

# **Total Maximum Daily Load for Total Phosphorus For Lake Beauclair, Lake County, Florida**

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# Phosphorus TMDL for Lake Beauclair

## 1.0 Introduction

### 1.1 Purpose of Report

This report presents a Total Maximum Daily Load (TMDL) for Total Phosphorus (TP) for Lake Beauclair and describes the projected impact of proposed TP reductions on the concentration of unionized 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, which is commonly referred to as the Impaired Waters Rule, or IWR), the lake was verified as impaired 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

### 1.2 Identification of Waterbody

Lake Beauclair, located in central Florida approximately 25 miles northwest of Orlando, is part of the Upper Ocklawaha River Basin (UORB) (Figure 1). It has a drainage area of approximately 9,296 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 439 ha (1,085 acres) and an average depth of 2.05 m (6.7 ft). Surface outflow from the lake is to Lake Dora. Surface elevations in Lakes Eustis, Harris, Dora, and Beauclair are controlled by the Burrell Lock and Dam located on Haines Creek and is operated by the SJRWMD.

For assessment purposes, the watersheds within the Ocklawaha River Basin have been broken out into smaller watersheds, with a unique **waterbody identification** (WBID) number for each watershed. Lake Beauclair has been assigned WBID 2834C.

## 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 St. Johns River Water Management District (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. Fulton (1995) estimated that Apopka-Beauclair Canal discharges accounted for 85% of the phosphorus loading and 91.5% of the nitrogen loading to Lake Beauclair.

Plots of key water quality parameters over the 1989 – 2002 period indicate that certain water quality parameters have improved while others declined over this period, but that the ranges for some parameters have decreased over time (Figures 2<sup>1</sup> and 3<sup>2</sup>). Table 1 summarizes the Trophic State Index (TSI) annual averages used to assess Lake Beauclair under the IWR. Statistical summaries of key water quality parameters are presented for the lake 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 Beauclair 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 Beauclair. 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 above the World Health Institute threshold for drinking water in a number of samples between November 2001 and June 2002. It appears, however, that there has been a decline in the microcystin levels from the peak levels in November 2001.

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

Lake Beauclair is a Class III waterbody 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 narrative nutrient criterion (nutrient concentrations of a body of water shall not be altered so as to cause

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<sup>1</sup>). Figure 2 presents water quality information on an annual basis and suggests some reduction in ranges for some parameters over time.

<sup>2</sup> Figure 3 presents the individual observations over time and includes trendlines. Although the  $r^2$  values were low, slopes (with the exception of total phosphorus, and un-ionized ammonia) were positive, suggesting declining water quality with time.

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 Beauclair 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. These approaches yielded a TP target of 32 ug/l for Lake Beauclair.

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 lake chlorophyll a levels 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, 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, 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 Beauclair data. Based on Pearson correlation coefficients for this data set (Table 4), total phosphorus is positively correlated with turbidity, DO, corrected chlorophyll a, ammonia,  $\text{NO}_2\text{NO}_3$  and TKN, and organic nitrogen. The correlation is negative between pH and total phosphorus.

This positive correlation between pH and chlorophyll a reflects changes to the carbonate balance in the water column as  $\text{CO}_2$  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 °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.

It should be noted that 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 Beauclair over the 1989 – 2002 period. Approximately half of the values fall in the co-limiting range and half are 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 7). 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 Beauclair, 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 the Apopka-Beauclair Canal and Lake Carlton 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 21,171.2 kg. The Apopka-Beauclair Canal discharge represented 93.3% of the load to Lake Beauclair. Total nitrogen was estimated at 326,013.4 kg/year, with the Apopka-Beauclair Canal discharge representing 95.33% of the total load. No permitted industrial or domestic wastewater sources were identified as contributors of either the phosphorus or nitrogen load to the lake.

#### 5.0 Loading Capacity – Linking Water Quality and Pollutant Sources

Fulton et al. (2003) calculated a mean lake TP concentration of 209 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 Beauclair was 32 ug/l. Fulton estimated that a 85 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 (32 ug/l) to the existing phosphorus concentration (209 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 209 ug/l and an average TN of 4.0 mg/l, the  $Nutrient_{TSI}$  would be 82.2, and using a long-term average  $Chla$  of 180 ug/l, the  $Chla_{TSI}$  would be 91.6. Thus, the long-term average TSI under the current conditions is approximately 87. Reducing the in-lake phosphorus concentration to 32 ug/l would result in a  $Nutrient_{TSI}$  of 58. Fulton (2003a) provided a preliminary evaluation of the effects of the interim PLRG and predicted a mean  $Chla$  of 30 ug/l. At this concentration, the  $Chla_{TSI}$  would drop too less than 66.

## 6.0 Critical Conditions

Phosphorus reductions proposed by the SJRWMD were based upon a 10-year average phosphorus load to Lake Beauclair. 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:

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

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:

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

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(l)], 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 Beauclair (Table 6) is expressed in terms of pounds per year, and represent the annual load the lake can assimilate and maintain the narrative nutrient criterion. The LA includes the atmospheric contribution (311 lbs/year).

