was used to evaluate load reduction scenarios for the lake. These scenarios address the question, "What degree of reduction in existing nutrient loads, from all sources, would be required to achieve water quality standards in the listed portions of the reservoir?" Results of these scenarios were used to help formulate nutrient loading targets for all parts of the reservoir, including the 303(d) listed portion. Figure 12 presents the final scenario recommended for target setting representing summer season chlorophyll *a* response to changes in nutrient load to the Upper New Hope. Results are based on aggregated model segments, weighted by segment volume, considering summer seasons from 1997 – 2001 collectively.

Using the 8% exceedance line to incorporate an explicit margin of safety, a 35% reduction in existing TN loading will be needed for the Upper New Hope Arm. A large fraction of TP load would have to be reduced to discern an effect on chlorophyll *a* concentrations if less TN reduction were sought. Since P is limiting for certain algal groups and during certain times of the year, a small reduction will be sought (5%) along with the TN reductions in this nutrient-rich system. In addition, model analysis indicates that changes in loads from the Haw River Arm have little effect on conditions in the Upper Hew Hope Arm (Tetra Tech 2003). Since the Upper New Hope Arm of the reservoir is currently on the state 303(d) list of impaired waters, this target is also equal to the TMDL for the Upper New Hope Arm of Jordan Reservoir.

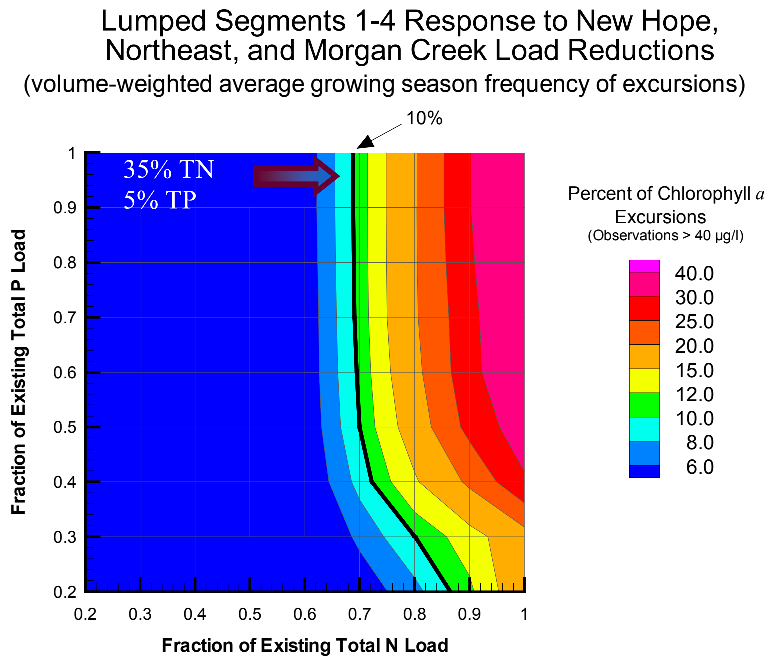

Figure 12. Volume-weighted aggregate responses to Jordan Reservoir load reductions in the Upper New Hope Arm

The nutrient response model output was also reviewed to determine the TMDL for the Haw River Arm of the reservoir. A bivariate plot of potential reductions in TP and TN was generated for the Haw River Arm, using model segments 14 and 15, to evaluate appropriate actions. Results are based on aggregated model segments, weighted by segment volume, considering summer seasons from 1997 – 2001 collectively. Unlike the Upper New Hope Arm, chlorophyll *a* in the Haw River Arm is predicted to react to smaller reductions in both nitrogen and phosphorus. As seen in Figure 13, a diagonal response line is associated with chlorophyll *a* standard compliance. Using the 8% exceedance line to incorporate an explicit margin of safety, an 8% reduction in existing TN loading and a 5% reduction in existing TP loading is needed for the Haw River Arm. Since the Haw River Arm of the reservoir is currently on the state 303(d) list of impaired waters, this target is also equal to the TMDL for the Haw River Arm of Jordan Reservoir.

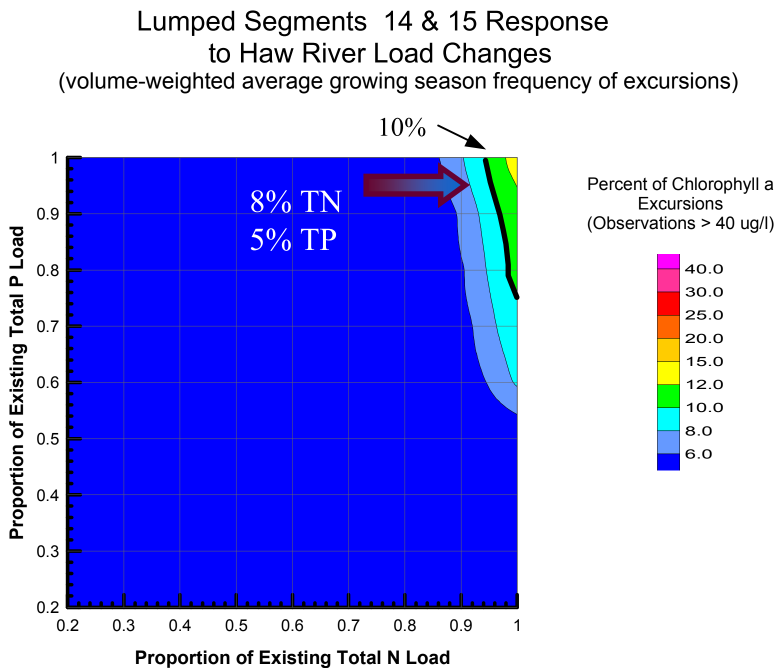

Figure 13. Volume-weighted aggregate responses to Jordan Reservoir load reductions in the Haw River Arm

The model predicted a very low frequency of standard violations in the Lower New Hope Arm. Thus, a chart similar to those presented above in Figures 12 and 13 was not produced. Since the model provides no basis for loading reductions in this portion of the lake, a cap on nutrient loading is proposed for the watershed draining to this section of the reservoir. DWQ believes the derivation of this cap is consistent with existing TMDL guidance. Since the Lower New Hope Arm of the reservoir is currently on the state 303(d) list of impaired waters, this cap is also equal to the TMDL for the Lower New Hope Arm of Jordan Reservoir. It should be noted that nutrient reductions in the Upper New Hope and Haw River watershed areas are likely to have an impact on the Lower New Hope Arm of the reservoir, resulting in less available nutrients for algal uptake.

A summary of loading targets for the management areas of Jordan Reservoir is shown in Table 12.

Table 12. Loading targets for the Jordan Reservoir management areas

	Existing Load (lbs/yr)	TMDL Reduction	TMDL
Upper New Hope Arm			
Total nitrogen	986,186	35%	641,021
Total phosphorus	87,245	5%	82,883
Lower New Hope Arm			
Total nitrogen	221,929	N/A (a)	221,929
Total phosphorus	26,574	N/A (a)	26,574
Haw River Arm			
Total nitrogen	2,790,217	8%	2,567,000
Total phosphorus	378,569	5%	359,641

(a) Loading capped at level equal to 1997-2001 baseline delivered loads.

6.3 Critical Conditions

Critical conditions can be considered a subset of seasonality: the most stringent of the seasons. The years on which the model is developed are somewhat biased toward drier conditions, which tend to promote algal growth by increasing residence time. The model simulation period contains a wet year (1998) a normal year (1997) and three years that were drier than normal, although each with different characteristics (1999-2001). However, the seasonal analysis shows that inflows and precipitation were not extraordinarily low, except for local precipitation during the summer of 1999. The drought, in terms of water supply availability, was the cumulative effect of several years of below normal precipitation and flow, and conditions, when examined on a seasonal basis, was generally not so extraordinarily rare as to be unrepresentative of the expected range of lake response. In addition, the TMDL is based on an annual load allocation necessary to achieve the chlorophyll *a* target during the critical conditions (May through September).

6.4 Seasonal Variation

Seasonal variation is considered in the development of the TMDL. The allocation applies to all seasons. Seasonal variation in hydrology, climatic conditions, and watershed activities are represented through the use of a continuous flow gage and the use of all readily available water quality data collected in the watershed. A wide range of flow conditions is modeled for this TMDL, demonstrated by the inter-annual variation in hydrology.

6.5 Attainment of other Water Quality Standards

Allocations for nutrients in the Jordan Reservoir TMDL cannot result in violations of other water quality standards (CWA § 303(d)(1)(C)), such as low dissolved oxygen or elevated pH. The North Carolina fresh water standard for pH in Class C waters (T15A: 02B.0211) states that pH shall be normal for the waters in the area, which generally shall range between 6.0 and 9.0 except that swamp waters may have a pH as low as 4.3 if it is the result of natural conditions. Use support assessment in the Haw Arm of Jordan Reservoir has revealed elevated pH with respect to the standard in greater than 10 percent of samples since the time the lake was listed for chlorophyll *a*. The Haw Arm was subsequently placed on the 2006 303(d) list for pH impairment. Algal blooms can affect pH of fresh waters through the consumption of CO_2 in photosynthesis during the day (which effectively raises pH), and the release of CO_2 in respiration during the night (which effectively lowers pH). Attainment of the chlorophyll *a* standard as a result of this TMDL should reduce the frequency of pH standard excursions. However, it is not known whether the number of excursions will be reduced sufficiently to delist the reservoir for pH impairment. Further study will be necessary to confirm or refute this possibility.

6.6 Model Uncertainty and Margin of Safety

There is uncertainty (in data, modeling tools, and scientific understanding) in the analysis connecting specific levels of nutrient loads to predicted frequency of chlorophyll *a* concentrations greater than 40 µg/L. The inability to accurately predict specific observed concentrations of nutrients and chlorophyll *a* can be attributed to many sources: model error, lack of sufficient information in source assessment, gaps in our scientific knowledge, natural variability, field and laboratory measurement error, and lack of current site specific model input parameters and land use information. Because of certain lack of site-specific information, professional judgment and literature values were sometimes used. In sum, the model results should be interpreted in light of the model limitations and prediction uncertainty.

The margin of safety is an additional factor of the TMDL that accounts for some of the uncertainty in the relationship between pollutant loads and receiving water quality. This margin of safety can be provided implicitly through conservative analytical assumptions and/or explicitly by reserving a portion of the load capacity.

This TMDL utilizes an explicit margin of safety (MOS) applied to the water quality criterion. The frequency of exceeding the criterion (40µg/L) has been reduced from 10% to 8%. In addition, 4 of 5 years (1997-2000) of chlorophyll *a* data used for model calibration represent uncorrected chlorophyll *a*, which is a conservation estimate of corrected chlorophyll *a*.

6.6.1 Data Uncertainty

Uncorrected chlorophyll *a* data were used for model calibration during years 1997 through 2000. In 2001, corrected chlorophyll *a* data are available, and were analyzed using the fluorometric nonacidified method, which reduces pigment interference and does not actually require a "correction" step. The correction is for pheophytin pigment, which is a degradation product that can interfere with the chlorophyll *a* measurement. DWQ used the acidification method from 1981 to January 2001.

