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FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Water Resource Management, Bureau of Watershed Management

CENTRAL DISTRICT • MIDDLE ST. JOHNS BASIN

TMDL Report

Nutrient and Unionized Ammonia TMDLs for Lake Jesup, WBIDs 2981 and 2981A

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April 14, 2006

Executive Summary

This report presents the Total Maximum Daily Load (TMDL) for nutrients and unionized ammonia for Lake Jesup (including Lake Jesup outlet), in the Middle St. Johns Basin. The lake was verified as impaired for nutrients and unionized ammonia due to elevated annual average Trophic State Index (TSI) values and exceedances of the unionized ammonia criterion (0.02 milligrams per liter [mg/L]), and was included on the Verified List of impaired waters for the Middle St. Johns Basin that was adopted by Secretarial Order on May 27, 2004. According to the 1999 Florida Watershed Restoration Act (FWRA), Chapter 99-223, Laws of Florida, once a waterbody is included on the Verified List, a TMDL must be developed. The purpose of the TMDL is to establish the allowable loadings of pollutants to Lake Jesup that would restore the waterbody so that it meets its applicable water quality criteria for nutrients and unionized ammonia.

The nutrient TMDL for Lake Jesup was developed through four major steps:

1. Establish the TSI target
2. Model the existing nutrient load
3. Model the load that would achieve the TSI target (the TMDL)
4. Estimate the percent load reduction needed to meet the TMDL.

To establish the TSI target, the Department first estimated the background TSI for the lake by comparing results from several methods, including a historic sedimentation rate method, literature published values, a TSI defined by the Florida Impaired Waters Rule, an Ecoregion approach, a hydrogeomorphologic method, and a model simulated background condition. Results from these different methods all converged on a TSI of 60. To allow some assimilative capacity above background, the Department added 5 TSI units to the estimated background TSI and defined 65 as the target TSI for Lake Jesup.

Nutrient loads from the watershed were simulated using a watershed pollutant loading model developed by PBS&J. This model is based on the Soil Conservation Service curve number approach, which takes into consideration the landuse, soil, and antecedent moisture condition of the soil in simulating the watershed loads. Nutrient loads from other sources, including groundwater input through baseflow and Artesian flow, loading from septic tanks, atmospheric deposition directly on to the lake surface, and nitrogen fixation were also considered.

Estimates of nutrient loads from all these sources were entered into the Bathtub model to estimate in-lake TN, TP, and chlorophyll *a* concentrations, and model calibration was conducted through fitting model simulated concentrations with measured results. The watershed nutrient loads that resulted in existing TN, TP, and chlorophyll a concentrations were considered the existing nutrient loads.

To estimate the nutrient TMDL, nutrient loads from different sources were adjusted using the calibrated PBS&J-Bathtub model suite until the target TSI was achieved. The nutrient loads that resulted in the target TSI were considered the TMDL. The percent load reduction required to achieve the TMDL was then calculated by dividing the difference between the existing load and the TMDL by the existing load. The following table provides the TN and TP TMDLs and required percent load reductions to achieve the TMDLs. As there are no major wastewater facilities discharging to surface waters in the Lake Jesup watershed, no wasteload allocation for conventional point source ($WLA_{NPDES\ wastewater}$) was estimated.

TMDL components for Lake Jesup

WBID	Parameter	TMDL (kg/year)*	$WLA_{NPDES\ Stormwater}$	LA	MOS
2981 (including 2981A)	TN	247,300	50%	50%	Implicit
2981 (including 2981A)	TP	19,000	34%	34%	Implicit

* = Kilograms per year

Un-ionized ammonia TMDL was not directly addressed in this TMDL report. Based on the observed relationship between pH and chlorophyll a concentrations, and the relationship between pH and un-ionized ammonia concentrations, the lake un-ionized ammonia concentration should meet the water quality criterion of 0.02 mg/L, once the target TSI of the lake is achieved.

Acknowledgments

This analysis could not have been accomplished without substantial support and assistance from the Seminole County Public Works Department and PBS&J. The county has very actively assisted the Florida Department of Environmental Protection (Department) in obtaining the needed information for total maximum daily load (TMDL) development and in providing valuable comments and suggestions. PBS&J, an environmental consulting company hired by Seminole County, played an indispensable role in coordinating information collection and assembly for the Department, providing the watershed model, and actively updating the model. The Department recognizes and appreciates the help received from Kim Ornberg, Mark Flomerfel, Gloria Eby, and Donald E. McKenna from Seminole County; and Joe Walter and his staff from PBS&J.

The Department acknowledges the significant input of the St. Johns River Water Management District, especially the contributions of Troy Keller and Yanbing Jia. Both provided valuable suggestions on the modeling approach and constantly exchanged information with the Department on their efforts in developing the pollutant load reduction goal (PLRG) for Lake Jesup. The studies conducted by Troy Keller on potential water quality targets for the PLRG provided an important basis for the Department to develop its water quality targets for the TMDL.

The Department would like to thank the Orange County Public Works Department and the cities of Orlando, Winter Park, Maitland, Altamonte Springs, Casselberry, Winter Springs, Oviedo, and Lake Mary. All these agencies provided valuable information to help the Department better understand the Lake Jesup watershed, and also provided a significant amount of data to support the modeling efforts.

Our appreciation goes to the Friends of Lake Jesup (Robert King and his colleagues). The concerns raised by this environmental group helped the Department to consider various issues related to TMDL development and the management of the overall watershed and lake. The Department also thanks Doug Dycus (PBS&J) and Steve Lienhart (URS Corporation) for their valuable input and suggestions.

Finally, this TMDL could not have been completed without close cooperation among Department staff. Mary Paulic did a great job of organizing local stakeholder meetings. Barbara Donner provided assistance in basin delineation and estimated the forest/wetlands ratio for background condition. Rick Hicks and Haizhi Chen provided data for ground water quality. Douglas Gilbert, Wayne Magley, Jan Mandrup-Poulsen, Fred Calder, and Paul Lee all provided valuable suggestions and comments regarding water quality modeling, ground water simulation, water management policy and regulation, and public involvement in TMDL development and implementation.

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Criteria for Surface Water Quality Classifications

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Allocation Technical Advisory Committee (ATAC) Report

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U.S. Environmental Protection Agency

Region 4: Total Maximum Daily Loads in Florida

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Chapter 1: INTRODUCTION

1.1 Purpose of Report

This report presents the Total Maximum Daily Load (TMDL) for nutrients and unionized ammonia for Lake Jesup, in the Middle St. Johns Basin. The lake was verified as impaired for nutrients and unionized ammonia due to elevated annual average Trophic State Index (TSI) values and exceedances of the unionized ammonia criterion (0.02 milligrams per liter [mg/L]), and was included on the Verified List of impaired waters for the Middle St. Johns Basin that was adopted by Secretarial Order on May 27, 2004. According to the 1999 Florida Watershed Restoration Act (FWRA), Chapter 99-223, Laws of Florida, once a waterbody is included on the Verified List, a TMDL must be developed. The purpose of the TMDL is to establish the allowable loadings of pollutants to Lake Jesup that would restore the waterbody so that it meets its applicable water quality criteria for nutrients and unionized ammonia.

1.2 Identification of Waterbody

Lake Jesup, located in central Florida **(Figure 1.1),** has a surface area of about 10,660 acres (16.7 square miles [mi^2]) and drains a watershed of about 87,331 acres (136.5 mi^2) to the St. Johns River on the northeast side of the Middle St. Johns Basin. The majority of the watershed lies within Seminole County, but a small portion on the southwest end extends into Orange County.

The lake is low-lying, with an average stage of about 1.86 feet National Geodetic Vertical Datum (NGVD). Lake elevations tend to follow the water surface elevations of the St. Johns River at its confluence with Lake Jesup. When local rainfall is lower than regional rainfall (particularly to the south), the river rises, and water flows from the St. Johns River into the lake (Keesecker, 1992). Surface runoff discharges into Lake Jesup primarily through three tributaries—Howell Creek, Gee Creek, and Soldier Creek—that are located to the south and southwest of the lake. The mean hydraulic residence time for lake waters has been estimated variously at approximately 99 days (Brezonik and Fox, 1976), 82 days (U. S. Environmental Protection Agency [EPA], 1977), and 87 days (Keesecker, 1992).

The watershed occupies a highly urbanized area. Eleven municipalities are located within or associated with the watershed: Sanford and Lake Mary on the northwest end, and Oviedo, Winter Springs, Longwood, Casselberry, Altamonte Springs, Maitland, Winter Park, Eatonville, and Orlando in the southern part. According to 2003 data from the U. S. Census Bureau, the population densities in Seminole and Orange Counties were 1,184.9 and 987.8 persons/mi^2, respectively, which were significantly higher than the state average of 296.4 persons/mi^2. The area is also undergoing rapid population growth. From 1990 through 2000, the population of Seminole and Orange Counties increased by 27.0% and 32.3%, respectively, compared with a 23.5% average increase for the state.

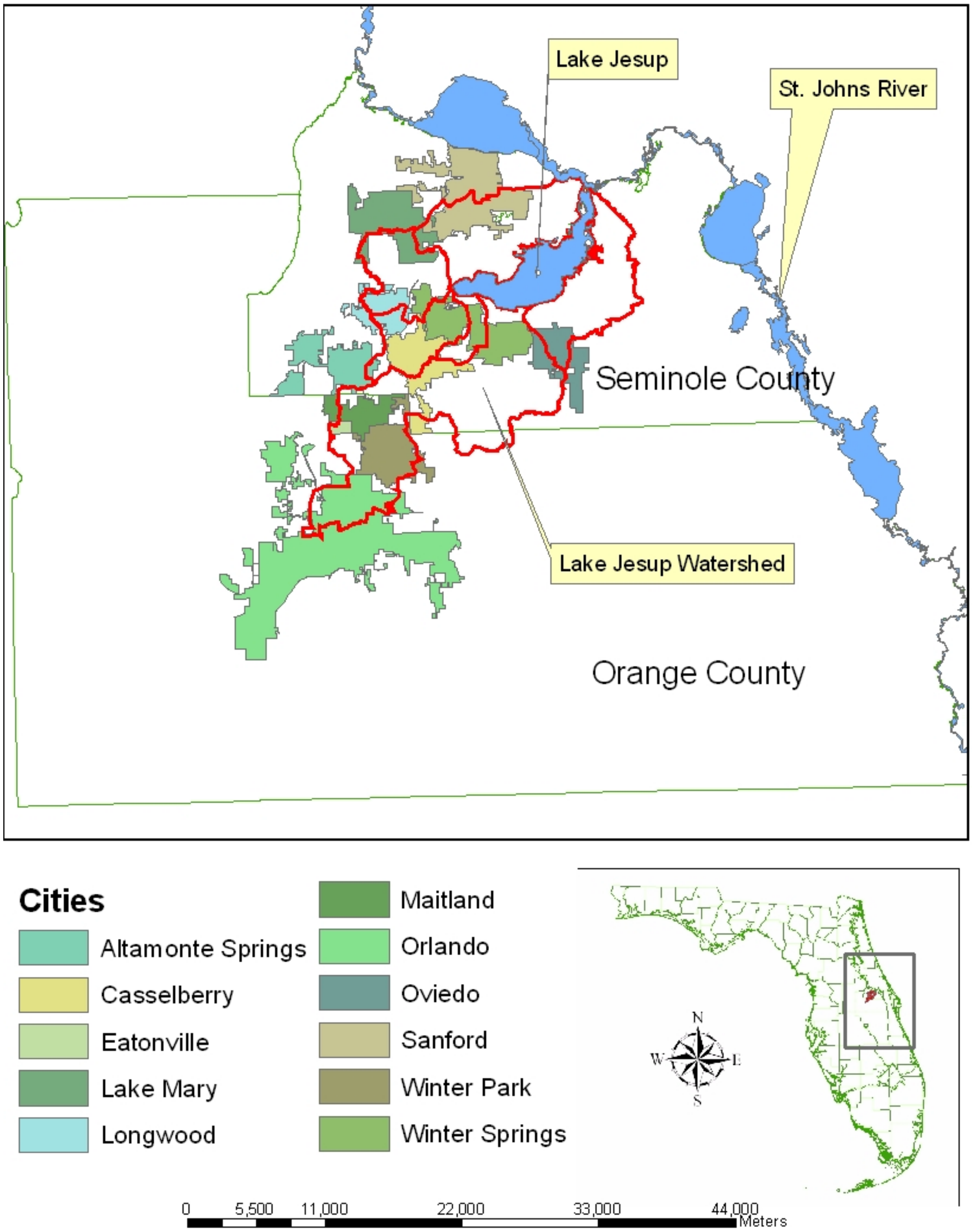


Figure 1.1. Locations of Lake Jesup and major cities in the Lake Jesup watershed

Both Seminole and Orange Counties, and all the other municipalities in the Lake Jesup watershed, are National Pollutant Discharge Elimination System (NPDES) Phase I municipal separate storm sewer system (MS4) permittees, and will be potentially affected by this TMDL.

For assessment purposes, the Department has divided the Middle St. Johns Basin into water assessment polygons with a unique waterbody identification (WBID) number for each watershed or stream reach. Lake Jesup includes two WBIDs on the Middle St. Johns Verified List of impaired waters, WBIDs 2981 and 2981A, which are addressed by this TMDL. WBID 2981 represents the majority of the lake. A very small portion of the lake directly connecting to the St. Johns River is designated as WBID 2981A. **Figure 1.2** shows the relative sizes of both WBIDs. As WBID 2981A is very small compared with the size of the whole lake, the TMDL development effort mainly focuses on the lake, under the assumption that once the eutrophication problem for the lake is solved, the water quality problem of the outlet will also be addressed.

1.3 Background

This report was developed as part of the Department's watershed management approach for restoring and protecting state waters and addressing TMDL Program requirements. The watershed approach, which is implemented using a cyclical management process that rotates through the state's 52 river basins over a 5-year cycle, provides a framework for implementing the TMDL Program–related requirements of the 1972 federal Clean Water Act and the FWRA.

A TMDL represents the maximum amount of a given pollutant that a waterbody can assimilate and still meet water quality standards, including its applicable water quality criteria and its designated uses. TMDLs are developed for waterbodies that are verified as not meeting their water quality standards, and provide important water quality restoration goals that will guide restoration activities.

This TMDL report will be followed by the development and implementation of a Basin Management Action Plan, or BMAP, to reduce the amount of nutrients that caused the verified impairment of Lake Jesup. These activities will depend heavily on the active participation of the St. Johns River Water Management District (SJRWMD), local governments, businesses, and other stakeholders. The Department will work with these organizations and individuals to undertake or continue reductions in the discharge of pollutants and achieve the established TMDLs for impaired waterbodies.

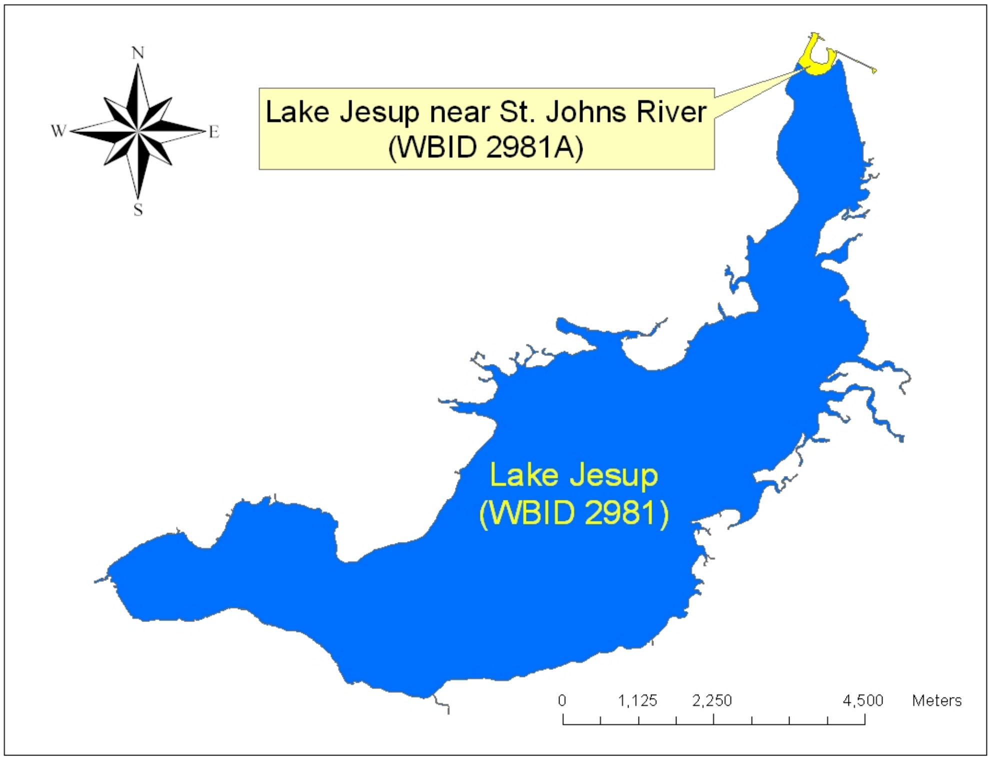


Figure 1.2. Relative sizes of WBIDs 2981 and 2981A

Chapter 2: DESCRIPTION OF WATER QUALITY PROBLEM

2.1 Statutory Requirements and Rulemaking History

Section 303(d) of the Clean Water Act requires states to submit to the EPA a list of surface waters that do not meet applicable water quality standards (impaired waters) and establish a TMDL for each pollutant source in each of these impaired waters on a schedule. The Department has developed these lists, commonly referred to as 303(d) lists, since 1992. The list of impaired waters in each basin is also required by the FWRA (Subsection 403.067[4)] Florida Statutes [F.S.]), and the list is amended annually to include updates for each basin statewide.

Florida's 1998 303(d) list included 22 waterbodies in the Middle St. Johns Basin. However, the FWRA (Section 403.067, F.S.) stated that all previous Florida 303(d) lists were for planning purposes only and directed the Department to develop, and adopt by rule, a new science-based methodology to identify impaired waters. After a long rulemaking process, the Environmental Regulation Commission adopted the new methodology as Chapter 62-303, Florida Administrative Code (F.A.C.) (Identification of Impaired Surface Waters Rule, or IWR), in April 2001. The list of waters for which impairments have been verified using the methodology in the IWR is referred to as the Verified List.

2.2 Information on Verified Impairment

The Department used the IWR to assess water quality impairments in the Middle St. Johns Basin and verified impairments for Lake Jesup **(Table 2.1).** The lake was verified as impaired for nutrients based on the fact that, in the verified period (January 1, 1996, through June 30, 2003), annual average TSI values exceeded 60 every year **(Table 2.2).** Based on the long-term median total phosphorus/total nitrogen (TN/TP) ratio of 17 (weight ratio), Lake Jesup phytoplankton communities were considered co-limited by phosphorus and nitrogen. The impairment for unionized ammonia was based on the fact that 27 out of 154 observations of unionized ammonia exceeded the water quality criterion (0.02 milligrams per liter [mg/L]).

Table 2.1. Verified impaired waterbody segments in the Lake Jesup watershed

WBID	Waterbody Segment	Parameters of Concern
2981	Lake Jesup	Nutrients
2981	Lake Jesup	Unionized Ammonia
2981A	Lake Jesup near St. Johns River	Nutrients

Table 2.2. Summary of annual TSI values for Lake Jesup in the verified period, 1996–2002 (WBIDs 2981 and 2981A)

Year	WBID 2981		WBID 2981A	
	Mean Color (PCUs*)	TSI	Mean Color (PCUs*)	TSI
1996	113	76	127	69
1997	61	74	97	68
1998	58	77	71	68
1999	123	81	132	74
2000	65	83	69	-
2001	70	84	-	-
2002	92	74	-	-

* = Platinum cobalt units
- = Not enough data to calculate annual mean TSI

Chapter 3. DESCRIPTION OF APPLICABLE WATER QUALITY STANDARDS AND TARGETS

3.1 Classification of the Waterbody and Criteria Applicable to the TMDL

Florida's surface waters are protected for five designated use classifications, as follows:

Class I	**Potable water supplies**
Class II	**Shellfish propagation or harvesting**
Class III	**Recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife**
Class IV	**Agricultural water supplies**
Class V	**Navigation, utility, and industrial use (there are no state waters currently in this class)**

Lake Jesup is a Class III waterbody, with a designated use of recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criteria applicable to the impairment addressed by this TMDL are unionized ammonia and nutrients.

3.2 Applicable Water Quality Standards and Numeric Water Quality Target

3.2.1 Unionized Ammonia Criterion

The Class III water quality criterion for unionized ammonia is 0.02 mg/L.

3.2.2 Interpretation of Narrative Nutrient Criterion

Florida's nutrient criterion is narrative only—i.e., nutrient concentrations of a body of water shall not be altered so as to cause an imbalance in natural populations of aquatic flora or fauna. Accordingly, a nutrient-related target was needed to represent levels at which an imbalance in flora or fauna is expected to occur. While the IWR provides a threshold for nutrient impairment for lakes based on annual average TSI levels, the threshold is not a standard and need not be used as the nutrient-related water quality target for TMDLs. In fact, in recognition that the IWR threshold was developed using statewide average conditions, the IWR (Subsection 62-303.450, F.A.C.) specifically allows the use of alternative, site-specific thresholds that more accurately reflect conditions beyond which an imbalance in flora or fauna occurs in a waterbody.

For this analysis, the Department established the TSI target by comparing the target TN and TP concentrations proposed by the SJRWMD **(Table 3.1)** with the target TN and TP concentrations estimated by the Department using watershed and water quality models. The SJRWMD used three major approaches to develop the target TN and TP concentrations. These include (1) examining Lake Jesup phytoplankton and zooplankton abundance and diversity against TN and

TP concentrations, analyzing historical sedimentation rates, and using water clarity targets defined by the lake area covered by submerged aquatic vegetation (SAV) to derive the TN and TP concentrations; (2) using literature methods to define the target concentration; and (3) using the ecoregion method or hydrogeomorphologic information to define the water quality targets.

Table 3.1. Summary of different SJRWMD approaches to determine Lake Jesup's water quality target concentrations for TP and TN

Approach	Period	Nutrient Target Concentration (mg/L)		Notes
		TP	TN	
Lake-specific Approach				
Chlorophyll *a* (chl *a)*	2/95–7/02	-	2.0	Chl *a* uncorrected
Zooplankton abundance	1/01–2/03	-	2.4	Rotifer abundance
25% SAV coverage	2/01–7/03	0.044	0.61	Estimated from compensation depth
Historical sedimentation rates	Pre-1920 and 1985–96	0.076	-	Estimated using sediment cores and models
Literature Reference Approach				
Literature	1993–97	0.040	1.1	Paul and Gerritsen, 2002
Chl *a* bloom frequency	1989–2000	0.050	0.70	Bachmann et al., 2003
Modified from IWR	Pre-1980	0.070	1.2	Huber et al., 1982
Florida Lake Comparisons				
Ecoregion	1980-1990	0.074	1.5	Hendrickson, unpublished
Hydrogeomorphologic	Pre-1980	0.041	0.80	Huber et al., 1982
PLRG target		**0.050**	**1.2**	

- = Inconclusive in defining target concentrations

Based on input from the SJRWMD (T. Keller, SJRWMD, personal communication), the major purpose of examining the abundance and biodiversity of phytoplankton and zooplankton communities against TN and TP concentrations in Lake Jesup was to find out whether there are threshold TN and TP concentrations above which dramatic changes in abundance or community diversity were observed. For the period of record examined, however, the TP concentration stayed constantly high, thus providing no hint of abundance and diversity under low TP concentrations. Therefore, no threshold could be identified for phosphorus using this method.

Apparent changes of abundance for both phytoplankton (chl *a* concentration) and zooplankton (mainly rotifer abundance) were observed at TN concentrations of 2.0 and 2.4 mg/L, respectively **(Table 3.1).** Because of the possible existence of significant nitrogen fixation, however, the Department believes that it is difficult to determine whether nitrogen is the cause of the change in the community structure, or the consequence of the change in the community structure. Therefore, the Department deemed inconclusive the target TN concentrations of 2.0 or 2.4 mg/L for phytoplankton and zooplankton, respectively.

Water quality targets were also studied by examining the relationship between TN and TP concentrations and water clarity (T. Keller, SJRWMD, personal communication). The major purpose of this study was to find out what TN and TP concentrations would provide sufficient water clarity to facilitate the growth of SAV over 25% of Lake Jesup's benthos. The use of this method was stimulated by the Florida Fish and Wildlife Conservation Commission's (FWCC) SAV goals for Lake Jesup. The 25% SAV coverage was thought to enhance fisheries and provide habitat for wildlife. SAV may also reduce the resuspension of flocculent organic sediments.

Water clarity in this case is measured using compensation depth, which is considered to be the water depth at which the incoming photosynthetically active radiation (PAR) decreases to about 5% of its original intensity (the definition of compensation depth adopted by the Department is 1% of the incoming radiation). In this analysis, compensation depth could be determined using the characteristic curve of the lake and 25% area coverage. The target TN and TP concentrations could then be determined using regression curves between compensation depth and TN and TP concentrations. As shown in **Table 3.1,** TN and TP targets established using this method are 0.61 and 0.044 mg/L, respectively.

Based on the SJRWMD, however, the TP target was established using a regression curve with a low regression coefficient ($R^2 = 0.2$). The Department believes that the TN target could once again be influenced by nitrogen coming from nitrogen fixation, which, by itself, is the consequence instead of the cause of the eutrophication. In addition, TN and TP targets established using this technique are tied to the usage of the lake, instead of the lake's natural assimilative capacity. Therefore, the Department gave lesser weight to the TN and TP targets developed using the water clarity technique.

The SJRWMD also used lake TN and TP concentrations prior to rapid development in the Lake Jesup watershed to infer the target concentrations. This technique assumed that the TN and TP sedimentation rates are proportional to the TN and TP concentrations in the water column. Therefore, if historical and current sedimentation rates and current lake TN and TP concentrations are known, assuming that the specific sedimentation rates for TN and TP are the same for current and historical conditions, TN and TP concentrations prior to the rapid development could be determined. Using this technique, the SJRWMD proposed a target TP concentration of about 0.076 mg/L **(Table 3.1).** No TN target was proposed using this technique, because possible denitrification in the sediment may lead to an underestimation of the actual TN sedimentation rate.

TN and TP targets for Lake Jesup could also be derived from a study conducted by Tetra Tech, Inc., based on data collected from 200 Florida lakes between 1993 and 1997 (Paul and Gerritsen, 2002). A variety of exploratory analyses of these data suggested that the strongest organizing forces on the biota of the relatively undisturbed lakes were water color and pH (Gerritsen et al., 2000). On the basis of these results, the sampled lake regions were aggregated into 5 lake biological classes, such that the lakes within each class have similar biological assemblages. The lake classes were divided based on water color (greater than or less than 20 PCUs, pH (greater than or less than 6.5), and ecoregion for acid clear lakes only (Omernik, 1987: Region 65 in northwest Florida and Region 75 in peninsular Florida).

Several techniques were used in each lake class to establish TN and TP target concentrations. These included the reference lake technique, sediment diatom reconstructions, morphoedaphic indices, LOESS regression of lake trophic condition index (tLCI) versus nutrients, and multiple linear regression (Paul and Gerritsen, 2002). Among all the techniques used, the reference lake technique, LOESS regression of tLCI versus nutrients, and diatom reconstruction based on paleolimnological data provided meaningful results **(Table 3.2).**

Table 3.2. Summary of phosphorus/nitrogen concentrations (micrograms per liter [µg/L]) suggested as potential criteria for five different lake classes in Florida

Lake Class	Methodological Approach		
	75^{th} Percentile of Reference Distribution	LOESS Regression (tLCI versus Nutrients)	Paleolimnology (TROPH1 model)
Acid clear lakes			
EcoRegion 65	10/330	21/473	4*/NA
EcoRegion 75	10/470	23/776	67*/NA
Acid colored lakes	42/910	43/1202	17*/NA
Alkaline clear lakes	10/750	17/692	25/NA
Alkaline colored lakes	73/1110	40/1148	32/NA

* = N < 6
NA = Not applicable

Since the long-term average color of Lake Jesup is greater than 20 PCUs and the long-term average pH is greater than 6.5, the lake is considered an alkaline colored lake. Based on a study by the SJRWMD, the diatom reconstruction technique failed to predict accurately the current phosphorus concentration in Lake Jesup (T. Keller, SJRWMD, personal communication). Therefore, the Department did not use the result from this technique. While the reference lake technique and LOESS regression produced relatively similar results for TN, about 1,100 mg/L for alkaline colored lakes, the TP results from these 2 techniques appeared to be different **(Table 3.2).** Paul and Gerritsen (2002) believed that the difference could be caused by the different responses of different communities to the same nutrient concentration. These authors suggested that 40 µg/L of TP should be used as the target concentration, just to be more conservative and to protect downstream waters

In contrast, the Department believes that as the LOESS regression relies heavily on the biological response to the nutrient concentration, and many factors other than nutrient concentration per se can influence the response, the results from LOESS are not as easily interpretable as the results from the reference lake technique. A large standard deviation is indeed associated with the regression curve between tLCI and TP concentration in Paul and Gerritsen (2002). The Department therefore believes that target TN and TP concentrations from the reference lake technique, which are 1.100 and 0.073 mg/L, respectively, are more direct results and should be used for Lake Jesup.

Potential TN and TP targets were also derived based on a relationship developed by Bachmann et al. (2003) between the frequency of algal blooms and TN and TP concentrations. These authors analyzed 1,473 lake-years of data on 438 Florida lakes to develop a series of tables. These can be used to predict the frequencies that phytoplankton chlorophylls will exceed concentrations of 10, 20, 30, 40, 50, and 60 µg/L in Florida lakes, based on the annual average concentrations of chlorophyll, TP, or TN. In their studies, the authors created different tables for lakes grouped by TN/TP ratios of > 17, < 17 but > 10, and < 10. Since the TN/TP ratio for Lake Jesup appears to fall between 10 and 17 most of the time, suggesting that the lake's phytoplankton community is co-limited by nitrogen and phosphorus, the target TN and TP concentrations for Lake Jesup were developed based on the table for lakes with the corresponding TN/TP ratio.

Table 3.3 shows the frequency of algal blooms at different TN and TP concentrations. A large standard deviation, however, is associated with the relationship between TN and TP concentrations and chl *a* concentration and bloom frequency when TN/TP ratios fall between 10 and 17, especially when TN and TP concentrations are low (Bachmann et al., 2003). The Department therefore gave lesser weight to the TN and TP targets developed using this method.

The SJRWMD proposed a critical chl *a* threshold to define a bloom as 40 µg/L and an exceedance frequency of 2 months per year, which is about 17% of the bloom frequency. The TP and TN associated with these target numbers, based on **Table 3.3**, are 50 µg/L (0.05 mg/L) and 700 µg/L (0.7 mg/L), respectively.

Target TN and TP concentrations could also be derived, based on the threshold TSI of 60 for lakes with water color higher than 40 PCUs. This TSI target is defined in the IWR (Section 62-303.352, F.A.C.). Huber et al. (1982) developed the equation on which the target TSI is based. For lakes with a TN/TP ratio falling between 10 and 30, the equation is as follows:

$$TSI\ (TN) = 10*(5.6 + 1.98*LnTN)$$
$$TSI\ (TP) = 10*(1.86*LnTP - 1.84)$$

The TN and TP concentrations for a TSI of 60 are 1.22 and 0.068 mg/L, respectively.

The SJRWMD used Hendrickson's ecoregion approach (unpublished study) to select lakes that are considered to be in Lake Jesup's ecoregion. In this analysis, Lake Jesup was classified as a 5th-order Atlantic Coast Forest Rivers lake. To improve the sample size, the analysis also included some 4th-order Atlantic Coast Forest Rivers lakes (T. Keller, SJRWMD, personal communication). Based on this information, the target TP is 0.074 mg/L, and the target TN is about 1.5 mg/L.