**Table 6. TMDL Components**

| WBID  | Parameter | WLA                      |                                      | LA<br>(lbs/year) | MOS      | TMDL<br>(lbs/year) | Percent<br>Reduction |
|-------|-----------|--------------------------|--------------------------------------|------------------|----------|--------------------|----------------------|
|       |           | Wastewater<br>(lbs/year) | NPDES<br>Stormwater<br>(% Reduction) |                  |          |                    |                      |
| 2834C | TP        | N/A                      | 85%                                  | 7,056            | Implicit | 7,056              | 85 <sup>1</sup>      |

<sup>1</sup> 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 7,056 lbs/year for TP. This corresponds to reductions from the existing loadings of 85 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, the Apopka-Beauclair Canal discharge contributes over 93% of both the phosphorus and nitrogen load to Lake. Since a TMDL has recently been completed for Lake Apopka for phosphorus and requires a major reduction in phosphorus loading, there should be a significant reduction in the Apopka-Beauclair Canal discharge to Lake Beauclair.

### 7.2 Wasteload Allocations (WLAs)

#### NPDES Stormwater Discharges

As noted previously, 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 Beauclair watershed includes areas that will be covered by the MS4 Program, and the WLA for stormwater discharges is an 85 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 Beauclair will also influence the percent reduction that MS4 areas will need to meet for the TMDL for the lake to be achieved.

#### NPDES Wastewater Discharges

There were no wastewater facilities authorized to discharge wastewater to Lake Beauclair and the WLA for wastewater is not applicable.

### **7.3 Relationship between Lake Apopka, Lake Carlton, Lake Beauclair and Lake Dora TMDLs**

It should also be noted with respect to possible reductions in either the WLA or LA to achieve the TMDL, discharge from Lake Apopka via the Apopka-Beauclair Canal currently represents approximately 93 percent of the annual load of phosphorus to Lake Beauclair. A TMDL has been adopted for Lake Apopka that specifies a significant phosphorus load reduction. Lake Carlton is a sub-basin of the Lake Beauclair watershed, and a TMDL for Lake Carlton has also been proposed for phosphorus. Consequently, implementation of these TMDLs will reduce their contributions to Lake Beauclair and assist in achieving the TMDL for the lake.

The proposed TMDL for Lake Dora estimated that discharge from Lake Beauclair currently contributes nearly 91 percent of the total annual phosphorus load for Lake Dora. Reductions in phosphorus loading to and from Lake Beauclair as a result of this TMDL will also become a factor in how the TMDL for Lake Dora 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.

## **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.

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Figure 1. Upper Ocklawaha River Chain of Lakes

