Total Maximum Daily Load for Total Phosphorus For Lake Eustis and Haines Creek Reach Lake County, Florida

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1.0 Introduction

1.1 Purpose of Report

This report presents a Total Maximum Daily Load (TMDL) for Total Phosphorus (TP) for Lake Eustis and describes the projected impact of proposed TP reductions on the concentration of un-ionized ammonia in the lake. Using the methodology to identify and verify water quality impairments described in Chapter 62-303, Florida Administrative Code, (Identification of Impaired Surface Waters or IWR), the lake was verified as impaired by un-ionized ammonia and nutrients, and was included on the verified list of impaired waters for the Ocklawaha Basin that was adopted by Secretarial Order on August 28, 2002. The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions

Lake Eustis discharges to Lake Griffin through the Haines Creek Reach, which was also verified as impaired under the IWR and included in the August 28 Secretarial Order. Haines Creek Reach was verified as impaired for dissolved oxygen (DO) [with low values due to elevated BOD and nutrients] and nutrients. The TMDL for Lake Eustis is expected to address the DO and nutrient impairments in Haines Creek Reach.

1.2 Identification of Waterbody

Lake Eustis, located in central Florida approximately 30 miles northwest of Orlando, is part of the Upper Ocklawaha River Basin (UORB) (Figure 1). It has a drainage basin of approximately 27,878 acres (Fulton et al., 2003). At a lake surface elevation of 63 ft National Geodetic Vertical Datum (NGVD), the lake has a surface area of approximately 3,139 ha (7,757 acres) and an average depth of 3.46 m (11.4 ft). Both Lake Dora and Lake Harris discharge into Lake Eustis. Lake Eustis flows into Lake Griffin through Haines Creek. Surface elevations in Lakes Eustis, Harris, Dora, and Beauclair are controlled by the Burrel Lock and Dam located on Haines Creek and operated by the St. Johns River Water Management District (SJRWMD). The regulation schedule maintains an elevation range between 62 to 63.5 feet NGVD in Lake Eustis.

For assessment purposes, the watersheds within the Ocklawaha River Basin have been broken out into smaller watersheds, with a unique **w**ater**b**ody **id**entification (WBID) number for each watershed. Lake Eustis has been assigned WBID 2817B and Haines Creek Reach has been assigned WBID 2817A.

2.0 Statement of Problem

The UORB is located primarily in a large lowland area between the Mount Dora Ridge to the east and the Ocala Uplift District to the west. In many areas, the valley floor intersects the potentiometric surface resulting in numerous springs and spring-fed lakes.

Karst terrains are present throughout the area due to the soluble carbonate rock and the nutrient rich soils have combined to produce naturally productive hardwater lakes.

During the 1800s resources were developed for tourism, agricultural, and commercial industry. According to the SWIM Plan (Fulton, 1995), impacts of urban development within the basin were first documented in the late 1940s. Eutrophication of surface waters was accelerated by the direct discharge of domestic, industrial, and agricultural wastes. In addition, construction of control structures and channelization of the system along with destruction of aquatic habits contributed to declines in water quality.

In 1987, the Florida Legislature adopted the Surface Water Improvement and Management (SWIM) Act, which directed Water Management Districts to adopt methodologies to identify waters in need of restoration and/or preservation. In 1989, the SJRWMD adopted a SWIM plan for the restoration of the UORB.

In 1995, the SJRWMD developed an interim Pollutant Load Reduction Goal (PLRG) for phosphorus (Fulton, 1995) based upon trophic state modeling. PLRGs represent estimated reductions in pollutant loadings from stormwater needed to preserve or restore beneficial uses of receiving waters. In this preliminary analysis, discharges from Lake Dora represented the largest loading source of phosphorus, followed by muck farm discharges and runoff from other types of agriculture in the watershed.

Plots of key water quality parameters over the 1989 – 2002 period indicate that overall there has been little change in water quality over this period, but that the ranges for some parameters have decreased over time (Figures 2[1] for Lake Eustis and Haines Creek and Figure 3[2] for Lake Eustis). Table 1 summarizes DO, un-ionized ammonia, and chlorophyll <u>a</u> or Trophic State Index (TSI) annual averages used to assess Lake Eustis and Haines Creek Reach under the IWR. Statistical summaries of key water quality parameters are presented for the two WBIDs in Table 2.

In recent years, additional attention has been focused on blue-green algal (cyanobacteria) blooms in Florida lakes. Burns, et al. (2001) reported the presence of *Cylindrospermopsis sp.* and *Microcystis sp.* in samples collected in Lake Eustis during the summer of 1999. Measurable levels of microcystins (a cyanotoxin) were also reported in some samples. The *Cylindrospermopsis* genera represents a filamentous bloom-forming cyanobacteria that can fix nitrogen from the atmosphere. The *Microcystis* genera is a non-filamentous bloom-forming cyanobacteria that has not been demonstrated to have the ability to fix nitrogen.

In response to the blue-green algal blooms, the Lake County Water Authority (LCWA) funded a monitoring program that measures cyanobacteria abundance and microcystin levels in lakes in the UORB, including Lake Eustis. Results of the monitoring to date are shown in Figures 4 and 5 (provided by Mr. Mike Perry, personal communication of the LCWA). Figure 5 indicates that microcystin levels were temporarily above the World Health Institute threshold for drinking water in December 2001 and January 2002, but that microcystin levels have declined from the peak levels in January 2002.

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[1] . Figure 2 presents water quality information on an annual basis and suggests some reduction in ranges for some parameters over time.
[2] Figure 3 presents the individual observations over time and includes trendlines. Although the r^2 values were low, slopes were nearly zero or negative, suggesting improving water quality with time.

3.0 Description of the Applicable Water Quality Standards and Numeric Water Quality Target

Lake Eustis and Haines Creek Reach are Class III waterbodies with designated uses of recreation, propagation and maintenance of a healthy, well balanced population of fish and wildlife. Class III water quality criteria applicable to the observed impairment include the un-ionized ammonia criterion (0.02 mg/l), a minimum DO of 5.0 mg/l, and the narrative nutrient criterion (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). Because the nutrient criterion is narrative only, a nutrient related target was needed to represent levels at which imbalance in flora or fauna are expected to occur.

As part of the ongoing SWIM Program assessments of the lake, the SJRWMD developed a new interim PLRG for phosphorus in Lake Eustis that considered two approaches to determine an appropriate phosphorus target. The first approach involved modeling both the external loading and resultant lake water quality under historic (natural background) conditions. In the second approach, an appropriate TP target was determined using reference conditions from lakes in the region based upon three estimates (state lake ecoregion data, SJRWMD ecoregion dataset, and a selection of lakes with similar morphology and hydrology). All of these methods relied upon information and/or relationships developed from long-term datasets or steady state conditions. In this case, the TP target developed for the lake by the SJRWMD (25 ppb) as part of the PLRG development for the lake was used as the water quality target for the TMDL.

It should be noted that the IWR provides a threshold of impairment for nutrients in lakes based on a Trophic State Index (TSI). While the IWR thresholds were not used as the water quality target for this TMDL (they are not water quality criteria), resultant changes in the TSI for the lake are included in the document to demonstrate that reductions in TP would be expected to result in decreases in the lake TSI that would be consistent with a nonimpaired lake.

Reductions in TP loading are also expected to result in additional benefits with respect to other parameters of concern, including dissolved oxygen, un-ionized ammonia, turbidity, BOD, and total suspended solids. Reductions in phosphorus will result in lower algal biomass levels in the lake, and lower algal biomass levels will mean smaller diurnal fluctuations in dissolved oxygen, less algal based total suspended solids and turbidity, reduced BOD, and lower pH levels in the lake. Since the fraction of ammonia that is un-ionized is directly related to pH, lower pH levels will also result in fewer exceedances of the un-ionized criterion (Table 3).

The expectation that reductions in phosphorus loading will provide improvements in other parameters is supported by statistical evaluation of the Lake Eustis data. Based on Pearson correlation coefficients for this data set (Table 4), Total phosphorus is positively correlated with turbidity, corrected chlorophyll a, uncorrected chlorophyll a, ammonia, organic nitrogen, TKN, and TN. The correlation is negative between dissolved oxygen and total phosphorus. The simple linear regression of total phosphorus versus uncorrected Chla was significant at an alpha level of 0.05. The simple linear regressions of corrected Chla or uncorrected Chla versus either pH or DO were also significant at an alpha level of 0.05.

This positive correlation between pH and chlorophyll a reflects changes to the carbonate balance in the water column as CO_2 is used in algal photosynthesis. Reductions in pH in response to lower algal biomass and lower overall photosynthesis will reduce the occurrence of un-ionized ammonia exceedances even without a reduction in ammonia. For example, at a temperature of 20 ^{0}C, a pH reduction from 8.5 to 8 s.u. changes the total ammonia that would result in an un-ionized exceedance from 0.15 to 0.5 mg/l, respectively.

Proposed reductions in phosphorus will also result in a smaller input of nitrogen from nitrogen fixation by cyanobacteria that gets recycled in the lake through processes such as grazing and settling. In addition, additional treatment in the watershed to achieve the proposed phosphorus reduction will also result in additional nitrogen removal. Fulton et al.'s (2003) summary of 13 storm water treatment systems in Florida suggested a mean treatment efficiency of 42% for nitrogen. Those same treatment systems had a mean treatment efficiency of 63% for phosphorus.