Table 3.3. Estimated percent of the time that chlorophyll concentrations will exceed the listed concentrations in lakes with a TN/TP ratio between 10 and 17

Concentrations of chlorophyll (CHL), TN, and TP are in µg/L (Bachmann et al., 2003)

TP	CHL > 10	CHL > 20	CHL > 30	CHL > 40	CHL > 50	CHL > 60
10	19	3	0	0	0	0
25	23	4	0	0	0	0
35	73	32	6	0	0	0
40	79	47	15	6	2	1
45	85	53	21	11	6	2
50	87	61	27	17	10	5
55	90	67	32	22	15	7
60	92	70	38	30	19	10
65	94	74	44	35	25	14
70	95	78	48	40	28	17
75	96	81	53	46	33	20
80	96	85	60	52	38	24
85	96	90	68	58	44	27
90	96	92	72	64	49	32
95	96	95	77	68	55	38
103	96	95	85	78	65	44
127	96	95	86	79	69	58
139	96	95	86	80	70	65
157	96	95	86	81	72	68
197	96	95	86	82	75	73
TN	**CHL > 10**	**CHL > 20**	**CHL > 30**	**CHL > 40**	**CHL > 50**	**CHL > 60**
124	10	2	0	0	0	0
372	32	4	1	0	0	0
500	74	38	12	4	1	1
600	82	48	24	10	4	2
700	85	55	35	16	10	3
800	89	62	41	22	15	6
900	93	69	46	26	22	11
1,000	95	76	50	33	28	17
1,100	97	81	58	44	40	26
1,200	99	87	65	53	48	30
1,221	99	89	70	55	50	32
1,292	100	94	81	65	56	37
1,400	100	100	96	84	67	46
1,600	100	100	96	89	78	59
1,800	100	100	96	89	78	67
2,000	100	100	96	89	78	71
2,491	100	100	96	89	78	73

In developing target TN and TP concentrations for Lake Jesup, the SJRWMD used a hydrogeomorphic approach that was also used to establish the Lake Apopka water quality target. Huber et al.'s (1982) data were used to define lakes that have hydrologic and morphologic characteristics similar to those of Lake Jesup. The criteria used to filter this data set included detention time (> 0.5* and < 4* 0.22 years; Lake Jesup detention time is about 0.25 years), lake area (> 0.2* and < 5* 10,339 acres; Lake Jesup surface area is about 10,660 acres), mean depth (> 0.3* and < 3* 1.96 feet NGVD; Lake Jesup mean surface elevation is about 1.86 feet NGVD), and drainage area/lake area (>0.2* and < 5* 8.97; Lake Jesup drainage area/lake area ratio is about 8.19) (here, * means multiplying). The TN and TP concentrations derived from this method are 0.80 and 0.041 mg/L, respectively.

Table 3.4 lists some of the potential water quality targets from the SJRWMD's target matrix. The Department believes these targets can be used for further analysis.

Table 3.4. Summary of the SJRWMD's Lake Jesup water quality targets kept for further analysis by the Department

Approach	Period	Nutrient Target Concentration (mg/L)		Notes
		TP	TN	
Lake-Specific Approach				
Historical sedimentation rates	Pre-1920 and 1985–96	0.076	-	Estimated sediment cores and models
Literature Reference Approach				
Literature	1993–97	0.073	1.100	Paul and Gerritsen, 2002
Modified from IWR	Pre-1980	0.070	1.200	Huber et al., 1981
Florida Lake Comparisons				
Ecoregion	1980–90	0.074	1.500	Hendrickson unpublished
Hydrogeomorphologic	Pre-1980	0.041	0.80	Huber et al., 1981

- = No conclusive target was reached using the method.

Based on **Table 3.4**, the potential target TP concentrations ranged from 0.041 to 0.076 mg/L, with the majority of the methods appearing to support a TP concentration above 0.070 mg/L. The target TN concentration ranged from 0.800 to 1.500 mg/L, with more methods supporting a concentration above 1.00 mg/L. The Department, therefore, averaged all the TP concentrations above 0.070 mg/L and all the TN concentrations above 1.00 mg/L, resulting in target TP and TN concentrations of 0.073 and 1.30 mg/L, respectively. Based on these TN and TP concentrations, the Department predicted a target chl *a* concentration of 22 µg/L, using the chl *a*–TP relationship developed by Huber et al. (1982) for lakes with a TN/TP ratio between 10 and 30. Using the TSI calculation procedure defined in the 1996 305(b) report, the estimated target TSI is 61, based on concentrations of 1.30 mg/L TN, 0.073 mg/L TP, and 22 µg/L chl *a*.

Because this potential target TSI of 61 is primarily developed based on information not specific to Lake Jesup, it is reasonable to ask whether the target is even achievable for Lake Jesup. The Department examined this question by simulating background water quality conditions using watershed and water quality models. Later sections of this report describe the detailed model calibration and simulation. The simulated, long-term annual average background TN, TP, and chl *a* concentrations from these models are 1.20 mg/L, 0.070 mg/L, and 20.7 µg/L, respectively, which are similar to target values established using the methods mentioned above. The background TSI value, based on background TN, TP, and chl *a* concentrations, is 60.

In modeling the background TSI value, the Department assumed that all human land use areas discharge TN and TP loadings in the same way as natural areas such as upland forests and wetlands. Considering the development that has already occurred in the Lake Jesup watershed, using this background condition as the water quality target for the lake may not be realistic. Furthermore, some increases over background condition should be allowable without causing an imbalance in the lake's flora or fauna.

The Department therefore set the target for Lake Jesup as a 5-unit increase in the TSI over the background condition, which allows for some increase in nutrient loading above the background condition but prevents a significant change in the trophic status of the lake. Using this approach, the water quality target for Lake Jesup is a TSI of 65, which corresponds to long-term annual average TN, TP, and chl *a* concentrations of 1.32 mg/L, 0.094 mg/L, and 30.5 µg/L, respectively.

Chapter 4: ASSESSMENT OF SOURCES

4.1 Types of Sources

An important part of the TMDL analysis is the identification of pollutant source categories, source subcategories, or individual sources of the pollutant of concern in the target watershed and the amount of pollutant loading contributed by each of these sources. Sources are broadly classified as either point sources or nonpoint sources. Historically, the term "point sources" has meant discharges to surface waters that typically have a continuous flow via a discernable, confined, and discrete conveyance, such as a pipe. Domestic and industrial wastewater treatment facilities (WWTFs) are examples of traditional point sources. In contrast, the term "nonpoint sources" was used to describe intermittent, rainfall-driven, diffuse sources of pollution associated with everyday human activities, including runoff from urban land uses, agriculture, silviculture, and mining; discharges from failing septic systems; and atmospheric deposition.

However, the 1987 amendments to the Clean Water Act redefined certain nonpoint sources of pollution as point sources subject to regulation under the EPA's NPDES Program. These nonpoint sources included certain urban stormwater discharges, including those from local government master drainage systems, construction sites over five acres, and a wide variety of industries (see **Appendix A** for background information on the federal and state stormwater programs).

To be consistent with Clean Water Act definitions, the term "point source" is used to describe traditional point sources (such as domestic and industrial wastewater discharges) **AND** stormwater systems requiring an NPDES stormwater permit when allocating pollutant load reductions required by a TMDL (see **Section 6.1** on **Expression and Allocation of the TMDL).** However, the methodologies used to estimate nonpoint source loads do not distinguish between NPDES and non-NPDES stormwater discharges, and as such, this source assessment section does not make any distinction between the two types of stormwater.

4.2 Potential Sources of Nutrients in the Lake Jesup Watershed

4.2.1 Point Sources

4.2.1.1 Wastewater Point Sources

Lake Jesup was one of the most eutrophic bodies of water in Florida for many years, primarily due to the input of secondary wastewater effluent for over 20 years (EPA, 1977). By 1983, direct discharge from wastewater treatment plants to Lake Jesup had been either routed outside the watershed or discharged to land application systems or percolation ponds (Seminole County, 1991). At the time this analysis was conducted, no wastewater point sources were identified in the watershed that discharge directly to surface waters.

4.2.1.2 Municipal Separate Storm Sewer System Permittees

Within the Lake Jesup watershed, the stormwater collection systems owned and operated by Seminole and Orange Counties; a number of municipalities, including Altamonte Springs, Casselberry, Eatonville, Lake Mary, Longwood, Maitland, Orlando, Oviedo, Sanford, Winter Garden, and Winter Springs; and the Florida Department of Transportation are covered by an NPDES MS4 Phase I permit. No Phase II permittees were identified in the watershed.

4.2.2 Nonpoint Sources

Additional nutrient loadings to Lake Jesup are primarily generated from nonpoint sources in the Lake Jesup watershed. As discussed earlier in this report, the watershed occupies a highly urbanized area. Eleven municipalities are located within or associated with the watershed: Sanford and Lake Mary on the northwest end of the watershed, and Oviedo, Winter Springs, Longwood, Casselberry, Altamonte Springs, Maitland, Winter Park, Eatonville, and Orlando in the southern part. According to 2003 data from the U. S Census Bureau, the population densities in Seminole and Orange Counties were 1,184.9 and 987.8 persons/mi^2, respectively, significantly higher than the state average of 296.4 persons/mi^2 (U. S. Census Bureau Web site, 2003). The area is also growing rapidly. From 1990 through 2000, the population of Seminole and Orange Counties increased by 27.0% and 32.3%, which is greater than the state average of 23.5%.

Nonpoint sources addressed in this analysis primarily include loadings from surface runoff, baseflow from the surficial aquifer (including septic tank and sewer line contributions), input from the Floridan aquifer through either spring flow or lake bottom leakage, precipitation directly onto the lake's surface, and inflow from the St. Johns River when regional rainfall is higher than local rainfall. Based on previous studies conducted in the Lake Jesup watershed, the majority of the nutrient load is generated from surface runoff or baseflow from the surficial aquifer (Keesecker, 1992; Parsons Engineering Science, Inc., 2000).

In this analysis, nutrient loadings from the watershed were estimated using a geographic information system (GIS) model provided by PBS&J. This model estimates the nutrient loadings from the watershed primarily based on the U. S. Soil Conservation Service (SCS, which is now the U. S. Department of Agriculture's National Resources Conservation Service, or NRCS) curve number approach. This approach takes into account the influence on pollutant loadings from land use categories, soil types, antecedent soil moisture condition, and best management practices (BMPs). PBS&J (contracted by Seminole County) provided the Department with the SJRWMD's 2000 land use GIS coverage (scale 1:40,000), after some recent updates from counties and municipalities were incorporated into the coverage. Soil hydrologic characteristics for the watershed were obtained from the SJRWMD's SSURGO GIS coverage and updated with local information on the Type U soil hydrologic group. PBS&J collected and provided septic tank and BMP information to the Department . The following sections describe in detail the methods used to estimate nutrient loadings from various nonpoint sources.

4.2.2.1 Land Uses

The Lake Jesup watershed drains about 87,331 acres into Lake Jesup. Land use categories in the watershed were aggregated based on the classification system in **Table 4.1. Figure 4.1** shows the distribution of the principal land uses in the watershed.

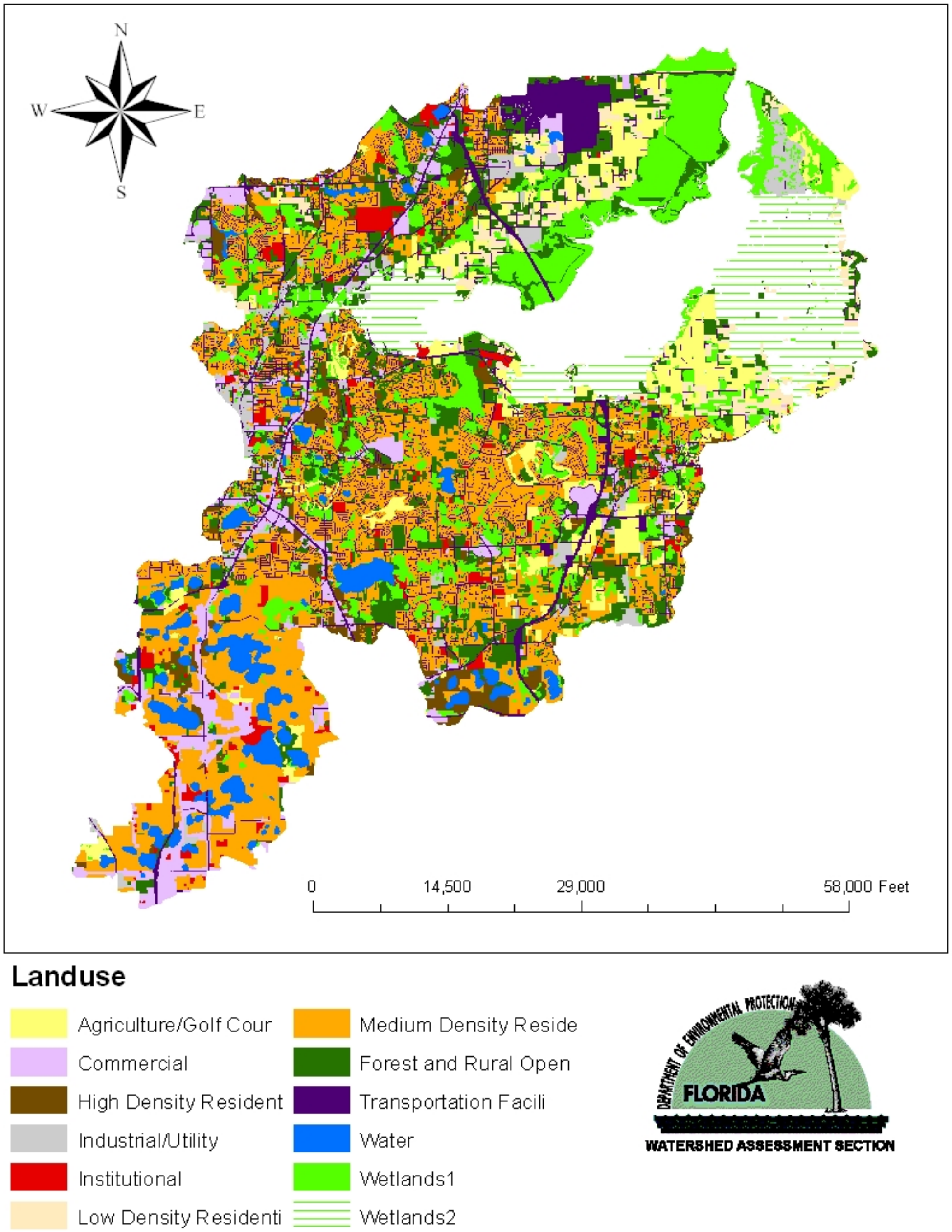


Figure 4.1. Principal land uses in the Lake Jesup watershed

Table 4.1. Classification of land use categories in the Lake Jesup watershed

Land Use	Acreage	Percent
Agriculture/Golf Course	6,264	7.2
Forest and Rural Open	11,505	13.2
Low-Density Residential	2,504	2.9
Medium-Density Residential	22,697	26.0
High-Density Residential	2,682	3.1
Commercial	4,807	5.5
Institutional	2,045	2.3
Industrial/Utility	2,375	2.7
Transportation Facilities	8,490	9.7
Water	3,863	4.4
Wetlands 1 (impacted)	11,745	13.4
Wetlands 2 (unimpacted)	8,355	9.6
Total	**87,331**	**100**

Based on **Table 4.1**, human land use areas—including agriculture/golf course, residential, commercial, institutional, industrial/utility, and transportation facilities—occupy about 51,863 acres of the Lake Jesup watershed, accounting for about 59% of the total watershed area. The remaining 41% of the watershed consists of natural areas, including forest and rural open, water, and wetlands. Although this analysis generally considered wetlands as natural areas, some of the wetland areas in the watershed that were previously used for agriculture are now recovering from human impacts. These areas were designated as Wetlands 1. The wetland areas that were not significantly affected by previous human activities were designated as Wetlands 2. PBS&J provided information regarding the locations **(Figure 4.1)** and scales **(Table 4.1)** of these 2 wetland subcategories. This analysis assumed different event mean concentrations (EMCs) of pollutants for impacted and unimpacted wetland areas; these will be discussed in detail in later sections of this report.

About 53% of the human land use area is residential, with medium-density residential claiming 22,697 acres, or about 44% of the total human land use area. Low-density and high-density residential areas both occupy about 5% of the total human land use area. Another major human land use category is transportation facilities, primarily roads, which occupy about 8,490 acres of land, or about 16% of the total human land use area. As **Figure 4.1** shows, urban and built-up areas almost cover the entire western and southern parts of the Lake Jesup watershed, with only some isolated lakes standing out among the human land use matrix.

Agricultural land use accounts for about 7% of the total watershed, mostly the part that is immediately connected to Lake Jesup. Citrus groves, tree crops, row crops, field crops, horse farms, and improved or unimproved pasturelands are some of the major agricultural activities. Nutrient inputs to the lake through surface runoff due to the application of fertilizer in the area could be a significant source of pollutants leading to lake eutrophication.

The SJRWMD began working with local governments in 1984 to purchase land around the lake for preservation. This is important not only because the land provides public recreational opportunities, but also because the marshes that are part of those lands help to maintain animal habitat, improve water quality, and allow for the storage of large volumes of water during rainy periods, thus offering flood protection to surrounding communities. The SJRWMD subsequently brought about 3,850 acres around the lake into public ownership and has targeted additional areas for acquisition. Other government agencies have purchased an additional 4,700 acres of floodplain around the lake.

4.2.2.2 Hydrologic Soil Groups

The hydrologic characteristics of soil can significantly influence the capability of a given watershed to hold rainfall or produce surface runoff. Soils of the Lake Jesup watershed are classified as Types A, B, C, or D, according to the following criteria (Viessman et al., 1989):

- **Type A soil (low runoff potential):** Soils having high infiltration rates even if thoroughly wetted and consisting chiefly of deep, well-drained to excessively drained sands or gravels. These soils have a high rate of water transmission.
- **Type B soil:** Soils having moderate infiltration rates if thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well-drained to well-drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
- **Type C soil:** Soils having slow infiltration rates if thoroughly wetted and consisting chiefly of soils with a layer that impedes the downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.
- **Type D soil (high runoff potential):** Soils having very slow infiltration rates if thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission.

Figure 4.2 shows the spatial distribution of the hydrologic soil groups in the Lake Jesup watershed. Type D soil dominates the northern part of the watershed, especially the areas that directly connect to the lake. Type A soil primarily dominates the southern part of the watershed. In this analysis, Type B soil is designated as Type B/D to indicate that when Type B soil is water saturated, its characteristics are similar to those of Type D soil. Soil hydrologic characteristics for the watershed were obtained from the SJRWMD's SSURGO GIS coverage and were updated with local information about Type U soil.

4.2.2.3 Estimating Nonpoint Loadings from the Lake Jesup Watershed

A. Estimating nonpoint TN and TP loadings using the PBS&J pollutant loading model. The PBS&J pollutant loading model is based on the SCS curve number approach, which calculates pollutant loadings from a given watershed based on the runoff coefficients for different land use–soil type combinations and EMCs for different land use categories and for different pollutants. The annual runoff coefficient for a given land use category for a given year is estimated as the ratio between the annual runoff (Q_A) from the land use area and the annual rainfall (P_A), which are the sum of daily runoff and daily rainfall, respectively. The daily runoff is calculated using Equation (1):

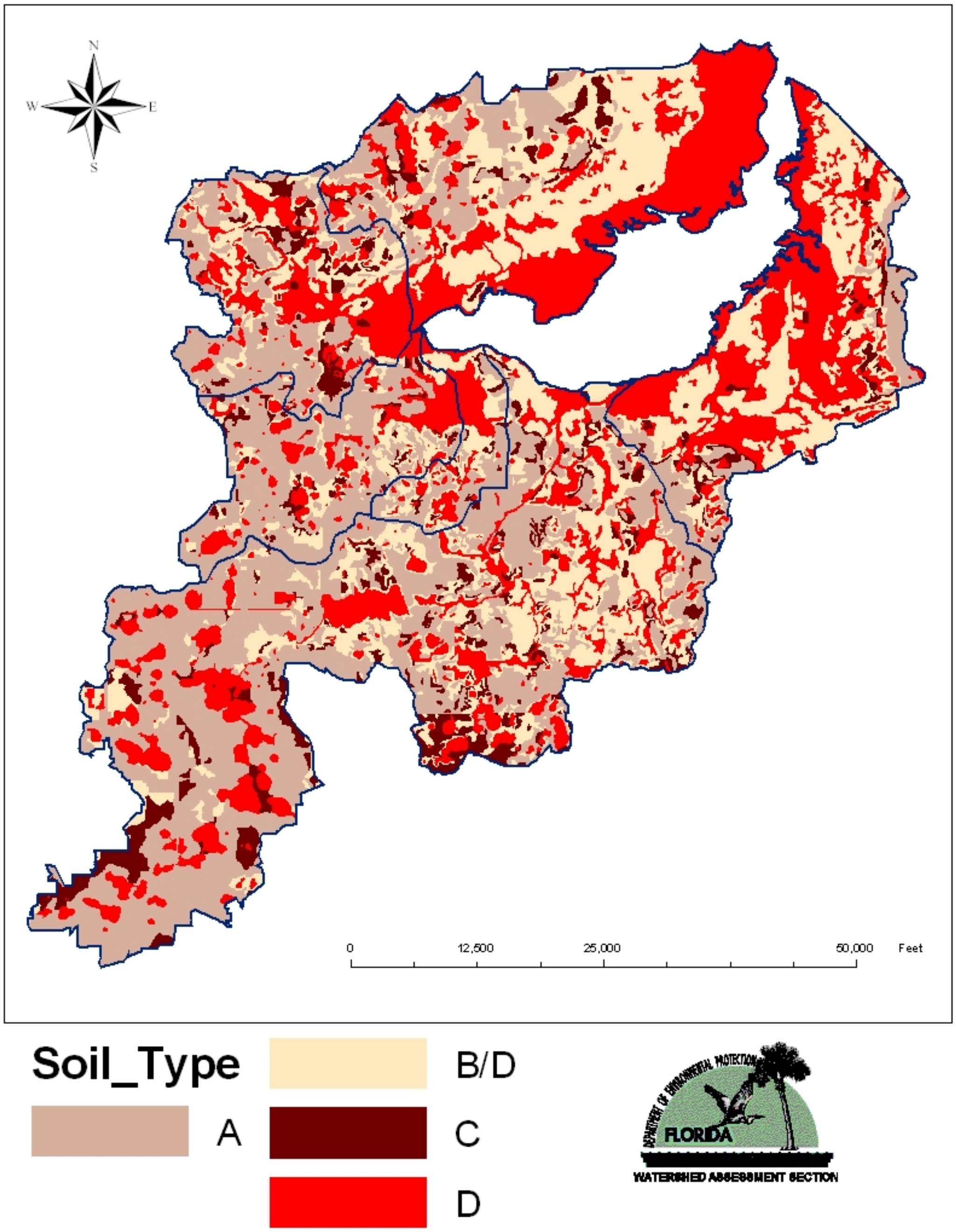


Figure 4.2. Spatial distribution of hydrologic soil groups in the Lake Jesup watershed

$$Q = \frac{(P-I)^2}{(P-I)+S} \qquad P > I \qquad (1)$$

Where:

Q is daily flow;
P is daily rainfall;
S is watershed storage; and
I is defined as the initial abstraction of the rainfall, which, according to the SCS, mainly consists of interception, depression storage, and infiltration occurring prior to runoff (Suphunvorranop, 1985).

To eliminate the necessity of estimating both *S* and *I*, the relation between *I* and *S* was developed by analyzing rainfall runoff data for many small and large watersheds from various parts of the United States. The empirical relationship is:

$$I = 0.2\,S \qquad (2)$$

Substituting Equation (2) into Equation (1) yields:

$$Q = \frac{(P-0.2S)^2}{P+0.8S} \qquad (3)$$

S is related to the curve number (CN) by:

$$S = \frac{1000}{CN} - 10 \qquad (4)$$

CN is a function of hydrologic soil group, land use, and the antecedent moisture condition (AMC) of the soil. It is dimensionless and has values ranging from 0 to 100, with 0 representing no runoff being produced and 100 representing a situation in which all the rainfall is converted to runoff.

CN associated with each land use–soil hydrologic group can vary with the AMC. The overall AMCs can be divided into three different classes, based on the growth season and the total five-day antecedent rainfall (in centimeters [cm]). **Table 4.2** lists the classification of AMCs, and **Table 4.3** lists the equivalent curve numbers under different AMC conditions.

PBS&J provided the Department with CNs for different land use–hydrologic soil group combinations. **Table 4.4** lists these CNs at AMC II. Corresponding CNs under AMC I and AMC III can be derived based on **Table 4.3**.

Table 4.2. Classifications of AMCs

Total Five-day Antecedent Rainfall (cm)		
AMC	**Dormant Season**	**Growing Season**
I	Less than 1.3	Less than 3.6
II	1.3 to 2.8	3.6 to 5.3
III	Over 2.8	Over 5.3

Table 4.3. Equivalent curve numbers under different AMC conditions

AMC I	AMC II	AMC III
0.0	0.0	0.0
2.0	5.0	17.0
4.0	10.0	26.0
7.0	15.0	33.0
9.0	20.0	39.0
12.0	25.0	45.0
15.0	30.0	50.0
19.0	35.0	55.0
23.0	40.0	60.0
23.8	41.0	61.0
24.6	42.0	62.0
25.4	43.0	63.0
26.2	44.0	64.0
27.0	45.0	65.0
27.8	46.0	66.0
28.6	47.0	67.0
29.4	48.0	68.0
30.2	49.0	69.0
31.0	50.0	70.0
31.8	51.0	71.0
32.6	52.0	72.0
33.4	53.0	73.0
34.2	54.0	74.0
35.0	55.0	75.0
36.0	56.0	75.8
37.0	57.0	76.6
38.0	58.0	77.4
39.0	59.0	78.2
40.0	60.0	79.0
41.0	61.0	79.8

AMC I	AMC II	AMC III
42.0	62.0	80.6
43.0	63.0	81.4
44.0	64.0	82.2
45.0	65.0	83.0
46.2	66.0	83.8
47.4	67.0	84.6
48.6	68.0	85.4
49.8	69.0	86.2
51.0	70.0	87.0
52.2	71.0	87.8
53.4	72.0	88.6
54.6	73.0	89.4
55.8	74.0	90.2
57.0	75.0	91.0
58.2	76.0	91.6
59.4	77.0	92.2
60.6	78.0	92.8
61.8	79.0	93.4
63.0	80.0	94.0
64.4	81.0	94.6
65.8	82.0	95.2
67.2	83.0	95.8
68.6	84.0	96.4
70.0	85.0	97.0
71.6	86.0	97.2
73.2	87.0	97.4
74.8	88.0	97.6
76.4	89.0	97.8
78.0	90.0	98.0
79.8	91.0	98.2
81.6	92.0	98.4
83.4	93.0	98.6
85.2	94.0	98.8
87.0	95.0	99.0
89.6	96.0	99.2
92.2	97.0	99.4
94.8	98.0	99.6
97.4	99.0	99.8
100.0	100.0	100.0

Table 4.4. Curve numbers for different land use–hydrologic soil group combinations under AMC II

Land Use	Hydrologic Soil Group	AMC II
Agriculture/Golf Course	A	49
Agriculture/Golf Course	B/D	69
Agriculture/Golf Course	C	79
Agriculture/Golf Course	D	84
Commercial	A	89
Commercial	B/D	92
Commercial	C	94
Commercial	D	95
High-Density Residential	A	77
High-Density Residential	B/D	85
High-Density Residential	C	90
High-Density Residential	D	92
Industrial/Utility	A	81
Industrial/Utility	B/D	88
Industrial/Utility	C	91
Industrial/Utility	D	93
Institutional	A	77
Institutional	B/D	85
Institutional	C	90
Institutional	D	92
Low-Density Residential	A	51
Low-Density Residential	B/D	68
Low-Density Residential	C	79
Low-Density Residential	D	84
Medium-Density Residential	A	57
Medium-Density Residential	B/D	72
Medium-Density Residential	C	81
Medium-Density Residential	D	86
Forest and Rural Open	A	49
Forest and Rural Open	B/D	69
Forest and Rural Open	C	79
Forest and Rural Open	D	84
Transportation Facilities	A	83
Transportation Facilities	B/D	89
Transportation Facilities	C	92
Transportation Facilities	D	93
Water	A	95
Water	B/D	95

Land Use	Hydrologic Soil Group	AMC II
Water	C	95
Water	D	95
Wetlands	A	95
Wetlands	B/D	95
Wetlands	C	95
Wetlands	D	95

In this analysis, the annual average runoff coefficient for each land use–soil combination was calculated for each year for the period from 1995 through 2002. The runoff coefficient was calculated as the quotient between annual total runoff and annual total rainfall. The annual total runoff is the sum of runoff of all days within a given year. To calculate the daily runoff (*Q*) for each day using Equation (3), the total rainfall for a five-day period prior to the day under question was calculated and compared with the threshold values listed in **Table 4.2** to determine the AMC. A CN was then assigned to the day in question, based on the AMC and the daily runoff calculated. The same process was applied to all the land use–hydrologic soil group combinations listed in **Table 4.4,** and runoff coefficients for all the land use–soil combinations for all the years from 1995 through 2002 were calculated **(Table 4.5.)**

Table 4.5. Annual runoff coefficients for different land use–hydrologic soil group combinations, 1995–2002

Land Use	Hydro-logic Soil Group	1995	1996	1997	1998	1999	2000	2001	2002
Agriculture/Golf Course	A	0.015	0.026	0.013	0.019	0.009	0.044	0.026	0.017
Agriculture/Golf Course	B/D	0.069	0.112	0.071	0.103	0.061	0.097	0.096	0.100
Agriculture/Golf Course	C	0.131	0.206	0.145	0.192	0.125	0.142	0.176	0.207
Agriculture/Golf Course	D	0.184	0.275	0.207	0.257	0.176	0.178	0.240	0.288
Commercial	A	0.252	0.347	0.274	0.327	0.236	0.223	0.314	0.367
Commercial	B/D	0.313	0.406	0.330	0.387	0.291	0.267	0.377	0.429
Commercial	C	0.370	0.458	0.382	0.441	0.343	0.312	0.433	0.483
Commercial	D	0.405	0.490	0.414	0.474	0.376	0.342	0.467	0.515
High-Density Residential	A	0.116	0.184	0.127	0.172	0.110	0.132	0.157	0.182
High-Density Residential	B/D	0.198	0.292	0.223	0.273	0.190	0.188	0.258	0.308
High-Density Residential	C	0.269	0.364	0.290	0.344	0.251	0.235	0.332	0.385
High-Density Residential	D	0.313	0.406	0.330	0.387	0.291	0.267	0.377	0.429
Industrial/Utility	A	0.149	0.230	0.166	0.214	0.142	0.155	0.198	0.235
Industrial/Utility	B/D	0.236	0.332	0.259	0.312	0.223	0.212	0.298	0.351
Industrial/Utility	C	0.290	0.384	0.309	0.364	0.270	0.250	0.353	0.406
Industrial/Utility	D	0.340	0.430	0.354	0.412	0.315	0.288	0.403	0.454

Land Use	Hydro-logic Soil Group	1995	1996	1997	1998	1999	2000	2001	2002
Institutional	A	0.116	0.184	0.127	0.172	0.110	0.132	0.157	0.182
Institutional	B/D	0.198	0.292	0.223	0.273	0.190	0.188	0.258	0.308
Institutional	C	0.269	0.364	0.290	0.344	0.251	0.235	0.332	0.385
Institutional	D	0.313	0.406	0.330	0.387	0.291	0.267	0.377	0.429
Low-Density Residential	A	0.018	0.031	0.016	0.024	0.012	0.049	0.030	0.021
Low-Density Residential	B/D	0.065	0.104	0.066	0.096	0.057	0.094	0.091	0.093
Low-Density Residential	C	0.131	0.206	0.145	0.192	0.125	0.142	0.176	0.207
Low-Density Residential	D	0.184	0.275	0.207	0.257	0.176	0.178	0.240	0.288
Medium-Density Residential	A	0.030	0.050	0.029	0.043	0.023	0.064	0.046	0.039
Medium-Density Residential	B/D	0.084	0.136	0.089	0.126	0.077	0.109	0.116	0.127
Medium-Density Residential	C	0.149	0.230	0.166	0.214	0.142	0.155	0.198	0.235
Medium-Density Residential	D	0.209	0.304	0.234	0.285	0.200	0.195	0.270	0.322
Forest and Rural Open	A	0.015	0.026	0.013	0.019	0.009	0.044	0.026	0.017
Forest and Rural Open	B/D	0.069	0.112	0.071	0.103	0.061	0.097	0.096	0.100
Forest and Rural Open	C	0.131	0.206	0.145	0.192	0.125	0.142	0.176	0.207
Forest and Rural Open	D	0.184	0.275	0.207	0.257	0.176	0.178	0.240	0.288
Transportation Facilities	A	0.171	0.259	0.192	0.241	0.164	0.169	0.225	0.269
Transportation Facilities	B/D	0.252	0.347	0.274	0.327	0.236	0.223	0.314	0.367
Transportation Facilities	C	0.313	0.406	0.330	0.387	0.291	0.267	0.377	0.429
Transportation Facilities	D	0.340	0.430	0.354	0.412	0.315	0.288	0.403	0.454
Water	A	0.405	0.490	0.414	0.474	0.376	0.342	0.467	0.515
Water	B/D	0.405	0.490	0.414	0.474	0.376	0.342	0.467	0.515
Water	C	0.405	0.490	0.414	0.474	0.376	0.342	0.467	0.515
Water	D	0.405	0.490	0.414	0.474	0.376	0.342	0.467	0.515
Wetlands 1	A	0.405	0.490	0.414	0.474	0.376	0.342	0.467	0.515
Wetlands 1	B/D	0.405	0.490	0.414	0.474	0.376	0.342	0.467	0.515
Wetlands 1	C	0.405	0.490	0.414	0.474	0.376	0.342	0.467	0.515
Wetlands 1	D	0.405	0.490	0.414	0.474	0.376	0.342	0.467	0.515
Wetlands 2	A	0.405	0.490	0.414	0.474	0.376	0.342	0.467	0.515
Wetlands 2	B/D	0.405	0.490	0.414	0.474	0.376	0.342	0.467	0.515
Wetlands 2	C	0.405	0.490	0.414	0.474	0.376	0.342	0.467	0.515
Wetlands 2	D	0.405	0.490	0.414	0.474	0.376	0.342	0.467	0.515

The PBS&J model calculates the gross runoff and gross TN and TP loadings before BMP removal is applied to the model, as well as the net runoff and net TN and TP loadings after BMP removal is applied. The equations used to calculate these values are as follows:

Gross runoff = rainfall * runoff coefficient * area
Gross loading = Gross runoff * EMC

Net runoff = Gross runoff * (1 – water removal efficiency)
Net loading = Gross loading (1 – pollutant removal efficiency)
The model input required for simulating the watershed TN and TP loadings includes the following:

- Annual precipitation,
- Areas of all the land use–soil combinations, runoff coefficient for each land use–soil combination, and EMCs for each land use category,
- Areas covered by different BMPs and pollutant removal efficiency for each BMP, and
- Baseflow separation results to show the ratio between surface runoff and baseflow and ground water nutrient concentrations

A. Daily rain precipitation data were obtained from a weather station located in the city of Sanford, Seminole County (UCAN: 4129 COOP: 087982). These data were retrieved from the Climate Interactive Rapid Retrieval User System (CIRRUS), hosted by the Southeast Regional Climate Center. **Table 4.6** depicts annual average precipitation at this weather station from 1995 through 2002.