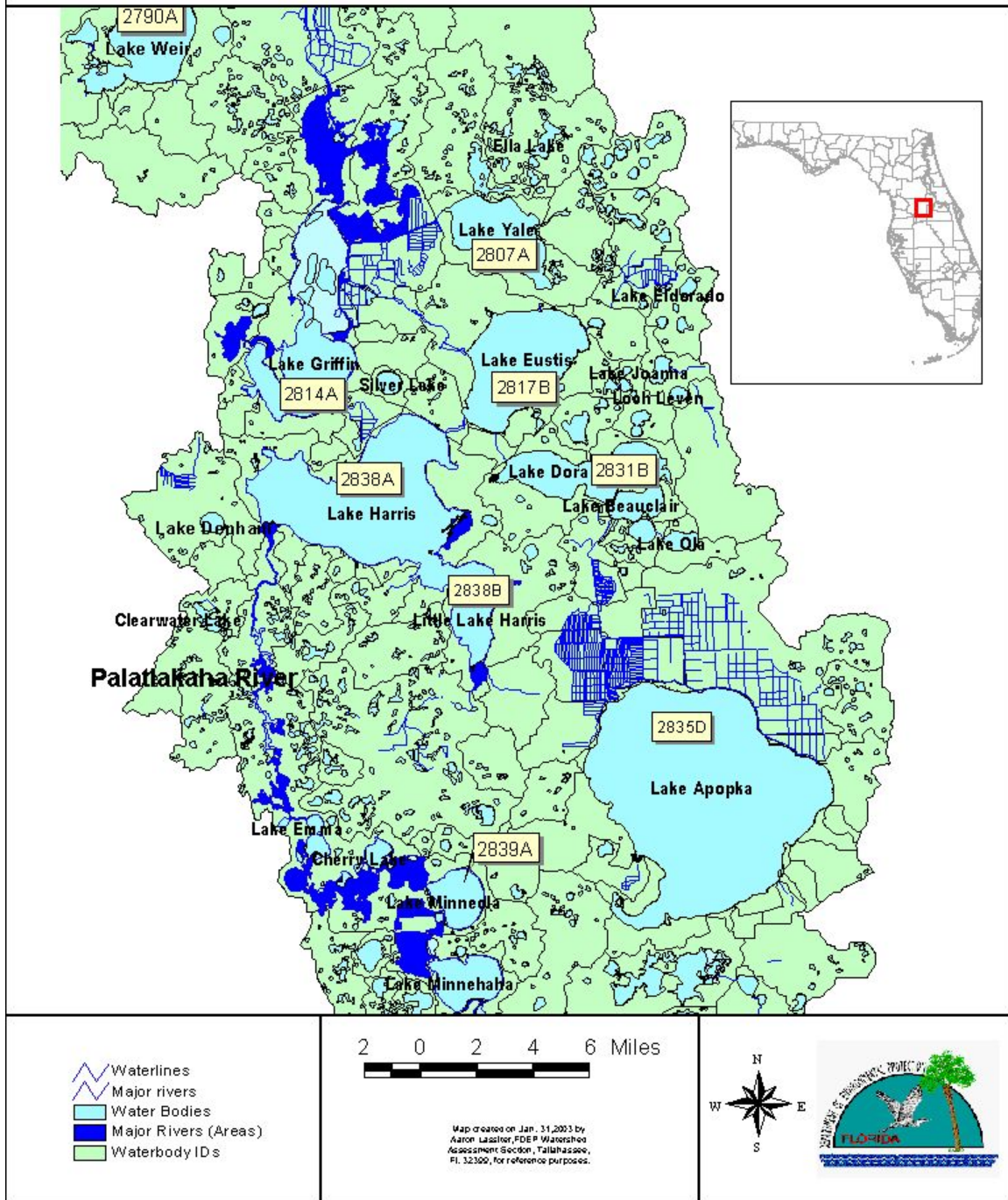


Figure 2. Boxplots of water quality by year in Lake Beauclair (WBID 2834C) for the 1989 - 2002 period.