As discussed in Tetra Tech (2003), there is a high correlation between corrected and uncorrected chlorophyll *a*. The ratio of uncorrected to corrected chlorophyll *a* data was close to one during July- September, increasing during other seasons. Since the nutrient reduction targets are based on model predictions in the summer season, overestimation of algal biomass due to use of uncorrected chlorophyll *a* data is minimized. Other issues contributing to uncertainty regarding chlorophyll *a* and nutrient data are discussed in Tetra Tech (2003).

6.6.2 Lake Model Uncertainty

The lake model is best judged on its ability to replicate longer-term spatial and temporal trends and the frequency distribution of chlorophyll *a* concentrations greater than the criterion, rather than focusing exclusively on uncertainty in model predictions of point-in-time/point-in-space observations.

Model output should be viewed as a range of potential values based on their probability density functions rather than as a precise single output number. The model provides a reasonable representation of the expected distribution of concentrations (Tetra Tech, 2004). Error statistics do indicate some deviations between observations and predictions for individual point-in-time/point-in-space values (Tetra Tech, 2003a). Statistics for the volume-weighted aggregate segment responses of the Jordan Reservoir model are presented in Appendix III.

In general, the calibration strategy for the model was to capture broad spatial trends and fit multiple parameters simultaneously. The relationships between concentrations of multiple parameters at multiple stations are more significant than the fit to individual points at individual stations. The model fit is aimed at reproducing the central tendency of trends in time and the approximate frequency distribution, rather than replicating individual observations of chlorophyll *a*. For these purposes the model performs reasonably well.

Despite that model prediction of lake response is an inexact science, water quality models are essential to management, providing quantitative guidance for decision-making. As with all modeling projects, there is uncertainty in the data and the models used for Jordan Reservoir. However, even the most well studied, data-rich systems will not allow for certainty in model prediction (e.g., Neuse Estuary). Uncertainty does not preclude a decision to pursue a reasonable management strategy. Post-implementation monitoring of the nutrient management strategy will provide feedback for appropriate adaptive management.

6.6.3 Watershed Model Uncertainty

The combined load generation and delivery models provide a comprehensive analysis of nutrient load delivery to Jordan Reservoir on a seasonal basis. Performance of the model was calibrated against detailed information on point source discharges and FLUX analyses of delivered loads for 1996-1998, using hydrology derived from the Cape Fear Hydrologic Model (DHI and Moffett and Nichols, 2000). All modeling components have been incorporated into a deliverable spreadsheet, which can be readily modified to evaluate impacts of land use changes, alteration of unit loading rate by Best Management Practices (BMPs), or changes in point source wasteload allocations.

Model calibration was performed for the 1996-1998 time period, which corresponded to the availability of the detailed time series of point source reduction ratios calculated by RTI using the CFHM hydrology ratios. Model results were compared to FLUX analysis estimates of actual load in each of the tributary arms (Haw River, Morgan Creek, New Hope Creek, and Northeast Creek).

The FLUX analyses were performed previously for the Jordan Reservoir nutrient response model (Tetra Tech, 2002). An additional FLUX analysis was performed at an intermediate location on the Haw River mainstem using data from the DWQ monitoring station at Saxapahaw, NC (station B2000000). Since FLUX estimates loads from actual monitoring data, both delivered point source and nonpoint source loads were included in the calibration.

After the adjustments to instream loss rates, the model provides a good approximation of the FLUX estimates of loads for the calibration period. Apparent percent differences between the model and FLUX estimates are less than or equal to 10 percent, except for phosphorus in Northeast Creek. The difference in phosphorus for Northeast Creek is primarily due to an over-estimation in 1998, and could reflect an inaccurate estimate of the point source loading component, estimated at 43 percent of the total phosphorus load for 1998.

Watershed models of nutrient loading are inherently subject to high levels of variability, consisting of both uncertainty and natural variability. The natural variability arises because of year-to-year changes in meteorology, plant/growth cover, and land management. Uncertainty reflects the facts that simulation models are, at best, an approximation of reality, and the parameters of simulation models are not known with a high level of precision. Natural variability, or at least that part of it due to meteorology, is best addressed by simulation over a number of years that provide a selection of different weather patterns. This section focuses on the portion of variability that is due to prediction uncertainty.

GWLF application for the majority of the Jordan watershed is not calibrated to site-specific observations (although it uses calibrations from watersheds in the area), which will increase uncertainty. It appears reasonable, based on the Cadmus (1995, 1996) studies, to assume that uncertainty in the estimation of cumulative loads is on the order of 10 percent. The load generation and transport uncertainties are multiplicative. If the transport uncertainty is taken as ± 5 percent, this leads to a range from -14 to +16 percent about the central estimate.

Some further evidence on uncertainty is provided by the comparison of 1996-1998 total loads (point and nonpoint) from the model and FLUX. Error relative to FLUX on annual loads appears to be on the order of ± 10 percent. This results, however, from adjustment of loss rates to achieve a better fit. Bringing together lines of evidence suggests that the total uncertainty on cumulative nutrient loads is likely to be on the order of 20 percent.

6.7 Blue Green Algae

Blue-green algae frequently dominate the summer phytoplankton community in eutrophic lakes, including management areas of North Carolina's Jordan Reservoir. Phytoplankton communities in eutrophic waters may contain the particularly noxious genera of Anabaena, Aphanizomenon, and Mycrocystis. However, these genera are not dominant in Jordan Reservoir at present. Will the proposed nutrient management targets for the lake unintentionally promote a dominance of these noxious genera? The following discussion illuminates the issue.

There are many potential physical, chemical, and biological factors that can lead to blue green dominance of an algal assemblage. Hyenstrand et al. (1998) discusses nine factors: nutrient ratio competition, differential light requirements, carbon dioxide competition, buoyancy, high temperature tolerance, herbivory avoidance, cellular nutrient storage, ammonium-nitrogen exploitation, and trace element competition.

Heterocysts are found in certain filamentous blue-green algae (e.g., Anabaena, Aphanizomenon) enabling fixation of dinitrogen from the atmosphere for growth. In Jordan Reservoir, the dominant blue-green algae (Oscillatoria) during 2003, and indeed in most years, were algae that do not have heterocysts and thus incapable of N fixation (Vander Borgh, 2003).

The ability to fix N has been thought to play a factor in enabling certain blue-green algae to out-compete other species and form noxious blooms when N is in limited supply at low N:P ratios. This hypothesis was initiated by Schindler (1977) and Smith (1983). Along these lines, Smith (2001) cautions against implementing N reduction, alone, or reducing the N:P loading ratios to levels that may promote blue-green algae. Note that in Jordan Reservoir reductions to both nutrients have been proposed.

On average, algae require nutrients in N:P ratios of approximately 7 to 1 by weight, known as the Redfield (1958) ratio (16:1 molar; 7.2:1 weight). Deviations from this ratio in ambient water samples may indicate a potential nutrient limitation. Ratios less than 7:1 tend toward N limitation and higher ratios tend toward P limitation. In systems with an abundance of both nutrients, algal growth may be limited by other factors such as light availability. Due to variability in algal stoichiometry, the ratio should not be considered as an absolute threshold. Accordingly, Thomann and Mueller (1987) suggested that ratios greater than 20:1 likely reflect P limited systems while ratios of 5:1 or less may reflect N limited systems.

In Jordan Reservoir, the currently proposed nutrient reductions will result in average TN:TP watershed loading to the lake in ratios equal to 8:1 to the Upper New Hope Arm, representing a slight decrease for the Upper New Hope Arm. The targets for Jordan Reservoir will result in point source-loading ratio of 14:1 or greater in the Upper New Hope Arm. The proposed reductions should not result in dramatic alterations of the N:P ratios and the target loading ratios exceed the Redfield ratio.

New light has been shed on the prevailing suggestion that low N:P ratios lead to blue-green algal dominance. Ferber et al. (2004) and Downing et al. (2001) cast considerable doubt on the use of N:P ratios as sole predictors of blue-green algal dominance. A multitude of factors contribute to dominance by blue-green algae. Therefore, while the issue may remain somewhat equivocal, the most recent science does not support the use of this hypothesis as a reason not to pursue nutrient reductions. Continued monitoring, including monitoring of the algal community composition, will enable DWQ to evaluate future lake response to these management strategies, allowing for adaptive management as conditions in the lake warrant.

7 Allocations

Both point and nonpoint sources bear an equal burden for nutrient reductions. For example, point and nonpoint sources in the Upper New Hope Arm of Jordan Reservoir must individually reduce nitrogen loads by 35%. This type of reduction strategy is consistent with North Carolina General Statute 143-215.8B(b)(1).

The total allowable nitrogen and phosphorus loads to the reservoir were derived using the modeling tools described previously. In each subdrainage of the reservoir, these loads were divided into the allowable point and nonpoint source loads, referred to as the wasteload and load allocations (i.e., WLA and LA). The allowable loads are divided in the same PS:NPS proportions as were estimated for the baseline period. The WLA was then divided among the existing NPDES dischargers as described below.

The modeling tools take into account that some portion of the nutrients from any given source is lost in transport to the reservoir due to instream processes. The load reaching the reservoir from a particular source is less than the load generated at that source, and the percent loss depends on the source's location in the drainage. As a result of these losses, allowable mass loadings for point sources must be expressed in two different but equivalent forms: the load as it leaves the effluent pipe (i.e., the generated load) and the load as it reaches the reservoir (i.e., the delivered load). The wasteload allocation and the allocations for individual NPDES facilities are expressed as delivered loads. However, permit limits are measured at the point of discharge, so nutrient limits are given in terms of generated loads.

The allowable point and nonpoint source loads, referred to as the wasteload and load allocations, were calculated using information from the modeling tools. Allowable mass loading for point sources is calculated in two forms, the load as it reaches the reservoir (i.e., the delivered load) and the load as it leaves the effluent pipe (i.e., the generated load). These are two different loading rates and, due to instream losses, the load reaching the reservoir is always less than the load leaving the effluent pipe or discharged from an upstream watershed. Thus, the wasteload allocation can be expressed in terms of both the generated and the delivered loads. Wasteload and load allocations presented below are in terms of the load delivered to the reservoir.

No attempt was made to separate permitted (WLA-SW) and nonpermitted (LA) loading associated with nonpoint sources. EPA requires that loads allocated to NPDES permitted stormwater be placed in the wasteload allocation, which had previously been reserved for continuous point source loads (EPA 2002). Since the WLA allocation associated with NPDES permitted stormwater was not separated in a formal manner, the percent reduction associated with the management area (i.e. Upper New Hope Arm, Lower New Hope Arm, and Haw River Arm) will apply. According to the Phase II rules, MS4 permittees are responsible for reducing the loads associated with stormwater outfalls for which it owns or otherwise has responsible control.

The loading allocation for the Upper New Hope Arm of Jordan Reservoir is shown below in Table 13. This table presents the existing nutrient load at the lake, the fraction of that load from point sources, the TMDL loads and the allocations between continuous discharging facilities (wastewater) and permitted and non-permitted stormwater. The wasteload allocation for wastewater was calculated by multiplying the TMDL by the fraction of the baseline load due to point sources.