Both the PLRG and this TMDL establish the allowable load for phosphorus only, and not nitrogen. Fulton et al. (2003) reported that ratios of nitrogen to phosphorus in the UORB suggest that algal production is potentially limited by phosphorus availability, except in lakes where excessive phosphorus loading has led to potential nitrogen or co-limitation of nitrogen and phosphorus. Total nitrogen to total phosphorus values less than 10 indicate nitrogen limitation, while ratios greater than 30 indicate phosphorus limitation. Figure 6 illustrates the distribution of this ratio for measurements in Lake Eustis over the 1989 – 2002 period. The ratio is typically above 30, indicating phosphorus limitation.

Loehr et al. (1980) point out that due to the ability of various cyanobacterial species to fix gaseous nitrogen, it is very difficult to control eutrophication problems in freshwater systems through limitations on nitrogen input. They indicate that phosphorus inputs must be lowered to the point where phosphorus replaces nitrogen as the limiting factor, and then further reduced so that the growth and yield of algal forms is reduced.

Whitton and Potts (2000) cite a study by Sas (1989) where phytoplankton and cyanobacterial components responded to phosphorus reduction in four stages:

- Stage 1: no biomass reduction because phosphorus is in excess of algal requirements
- Stage 2: declining amount of unused phosphorus results in a small reduction in Algal biomass
- Stage 3: phytoplankton biomass falls, with minimal unused phosphorus remaining
- Stage 4: further decline in biomass and changes in composition of the phytoplankton.

4.0 Assessment of Sources

4.1 Types of Sources

An important part of the TMDL analysis is the identification of source categories, source subcategories, or individual sources of phosphorus in the 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, runoff from agriculture, runoff from silviculture, runoff from 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 EPA’s National Pollutant Discharge Elimination Program (NPDES). These nonpoint sources included certain urban stormwater discharges, including those from local government master drainage systems, construction sites over five acres, and from a wide variety of industries (see Appendix A for background information about the State and Federal Stormwater Programs).

To be consistent with Clean Water Act definitions, the term “point source” will be 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). However, the methodologies used to estimate nonpoint source loads do not distinguish between NPDES stormwater discharges 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 Source Loads

As part of the development of a phosphorus PLRG for Lake Eustis, Fulton et al. (2003) estimated average annual nitrogen and phosphorus loads to the lake from various sources over the 1991 – 2000 period (Table 5). Loads are presented to the nearest 0.1 kg to illustrate the magnitude of some of the smaller sources that were evaluated. Sources included runoff from land uses such as residential, commercial, industrial, mining, openland/recreational, muck farms, pastures, croplands, silviculture, wetlands, and other agriculture (Figure 7). Atmospheric contributions from wet and dry deposition directly on the lake surface were accounted for based upon measurements in the basin. Inputs from tributaries to the lake such as from Lake Dora and Lake Harris were also incorporated into the nitrogen and phosphorus loading estimates. Permit files from the DEP Central District were also reviewed to develop loading estimates from domestic and wastewater spill at facilities within the watershed.

The mean annual TP load over this period was estimated at 16,105.0 kg. The three major sources for phosphorus were Lake Dora discharge (53.77%), Lake Harris discharge (17.70%), and septic tanks (4.30%). Total nitrogen was estimated at 528,414.8 kg/year, with the Lake Dora and Lake Harris discharges accounting for about 89% of the total load. Spills from domestic wastewater facilities represented less than 0.01% of either the phosphorus or nitrogen load.

5.0 Loading Capacity – Linking Water Quality and Pollutant Sources

Fulton et al. (2003) calculated a mean lake TP concentration of 43 ug/l over the 1991 – 2000 period. Based upon results from the two approaches used to determine a target TP, the proposed TP target for Lake Eustis was 25 ug/l. Fulton estimated that a 43 percent reduction in annual phosphorus loading to the lake was needed to meet this TP target. This was based upon the ratio of the target phosphorus concentration (25 ug/l) to the existing phosphorus concentration (43 ug/l). Fulton et al. (2003) made the simplifying assumption that the phosphorus concentration in the lakes is directly proportional to external loading. Consequently, the ratio was then applied to the long-term annual phosphorus load to determine an allowable load and percent reduction necessary to achieve the TP target.

As discussed earlier, the IWR uses a TSI to assess possible nutrient impairments in lakes. The TSI represents the average of a $Chla_{TSI}$ and $Nutrient_{TSI}$. Assuming an average TP of 43 ug/l, the $Nutrient_{TSI}$ would be 65.0, and using a long-term average Chla of 68 ug/l, the $Chla_{TSI}$ would be 77.5. Thus, the long-term average TSI under current conditions is approximately 71. Reducing the in lake phosphorus concentration to 25 ug/l would result in a $Nutrient_{TSI}$ of 52. Fulton (2003a) provided a preliminary evaluation of the effects of the interim PLRG and predicted a mean Chla of 20 ug/l. At this concentration, the $Chla_{TSI}$ would drop to 60 and the TSI would be 56.

Processes that consume oxygen from the water column such as microbial breakdown of organic material and sediment oxygen demand are fairly constant over the short term. Algal populations, however, can increase rapidly and the production of oxygen as a result of photosynthesis during daylight hours and respiration or consumption of water from the water column at night can result in large diurnal fluctuations of DO in the water column. A fraction of increased biomass will also become part of the organic material that will be broken down by microbes or settle to the bottom. The proposed phosphorus reduction is predicted to decrease algal biomass from the current Chla average of 68 ug/l to approximately 20 ug/l. This will have a positive affect on reducing the diurnal fluctuations in DO and improve the DO levels of water leaving Lake Eustis through Haines Creek. Reduced algal biomass also means that BOD levels in the lake and discharges from the lake will also be lower.

6.0 Critical Conditions

Phosphorus reductions proposed by the SJRWMD were based upon a 10-year average phosphorus load to Lake Eustis. Nitrogen loads to the lake were also based upon a 10-year average. Fulton et al. (2003) note that the phosphorus load reduction goals should be treated as long-term average annual loads and that there is substantial year to year variation in the phosphorus load to the UORB lakes. They also pointed out that the estimated external phosphorus load was lower than the reduction goal in at least one of the years 1991-2001 in all of the lakes, except for Lake Griffin.

The TMDL was based on long-term average conditions rather than critical/seasonal conditions because a) the methodology used to determine the assimilative capacity does not lend itself very well to short-term assessments, b) we are generally more concerned with the net change in overall primary productivity, which is better addressed on an annual basis, and c) the methodology used to determine impairment is based upon an annual average and requires data from all four quarters of a calendar year.

7.0 Determination of 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 (Waste Load Allocations), nonpoint source loads (Load Allocations), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\mathbf{TMDL = \sum WLAs + \sum LAs + MOS}$$

As mentioned in Section 4.1, the WLA is broken out into separate subcategories for wastewater discharges and stormwater discharges regulated under the NPDES Program:

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

It should be noted that the various components of the TMDL equation may not sum up to the value of the TMDL because a) the WLA for NPDES stormwater is typically based on the percent reduction needed for nonpoint sources and is accounted for within the LA, and b) 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 a 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 loads from MS4s from other nonpoint sources (given the nature of stormwater transport). The permitting of stormwater discharges is also different than 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 Best Management Practices.

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**. The TMDL for Lake Eustis (Table 6) is expressed in terms of pounds per year, and represents the annual load the lake can assimilate and maintain the narrative nutrient criterion. The LA includes the atmospheric contribution (2,250 lbs/year).

Table 6. TMDL Components

WBID	Parameter	WLA		LA (lbs/year)	MOS	TMDL (lbs/year)	Percent Reduction
		Wastewater (lbs/year)	NPDES Stormwater (% Reduction)				
2817A	TP	N/A	43	20,286	Implicit	20,286	43[1]

[1] Note that this percent reduction was based upon the total annual average load which included atmospheric contributions

7.1 Load Allocations (LAs)

The allowable LA is 20,286 lbs/year for TP. This corresponds to reductions from the existing nonpoint source loadings of 43 percent for TP. It should be noted that the LA includes loading from stormwater discharges regulated by the Department and the Water Management Districts that are not part of the NPDES Stormwater Program (see Appendix A).

As noted earlier, two of the largest existing sources are Lake Dora (53.77%) and Lake Harris (17.70%). Since TMDLs are being developed for the upstream lakes, there should be a significant reduction in both of these tributary discharges to Lake Eustis.

7.2 Wasteload Allocations (WLAs)

NPDES Stormwater Discharges

As noted in Sections 4 and 7.1, load from stormwater discharges permitted under the NPDES Stormwater Program are placed in the WLA, rather than the LA. This includes loads from municipal separate storm sewer systems (MS4). Based on the 2000 census, the Lake Eustis watershed includes areas that will be covered by the MS4 Program, and the WLA for stormwater discharges is a 43 percent reduction of current loading from the MS4. It should be noted that any MS4 permittees will only be responsible for reducing the loads associated with stormwater outfalls for which it owns or otherwise has responsible control, and is not responsible for reducing other nonpoint source loads within its jurisdiction. In addition, implementation of TMDLs for upstream waterbodies that flow into Lake Eustis will also influence the percent reduction that MS4 areas will need to meet in order for the TMDL for the lake to be achieved.

NPDES Wastewater Discharges

There are no wastewater facilities authorized to discharge wastewater to Lake Eustis. The loading analysis included estimated loading from domestic wastewater spills and runoff, however, the TN and TP discharged was very small, less than 0.01% of the load to the lake.