Table 4.6. Annual precipitation at the city of Sanford weather station, 1995–2002

Year	Total Rainfall (inches/year)
1995	59.32
1996	62.82
1997	53.69
1998	48.83
1999	47.04
2000	32.83
2001	52.73
2002	66.24

B. Areas of different land use–hydrologic soil group combinations in Lake Jesup were obtained by overlaying the land use coverage with the coverage of hydrologic soil groups. **Table 4.7** lists these areas.

Table 4.7. Areas of different land use–hydrologic soil group combinations in the Lake Jesup watershed

Land Use	Hydrologic Soil Group	Acreage
Agriculture/Golf Course	A	1,030
Agriculture/Golf Course	B/D	3,579
Agriculture/Golf Course	C	470
Agriculture/Golf Course	D	1,184
Commercial	A	3,393
Commercial	B/D	798
Commercial	C	390
Commercial	D	225
High-Density Residential	A	1,453
High-Density Residential	B/D	540
High-Density Residential	C	504
High-Density Residential	D	184
Industrial/Utility	A	802
Industrial/Utility	B/D	1,055
Industrial/Utility	C	142
Industrial/Utility	D	377
Institutional	A	1,257
Institutional	B/D	460
Institutional	C	181
Institutional	D	148
Low-Density Residential	A	329
Low-Density Residential	B/D	1,297
Low-Density Residential	C	133
Low-Density Residential	D	745
Medium-Density Residential	A	14,336
Medium-Density Residential	B/D	4,108
Medium-Density Residential	C	2,353
Medium-Density Residential	D	1,900
Forest and Rural Open	A	3,709
Forest and Rural Open	B/D	4,140
Forest and Rural Open	C	965
Forest and Rural Open	D	2,691
Transportation Facilities	A	4,429
Transportation Facilities	B/D	2,510
Transportation Facilities	C	827
Transportation Facilities	D	724
Water	A	148

Land Use	Hydrologic Soil Group	Acreage
Water	B/D	61
Water	C	33
Water	D	3,621
Wetlands 1	A	442
Wetlands 1	B/D	2,218
Wetlands 1	C	216
Wetlands 1	D	8,870
Wetlands 2	A	347
Wetlands 2	B/D	2,450
Wetlands 2	C	237
Wetlands 2	D	5,321

Runoff coefficients for each land use–hydrologic soil group combination were calculated using the SCS curve number procedures described above; **Table 4.5** lists the values for different combinations.

TN and TP EMCs for different land use categories were mainly cited from Harper (1994). Agriculture/golf course land use in this analysis was considered the same as the general agriculture category in Harvey's study. There is no forest/rural open category in Harvey's system, and the forest/rural open category for this analysis was considered the same as recreational/open space in Harvey's system. Medium- and high-density residential categories were considered the same as the single-family and multifamily categories in Harvey's system. The high- and low-density commercial areas were combined into one single category called commercial, and its EMCs are considered to be the average values of the high- and low-density commercial category in Harvey's system. The wetland TP EMC in Harvey's analysis is commonly considered to be the result from wetlands that were influenced by human activities. The TP EMC for this type of wetland area (Wetlands 1) is about 0.09 mg/L. The TP EMC for relatively unimpacted wetlands (Wetlands 2), which is 0.06 mg/L, was cited from Fulton et al. (2003). Harvey's work does not include institutional and transportation facilities, and PBS&J provided EMC values for these categories. In addition, PBS&J provided updated values for low- and medium-density residential. **Table 4.8** lists the TN and TP EMCs for different land use categories.

Table 4.8. TN and TP EMCs for different land use categories (mg/L)

Land Use Category	TN	TP
Agriculture/Golf Course	2.32	0.34
Forest and Rural Open	1.25	0.05
Low-Density Residential	1.97	0.44
Medium-Density Residential	2.04	0.45
High-Density Residential	2.42	0.49
Commercial	2.01	0.29
Institutional	2.29	0.15
Industrial/Utility	1.79	0.31
Transportation Facilities	1.87	0.28
Water	1.25	0.11
Wetlands 1	1.6	0.09
Wetlands 2	1.6	0.06

C. Areas covered by different BMPs: **Table 4.9** lists the areas covered by various BMP structures, and **Table 4.10** lists the water and pollutant removal efficiency of all the different BMPs. **Figure 4.3** shows the spatial distribution of BMPs in the Lake Jesup watershed. PBS&J provided the Department with the information on pollutant removal efficiencies and BMP coverage.

According to **Table 4.9**, some sort of BMP structure is used to treat stormwater from about 32% of the Lake Jesup watershed. The most common stormwater facilities appear to be dry and wet detention ponds, which address runoff from about 27% of the total Lake Jesup watershed area and account for about 83% of the area covered by BMPs. The drainage wells located in the southern end of the watershed are another major feature that retains water and nutrients. These drain about 3,081 acres of the watershed, accounting for about 3.5% of the total watershed area. Orange County has about 400 drainage wells, with 154 of them in the city of Orlando (Sheffield et al., March 1995). While these wells indeed contribute to pollutant removal and ground water recharge, their effect on ground water quality is a concern.

It should be noted that, in **Table 4.10,** water removal efficiency for most of the stormwater facilities is 0, meaning that no water is removed by stormwater treatment facilities. This may not be a valid assumption. As most of the published removal efficiencies consider only pollutant removal, however, it becomes a commonly accepted practice that, when estimating the net pollutant loadings after BMP treatment, water discharge is considered unchanged. This assumption adds to the margin of safety because it tends to overestimate the net load when assuming a larger runoff from the watershed.

Table 4.9. Areas covered by various BMPs in the Lake Jesup watershed

BMP Type	Area Covered (acres)	Percent Area Covered
No Stormwater Facility	59,418	68.04%
Combination (Swale/Dry Pond)	311	0.36%
Dry Detention	11,068	12.67%
Swales	1,217	1.39%
Wet Detention Pond	12,187	13.96%
Orlando 100% On-Site Retention	33	0.04%
Orlando Private BMPs	6	0.01%
Lake Drainage Wells	3,081	3.53%

Table 4.10. Pollutant and water removal efficiency for different BMPs

BMP Type	Pollutant Removal Efficiency		Water Removal Efficiency
	TN	TP	
No Stormwater Facility	0	0	0
Combination (Swale/Dry Pond)	0.3	0.25	0
Combination (Swale/Wet Pond)	0.86	0.63	0
Dry Detention	0.2	0.2	0
Swales	0.1	0.05	0
Wet Detention Pond	0.8	0.6	0
Orlando 100% On-Site Retention	1	1	0
Orlando Private BMPs	0.2	0.2	0
Lake Drainage Wells	0.64	0.64	0.64

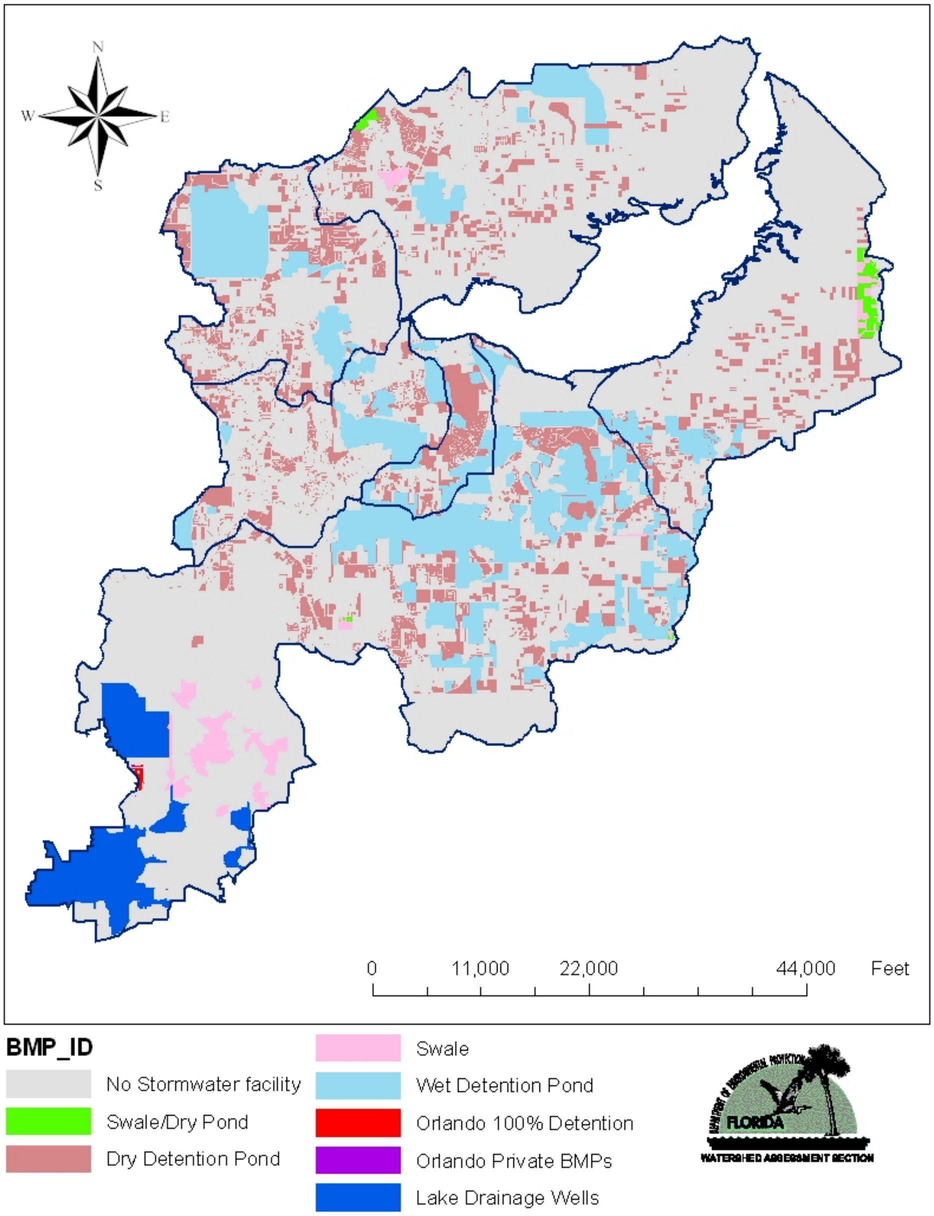


Figure 4.3. Spatial distribution of BMPs in the Lake Jesup watershed

D. Baseflow analysis and ground water TN and TP concentrations: Baseflow analysis is used to separate surface runoff from the ground water contribution. The separation is important in this analysis because surface runoff and baseflow come from different sources and may have different nutrient concentrations. Baseflow could come from both the surficial and Floridan aquifers. The Lake Jesup watershed is mostly confined by the Hawthorn Layer (Florida Geological Survey, 1991), and except for the areas immediately adjacent to the lake, the surface elevation of most of the watershed is higher than the potentiometric surface of the Floridan aquifer (Florida Geological Survey, 1991, U. S. Geological Survey [USGS] Quad Map 1:24,000). The contribution from the Floridan aquifer to the total stream flow was therefore considered negligible, and base flow was mainly from the surficial aquifer.

Baseflow analysis was conducted using the daily flow data from a USGS gauging station located on Howell Creek near Slavia, Florida (Station ID: 02234324, **Figure 4.4**). A graphical separation technique, based on the hydrograph, was used in the separation analysis. Because of the possible water detention effect from the many lakes located in the upper reach of Howell Creek, this analysis does not use day-to-day baseflow separation. Rather, it uses a modified local minimum method that targets the lowest flow measurement for each major flow period **(Figure 4.5).** Based on the daily flow measurements from 1988 through 2003, baseflow accounts for about 20% of the total stream flow on an annual average basis.

Nutrient concentrations for the surficial aquifer were retrieved from the Department's HydroPort database. Data were collected primarily from the 5 surficial aquifer background water quality monitoring wells located within or adjacent to the Lake Jesup watershed **(Figure 4.4).** Nutrient data from these wells were collected in 1990, 1992, 1993, 1994, 2002, and 2004. The long-term average TN concentration, which is 0.483, was calculated from all 5 wells due to the lack of nitrate/nitrite data for wells located upgrade of the lake. The long-term average TP concentration (0.155 mg/L) was calculated based on results from Wells 284052081212602, 284317081182501, and 284320081090001, which are located upgrade of the lake. Since only limited amounts of water quality data were available when this analysis was conducted, long-term average TN and TP concentrations were used as constants for the entire modeling period (1995–2002).

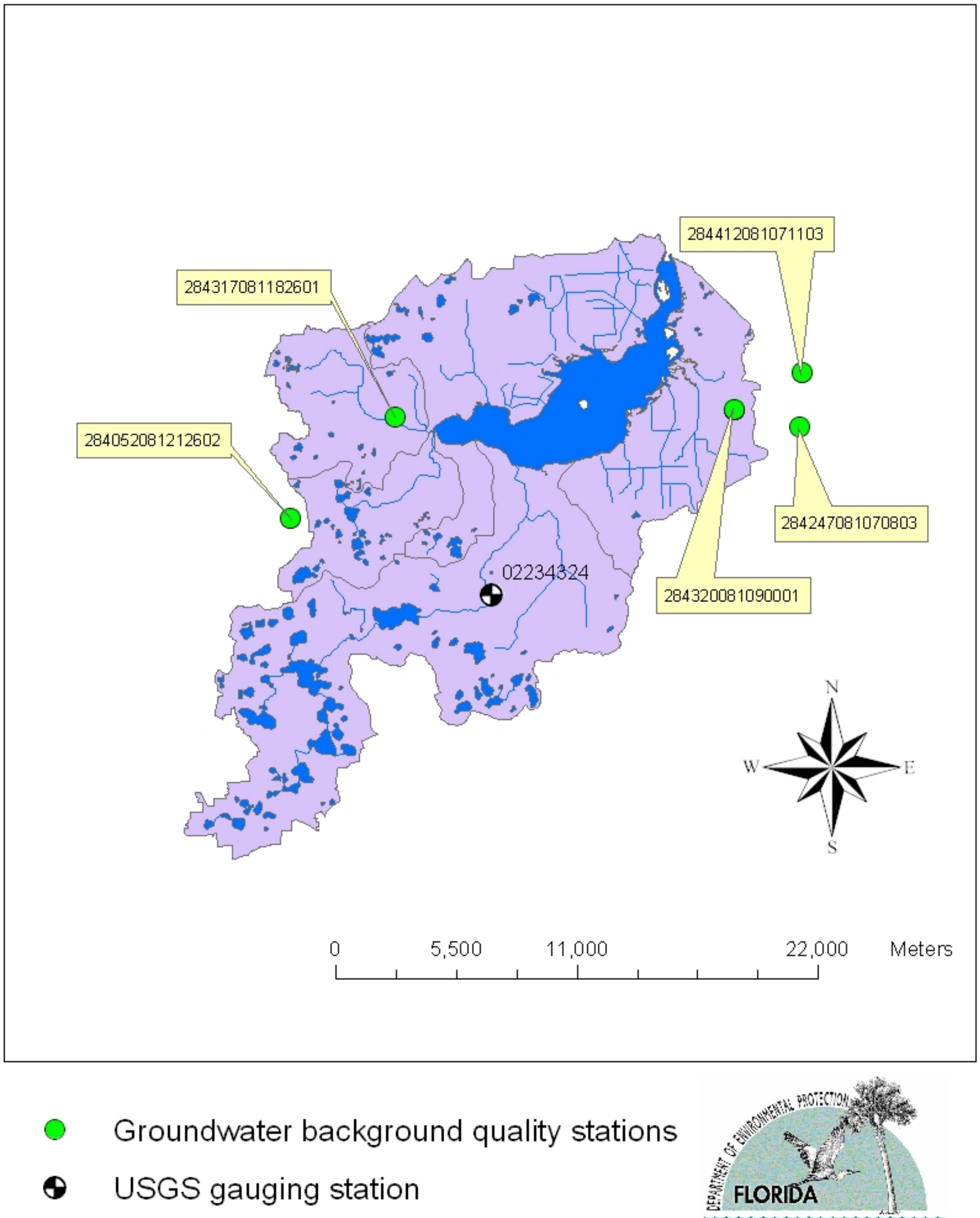


Figure 4.4. Locations of Department background ground water quality monitoring stations and a USGS gauging station

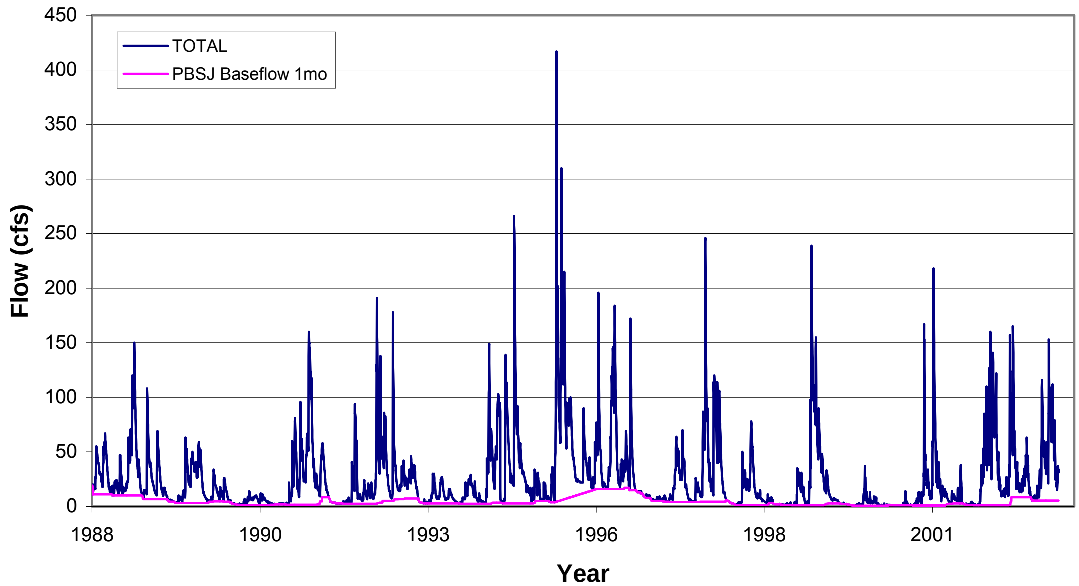


Figure 4.5. Results of the baseflow analysis, 1988–2003

E. Surface runoff and TN and TP loadings from the watershed into Lake Jesup: To simulate surface runoff and TN and TP loadings from the watershed into Lake Jesup, the entire watershed was delineated into five sub-basins: Gee Creek, Howell Creek, Lake Jesup (the area immediately connected to Lake Jesup), Little Lake Howell, and Soldiers Creek **(Figure 4.6). Tables 4.11-a, 4-11b,** and **4-11c** list the annual surface runoff, TN loading, TP loading, and percent contribution from these sub-basins for 1995 through 2002.

As shown in **Table 4.11-a,** a long-term average of about 70,052 acre-feet of surface runoff is discharged into Lake Jesup annually. The area directly connected to Lake Jesup has the highest discharge, accounting for about 45% of the total surface runoff. Because the sub-basin has one of the largest areas among the 5 sub-basins, this may contribute to the large quantity of surface runoff that it creates. In addition, it is predominately wetlands and has a relatively high potential to create surface runoff.

Discharge from the Howell Creek sub-basin ranks second, creating 34% of the total surface runoff. Although the area of the Howell Creek sub-basin is the largest among all the sub-basins, a significant portion of the southern part of the sub-basin drains to drainage wells (**Figure 3.4**). The Soldiers Creek and Gee Creek sub-basins together contribute about 19% of the surface runoff, while Little Lake Howell contributes the smallest quantity of water, about 3% of the total runoff for the watershed.

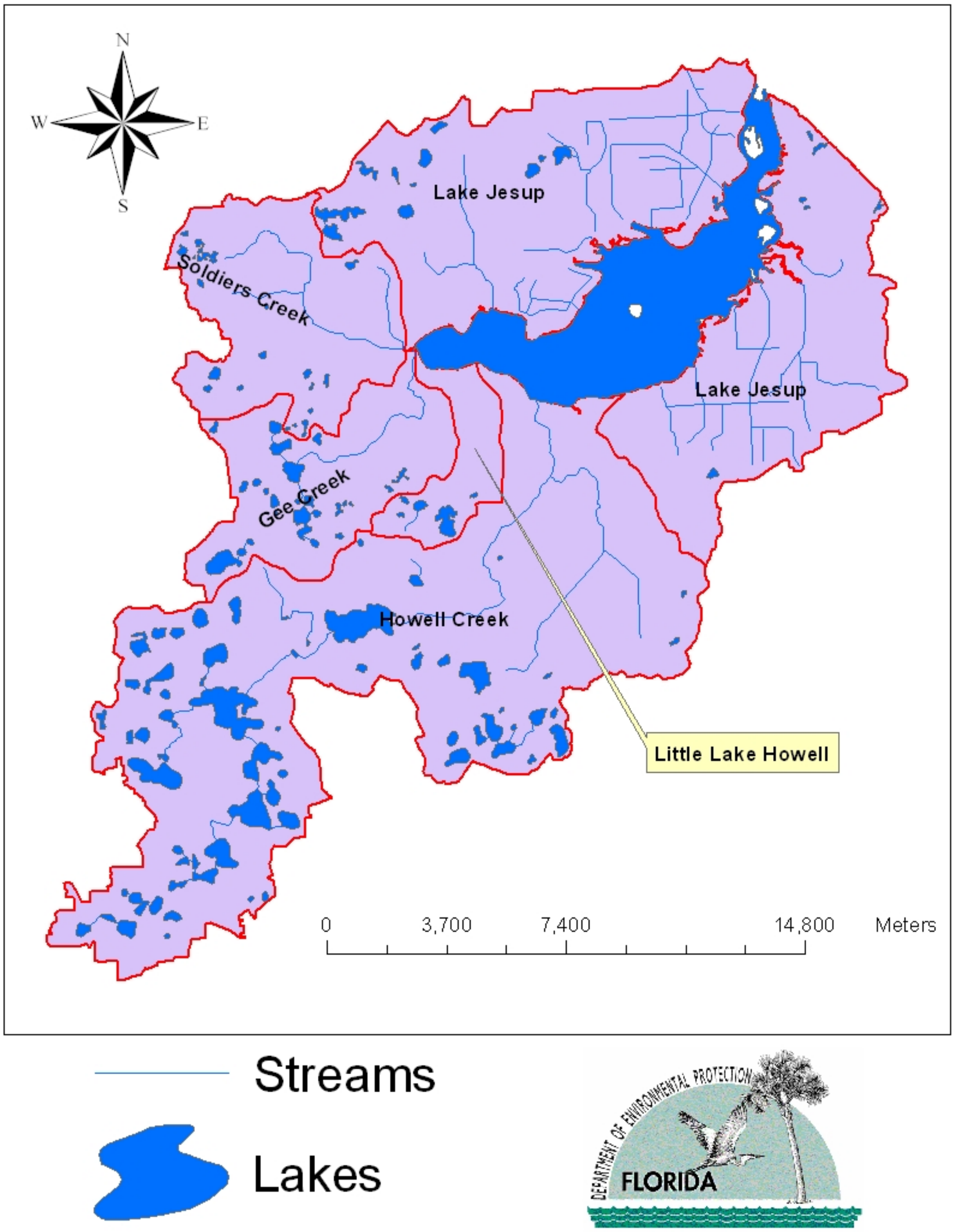


Figure 4.6. Sub-basins of the Lake Jesup watershed

Table 4.11-a. Annual surface runoff into Lake Jesup, 1995–2002 (acre-feet/year)

Sub-basin	1995	1996	1997	1998	1999	2000	2001	2002	Mean	Percent
Gee Creek	5,153	7,473	4,937	5,472	3,789	2,821	5,716	8,052	5,426	8%
Howell Creek	22,602	32,478	21,530	23,812	16,570	12,376	24,945	34,912	23,653	34%
Lake Jesup	30,898	42,140	29,089	31,293	22,753	15,514	32,897	46,061	31,330	45%
Little Lake Howell	1,895	2,697	1,798	1,983	1,391	1,027	2,077	2,899	1,971	3%
Soldiers Creek	7,390	10,467	7,044	7,709	5,447	3,879	8,063	11,370	7,671	11%
Total	**67,938**	**95,254**	**64,396**	**70,269**	**49,950**	**35,616**	**73,697**	**103,293**	**70,052**	**100%**

Table 4.11-b. Annual TN loading into Lake Jesup, 1995–2002 (tons/year)

Sub-basin	1995	1996	1997	1998	1999	2000	2001	2002	Mean	Percent
Gee Creek	9.5	13.8	9.1	10.1	7.0	5.2	10.5	14.8	10.0	8%
Howell Creek	40.2	58.3	38.4	42.6	29.5	22.3	44.6	62.5	42.3	33%
Lake Jesup	60.4	82.6	56.8	61.3	44.4	30.4	64.4	90.1	61.3	47%
Little Lake Howell	3.0	4.2	2.8	3.1	2.2	1.6	3.3	4.6	3.1	2%
Soldiers Creek	12.7	18.0	12.1	13.2	9.3	6.6	13.8	19.5	13.2	10%
Total	**125.7**	**176.8**	**119.2**	**130.4**	**92.4**	**66.1**	**136.6**	**191.6**	**129.9**	**100%**

Table 4.11-c. Annual TP loading into Lake Jesup, 1995–2002 (tons/year)

Sub-basin	1995	1996	1997	1998	1999	2000	2001	2002	Mean	Percent
Gee Creek	1.2	1.8	1.2	1.3	0.9	0.7	1.4	1.9	1.3	9%
Howell Creek	5.3	8.0	5.1	5.8	3.9	3.1	6.1	8.5	5.7	41%
Lake Jesup	4.9	7.0	4.7	5.2	3.6	2.6	5.4	7.6	5.1	37%
Little Lake Howell	0.3	0.5	0.3	0.4	0.2	0.2	0.4	0.5	0.4	3%
Soldiers Creek	1.4	2.1	1.4	1.5	1.0	0.8	1.6	2.2	1.5	10%
Total	**13.1**	**19.4**	**12.6**	**14.2**	**9.6**	**7.4**	**14.7**	**20.7**	**14.0**	**100%**

Contributions of TN and TP loadings from the different sub-basins show a trend similar to that of surface runoff. On an annual average basis, about 130 tons of TN are discharged into Lake Jesup through surface runoff. Of the total TN loading, the watershed immediately connected to Lake Jesup contributes about 47%; the Howell Creek sub-basin contributes 33%; the Soldiers Creek and Gee Creek sub-basins contribute about 10% and 8%, respectively; and the Little Lake Howell sub-basin contributes the smallest amount, about 2%.

The long-term annual average TP discharge through surface runoff is about 14 tons. The watershed immediately connected to Lake Jesup produces about 37% of the total TP loading through surface runoff; the Howell Creek sub-basin contributes 41%; the Soldiers Creek and

Gee Creek sub-basins contribute about 10% and 9%, respectively; and the Little Lake Howell sub-basin contributes the smallest amount, about 3%.

Surface runoff and TN and TP loadings into Lake Jesup were also analyzed based on land use classification. **Tables 4.12-a, 4.12-b,** and **4.12-c** list the annual surface runoff, TN loading, TP loading, and percent contribution from different land use categories for Lake Jesup from 1995 through 2002.

Total human land use areas contribute about 41.2% of the surface runoff, 73.1% of the annual TP loading, and 44.8% of the annual TN loading (**Tables 4.12-a, 4.12-b,** and **4.12-c**). The human land use categories that contribute the largest quantity of surface runoff and nutrient loadings are commercial, medium-density residential, and transportation facilities, which contribute totally about 28.1% of the annual surface runoff, 47.5% of the annual TP loading, and 28% of the annual TN loading, respectively.

The single land use category with the largest contribution to runoff, TN, and TP loadings is wetlands, which contribute 44.9% of the total annual surface runoff, 20.2% of the watershed TP loading, and 44.6% of the watershed TN loading. The high loading from wetland areas mainly results from the high potential to produce surface runoff. It should be noted, however, that although the total nutrient loadings from the wetland area are high, the nutrient EMCs for the wetland area are lower than most of the human land use areas **(Table 4.8).** The water with low nutrient concentrations flowing from wetland areas to the lake ultimately dilutes the lake's nutrient concentration, improving water quality. In addition, human activities currently affect the watershed's wetlands and Lake Jesup significantly. If human influence in the watershed is efficiently controlled, wetland water quality should improve and nutrient concentrations will decrease even further.