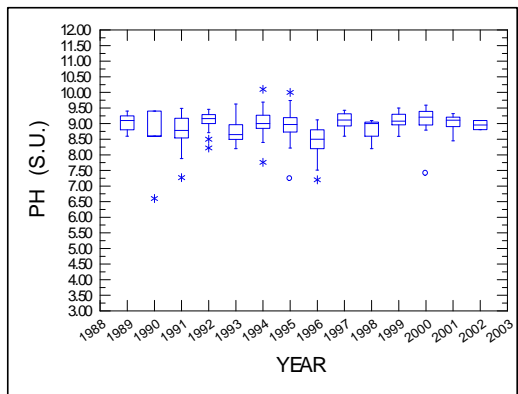
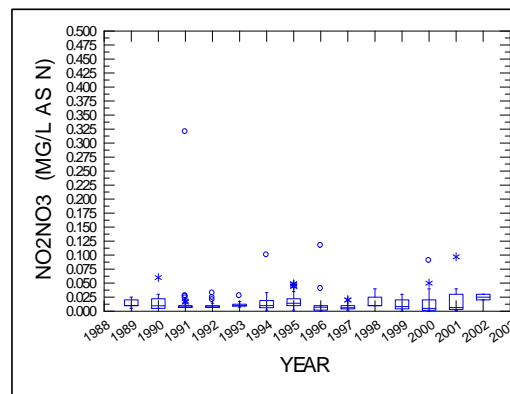
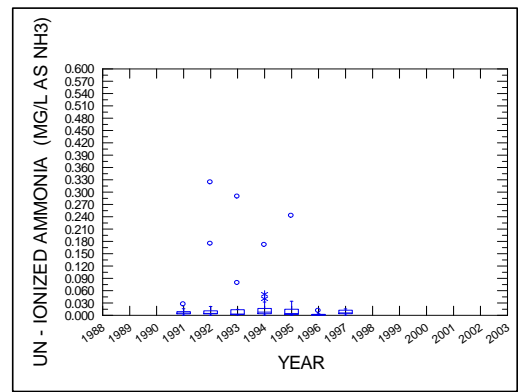
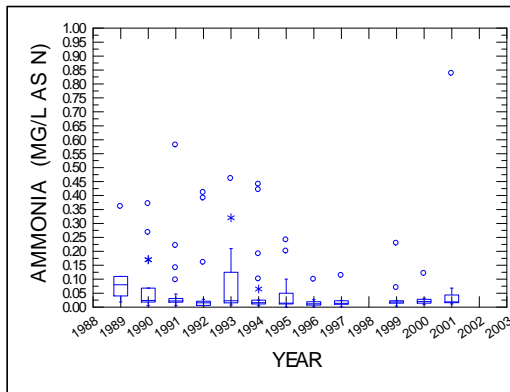
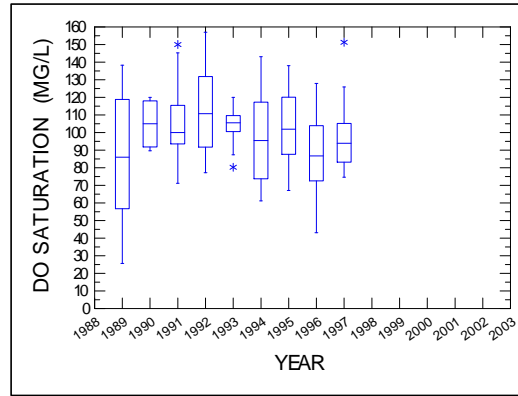
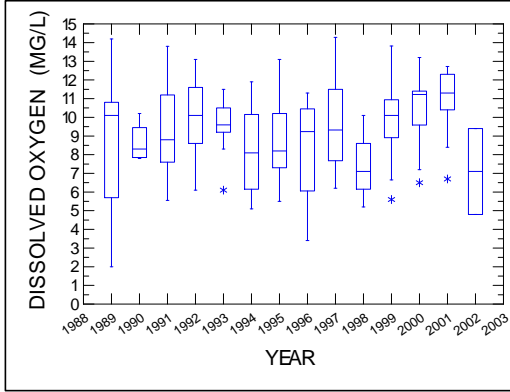
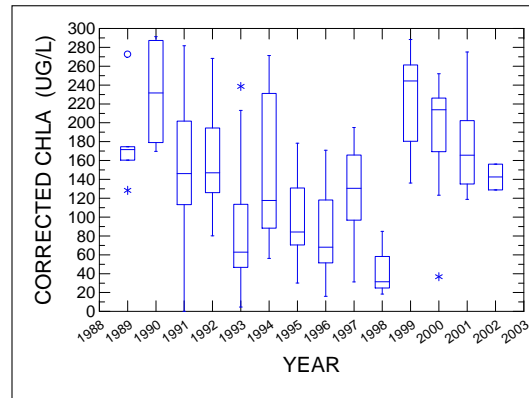
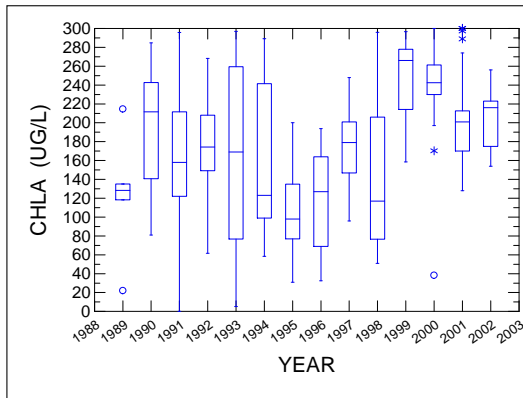
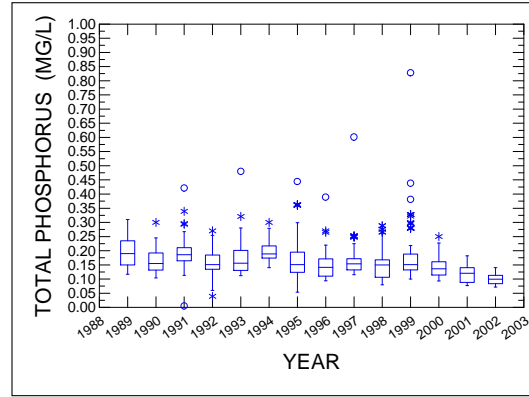
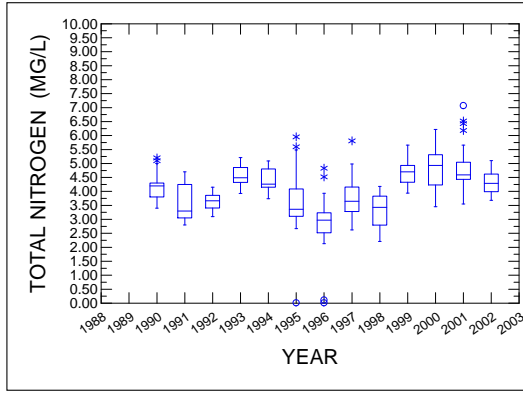


Figure 2. Continued.