Table 13. Wasteload and load allocations for the three management areas of Jordan Reservoir (a)

	Existing Load (lbs/yr)	% Point Source Load	TMDL Reduction	TMDL	WLA-wastewater	LA plus WLA stormwater
Upper New Hope Arm						
Total nitrogen	986,186	52%	35%	641,021	336,079	304,942
Total phosphorus	87,245	28%	5%	82,883	23,106	59,777
Lower New Hope Arm (c)						
Total nitrogen	221,929	3%	N/A (b)	221,929	6,836	215,093
Total phosphorus	26,574	2%	N/A (b)	26,574	498	26,076
Haw River Arm						
Total nitrogen	2,790,217	35%	8%	2,567,000	895,127	1,671,873
Total phosphorus	378,569	29%	5%	359,641	106,001	253,640

(a) Wasteload and load allocations presented as delivered loads.
(b) Loading capped at level equal to 1997-2001 baseline nutrient loads.
(c) WLA-wastewater data for Lower New Hope Arm was inadvertently input as end-of-pipe load instead of delivered load in the Public Review Draft TMDL. Data presented here reflect delivered loads. LA plus WLA-stormwater load was also revised to reflect the change in WLA.

The following sections describe the point and nonpoint source strategies developed as part of the nutrient management strategy. Each portion of this strategy was developed over a 1½ year period in a series of open meetings with extensive participation and input of the affected stakeholders.

7.1 Wasteload Allocations

The wasteload allocation (WLA) presented in Table 13 provides the total poundage of nitrogen and phosphorus that continuous point sources may contribute. This loading is the load delivered to the lake, versus the load generated at the wastewater treatment facility. As previously stated, the load generated at the wastewater treatment facility naturally attenuates and a reduced load is delivered to Jordan Lake. However, wastewater treatment NPDES permits are provided in terms of the load generated at the facility, thus the allocation needs to reflect these loads. Non-nutrient bearing loads, such as those from water treatment plants and cooling water, are not included in the allocations.

There are numerous factors considered in the point source allocation strategy. These include the distance from the reservoir and the amount and type of waste discharged. Weighting of the amount of wasteload allocations for each facility was evaluated using the actual annual average flow during the 1997-2001 period, the permitted flow during the 1997-2001 period, and the permitted flow in 2004. Although all three of these scenarios were considered, the final allocations are based on the permitted flow in 2004.

The equivalent treatment concentration method was used to determine allocations. This method satisfies NC General Statute 143-215.8B(b)(1) which requires equitable allocations. Thus, all wastewater treatment plants received allocations based on equitable levels of technology. Allocated annual generated loads were calculated by multiplying the maximum permitted flow by the equivalent treatment concentration and a conversion factor (3,044). These loads will be used in NPDES permits as annual loading targets. Compliance will be judged using the annual loads, not the equivalent treatment concentration. Allocated annual delivered loads calculated by multiplying allocated generated loads by the appropriate transport factor in Table 6. The sum of the allocated annual delivered loads must equal the WLA in Table 13. Summaries of the wasteload allocation analyses for the Upper New Hope Arm and Haw River Arm are listed below.

Upper New Hope Arm. All of the available loading was allocated to the existing facilities. Therefore, there will be no new nitrogen or phosphorus bearing loads permitted in this watershed. There are four facilities discharging greater than 100,000 gallons per day in the watershed of the Upper New Hope Arm: The City of Durham- South Durham WRF, the Orange Water & Sewer Authority- Mason Farm WWTP, the Durham County- Triangle WWTP, and the Whippoorwill LLC- Carolina Meadows WWTP. These facilities account for 99.7% of the total permitted flow from point sources. The discharge allocations for these four facilities provide equivalent concentrations for each facility. For nitrogen, this equivalent concentration is 3.04 mg/L, and for phosphorus this equivalent is 0.23 mg/L. The remaining facilities in the Upper New Hope watershed were allocated at equivalent concentrations of 12.0 mg/L and 2.0 mg/L for nitrogen and phosphorus, respectively.

Haw River Arm. All of the available loading was allocated to the existing facilities. Therefore, there will be no new nitrogen or phosphorus bearing loads permitted in this watershed. There are ten facilities discharging greater than 100,000 gallons per day in watershed of the Haw River Arm: The City of Greensboro- T.Z. Osborne WWTP, the City of Greensboro- North Buffalo Creek WWTP, the City of Burlington- Eastside WWTP, the City of Burlington- Southside WWTP, the City of Reidsville- Reidsville WWTP, the City of Graham- Graham WWTP, the City of Mebane-Mebane WWTP, the Town of Pittsboro- Pittsboro WWTP, the Quarterstone Farm Homeowners Association- Quarterstone Farm WWTP, and the Glen Raven Inc- Altamahaw Division plant. These facilities account for 99.3% of the total permitted flow from point sources. The discharge allocations for these ten facilities provide equivalent treatment levels for each facility. For nitrogen, this equivalent treatment level is 5.3 mg/L, and for phosphorus this equivalent is 0.67 mg/L. The remaining facilities in the Upper New Hope watershed were allocated at equivalent concentrations of 12.0 mg/L and 2.0 mg/L for nitrogen and phosphorus, respectively.

7.1.1 Permitting Options

The strategy for point sources (i.e., wastewater dischargers) calls for all affected dischargers to implement appropriate nutrient controls. Each facility will receive annual mass discharge limits for total nitrogen and for total phosphorus in its NPDES permit. Limits will be expressed as end-of-pipe limits, that is, limits that will apply at the point of discharge. In order to meet the new limits, it will be necessary for most dischargers to upgrade their facilities to effectively remove nutrients. The strategy also calls for all dischargers to optimize nutrient removal in their existing facilities while modifications are designed and built.

The compliance schedule for meeting the nutrient management strategy is outlined in NCGS §143-215.1B(b)(iv). This section describes the following timeline for compliance: "a maximum of three years to plan, design, finance, and construct a facility that will comply with those maximum mass loads and concentration limits. If the Commission finds that additional time is needed to complete the construction of a facility, the Commission may further extend an extended compliance date by a maximum of two additional years."

The strategy provides two permitting options to interested dischargers in order to allow some flexibility with target compliance. One option is a "bubble" permit, which allows individual permittees with multiple permitted facilities to pool its nutrient limits. The second option is a "group compliance" option, which allows multiple dischargers to pool the nutrient limits for their various facilities and work collectively to meet their combined limits. Each of these options is discussed in more detail below.

7.1.1.1 Bubble Permits

A bubble permit option allows any permittee with more than one permitted facility to meet the combined nutrient limits of its facilities, rather than the individual limits for each facility. This option is only available to the municipalities of Burlington and Greensboro, which own and operate two wastewater treatment plants each. The option is voluntary and, if pursued, will be implemented through modification of the affected NPDES permits.

Conformance with this TMDL will be determined in terms of the nutrient loads delivered to the reservoir. Generated, or end-of-pipe, load limits for different facilities cannot be combined directly because each discharger's transport losses are different. Thus, nutrient limits under a bubble permit must be expressed as total delivered loads for the affected facilities.

The following equations will be used to establish combined limits in any such bubble permits and to measure compliance with the TMDL:

For total nitrogen loading:

$$(M_{1,N} * TF_{1,N}) + (M_{2,N} * TF_{2,N}) = DL_{M,N}$$

where

$M_{1,N}$ = End-of-pipe annual nitrogen loading from facility 1, lbs/yr
$M_{2,N}$ = End-of-pipe annual nitrogen loading from facility 2, lbs/yr
$TF_{1,N}$ = Nitrogen transport factor for facility 1,
$TF_{2,N}$ = Nitrogen transport factor for facility 2,
$DL_{M,N}$ = Allowable delivered nitrogen load from the municipality, lbs/year.

For total phosphorus loading:

$$(M_{1,P} * TF_{1,P}) + (M_{2,P} * TF_{2,P}) = DL_{M,P}$$

where

$M_{1,P}$ =	End-of-pipe annual phosphorus loading from facility 1, lbs/yr
$M_{2,P}$ =	End-of-pipe annual phosphorus loading from facility 2, lbs/yr
$TF_{1,P}$ =	Phosphorus transport factor for facility 1,
$TF_{2,P}$ =	Phosphorus transport factor for facility 2,
$DL_{M,P}$=	Allowable delivered phosphorus load from the municipality, lbs/yr.

NPDES Compliance Group

Similar to the bubble permit option, the group compliance option allows one or more groups of permittees in the same subdrainage to work collectively to meet the combined nutrient limits of its member facilities, rather than each facility being subject to its individual limits. Thus, it provides interested dischargers to pursue an alternative approach to meeting the nutrient reduction goals of the TMDL and allows dischargers, as a group, the flexibility to develop their own strategy for doing so. This option is voluntary and is open to any interested discharger.

Each group will be governed through a group NPDES permit. The group permit will contain limits for nitrogen and phosphorus only and will supplement the individual NPDES permits of the member facilities. The individual permits will remain in full effect, including other effluent limits and monitoring, reporting, and other requirements. The group permit will include a detailed list of the co-permittee members, their individual and group nutrient allocations, reporting requirements for the group, and procedures for modifying the permit to reflect changes in membership or changes in individual or group allocations. The group permitting approach is expected to be similar to that already employed in the Neuse River basin.

As with the bubble permit, the end-of-pipe limits for each facility under a compliance permit must be converted and the new limits expressed in terms of delivered load. An association's nutrient limits will be the sum of delivered nutrient allocations for its co-permittee members. Transfers of mass loads would be allowed within management areas (i.e., Upper New Hope Arm watershed, Haw River watershed), but not outside of the areas (i.e., load transfer from the Upper New Hope Arm to the Haw River Arm watershed).

7.2 Load Allocations

The management of load allocations (i.e. nonpoint source loads) falls outside the requirements of the TMDL, with the exception of developed lands that fall under the NPDES stormwater program. The state is currently addressing NPDES stormwater statewide, including within the Jordan watershed, as a separate effort. However, a conceptual nonpoint source management strategy was developed as part of the Jordan stakeholder process. Using the stakeholders' recommendations, the Division subsequently developed a proposed NPS management strategy. This strategy, rules, and fiscal analysis can be found on the Environmental Management Commissions website at http://h2o.enr.state.nc.us/admin/emc/2007/Mar08Agenda.htm under action item number three.

Reasonable Assurance. EPA requires reasonable assurance that allocations will result in the water body of concern meeting water quality standards. Reasonable assurance is a demonstration that TMDLs will be implemented through regulatory or voluntary actions, including management measures or other controls, by Federal, State or local governments, authorized Tribes, or individuals. For nonpoint sources, storm water sources for which an NPDES permit is not required, atmospheric deposition, ground water or background sources of a pollutant, the demonstration of reasonable assurance must show that management measures or other control actions to implement the load allocations contained in each TMDL meet the following four-part test:

1. They specifically apply to the pollutant(s) and the waterbody for which the TMDL is being established;
2. They will be implemented as expeditiously as practicable;
3. They will be accomplished through reliable and effective delivery mechanisms; and
4. They will be supported by adequate water quality funding.