Table 4.12-a. Annual surface runoff into Lake Jesup from different land use categories, 1995–2002 (acre-feet/year)

Land Use Category	1995	1996	1997	1998	1999	2000	2001	2002	Mean	Percent
Agriculture/Golf Course	2,115	3,514	2,051	2,515	1,531	1,449	2,558	3,545	2,410	3.4%
Commercial	4,905	6,928	4,750	5,106	3,631	2,365	5,331	7,719	5,092	7.3%
High-Density Residential	1,830	2,823	1,809	2,062	1,370	995	2,096	3,068	2,007	2.9%
Industrial/Utility	2,113	3,124	2,075	2,288	1,577	1,069	2,357	3,454	2,257	3.2%
Institutional	1,287	2,018	1,275	1,472	966	717	1,488	2,180	1,425	2.0%
Low-Density Residential	968	1,580	946	1,137	708	634	1,160	1,632	1,096	1.6%
Medium-Density Residential	5,788	9,637	5,559	6,818	4,098	4,423	7,146	9,526	6,624	9.5%
Open	3,796	6,257	3,708	4,458	2,752	2,574	4,588	6,392	4,316	6.2%
Transportation Facilities	7,423	11,052	7,329	8,080	5,552	3,766	8,315	12,227	7,968	11.4%
Water	5,573	7,140	5,156	5,369	4,103	2,604	5,712	7,913	5,446	7.8%
Wetlands 1	18,760	24,036	17,357	18,073	13,811	8,767	19,229	26,638	18,334	26.2%
Wetlands 2	13,381	17,145	12,380	12,891	9,851	6,254	13,715	19,000	13,077	18.7%
Grand Total	**67,938**	**95,254**	**64,396**	**70,269**	**49,950**	**35,616**	**73,697**	**103,293**	**70,052**	**100.0%**

Table 4.12-b. Annual TP loading into Lake Jesup from different land use categories, 1995–2002 (tons/year)

Land Use Category	1995	1996	1997	1998	1999	2000	2001	2002	Mean	Percent
Agriculture/Golf Course	0.8	1.4	0.8	1.0	0.6	0.6	1.0	1.4	1.0	6.8%
Commercial	1.5	2.2	1.5	1.6	1.1	0.7	1.7	2.4	1.6	11.4%
High-Density Residential	1.0	1.5	1.0	1.1	0.7	0.5	1.1	1.6	1.1	7.6%
Industrial/Utility	0.7	1.1	0.7	0.8	0.6	0.4	0.8	1.2	0.8	5.6%
Institutional	0.2	0.3	0.2	0.2	0.2	0.1	0.2	0.3	0.2	1.5%
Low-Density Residential	0.5	0.8	0.5	0.6	0.3	0.3	0.6	0.8	0.6	3.9%
Medium-Density Residential	2.5	4.1	2.4	2.9	1.7	1.9	3.1	4.0	2.8	20.2%
Open	0.2	0.3	0.2	0.2	0.2	0.1	0.3	0.4	0.2	1.7%
Transportation Facilities	2.1	3.1	2.0	2.3	1.5	1.1	2.3	3.4	2.2	15.9%
Water	0.7	0.9	0.7	0.7	0.5	0.3	0.7	1.0	0.7	4.9%
Wetlands 1	1.9	2.5	1.8	1.8	1.4	0.9	2.0	2.7	1.9	13.4%
Wetlands 2	1.0	1.2	0.9	0.9	0.7	0.5	1.0	1.4	1.0	6.8%
Grand Total	**13.1**	**19.4**	**12.6**	**14.2**	**9.6**	**7.4**	**14.7**	**20.7**	**14.0**	**100.0%**

Table 4.12-c. Annual TN loading into Lake Jesup from different land use categories, 1995–2002 (tons/year)

Land Use Category	1995	1996	1997	1998	1999	2000	2001	2002	Mean	Percent
Agriculture/Golf Course	5.6	9.3	5.4	6.6	4.0	3.8	6.7	9.4	6.4	4.9%
Commercial	10.4	14.7	10.1	10.8	7.7	5.0	11.3	16.4	10.8	8.3%
High-Density Residential	4.6	7.1	4.6	5.2	3.5	2.5	5.3	7.7	5.1	3.9%
Industrial/Utility	4.3	6.3	4.2	4.6	3.2	2.2	4.8	7.0	4.6	3.5%
Institutional	3.0	4.8	3.0	3.5	2.3	1.7	3.5	5.1	3.4	2.6%
Low-Density Residential	2.1	3.5	2.1	2.5	1.6	1.4	2.6	3.6	2.4	1.9%
Medium-Density Residential	10.3	17.3	9.9	12.2	7.3	8.1	12.8	16.9	11.9	9.1%
Open	5.2	8.5	5.0	6.1	3.7	3.5	6.2	8.7	5.9	4.5%
Transportation Facilities	12.8	19.1	12.6	13.9	9.6	6.5	14.3	21.1	13.7	10.6%
Water	8.1	10.3	7.5	7.8	5.9	3.8	8.3	11.4	7.9	6.1%
Wetlands 1	33.5	42.9	31.0	32.2	24.6	15.6	34.3	47.5	32.7	25.2%
Wetlands 2	25.8	33.1	23.9	24.9	19.0	12.1	26.5	36.7	25.3	19.4%
Grand Total	**125.7**	**176.8**	**119.2**	**130.4**	**92.4**	**66.1**	**136.6**	**191.6**	**129.9**	**100.0%**

F. Nutrient loadings from baseflow. As discussed in the previous section, nutrient loadings from baseflow were mainly through the surficial aquifer, because the majority of the watershed is confined and the surface elevation is higher than the potentiometric head of the Floridan aquifer in most parts of the watershed. Based on the baseflow separation analysis, about 20% of the total stream flow in the Lake Jesup watershed comes from baseflow. The total nutrient loading through baseflow was estimated by multiplying the baseflow quantity by the long-term average TN and TP concentrations, calculated based on the ground water quality data retrieved from the Department's HydroPort database. These concentrations, which represent results from background wells, assume relatively low, if any, human impacts. **Table 4.13** lists the annual flow, background TN and TP concentrations, and background TN and TP loadings through baseflow into Lake Jesup from 1995 through 2002.

Table 4.13. Annual nutrient loadings into Lake Jesup through baseflow, 1995–2002

	1995	1996	1997	1998	1999	2000	2001	2002	Mean
Flow (acre-feet/year)	16,985	23,814	16,099	17,567	12,487	8,904	18,424	25,823	17,513
TP concentration (mg/L)	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
TN concentration (mg/L)	0.483	0.483	0.483	0.483	0.483	0.483	0.483	0.483	0.483
TP loading (tons/year)	3.2	4.5	3.1	3.3	2.4	1.7	3.5	4.9	3.3
TN loading (tons/year)	10.1	14.2	9.6	10.5	7.4	5.3	11.0	15.4	10.4

Background nitrogen and phosphorus are not the only nutrients carried through baseflow. Septic tanks may contribute significantly to the nutrients that can be carried through baseflow. In this analysis, septic tank nutrient loadings were estimated based on septic tank GIS coverage provided to the Department by PBS&J **(Figure 4.7).** The analysis considered only those septic tanks located within 200 meters of any receiving waterbodies that discharge to Lake Jesup. The nutrient loads contributed by septic tanks were calculated using the following equation:

$$W = A * D * C * (1- R)$$

Where:

A is the area (in acres) covered by septic tanks within 200 meters of any receiving waterbodies that discharge into Lake Jesup,
D is the per-acre population density,
C is the per-capita TN and TP generation rate, and
R is the nutrient removal efficiency through septic tank systems and soil.

About 789 acres of the watershed with septic tanks are located within 200 meters of receiving waters that discharge to Lake Jesup. Of the 789 acres, about 637 acres are primarily associated with single-family residential areas, and the remaining 153 acres are associated with commercial areas (occupied by institutions). Septic tank areas located in different planning areas have different population densities. **Table 4.14** lists the population densities for single-family residential and commercial areas in each planning area in the Lake Jesup watershed.

Table 4.14. Population density for single-family residential and commercial areas in different planning areas of the Lake Jesup watershed (people/acre)

Planning Area	Single-family Residential	Commercial
2	7.2	20.2
3	10.9	31.3
4	9.1	30.2
6	8.6	32.9
7	8.0	21.6
8	8.2	21.5
9	1.3	20.9
10	1.7	67.2

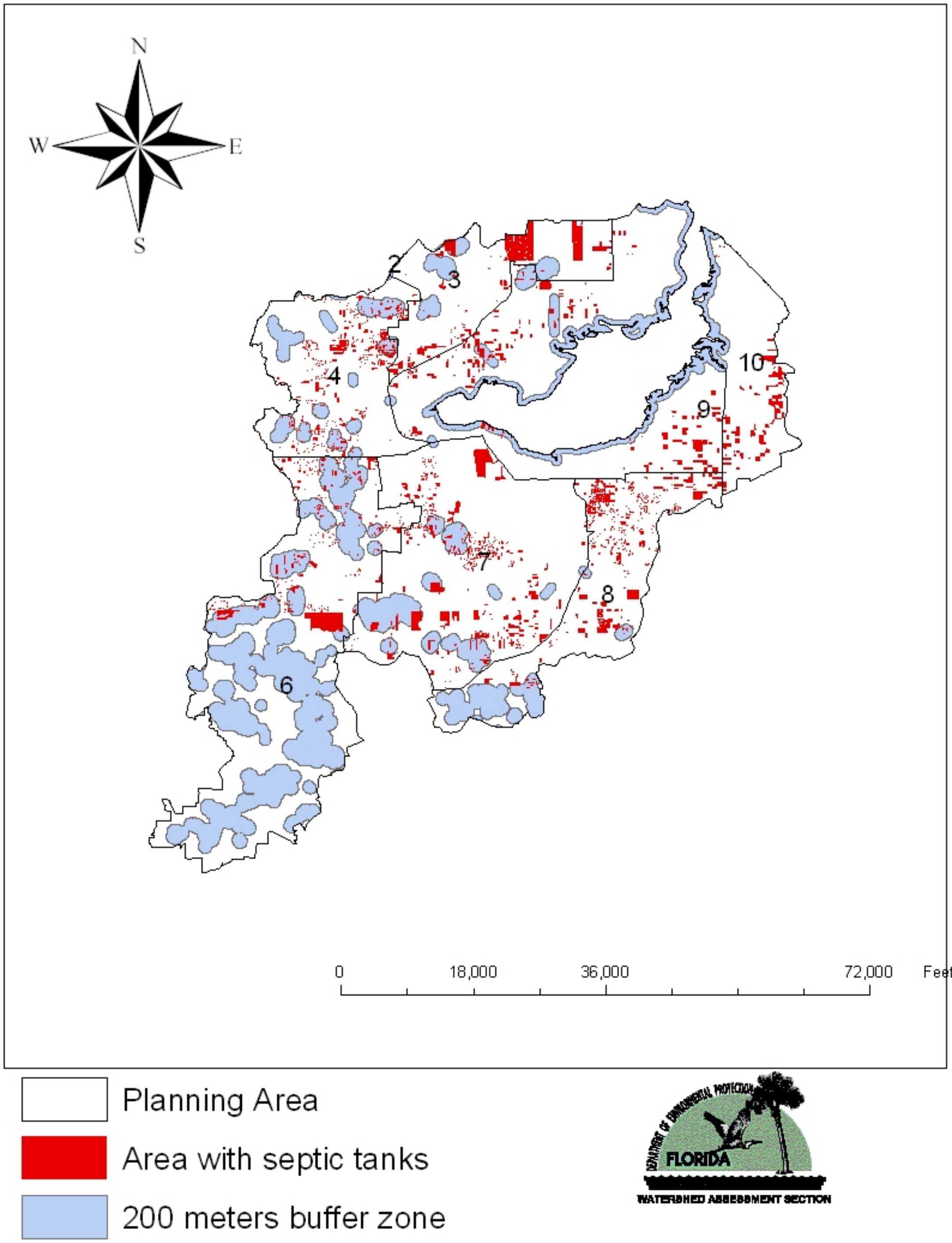


Figure 4.7. Areas with septic tanks, areas within 200 meters of any receiving waters that discharge to Lake Jesup, and planning areas

The per-capita TN and TP generation rates (*C*) were cited from published literature values **(Table 4.15).** This analysis used the median values of these generation rates to estimate the final loads. The per-capita TN and TP generation rates for the commercial area are usually assumed to be one-third of those for the residential area (Tchobanoqlous et al., 2003). According to Reckhow (1980), it is a common practice to assume that within 200 meters of any receiving waterbody, septic tanks and soil can remove 70% of the phosphorus and 30% of the nitrogen generated. Beyond the 200-meter zone, septic tank influences are usually considered insignificant.

The estimated septic tank annual TN and TP loadings are 19.7 and 2.7 tons, respectively. Because time-variable septic tank discharge rates were not available at the time of this analysis, these annual loading numbers were assumed to be constant throughout the modeling period (1995–2002).

Table 4.15. Nutrient load for household wastewater discharge into septic tanks (kilograms/capita/year) (cited from Reckhow, 1980)

TP	TN	Reference
1.49	6.45	Ligman et al., 1974
1.43	5.99	Laak, 1975
N/A	2.65	Bennet and Linstedt, 1975
0.74	4.61	Chan, 1978
1.59	N/A	Ellis and Childs, 1973
1.49	2.15	Siegrist et al., 1976
3	N/A	Bernhard, 1975
0.8	N/A	Otis et al., 1975
N/A	8.2	Walker et al., 1973
1.28	3.2	EPA, 1974
1.46	**4.61**	**Median**

N/A = Not available

G. Nutrient loadings from the Floridan aquifer: Lake Jesup lies in an artesian area for the Floridan aquifer. Water in the Floridan aquifer can rise to the ground surface through springs or leak through the confined layer in areas where the potentiometric head is higher than the surface elevation of ambient waters. Springs occur where there is a discrete breach in the relatively impermeable confining layer that overlies the aquifer, allowing water to flow to the surface. Water can also flow upward through the confining layer as diffuse leakage (Keesecker, 1992).

Two springs, Clifton Springs and Lake Jesup Spring, discharge Floridan aquifer water directly into Lake Jesup. Their flows are given by Rosenau et al. (1977, cited from Keesecker, 1992) as 1.7 cubic feet per second (cfs) and 1.36 cfs, respectively. These values were from single measurements, since no long-term data were available. The sum of the individual flow rates was assumed constant over the modeling period. The annual discharge from these springs is calculated using the following equation:

Spring flow = (1.7 + 1.36) * convs * days/year

Where:

Spring flow is the annual total flow from the 2 springs,
1.7 is the Clifton Springs discharge rate (cfs),
1.36 is the Lake Jesup Spring discharge rate (cfs), and
Convs is the conversion factor between cfs and acre-feet/year.

Upward leakage through the confined layer is possible for Lake Jesup, because the potentiometric head of the Floridan aquifer directly below Lake Jesup is about 25 feet NGVD (Spechler et al., 1991, cited from Keesecker, 1992), while the surface elevation of Lake Jesup fluctuated between 0.23 and 7.04 feet NGVD during the modeling period (based on a USGS gauging station located at the outlet of Lake Jesup [Site ID 02234435]). The upward leakage into Lake Jesup through the confining layer was determined using an equation suggested by Keesecker (1992):

LEAK = LEAKC * (PSURF – LJSTG) * days/year * A

Where:

LEAK is the annual upward leakage through the bottom of Lake Jesup (acre-feet/year),
LEAKC is the leakage coefficient (feet per day per foot [ft/day/ft] head difference between PSURF and STG),
PSURF is the average potentiometric surface of the Floridan aquifer (feet NGVD),
STG is the Lake Jesup annual average stage (feet NGVD), and
A is the annual average surface area for Lake Jesup (acres).

LEAKC (0.000025 ft/day/ft) was set at the median of the range of values given by Tibbals (1990, cited from Keesecker, 1992) for the area occupied by Lake Jesup. PSURF (25 feet NGVD) is an estimate of the average potentiometric surface of the Floridan aquifer over the lake surface (Spechler et al., 1991, cited from Keesecker, 1992). This value was assumed to remain constant for the period of modeling. STG was estimated based on the daily lake stage data from USGS 02234435. A, the annual average surface area for Lake Jesup, was estimated based on the daily lake stage data and the characteristic curve for Lake Jesup. **Table 4.16** shows the characteristic curve for Lake Jesup.

Multinomial equations were developed, based on the data tabulated in **Table 4.16,** for calculating the daily lake surface area and daily cumulative lake volume. The annual average lake surface area and annual lake volume were calculated as the mean value of all the daily surface areas and lake volume in each calendar year. **Figures 4.8** and **4.9** show the multinomial equations between lake stage and lake surface area, and between lake stage and cumulative lake volume, respectively.

Table 4.16. Characteristic curve for Lake Jesup

Lake Surface Elevation (feet NGVD)	Lake Surface Area (acres)	Cumulative Lake Volume (acre-feet)
-8	0	0
-7	50	25
-6	140	120
-5	380	380
-4	1,331	1,236
-3	3,194	3,498
-2	6,007	8,099
-1	7,578	14,891
0	9,150	23,255
1	10,011	32,836
2	10,767	43,224
3	11,523	54,369
4	12,278	66,269
5	13,034	78,926
6	13,790	92,337
7	14,546	106,505

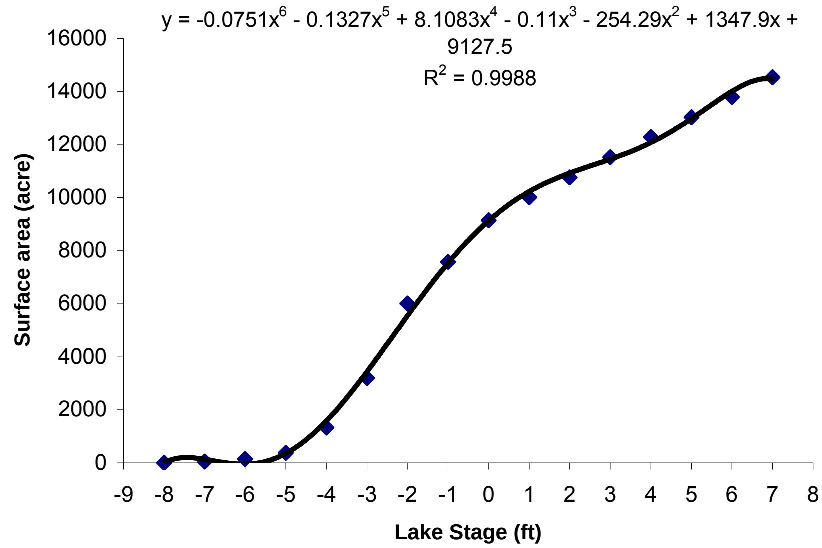


Figure 4.8. Characteristic curve between lake stage and lake surface area for Lake Jesup

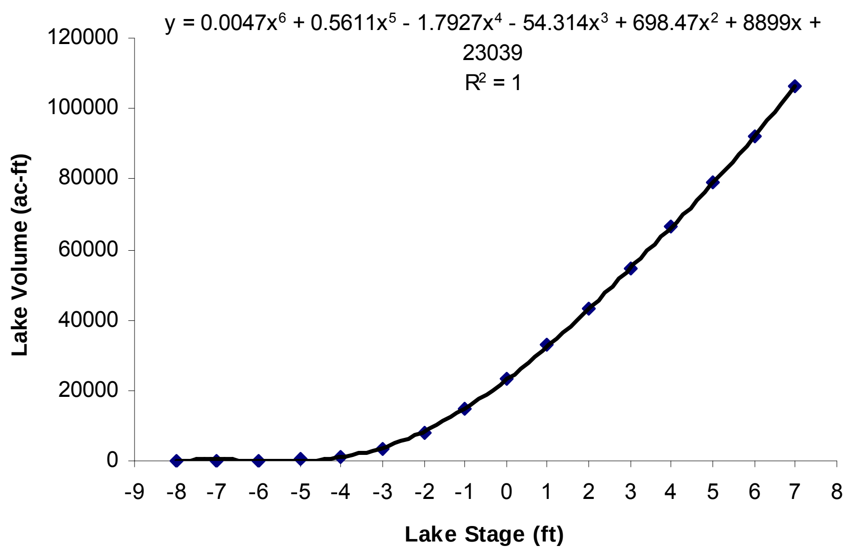


Figure 4.9. Characteristic curve between lake stage and lake cumulative volume for Lake Jesup

Table 4.17 lists the annual calculated upward bottom leakage through the confining layer and spring discharge into Lake Jesup, as well as the average lake stage and lake surface area, from 1995 through 2002.

Nutrient loadings from the Floridan aquifer to Lake Jesup through both spring discharge and upward bottom leakage were calculated by multiplying the calculated flow by the TN and TP concentrations of the Floridan aquifer. These concentrations were retrieved from the Department's HydroPort database. The long-term average TN and TP concentrations were 0.611 and 0.11 mg/L, respectively (Parsons Engineering Science, Inc., 2000). These values represent summaries from several Floridan aquifer wells. **Table 4.18** lists the annual nutrient loadings into Lake Jesup from 1995 through 2002.

Table 4.17. Annual average lake stage and surface area, and annual flow from the Floridan aquifer to Lake Jesup, 1995–2002

	1995	1996	1997	1998	1999	2000	2001	2002	Mean
Annual average lake stage (feet)	3.42	2.44	1.94	3.08	2.30	1.29	2.15	2.69	2.41
Annual average lake surface area (acres)	11,688	11,163	10,890	11,493	11,089	10,467	11,007	11,291	11,136
Calculated upward bottom leakage (acre-feet/year)	2,370	2,341	2,305	2,365	2,332	2,234	2,322	2,353	2,328
Calculated spring discharge (acre-feet/year)	2,215	2,215	2,215	2,215	2,215	2,215	2,215	2,215	2,215

Table 4.18. Annual TN and TP loadings from the Floridan aquifer into Lake Jesup, 1995–2002 (tons/year)

Loading	1995	1996	1997	1998	1999	2000	2001	2002	Mean
TN annual loading	3.5	3.4	3.4	3.5	3.4	3.4	3.4	3.4	3.4
TP annual loading	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6

***H. Atmospheric loading of TN and TP into Lake Jesup*.** TN and TP loading through atmospheric deposition directly on the surface of Lake Jesup were calculated using the following equation:

ATMLoad = PRECP * A * CON

Where:

ATMLoad is the annual atmospheric loading,
PRECP is the annual precipitation (**Table 4.6**),
A is the annual average surface area of the lake, which was calculated based on the lake stage data (**Table 4.17**), and
CON is the atmospheric TN and TP concentrations.

In this analysis, CON values were set at 0.630 mg/L for TN and 0.05 mg/L for TP. These values represent the concentrations in agricultural areas (similar to the land use types along the shoreline of Lake Jesup) and were cited from a study conducted by Ahn and James (1999). **Table 4.19** lists the annual TN and TP loadings from atmospheric deposition directly onto the surface of Lake Jesup from 1995 through 2002.

Table 4.19. Annual TN and TP loadings through atmospheric deposition directly onto the surface of Lake Jesup, 1995–2002 (tons/year)

Loading	1995	1996	1997	1998	1999	2000	2001	2002	Mean
TN annual loading	46.2	46.3	38.1	37.4	34.3	22.0	38.0	49.6	39.0
TP annual loading	3.7	3.7	3.0	3.0	2.7	1.7	3.0	3.9	3.1

I. TN and TP input from the St. Johns River into Lake Jesup. The water level of the St. Johns River influences the level of Lake Jesup and water output from the lake to the St. Johns River. When regional rainfall is higher than local rainfall in the Lake Jesup area, inflow from the St. Johns River into Lake Jesup is expected. TN and TP loadings from the St. Johns River into Lake Jesup were calculated by multiplying the inflow from the St. Johns River by the TN and TP concentrations of the St. Johns River. The inflow measurements were obtained from a gauging station located at the outlet of Lake Jesup (USGS 02234435, now maintained by the SJRWMD). TN and TP concentrations in the St. Johns River above Lake Jesup were retrieved from the Department's IWR database, Run 18.2. **Table 4.20** lists the annual inflow from the St. Johns River into Lake Jesup, TN and TP concentrations in the St. Johns River above Lake Jesup, and TN and TP loadings from the St. Johns River into Lake Jesup, from 1995 through 2002.

Table 4.20. Annual flow and TN and TP loadings from the St. Johns River into Lake Jesup, 1995–2002

	1995	1996	1997	1998	1999	2000	2001	2002	Mean
St. Johns River inflow (acre-feet/year)	11,639	10,108	55,194	16,278	88,580	51,617	96,754	26,758	44,616
TN (mg/L)	1.134	1.254	1.329	1.367	1.704	1.897	2.472	1.441	1.575
TP (mg/L)	0.058	0.067	0.073	0.083	0.086	0.078	0.128	0.093	0.083
TN loading (tons/year)	16.3	15.6	90.5	27.4	186.2	120.7	295.0	47.6	99.9
TP loading	0.8	0.8	5.0	1.7	9.4	5.0	15.2	3.1	5.1

(tons/year)									

J. Summary of TN and TP loadings into Lake Jesup from various sources. As noted previously, there are no wastewater facilities that discharge directly to surface waters in the Lake Jesup watershed, and nutrient inputs to Lake Jesup are primarily from nonpoint sources. The nonpoint sources estimated in this analysis include the following:

- Surface runoff from the watershed,
- Background TN and TP loadings through baseflow from the surficial aquifer,
- Septic tank TN and TP loadings,
- Artesian input through springs and upward lake bottom leakage from the Floridan aquifer,
- Atmospheric deposition directly onto the surface of Lake Jesup (including wet and dry deposition), and
- St. Johns River inflow.

Tables 4.21-a, 4.21-b, and **4.21-c** summarize the annual flow and TN and TP loadings from all these sources into Lake Jesup for 1995 through 2002.

Table 4.21-a. Annual flow from various sources into Lake Jesup, 1995–2002 (acre-feet/year)

Source	1995	1996	1997	1998	1999	2000	2001	2002	Mean	Percent
Surface runoff	67,938	95,254	64,396	70,269	49,950	35,616	73,697	103,293	70,052	37.5%
Baseflow (background)	16,985	23,814	16,099	17,567	12,487	8,904	18,424	25,823	17,513	9.4%
Artesian input	4,585	4,556	4,520	4,580	4,547	4,449	4,537	4,568	4,543	2.4%
Atmospheric deposition	59,513	59,535	49,003	48,114	44,136	28,259	48,921	63,801	50,160	26.8%
St. Johns River inflow	11,639	10,108	55,194	16,278	88,580	51,617	96,754	26,758	44,616	23.9%
Total	**160,660**	**193,267**	**189,212**	**156,808**	**199,700**	**128,845**	**242,333**	**224,243**	**186,884**	**100.0%**

Table 4.21-b. Annual TN loading from various sources into Lake Jesup, 1995–2002 (tons/year)

Source	1995	1996	1997	1998	1999	2000	2001	2002	Mean	Percent
Surface runoff	125.7	176.8	119.2	130.4	92.4	66.1	136.6	191.6	129.9	43.0%
Base flow (background)	10.1	14.2	9.6	10.5	7.4	5.3	11.0	15.4	10.4	3.4%
Septic tanks	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	6.5%
Artesian input	3.5	3.4	3.4	3.5	3.4	3.4	3.4	3.4	3.4	1.1%
Atmospheric deposition	46.2	46.3	38.1	37.4	34.3	22.0	38.0	49.6	39.0	12.9%

St. Johns River inflow	16.3	15.6	90.5	27.4	186.2	120.7	295.0	47.6	99.9	33.0%
Total	**221.5**	**276**	**280.5**	**228.9**	**343.4**	**237.2**	**503.7**	**327.3**	**302.3**	**100.0%**

Table 4.21-c. Annual TP loading from various sources into Lake Jesup, 1995–2002 (tons/year)

Source	1995	1996	1997	1998	1999	2000	2001	2002	Mean	Percent
Surface runoff	13.1	19.4	12.6	14.2	9.6	7.4	14.7	20.7	14.0	48.6%
Baseflow (background)	3.2	4.5	3.1	3.3	2.4	1.7	3.5	4.9	3.3	11.5%
Septic tanks	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	9.4%
Artesian input	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	2.1%
Atmospheric deposition	3.7	3.7	3.0	3.0	2.7	1.7	3.0	3.9	3.1	10.8%
St. Johns River inflow	0.8	0.8	5.0	1.7	9.4	5.0	15.2	3.1	5.1	17.7%
Total	**24.1**	**31.7**	**27**	**25.5**	**27.4**	**19.1**	**39.7**	**35.9**	**28.8**	**100.0%**

All totaled, about 186,884 acre-feet of water are discharged into Lake Jesup on a long-term annual average basis from various sources. About 46.9% of the discharge comes from the watershed through either surface runoff or baseflow. Contributions from rainfall directly onto the surface of the lake and inflow from the St. Johns River are comparable; these account for about 26.8% and 23.9% of the annual discharge, respectively. The water contribution from the Floridan aquifer is relatively minor, at about 2.4% of the total annual discharge.

The watershed contributes about 51.9% of the 302.3 tons of TN discharged into Lake Jesup annually through surface runoff, baseflow, and septic tanks. Another major source is the St. Johns River inflow, which accounts for about 33% of the TN input to the lake. Atmospheric deposition contributes about 12.9%, and again, the contribution from the Floridan aquifer is insignificant, about 1.1% of the total TN annual load.

The majority of TP loading into Lake Jesup comes from the watershed, through surface runoff, baseflow, and septic tanks. Of the 28.8 tons of TP loading into the lake, about 69.5% comes from within the watershed. Of this 69.5%, surface runoff produces about 48.6%, and baseflow and septic tanks contribute 11.5% and 9.4%, respectively. Surface runoff is apparently the most important source of phosphorus for the lake. Another major source of phosphorus is the St. Johns River, which contributes about 17.7% of TP on a long-term annual average basis. Atmospheric deposition directly onto the surface of the lake and artesian input produce about 10.8% and 2.1% of the total TP loading, respectively.

Based on the above analyses, the watershed is the major contributor for TN and TP loadings into Lake Jesup. However, two other sources whose importance has not been evaluated so far are nutrient releases from lake sediments and nitrogen fixation; the next chapter discusses these sources in detail.

Chapter 5: DETERMINATION OF ASSIMILATIVE CAPACITY

5.1 Overall Approach

The goal of TMDL development for Lake Jesup is to identify the maximum allowable TP and TN loadings to the lake, so that the lake will meet water quality standards and maintain its functions and designated uses as a Class III water. Specifically, the water quality target in this analysis is a TSI of 65 (Chapter 3). The following three steps were taken to achieve this goal:

1. TP and TN loadings from the Lake Jesup watershed were estimated using the PBS&J model (see Chapter 4). Loadings from other sources, including artesian input, atmospheric deposition directly onto the lake's surface, and input from the St. Johns River were also considered in the loading estimation.

2. Loading estimates from all sources were entered into the Bathtub Eutrophication Model to establish the relationship between TN and TP loadings and in-lake TN, TP, and chl a concentrations by calibrating the Bathtub model against the measured in-lake TN, TP, and chl a concentrations. The calibrated Bathtub model was then used to predict in-lake TN, TP, and chl a concentrations and calculate TSI-predicted (TSI-P) for several different loading scenarios discussed later in this report.

3. The loadings to the lake were adjusted until the TSI-P calculated from the model results reached the target TSI, and the TN and TP loadings that resulted in a TSI of 65 provided the TN and TP (nutrient) TMDLs for Lake Jesup.

Ionized ammonia is part of the ammonia that is unionized, and its concentration usually increases along with an increase in pH (Wetzel, 2001). The pH of lake water can be significantly controlled by photosynthetic activity. Photosynthesis takes up the carbon dioxide (CO_2) and bicarbonate (HCO_3^{-1}) in the water and increases the pH. When nutrients, including TN and TP, decrease, the total algal biomass in the lake and photosynthetic activity are expected to decrease. This decreases the pH of the water and therefore the concentration of unionized ammonia. In this analysis, the target TN, TP, and chl *a* concentrations; the relationship between unionized ammonia and pH; and the relationship between pH and chl *a* concentration were examined to ensure that the TN and TP targets will also decrease unionized ammonia.

5.1.1 Entering Loading Estimates from All Sources into the Bathtub Eutrophication Model

Bathtub is a suite of models developed by the U. S. Army Corps of Engineers (USACOE) Waterways Experimental Station. The primary function of these models is to estimate nutrient concentrations and algal biomass resulting from different patterns of nutrient loadings. The procedures for selecting the appropriate model(s) for a particular lake are described in the Users' Manual (Walker, 1999). The model suite is composed of two types of models, as follows:

- **Nutrient balance models** relate in-lake nutrient concentration to external nutrient loadings, morphometry, and hydrology, and
- **Eutrophication response models** estimate chlorophyll concentration, transparency, and hypolimnetic oxygen depletion, based on the in-lake nutrient concentration established by the nutrient balance models.

Figure 5.1 describes the conceptual scheme used by Bathtub to relate the external loading of nutrients to the in-lake nutrient concentrations and the physical, chemical, and biological response of the lake to the level of nutrients.

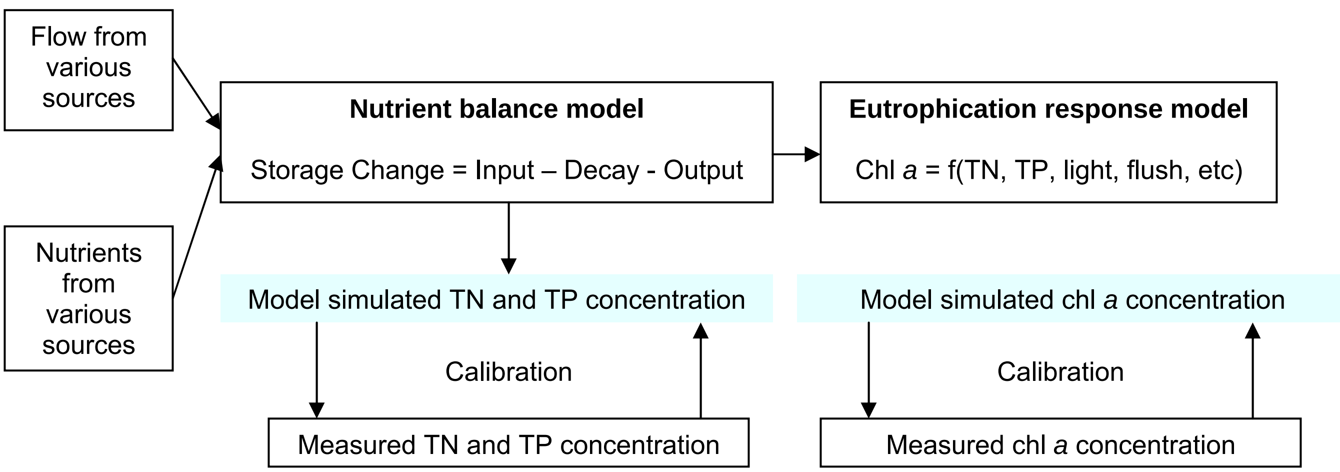


Figure 5.1. Bathtub concept scheme

The *nutrient balance model* adopted by Bathtub assumes that the net accumulation of nutrients in a lake is the difference between nutrient loadings into the lake from various sources and the nutrients carried out through outflow and the losses of nutrients through whatever decay processes occur inside the lake, as follows:

Net accumulation = Input - Decay - Output

In this analysis, "input" included TN and TP loadings though stormwater surface runoff from various land use categories, baseflow contribution (including contributions from septic tanks), artesian input, atmospheric precipitation, and inflow from the St. Johns River. Nutrient output was considered primarily through the lake's outflow to the St. Johns River.