7.3 Relationship between Lake Eustis, Lake Dora, Lake Harris and Lake Griffin TMDLs

It should also be noted with respect to possible reductions in either the WLA or LA to achieve the TMDL, discharge from Lake Dora via the Dora Canal currently represents approximately 54 percent of the annual load of phosphorus to Lake Eustis. Similarly, discharge from Lake Harris to Lake Eustis through the Dead River represents nearly 18 percent of the annual phosphorus load. Draft TMDLs have been proposed for both lakes that specify significant phosphorus load reductions. Consequently, implementation of those TMDLs will reduce their contributions to Lake Eustis and assist in achieving the TMDL for the lake.

The proposed TMDL for Lake Griffin estimated that discharge from Lake Eustis via Haines Creek Reach currently contributes nearly 29 percent of the total annual phosphorus load for Lake Griffin. Reductions in phosphorus loading to and from Lake Eustis as a result of this TMDL will also be a factor in how the TMDL for Lake Griffin is met.

7.4 Margin of Safety (MOS)

An implicit margin of safety is assumed based upon a long-term (10-year) annual load budget. Calculations of storm water runoff also assumed that there was no storm water treatment for lands already developed in 1987, while lands developed after 1987 were assumed to provide storm water treatment at levels equal to the average of 13 studies in Florida. Finally, in the determination of the target phosphorus concentration, the SJRWMD used the 25th percentile value from each estimate, which is considered a conservative level.

8.0 Seasonal Variation

As discussed earlier, potential nutrient impairments in lakes are based upon calculated annual TSI values. The IWR requires that water quality data from all four quarters of the calendar year in order to calculate a TSI.

With respect to un-ionized ammonia, the fraction of total ammonia that is un-ionized is a function of water temperature and pH. While both water temperature and pH vary seasonally, summer is the most likely period where both increased water temperature and pH are most likely occur together and result in a low allowable total ammonia concentration.

Since DO is a gas, its saturation level is a function of water temperature and salinity. Increased water temperatures and/or salinities reduce the amount of oxygen that can remain in solution. Salinity is not a factor in Lake Eustis. Consequently, summer and early fall would represent periods of highest water temperature where DO saturation and DO would be expected to be lower. Algal production during these periods can increase oxygen levels during the day, however, the increased respiration will result in lower levels at night and the possibility of large diurnal fluctuations. Reductions in the algal biomass will reduce these fluctuations.

9.0 Next Steps: Implementation PLAN development and beyond

Following adoption of this TMDL by rule, the next step in the TMDL process is to develop an implementation plan for the TMDL, which will be a component of the Basin Management Action Plan for the Ocklawaha Basin. This document will be developed in cooperation with local stakeholders and will attempt to reach consensus on more detailed allocations and on how load reductions will be accomplished.

The Basin Management Action Plan (B-MAP) will include:

- Appropriate allocations among the affected parties.
- A description of the load reduction activities to be undertaken.
- Timetables for project implementation and completion.
- Funding mechanisms that may be utilized.
- Any applicable signed agreements.
- Local ordinances defining actions to be taken or prohibited.
- Local water quality standards, permits, or load limitation agreements.
- Monitoring and follow-up measures.

It should be noted that TMDL development and implementation is an iterative process, and this TMDL will be re-evaluated during the BMAP development process and subsequent Watershed Management cycles. The Department acknowledges the uncertainty associated with TMDL development and allocation, particularly in estimates of nonpoint source loads and allocations for NPDES stormwater discharges, and fully expects that it may be further refined or revised over time. If any changes in the estimate of the assimilative capacity AND/OR allocation between point and nonpoint sources are required, the rule adopting this TMDL will be revised, thereby providing a point of entry for interested parties.

10.0 References

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Figure 1. Upper Ocklawaha River Chain of Lakes

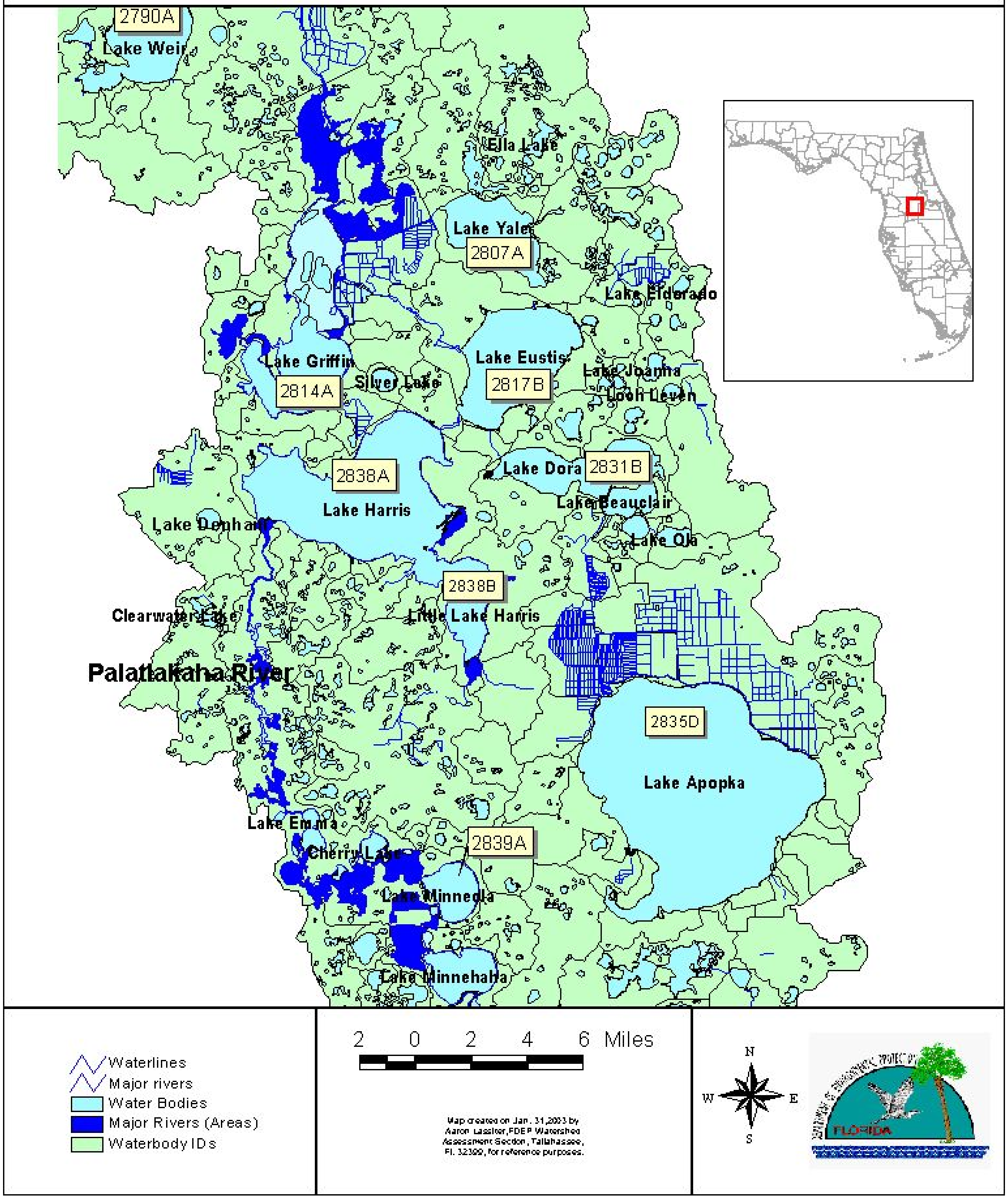
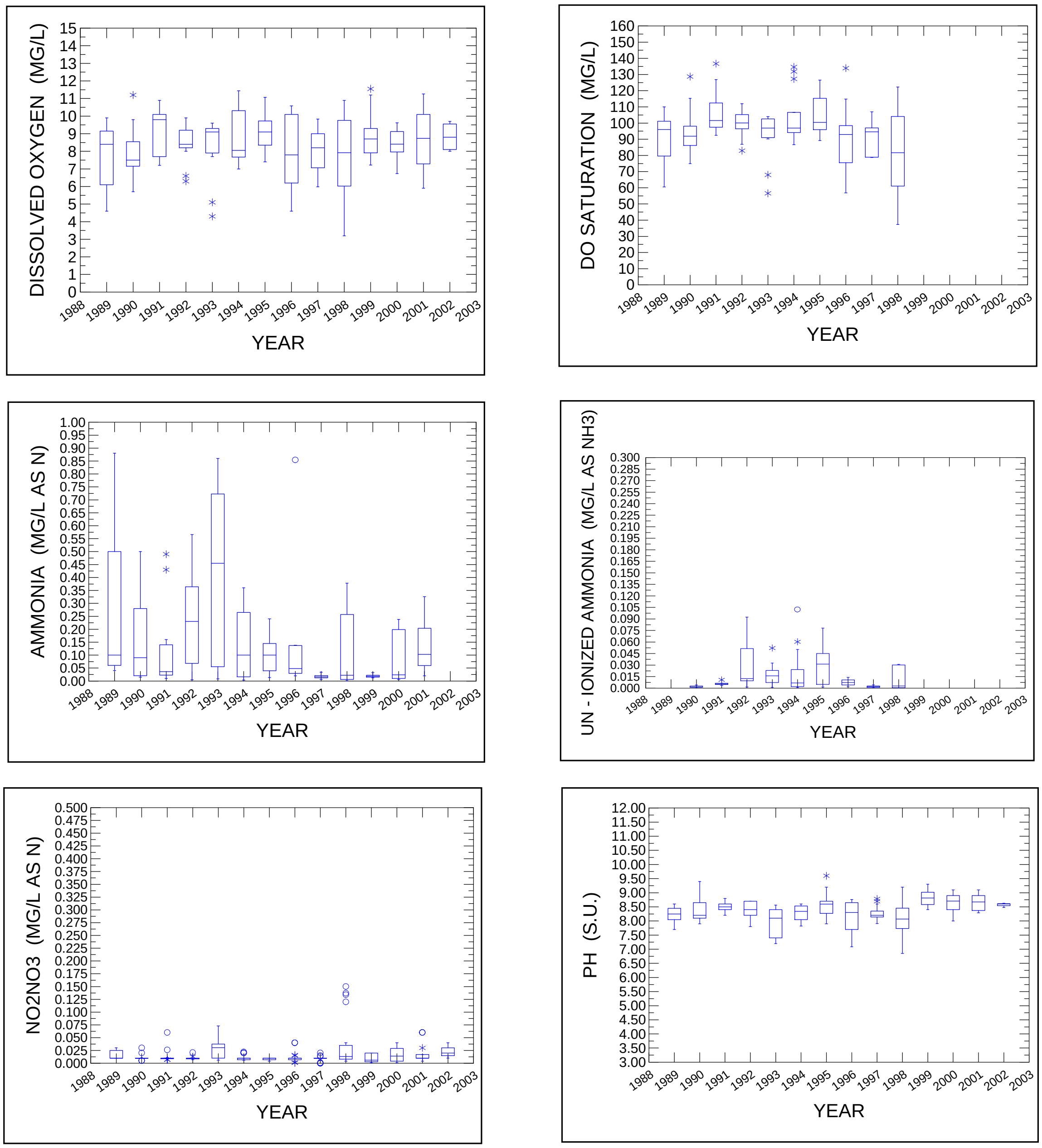