**Figure 3. Time series of Lake Beauclair (WBID 2834C) water quality data over the 1989 – 2002 period.**

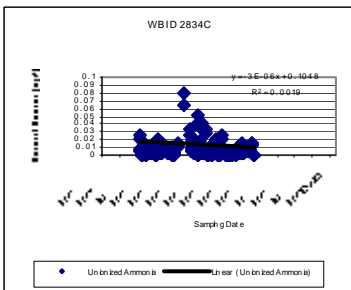
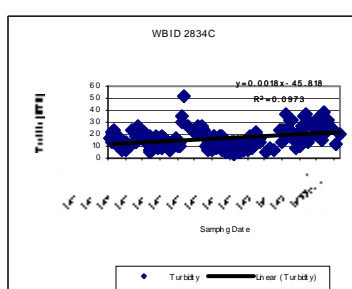
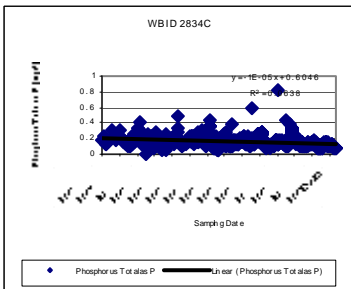
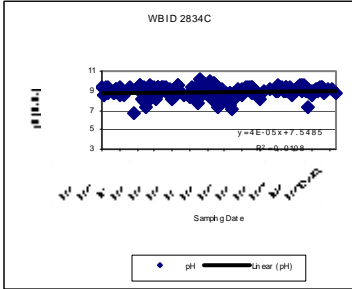
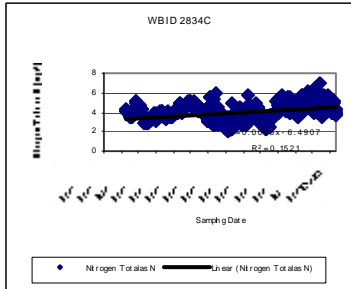
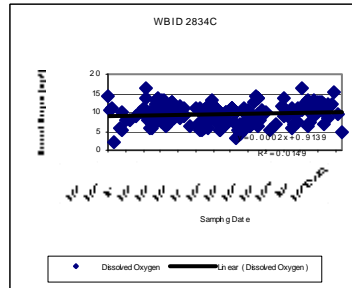
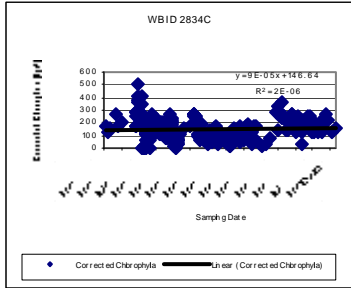




Figure 4. Cyanobacteria levels (biovolumes) in Lake Beauclair from Lake County Water Authority.