Rules have been established for the Jordan Reservoir watershed that strive to reduce nitrogen and phosphorus loading to the lake. These rules include provisions for nutrient management, runoff from agricultural operations, stormwater controls for both existing and new development, and the protection and maintenance of riparian buffers. These rules will be effective soon after they become implemented.

8 Future Efforts

This nutrient management strategy and TMDL represents an early phase of a long-term restoration project to reduce nutrient loading in the Jordan Reservoir watershed. The implementation of these reductions will take many years, particularly in the case of nonpoint sources of pollution. As such, it may be many years before improvement in Jordan Reservoir is noted.

Using the results of the trend analysis of watershed loading and lake response, the NCDWQ will determine if progress has been made towards meeting the water quality standards and loading targets. If the trend analyses indicate that the reservoir is improving or that nutrient loads are decreasing, NCDWQ will not reopen the TMDL to adjust target loading rates downward.

The Division currently considers equivalent concentrations of 3.0 mg/L TN and 0.18 mg/L TP as the limits of wastewater treatment technology. While the equivalent concentrations for wastewater dischargers in the Haw River Arm watershed of Jordan Reservoir are greater than the limits of technology, the margin is significantly less for those in the Upper New Hope Arm watershed. This will affect any potential expansion of major wastewater treatment facilities in Durham, Chapel Hill, and Durham County. These large wastewater treatment facilities in the upper New Hope Arm watershed of Jordan Reservoir are allocated at equivalent concentrations of 3.04 mg/L TN. These facilities would, therefore, be subject to the limits of wastewater treatment technology for total nitrogen. Future opportunities to increase wastewater treatment capacity without increasing nitrogen loading will come from technological improvements in the industry or from effluent re-use programs. Equivalent concentrations of total phosphorus are greater than the level considered the limit of wastewater technology. Thus, opportunities to increase wastewater treatment capacity without increasing phosphorus loading can be achieved by utilizing the best available technology.

The NCDWQ has an approved nutrient criteria development plan that includes a re-evaluation of the existing chlorophyll *a* standard and a review of other potential indicators of nutrient enrichment. Changes to the water quality standard will warrant a re-opening of the TMDL to evaluate if the reduction targets continue to be appropriate.

Phase II of this TMDL addressing pH impairment of the Haw River arm of Jordan Reservoir has been scheduled to begin in 2012. This effort will require additional field monitoring and modeling to allocate nutrient loading among point and non-point sources in the watershed.

Public Participation

Two stakeholder processes occurred during the development of this nutrient management strategy and TMDL. The first process was through the efforts of the Project Partners. During the initial development of the data review technical memorandum and the nutrient response model, the Project Partners held regular meetings with DWQ staff. At major completion steps, the Project Partners convened greater stakeholder meetings to share and discuss results of the data review and the modeling.

DWQ staff, the Triangle J Council of Governments, and the Piedmont Triad Council of Governments initialized a more formal stakeholder process to carry a greater group of stakeholders forward through the development of management targets and the management strategy. A USEPA grant, in the amount of $29,730, was used to support this stakeholder process. A total of 21 stakeholder meetings were held between May 2003 and December 2004 to discuss TMDL development, modeling issues, target setting, and management strategy development. The councils of governments prepared a stakeholder report that includes descriptions of the meetings, stakeholder comments and concerns, and recommendations (TJCOG 2005). The Triangle J Council of Governments also continues to maintain a project website, with links to presentations and handouts posted regularly. Materials can be downloaded from this website at http://www.tjcog.dst.nc.us/regplan/jorlknm.htm#.

The following excerpt was taken from the stakeholder report:

> *Source: TJCOG 2005*
> The stakeholders generated many recommendations for the Jordan Lake TMDL and nutrient management strategy. These recommendations are condensed into the Results section and address the TMDL, nutrient targets, nutrient allocations, nutrient management strategies and water quality monitoring for Jordan Lake and its watershed. The recommendations and concerns are grouped by topic and represent a summary of the entire series of stakeholder meetings.
>
> All of the stakeholder recommendations are consistent with three overarching recommendations, and all stakeholder concerns could be addressed within that framework. The three overarching stakeholder recommendations are as follows:
>
> 1. All of the stakeholders supported an adaptive management approach for the TMDL, nutrient targets, and nutrient management strategy.
> 2. All of the stakeholders supported a phased implementation of the nutrient management strategy.
>
> Most of the stakeholders were interested in exploring the possibility of a nutrient trading program.
>
> The three overarching recommendations could address the concerns about data quality, model uncertainty, and model validity, as well as the concerns about the costs and feasibility of implementation, while at the same time providing certainty that the water quality objective for Jordan Lake would be achieved. The adaptive management approach with phased implementation supported by the stakeholders is more conservative than typical adaptive management approaches to TMDLs, because an explicity margin of safety would be included in the TMDL and nutrient target calculations from the beginning. The phased implementation approach for the nutrient management strategy would apply to the point and nonpoint source nutrient management strategies.

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Appendix I. Supporting documents for the Jordan Reservoir Phase I TMDL

The following titles are available for download at http://h2o.enr.state.nc.us/tmdl/SpecialStudies.htm#Jordan.

Jordan Reservoir Watershed Model Development
Jordan Reservoir Nutrient Response Model Enhancement
Jordan Additional Target Analysis and Figures
Nitrogen and Phosphorus Delivery from Small Watersheds to Jordan Reservoir
Point Source Delivery Model for Jordan Reservoir
Jordan Reservoir Nutrient Response Model
Jordan Reservoir Nutrient Response Modeling Project: Existing Data Memorandum
Jordan Reservoir Nutrient Response Model Uncertainty

Additional project information is available at http://www.tjcog.dst.nc.us/regplan/jorlkstk.htm#tabcont

In particular, the Jordan Lake Stakeholder report is available at ftp://ftp.tjcog.org/pub/jorlake/jlsprep1.pdf

Appendix II. EPA letter to DWQ dated November 23, 2003

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

November 23, 2003

Michelle Woolfolk
North Carolina Department of
Environment and Natural Resources
Division of Water Quality
1617 Mail Service Center
Raleigh, NC 27699-1617

Subject: **Application of chlorophyll *a* criterion in Jordan Lake to address nutrient enrichment**

Dear Ms. Woolfolk:

Earlier this month, by phone, you requested U.S. Environmental Protection Agency (EPA) review of the method for interpretation of the 40 ppb chlorophyll *a* numeric criterion for the development of a Total Maximum Daily Load (TMDL) for nutrient load reductions in the Jordan Lake watershed. North Carolina's water quality standards do not specify the frequency or duration for application of this numeric criterion.

Specifically, you stated that North Carolina intended to implement this criterion for Jordan Lake as a maximum value for a specified growing season, with an allowable exceedance frequency of 10% for the criterion during each growing season. EPA notes that this approach has been used before, but is somewhat different than previous implementation of this criterion by the State in the development of certain TMDLs for other water bodies in North Carolina. In those cases, the State applied this criterion as an annual maximum value with an allowable frequency of exceedance of 10%. EPA has previously approved TMDLs for water bodies using this annual maximum approach.

EPA believes that, in the development of a TMDL, the unique conditions of a water body should be examined to determine the correct application of a criterion related to nutrient enrichment where it is not otherwise specified, since the conditions that lead to nutrient enrichment impairment may vary considerably by water body and ecoregion. The use of non-growing season chlorophyll *a* data would tend to mask the growing season impact of nutrient enrichment in reservoirs such as Jordan Lake. Algal biomass in the reservoir during winter periods is significantly less than during the growing season. Typically, algal production peaks during the spring, summer and fall when water temperatures are elevated, stratification occurs, and hydraulic retention time in epilimnetic waters is maximized. The winter meteorological conditions impose physical and thermal limits on algal production and chlorophyll *a* concentrations. Considering these factors, EPA believes that, for slow moving reservoirs that experience defined growing seasons, such as Jordan Lake, the State should use discretion in determining an appropriate period for assessment of the numeric chlorophyll *a* criterion in order to avoid the use of data collected during non-productive periods.

This is because the State also has the obligation to ensure attainment of ***all*** applicable water quality standards in the development of a TMDL. For Jordan Lake, this includes the numeric chlorophyll *a* criteria as well as North Carolina's narrative criteria for maintenance of biological integrity. Chlorophyll-a concentration trends are commonly used to indicate if narrative criteria are being met and designated uses are being maintained.

North Carolina's water quality standards include the following narrative criteria (15A NCAC 02B .0211):

> *The waters shall be suitable for aquatic life propagation and maintenance of biological integrity, wildlife, secondary recreation, and agriculture; sources of water pollution which preclude any of these uses on either a short-term or long-term basis shall be considered to be violating a water quality standard.*
>
> Biological integrity is defined in North Carolina standards as:
>
> *the ability of an aquatic ecosystem to support and maintain a balanced and indigenous community of organisms having species composition, diversity, population densities and functional organization similar to that of reference conditions.*

EPA understands the State has determined that a maximum growing season chlorophyll *a* concentration of 40 ppb, with a frequency of 10% exceedance, is the most appropriate indicator for assuring compliance with the applicable State standards for chlorophyll *a* and biological integrity. Although this is more stringent than using data on an annual basis, it is more likely to ensure attainment of the narrative criteria requiring that a balanced and indigenous community can thrive under the most critical conditions, which in this case occurs during the growing season for the lake.

For the reasons set forth above, EPA concurs with the use of a "growing season maximum with a 10% exceedance frequency" for chlorophyll a for the development of a TMDL for Jordan Lake. Please let me know if you have any questions or concerns by contacting me directly at (404) 562-9478. Thank you.

Sincerely,

Andrew Bartlett, Chief
East Standards, Monitoring and TMDL Section

Appendix III. Volume-weighted statistics for the Jordan Reservoir nutrient response model

The following is taken from an analysis by Tetra Tech (March 29, 2004).

Results are provided for aggregated segments 1-4 and aggregated segments 14- 15. Accomplishing this required calculation of volume-weighted concentrations for each observation date. As not all stations are present with valid data on all dates, weighting was performed over the set of stations that are available on each date. Volume-weighted predictions from the model were then retrieved for the matched set of dates.

In addition to volume weighting, the statistics calculated differ from those presented in the two model calibration reports in the following respects:

- Statistics for chlorophyll a are provided in relation to the observed values. That is, the model results in segments 4, 14, and 15 are corrected for depth support, rather than correcting the observed values, as was done previously.
- The depth correction factor for segment 4 was set at the revised value of 0.84, as described in Table 11 of the B. Everett Jordan Lake Nutrient Response Model Enhancement report of September 2003.
- Observed data were re-accessed from the most up-to-date spreadsheets provided by DWQ. This resulted in the identification of several valid data points that were omitted from the previous statistical tabulation.

Reported non-detects were set at one half the quantification limit for the statistical analysis. However, observations with non-detects at abnormally high detection limits were eliminated from the analysis. Results for TN, TP, and chlorophyll a are provided in Table 1. Statistics are provided both with and without 2000. As noted previously, 2000 results are believed to be less reliable due to a shortage of tributary monitoring data in this year.