Figure 2a. Boxplots of water quality by year in Lake Eustis (WBID 2817B) for the 1989 - 2002 period.



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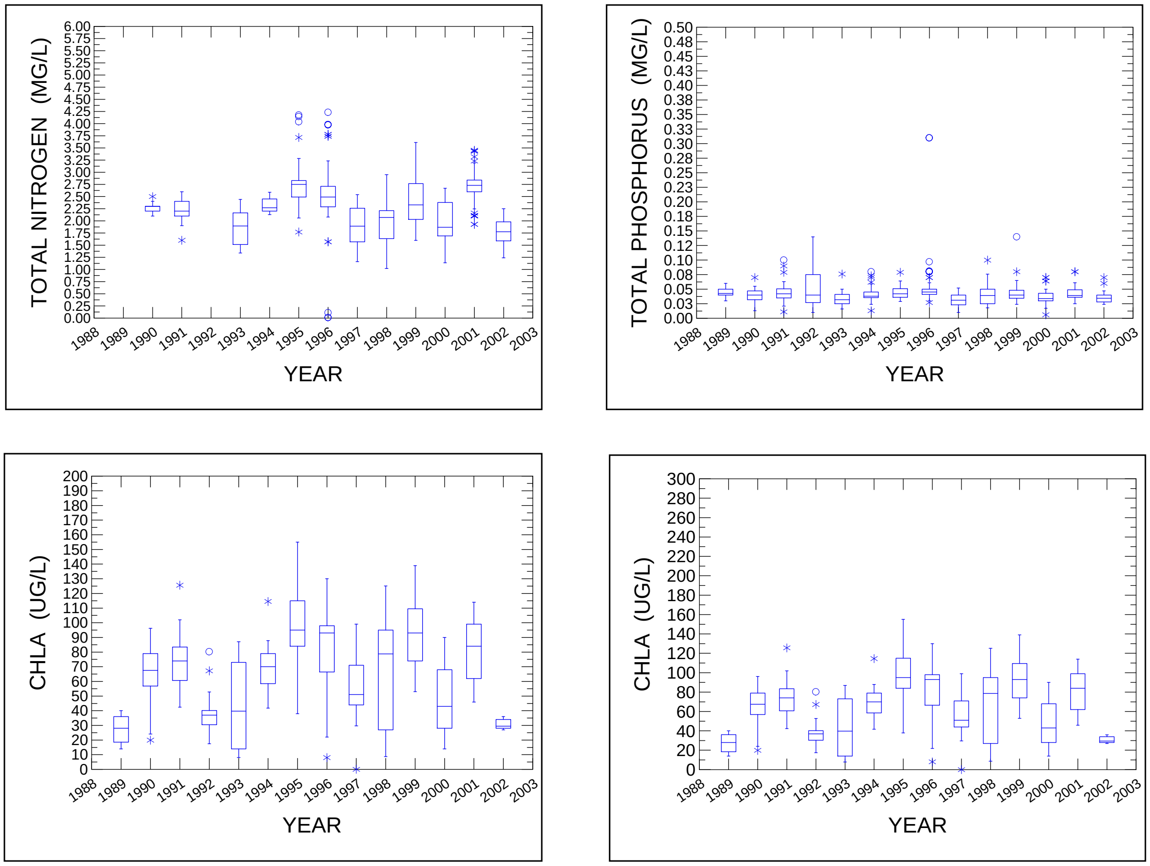
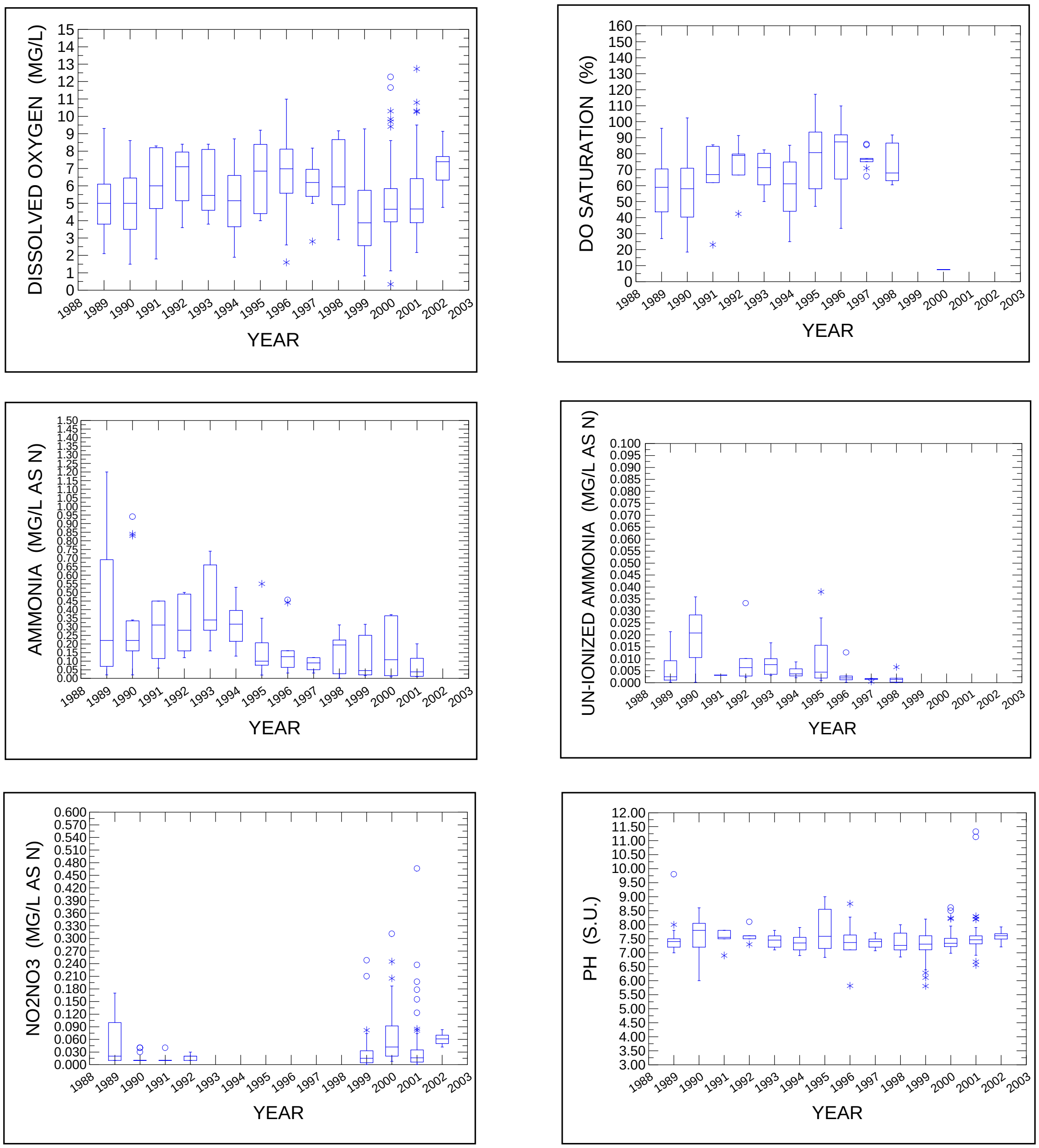


Figure 2b. Boxplots of water quality by year in Haines Creek Reach (WBID 2817A) for the 1989 - 2002 period.