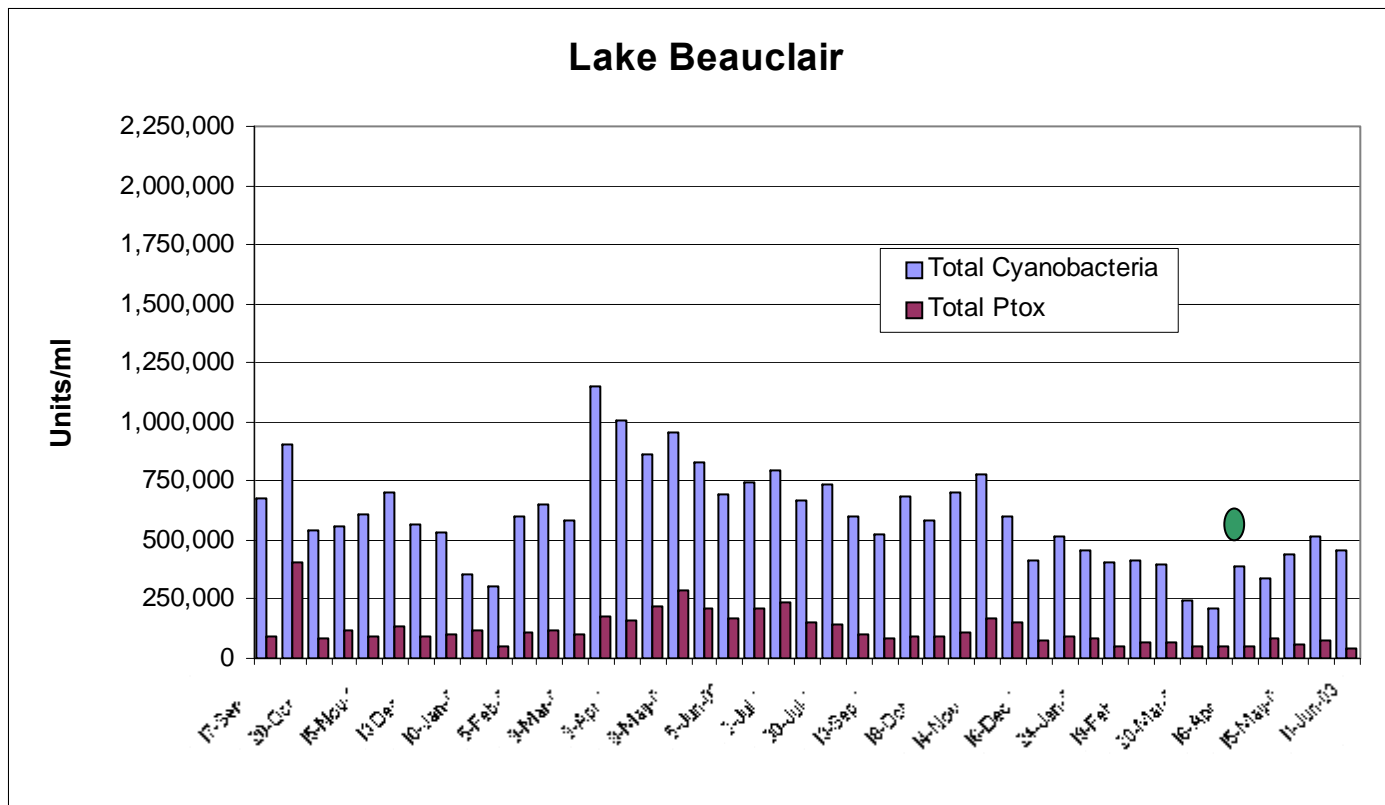
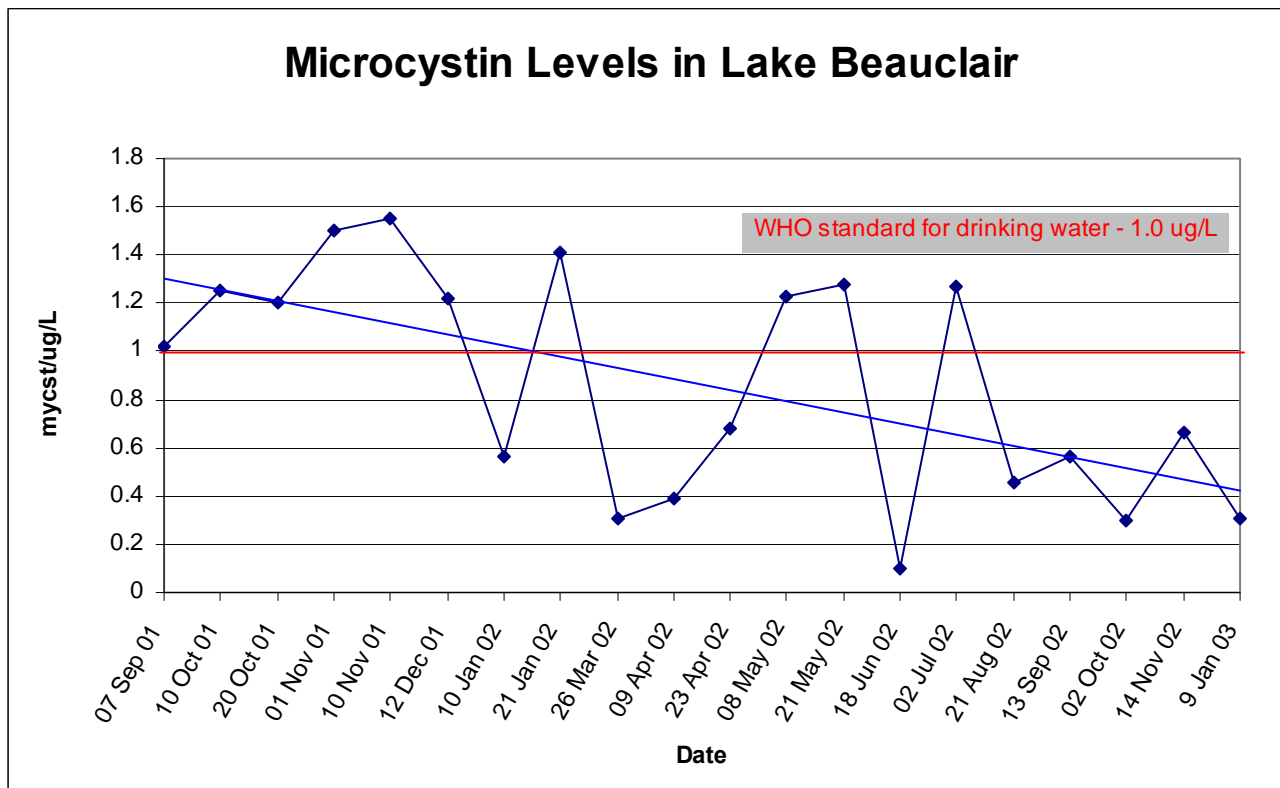
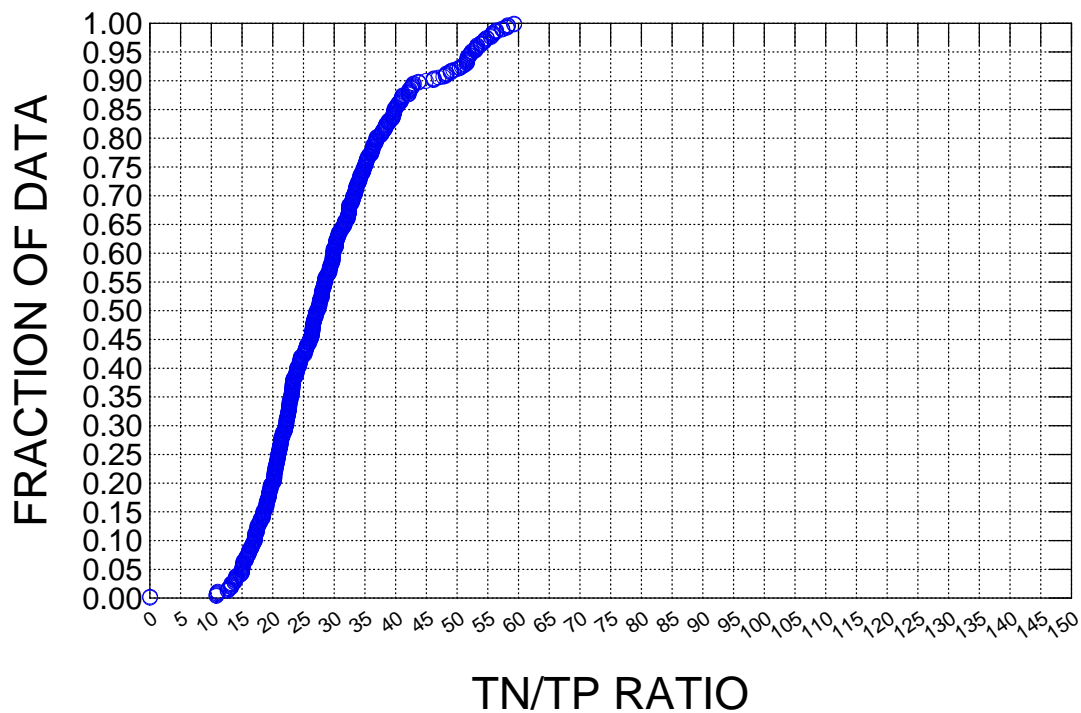