To address nutrient decay within the lake, Bathtub provides several alternatives, depending on the inorganic/organic nutrient partitioning coefficient and reaction kinetics. The major pathway of decay for TN and TP in the model is through sedimentation to the bottom of the lake. The actual sedimentation rate is the net difference between the gross sedimentation rate and sediment resuspension rate.

The prediction of the *eutrophication response model* by Bathtub involves choosing one of several alternative models, depending on whether algal communities are limited by phosphorus or nitrogen, or co-limited by both nutrients. The suite of models also includes scenarios for algal communities limited by light intensity or controlled by the lake flushing rate. In addition, the response of chl *a* concentration to the in-lake nutrient level is characterized by two different kinetic processes: linear or exponential. The variety of models available in Bathtub allows the user to choose specific models based on the specific condition of an individual lake.

The data requirements for the Bathtub model include the following:

- The lake's physical characteristics (surface area, mean depth, length, and mixed layer depth),
- Meteorological data (precipitation and evaporation retrieved from CIRRUS),
- Measured water quality data (including TN, TP, and chl a concentrations of the lake water and TN and TP concentrations in precipitation), and
- Loading data (flow combined with concurrent TN and TP concentrations from various sources).

One feature offered by Bathtub is the "calibration factor." The empirical models implemented in Bathtub are mathematical generalizations about lake behavior. When applied to data from a particular reservoir, measured data may differ from predictions by a factor of two or more. Such differences reflect data limitations (measurement or estimation errors in the average inflow and outflow concentrations), the unique features of a particular lake (Walker, 1999), and unexpected processes inherent to a lake. The calibration factor offered by Bathtub allows model users to calibrate the magnitude of lake response predicted by the empirical models. The model calibrated to current conditions against measured data from the lake can then be applied to predict the changes in lake conditions that are likely to result from specific management scenarios, under the assumption that the calibration factor remains constant for all prediction scenarios.

5.1.1.1 Calculation of the Trophic State Index

TSI values were calculated using the procedures outlined in Florida's 1996 305(b) report, as follows:

$$TSI = (CHLA_{TSI} + NUTR_{TSI})/2$$

Where:

$$CHLA_{TSI} = 16.8 + 14.4 \times LN(CHLA)$$
$$TN_{TSI} = 56 + [19.8 \times LN(TN)]$$

$$TN2_{TSI} = 10 \times [5.96 + 2.15 \times LN(TN + 0.0001)]$$

$TP_{TSI} = [18.6 \times LN(TP \times 1000)] - 18.4$
$TP2_{TS} = 10 \times [2.36 \times LN(TP \times 1000) - 2.38]$

The procedure addresses limiting nutrient considerations by calculating $NUTR_{TSI}$:

If $TN/TP > 30$ then $NUTR_{TSI} = TP2_{TSI}$
If $TN/TP < 10$ then $NUTR_{TSI} = TN2_{TSI}$
If $10 < TN/TP < 30$ then $NUTR_{TSI} = (TP_{TSI} + TN_{TSI})/2$

5.1.1.2 TMDL Scenario Development for Lake Jesup

The TMDL of the lake was developed by evaluating TSIs for the following scenarios:

A. TSI for current conditions. The current TSI for Lake Jesup was calculated based on the annual average TN, TP, and chl *a* concentrations obtained from the Department's IWR database.

B. Natural background TSI. This is the TSI calculated based on the TN, TP, and chl *a* concentrations resulting from a watershed condition in which all human land uses—including agriculture/golf course; low-, medium-, and high-density residential; commercial; industrial/utilities; institutional; and transportation facilities—discharge pollutants with the same characteristics as those associated with natural land uses. In the actual modeling process, all the areas covered by human land uses were converted to forest/rural open and wetland areas. The target TSI is considered the background TSI plus 5 TSI units.

The background TSI was estimated using the model settings calibrated against the measured data, which included the lake outflow measured at the lake outlet (Gauging Station ID: 02234324) and measured TN, TP, and chl *a* concentrations for Lake Jesup. Because daily flow measurements at the outlet of Lake Jesup only started in 1995, the period of record used for model calibration was 1995 through 2002.

5.1.1.3 Data Analysis

Historical trends in the trophic status of Lake Jesup. TN, TP, and chl *a* concentrations for Lake Jesup from 1995 through 2002 were retrieved from the IWR database. **Table 5.1** shows station IDs and the latitude and longitude of the water quality stations from which TN, TP, and chl *a* concentrations were measured. **Figure 5.2** shows the locations of these water quality stations.

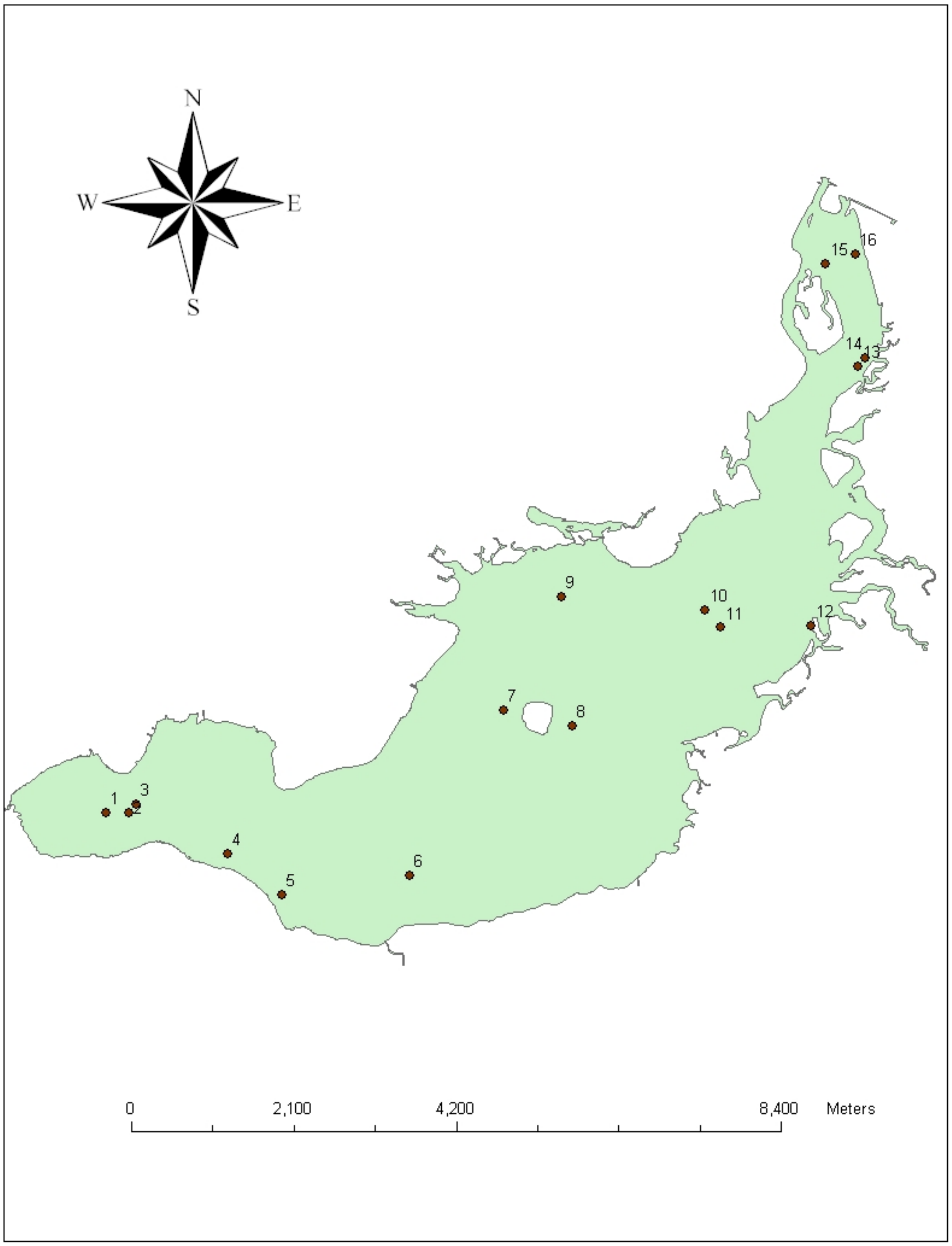


Figure 5.2. Locations of water quality stations in Lake Jesup

Table 5.1. Water quality stations from which TN, TP, and chl a concentrations were measured

Station Number	Station ID	Latitude	Longitude
1	21FLSJWM44059	28.715	81.277
2	21FLSJRWOW-6	28.715	81.274
3	21FLSJWMWLJESS	28.716	81.273
4	21FLSJRWOW-5	28.710	81.261
5	21FLSJWM44057	28.705	81.254
6	21FLSJRWOW-4	28.707	81.237
7	21FLGFWFGFCCR0477	28.726	81.224
8	21FLKWATSEM-JESUP-1	28.724	81.215
9	21FLSJRWOW-7	28.739	81.216
10	21FLSJWMELJESS	28.737	81.197
11	21FLA 20010183	28.735	81.195
12	21FLSJRWOW-3	28.735	81.183
13	21FLSJWM44055	28.765	81.176
14	21FLSJRWOW-2	28.766	81.175
15	21FLSJWMUSJ027	28.777	81.180
16	21FLVEMDSJ07	28.778	81.176

Quarterly mean values for TN, TP, and chl *a* concentrations were calculated based on the TN, TP, and chl *a* concentrations measured for the sites listed in **Table 5.1,** and quarterly TSIs were calculated based on the quarterly mean values of TN, TP, and chl *a* concentrations. Quarterly TN, TP, chl *a*, and TSI values were then used to calculate annual mean values. The long-term annual average values of these data were calculated based on annual mean values of each year from 1995 through 2002. The long-term annual average values for the entire verified period were calculated based on the individual mean values of each year from 1996 through 2002 (the verified period only includes a half-year for 2003, and the annual average values for 2003 were not calculated). Seasonal trends for TN, TP, chl *a*, and TSI were examined by calculating the long-term quarterly mean values based on the quarterly mean values of each year from 1995 through 2002. The quarterly means for the verified period were calculated using the data from 1996 through 2002. **Table 5.2** lists the individual annual mean TN, TP, chl *a*, and TSI values for Lake Jesup for 1995 through 2002, and **Table 5.3** lists the quarterly mean for TN, TP, chl *a*, and TSI over the long term and for the verified period.

Table 5.2. Annual averages of TN, TP, chl a, and TSI values of Lake Jesup, 1995–2002. Data represent the mean ± 1 standard deviation (n = 4)

Year	TP (mg/L)	TN (mg/L)	Chl *a* (µg/L)	TSI
1995	0.19 ± 0.09	2.30 ± 1.09	64.0 ± 45.9	74.5 ± 8.2
1996	0.17 ± 0.03	2.46 ± 0.35	64.8 ± 16.3	75.9 ± 2.9
1997	0.14 ± 0.03	2.44 ± 0.40	51.3 ± 7.7	73.4 ± 2.4
1998	0.15 ± 0.04	2.59 ± 0.72	87.8 ± 37.4	77.4 ± 5.7
1999	0.16 ± 0.04	3.44 ± 0.86	110.2 ± 25.7	81.0 ± 4.5
2000	0.14 ± 0.03	3.75 ± 0.72	159.9 ± 59.4	83.2 ± 4.2
2001	0.14 ± 0.02	4.47 ± 1.21	143.5 ± 35.9	83.6 ± 3.8
2002	0.16 ± 0.04	1.99 ± 0.50	64.8 ± 25.4	74.2 ± 4.8
Mean	0.16 ± 0.02	2.93 ± 0.31	93.3 ± 16.5	77.9 ± 1.8
Mean–Verified Period	**0.15 ± 0.01**	**3.02 ±0.30**	**97.5 ± 16.7**	**78.4 ± 1.1**

Table 5.3. Seasonal variation of TN, TP, chl a, and TSI in Lake Jesup

Long-term Quarterly Mean				
	TP (mg/L)	**TN (mg/L)**	**Chl *a* (mg/L)**	**TSI**
1st Quarter	0.15 ± 0.03	2.58 ± 1.10	77.4 ± 49.8	75.7 ± 6.0
2nd Quarter	0.20 ± 0.05	3.66 ± 1.09	115.2 ± 38.3	82.3 ± 4.0
3rd Quarter	0.16 ± 0.04	3.02 ± 1.07	102.5 ± 57.8	78.7 ± 5.9
4th Quarter	0.12 ± 0.02	2.46 ± 0.72	77.9 ± 48.5	74.8 ± 4.7
Verified Period Quarterly Mean				
	TP (mg/L)	**TN (mg/L)**	**Chl *a* (mg/L)**	**TSI**
1st Quarter	0.15 ± 0.02	2.71 ± 1.12	83.37 ± 50.5	76.4 ± 6.1
2nd Quarter	0.18 ± 0.02	3.62 ± 1.18	112.77 ± 40.7	81.7 ± 4.0
3rd Quarter	0.16 ± 0.04	3.19 ± 1.05	110.17 ± 57.9	79.6 ± 5.8
4th Quarter	0.12 ± 0.02	2.57 ± 0.71	83.50 ± 49.59	75.7 ± 4.3

As shown in **Table 5.2**, the annual average TP concentration in Lake Jesup ranged from 0.14 to 0.19 mg/L (1995–2002), and from 0.14 to 0.17 mg/L in the verified period (1996–2002). The variation in the annual average TP during the period of record appeared to be relatively small. The long-term and verified period annual average TP concentrations for the lake are both about 0.16 mg/L. Larger variations were observed for annual average TN and chl *a* concentrations. Annual average TN and chl *a* concentrations from 1995 through 2002 ranged from 1.99 to 4.47 mg/L, and from 51.3 to 159.9 µg/L, respectively. These variations were also observed in the verified period (1996–2002). The long-term annual average TN and chl *a* concentrations were 2.93 and 93.3 µg/L, respectively, and for the verified period, these were 3.02 and 97.5 µg/L, respectively. The long-term annual average TSI for the lake is about 77.9, and the verified period TSI is about 78.4.

Nutrient and chl *a* concentrations in the lake do not always correlate with the amount of rainfall. **Figures 5.3-a, 5.3-b, 5.3-c,** and **5.3-d** show the relationships between TP, TN, and chl *a* concentrations and TSI, respectively, with annual rainfall. No obvious relationship was observed between annual rainfall and annual average TP concentration (**Figure 5.3-a**). In contrast, correlations were observed between annual rainfall and annual average TN concentration, and between annual rainfall and annual average chl *a* concentration (**Figures 5.3-b** and **5.3-c**). It appears that whenever annual rainfall is high, TN and chl *a* concentrations are low, and when annual rainfall is low, TN and chl *a* concentrations are high. The highest TN and chl *a* concentrations observed in 1999, 2000, and 2001 appear to be associated with low annual rainfall in these three years.

The concentration effect due to the decrease of lake volume could have caused the increase in concentration; however, the simple concentration effect could not fully explain nutrient dynamics under the low rainfall condition, because no significant increase of TP concentration was observed during these same dry years. Some in-lake chemical and biochemical processes must also be affecting the nutrients and algal biomass dynamics observed. Nitrogen fixation may be an important process contributing to nitrogen dynamics. The change in cellular chl *a* content from some blue-green algal species could have contributed to the change in chl *a* concentrations in the lake water. The following section explores these possibilities in more detail.

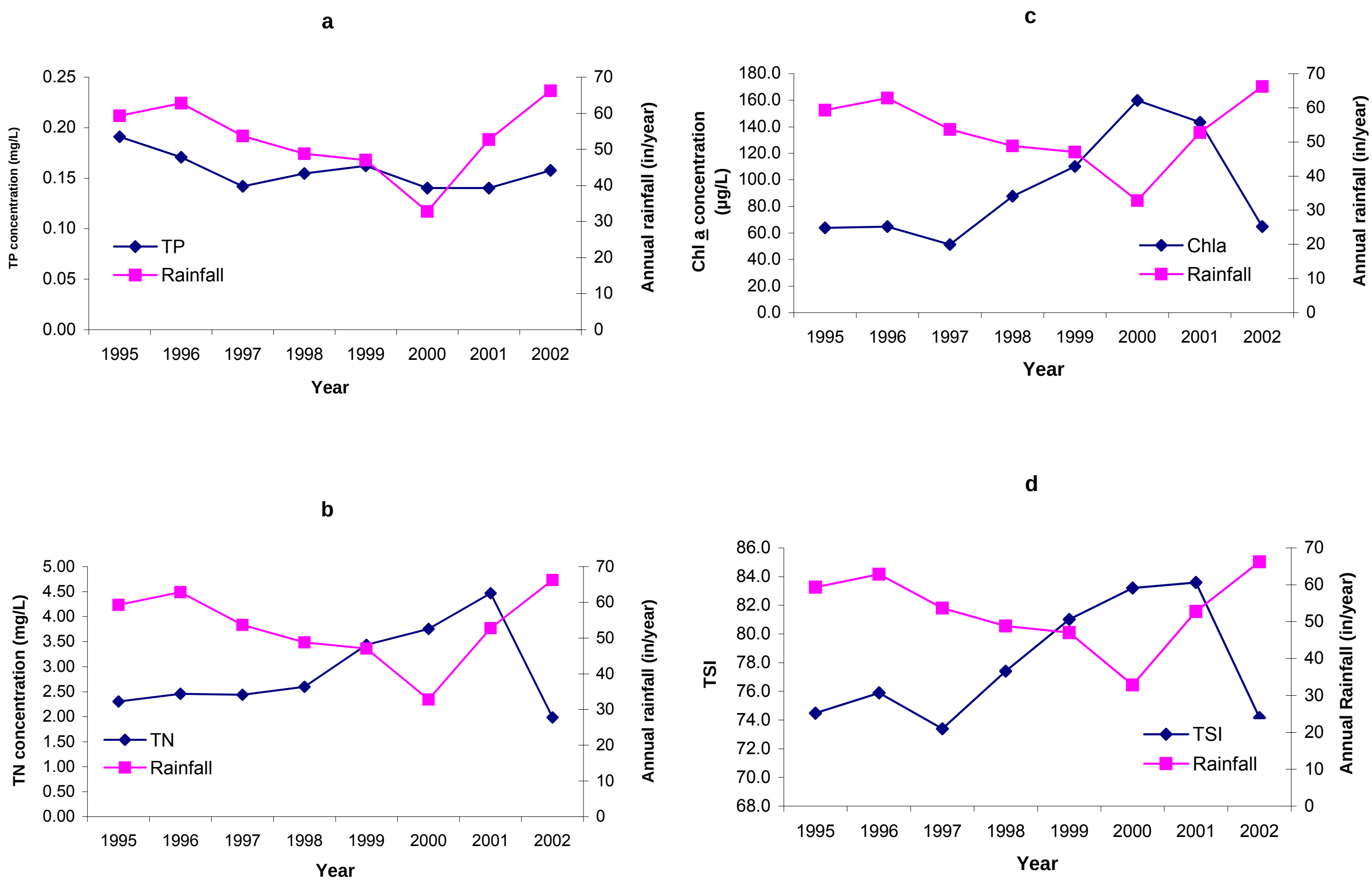
Nutrient and chl *a* concentrations tend to be higher in the second and third quarters of the year. However, when taking into account the high standard deviations in these seasons, the quarterly mean values of TN, TP, and chl *a* concentrations in the second and third quarters are not significantly different from those of the first and fourth quarters **(Table 5.3).**

5.1.1.4 Establishing the Relationship between TN and TP Loadings and In-lake TN, TP, and Chl *a* Concentrations Using the Bathtub Model; Model Calibration

The relationship between TN and TP loadings and in-lake TN and TP concentrations was established by fitting the Bathtub predictions with the measured TN and TP concentrations of the lake. To calibrate the model, the following data were required:

- The lake's physical characteristics,
- Meteorological data (precipitation and evaporation),
- Areal atmospheric deposition of nutrients directly onto the surface of the lake,
- Measured water quality data (TN, TP, and chl a concentrations of the lake water), and
- Loading data (flow and TN and TP concentrations in the flow from various sources).

The lake's physical characteristics, including surface area, change of lake storage, mean depth, and mixed layer depth, were calculated based on the characteristic curve of Lake Jesup **(Figures 4.8** and **4.9)** and the lake stage measurements obtained from the gauging station located at the outlet of Lake Jesup. **Table 5.4** lists the annual lake stage, lake surface area, change of lake storage, mean depth, and mixed layer depth of Lake Jesup from 1995 through 2002.



Figures 5.3-a, 5.3-b, 5.3-c. Relationship between annual rainfall; concentrations of TN, TP, and chl *a*; and TSI in Lake Jesup, 1995–2002

Table 5.4. Annual lake characteristics of Lake Jesup for the modeling period, 1995–2002

Year	Annual Average Lake Stage (feet)	Annual Average Lake Surface (square kilometers)	Annual Average Lake Volume (square kilometers)	Annual Average Mean Depth (meters)	Annual Average Mixing Depth (meters)	Annual Change of Lake Storage (meters)
1995	3.42	47.30	0.071	1.51	1.51	-0.88
1996	2.44	45.18	0.058	1.28	1.28	-0.61
1997	1.94	44.07	0.051	1.16	1.16	1.37
1998	3.08	46.51	0.067	1.43	1.43	-1.30
1999	2.30	44.88	0.056	1.24	1.24	0.56
2000	1.29	42.36	0.043	1.01	1.01	-0.64
2001	2.15	44.54	0.054	1.21	1.21	0.33
2002	2.69	45.69	0.061	1.34	1.34	0.46
Mean	**2.42**	**45.07**	**0.058**	**1.27**	**1.27**	**-0.09**

The annual change in lake storage shown in **Table 5.4** was calculated as the difference between lake stage at the beginning (January 1) and the end (December 31) of each year (Walker, 1999). Because the mean depth of the lake is relatively low (a long-term average of 1.27 meters), it was assumed that most of the time the lake was completely mixed vertically, and therefore the annual average mixing depth was assumed to be equal to the mean depth of the lake.

Meteorological data were retrieved from CIRRUS, which has 2 weather stations in the area. Daily rainfall measurements were obtained from a weather station located in Sanford (UCAN: 4129, COOP: 087982), and the daily evaporation data were obtained from Lisbon (UCAN: 4025, COOP: 085076). **Table 5.5** lists annual rainfall and evaporation values for 1995 through 2002. The daily evaporation data were adjusted using a lake-pan evaporation coefficient of 0.86 (Keesecker, 1992).

Table 5.5. Annual meteorological data used for Bathtub modeling, 1995–2002

Year	Annual rainfall (meters/year)	Annual evaporation (meters/year)
1995	1.51	1.07
1996	1.60	1.18
1997	1.36	1.11
1998	1.24	0.92
1999	1.19	1.00
2000	0.83	1.17
2001	1.34	1.01
2002	1.68	1.10
Mean	**1.34**	**1.07**

Areal atmospheric nutrient loadings: nutrient loads through atmospheric deposition directly onto the surface of the lake were calculated in Bathtub based on areal atmospheric loading rates, which in turn were calculated using the following equation:

$$L = R * C$$

Where:

L is the areal atmospheric nutrient-loading rate,
R is the annual rainfall, and
C is the atmospheric TN and TP concentration (bulk concentration including both wet and dry deposition [Redfield, 2002]).

Table 5.6 lists the areal atmospheric deposition rate for each year of the modeling period from 1995 through 2002. **Table 5.2** provides annual measured water quality data for Lake Jesup from 1995 through 2002. **Tables 5.7-a, 5.7-b,** and **5.7-c** contain the annual flow and nutrient concentrations from each major nonpoint source into Lake Jesup from 1995 through 2002.

Table 5.6. Annual areal atmospheric nutrient loadings to Lake Jesup, 1995–2002

Year	Annual Rainfall (inches/year)	Annual Mean Lake Surface (km^2)	Atmospheric TP concentration (mg/L)	Atmospheric TN concentration (mg/L)	Areal atmospheric load for TP ($kg/km^2/year$)	Areal atmospheric load for TN ($kg/km^2/year$)
1995	59.32	47.30	0.05	0.63	75	949
1996	62.82	45.18	0.05	0.63	80	1005
1997	53.69	44.07	0.05	0.63	68	859
1998	48.83	46.51	0.05	0.63	62	781
1999	47.04	44.88	0.05	0.63	60	753
2000	32.83	42.36	0.05	0.63	42	525
2001	52.73	44.54	0.05	0.63	67	844
2002	66.24	45.69	0.05	0.63	84	1060
Mean	**52.94**	**45.07**	**0.05**	**0.63**	**67**	**847**

Table 5.7-a. Annual flow from major nonpoint sources into Lake Jesup, 1995–2002 (cubic hectometers [HM^3]/year)

Source	1995	1996	1997	1998	1999	2000	2001	2002	Mean
Gee Creek	6.4	9.2	6.1	6.7	4.7	3.5	7.1	9.9	6.7
Howell Creek	27.9	40.1	26.6	29.4	20.4	15.3	30.8	43.1	29.2
Lake Jesup	38.1	52.0	35.9	38.6	28.1	19.1	40.6	56.8	38.6
Little Lake Howell	2.3	3.3	2.2	2.4	1.7	1.3	2.6	3.6	2.4
Soldiers Creek	9.1	12.9	8.7	9.5	6.7	4.8	9.9	14.0	9.5
Baseflow	21.0	29.4	19.9	21.7	15.4	11.0	22.7	22.7	31.9
Artesian leakage through the lake bottom	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Spring inflow	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
St. John River's inflow	14.0	12.0	68.0	20.0	109.0	64.0	119.0	33.0	55.0

Table 5.7-b. Annual TN concentration of flows from major nonpoint sources into Lake Jesup, 1995–2002 (parts per billion [ppb])

Source	1995	1996	1997	1998	1999	2000	2001	2002	Mean
Gee Creek	1,488	1,495	1,490	1,494	1,488	1,494	1,492	1,494	1,492
Howell Creek	1,443	1,454	1,446	1,452	1,442	1,458	1,451	1,452	1,450
Lake Jesup	1,584	1,588	1,584	1,588	1,583	1,591	1,586	1,586	1,586
Little Lake Howell	1,275	1,275	1,276	1,276	1,277	1,266	1,274	1,277	1,275
Soldiers Creek	1,390	1,390	1,391	1,390	1,390	1,387	1,390	1,391	1,390
Baseflow*	1,423	1,154	1,475	1,392	1,762	2,276	1,350	1,102	1,492
Artesian leakage through the lake bottom	611	611	611	611	611	611	611	611	611
Spring inflow	611	611	611	611	611	611	611	611	611
St. John River inflow	1,134	1,254	1,329	1,367	1,704	1,897	2,472	1,441	1,575

* Baseflow TN concentration includes the contribution from septic tanks.

Table 5.7c. Annual TP concentration of flows from major nonpoint sources into Lake Jesup, 1995–2002 (ppb)

Source	1995	1996	1997	1998	1999	2000	2001	2002	Mean
Gee Creek	187	195	189	193	187	200	192	193	192
Howell Creek	191	200	193	198	190	206	197	197	197
Lake Jesup	128	135	130	134	128	137	132	133	132
Little Lake Howell	140	148	142	146	140	151	145	146	145
Soldiers Creek	153	161	156	160	153	163	158	160	158
Baseflow*	282	246	289	278	328	398	272	238	291
Artesian leakage through the lake bottom	110	110	110	110	110	110	110	110	110
Spring inflow	110	110	110	110	110	110	110	110	110
St. John River's inflow	58	67	73	83	86	78	128	93	83

* Baseflow TP concentration includes the contribution from septic tanks.

The flow and nutrient concentrations from the Lake Jesup watershed were divided into flows and nutrient concentrations from five sub-basins: Gee Creek, Howell Creek, the area directly connecting to Lake Jesup, Little Lake Howell, and Soldier Creek. Net flow and net TN and TP concentrations after the BMP treatments were used for model calibration because existing BMPs were considered as part of the current condition for the modeling.

5.1.1.5 Calibrating the Bathtub Eutrophication Model

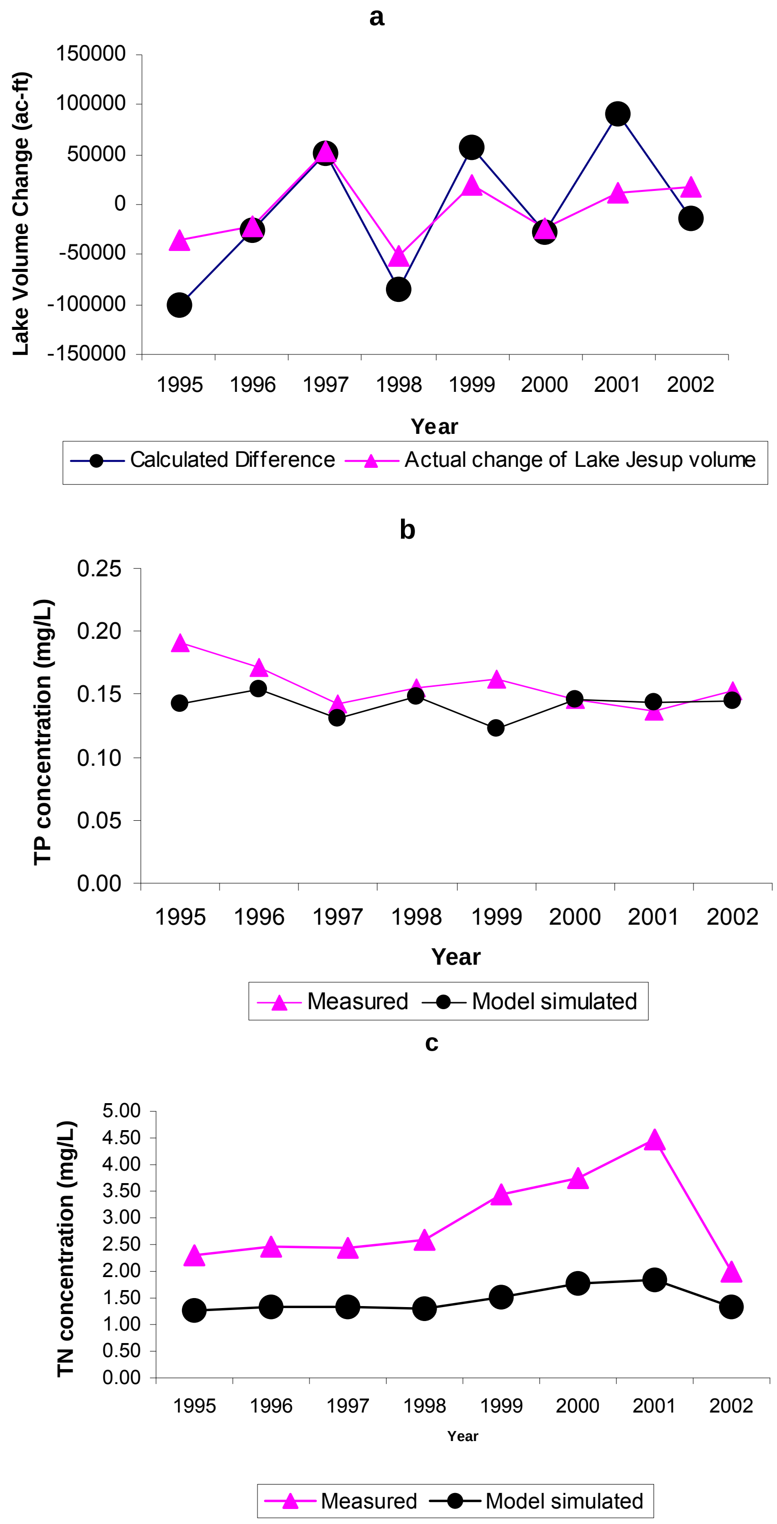
To calibrate the Bathtub model, each source of TN and TP previously identified was entered into the model as an independent tributary (**Tables 5.7-a, 5.7-b,** and **5.7-c**). **Figures 5.4-a, 5.4-b**, and **5.4-c** show the model results for lake volume and TP and TN calibration, respectively, for 1995 through 2002.