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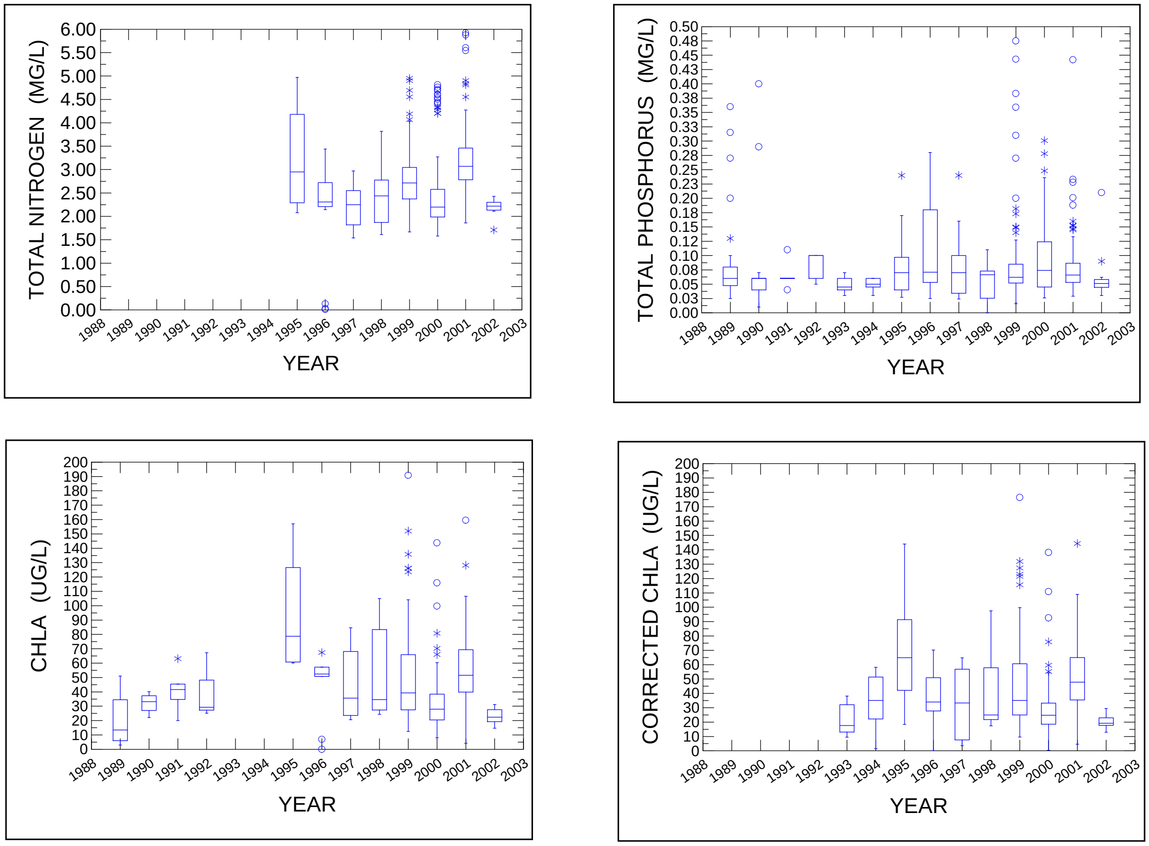
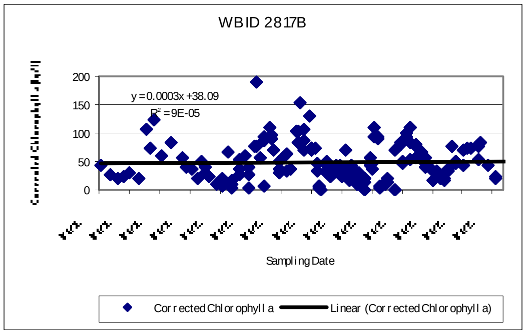
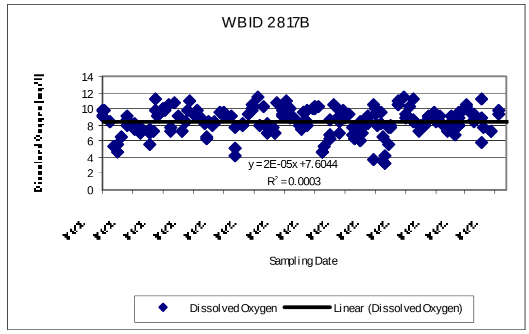
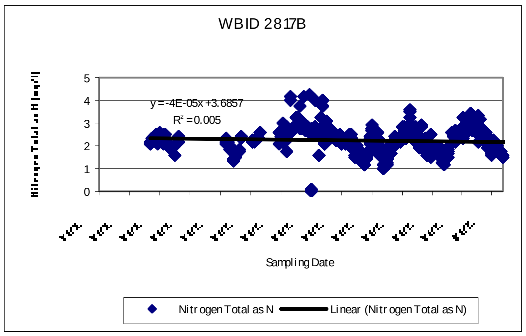
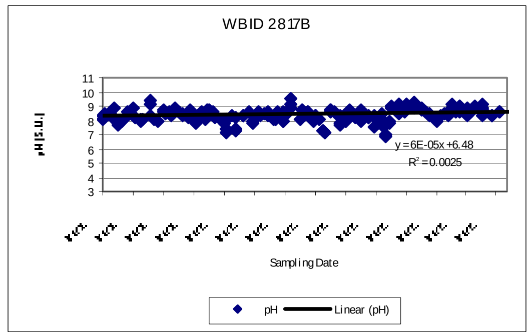


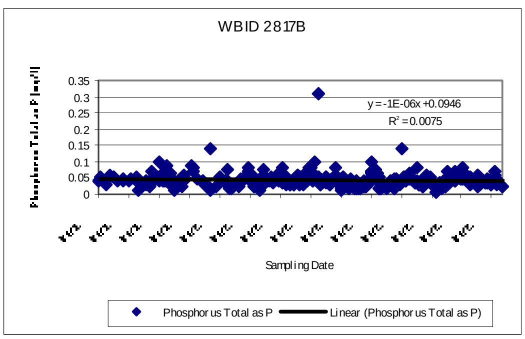
FIGURE 3. PLOTS OF WATER QUALITY FOR LAKE EUSTIS FOR THE 1989-2002 PERIOD WITH TRENDLINES.

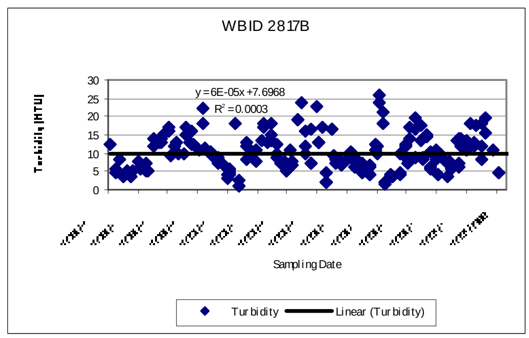












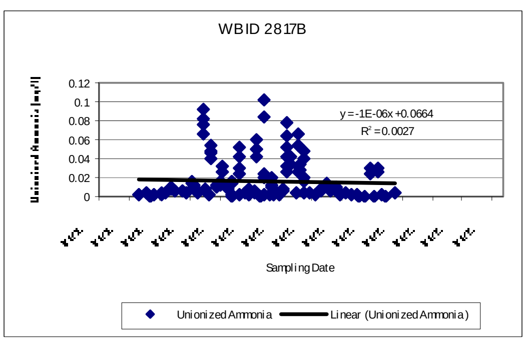


Figure 4. Cyanobacteria levels (biovolumes) in Lake Eustis from Lake County Water Authority

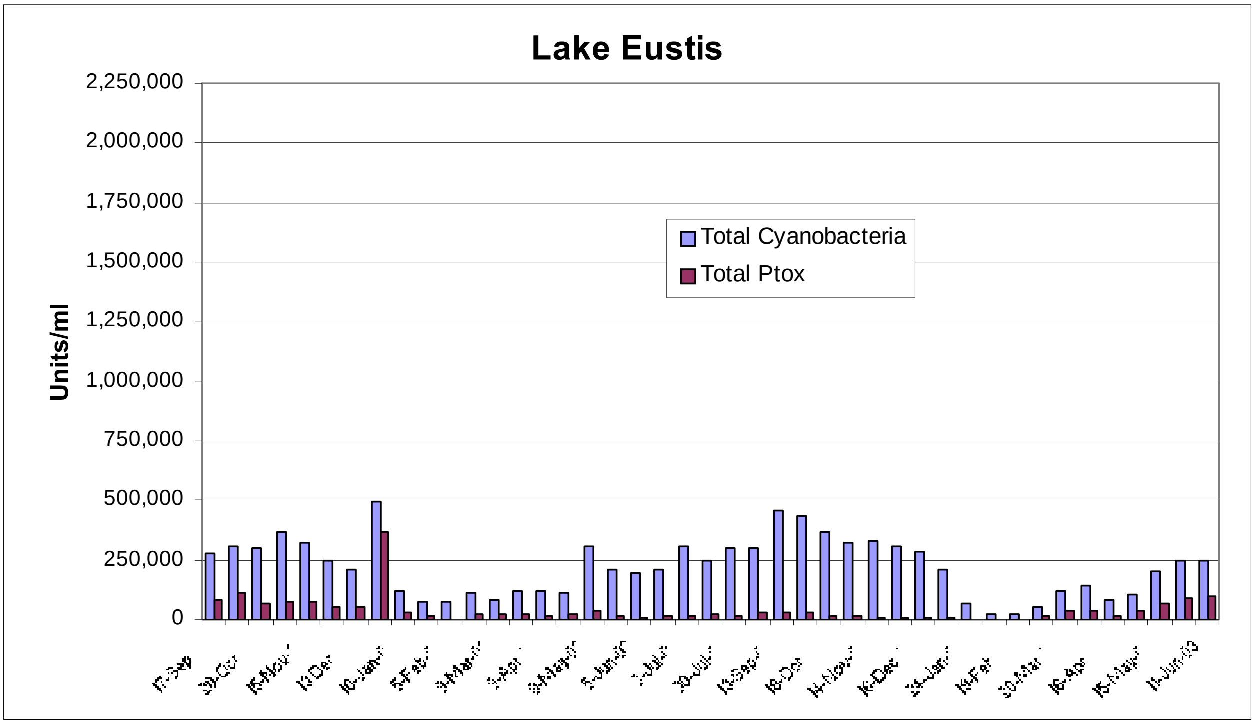


Figure 5. Microcystin levels in Lake Eustis from Lake County Water Authority.