Table 1. WASP Calibration Statistics for Volume-Weighted Aggregate Segment Average Concentrations (Full Year)

	1997-1999, 2001		1997-2001	
Segment	1-4	14-15	1-4	14-15
TN-AvObs	0.682	0.748	0.654	0.715
TN-AvSim	0.755	0.796	0.760	0.776
TP-AvObs	0.084	0.075	0.081	0.072
TP-AvSim	0.075	0.065	0.076	0.066
CHL-AvObs	35.957	26.588	41.030	29.222
CHL-AvSim	34.187	27.413	34.057	25.058
CHL-GMObs	33.196	23.216	36.374	25.537
CHL-GMSim	30.412	23.436	30.564	19.967
TN-AvErr	0.076	0.048	0.108	0.061
TP-AvErr	-0.009	-0.010	-0.006	-0.006
CHL-AvErr	-0.208	2.032	-5.924	-3.476
TN-AvABSErr	0.310	0.186	0.293	0.198
TP-AvABSErr	0.022	0.027	0.023	0.027
CHL-AvABSErr	13.077	15.250	18.389	17.140
TN-RMSE	0.355	0.267	0.334	0.264
TP-RMSE	0.029	0.052	0.029	0.047
CHL-RMSE	16.444	19.652	26.185	23.035
TN-CV	0.521	0.356	0.511	0.369
TP-CV	0.346	0.695	0.355	0.648
Chl-CV	0.457	0.739	0.638	0.788

Key:
- TN Total Nitrogen
- TP Total Phosphorus
- Chl Chlorophyll a
- AvObs Average Observed
- AvSim Average Simulated
- GMObs Geometric Mean Observed
- GMSim Geometric Mean Simulated
- AvErr Average Error
- AvABSErr Average Absolute Error
- RMSE Root Mean Squared Error
- CV Coefficient of Variation (error standard deviation divided by observed mean)

Appendix IV. TMDL summary sheet

Summary Sheet
Total Maximum Daily Load (TMDL)

1. 303(d) List Information

State: North Carolina

County: Alamance, Caswell, Chatham, Durham, Forsyth, Guilford, Orange, Randolph, Rockingham, and Wake

Major River Basin: Cape Fear River Basin

Watershed: Upper New Hope Creek, Lower New Hope Creek, and Haw River Arms of B. Everett Jordan Reservoir (Jordan Lake)

303(d) Listed Waters (North Carolina)

Name of stream	Description	Class	Index #	Subbasin	Acres
Morgan Creek	From Chatham County SR 1726 (Durham County SR1109) to New Hope Creek Arm of New Hope Creek River Arm of B. Everett Jordan Reservoir	WS-IV NSW CA	16-41-2-(9.5)	30605	851
New Hope Creek	From a point 0.8 mile downstream of Durham County SR 1107 to confluence with Morgan Creek Arm of New Hope River Arm of B. Everett Jordan Reservoir	WS-IV NSW CA	16-41-1-(14)	30605	1377
New Hope River Arm of B. Everett Jordan Reservoir	From source at confluence of Morgan Cr and New Hope Cr. Arms of B. Everett Jordan Reservoir (an east-west line across the southern tip of the formed peninsula) to Chatham County SR 1008	WS-IV B NSW CA	16-41-(0.5)	30605	1205
New Hope River Arm of B. Everett Jordan Reservoir	From Chatham County SR 1008 to Haw River Arm of B. Everett Jordan Lake	WS-IV B NSW CA	16-41-(3.5)a	30605	5673
Haw River	From a point 0.5 mile downstream of U.S. Hwy. 64 to approximately 1.0 mile below US Hwy 64	WS-IV NSW CA	16-(37.3)	30604	53
Haw River Arm of B. Everett Jordan Reservoir	From a point 1.0 mile downstream of U.S. Hwy. 64 to dam at B. Everett Jordan Lake	WS-IV B NSW CA	16-(37.5)	30604	1392

Constituents of Concern: Total nitrogen, total phosphorus, and chlorophyll *a*

Designated Uses: Biological integrity, aquatic life propagation, secondary and primary recreation, and water supply

Applicable Water Quality Standards for Class C Waters in NC:

> Chlorophyll *a* (corrected): not greater than 40 ug/L for lakes, reservoirs, and other waters subject to growths of macroscopic or microscopic vegetation not designated as trout waters, and not greater than 15 ug/L for lakes, reservoirs, and other waters subject to growths of macroscopic or microscopic vegetation designated as trout waters (not applicable to lakes and reservoirs less than 10 acres in surface area).

2. TMDL Development

Development tools: EFDC, WASP, Jordan Reservoir Point Source Delivery Model, GWLF

Critical condition: The TMDL has been determined using the average of a 5-year simulation (1997-2001) covering a wide range of hydrologic conditions with three years that were drier than normal. The TMDL is based on meeting the criterion exceedance frequency of 10% during the period from May through September.

Seasonality: Seasonal variation in hydrology, climatic conditions, and watershed activities are represented through the use of a continuous flow gage and the use of all readily available water quality data collected in the watershed.

3.0 Allocation Watershed/Stream Reach

3.1 Upper New Hope Arm

Total Nitrogen
- Percent reduction: 35%
- Total maximum daily load (TMDL): 641,021 lbs/yr
- Continuous waste load allocation (WLA): 336,081 lbs/yr
- LA plus WLA-SW: 304,940 lbs/yr
- WLA-SW: 35% reduction
- Load allocation (LA): 35% reduction

Total Phosphorus
- Percent reduction: 5%
- Total maximum daily load (TMDL): 82,883 lbs/yr
- Continuous waste load allocation (WLA): 23,108 lbs/yr
- LA plus WLA-SW: 59,775 lbs/yr
- WLA-SW: 5% reduction
- Load allocation (LA): 5% reduction

3.2 Lower New Hope Arm

Total Nitrogen
- Percent reduction: 0% (a)
- Total maximum daily load (TMDL): 221,929 lbs/yr
- Continuous waste load allocation (WLA): 6,836 lbs/yr
- LA plus WLA-SW: 215,093 lbs/yr
- WLA-SW: 0% reduction
- Load allocation (LA): 0% reduction

Total Phosphorus
- Percent reduction: 0%
- Total maximum daily load (TMDL): 26,574 lbs/yr
- Continuous waste load allocation (WLA): 498 lbs/yr
- LA plus WLA-SW: 26,076 lbs/yr
- WLA-SW: 0% reduction
- Load allocation (LA): 0% reduction

(a) Provides a loading cap equal to 1997-2001 baseline nutrient loads.

3.3 Haw River Arm

Total Nitrogen
- Percent reduction: 8%
- Total maximum daily load (TMDL): 2,567,000 lbs/yr
- Continuous waste load allocation (WLA): 895,127 lbs/yr
- LA plus WLA-SW: 1,671,873 lbs/yr
- WLA-SW: 8% reduction
- Load allocation (LA): 8% reduction

Total Phosphorus
- Percent reduction: 5%
- Total maximum daily load (TMDL): 359,641 lbs/yr
- Continuous waste load allocation (WLA): 106,001 lbs/yr
- LA plus WLA-SW: 253,640 lbs/yr
- WLA-SW: 5% reduction
- Load allocation (LA): 5% reduction

WLA-WW = wasteload allocation for wastewater facilities
LA = load allocation for nonpoint sources
WLA-SW = wasteload allocation for permitted stormwater

Margin of Safety: This TMDL utilizes an explicit margin of safety (MOS) applied to the water quality criterion. The frequency of exceeding the criterion (40 ug/L) has been reduced from 10% to 8%. In addition, 4 of 5 years (1997-2000) of chlorophyll *a* data used for model calibration represent uncorrected chlorophyll *a*, which is a conservation estimate of corrected chlorophyll *a*.

4. **Public Notice Date: April 1, 2007 - May 15, 2007**

5. **Submittal Date: September 12, 2007**

6. **Establishment Date:**

7. **Endangered Species (yes or blank):**

8. **EPA Lead on TMDL (EPA or blank):**

Appendix V. WLA calculations for the Upper New Hope and Haw River Management Areas

The following spreadsheets detail the calculations involved in determining the WLAs of this TMDL.

UPPER NEW HOPE WLA CALCULATIONS

				Nitrogen				Phosphorus			
Permit	Owner	Facility	Permitted Flow (MGD)	Equivalent Concentration (mg/L)	Load at EOP (lb/yr)	Transport Factor	Load to Lake (lb/yr)	Equivalent Concentration (mg/L)	Load at EOP (lb/yr)	Transport Factor	Load to Lake (lb/yr)
NC0047597	City of Durham	South Durham WRF	20.0	3.04	185345	75%	139009	0.23	14053	67%	9415
NC0025241	Orange Water & Sewer Authority	Mason Farm WWTP	14.5	3.04	134375	63%	84656	0.23	10188	47%	4789
NC0026051	Durham County	Triangle WWTP	12.0	3.04	111207	96%	106759	0.23	8432	97%	8179
NC0056413	Whippoorwill LLC	Carolina Meadows WWTP	0.35	3.04	3244	63%	2043	0.23	246	47%	116
NC0051314	North Chatham Water & Sewer Company, LLC	Cole Park Plaza	0.05	12.00	1826	81%	1479	2.00	304	84%	256
NC0043257	Nature Trails Association, CLP	Nature Trails Mobile Home Park WWTP	0.04	12.00	1461	81%	1184	2.00	244	84%	205
NC0042803	Birchwood Mobile Home Park	Birchwood Mobile Home Park	0.018	12.00	658	70%	460	2.00	110	64%	70
NC0074446	Hilltop Mobile Home Park	Hilltop Mobile Home Park	0.012	12.00	438	70%	307	2.00	73	64%	47
NC0048429	Cedar Village Apartments	Cedar Village Apartments	0.005	12.00	183	100%	183	2.00	30	100%	30