Bathtub provides alternative models for estimating the influence of sedimentation on in-lake TN and TP concentrations (Walker, 1999). In this analysis, the Settling Velocity Model was chosen for both TN and TP. This model assumes that the sedimentation of TN and TP follows first-order kinetics and should linearly correlate with in-lake TN and TP concentrations. The model also assumes that the depth of the lake influences sedimentation, i.e., the deeper the lake, the slower the sedimentation. This model fits the condition of Lake Jesup, because the lake is relatively shallow and large in surface area. Continued wind mixing prevents the lake from forming thermal stratification, which would otherwise prevent the particles from being resuspended once they settled to the bottom. Continued wind mixing through the entire water column also reduces the particle-settling rate by bringing the settled particles back into the water column. These processes produce a relatively low net settling rate in Lake Jesup.

Other sedimentation models provided by Bathtub assume second-order kinetics, which fit reasonably well with lakes that form thermal stratification during the summer. However, these models would overestimate the net sedimentation of Lake Jesup, and in turn cause the in-lake TN and TP concentrations to be underestimated.

Figure 5.4-a shows the calculated change of lake volume, based on model-simulated flow from the watershed, and the measured change of lake volume, based on the lake stage from the gauging station located at the outlet of Lake Jesup. The model-simulated lake volume change traces the measured volume change reasonably well for most years in the modeling period, except for 1995 and 2001. Increases in lake volume were apparently underestimated in 1995 and overestimated in 2001. Based on the rainfall data analysis, 1995 was the end of three consecutive wet years, and the soil moisture condition designated by the SCS curve number technique may not fully reflect the actual soil moisture condition, resulting in an underestimate of runoff to the lake. In contrast, 2001 was the end of three consecutive dry years; the watershed model may not fully represent the moisture debt of the soil and may result in an overestimate of the amount of runoff discharged into the lake.

The model-simulated TP concentrations were also reasonably consistent with the measured TP concentration **(Figure 5.4-b).** The long-term average error for model estimates was about 10%. In contrast, there was a large gap between model-simulated TN and measured TN concentrations for all the years in the modeled period **(Figure 5.4-c).** The following three possibilities were examined to address the difference between the measured and model-simulated TN concentrations:



Figures 5.4-a, 5.4-b, 5.4-c. Results for flow and TN and TP calibrations, using the Bathtub model, 1995–2002

Possibility A: The TN concentration of the flow (including surface runoff and baseflow) from the watershed could be underestimated.

The TN concentration of the flow from the watershed was examined because (1) artesian inputs (spring flow and bottom leakage) only account for a very small portion of the total flow and nitrogen budget, and therefore an error in the artesian input should not influence the final lake concentration too dramatically; (2) since TN concentrations for the St. Johns River inflow are measured values, and the TN concentration is consistently and sufficiently higher than the minimum detection limit, long-term dramatic errors are not very likely; and (3) the rainfall TN concentration appears to be reasonable. Based on these analyses, if there is a major model error, the error should be associated with the watershed flow into the lake.

If the SCS curve number approach underestimated the TN concentration of the flow from the watershed, observed tributary TN concentrations should be significantly higher than the model-simulated TN concentration for the watershed flow. The long-term average TN concentrations for waterbodies discharging into Lake Jesup were analyzed, and **Table 5.8** lists the results. Based on **Table 5.8**, the average TN concentration of the waterbodies discharging into Lake Jesup is about 1.181 $\pm$ 0.523 mg/L, which is not significantly different from the model-simulated average TN concentration of the flow from the watershed, or about 1.444 $\pm$ 0.115 mg/L **(Table 5.7-b).** This result indicates that the SCS curve number–based PBS&J model did not underestimate the TN concentration from the watershed flow. Therefore, Possibility 1 is rejected. In fact, **Table 5.8** also demonstrates that, even for measured TN values, the Lake Jesup TN concentration is about 2 times higher than the TN concentration for tributaries, suggesting that in-lake processes could be responsible for the higher TN concentration in Lake Jesup.

Table 5.8. Long-term average TN concentrations for waterbodies discharging into Lake Jesup, calculated based on measured TN concentrations

Waterbody	WBID	TN (mg/L)
Soldier Creek	2986	0.970
Gee Creek	2994A	0.907
Howell Creek	2997	0.957
Bear Creek	2999	0.960
Lake Jesup Drain	2981E	1.041
Sweetwater Creek	2996	1.689
Lake Charm Shortcut	2995A	0.630
Sweetwater Creek	2992	1.222
Salt Creek	2990	1.710
Chub Creek	2985	2.321
Phelps Creek	2982	0.584
Mean		**1.181**
Lake Jesup	**2981**	**2.445**

Possibility B: Nutrient release from the sediment is responsible for the fact that TN concentrations in Lake Jesup are higher than those of the waterbodies discharging into the lake.

Nutrient release from the sediment could take several different pathways: (1) the nutrient resuspension of sediment through wind mixing; (2) the direct diffusion of nutrients into the water column; and (3) nutrient translocation through biological activity.

If the high TN concentration in Lake Jesup were mainly caused by the resuspension of sediment, a significant enhancement of this concentration should also be observed with TP, because TP is more electrically charged than TN and has a stronger tendency to bind with sediment particles and re-enter the water column together with suspended sediment. In contrast, TN is more soluble in the water and less easily associated with particulate materials.

Table 5.9 shows the TP concentrations of Lake Jesup and the TP concentration of waterbodies discharging into Lake Jesup. The long-term average TP concentration for the waterbodies that discharge into Lake Jesup is about 0.199 $\pm$ 0.114 mg/L, which is not significantly different from the long-term average TP concentration for Lake Jesup of 0.142 mg/L. Apparently, the TP concentration of Lake Jesup is not significantly higher than the TP concentrations of the waterbodies that discharge into Lake Jesup, suggesting that the sediment resuspension may not be the major cause for TN enhancement.

Table 5.9. Long-term average TP concentrations for waterbodies discharging into Lake Jesup, calculated based on measured TN concentrations

Waterbody	WBID	TP (mg/L)
Soldier Creek	2986	0.140
Gee Creek	2994A	0.119
Howell Creek	2997	0.120
Bear Creek	2999	0.140
Lake Jesup Drain	2981E	0.133
Sweetwater Creek	2996	0.355
Lake Charm Shortcut	2995A	0.300
Sweetwater Creek	2992	0.302
Salt Creek	2990	0.224
Chub Creek	2985	0.351
Phelps Creek	2982	0.005
Mean		**0.199**
Lake Jesup	**2981**	**0.142**

Another observation working against the supposition that TN enhancement in Lake Jesup is due to sediment resuspension is the dissolved oxygen (DO) concentration of the lake. **Figure 5.5** shows the annual average DO concentration in Lake Jesup from 1995 through 2002. If constant sediment resuspension were an important process in Lake Jesup, nutrients should not be the only materials being brought back to the water column. Organic materials in the sediment would also be resuspended in the water column, and this process should consume DO and cause the DO concentration to decrease.

Of course, if the water can support a large quantity of phytoplankton, photosynthetic oxygen production may counterbalance DO consumption. When sediment resuspension becomes a problem, however, the enhanced turbidity could significantly shield light irradiance and limit algal growth, as well as DO production through photosynthesis. Therefore, the overall effect of the constant sediment resuspension should be a decrease of DO concentration in the water. However, this is not what is observed in **Figure 5.5**. The annual average DO concentrations of the lake were consistently higher than 8 mg/L from 1995 through 2002. DO concentrations did not change significantly when the TN concentration increased from around 2 mg/L to more than 4 mg/L, indicating that the sediment resuspension may not be a very significant cause of the TN enhancement in Lake Jesup

The assumption that nitrogen is being resuspended in Lake Jesup is also contradictory to the observation in a sediment core study conducted by the SJRWMD that the TN deposition rate for Lake Jesup is positive, i.e., the direction for TN in Lake Jesup is a net deposition to the sediment (Cable et al., 1997).

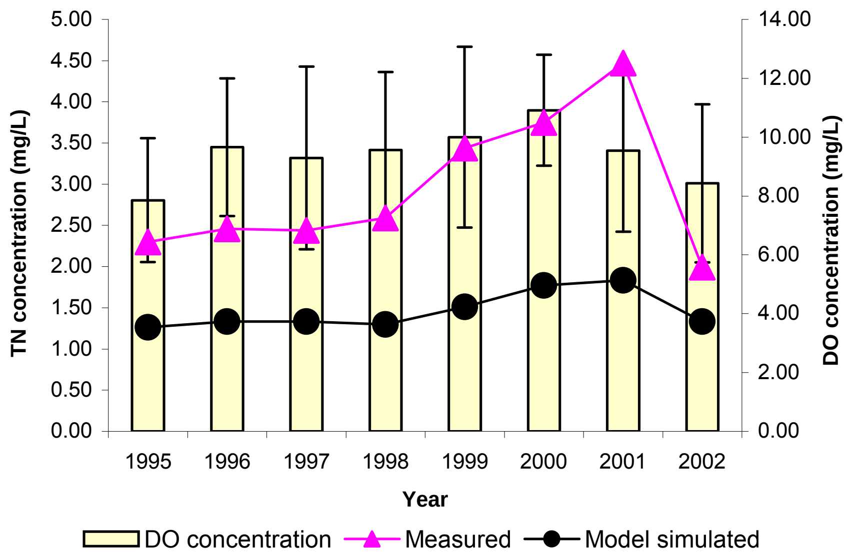


Figure 5.5. Annual average DO concentration in Lake Jesup, 1995–2002

Diffusion could be another pathway through which nitrogen enters the water column from the sediment. Ammonia is the major form of nitrogen for sediment nutrient diffusion (Chiario and Burke, 1980; Hu et al., 2001). In sediments, the majority of ammonia is usually adsorbed on sediment particles (Wetzel, 2001). Under anaerobic conditions, however, the adsorptive capacity of the sediments is greatly reduced, and a marked release of ammonia from the sediments occurs (Kamiyama et al., 1977; Verdouw et al., 1985).

During the time this analysis was conducted, no reliable data were available for sediment nutrient diffusion in Lake Jesup. Anaerobic conditions at the bottom of Lake Jesup are not likely to be a frequent phenomenon, however, because the lake is very shallow and its surface area is relatively large. The water column is well mixed vertically most of the time. The DO results from investigations conducted by the SJRWMD in 1995 and 1996 indicated no anaerobic conditions at the bottom of the lake. In most cases, the bottom DO concentration was not significantly different from the DO concentration measured at the surface of the lake **(Appendix B).** These observations are supported by an investigation conducted by the Department in January 2004, in which no DO hypoxia was found at the bottom of Lake Jesup in any part of the lake sampled. These observations rule out any long-lasting anaerobic condition, which would be required for a significant release of ammonia from the sediment through diffusion.

In addition, the dynamics of ammonia concentration in Lake Jesup do not support the significant release of ammonia from the sediment. As shown in **Figure 5.6**, when the TN concentration increased from 1999 through 2001, no increase in ammonia concentration was observed. Instead, ammonia concentrations decreased during this period. While it is commonly accepted that ammonia is the form of nitrogen favored by phytoplankton in ambient water and can be taken up very rapidly when added into the water, if the increase of TN concentration were caused by the release of a large amount of ammonia into the water column, the ammonia concentration for 1999 through 2001 should at least have stayed the same as in the years before 1999. The decrease in ammonia concentration suggests that the TN concentration in Lake Jesup did not increase because ammonia was being added to the total amount of the TN pool. Instead, it is likely that the decrease in available ammonia caused the phytoplankton to find nitrogen from other sources, such as through atmospheric nitrogen fixation.

At the time this analysis was conducted, no data were available to the Department on the scale of nutrient translocation that could be caused by zooplankton and/or fish that feed on the sediment and excrete in the water column. The activities of invertebrates in the sediment could increase severalfold the release of ammonia from the sediment (Henriksen et al., 1983; Fukuhara and Sakamoto, 1987; Svensson, 1997). All these processes, however, add ammonia back to the water column. If these processes are important in controlling the enhancement of the overall TN pool, the decrease of ammonia shown in **Figure 5.6** should not have been observed. The decrease in ammonia concentration when the total TN pool increases suggests that nutrient translocation might not be responsible for the increase of TN concentration. Phytoplankton may obtain nitrogen from other sources, such as nitrogen fixation.

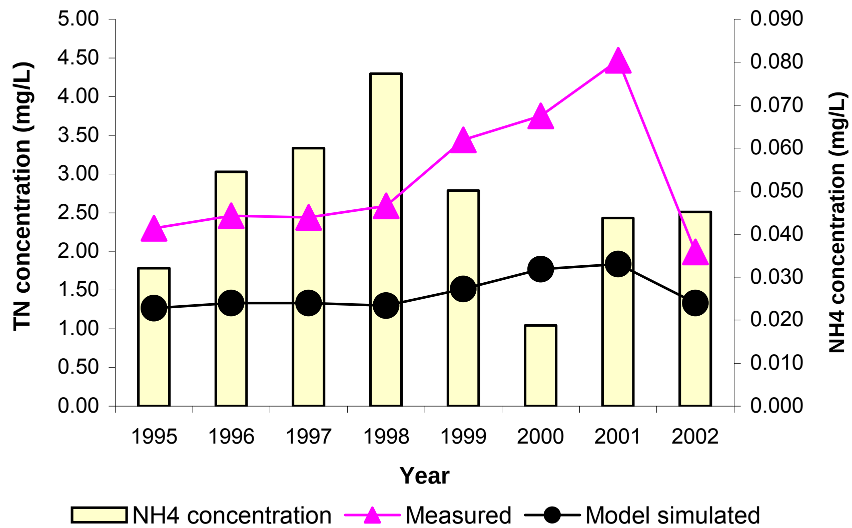


Figure 5.6. Dynamics of ammonia concentration in Lake Jesup, 1995–2002

Possibility C: Nitrogen fixation is the major factor responsible for the enhanced TN concentration observed in Lake Jesup.

Based on the above analyses, the enhanced TN concentration in Lake Jesup is not very likely caused by sediment resuspension or direct diffusion. It is possible that nitrogen fixation caused the large gap between the measured and model-simulated TN concentration. Many studies have documented the importance of nitrogen fixation in eutrophic lakes (Keirn and Brezonik, 1971; Horne and Goldman, 1972; Ashton, 1981). Up to 82% of the TN loading into eutrophic lakes could come from nitrogen fixation (Howarth et al., 1988). In freshwater lakes, blue-green algae, especially filamentous blue-green algae with a heterocystic structure, appear to be the most important organisms in nitrogen fixation (Stewart, 1969), although nitrogen fixation by other photosynthetic or heterotrophic bacteria has also been documented (Keirn and Brezonik, 1971; Hill, 1992).

The rates of nitrogen fixation are reasonably correlated with the biomass of nitrogen-fixing blue-green algae (Wetzel, 1983; Goldman and Horne, 1983). The major blue-green algal taxa capable of fixing nitrogen include *Anabaena, Anabaenopsis, Aphenezomenon, Nodularia, Cylindrospermopsis,* and *Lyngbya* (D. Dobberfuhl, SJRWMD, personal communication). The critical condition that triggers nitrogen fixation by blue-green algae is when the molar ratio between dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) is lower than the Redfield ratio of 16:1 (Flett et al., 1980).

No data were available regarding the importance and rate of nitrogen fixation in Lake Jesup when this analysis was conducted. However, the annual DIN/DIP ratio of Lake Jesup was always lower than 16 for the period of analysis, from 1995 through 2002 **(Table 5.10).** This low ratio provides the necessary condition for a significant amount of nitrogen fixation in Lake Jesup. In addition, a phytoplankton community study conducted by the SJRWMD between 1995 and 2002 in Lake Jesup identified several major nitrogen-fixing blue-green algae, including *Anabeana, Anabeanopsis, Aphanizomenon, Cylindrospermopsis,* and *Lyngbya*. The total cell counts for these nitrogen-fixing taxa typically account for about 20 to 30% of the total community cell counts during the growth season, and sometimes as high as 60% of the total cell counts for the phytoplankton community. The long-term average cell density for nitrogen-fixing blue-green algae from 1995 through 2002 is about 3.9×10^4 cells/mL, and can reach as high as 1.8×10^5 cells/mL (data provided by D. Dobberfuhl, SJRWMD). This information suggests that nitrogen fixation could be a very important source of nitrogen in Lake Jesup.

Table 5.10. Annual DIN/DIP ratio of Lake Jesup, 1995–2002 (micro molar [µM]). DIN is the sum of NH4-N and NO3-N. DIP is primarily soluble reactive phosphorus (SRP).

Year	1995	1996	1997	1998	1999	2000	2001	2002
DIN	2.89	4.60	5.14	6.53	4.23	2.27	4.50	4.41
DIP	1.93	1.65	1.65	1.80	1.88	1.69	1.58	1.77
Ratio	1.5	2.8	3.1	3.6	2.3	1.3	2.8	2.5

The annual nitrogen fixation rates listed in **Table 5.11** for 1995 through 2002 were entered into the Bathtub model to make the model-simulated TN concentration match the measured TN concentration. The nitrogen fixation rates required to balance the model results ranged from 8.0 to 37.4 milligrams per square meter per day (mg/m^2/day). For the majority of the year simulated, the nitrogen fixation rates ranged from 9.2 to 13.4 mg/m^2/day. High fixation rates were used in 1999 and 2001.

Table 5.11. Annual nitrogen fixation rate used to match model-simulated TN concentrations to observed TN concentrations, 1995–2002 (mg/m^2/day)

Year	1995	1996	1997	1998	1999	2000	2001	2002
Fixation rate	9.5	13.4	12.4	12.0	23.5	13.2	39.0	9.2

In 2000, 2001, and 2002, a research team led by Dr. Hans Paerl conducted nitrogen fixation studies in Lake George (WBID 2893A), which is located on the St. Johns River downstream of Lake Jesup. Dr. Paerl provided the Department with some results of nitrogen fixation rates from the study. **Table 5.12** shows the nitrogen fixation rates and chl *a* concentration measured in Lake George in July and October 2002, and in March and August 2002.

Table 5.12. Nitrogen fixation rates and nutrient concentrations in Lake George, July and October 2000, and March and August 2002

	July 2000	October 2000	March 2002	August 2002
Nitrogen fixation rate (µg N/m^3/hr)*	18	78	63	23
Nitrate (µg/L)	12	7	5	80
NH_4 (µg/L)	below detection limit	below detection limit	19	36
PO_4 (µg/L)	6	6	10	45
Chl *a* (µg/L)	26	55	20	30

** µg N/m^3/hr - Micrograms of nitrogen per cubic meter per hour

Taking into account the dynamics of the volume, surface area **(Table 5.4),** and chl *a* concentration **(Table 5.2)** for Lake Jesup, the volumetric nitrogen fixation rate of Lake George can be translated into the nitrogen fixation rate for Lake Jesup, which ranged from 1.6 mg/m^2/day to 10.7 mg/m^2/day. This overlaps the range of nitrogen fixation rate required to balance model-simulated TN with measured TN in Lake Jesup **(Table 5.11).**

Based on Paerl et al.'s study in Lake George, phosphate was found to be the factor regulating the nitrogen fixation rate. In most of their nutrient amendment studies, adding phosphate into the phytoplankton community stimulated the nitrogen fixation rate (H. Paerl, personal communication). For Lake George, the phosphate concentration ranged between 6 and 45 µg PO_4/L (**Table 5.12**). For Lake Jesup, the phosphate concentration ranged between 157 and 251 µg PO_4/L, based on the data from IWR Run 19.1, which is almost an order of magnitude higher than the phosphate concentration for Lake George. The higher nitrogen fixation rate is therefore not unreasonable for Lake Jesup.

Higher nitrogen fixation rates were used in the modeling in 1999 and 2001. These are the two dry years in which regional rainfall was higher than rainfall in the Lake Jesup area, leading to significant increases in the inflow from the St. Johns River into Lake Jesup **(Table 5.7-a).** The dissolved organic carbon concentration for the St. Johns River is usually high, as the river has a large riparian wetland area. It has been found that nitrogen fixation can correlate positively with concentrations of dissolved organic carbon, because the growth of heterotrophic bacteria can be stimulated by increased organic carbon availability. Some of these heterotrophic bacteria can colonize nitrogen-fixing blue-green algae and form bacteria–algae aggregates. Because of the oxygen consumption activity from bacteria, the bacteria–algae aggregates usually have a distinct low redox microenvironment, which helps to enhance the activity of oxygen-sensitive nitrogenase and increases the nitrogen fixation rate (Horne et al., 1972; Paerl and Prufert, 1987). High nitrogen fixation rates in 1999 and 2001 could have resulted from the increase of dissolved organic carbon concentrations in the water.

Tables 5.13-a and **5.13-b** summarize the annual total nutrient loadings into Lake Jesup after the nitrogen fixation was taken into consideration, for 1995 through 2002.

Table 5.13-a. Annual TN loading from various sources into Lake Jesup, 1995–2002 (tons/year)

Source	1995	1996	1997	1998	1999	2000	2001	2002	Mean	Percent
Surface runoff	125.7	176.8	119.2	130.4	92.4	66.1	136.6	191.6	129.9	23.5%
Baseflow (background)	10.1	14.2	9.6	10.5	7.4	5.3	11.0	15.4	10.4	1.9%
Septic tanks	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	3.6%
Artesian input	3.5	3.4	3.4	3.5	3.4	3.4	3.4	3.4	3.4	0.6%
Atmospheric deposition	46.2	46.3	38.1	37.4	34.3	22	38	49.6	39	7.0%
St. Johns River inflow	16.3	15.6	90.5	27.4	186.2	120.7	295	47.6	99.9	18.0%
Nitrogen fixation	164.1	221.1	199.6	203.9	385.2	204.2	634.4	153.5	270.8	48.9%
Total	**385.6**	**497.1**	**480.1**	**432.8**	**728.6**	**441.4**	**1,138.1**	**327.3**	**553.9**	**100.0%**

Table 5.13 -b. Annual TP loading from various sources into Lake Jesup, 1995–2002 (tons/year)

Source	1995	1996	1997	1998	1999	2000	2001	2002	Mean	Percent
Surface runoff	13.1	19.4	12.6	14.2	9.6	7.4	14.7	20.7	14.0	48.6%
Baseflow (background)	3.2	4.5	3.1	3.3	2.4	1.7	3.5	4.9	3.3	11.5%
Septic tanks	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	9.4%
Artesian input	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	2.1%
Atmospheric deposition	3.7	3.7	3.0	3.0	2.7	1.7	3.0	3.9	3.1	10.8%
St. Johns River inflow	0.8	0.8	5.0	1.7	9.4	5.0	15.2	3.1	5.1	17.7%
Total	**24.1**	**31.7**	**27**	**25.5**	**27.4**	**19.1**	**39.7**	**35.9**	**28.8**	**100.0%**

Based on **Table 5.13-a**, TN loadings through nitrogen fixation in most years ranged from 153 to 270 tons/year, which account for anywhere between 42 and 53% of the total nitrogen loading into Lake Jesup. This appears to be consistent with the observation in Lake George, where up to 50% of the TN loading came from nitrogen fixation (J. Hendrickson, personal communication). High nitrogen fixation was observed for 1999 and 2001. This may be related to the organic carbon input from the St. Johns River, as discussed previously.

The nitrogen fixation rates that were required to make model-simulated annual TN concentrations match measured annual average TN concentrations were correlated with the chl *a* concentrations for 1995 through 2002. A tight correlation was found between the nitrogen fixation rate and chl *a* concentration **(Figure 5.7).** This observation is consistent with the hypothesis that the enhanced TN concentration in Lake Jesup is from biological activities.

An interesting prediction from **Figure 5.7** is that when the chl *a* concentration in Lake Jesup decreases to about 28 µg/L, the nitrogen fixation rate from phytoplankton communities becomes zero. The nitrogen fixation rate–chl *a* correlation equation was used in predicting the background TN concentration of Lake Jesup in the text below.

This analysis tested the Bathtub eutrophication response model suite to calibrate the chl *a* concentration. Bathtub provides two chl *a*–responding models based on the assumption of nitrogen and phosphorus co-limitation: Models 1 and 3. Model 1 assumes that algal communities are co-limited, not only by nitrogen and phosphorus, but also by light intensity. Model 3 assumes that the primary production of the lake is co-limited by nitrogen and phosphorus, but not by light intensity (Walker, 1999). In this analysis, neither model provided reasonable chl *a* predictions that matched with the measured values. Therefore, Bathtub's model suite was not used to predict chl *a* concentrations.

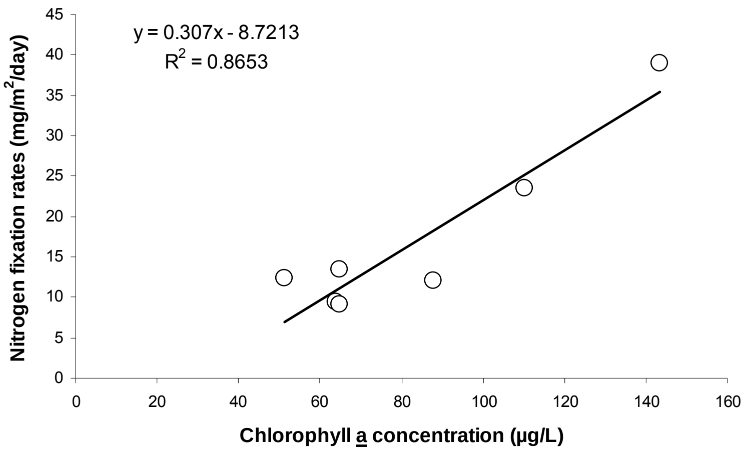


Figure 5.7. Correlation between nitrogen fixation rate and chl *a* concentration

A multivariate correlation analysis was conducted between the chl *a* concentration and the TN and TP concentration for Lake Jesup. Two factors, however, made the Department decide not to use the correlation equation to predict the chl *a* concentration under different nutrient scenarios. First, a significant portion of the TN concentration in Lake Jesup is not the cause of the chl *a* concentration. Instead, it comes from nitrogen fixation, which is the consequence of the chl *a* concentration. Second, TP concentrations remained stable and very high for the modeling period **(Table 5.2).** No TP concentrations below 0.100 mg/L were observed during this analysis. Using a multivariate equation developed based only on such a high and narrow range of TP concentrations may not give reliable chl *a* predictions when the TP concentration is decreased to a low level. Therefore, this analysis did not use the multivariate equation approach, either.

The Department eventually decided to use the chl *a*–TP empirical equation developed by Huber et al. (1982) for lakes co-limited by phosphorus and nitrogen. These authors defined the phosphorus and nitrogen co-limitation using a TN/TP ratio between 10 and 30 (weight ratio), which fits the TN/TP ratio for Lake Jesup. Huber et al.'s equation is:

$$\text{Ln chl } a = 1.29 * \text{LnTP} - 2.44$$

Where:

Ln is the natural log,
chl *a* is the chlorophyll *a* concentration, and
TP is the total phosphorus concentration of the lake.

This equation, however, also fails to accurately predict the chl *a* concentrations that were recently measured in Lake Jesup. In most cases, the equation underestimates the chl *a* concentration. A possible reason for the underestimation is that the phytoplankton community in Lake Jesup may have a different chl *a*-to-biomass ratio. Dobberfuhl (2003) observed a steady increase in the abundance of *Cylindrospermopsis raciborskii* in Lake Jesup since 1997, and the species makes up a significant portion of the blue-green algal cell counts. As discussed previously, it is also an important nitrogen fixation species. Phlips et al. (2004) found that under the same light and nutrient regimes, the chl *a* content of *C. raciborskii* was at least two times higher than that of *Anabeana* and *Microsystis*, suggesting that chl *a* concentration may not always be the best surrogate for algal biomass.

Whether this observation applies to some other algal species in Lake Jesup is unknown but certainly a possibility. The underestimation from Huber's equation is therefore not a surprise. The Department eventually decided to use this equation for chl *a* prediction because (1) the equation was derived based on 165 Florida lakes with TN/TP ratios similar to that of Lake Jesup and therefore should, to a certain extent, reflect the nutrient–chl *a* relationship of Lake Jesup; and (2) predicting the current chlorophyll concentration is not as important as predicting the chl *a* concentration when the overall water quality of the lake is improved. In fact, this analysis only used Huber's equation to predict the chl *a* concentration under improved TN and TP loadings. Under these nutrient loadings, the amount of blue-green algae should be significantly decreased and the interference from the high chl *a*–biomass ratio described above is expected to be minimal. Huber's equation should provide reasonably accurate chlorophyll predictions under the circumstances described**.**

To summarize the calibration findings, the total flow into Lake Jesup and TP concentration predicted by PBS&J and the Bathtub model reasonably match the measured values. The Bathtub-simulated TN concentrations were made to match the measured TN concentrations by adding into Bathtub the component of nitrogen fixation. Chl *a* concentrations were not calibrated in this analysis because of potential interference from the higher chl *a* content of some algal species. The chl *a* concentration under improved water quality conditions was predicted using Huber's equation.

Evaluating the natural background TSI of Lake Jesup. Once the model was calibrated, the background TN and TP loadings without the loadings generated from the existing level of human activities were estimated using the following procedures:

1. *All the man-made land use categories (agriculture/golf course; commercial; low-, medium-, and high density residential; industrial/utility; and transportation facilities) were evaluated as forest/rural open or wetlands, with a ratio of 1:2 between the forest/rural open to wetlands areas. This ratio was derived from late 1930s' aerial photographs of the area provided by Seminole and Orange*

Counties. The ratio between forest/rural open and wetlands areas for that period was assumed to represent, to some extent, the background ratio between forest/rural open and wetlands areas. In addition, the wetland TN and TP EMCs were changed from TN = 1.6 mg/L and TP = 0.09 mg/L (Harper, 1994) to TN = 1.25 mg/L and TP = 0.06 mg/L (Fulton et al., 2003). The TN and TP EMCs were changed to relatively low values because Harper's 1994 wetlands EMCs primarily represent the impacted wetlands area, while the unimpacted wetland EMCs should have low values (R. Fulton and J. Hendrickson, personal communication).

2. *The loading from septic tanks was removed, which decreases the TN and TP loading through baseflow.*

3. *Background TN and TP loadings from the watershed were then re-estimated with the PBS&J model, using the rainfall measurements in the period from 1995 through 2002.*

4. *TN and TP concentrations of the inflow from the St. Johns River were assumed to meet the EMCs of relatively unimpacted wetlands (TN = 1.25 mg/L and TP = 0.06 mg/L).*

5. *TN and TP loadings from all the other sources were kept the same as for the current condition.*

6. *Background TN and TP concentrations and chl* a *concentration were estimated using Bathtub and Huber's equation described above.*

7. *The in-lake TN concentration was adjusted by taking into account the residual nitrogen fixation using the regression curve developed between nitrogen fixation rate and chl* a *concentration* ***(Figure 5.7).***

8. *The background TSI was calculated based on Bathtub-predicted background TP concentration, nitrogen fixation–adjusted background TN concentration, and background chl* a *concentrations predicted based on the Bathtub TP and Huber's chl* a*–TP equation. Any further reduction of the TSI below the background TSI of the lake by additional reductions in the loadings was not considered.*

Table 5.14 lists annual concentrations of TN, TP, and chl *a* and TSI in Lake Jesup under background conditions for 1995 through 2002.

Table 5.14. Annual background TP, TN, and chl *a* concentrations and TSI for Lake Jesup, 1995–2002

Year	TP (mg/L)	TN (mg/L)	Chl *a* (µg/L)	TSI
1995	0.073	1.111	22.0	61
1996	0.074	1.12	22.4	61
1997	0.071	1.163	21.3	60
1998	0.072	1.105	21.7	60
1999	0.069	1.178	20.5	60
2000	0.076	1.287	23.2	61
2001	0.069	1.158	20.5	60
2002	0.072	1.11	21.7	60
Mean	**0.072**	1.154	**21.7**	**60**

As shown in **Table 5.14**, after all the human land use categories are "converted" to forest/rural open and wetlands area based on the 1:2 ratio, all the septic tank loadings are removed, and TN and TP concentrations of the St. Johns River inflow are decreased to the level of those found in unimpacted wetlands (TP = 0.06 mg/L and TN = 1.29 mg/L), the long-term annual average TN, TP, and chl *a* concentrations decreased from 3.02 mg/L, 0.15 mg/L, and 97.5 µg/L to 1.15 mg/L, 0.072 mg/L, and 21.7 µg/L, respectively. This represents a 62% decrease in TN, a 52% decrease in TP, and a 78% decrease in chl *a* concentrations over the existing condition **(Table 5.2).** The resultant calculated TSI value decreased from 78 to 60. Corresponding with these water quality indices, **Tables 5.15-a** and **5.15-b** list the annual TN and TP loadings into Lake Jesup under background conditions for 1995 through 2002.