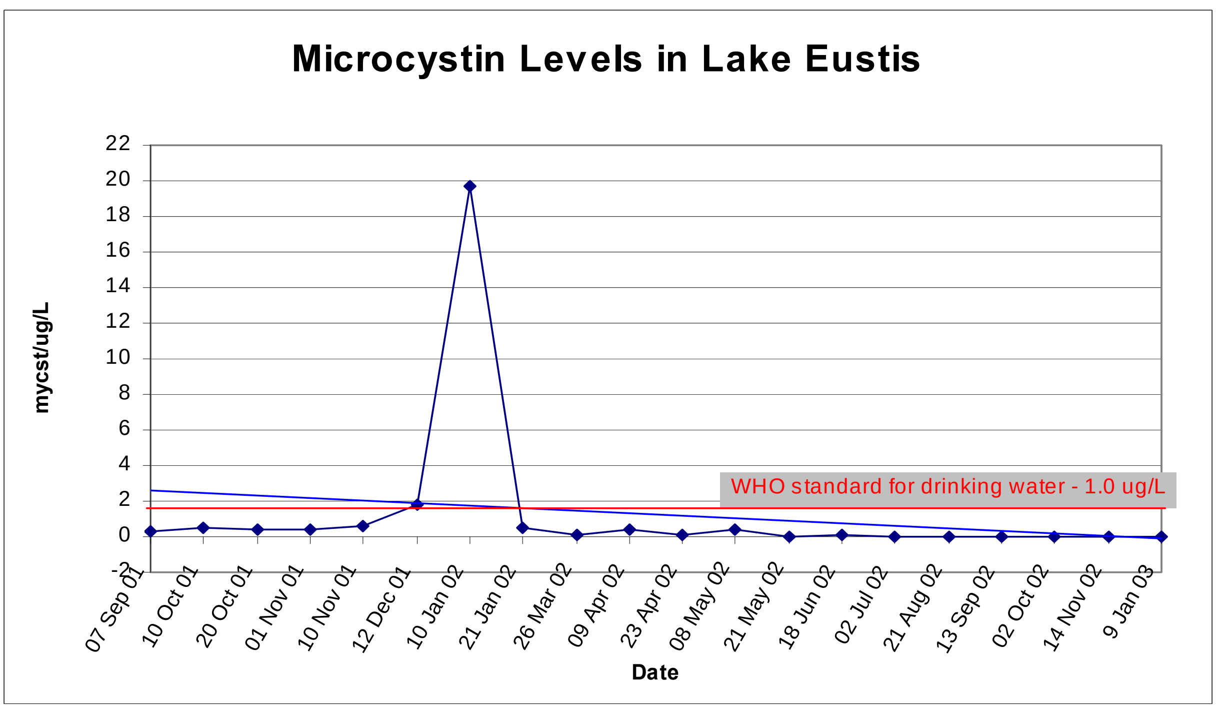


Figure 6. TN/TP cumulative frequency distribution for measurements in Lake Eustis over the 1989 – 2002 period.

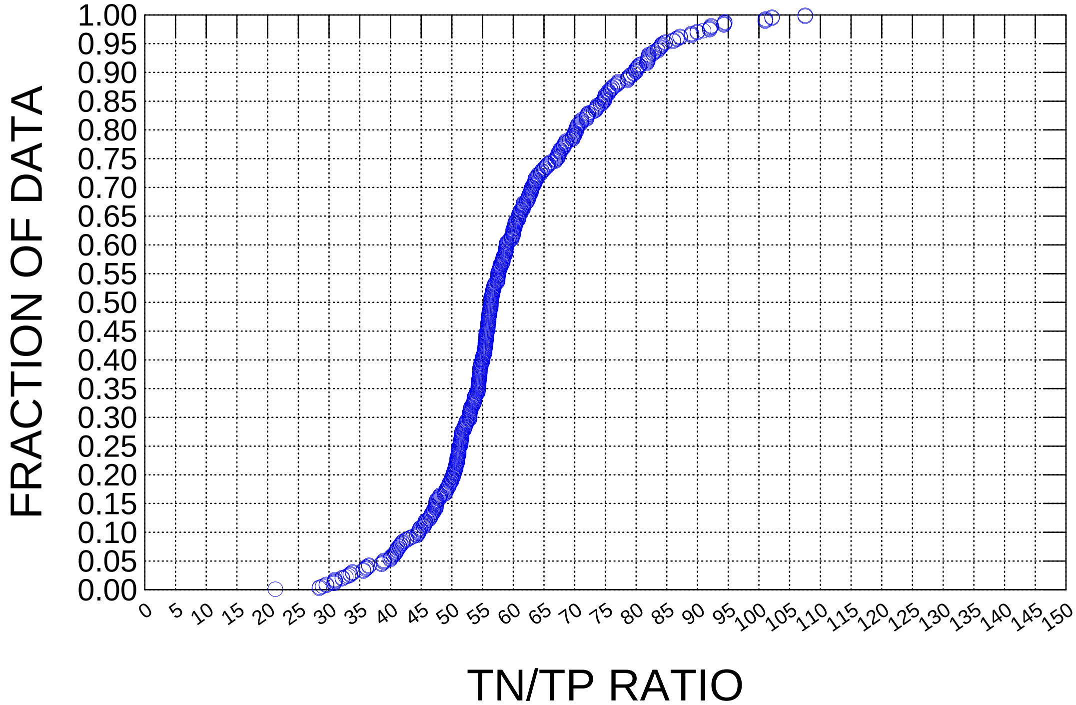
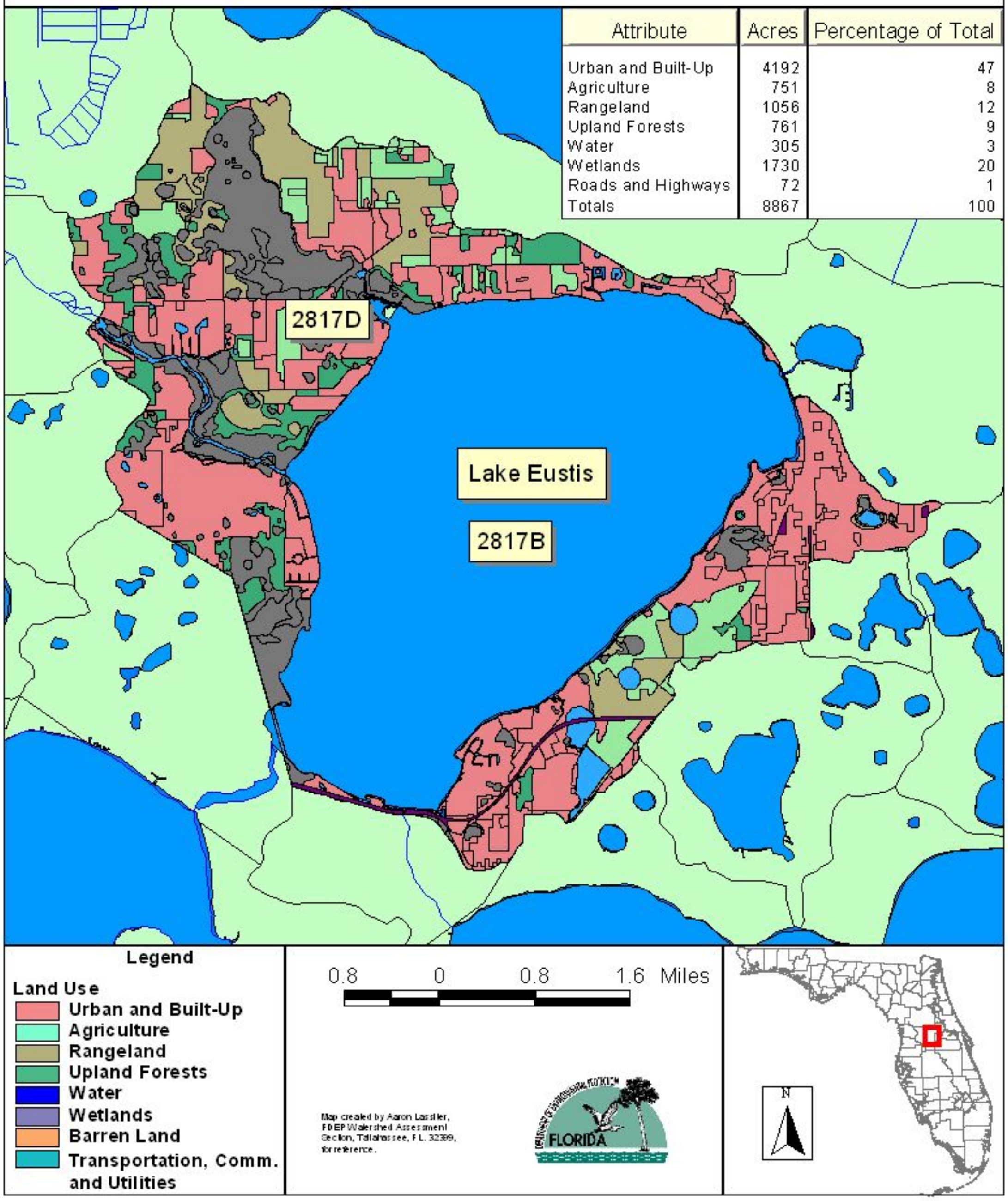


Figure 7: Lake Eustis Landuse



Attribute	Acres	Percentage of Total
Urban and Built-Up	4192	47
Agriculture	751	8
Rangeland	1056	12
Upland Forests	761	9
Water	305	3
Wetlands	1730	20
Roads and Highways	72	1
Totals	8867	100

Table 1. Lake Eustis and Haines Creek Reach dissolved oxygen, un-ionized ammonia, Chlorophyll a and/or TSI assessments under the IWR.