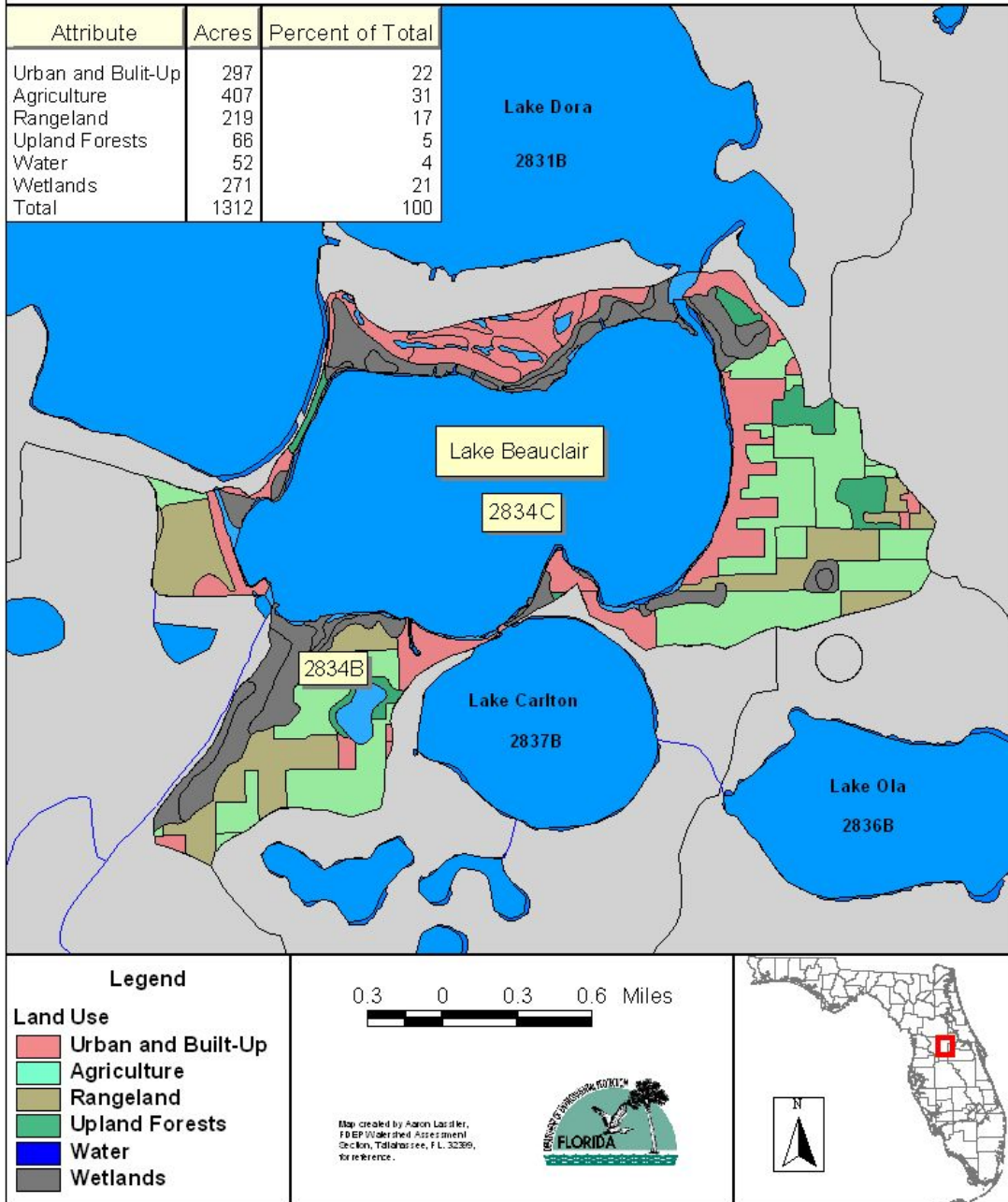
Figure 5. Microcystin levels in Lake Beauclair from Lake County Water Authority.