Table 5.15-a. Annual TN background loading from various sources into Lake Jesup, 1995–2002 (tons/year)

Source	1995	1996	1997	1998	1999	2000	2001	2002	Mean	Percent
Surface runoff	121.9	160.8	113.3	120	89.5	60	127.3	176.1	121.1	49%
Baseflow (background)*	14.4	18.9	13.4	14.1	10.6	7.0	15.0	20.7	14.3	6%
Artesian input	3.5	3.4	3.4	3.5	3.4	3.4	3.4	3.4	3.4	1%
Atmospheric deposition	46.2	46.3	38.1	37.4	34.3	22	38	49.6	39.0	16%
St. Johns River inflow	17.9	15.6	85.1	25.1	136.6	79.6	149.2	41.3	68.8	28%
Total	**203.9**	**245**	**253.3**	**200.1**	**274.4**	**172**	**332.9**	**291.1**	**246.6**	**100%**

Table 5.15-b. Annual TP background loading from various sources into Lake Jesup, 1995–2002 (tons/year)

Source	1995	1996	1997	1998	1999	2000	2001	2002	Mean	Percent
Surface runoff	6	7.9	5.6	5.9	4.4	2.9	6.2	8.6	5.6	33%
Baseflow (background)*	4.6	6.0	4.3	4.5	3.4	2.3	4.8	6.6	4.6	25%
Artesian input	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	4%
Atmospheric deposition	3.7	3.7	3	3	2.7	1.7	3	3.9	3.0	18%
St. Johns River inflow	0.9	0.7	4.1	1.2	6.6	3.8	7.2	2	3.5	21%
Total	**15.8**	**18.9**	**17.6**	**15.2**	**17.7**	**11.3**	**21.8**	**21.7**	**16.9**	**100%**

* The background TN and TP loadings from the baseflow in **Tables 5.15-a** and **5.15-b** are higher than those in previous tables because of the increased baseflow volume when a significant portion of the watershed was converted to wetlands.

The model-simulated background TN and TP concentrations, which are 1.150 and 0.072 mg/L, respectively **(Table 5.14),** appear to be very similar to the target TN and TP concentrations evaluated using approaches described in Chapter 3, which are 1.20 and 0.073 mg/L for TN and TP, respectively. When the errors in the modeling processes are taken into account, these 2 sets of numbers should be considered not significantly different.

Estimating assimilative capacity. To estimate the TN and TP TMDLs for Lake Jesup, nutrient concentrations from all the human land use categories and septic tanks were decreased in a stepwise manner, until in-lake TN and TP concentrations resulted in a TSI of 65.5. For this analysis, EMCs for waters and wetlands were set at 1.25 mg/L TN and 0.060 mg/L TP, which is considered a more natural condition for relatively unimpacted wetlands. As TN and TP concentrations for the St. Johns inflow have been very close to the unimpacted wetlands' EMCs, for TMDL development purposes, TN and TP concentrations for the St. Johns River inflow were also set at 1.25 mg/L for TN and 0.060 mg/L for TP. It should be noted that the TN loading from nitrogen fixation will decrease along with the TP loading from the watershed because (1) the overall decrease of nutrient loading will decrease the overall biomass of the phytoplankton and also the biomass of nitrogen fixers, and (2) the decrease of TP loading into the system may make the system less nitrogen limited.

Table 5.16 lists the annual in-lake TP, chl *a*, and TN concentrations (adjusted with residual nitrogen fixation using the nitrogen fixation rate–chl *a* equation) that achieve the target TSI, for 1995 through 2002.

Table 5.16. Annual water quality conditions that achieve the target TSI, 1995–2002

Year	TP (mg/L)	TN Adjusted with Nitrogen Fixation (mg/L)	Chl *a* (µg/L)	Remaining Nitrogen Fixation Rate ($mg/m^2/day$)
1995	0.096	1.26	31.4	0.91
1996	0.099	1.25	32.7	1.30
1997	0.093	1.26	30.1	0.53
1998	0.095	1.23	31.0	0.78
1999	0.094	1.29	30.5	0.65
2000	0.094	1.41	30.5	0.65
2001	0.098	1.26	32.2	1.17
2002	0.095	1.19	31.0	0.78
Mean	**0.096**	**1.27**	**31.2**	**0.85**

Tables 5.17-a and **5.17-b** list the annual TN and TP loadings from all sources at the target TSI for 1995 through 2002. **Tables 5.18-a** and **5.18-b** list the annual TN and TP load reductions required to achieve the water quality target, the TMDLs for TN and TP, and the long-term average annual load reductions required to achieve the TMDL.

Table 5.17-a. Annual TN loading from various sources into Lake Jesup, 1995–2002 (tons/year)

Source	1995	1996	1997	1998	1999	2000	2001	2002	Mean	Percent
Surface runoff	96.8	135.6	91.7	100	71.1	50.7	104.9	147	99.7	40.3%
Baseflow (background)	10.1	14.2	9.6	10.5	7.4	5.3	11	15.4	10.4	4.2%
Septic tanks	13.8	13.8	13.8	13.8	7.5	5.3	13.8	13.8	12.0	4.8%
Artesian input	3.5	3.4	3.4	3.5	3.4	3.4	3.4	3.4	3.4	1.4%
Atmospheric deposition	46.2	46.3	38.1	37.4	34.3	22	38	49.6	39.0	15.8%
St. Johns River inflow	17.9	15.6	85.1	25.1	136.6	79.6	149.2	41.3	68.8	27.8%
Nitrogen fixation	15.7	21.5	8.5	13.3	10.7	10.1	19	13	14.0	5.7%
Watershed Total	120.7	163.6	115.1	124.3	86	61.3	129.7	176.2	122.1	49.4%
Total	**204**	**250.4**	**250.2**	**203.6**	**271**	**176.4**	**339.3**	**283.5**	**247.3**	**100.0%**

Table 5.17-b. Annual TP loading from various sources into Lake Jesup, 1995–2002 (tons/year)

Source	1995	1996	1997	1998	1999	2000	2001	2002	Mean	Percent
Surface runoff	6.6	9.5	6.3	7	6.5	3.6	10	10.2	7.5	39.3%
Baseflow (background)	3.2	4.5	3.1	3.3	2.4	1.7	3.5	4.9	3.3	17.5%
Septic tanks	1.1	1.1	1.7	1.1	0.8	0.7	2.1	1.1	1.2	6.4%
Artesian input	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	3.2%
Atmospheric deposition	3.7	3.7	3	3	2.7	1.7	3	3.9	3.1	16.3%
St. Johns River inflow	0.9	0.7	4.1	1.2	6.6	3.8	7.2	2	3.3	17.4%
Watershed total	10.9	15.1	11.1	11.4	9.7	6	15.6	16.2	12.0	63.2%
Total	**16.1**	**20.1**	**18.8**	**16.2**	**19.6**	**12.1**	**26.4**	**22.7**	**19.0**	**100.0%**

Table 5.18-a. Annual TN load reductions required to achieve the water quality target for Lake Jesup, 1995–2002

Year	Current Loading	Target Loading	Required Load Reduction	Percent Required Load Reduction
1995	385.6	204	181.6	47%
1996	497.1	250.4	246.7	50%
1997	480.1	250.2	229.9	48%
1998	432.8	203.6	229.2	53%
1999	728.6	271	457.6	63%
2000	441.4	176.4	265	60%
2001	1,138.1	339.3	798.8	70%
2002	327.3	283.5	43.8	13%
Mean	**553.9**	**247.3**	**306.6**	**50%**

Table 5.18-b. Annual TP load reductions required to achieve the water quality target for Lake Jesup, 1995–2002

Year	Current Loading	Target Loading	Required Load Reduction	Percent Required Load Reduction
1995	24.1	16.1	8.0	33%
1996	31.7	20.1	11.6	37%
1997	27	18.8	8.2	30%
1998	25.5	16.2	9.3	36%
1999	27.4	19.6	7.8	28%
2000	19.1	12.1	7.0	37%
2001	39.7	26.4	13.3	34%
2002	35.9	22.7	13.2	37%
Mean	**28.8**	**19.0**	**9.8**	**34%**

Assimilative capacity for unionized ammonia. As noted previously, this TMDL analysis also represents the effort to determine the TMDL for unionized ammonia, because the reductions needed to meet the nutrient criteria are also expected to address exceedances of the unionized ammonia criterion. In ambient water, unionized ammonia is in a chemical equilibrium with ammonia, and the equilibrium coefficient is primarily controlled by pH, water temperature, and sometimes ionic strength, especially water pH (Wetzel, 2001). Usually, a higher fraction of the ammonia is in the form of unionized ammonia under a high pH condition. For many eutrophic freshwater lakes, phytoplankton biomass and photosynthetic activities can significantly influence pH. The photosynthetic consumption of carbon dioxide (CO_2) and bicarbonate (HCO_3^-) creates hydroxide ions (OH^-) in the water and increases the pH of the water, which in turn raises the portion of unionized ammonia in the equilibrium.

Figure 5.8 shows the relationship between the unionized ammonia concentration and pH in Lake Jesup. Based on the graph, when the pH of Lake Jesup water decreases below 8.5, in most cases the unionized ammonia concentration should be lower than 0.02 mg/L. **Figure 5.9** shows the relationship between pH and the chl *a* concentration in Lake Jesup. As shown, when the chl *a* of the lake decreases to about 30 µg/L, the pH of the lake water can be expected to be lower than 9.0 standard units (SU), which, according to **Figure 5.8**, should create a pH environment that will result in unionized ammonia concentrations lower than 0.02 mg/L. Therefore, the established target TSI for this analysis not only addresses the nutrient impairment, but also addresses the impairment for unionized ammonia. Of course, the Department realized that water pH can be influence by factors other than algal photosynthetic activities. To make sure that unionized ammonia concentration will indeed decrease with the decrease of the overall phytoplankton biomass, the Department would encourage monitoring programs that track the change of pH and un-ionized ammonia concentration once the TMDL implementation starts.

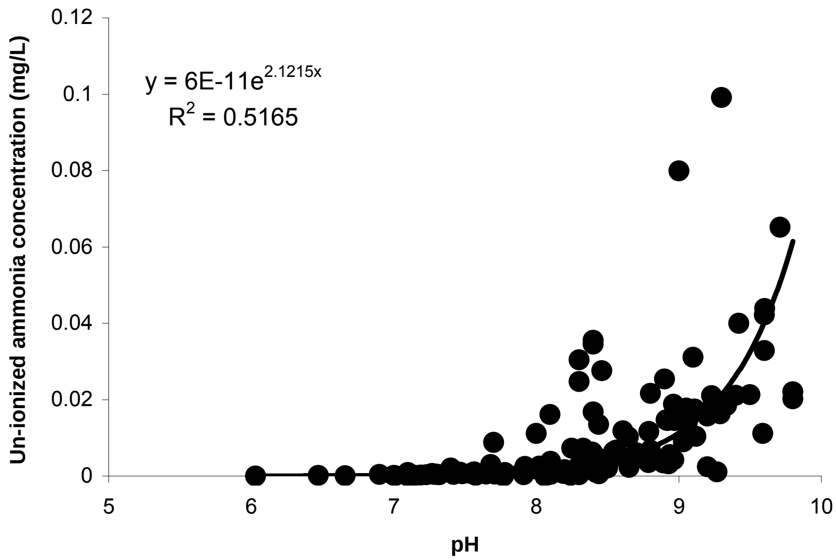


Figure 5.8. Relationship between unionized ammonia and pH for Lake Jesup

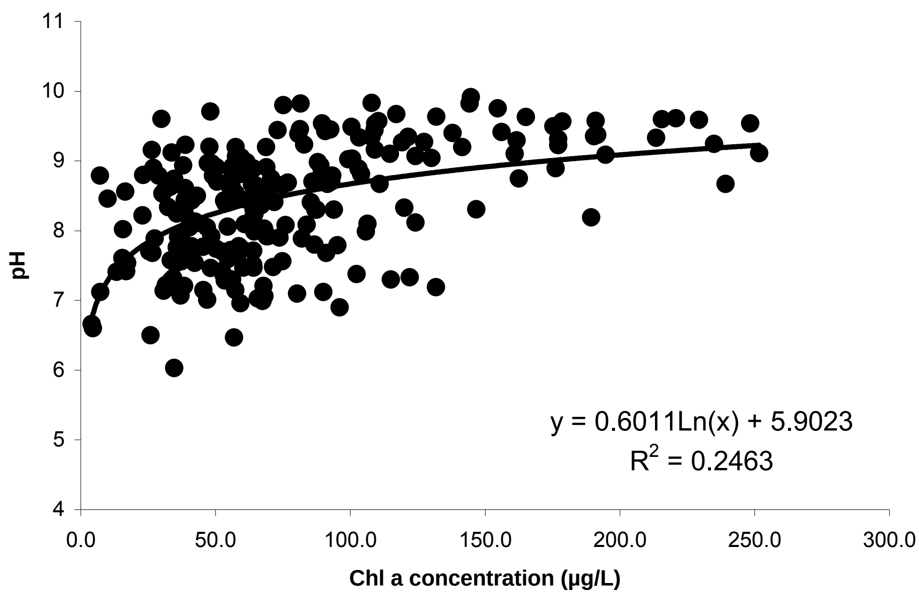


Figure 5.9. Relationship between pH and chl *a* concentration for Lake Jesup

Chapter 6: DETERMINATION OF THE TMDL

6.1 Expression and Allocation of the TMDL

The objective of a TMDL is to provide a basis for allocating acceptable loads among all of the known pollutant sources in a watershed so that appropriate control measures can be implemented and water quality standards achieved. A TMDL is expressed as the sum of all point source loads (wasteload allocations, or WLAs), nonpoint source loads (load allocations, or LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

As discussed earlier, the WLA is broken out into separate subcategories for wastewater discharges and stormwater discharges regulated under the NPDES Program:

$$TMDL \cong \sum WLAs_{wastewater} + \sum WLAs_{NPDES\ Stormwater} + \sum LAs + MOS$$

It should be noted that the various components of the revised TMDL equation may not sum up to the value of the TMDL because (1) the WLA for NPDES stormwater is typically based on the percent reduction needed for nonpoint sources and is also accounted for within the LA, and (2) TMDL components can be expressed in different terms (for example, the WLA for stormwater is typically expressed as a percent reduction, and the WLA for wastewater is typically expressed as mass per day).

WLAs for stormwater discharges are typically expressed as percent reduction because it is very difficult to quantify the loads from MS4s (given the numerous discharge points) and to distinguish the loads from MS4s from other nonpoint sources (given the nature of stormwater transport). The permitting of stormwater discharges also differs from the permitting of most wastewater point sources. Because stormwater discharges cannot be centrally collected, monitored, and treated, they are not subject to the same types of effluent limitations as wastewater facilities, and instead are required to meet a performance standard of providing treatment to the “maximum extent practical” through the implementation of BMPs.

This approach is consistent with federal regulations (40 CFR § 130.2[I]), which state that TMDLs can be expressed in terms of mass per time (e.g., pounds per day), toxicity, or **other appropriate measure**. TMDLs for Lake Jesup are expressed in terms of pounds per year (lbs/year) and percent reduction of TN and TP, and represent the maximum long-term annual average TN and TP loadings Lake Jesup can assimilate and maintain a balanced aquatic flora and fauna **(Table 6.1).**

Table 6.1. TMDL components for Lake Jesup

WBID	Parameter	TMDL (kg/year)*	$WLA_{NPDES\ Stormwater}$	LA	MOS
2981 (including 2981A)	TN	247,300	50%	50%	Implicit
2981 (including 2981A)	TP	19,000	34%	34%	Implicit

* = Kilograms per year

6.2 Load Allocation

Because there are no wastewater point sources that discharge directly into any surface water in the watershed, the TMDLs for TN and TP were assigned to the LA (and, as discussed below, to the MS4 as well). The long-term annual average LAs for TN and TP into Lake Jesup are 247,300 and 19,000 kg/year, respectively. Nonpoint sources (including the loadings from MS4s) are responsible for all these loads. The current long-term annual average TN and TP loads are 553,900 kg/year for TN and 28,800 kg/year for TP; these figures include the loadings from surface runoff, baseflow from the surficial aquifer, septic tanks, artesian input, atmospheric deposition directly onto the surface of the lake, and the inflow from the St. Johns River. A significant portion of the TN load also comes from nitrogen fixation.

To achieve the LA, current TN and TP loadings require a 50% and 34% reduction, respectively. The load reduction needs to apply to surface runoff, septic tanks, St. Johns River input for both TN and TP, and nitrogen fixation for TN. It should be noted that the load reduction for nitrogen fixation is associated with the watershed load reduction. As long as nutrient loadings from all human nonpoint sources are reduced, the TN loading from nitrogen fixation should decrease as well.

6.3 Wasteload Allocation

Because no wastewater facilities discharge to surface waters in the watershed, the only WLA considered in this analysis is the stormwater load from MS4 areas.

6.3.1 National Pollutant Discharge Elimination System Wastewater Discharges

No NPDES-permitted wastewater discharges were identified in the Lake Jesup watershed.

6.3.2 National Pollutant Discharge Elimination System Stormwater Discharges

Because no information was available to the Department at the time this analysis was conducted regarding the boundaries and locations of all the NPDES stormwater dischargers, the exact stormwater TN and TP loadings from MS4 areas were not explicitly estimated. Within the Lake Jesup watershed, the stormwater collection systems owned and operated by Seminole and Orange Counties; a number of municipalities, including Altamonte Springs, Casselberry, Eatonville, Lake Mary, Longwood, Maitland, Orlando, Oviedo, Sanford, Winter Garden, and

Winter Springs; and the Florida Department of Transportation are covered by an MS4 Phase I permit. No Phase II permittees were identified in the watershed. The $WLA_{NPDESStormwater}$ was set as the same percent reduction required to achieve the TMDL as for the other conventional nonpoint sources, which are 50% for TN and 34% for TP.

6.4 Margin of Safety

Consistent with the recommendations of the Allocation Technical Advisory Committee (Department, February 2001), an implicit MOS was used in the development of this TMDL. An implicit MOS was provided by the conservative decisions associated with a number of modeling assumptions, the development of site-specific alternative water quality targets, and the development of assimilative capacity.

In this analysis, the MOS was primarily associated with the watershed pollutant loading estimation. The current TN and TP loadings were estimated as the loadings after existing BMP treatments. Since most of the published pollutant loading removal efficiencies target the decrease of pollutant concentration after BMP treatment, and very limited information was available regarding the water removal efficiency for stormwater BMPs, this analysis assumed that there was no water removal for most of the BMP facilities, except for drainage wells. This approach has the potential to overstate the current nutrient load estimation and therefore add to the MOS. In addition, this analysis considered only the pollutant load reduction from structural BMPs. The modeling process did not include loading reductions from other, nonstructural BMPs such as street sweeping. This could also lead to an overestimate of the current nutrient loadings into the lake and therefore adds to the MOS.

In estimating nutrient loadings from septic tanks, it was assumed that all the septic tanks located within 200 meters of any receiving water that discharges to Lake Jesup contribute TN and TP to the lake to some extent, instead of just attributing the loading to failed septic tanks. This also has the potential to result in an overestimate of the current nutrient loadings into the lake and therefore adds to the MOS.

6.5 Recommendations for Further Studies

Because of the short period available for this analysis and also the lack of data regarding some functions of the lake system, the Department acknowledges the uncertainties associated with this TMDL. Further studies, described below, are recommended to address these issues to refine the TMDL goals developed in this analysis.

6.5.1 How Sediment Dredging Will Influence Nutrient Loading into Lake Jesup

Sediment dredging has been carried out as part of the Lake Jesup Restoration Program. The decision that dredging is important for the functions of the Lake Jesup ecosystem was based, in part, on the sediment study conducted by Cable et al. (1997). The study indicated that there are approximately 102 million cubic yards of soft sediment in Lake Jesup. Data from the study also showed that the soft sediment was characterized by high organic and nutrient content throughout the sediment volume. During the 2001–02 state legislative session, the Florida legislature provided $2.9 million for the first 2 years of the 5-year Lake Jesup Enhancement Project. This project involves the hydraulic dredging of flocculent sediments from the lake bottom, removing organic sediments from 200 acres of former marsh, carrying out nuisance vegetation control, and revegetating with desirable native aquatic plant species.

An important issue for the dredging program specifically related to TMDL development is that if the dredging spoil is disposed of in the Lake Jesup watershed, it will create an extra source of nutrients to the lake. Currently, funding for the dredging has expired, because the Department has not granted the permit for the program. It is not expected that the dredging will be finished before the final load allocation is completed as part of the BMAP for the TMDL. As such, the potential spoil disposal site may not have a load allocation by the time the dredging of the lake is finished.

One possible solution is to give a nutrient reduction “credit” to the dredging activity, because sediment removal may decrease the nutrient loading from the sediment to the lake water column. The problem with this approach is that it will be difficult to quantify the credit that should be assigned to the dredging. As discussed previously, nutrient release from the sediment does not appear to be an important part of the nutrient budget for Lake Jesup. However, no direct information on the actual nutrient release rates was available to the Department when this analysis was conducted. Direct measurements of sediment nutrient release and the environmental factors that control sediment nutrient release could be very important for refining the TMDL, and will also help to quantify the possible credit assigned to sediment dredging.

Sediment dredging, especially sediment dredging in the former marsh area, could also help to restore the littoral zone SAV, which will restore the habitats for fish and may also help prevent nutrients from entering the lake. Studies on the extent to which littoral zone aquatic plants can develop and their capability to hold nutrients from the watershed will also help to quantify the possible credit assigned to sediment dredging.

6.5.2 Nitrogen Fixation

Another issue worth further study is nitrogen fixation by blue-green algae. Based on this TMDL, nitrogen fixation could account for about 45% of the total TN budget for Lake Jesup. However, the nitrogen fixation rates used in this analysis were determined using the mass balance approach of the modeling process, instead of directly measured rates. The nitrogen fixation rates used in this analysis fall into the range of published values in the literature and overlap with the areal fixation rates calculated based on the volumetric fixation rates observed in Lake George, which is located relatively close to Lake Jesup. The DIN/DIP molar ratio of Lake Jesup is also consistently lower than the Redfield ratio of 16, which implies strong nitrogen limitation. The phosphate concentration, which was identified as the major driving factor for nitrogen fixation in Lake George, was almost an order of magnitude higher in Lake Jesup than in Lake George. In addition, a significant portion of the phytoplankton communities of Lake Jesup was composed of nitrogen fixers, and most of the nitrogen fixation taxa were identified in Lake Jesup.

All these observations are consistent with the assumption that nitrogen fixation is important in the nitrogen budget of Lake Jesup. However, no directly measured nitrogen fixation rate data were available to the Department when this analysis was carried out. The Department believes that, to address the nitrogen fixation in Lake Jesup more thoroughly, more studies need to be conducted, including analyses of the diurnal pattern, seasonal pattern, spatial pattern (including vertical and horizontal directions), and major factors that control the intensity of nitrogen fixation and the biomass of nitrogen fixers in Lake Jesup. The results of these studies will not only help to quantify nitrogen fixation more accurately, but will also help to evaluate the importance of residual nitrogen fixation when TN and TP loadings from the watershed are decreased.

Chapter 7: NEXT STEPS: IMPLEMENTATION PLAN DEVELOPMENT AND BEYOND

7.1 Basin Management Action Plan

Following the adoption of this TMDL by rule, the next step in the TMDL process is to develop an implementation plan for the TMDL, referred to as the BMAP. This document will be developed over the next two years in cooperation with local stakeholders, who will attempt to reach consensus on detailed allocations and on how load reductions will be accomplished. The BMAP will include, among other things:

- Appropriate load reduction allocations among the affected parties,
- A description of the load reduction activities to be undertaken, including structural projects, nonstructural BMPs, and public education and outreach,
- A description of further research, data collection, or source identification needed in order to achieve the TMDL,
- Timetables for implementation,
- Confirmed and potential funding mechanisms,
- Any applicable signed agreement(s),
- Local ordinances defining actions to be taken or prohibited,
- Any applicable local water quality standards, permits, or load limitation agreements,
- Milestones for implementation and water quality improvement, and
- Implementation tracking, water quality monitoring, and follow-up measures.

An assessment of progress toward the BMAP milestones will be conducted every five years, and revisions to the plan will be made as appropriate, in cooperation with basin stakeholders.

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Appendices

Appendix A: Background Information on Federal and State Stormwater Programs

In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of nonpoint source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as authorized in Chapter 403, F.S., was established as a technology-based program that relies on the implementation of BMPs that are designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Chapter 62-40, F.A.C. In 1994, the Department's stormwater treatment requirements were integrated with the stormwater flood control requirements of the state's water management districts, along with wetland protection requirements, into the Environmental Resource Permit regulations.

Chapter 62-40, F.A.C., also requires the water management districts to establish stormwater pollutant load reduction goals (PLRGs) and adopt them as part of a SWIM plan, other watershed plan, or rule. Stormwater PLRGs are a major component of the load allocation part of a TMDL. To date, stormwater PLRGs have been established for Tampa Bay, Lake Thonotosassa, the Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka. No PLRG had been developed for Newnans Lake when this report was published.

In 1987, the U.S. Congress established Section 402(p) as part of the federal Clean Water Act Reauthorization. This section of the law amended the scope of the federal NPDES permitting program to designate certain stormwater discharges as "point sources" of pollution. The EPA promulgated regulations and began implementing the Phase I NPDES stormwater program in 1990. These stormwater discharges include certain discharges that are associated with industrial activities designated by specific standard industrial classification (SIC) codes, construction sites disturbing 5 or more acres of land, and master drainage systems of local governments with a population above 100,000, which are better known as municipal separate storm sewer systems (MS4s). However, because the master drainage systems of most local governments in Florida are interconnected, the EPA implemented Phase I of the MS4 permitting program on a countywide basis, which brought in all cities (incorporated areas), Chapter 298 urban water control districts, and the Florida Department of Transportation throughout the 15 counties meeting the population criteria. The Department received authorization to implement the NPDES stormwater program in 2000.

An important difference between the federal NPDES and the state's stormwater/environmental resource permitting programs is that the NPDES Program covers both new and existing discharges, while the state's program focuses on new discharges only. Additionally, Phase II of the NPDES Program, implemented in 2003, expands the need for these permits to construction sites between 1 and 5 acres, and to local governments with as few as 1,000 people. While these urban stormwater discharges are now technically referred to as "point sources" for the purpose of regulation, they are still diffuse sources of pollution that cannot be easily collected and treated by a central treatment facility, as are other point sources of pollution such as domestic and industrial wastewater discharges. It should be noted that all MS4 permits issued in

Florida include a re-opener clause that allows permit revisions to implement TMDLs when the implementation plan is formally adopted.

Appendix B: Vertical Distribution of DO Concentrations in Lake Jesup (mg/L), 1995–1996. Data provided by the SJRWMD.

Station	Date	Depth	DO	Temperature
OW-01	02/15/95	0.5	9.40	18.47
		1	9.45	18.38
		1.5	9.30	18.40
		2	9.25	18.26
		2.5	9.23	18.25
	02/15/95 Mean		9.33	18.35
	03/15/95	0.5	9.26	20.11
		1	9.12	19.94
		1.5	8.98	19.98
		2	8.89	19.81
	03/15/95 Mean		9.06	19.96
	04/12/95	0.5	7.79	24.67
		1	7.73	24.56
		1.5	7.50	24.50
		2	7.44	24.47
	04/12/95 Mean		7.62	24.55
	05/17/95	0.5	8.91	30.73
		1	7.58	30.06
		1.5	7.40	29.91
		2	7.42	29.91
	05/17/95 Mean		7.83	30.15
	06/14/95	0.5	6.46	29.42
		1	6.16	29.41
		1.5	6.11	29.41
	06/14/95 Mean		6.24	29.41
	07/18/96	0.5	8.52	30.39
		1	7.05	29.96
		1.5	5.92	29.75
		2	5.73	29.72
	07/18/96 Mean		6.81	29.96
	08/15/96	0.5	5.45	29.51
		1	3.85	28.52
	08/15/96 Mean		4.65	29.02
	09/18/96	0.5	5.45	28.72
		1	5.44	28.71
		1.5	5.44	28.71

Station	Date	Depth	DO	Temperature
		2	5.44	28.72
	09/18/96 Mean		5.44	28.72
	10/16/96	0.5	6.47	23.94
		1	6.48	23.82
		1.5	6.42	23.79
		2	6.35	23.76
		2.5	6.29	23.74
		3	6.22	23.73
		3.5	6.18	23.74
	10/16/96 Mean		6.34	23.79
	11/13/96	0.5	9.18	17.10
		1	9.19	17.14
		1.5	9.20	16.89
		2	9.20	16.74
		2.5	9.08	16.69
	11/13/96 Mean		9.17	16.91
	12/11/96	0.5	14.04	16.43
		1	14.05	16.01
		1.5	13.88	15.91
		2	12.97	15.60
	12/11/96 Mean		13.74	15.99
OW-01 Total			**7.98**	**23.62**
OW-02	02/15/95	0.5	10.51	18.29
		1	10.49	18.26
		1.5	10.44	18.23
	02/15/95 Mean		10.48	18.26
	03/15/95	0.5	9.81	19.96
		1	9.43	19.74
		1.5	9.38	19.78
	03/15/95 Mean		9.54	19.83
	04/12/95	0.5	8.18	24.78
		1	7.94	24.76
	04/12/95 Mean		8.06	24.77
	05/17/95	0.5	11.98	31.06
		1	7.30	30.86
	05/17/95 Mean		9.64	30.96
	06/14/95	0.5	10.90	27.79
		1	10.39	27.59
	06/14/95 Mean		10.65	27.69
	07/18/96	0.5	10.00	30.69
		1	7.28	29.52

Station	Date	Depth	DO	Temperature
		1.5	2.32	29.49
	07/18/96 Mean		6.53	29.90
	08/15/96	0.5	10.93	29.47
		1	9.66	28.76
	08/15/96 Mean		10.30	29.12
	09/18/96	0.5	7.74	28.76
		1	7.72	28.76
		1.5	6.47	28.76
	09/18/96 Mean		7.31	28.76
	10/16/96	0.5	9.37	24.09
		1	9.37	24.07
		1.5	9.37	24.05
	10/16/96 Mean		9.37	24.07
	11/13/96	0.5	10.55	16.85
		1	10.57	16.84
		1.5	6.34	17.03
	11/13/96 Mean		9.15	16.91
	12/11/96	0.5	14.48	17.10
		1	12.52	16.16
	12/11/96 Mean		13.50	16.63
OW-02 Total			**9.34**	**23.98**
OW-03	03/15/95	0.5	10.40	19.48
		1	9.05	18.76
		1.5	8.20	18.69
	03/15/95 Mean		9.22	18.98
	04/12/95	0.5	9.03	24.55
		1	9.01	24.56
	04/12/95 Mean		9.02	24.56
	05/17/95	0.5	8.20	30.43
		1	2.05	30.31
		1.5	1.48	30.26
	05/17/95 Mean		3.91	30.33
	02/15/96	0.5	9.26	17.61
		1	9.26	17.55
		1.5	8.75	17.44
	02/15/96 Mean		9.09	17.53
	06/14/95	0.5	12.19	28.20
		1	11.43	27.60
	06/14/95 Mean		11.81	27.90
	07/18/96	0.5	7.83	29.65
		1	6.76	29.24

Station	Date	Depth	DO	Temperature
		1.5	1.55	29.21
	07/18/96 Mean		5.38	29.37
	08/15/96	0.5	8.69	28.32
		1	8.13	28.01
	08/15/96 Mean		8.41	28.17
	09/18/96	0.5	6.07	28.75
		1	6.06	28.75
		1.5	5.99	28.75
	09/18/96 Mean		6.04	28.75
	10/16/96	0.5	7.20	24.22
		1	7.20	24.22
		1.5	7.18	24.21
	10/16/96 Mean		7.19	24.22
	11/13/96	0.5	9.68	16.55
		1	9.67	16.55
		1.5	9.60	16.58
	11/13/96 Mean		9.65	16.56
	12/11/96	0.5	13.34	16.30
		1	10.70	15.09
	12/11/96 Mean		12.02	15.70
OW-03 Total			**8.07**	**23.79**
OW-04	03/15/95	0.5	8.65	19.10
		1	8.34	18.81
		1.5	8.01	18.75
		2	7.10	18.71
	03/15/95 Mean		8.03	18.84
	04/12/95	0.5	8.15	24.74
		1	8.12	24.75
		1.5	7.33	24.44
		2	7.07	24.37
	04/12/95 Mean		7.67	24.58
	05/17/95	0.5	7.07	29.92
		1	5.71	29.49
		1.5	3.94	29.39
		2	0.31	29.33
	05/17/95 Mean		4.26	29.53
	02/15/96	0.5	10.12	16.81
		1	9.71	16.71
		1.5	7.24	16.23
	02/15/96 Mean		9.02	16.58
	06/14/95	0.5	5.74	27.85