Parameter of concern	Haines Creek Reach	Lake Eustis
Annual Chlorophyll a or TSI	Chlorophyll a (ug/l))	Trophic State Index
1989	20.2	63.2
1990		67.1
1991	44.3	70.8
1992		68.0
1993		63.5
1994	34.6	71.6
1995	65.8	73.6
1996	34.8	74.7
1997	27.1	64.8
1998	29.1	68.6
1999	48.4	72.9
2000	26.5	65.9
2001	49.4	72.3
Dissolved Oxygen	PP – 51/137 Potentially Impaired VP – 213/375 Verified	PP – 8/138 Not Impaired VP – 6/108 Not Impaired
Un-ionized Ammonia	PP – 6/64 Not impaired VP – 2/28 Not impaired	PP – 21/78 Potentially impaired VP – 10/32 Verified
PP – Planning Period which was the January 1989 thru December 1998 period VP – Verified Period which was the January 1995 thru June 2002 period		

Table 2a. Summary statistics for Lake Eustis (WBID 2817B) of key water quality parameters over the 1989 – 2002 period.

	CHLA	CHLAC	DO	DOSAT	NH4
N of cases	457	173	201	127	142
Minimum	0.010	0.010	3.200	37.320	0.001
Maximum	155.000	188.400	11.550	136.746	0.880
Median	69.000	41.100	8.410	97.468	0.048
Mean	67.721	47.906	8.352	96.139	0.154
Standard Dev	31.169	33.215	1.641	17.553	0.207

	NO2	NO3	NO2O3	ORGN	PH
N of cases	0	0	204	51	200
Minimum	.	.	0.000	0.230	6.850
Maximum	.	.	21.700	3.130	29.700
Median	.	.	0.010	2.190	8.400
Mean	.	.	0.122	2.134	8.478
Standard Dev	.	.	1.518	0.557	1.578

	PO4	TKN	TN	TP	TURBIDITY
N of cases	0	151	707	786	206
Minimum	.	0.000	0.010	0.006	1.000
Maximum	.	4.380	4.231	0.310	26.000
Median	.	2.390	2.300	0.040	9.150
Mean	.	2.339	2.269	0.042	9.890
Standard Dev	.	0.782	0.540	0.020	5.118

	UNNH4	TNTPRATIO
N of cases	79	599
Minimum	0.000	21.286
Maximum	0.102	107.568
Median	0.007	56.389
Mean	0.018	59.363
Standard Dev	0.023	13.800

Table 2b. Summary statistics of key water quality parameters for Haines Creek Reach (WBID 2817A) over the 1989 – 2002 period.

	TEMP	TRANSM	COLOR	DO	DOSAT
N of cases	493	470	173	489	137
Minimum	7.330	0.075	5.000	0.340	7.500
Maximum	32.500	1.320	200.000	12.730	117.162
Median	23.900	0.600	30.000	4.800	65.979
Mean	23.583	0.652	41.139	5.107	65.339
Standard Dev	5.457	0.260	31.523	2.071	20.148

	BOD5	PH	TSS	TN	ORGN
N of cases	97	493	428	427	98
Minimum	1.000	5.810	2.000	0.010	0.250
Maximum	39.500	11.320	101.000	6.499	3.970
Median	3.000	7.400	14.000	2.624	1.720
Mean	3.634	7.439	15.255	2.763	1.833
Standard Dev	3.950	0.448	9.373	0.848	0.518

	AMMONIA	UNNH3	TKN	NO2NO3	TP
N of cases	148	64	400	392	529
Minimum	-0.002	0.000	0.000	0.000	0.000
Maximum	2.880	0.038	6.500	1.691	1.700
Median	0.180	0.003	2.531	0.020	0.062
Mean	0.292	0.007	2.592	0.047	0.095
Standard Dev	0.353	0.009	0.711	0.118	0.126

	ORTHOP	CHLA	CHLAC	TURBIDITY	TNTPRATIO
N of cases	343	385	394	244	84
Minimum	0.000	0.010	0.010	1.000	0
Maximum	1.362	261.330	255.481	100.000	20120
Median	0.008	38.526	34.125	8.200	45
Mean	0.025	46.060	41.862	9.545	492
Standard Dev	0.101	30.607	29.219	8.730	2891

Table 3. Ammonia Concentration (in mg/l as N) that results in un-ionized ammonia of 0.02 mg/ as NH_3

PH (s.u.)	Water Temperature (^{0} C)				
	10	15	20	25	30
6.0	88.71	60.22	41.56	29.00	20.50
6.5	28.20	19.08	13.20	9.17	6.50
7.0	8.87	6.04	4.17	2.91	2.06
7.5	2.24	1.92	1.33	0.93	0.66
8.0	0.90	0.64	0.50	0.31	0.22
8.5	0.30	0.21	0.15	0.11	0.08
9.0	0.10	0.08	0.06	0.04	0.04

Note: At a given pH, as water temperature increases, the un-ionized ammonia fraction increases.
At a fixed water temperature, as pH increases, the un-ionized ammonia fraction increases.

Table 4a. Pearson correlation matrix for Lake Eustis (WBID 2817B).

	YEAR	MONTH	CHLA	CHLAC	DO
YEAR	1.000				
MONTH	-0.027	1.000			
CHLA	0.041	0.072	1.000		
CHLAC	0.006	0.033	0.972	1.000	
DO	0.030	-0.163	0.248	0.303	1.000
DOSAT	-0.143	0.091	0.306	0.308	0.864
NH4	-0.254	-0.198	-0.305	-0.279	-0.251
NO2	.	.	.	.	.
NO3	.	.	.	.	.
NO2O3	-0.029	-0.025	-0.016	0.017	0.087
ORGN	0.192	-0.070	0.196	.	0.207
PH	0.047	0.030	0.231	0.222	0.158
PO4	.	.	.	.	.
TKN	-0.091	-0.012	0.671	0.588	0.181
TN	-0.055	-0.081	0.699	0.705	0.249
TP	-0.069	-0.191	0.431	0.157	-0.075
TURBIDITY	0.021	-0.087	0.777	0.808	0.352
UNNH4	-0.058	0.067	-0.130	0.163	-0.156
TNTPRATIO	-0.050	0.157	-0.032	-0.133	-0.080

	DOSAT	NH4	NO2	NO3	NO2O3
DOSAT	1.000				
NH4	-0.456	1.000			
NO2	.	.	.		
NO3	.	.	.	.	
NO2O3	0.182	-0.059	.	.	1.000
ORGN	0.346	-0.236	.	.	-0.249
PH	0.252	-0.157	.	.	-0.002
PO4	.	.	.	.	.
TKN	0.327	-0.042	.	.	0.042
TN	.	.	.	.	0.015
TP	-0.158	0.066	.	.	-0.077
TURBIDITY	0.377	-0.259	.	.	0.039
UNNH4	-0.030	0.339	.	.	-0.087
TNTPRATIO	.	.	.	.	-0.329

	ORGN	PH	PO4	TKN	TN
ORGN	1.000				
PH	0.452	1.000			
PO4	.	.	.		
TKN	.	0.217	.	1.000	
TN	.	0.273	.	0.999	1.000
TP	0.157	-0.095	.	0.086	0.509
TURBIDITY	0.488	0.218	.	0.579	0.875
UNNH4	0.242	0.177	.	0.171	.
TNTPRATIO	.	-0.099	.	0.527	0.297

	TP	TURBIDITY	UNNH4	TNTPRATIO
TP	1.000			
TURBIDITY	0.049	1.000		
UNNH4	0.010	0.110	1.000	
TNTPRATIO	-0.621	0.396	.	1.000

Table 4a. Continued. Pairwise frequency table

	YEAR	MONTH	CHLA	CHLAC	DO
YEAR	976				
MONTH	976	976			
CHLA	457	457	457		
CHLAC	173	173	90	173	
DO	201	201	97	117	201
DOSAT	127	127	77	51	127
NH4	142	142	96	86	99
NO2	0	0	0	0	0
NO3	0	0	0	0	0
NO2O3	204	204	97	133	160
ORGN	51	51	6	0	29
PH	200	200	95	117	199
PO4	0	0	0	0	0
TKN	151	151	89	133	129
TN	707	707	332	16	18
TP	786	786	428	134	161
TURBIDITY	206	206	101	137	164
UNNH4	79	79	55	47	79
TNTPRATIO	599	599	330	16	18

	DOSAT	NH4	NO2	NO3	NO2O3
DOSAT	127				
NH4	79	142			
NO2	0	0	0		
NO3	0	0	0	0	
NO2O3	90	141	0	0	204
ORGN	29	51	0	0	51
PH	125	99	0	0	161
PO4	0	0	0	0	0
TKN	59	90	0	0	150
TN	0	0	0	0	18
TP	91	142	0	0	204
TURBIDITY	94	139	0	0	201
UNNH4	79	79	0	0	78
TNTPRATIO	0	0	0	0	18

	ORGN	PH	PO4	TKN	TN
ORGN	51				
PH	29	200			
PO4	0	0	0		
TKN	0	130	0	151	
TN	0	18	0	18	707
TP	51	162	0	151	599
TURBIDITY	49	165	0	150	18
UNNH4	29	79	0	49	0
TNTPRATIO	0	18	0	18	599