WLA- TN 336079

WLA- TP 23106

HAW RIVER WLA CALCULATIONS

				Nitrogen				Phosphorus			
Permit	**Owner**	**Facility**	**Permitted Flow (MGD)**	**Equivalent Concentration (mg/L)**	**Load at EOP (lb/yr)**	**Transport Factor**	**Load to Lake (lb/yr)**	**Equivalent Concentration (mg/L)**	**Load at EOP (lb/yr)**	**Transport Factor**	**Load to Lake (lb/yr)**
NC0047384	City of Greensboro	T.Z. Osborne WWTP	40.0	5.29	643595	45%	289618	0.66	80899	44%	35595
NC0024325	City of Greensboro	North Buffalo Creek WWTP	16.0	5.29	257438	43%	110698	0.66	32359	42%	13591
NC0023868	City of Burlington	Eastside WWTP	12.0	5.29	193078	77%	148670	0.66	24270	69%	16746
NC0023876	City of Burlington	Southside WWTP	12.0	5.29	193078	80%	154463	0.66	24270	73%	17717
NC0024881	City of Reidsville	Reidsville WWTP	7.50	5.29	120674	66%	79645	0.66	15169	56%	8494
NC0021211	City of Graham	Graham WWTP	3.50	5.29	56315	81%	45615	0.66	7079	71%	5026
NC0021474	City of Mebane	Mebane WWTP	2.50	5.29	40225	56%	22526	0.66	5056	55%	2781
NC0020354	Town of Pittsboro	Pittsboro WWTP	2.25	5.29	36202	76%	27514	0.66	4551	82%	3731
NC0066966	Quarterstone Farm Homeowners Association	Quarterstone Farm WWTP	0.20	5.29	3218	50%	1609	0.66	404	43%	174
NC0003913	Glen Raven Inc	Altamahaw Division plant	0.15	5.29	2413	58%	1400	0.66	303	49%	149
NC0022691	Chateau Communities, Inc.	Autumn Forest Manuf. Home Community	0.0820	12.00	2995	52%	1558	2.00	499	46%	230
NC0001210	Monarch Hosiery Mills Inc	Monarch Hosiery Mills Incorporated	0.0500	12.00	1826	58%	1059	2.00	304	49%	149
NC0022675	Country Club Communities LLC	Birmingham Place	0.0430	12.00	1571	55%	864	2.00	262	52%	136
NC0042285	Trails Property Owners Assoc	Trails WWTP	0.0400	12.00	1461	84%	1227	2.00	244	76%	185
NC0046043	Oak Ridge Military Academy	Oak Ridge Military Academy	0.0400	12.00	1461	46%	672	2.00	244	41%	100
NC0077968	Homers Mobile Home Park	Homers Mobile Home Park	0.0400	12.00	1461	58%	847	2.00	244	49%	119
NC0042528	B Everett Jordan & Son-1927 LLC	B Everett Jordan 1927 LLC	0.0360	12.00	1315	84%	1105	2.00	219	76%	167
NC0038156	Guilford County Schools	Northeast Middle & Senior High WWTP	0.0320	12.00	1169	52%	608	2.00	195	46%	90
NC0073571	Mervyn R. King	Countryside Manor WWTP	0.0300	12.00	1096	42%	460	2.00	183	38%	69
NC0001384	Burlington Industries, Inc	Williamsburg plant	0.0250	12.00	913	48%	438	2.00	152	47%	72
NC0029726	NC Department of Correction	Guilford Correctional Center WWTP	0.0250	12.00	913	36%	329	2.00	152	34%	52
NC0035866	County of Chatham	Bynum WWTP	0.0250	12.00	913	84%	767	2.00	152	76%	116
NC0065412	REA Enterprises, LLC	Pleasant Ridge WWTP	0.0235	12.00	858	51%	438	2.00	143	45%	64
NC0046809	Pentecostal Holiness Church	Pentecostal Holiness Church	0.0200	12.00	731	46%	336	2.00	122	41%	50
NC0060259	Willow Oak Mobile Home Park	Willow Oak Mobile Home Park	0.0175	12.00	639	51%	326	2.00	107	45%	48
NC0031607	Alamance-Burlington School System	Western Alamance Middle School	0.0150	12.00	548	64%	351	2.00	91	58%	53
NC0046019	Episcopal Diocese of North Carolina	The Summit WWTP	0.0150	12.00	548	46%	252	2.00	91	41%	37
NC0045161	Alamance-Burlington School System	Altamahaw/Ossipee Elementary School	0.0120	12.00	438	58%	254	2.00	73	49%	36
NC0045144	Alamance-Burlington School System	Western Alamance High School	0.0115	12.00	420	64%	269	2.00	70	58%	41
NC0038172	Guilford County Schools	McLeansville Middle School WWTP	0.0113	12.00	413	36%	149	2.00	69	34%	23
NC0022098	Cedar Valley Communities LLC	Cedar Valley WWTP	0.0100	12.00	365	55%	201	2.00	61	52%	32
NC0045152	Alamance-Burlington School System	Jordan Elementary School	0.0075	12.00	274	84%	230	2.00	46	76%	35
NC0055271	Shields Mobile Home Park	Shields Mobile Home Park	0.0060	12.00	219	64%	140	2.00	37	58%	21
NC0048241	Staley Hosiery Mills	Staley Hosiery Mills	0.0050	12.00	183	74%	135	2.00	30	65%	20
NC0038164	Guilford County Schools	Nathanael Greene Elementary School WWTP	0.0045	12.00	164	75%	123	2.00	27	66%	18
NC0036994	Rockingham County Board of Education	Monroeton Elementary School	0.0042	12.00	153	42%	64	2.00	26	38%	10
NC0066010	Rockingham County Board of Education	Williamsburg Elementary School	0.0040	12.00	146	51%	75	2.00	24	45%	11
NC0045128	Alamance-Burlington School System	Sylvan Elementary School	0.0030	12.00	110	84%	92	2.00	18	76%	14

WLA-TN 895127

WLA-TP 106001

Appendix VI. DWQ responsiveness summary for public comments on the Jordan Reservoir Phase I TMDL

The B. Everett Jordan Reservoir, North Carolina Phase I Total Maximum Daily Load was public noticed in the relevant counties on 4/1/07 in four local newspapers (The Durham Herald-Sun, the Winston-Salem Journal, the Greensboro News & Record, and the Raleigh News & Observer). The TMDL was also public noticed through the North Carolina Water Resources Research Institute email list serve. Finally, the TMDL was available on DWQ's website http://h2o.enr.state.nc.us/tmdl/ during the comment period. The comment period lasted 45 days from April 1, 2007 until May 15, 2007. DWQ received ten public comments to the draft TMDL. Specific commenters are listed below.

Glen Whisler, Durham County
Stephen Shoaf, City of Burlington
Sean Brogan, NCDFR
Sheri Bryant, NC Wildlife Resources Commission
Gregory Thorpe, NCDOT
Elaine Chiosso, Haw River Assembly
James Gray and Henry Randolph, Society of American Foresters, Sandhills Chapter
Howard "Bud" Taylor, Central Carolina Forestry Club
Loren Hintz, Private Citizen
John Cox, City of Durham

Many of the comments received were related to the Jordan Reservoir Nutrient Management Strategy (the Jordan Rules) and were not relevant to the TMDL document. These comments will be forwarded to the DWQ Non-Point Source Planning Unit for incorporation into the Jordan Rules public comment documentation.

DWQ response to comments on the Jordan Lake Phase I TMDL document follows.

COMMENT: *Several commenters expressed support for the proposed nutrient reduction targets detailed in the TMDL.*

RESPONSE: DWQ appreciates support for the nutrient reduction targets.

COMMENT: *Three commenters noted that* on *page v, the note that "DWQ would protect existing riparian buffers" is inconsistent with the proposed regulations 15A NCAC 02B .0267 in which the local governments are responsible for protecting riparian buffers.*

RESPONSE: This is true. This sentence was revised as follows.

DWQ would require local governments to protect riparian buffers.

COMMENT: *On page v, the note that "All local governments would meet NPDES Phase II stormwater requirements of S1210", is incorrect as all local governments, such as the County of Durham, are not covered by the Phase II requirements.*

RESPONSE: This is true. The note was revised to provide further clarification on Phase II requirements as follows.

- Stormwater:
  - New development in unincorporated areas of all counties except Caswell and Rockingham are subject to the post-construction stormwater measure of the NPDES Phase II requirements and are permitted by DWQ beginning July 1, 2007
  - Seventeen of the twenty six municipalities in the watershed were issued permits by December 2005 to implement all six measures of the Phase II requirements, either alone or as part of another MS4's permit, and were required to begin implementing post-construction permitting under those permits by December 2007.
  - All local governments would achieve stormwater N and P export performance goals from all new and existing development.

COMMENT: *Two commenters believe that the TMDL Draft and Strategy should have been completed including an atmospheric deposition evaluation, and considering the strategy of improved air quality.*

RESPONSE: It is true that atmospheric deposition is a source of nutrients in the Jordan Lake watershed. The nutrient load associated with atmospheric deposition is accounted for in the TMDL as part of the non-point source load. The Jordan Lake watershed model, used for implementation of this TMDL, accounted for atmospheric deposition of nutrients in urban areas by using a "build up" rate (Tetra Tech, 2003). These loading rates were based on annual stormwater unit loading rates developed for the Town of Cary, NC in close proximity to Jordan Lake. Unfortunately, a more sophisticated approach to accounting for atmospheric deposition in the Jordan Lake watershed is not feasible at present since the scientific understanding of atmospheric deposition of nutrients is not yet adequate to be useful in modeling the spatial and temporal variation of deposition in watershed modeling and there are currently no deposition monitoring sites in the Jordan Lake watershed. DWQ intends to stay abreast of the latest research in atmospheric deposition and will incorporate these findings in adaptive management strategies as they emerge. DWQ is not pursuing an air quality strategy for this TMDL, but encourages local governments to pursue improvements in air quality to address nutrient loading to the lake.

COMMENT: *Design changes for the road crossings should be considered.*

RESPONSE: Road causeways do have the potential to affect the spatial distribution of nutrient concentrations in Jordan Lake, and removal of these causeways may improve water quality in terms of chlorophyll *a* concentrations in lake segments upstream. However, this proposal has the potential to cause additional impairments or worsen existing impairments in lake segments downstream of the present road causeways. Further, segments of the Cape Fear River just 4 miles downstream of the dam at Jordan Lake are currently listed as impaired for chlorophyll *a* standard exceedances on the 2006 303(d) list. While this proposal may have some merit, it is clear that we should proceed with caution in considering a strategy that could affect water quality downstream. At this point, DWQ believes we need to move forward with the current TMDL and nutrient management strategy, and if further actions are required to improve water quality in the lake as identified in the adaptive management strategy, alternatives such as removing road causeways will be considered.

The Jordan Lake TMDL does not prohibit the pursuit of this strategy. However, since the lake is impaired for chlorophyll *a* and is listed on the 303(d) list, a TMDL must be determined to address this impairment pursuant to the Clear Water Act. A TMDL addresses pollutant loads and reductions of those loads, it does not address other management alternatives such as modifications to road crossings.

COMMENT: ***Page iii*** *Senate Bill 1366 actually replaced the requirements of House Bill 515 regarding what would be required based on the results of the nutrient response model. The limits of 5.5 mg/L of TN and the 2.0 mg/L of TP did not apply in SB 1366. It did establish a compliance period as discussed in paragraph 3 of this page.*

RESPONSE: The third paragraph on page iii was revised as follows.