Station	Date	Depth	DO	Temperature
		1	3.96	27.58
		1.5	3.58	27.40
		2	2.15	27.42
	06/14/95 Mean		3.86	27.56
	07/18/96	0.5	8.26	30.68
		1	8.69	30.03
		1.5	6.78	29.56
		2	3.74	29.51
	07/18/96 Mean		6.87	29.95
	08/15/96	0.5	9.50	28.46
		1	8.19	28.08
		1.5	6.50	28.08
	08/15/96 Mean		8.06	28.21
	09/18/96	0.5	7.75	29.08
		1	6.83	29.09
		1.5	6.70	29.09
		2	6.65	29.07
	09/18/96 Mean		6.98	29.08
	10/16/96	0.5	8.32	24.04
		1	8.21	24.02
		1.5	8.05	24.00
		2	7.89	24.00
		2.5	4.12	24.05
	10/16/96 Mean		7.32	24.02
	11/13/96	0.5	9.85	16.87
		1	9.85	16.87
		1.5	9.85	16.85
		2	6.88	17.24
	11/13/96 Mean		9.11	16.96
	12/11/96	0.5	12.43	15.47
		1	12.42	15.17
		1.5	11.64	15.13
		2	9.09	15.28
	12/11/96 Mean		11.40	15.26
OW-04 Total			**7.45**	**23.76**
OW-05	02/15/95	0.5	10.09	17.05
		1	9.90	16.96
		1.5	9.55	16.80
		2	8.78	16.41
		2.5	8.36	16.26
		3	7.76	16.12

Station	Date	Depth	DO	Temperature
		3.5	6.09	15.65
	02/15/95 Mean		8.65	16.46
	03/15/95	0.5	8.42	19.28
		1	7.89	19.00
		1.5	7.86	18.92
		2	7.93	18.85
		2.5	7.94	18.82
		3	7.69	18.80
		3.5	7.51	18.80
	03/15/95 Mean		7.89	18.92
	04/12/95	0.5	7.30	24.69
		1	7.17	24.64
		1.5	7.13	24.59
		2	7.02	24.55
		2.5	5.85	24.33
		3	5.71	24.27
	04/12/95 Mean		6.70	24.51
	05/17/95	0.5	8.11	30.54
		1	8.04	30.33
		1.5	7.00	30.27
		2	7.70	30.21
		2.5	7.60	30.14
		3	7.37	30.07
	05/17/95 Mean		7.64	30.26
	06/14/95	0.5	7.75	27.78
		1	6.79	27.58
		1.5	5.49	27.32
		2	4.22	27.30
		2.5	1.72	27.30
	06/14/95 Mean		5.19	27.46
	07/18/96	0.5	8.25	30.47
		1	5.88	30.04
		1.5	4.55	29.97
		2	4.03	29.97
		2.5	5.10	29.92
		3	5.13	29.90
		3.5	4.86	29.90
	07/18/96 Mean		5.40	30.02
	08/15/96	0.5	7.87	29.25
		1	7.17	29.12
		1.5	7.27	29.00

Station	Date	Depth	DO	Temperature
		2	7.39	28.88
		2.5	4.68	28.80
	08/15/96 Mean		6.88	29.01
	09/18/96	0.5	7.57	29.04
		1	7.53	29.04
		1.5	7.04	29.01
		2	6.31	28.93
		2.5	5.76	28.90
		3	5.64	28.86
		3.5	5.51	28.85
		4	2.64	28.83
	09/18/96 Mean		6.00	28.93
	10/16/96	0.5	7.64	23.93
		1	7.67	23.93
		1.5	7.66	23.91
		2	7.58	23.90
		2.5	7.48	23.88
		3	7.31	23.87
		3.5	7.23	23.87
		4	5.62	23.88
	10/16/96 Mean		7.27	23.90
	11/13/96	0.5	9.12	17.35
		1	9.06	17.35
		1.5	9.04	17.36
		2	9.01	17.35
		2.5	8.98	17.34
		3	8.96	17.31
		3.5	7.68	17.37
		4	4.00	17.88
	11/13/96 Mean		8.23	17.41
	12/11/96	0.5	12.70	15.71
		1	12.67	15.33
		1.5	10.97	15.05
		2	8.19	14.83
		2.5	7.26	14.71
		3	6.99	14.65
		3.5	4.37	14.90
	12/11/96 Mean		9.02	15.03
OW-05 Total			**7.23**	**23.46**
OW-06	02/15/95	0.5	9.99	17.48
		1	9.57	17.43

Station	Date	Depth	DO	Temperature
		1.5	8.76	16.92
	02/15/95 Mean		9.44	17.28
	03/15/95	0.5	8.46	19.17
		1	8.11	18.96
		1.5	7.52	18.95
	03/15/95 Mean		8.03	19.03
	04/12/95	0.5	7.63	24.65
		1	7.62	24.66
		1.5	7.50	24.65
	04/12/95 Mean		7.58	24.65
	05/17/95	0.5	8.76	29.76
		1	8.71	29.76
		1.5	8.07	29.75
	05/17/95 Mean		8.51	29.76
	06/14/95	0.5	9.46	27.74
		1	9.33	27.74
		1.5	8.19	27.74
	06/14/95 Mean		8.99	27.74
	08/15/96	0.5	7.38	28.65
		1	6.85	28.55
		1.5	5.90	28.55
	08/15/96 Mean		6.71	28.58
	09/18/96	0.5	7.26	29.10
		1	7.24	29.10
		1.5	7.20	29.10
		2	4.32	29.10
	09/18/96 Mean		6.51	29.10
	10/16/96	0.5	7.89	24.40
		1	7.88	24.40
		1.5	7.86	24.40
		2	7.83	24.40
	10/16/96 Mean		7.87	24.40
	11/13/96	0.5	9.39	17.23
		1	9.39	17.22
		1.5	9.38	17.20
	11/13/96 Mean		9.39	17.22
	12/11/96	0.5	11.62	15.75
		1	11.66	15.62
		1.5	10.64	15.63
		2	5.83	16.23
	12/11/96 Mean		9.94	15.81

Station	Date	Depth	DO	Temperature
OW-06 Total			**8.28**	**23.33**
OW-07	02/15/95	0.5	8.33	17.50
		1	8.23	17.49
		1.5	7.91	17.42
	02/15/95 Mean		8.16	17.47
	03/15/95	0.5	8.96	19.32
		1	8.54	18.71
		1.5	7.73	18.69
	03/15/95 Mean		8.41	18.91
	04/12/95	0.5	7.94	24.34
		1	7.90	24.34
	04/12/95 Mean		7.92	24.34
	05/17/95	0.5	3.79	28.62
		1	3.56	28.60
	05/17/95 Mean		3.68	28.61
	06/14/95	0.5	10.05	27.20
		1	9.50	27.20
	06/14/95 Mean		9.78	27.20
	07/18/96	0.5	7.18	29.54
		1	5.79	29.17
	07/18/96 Mean		6.49	29.36
	08/15/96	0.5	10.05	28.90
		1	8.71	28.65
	08/15/96 Mean		9.38	28.78
	09/18/96	0.5	7.08	28.82
		1	6.98	28.82
		1.5	6.93	28.82
	09/18/96 Mean		7.00	28.82
	10/16/96	0.5	8.37	23.99
		1	8.34	23.99
		1.5	7.06	23.99
	10/16/96 Mean		7.92	23.99
	11/13/96	0.5	8.83	16.63
		1	8.83	16.63
		1.5	8.82	16.62
	11/13/96 Mean		8.83	16.63
	12/11/96	0.5	12.78	15.20
		1	12.88	14.81
		1.5	10.01	14.90
	12/11/96 Mean		11.89	14.97
OW-07 Total			**8.25**	**22.82**

Station	Date	Depth	DO	Temperature
OW-06	07/18/96	0.5	9.23	30.22
		1	8.92	30.13
		1.5	6.99	29.90
	07/18/96 Mean		8.38	30.08
OW-06 Total			**8.38**	**30.08**
OWSJR-1	07/18/96	0.5	5.49	29.72
		1	5.44	29.72
		1.5	5.50	29.72
		2	5.40	29.72
	07/18/96 Mean		5.46	29.72
	08/15/96	0.5	5.27	28.86
		1	5.23	28.76
		1.5	5.21	28.73
	08/15/96 Mean		5.24	28.78
	09/18/96	0.5	6.26	28.70
		1	6.19	28.70
		1.5	6.11	28.70
		2	6.09	28.70
		2.5	6.07	28.70
	09/18/96 Mean		6.14	28.70
OWSJR-1 Total			**5.69**	**29.06**
OWSJR-2	07/18/96	0.5	5.54	29.68
		1	5.39	29.68
		1.5	5.37	29.68
		2	5.11	29.66
		2.5	4.87	29.57
		3	4.78	29.56
		3.5	#DIV/0!	29.58
		4	4.76	29.58
	07/18/96 Mean		5.12	29.62
	08/15/96	0.5	5.38	29.13
		1	5.34	29.07
		1.5	5.28	29.05
		2	5.26	29.05
		2.5	5.27	29.04
		3	5.26	29.06
		3.5	5.22	29.07
		4	5.08	29.01
		4.5	5.08	28.98
	08/15/96 Mean		5.24	29.05
	09/18/96	0.5	6.71	28.15

Station	Date	Depth	DO	Temperature
		1	5.81	28.15
		1.5	5.60	28.14
		2	5.49	28.12
		2.5	5.40	28.12
		3	5.32	28.12
		3.5	5.22	28.12
		4	5.17	28.12
	09/18/96 Mean		5.59	28.13
OWSJR-2 Total			**5.32**	**28.94**
OW-SJR-1	10/16/96	0.5	6.34	23.56
		1	6.32	23.56
		1.5	6.31	23.56
		2	6.30	23.57
		2.5	6.29	23.57
		3	6.28	23.57
	10/16/96 Mean		6.31	23.57
	11/13/96	0.5	7.82	17.71
		1	7.82	17.71
		1.5	7.81	17.71
		2	7.81	17.71
	11/13/96 Mean		7.82	17.71
	12/11/96	0.5	9.08	15.68
		1	9.01	15.48
		1.5	8.97	15.48
		2	8.95	15.48
	12/11/96 Mean		9.00	15.53
OW-SJR-1 Total			**7.51**	**19.60**
OW-SJR-2	10/16/96	0.5	4.77	23.31
		1	4.77	23.33
		1.5	5.02	23.35
		2	5.25	23.32
		2.5	5.16	23.35
		3	5.32	23.39
		3.5	5.58	23.39
		4	5.76	23.39
		4.5	5.85	23.39
		5	5.90	23.39
		5.5	5.90	23.39
	10/16/96 Mean		5.39	23.36
	11/13/96	0.5	8.13	17.72
		1	8.11	17.72

Station	Date	Depth	DO	Temperature
		1.5	8.09	17.70
		2	8.07	17.72
		2.5	8.05	17.74
		3	8.01	17.77
		3.5	7.98	17.79
		4	7.96	17.80
	11/13/96 Mean		8.05	17.75
	12/11/96	0.5	9.42	15.24
		1	9.30	15.27
		1.5	9.17	15.33
		2	9.07	15.33
		2.5	9.00	15.32
	12/11/96 Mean		9.19	15.30

Appendix C: Comments from the public and responses from the Florida Department of Environmental Protection (DEP) on the nutrient and un-ionized ammonia TMDLs for Lake Jesup

Comments from Seminole County via PBS&J:

The comments concern three areas: Water Budget including groundwater and St Johns River inflows; nutrient balance including wetland EMC and pristine wetlands assessment; and the sediment load to Lake Jesup supported by recent sampling events and Harvey Harper's Sediment Loading Report.

WATER BUDGET

In revisiting the inflow to Lake Jesup, specifically the derivation of the groundwater contribution as compared to other studies, the 10% utilized (derived as a 17% of total surface runoff), is small compared to the typical 25% from USGS and others. Due to the lack of daily flow data in the tributaries to Lake Jesup, the baseflow percentage was derived a single tributary and extrapolated to the entire basin. The tributary however, drains an urbanized basin with high component of upstream storage and flow attenuation that can effectively masked the baseflow in with the storm flow. Additionally, the majority of the tributaries to Lake Jesup do not have storage characteristics and urban character. Further, other tributaries in the basin have significant groundwater influence, such as Salt Creek among others. In looking at the groundwater contribution as a calibration factor in the water balance it is revealed that a 20% groundwater contribution of total surface flow will provided a more accurate water balance than the 17% calculated from the Howell Creek Basin alone.

NUTRIENT LOAD

Another outstanding issue has been the wetlands EMC values in both the current period and the historic period. Historic conditions assume that wetlands are pristine and in as good of character as they can be, whereas it is assumed the current condition wetlands are impacted and discharge a higher level of nutrients. To investigate these issues further, a closer look was taken into Harvey Harper's documentation of wetland EMCs and selected current wetlands were evaluated to determine if their character and functionality has changed since anthropogenic impacts.

Closer look at the Harvey Harper report revealed that the wetland EMC of 0.19 mgl utilized as the anthropogenic wetland phosphorus contribution was derived based upon four values, (three from the Central Florida area and one from South Florida). The South Florida value was extremely high as compared to the Central Florida studies. When looking solely at the Central Florida values, the corresponding EMC for wetlands in an urban setting should be 0.14 mgl rather than 0.19 mgl.

Then an assessment was made on selected wetlands adjacent to Lake Jesup to determine if their condition was pristine and comparable to historical wetland characteristics and functionality. In total seven wetlands were evaluated based upon hydroperiod, soils, invasive species and connectivity / habitat. Of the systems evaluated, three met all aspects of the criteria while others were either determined to be some what impacted, separated, or improving.

SEDIMENT LOADING

In previous discussions regarding the nutrient load to Lake Jesup from bottom sediments, it was noted that due to lack of applicable studies, aerobic lake conditions, lack of bottom samples, and similarity of Lake Jesup phosphorus concentrations to the adjacent WBIDs, the sediment load would be neglected.

As stated in the Draft Lake Jesup TMDL table 5.9, an average of the concentrations of TP in Lake Jesup (0.142 mgl) is lower than in the WBIDs adjacent to Lake Jesup (0.199 mgl). However what this assessment failed to take into consideration is the flow weighted contribution of the adjacent WBIDs, when the magnitude of the contribution is considered, Lake Howell and Soliders Creek (0.11 and 0.14 mgl respectively), producing a weighted average of TP from these WBIDs the resulting TP concentration is at or below the concentration in the lake. Given the low concentrations present in direct rainfall on the lake and inputs from the SJR, it is plausible that the surface water contribution does not dictate the resulting concentration in the lake alone.

It was presumed that if sediments were resuspending and contributing to the nutrient load in the lake would lead to an oxygen demand and oxygen stratification in the lake. Observations and dissolved oxygen sampling has shown this not to be the case. However, given the shallow character of the lake relative to the large surface area has lead to significant mixing in the lake sufficient to elevate the DO in the entire water column. It was still inconclusive whether the nutrients were being released in the aerobic environment, so following the meeting on July 2nd 2005, Seminole County conducted samples of Lake Jesup at the sediment interface. Presumably, the concentrations would be in the range of expected values of Lake Jesup (0.14 to 0.25 TP mgl). However, what the samples showed was concentrations in the central and northeast sampling locations of 1.5 and 3.1 mgl of TP. These values are more than an order of magnitude higher than was expected if the sediments did not contribute nutrients to the water column. Further, due to the significant mixing present in the lake, the release observed at the interface is assuredly entering the water column. To gain further insight on these revealing samples, Harvey Harper was consulted, in the conversation, Harvey confirmed the conclusion and indicated that he actually performed a study of sediment load in Lake Jesup during the 1980’s. His study found that not only is the nutrient load from the sediments in Lake Jesup significant, it is in levels in excess of those found in Lake Apopka.

Responses from the DEP to comments from Seminole County via PBS&J

Regarding the estimation of baseflow from tributaries into Lake Jesup, the original baseflow estimates was based on the local minimum method provided by the Hydrological Separation Program (HYSEP) developed by the USGS. Results of baseflow separation can indeed be influenced by the upstream storages. A separate modeling effort from the SJRWMD using HSPF revealed the similar findings. Their study indicated that relatively low baseflow was observed in the upper reach of the Howell Creek, but high baseflow could be observed in the area close to the lake. The DEP therefore decided to adopt the 20% baseflow rate suggested by Seminole County. This result is still based on the local minimum method but adjusted based on the stream flow results from the lower reach of Howell Creek.

As for the TP wetland EMC, the DEP used 0.19 mg/L In the first draft of TMDL report. This number was cited from Harvey Harper's 1994 stormwater studies based on three central Florida wetlands and one south Florida wetland. Most of these wetlands are located in urbanized areas and was considered impacted by the surrounding urban area. Therefore, high TP concentrations from these wetlands were not beyond expectation. As the majority of wetland areas in the Lake Jesup watershed are located either downstream of urban areas or were converted from the previous agricultural lands, wetlands in Lake Jesup watershed were considered somewhat impacted or are recovering from previous impacts instead of being considered as under the pristine condition. This was the reason why 0.19 mg/L of TP was used as wetland EMC. The DEP later obtained an updated stormwater study by Harvey Harper (2003), which included 19 sets of wetland TP data. The mean TP EMC from these studies was 0.09 mg/L. As this latter study contains a larger data set, the mean derived from the data set was deemed more reliable than that of the previous study. In addition, the PBS&J also evaluated the extent at which the wetlands in the Lake Jesup watershed are impacted by human activities and provided to DEP the area and location of the wetlands that were considered impact and those that are relatively unimpacted, the DEP decided to divide the whole wetland areas in the Lake Jesup watershed into two categories, wetland1 and wetland2, with wetland1 being somewhat impacted and wetland2 being relatively pristine. A TP EMC of 0.06 mg/L has been used commonly for relatively unimpacted wetland area by the SJRWMD. This number was also adopted for unimpacted wetland in the Lake Jesup watershed. The 0.09 mg/L was used as the TP EMC for impacted wetlands. Description of using different TP EMCs for wetland of different impact extents can be found in the TMDL report on page 29-30.

As for the importance of sediment nutrient release, the DEP never denied that nutrient release from the sediment could be significant. However, the DEP explained in several public meeting the difference between gross sediment nutrient release and net sediment reslease. Bathtub, which is the model used to simulate TN, TP, and Chla in-lake mass balance processes, uses the net deposition rate (negative net release rate) for model simulation. The net nutrient deposition rate is the difference between the gross sediment nutrient release and gross nutrient deposition from the water column. While the gross sediment nutrient release could be significant, the release could be balanced out by nutrient deposition. The observations that the total nutrient output from Lake Jesup was not significantly different from the nutrient input into the lake, historic net accumulation of nutrient in the sediment, and nutrient concentrations in tributaries matching up with the in-lake nutrient concentration all supported the conclusion that the net sediment nutrient release is not a significant process in Lake Jesup.

Although the DEP believes that net sediment nutrient release is not a significant process for Lake Jesup and therefore does not significantly influence the TMDL estimation, we also acknowledge that control of the gross sediment release may speed up the restoration of the favored nutrient condition. Because, at the time this TMDL was developed, we did not have enough information to quantify how activities like sediment dredging would help the lake restoration, the DEP suggested further studies on the gross sediment nutrient release in the lake.

Comments from the St. Johns River Water Management District (SJRWMD):

Comments from the SJRWMD concerns four areas: the DEP should not add 5 TSI units on top of the background condition; Wetland TP EMC of 0.19 mg/L was too high; Several methods proposed by the

SJRWMD to establish the water quality target were rejected by the DEP; and the draft report allocate percent reduction of nutrient required to achieve water quality target to sediment nutrient release.

The DEP should not add 5 TSI units on top of the background condition: The IWR defines natural background as “the condition of water in the absence of man-induced alterations based on the best scientific information available to the Department”.

- ✓ The paragraph on page 22 (note from DEP: this page number is changed because of the revision of the report based on comments from local stakeholder and report editing) is unclear and should be rewritten: “…some increase over the background condition should be allowable without causing an imbalance of flora or fauna of the lake”.

  There is no evidence that a target TSI of 65 will not cause an imbalance of flora and fauna in Lake Jesup. The Impaired Waters Rule states that a TSI of 60 is the threshold for lake impairment.

- ✓ The draft report states that a TSI of 65 “would prevent the lake from becoming impaired as defined by the IWR”. Is this statement supported by dta, as required by the IWR?

- ✓ In the draft report, the addition of TSI points to the target is justfified by saying that “This approach also reserves 5 TSI units to allow for future changes in the basin and as part of the implicit margin of safety in estimation of the assimilative capacity”. However, future landuse changes are dealt with in the pollutant allocation phase fo the BMAP process, not in the setting of concentration targets. Also, the margin of safety should be calculated in the TMDL, not outside of the TMDL. In this case, the draft report implies that the margin of safety is the 5 TSI units between 65 (TMDL) and 70, at which point the lake is impaired.

  Also, the Allocation Technical Advisory Committee report endorsed FDEP’s continued use of an “implicit margin of safety (MOS) based on conservative assumptions in the modeling” rather than the use of an explicit MOS. The lake Jesup target TSI of 60 already contains an implicit MOS due to modeling assumptions. The fraft report, however, refers to an explicit MOS that is the difference between the TMDL and the lower limit of impairment.

Wetland EMCs:

- ✓ Different wetland EMCs were used to predict current and historic loading. The wetland EMC (0.19 mg/L) used in the draft report to predict current TP loading is too high. It is based on Harper’s EMC calculated for “impacted” wetland, which are those that receive treated effluent. None of the wetlnads around Lake jesup fit this definition of “impacted”.

According to a study conducted by John Hendrickson at the SJRWMD, based on water quality data collected in recent years from more than 20 watersheds in the lower St. Johns River area, the EMC of TP for wetlands is 0.06 mg/L.

Concentration target analyses provided by the SJRWMD:

The nine analyses used by SJRWMD to develop recommended concentration targets for TP and TN are accurately represented in the TMDL report. The draft TMDL, however, did not consider almost half (four) of these paths of investigation for various reasons.

The draft report states that:

- ✓ The relationship between nitrogen and plankton abundance is unclear because of the possibility of nitrogen fixation. The degree of nitrogen fixation in Lake Jesup has not been empirically measured, it is premature to disregard the possibility of a useful relationship between nitrogen and plankton abundance.

- ✓ The water clarity/SAV analysis is “tied to usage of the lake, instead of the natural assimilative capacity” because SAV coverage can be linked to sport fisheries. However, water clarity and SAV coverage are important metrics of a healthy lake, independent of links to recreational fishing use of the lake.

- ✓ There is a high standard deviation in TP/TN/chlorophyll-a/bloom frequency data. However, this should be considered part of the implicit margin of safety rather than eliminating the data from inclusion in the calculation of natural background condition.

Allocation to Internal Recycling

The draft TMDL report suggests allocating a nutrient reduction to FFWCC’s proposed lake-bottom dredging projects “because the sediment removal may decrease the nutrient loading from the sediment to the lake water column”. The report acknowledges that nutrient relase from the sediments does not “appear to be an important part of the nutrient budget for Lake Jesup” but states that “there is no direct information on the actual nutrient release rates available”.

The draft TMDL report should not allocate load reductions to internal recycling. Allocating a load reduction to a propose lake-bolttom dredging project would fall into this category. Lake bottom dredging designed to improve water quality should be handled as a project to help mee the TMDL, not as an allocation. In a statement agreed by both DEP and SJRWMD (dated May 13, 2005), it is stated:

“A strategy that addresses internal nutrient recycling is appropriate to include in a BMAP, but it will not replace external load recution or come into play in pollutant trading.”

Responses from the DEP to comments from the SJRWMD:

(1) Regarding comments that adding 5 TSI units on top of the natural background condition

The DEP acknowledges that the IWR uses TSI 60 or 40 (depend on water color) as the assessment thresholds for lake nutrient impairment. However, the IWR did not define TSI 60 or 40 as the only threshold for the assessment of lake nutrient impairment. In fact, the rule calls for developing, to the extent feasible, site-specific thresholds that more accurately reflect conditions beyond which an imbalance in flora or fauna occurs in the water segment. This was exactly why multiple methods were evaluated to establish nutrient targets instead of simply using TSI 60 or 40 as the target for the TMDL.

All the methods described in the TMDL report characterize the relatively unimpacted lake condition. For this TMDL, the unimpacted condition established using these methods was very close to the background condition simulated by the calibrated model suit. For the nutrient assessment purpose, the IWR does not call for meeting the exact background condition. Instead, 10 TSI units above the historic minimum are allowed before a lake would be assessed as impaired for nutrient. In establishing the nutrient target for Lake Jesup, the DEP allows only 5 TSI units above the natural background condition, which is a more conservative target and more protective for the lake than allowing 10 TSI units, and therefore added margin of safety to the final TMDL.

(2) Regarding the wetland TP EMCs

The same as the response from the DEP to comments from Seminole County via PBS&J. The DEP decided to divide wetland areas in the Lake Jesup watershed into two categories including Wetland1 (somewhat impacted) and Wetland2 (relatively pristine), and assigned 0.09 mg/L as TP EMC to Wetland1 and 0.06 mg/L as the TP EMC to Wetland2.

(3) Regarding the rejection of several methods proposed by the SJRWMD in establishing the target water quality condition

Several methods proposed by the SJRWMD in establishing the target water quality condition were not adopted by the DEP. The DEP described in the TMDL report in a very detailed fashion why these methods were not adopted. The reason why the DEP reject the method establishing the TN target based on a correlation between chlorophyll a and TN concentration was because of the possible complication from the nitrogen fixation. In this case, nitrogen is not the cause for the observed high chlorophyll a concentration. Instead, it is the consequence of the high chlorophyll a concentration. Although at the time the TMDL report was drafted there was no direct evidence showing that nitrogen fixation indeed existed in Lake Jesup, many indirect evidences, including the about two-fold higher TN concentration in the lake than in majority of the tributaries to the lake, the lack of evidence showing the significant release of nitrogen from the sediment, the existence and dominance of nitrogen fixing blue-green algae in the lake, and the low ratio between total inorganic nitrogen to total inorganic phosphorus that may trigger the nitrogen fixation, all support the possibility that nitrogen fixation not only exists in the lake, but could be very significant. All these details were discussed in the TMDL report. In fact, significant nitrogen fixation in Lake Jesup has been shown by Seminole County via PBS&J in a follow-up study. This was why the DEP reject the using the regression method to establish the TN target.

The major reason for the water clarity/SAV method to be rejected by the DEP was not because this method gears more toward usage instead of the natural assimilative capacity of nutrient of the lake although it is part of the reason. The major reason why this method was rejected was because it depends on the regression curve between the light extinction coefficient and TN and TP concentrations. The regression curve between light extinction coefficient and TP concentration established by the SJRWMD had a very low correlation coefficient and therefore was not deemed reliable. The correlation between the light extinction coefficient and TN concentration was again complicated by the possible existence of nitrogen fixation in the lake. In addition, it is very true that the final water quality target typically is the compromise between different designated uses, including the fishery. However, for nutrient target, the Florida Surface Water Quality Standard stresses the importance that the balance of natural aquatic flora and fauna should not be disturbed. It is also assumed that as long as the balance of natural aquatic flora and fauna is protected, healthy and well-balanced fish and wild life populations should also be maintained. Therefore, when considering the water quality target, the natural balance of aquatic flora and fauna was assigned the higher weight.

The concept of using both frequency and intensity of algal bloom to establish the water quality target is a very important one because the frequency includes a very important parameter to characterize a bloom, the length of time of the bloom, not just the biomass intensity. If strong correlation could be defined between the bloom strength and frequency and nutrient concentrations, this technique would be very promising for nutrient target development for Lake Jesup. However, as it was shown in Bachmann et al. (2003), the variance between algal bloom strength and frequency and TN and TP concentration was very significant when the TN/TP ratio fall between 10 and 17 (in most case this is the range that TN/TP ratios of Lake Jesup fall in). The variance did not always point to the low nutrient concentration, which would be more protective for the lake function and add to the margin of safety. The variance fluctuates both ways. It is therefore difficult for the DEP to develop reliable water quality target using this method.

(4) Sediment nutrient release and load allocation to lake-bottom sediment

The SJRWMD claimed that the TMDL report allocated a certain portion of the pollutant loading to the lake sediment. In fact, the report did not allocate any pollutant load to the sediment. The report assumed sediment nutrients release was not significant in Lake Jesup based on the comparison of nutrient input into and output from the lake, the tributary nutrient concentration and in-lake nutrient concentration, nitrogen fixation, and etc. As the report assumes no sediment nutrient release, there is no way that pollutant load can be allocated to the sediment. The DEP recognized that the “sediment nutrient release is not significant” conclusion was reached based on indirect information instead of directly measured sediment nutrient release. Therefore, in the Recommendation for Future Studies section, the DEP recommended sediment nutrient release study. If the entity that will dredge the lake can quantify the influence of sediment nutrient release on the in-lake nutrient concentration and the in-lake nutrient effects from the sediment dredge, credit may be awarded to the entity.

Comments from the United States Environmental Protection Agency (EPA):

1. Given the relative sizes of the WBIDs and the fact that there do not seem to be any additional sources discharging to just WBID 2981A, it seems reasonable to assume that the nutrient TMDL for WBID 2981 will address the nutrient TMDL for WBID 2981A.

2. The assumption that the nutrient TMDL for WBID 2981 will address the unionized ammonia impairment also seems reasonable. However, given the scatter in the relationships between pH and unionized ammonia, and between pH and chlorophyll, it is essential that implementation of the TMDL include continued monitoring for unionized ammonia to ensure that reductions are, in fact, being achieved. It might be a good idea to expressly state the intention for continued monitoring on page 82, when unionized ammonia is discussed.

3. FDEP was very comprehensive in using different approaches to develop targets for TN and TP. This lends some confidence to the initial/natural background targets, because the different approaches mostly converge on the same numbers. It is reasonable to assume that some increase in TSI above natural background would not cause a nutrient problem. However, the rationale for a 5-unit increase in TSI to arrive at the TMDL targets should not be based solely on the IWR. Rather, the sufficiency of the final targets should be justified by some analysis showing that a TSI of 65 and nutrient concentrations of 1.32 mg/l TN and 0.094 mg/l TP will not cause an imbalance of flora and fauna in the lake. At the very least, Best Professional Judgment could be used to support the targets. Similarly, it is best to stay away from the "we wouldn't consider it impaired based on the IWR" line of reasoning when discussing Margin of Safety and future assimilation capacity.

4. The document could really use a brief summary that provides the big picture of what the final targets and TMDLs are and how they were determined. The length of the document, the copious amount of information it contains, and the fact that it describes some analyses that were ultimately not used to develop targets or determine the TMDL, make it easy to get confused. For example, the interpretation of the narrative nutrient standard is discussed in Chapter 3 (Water Quality Standards and Targets), but really the target you ended up using is described in Chapter 4 (Assessment of Sources), and some in Chapter 5 (Determination of Assimilative Capacity). Having a summary near the beginning of the document would provide some context for understanding the details of the analyses in chapters 3, 4, and 5.

5. Please double-check the numbers for total phosphorus loading in all relevant tables. The estimates of total phosphorus loading coming from surface runoff in Table 4.11-c (p. 42) and Table 4.12-c (p. 44) are different from the surface runoff estimates in Table 4.21-c (p.53) and Table 5.13-b (p. 75). The estimates of TP loads for each year in each sub-watershed (Table 4.11-c), and from different land use categories (Table 4.12-c) do add to the total values provided. Also, even though the surface runoff values are different, the estimates for each source in Table 4.21-c and Table 5.13-b sum up to the totals provided. If the other two tables are correct, this implies that the totals in Table 4.21-c and 5.13-b are incorrect (or vice versa). So which numbers are correct, and which were used for the TMDL?

6. Many of the tables are split between pages. It makes them hard to read when the column headings are on one page, and the numbers are on another. I know this is just a formatting issue, but in the final version, please make it so that the column headings repeat on different pages, or so that the tables are not split.

Responses from the DEP to comments from the EPA:

Regarding EPA's Comment 2, the DEP added language on Page 84 to encourage monitoring programs that track the trend of water pH and un-ionized ammonia concentration when the TMDL implementation is started.

Regarding EPA's Comment 3, the DEP believes that direct application of natural background as the target TSI would not allow for any assimilative capacity. The IWR uses as one measure of impairment in lakes, a 10 unit change in TSI from "historical" levels. This 10 unit increase is assumed to represent the transition of a lake from one trophic state (say mesotrophic) to another nutrient enriched condition (eutrophic). The DEP has assumed that allowing a 5 unit increase in TSI over the natural background condition would prevent a lake from becoming impaired (changing trophic states) and reserve 5 TSI units to allow for future changes in the basin and as part of the implicit margin of safety in establishing the assimilative capacity.

Regarding EPA's Comment 4, the DEP created an Executive Summary for the report.

Regarding EPA's Comment 5, the DEP double checked the data in all the tables and text and removed some table fields that may cause confusion and made sure all the data and results are updated properly.

Regarding EPA's Comment 5, the DEP tried its best to ensure that majority of the tables are on just single one page except for the table in Appendix B, which is too long to fit in just one page.

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