	TP	TURBIDITY	UNNH4	TNTPRATIO
TP	786			
TURBIDITY	202	206		
UNNH4	79	78	79	
TNTPRATIO	599	18	0	599

Table 4b. Pearson correlation matrix for Haines Creek Reach (WBID 2817A)

	YEAR	TEMP	TRANSM	COLOR	DO
YEAR	1.000				
TEMP	-0.021	1.000			
TRANSM	-0.338	-0.059	1.000		
COLOR	-0.285	0.016	0.038	1.000	
DO	-0.051	-0.618	-0.242	-0.086	1.000
DOSAT	0.316	-0.233	-0.550	0.215	0.898
BOD5	0.148	0.090	-0.565	1.000	-0.273
PH	-0.029	-0.114	-0.207	-0.133	0.349
TSS	0.165	-0.040	-0.606	-0.232	0.243
TN	0.144	.	.	.	.
ORGN	0.488	0.197	-0.567	.	-0.051
AMMONIA	-0.341	-0.108	0.506	0.231	-0.382
UNNH3	-0.203	0.137	-0.269	-0.066	-0.007
TKN	0.111	0.031	-0.623	-0.078	0.119
NO2NO3	0.058	-0.166	0.190	0.255	0.045
TP	-0.032	-0.115	0.102	0.356	-0.095
ORTHOP	-0.096	-0.083	0.174	0.318	-0.117
CHLA	0.025	0.034	-0.663	-0.018	0.207
CHLAC	-0.011	0.030	-0.676	-0.028	0.218
TURBIDITY	0.310	-0.069	-0.631	0.014	0.050
TNTPRATIO	-0.036	.	.	.	.

	DOSAT	BOD5	PH	TSS	TN
DOSAT	1.000				
BOD5	-0.332	1.000			
PH	0.383	0.003	1.000		
TSS	0.332	0.370	0.173	1.000	
TN	.	.	.	.	1.000
ORGN	0.032	0.337	0.247	0.479	.
AMMONIA	-0.416	0.513	-0.243	-0.328	.
UNNH3	0.034	0.497	0.578	0.373	.
TKN	0.158	.	0.203	0.626	.
NO2NO3	-0.159	-0.202	-0.099	-0.013	.
TP	-0.398	0.721	-0.126	-0.019	-0.111
ORTHOP	.	.	-0.112	-0.091	.
CHLA	0.333	-0.219	0.132	0.631	.
CHLAC	0.322	.	0.138	0.628	.
TURBIDITY	-0.210	0.950	0.017	0.657	.
TNTPRATIO	.	.	.	.	-0.150

	ORGN	AMMONIA	UNNH3	TKN	NO2NO3
ORGN	1.000				
AMMONIA	0.062	1.000			
UNNH3	0.379	0.456	1.000		
TKN	.	-0.108	0.352	1.000	
NO2NO3	-0.160	0.232	0.048	-0.085	1.000
TP	0.153	0.479	0.338	0.031	0.103
ORTHOP	.	.	.	-0.093	0.120
CHLA	0.076	-0.253	-0.063	0.763	-0.170
CHLAC	.	-0.393	0.377	0.770	-0.175
TURBIDITY	0.328	0.382	0.397	0.702	-0.177
TNTPRATIO	.	.	.	.	.

	TP	ORTHOP	CHLA	CHLAC	TURBIDITY
TP	1.000				
ORTHOP	0.918	1.000			
CHLA	-0.016	-0.097	1.000		
CHLAC	-0.003	-0.098	0.993	1.000	
TURBIDITY	0.532	-0.141	0.537	0.852	1.000
TNTPRATIO	-0.156	.	.	.	.

	TNTPRATIO
TNTPRATIO	1.000

Table 4b. Continued. Pairwise frequency table

	YEAR	TEMP	TRANSM	COLOR	DO
YEAR	1038				
TEMP	493	493			
TRANSM	470	469	470		
COLOR	173	159	155	173	
DO	489	489	466	156	489
DOSAT	137	137	116	28	135
BOD5	97	47	30	2	45
PH	493	492	469	159	488
TSS	428	362	345	148	360
TN	427	0	0	0	0
ORGN	98	44	27	1	42
AMMONIA	148	81	61	51	78
UNNH3	64	64	44	21	62
TKN	400	373	369	171	372
NO2NO3	392	326	308	94	324
TP	529	373	354	122	370
ORTHOP	343	329	328	116	329
CHLA	385	356	347	143	354
CHLAC	394	342	337	142	341
TURBIDITY	244	181	160	150	178
TNTPRATIO	84	0	0	0	0

	DOSAT	BOD5	PH	TSS	TN
DOSAT	137				
BOD5	46	97			
PH	136	46	493		
TSS	40	56	362	428	
TN	0	0	0	0	427
ORGN	43	94	44	60	0
AMMONIA	64	95	80	109	0
UNNH3	63	44	64	36	0
TKN	26	1	373	368	0
NO2NO3	23	74	326	364	0
TP	49	96	372	397	84
ORTHOP	0	0	330	312	0
CHLA	34	10	355	362	0
CHLAC	21	1	341	360	0
TURBIDITY	70	92	180	204	0
TNTPRATIO	0	0	0	0	84

	ORGN	AMMONIA	UNNH3	TKN	NO2NO3
ORGN	98				
AMMONIA	98	148			
UNNH3	44	64	64		
TKN	0	50	20	400	
NO2NO3	76	76	22	314	392
TP	97	120	44	346	391
ORTHOP	0	0	0	343	312
CHLA	7	55	27	368	323
CHLAC	0	48	20	367	313
TURBIDITY	93	143	63	149	166
TNTPRATIO	0	0	0	0	0

	TP	ORTHOP	CHLA	CHLAC	TURBIDITY
TP	529				
ORTHOP	318	343			
CHLA	349	318	385		
CHLAC	339	317	367	394	
TURBIDITY	214	94	151	142	244
TNTPRATIO	84	0	0	0	0

	TNTPRATIO
TNTPRATIO	84

TABLE 5. ESTIMATED AVERAGE ANNUAL TOTAL PHOSPHORUS AND TOTAL NITROGEN LOADING TO LAKE EUSTIS, 1991-2000

	Lake Eustis		**Lake Eustis**	
	Mean TP load 1991-2000		**Mean TN load 1991-2000**	
Nutrient Source	**kg/year**	**%**	**kg/year**	**%**
Low density residential	22.0	0.14%	261.5	0.05%
Medium density residential	381.0	2.37%	3,005.1	0.57%
High density residential	294.6	1.83%	1,531.3	0.29%
Low density commercial	39.7	0.25%	332.0	0.06%
High density commercial	432.8	2.69%	2,963.9	0.56%
Industrial	41.5	0.26%	261.9	0.05%
Mining	0.2	0.00%	1.5	0.00%
Openland/recreational	1.0	0.01%	25.6	0.00%
Pine Meadows muck farm	338.6	2.10%	1,934.6	0.37%
Springhill muck farm	287.0	1.78%	1,602.5	0.30%
Pasture	14.9	0.09%	100.2	0.02%
Cropland	24.4	0.15%	169.6	0.03%
Tree crops	5.9	0.04%	87.1	0.02%
Feeding Operations	3.9	0.02%	46.6	0.01%
Other agriculture	9.0	0.06%	58.5	0.01%
Forest/rangeland	10.5	0.07%	249.8	0.05%
Water	39.7	0.25%	1,177.8	0.22%
Wetlands	384.0	2.38%	8,535.4	1.62%
Pine Meadows Restoration Area	552.2	3.43%	3,045.8	0.58%
Septic tanks	691.8	4.30%	12,210.8	2.31%
Precipitation	425.1	2.64%	15,220.4	2.88%
Dry deposition	595.6	3.70%	4,442.4	0.84%
Lake Dora dischargs	8,659.0	53.77%	307,572.2	58.21%
Lake Harris discharge	2,850.6	17.70%	163,574.5	30.96%
Domestic WWTP spills	0.0	0.00%	0.0	0.00%
Eustis WWTP runoff	0.2	0.00%	3.7	0.00%
Total	**16,105.0**	**100.00%**	**528,414.8**	**100.00%**

Appendix A

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, Florida Statutes (F.S.), was established as a technology-based program that relies upon 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, Florida Administrative Code (F.A.C.).

The rule requires Water Management Districts (WMDs) 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, Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka. No PLRG has been developed for Newnans Lake at the time this study was conducted.

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 to designate certain stormwater discharges as “point sources” of pollution. These stormwater discharges include certain discharges that are associated with industrial activities designated by specific Standard Industrial Classification (SIC) codes, construction sites disturbing five 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, EPA has implemented Phase 1 of the MS4 permitting program on a county-wide basis, which brings in all cities (incorporated areas), Chapter 298 urban water control districts, and the DOT (Department of Transportation) throughout the 15 counties meeting the population criteria.

An important difference between the federal and the state stormwater permitting programs is that the federal program covers both new and existing discharges while the state program focuses on new discharges. Additionally, Phase 2 of the NPDES stormwater permitting program will expand the need for these permits to construction sites between one and five acres, and to local governments with as few as 10,000 people. These revised rules require that these additional activities obtain permits by 2003. 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 can not be easily collected and treated by a central treatment facility similar to other point sources of pollution, such as domestic and industrial wastewater discharges. The DEP recently accepted delegation from EPA for the stormwater part of the NPDES program. It should be noted that most MS4 permits issued in Florida include a re-opener clause that allows permit revisions to implement TMDLs once they are formally adopted by rule.