The Clean Water Responsibility Act of 1997 (often referred to as House Bill 515) included legislation to further address water quality problems in NSW waters (NC General Statute 143-215.1(c1) to (c5)). The act set total nitrogen (TN) and total phosphorus (TP) NPDES permit limits for facilities discharging greater than 0.5 MGD into the Jordan Reservoir/Haw River watershed. A 5-year compliance period for limits of 5.5 mg/L of TN and 2.0 mg/L of TP was established for qualifying wastewater facilities. ~~The act provides conditions for an extended compliance period, including the development of a calibrated nutrient response model and the development of plans to optimize nutrient removal at the wastewater facility.~~ The act also established that a calibrated nutrient response model may be developed by DWQ in conjunction with affected parties, and the model may indicate the required TN and TP concentration limits for dischargers greater than 0.5 MGD are different from those listed above. In 1998, Senate Bill 1366 allowed the Environmental Management Commission (EMC) to extend the compliance deadline for these dischargers if additional time was needed to develop a calibrated nutrient response model. The municipalities of Greensboro, Mebane, Reidsville, Graham, Pittsboro, and Burlington, and the Orange Water and Sewer Authority (OWASA) were granted a compliance extension in 1999. Facilities that did not seek compliance extensions were the City of Durham/Durham South WWTP and the Durham County/ Triangle WWTP. Conditions associated with the extended compliance period were achieved and the calibrated nutrient response model was accepted by the Water Quality Committee (WQC) of the ~~Environmental Management Commission~~ EMC in July 2002.

COMMENT: *The lake was listed as impaired for chlorophyll a, however there has not been a determination that the intended uses are not being met. The statement that the TMDL is intended "…to estimate the allowable pollutant loads and allocate the loads to known sources so that the waterbody may be restored to its intended uses..." (paragraph 4) implies a curtailment of an intended use, and this has not been demonstrated.*

RESPONSE: EPA requires states to use the numeric water quality standard as endpoints for TMDLs when such a standard exists (EPA 1999). North Carolina has a chlorophyll *a* standard that is used both to conduct use support and to set TMDL endpoints. DWQ cannot vary from this water quality standard when developing target loads and concentrations.

COMMENT: ***Page v*** *The nonpoint source strategy includes provisions for agriculture that are not controlled by NCDENR/DWQ.*

RESPONSE: This is true. The agricultural operations bullet was revised as follows.

All agricultural operations collectively meet N and P export performance goals as implemented by local committees (EMC has no regulatory authority over this management area);

COMMENT: *In paragraph 2 there is an omission in the discussion of SB 1366. The way this paragraph is written, it leads the reader to conclude that the HB 515 TN and TP limits were/are still in effect. There is no mention that the calibrated nutrient response model would be used to generate new nutrient limits in the basin.*

RESPONSE: Revised paragraph as follows.

The Clean Water Responsibility Act of 1997 (CWRA, often referred to as House Bill 515) included legislation to further address water quality problems in NSW waters (NC General Statute 143-215.1(c1) to (c5)). The act set total nitrogen (TN) and total phosphorus (TP) NPDES permit limits for facilities discharging greater than 0.5 MGD into the Jordan Reservoir/Haw River watershed. A 5-year compliance period for limits of 5.5 mg/L of TN and 2.0 mg/L of TP was established for qualifying wastewater facilities. The act also established that a calibrated nutrient response model may be developed by DWQ in conjunction with affected parties, and the model may indicate the required TN and TP concentration limits for dischargers greater than 0.5 MGD are different from those listed above. Amendments to the act approved in 1998 (referred to as Senate Bill 1366) provided a compliance extension to the nutrient limits, with conditions. Those wastewater facilities granted a compliance extension by the Environmental Management Commission were required to develop a calibrated nutrient response model, evaluate and optimize the operation of all facilities to reduce nutrient loading, and evaluate methods to reduce nutrient mass loading to NSW waters. The municipalities of Greensboro, Mebane, Reidsville, Graham, Pittsboro, and Burlington, and the Orange Water and Sewer Authority (OWASA) were granted the compliance extension by the Environmental Management Commission in April 1999. This collective group is referred to as the Project Partners in subsequent chapters. Facilities that did not seek compliance extensions are the City of Durham/ Durham South WWTP and Durham County/ Triangle WWTP.

COMMENT: ***Page 7*** *The land use data seems to be dated and much of the 1992 NLCD is now over 15 years old.*

RESPONSE: This is true. However, because the model baseline period was 1997-2001, DWQ believes that the 1992 NLCD data are appropriate for this study.

COMMENT: ***Page 9*** *The discussion of the 40 ug/L chlorophyll a standard does not include discussion of the confusion about the standard. This standard was developed using an older analytical method (spectrophotometric method) and now the State is using a fluorometric method that is more sensitive by a factor of about 2X. Thus it appears that the 40 ug/L limit being enforced is equivalent to what was a 20 ug/L concentration.*

RESPONSE: The chlorophyll *a* standard was not developed based on any one analytical method. It was developed through consensus with researchers and managers in the late 1970's. The state was using an EPA approved spectrophotometric method when the chlorophyll *a* standard was adopted and then moved to using an EPA approved fluorometric method in 1981.

The US EPA (under contract # 68-C-04-006) published a summary of literature comparisons for all analytical methods. This report, entitled "Summary of literature Comparing Methods for the Analysis of

Chlorophyll in water Samples" noted differences in predicted analysis – but, most predictions were in the range of **10%** overestimation when spectrophotometric methods were used. To follow up on the literature search, US EPA region IV – conducted a study of 3 labs using split sample and the fluorometric method results indicated no large discrepancies. They completed their review by using 5 different methods and 2 laboratories. Only results from the HPLC methods indicated significantly lowered responses with the split sample results.

DWQ continues to work with certified laboratories to ensure that data used for assessment purposes are comparable.

COMMENT: ***Page 10*** *In the first paragraph, the final sentence states that the USEPA Region 4 supports the application of the 40 ug/L standard as a seasonal standard with less than 10% frequency of exceedance. In some instances this standard was applied using an annual interpretation. Upon reading the letter from Region 4, it seems that they cautioned NCDENR that this is not how the standard was applied in other circumstances, but that it could be applied that way if the State chose to do so. The final determination was left to the State's discretion.*

RESPONSE: The load reductions proposed in the Jordan Lake TMDL are based on a 10% chlorophyll *a* standard exceedance frequency during summer months (i.e. June – September). Other TMDLs (Neuse Estuary) were based on annual exceedance rather than summer months, while others (Robeson Creek) are based on summer months like the Jordan Lake TMDL. The EPA memo dated 11/23/03 (Appendix II of TMDL document) supports using summer months only, noting that "The use of non-growing season chlorophyll *a* data would tend to mask the growing season impact of nutrient enrichment in reservoirs such as Jordan Lake" and that considering the summer season only will be"…more likely to ensure attainment of the narrative criteria requiring that a balanced and indigenous community can thrive under the most critical conditions, which in this case occurs during the growing season for the lake." EPA guidance (Protocol for Developing Nutrient TMDLs, 1999) states that "an approvable TMDL will need to include…consideration of seasonal variation and high and low flow conditions such that water quality standards for the allocated pollutant will be met during all design environmental conditions."

COMMENT: ***Page 10*** *An additional monitoring effort was conducted by the UNC-CH Department of Environmental Sciences and Engineering under contract with the Army Corps of Engineers.*

RESPONSE: We added UNC-Chapel Hill to list of previous studies.

COMMENT: *It should be pointed out that there were analytical problems with the chlorophyll a analyses, and the region was experiencing a drought during 1999 – 2002 that was cumulative in its effects and became severe.*

RESPONSE: The chlorophyll *a* data issues are discussed in a later section of the Draft TMDL document (see section 6.6.1- Data Uncertainty). Due to analytical problems, laboratory samples for phaeophytin-corrected chlorophyll *a* processed in 1997-2000 were unusable (uncorrected chlorophyll *a* data were still valid). Data collected in 2001 did not have this problem. DWQ used the uncorrected chlorophyll *a* concentrations for model calibration during these years. The ratio between corrected and uncorrected chlorophyll *a* concentrations was found to be very close to unity during July-September (Tetra Tech, 2003), increasing during the remaining months. Since the nutrient load reductions proposed in the TMDL document are based on summer months, DWQ believes that using the uncorrected chlorophyll *a* data during 1997-2000 to establish load reduction targets is appropriate.

The low rainfall in 2000 and 2001 are discussed in a later section of the Draft TMDL document (see section 6.3- Critical Conditions). The model simulation period consisted of a wet year (1998) a normal year (1997) and three years that were drier than normal, although each with different characteristics (1999-2001). However, the seasonal analysis shows that inflows and precipitation were not extraordinarily low, except for local precipitation during the summer of 1999. The drought, in terms of water supply availability, was the cumulative effect of several years of below normal precipitation and flow. Conditions, when examined on a seasonal basis, were not so extraordinarily rare as to be unrepresentative of the expected range of lake response.

COMMENT: *Tetra Tech acknowledged the short-comings of the data and subsequent model and made suggestions of how to improve model performance. They recognized the complexity of the system and the difficulty in modeling it. The suggested improvements included better spatial and temporal coverage during sampling events. To date this has not been done.*

RESPONSE: As part of the original Jordan Lake modeling report, Tetra Tech presented recommendations for additional monitoring in Jordan Lake and its tributaries (Tetra Tech, 2002). These were presented for "further refinement of the Jordan Lake Nutrient Response Model." In these recommendations, Tetra Tech acknowledged that "the [2000-2001] data provided good coverage both temporally and spatially" but that "it would be desirable to improve temporal coverage for laboratory parameters even at the expense of less spatial coverage."

Any mathematical model of a natural system has some level of uncertainty and can be improved upon given sufficient time and financial resources. DWQ believes that the Jordan Lake Nutrient Response Model in its current form provides an adequate representation of nutrient response in the lake and that it can be used to evaluate nutrient management scenarios such as those presented in this TMDL document. Section 6.6.2- Lake Model Uncertainty provides additional discussion on this issue.

DWQ will continue to monitor water quality in the lake to gauge progress toward attainment of the chlorophyll *a* standard through adaptive management.

COMMENT: ***Pages 13, 14, and 15*** *The data sources should be identified for these graphs.*

RESPONSE: The data were collected by DWQ. This information was added to the figure captions.

COMMENT: ***Page 16*** *A statement should acknowledge which data in Table 2 contains estimated (uncorrected) data and the data source.*

RESPONSE: Added "Chlorophyll *a* data from 9/96-1/01 are uncorrected for phaeophytin concentrations" to the table caption.

COMMENT: ***Page 18*** *In Table 4. the NPDES permit number for the City of Burlington South Burlington WWTP is incorrect. The correct permit number is NC0023876.*

RESPONSE: The permit number was changed to read NC0023876.

COMMENT: ***Page 21*** *The last paragraph of this page discusses the Phase II stormwater permitting program. It should be pointed out that the Phase II programs have not been fully implemented and thus we cannot judge their impacts on future water quality.*

RESPONSE: The point of this paragraph is to simply discuss the background of Phase II and to list the permits issued in the Jordan Lake watershed. It is true that the program has not been completely implemented and it will remain to be seen the magnitude of water quality improvements achieved as a result of this program. DWQ will continue to monitor water quality in the Jordan Lake watershed to help assess the impact of the stormwater permitting process.

COMMENT: ***Page 22*** *The second paragraph under this section is either confusing or misleading. The statement that "…Agriculture makes up only approximately 4% of land use (Figure 3)" is not correct. Agriculture makes up 4% of the land use in the Upper New Hope Arm, 24% in the Haw River Arm, and 20% of the land use in the entire watershed based on Figure 3.*

RESPONSE: The paragraph was revised as follows.

Agricultural and urban land uses can contribute considerable amounts of nutrients due to fertilizer use. In the Upper New Hope Management Area, agriculture makes up only approximately 4% of land use (Figure 3). The Upper New Hope Arm is developed more intensely than the Haw River Arm, which has 24% agricultural land use. Impervious surfaces associated with developed areas increase the quantity and velocity of runoff and associated contaminants.

COMMENT: ***Page 23*** *In the third paragraph the discussion of sewer service should indicate that the percentages presented represent the population served and not the land area (ie. 62% of the population of Alamance County is served by sewer). I think that was intended but not 100% clear.*

RESPONSE: The paragraph was revised as follows.

No comprehensive, up-to-date coverage of sewer service areas is available for the entire watershed. Data from the 1990 census indicate the following sewer usage proportions (NC DEH, 1999). :

- Alamance County, 62% of population ~~sewer usage~~,
- Chatham County, 33% of population ~~sewer usage~~,
- Durham County, 91% of population ~~sewer usage~~, and
- Orange County, 68% of population ~~sewer usage~~.

COMMENT: ***Page 26*** *Header uses the word "validation" which is incorrect. The model has not been validated. The discussion that followed this header points out the problems with calibration, poor model fit, and the issues surrounding seasonal fit. There were very few data points outside of the summer growing season, so it is not surprising that the results were inconsistent for the fall data.*

RESPONSE: Typically, the output of water quality models is compared to measured data so that model input parameters can be adjusted to achieve the best agreement between simulated and measured water quality data. This process is known as calibration. After calibration, model output is compared to another set of measured data (from a different time period than the data used for calibration) in a process called validation.

The initial Jordan Lake Nutrient Response Model was calibrated using data from 1997-1999. When the Upper New Hope Arm of the lake was listed as impaired on the 303(d) list in 2002, it was decided to use the additional monitoring data collected in 2000 and 2001 to complement the initial modeling study for TMDL development. It was found that the initial model input parameters used for the 1997-1999 time period did not provide satisfactory results for 2001 (the model was not calibrated for 2000 because there were limited tributary data that year). This may have been due in part to using uncorrected chlorophyll *a* in 1997-1999 and corrected data in 2001. A constrained recalibration was undertaken to find a set of model input parameters that would allow the best compromise between both sets of data. The recalibrated model used monitoring data from 2000 for validation.

It is true that there were few monitoring data points that fell outside the summer season and that model fit with measured data outside the summer season is poor. However, this TMDL is based on the percentage of chlorophyll *a* standard exceedances *during the summer season*, where there are many monitoring data points and where the model fit with measured chlorophyll *a* concentrations was the best.

COMMENT: ***Page 31*** *In Table 7. the NPDES permit number for the City of Burlington South Burlington WWTP is incorrect. The correct permit number is NC0023876. Also, the average annual delivered load for TP for the South Burlington WWTP and the Reidsville WWTP are incorrect. There appears to be a decimal instead of a comma in those two numbers (typo's).*

RESPONSE: The permit number for the Burlington South WWTP was corrected. The decimal was replaced with a comma for the TP average annual delivered load for Burlington as well as Reidsville.

COMMENT: ***Page 37*** *The first sentence in this section should expressly state that the nitrogen and phosphorus loads shown in Figure 11 are for the Upper New Hope Arm.*

RESPONSE: The first sentence was revised as follows.

Sources of the nonpoint nitrogen and phosphorus load <u>in the Upper New Hope Management Area</u> are summarized in Figure 11.

COMMENT: ***Page 43*** *Figure 13 should use the same scale of 1:1 TN:TP like the Figure 12. This would present a truer picture of the two arms of the lake. It is misleading to present Figure 13 with a scale of 1.5:1.5.*

RESPONSE: Figure 13 was revised to show a scale of 1:1 TN:TP similar to that of Figure 12.

COMMENT: ***Page 46*** *In the first line on this page there is a typo with the word statistics used twice.*

RESPONSE: This has been corrected.

COMMENT: ***Page 47*** *It is important to note that blue green algae blooms occur in other waterbodies and some have no direct discharges of pollutants.*

RESPONSE: The TMDL document does not suggest that blue green blooms only occur in waterbodies with direct discharges; therefore no changes to the document were made.

COMMENT: ***Page 50*** *In the next to last paragraph on this page, the flow used for determining the allocation should be the flow related to the baseline nutrient determination. It doesn't make sense to use flows from 2004 and nutrient data from the 1997-2001 baseline period.*

RESPONSE: The discharger permitted flow is simply a means of dividing up the waste load allocation established by this TMDL among dischargers in the Jordan Lake watershed. The permitted flow for 2004 was used because there were permitted WWTP expansions already underway or completed during 2004 and 2005, after the 1997-2001 baseline period. Using the 2004 permitted flows thus accounted for these expansions and represents the most current representation of point source dischargers to Jordan Lake. These are the correct flows to use for allocation purposes.

COMMENT: *Three commenters believed that the statement "DWQ would work with DFR to require forestry pre-harvest notification (EMC has no control over this management area)" should be deleted from the document.*

RESPONSE: This statement was inadvertently left in the TMDL from a previous version. The statement was removed from the TMDL document.

COMMENT: *Two commenters expressed concern that reductions in chlorophyll a may affect the productivity of the lake for recreational fishing.*

RESPONSE: It is true that algal communities are the foundation of the aquatic food web in Jordan Lake, and that reductions in algal concentrations below a certain level could affect the productivity of the Jordan Lake fishery. DWQ acknowledges the need for a minimum level of chlorophyll *a* concentration in the lake. Model results indicate that mean summer chlorophyll *a* concentrations will remain above the 15 μg/l minimum concentration recommended by the NC Wildlife Resources Commission.

COMMENT: *The DOT was not invited to participate in the stakeholder process to develop the Jordan Reservoir TMDL and management strategy described on page 56 of the TMDL report.*

RESPONSE: This was an oversight by DWQ and the Triangle J Council of Governments who facilitated the stakeholder process for the development of the Jordan Lake Nutrient Management Strategy, and it was completely unintentional. DWQ apologizes for not specifically including DOT in the stakeholder process.

COMMENT: *The DOT is concerned that DWQ made no effort to quantify nutrient loads from DOT facilities in the TMDL.*

RESPONSE: DWQ assumes that DOT is referring to nutrient loads as they pertain to their MS4 permit. Permitted stormwater loading (WLA-SW) was not explicitly separated from non-permitted loading from non-point sources (LA) in this TMDL (see Section 7, page 49). As such, the percent reduction in nitrogen and phosphorus loads for all MS4s is the same as that indicated in the TMDL for non-point source loads. There are 20 stormwater MS4 permits in the Jordan Lake watershed. DWQ did not attempt to quantify nutrient loads from any of these individual permitees.

COMMENT: *The watershed model is poorly explained and documented in the TMDL report.*

RESPONSE: The watershed model was not used in the calculation of total maximum daily loads to Jordan Lake, rather it was used to estimate nutrient loading by point and non-point sources from 14-digit HUCs, counties, land uses, etc. for the implementation of the nutrient reductions proposed in this TMDL document. As a result, DWQ did not go into great detail regarding the development and implementation of the watershed model in the TMDL document. The DOT is encouraged to refer to the B. Everett Jordan Lake TMDL Watershed Model Development report (Tetra Tech, 2003) for watershed model details not presented in the TMDL document. DWQ will provide the DOT with a copy of this report if necessary.

COMMENT: *We are not convinced that the requirement for a Margin of Safety for the Jordan Lake TMDL has been met – since all assimilative capacity has been allocated.*

RESPONSE: It is true that all of the available mass loading was allocated to existing facilities with no additional mass allocations for future discharges or expansions. The TMDL document discusses the incorporation of an explicit margin of safety used to account for uncertainty in the relationship between pollutant loads and receiving water quality (Section 6.6, pages 44-45). The margin of safety was incorporated by reducing the maximum frequency of chlorophyll *a* exceedances from 10% to 8% when evaluating nutrient load reduction scenarios. The Jordan Lake Nutrient Management Strategy addresses future expansions of existing discharges in the watershed such that the total nutrient loading to the lake will not increase over the 1997-2001 baseline levels.

COMMENT: *The goal is to not exceed by more than 10% the chlorophyll a standard for water quality. If it's a standard, we do not see how the target includes allowing it to be violated.*

RESPONSE: This interpretation of the chlorophyll *a* standard is also used by DWQ (and supported by EPA) for use support determination. There can be unforeseen events both natural and human-induced that could occasionally cause chlorophyll *a* concentrations to exceed the chlorophyll *a* standard. Other TMDLs developed in North Carolina and approved by EPA have had similar interpretations of the standard (e.g. Neuse Estuary, Roberson Creek).

COMMENT: *Two commenters noted that this draft TMDL is proposed for the Jordan Reservoir sub-basins of the Cape Fear River Basin and that it is not being developed for the remainder of the basin. They oppose this rule being extended across the remainder of the basin without input from those parties impacted outside of the Jordan Reservoir sub-basin.*

RESPONSE: This TMDL applies only to the Jordan Lake watershed. It does not apply to the entire Cape Fear River basin.

COMMENT: *On page iii, third paragraph, a word is missing that reverses the meaning of the sentence: "Facilities that did not seeking compliance* ***extension*** *are the City of Durham/Durham South WWTP and the Durham County/Triangle WWTP…"*

RESPONSE: The sentence was revised to read:

Facilities that did not seek compliance extensions were the City of Durham/Durham South WWTP and the Durham County/Triangle WWTP.

COMMENT: *...From the Cape Fear River Basinwide Water Quality Plan. "DWQ performed a statistical trend analysis at site BA177 using total nitrogen, total phosphorus and total suspended solids data collected from 1990 to 2004. There was a significant decrease in total nitrogen of 0.17 mg/l per year in New Hope Creek. Downward trends were noted for total phosphorus and total suspended solids, although these trends were not significant."*

RESPONSE: It is true that nitrogen loads have decreased in New Hope Creek, and DWQ appreciates the efforts of the City of Durham in implementing plant improvements that make this possible. However, despite reductions in nitrogen loads from New Hope Creek, there are still many instances of exceedance of the chlorophyll *a* standard in the New Hope Creek arm of the lake as well as in downstream segments (see pages13-15). These excursions of the chlorophyll *a* standard indicate that the reductions in nitrogen loading in this tributary have not been enough to address the impairment in Jordan Lake and that further reductions are needed.

COMMENT: *The flux software was used to calculate loads into the lake and nonpoint sources loads were estimated by subtracting the nearby upstream wastewater loads. This appears to over-estimate the nonpoint source contribution.*

RESPONSE: The proportion of nutrient loading to Jordan Lake contributed by non-point sources was estimated by subtracting the total delivered point source loads to the lake from the total loading to the lake over the 1997-2001 time period. The total delivered point source loads were estimated using measured discharger loads adjusted for attenuation in the tributary network. The total loading (point and non-point source loading) to the lake was estimated using the FLUX software to create a daily time series of nutrient loading from each of the tributaries to the lake based on measured flow and nutrient concentrations. This is an accepted means of calculating non-point source loads.