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



# Figure 7: Lake Beauclair Landuse



**Table 1. Lake Beauclair un-ionized ammonia TSI assessments under the IWR.**

|                      |  |
|----------------------|--|
| Parameter of concern | Lake Eustis  |
| Annual TSI           | Trophic State Index                                |
| 1989                 |  |
| 1990                 |  |
| 1991                 | 86.0   |
| 1992                 | 84.7   |
| 1993                 | 88.4   |
| 1994                 | 86.0   |
| 1995                 | 83.0   |
| 1996                 | 80.2   |
| 1997                 | 85.0   |
| 1998                 | 82.8   |
| 1999                 | 81.8   |
| 2000                 | 92.0   |
| 2001                 | 91.0   |
| Un-ionized Ammonia   | PP – 14/132 Not impaired<br>VP – 4/46 Not impaired |

**Table 2. Summary statistics of key water quality parameters for Lake Beauclair (WBID 2834C) over the 1989 – 2002 period.**

|              | CHLA    | CHLAC   | DO      | DOSAT    | NH4   |
|--------------|---------|---------|---------|----------|-------|
| N of cases   | 659     | 271     | 213     | 155      | 212   |
| Minimum      | 0.000   | 0.000   | 2.000   | 25.652   | 0.000 |
| Maximum      | 438.000 | 498.514 | 415.950 | 4521.190 | 0.837 |
| Median       | 175.235 | 144.342 | 9.800   | 102.062  | 0.019 |
| Mean         | 180.108 | 149.807 | 11.587  | 138.560  | 0.052 |
| Standard Dev | 76.319  | 82.006  | 28.284  | 361.039  | 0.106 |

|              | NO2   | NO3 | NO2O3  | ORGN  | PH     |
|--------------|-------|-----|--------|-------|--------|
| N of cases   | 1     | 0   | 240    | 24    | 219    |
| Minimum      | 0.010 | .   | -0.003 | 0.000 | 6.600  |
| Maximum      | 0.010 | .   | 0.320  | 7.000 | 10.100 |
| Median       | 0.010 | .   | 0.009  | 3.915 | 9.000  |
| Mean         | 0.010 | .   | 0.015  | 3.790 | 8.933  |
| Standard Dev | .     | .   | 0.025  | 1.273 | 0.491  |

|              | PO4 | TKN   | TN    | TP    | TURBIDITY |
|--------------|-----|-------|-------|-------|-----------|
| N of cases   | 0   | 220   | 783   | 918   | 242       |
| Minimum      | .   | 0.000 | 0.010 | 0.005 | 3.700     |
| Maximum      | .   | 7.290 | 7.070 | 0.828 | 52.000    |
| Median       | .   | 4.340 | 4.050 | 0.150 | 14.950    |
| Mean         | .   | 4.348 | 3.997 | 0.161 | 16.208    |
| Standard Dev | .   | 1.084 | 0.888 | 0.062 | 7.384     |

|              | UNNH4 | TNTPRATIO |
|--------------|-------|-----------|
| N of cases   | 140   | 681       |
| Minimum      | 0.000 | 0.045     |
| Maximum      | 0.323 | 59.302    |
| Median       | 0.005 | 27.358    |
| Mean         | 0.016 | 29.072    |
| Standard Dev | 0.046 | 10.952    |



**Table 3. Ammonia Concentration (in mg/l as N) that results in un-ionized ammonia of 0.02 mg/ as NH<sub>3</sub>**

| PH (s.u.) | Water Temperature (° 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 4. Pearson correlation matrix for Lake Beauclair (WBID 2834C).

|           | YEAR   | MONTH  | CHLA   | CHLAC  | DO     |
|-----------|--------|--------|--------|--------|--------|
| YEAR      | 1.000  |        |        |        |        |
| MONTH     | -0.064 | 1.000  |        |        |        |
| CHLA      | 0.244  | 0.112  | 1.000  |        |        |
| CHLAC     | 0.002  | -0.009 | 0.888  | 1.000  |        |
| DO        | -0.070 | -0.075 | 0.130  | 0.148  | 1.000  |
| DOSAT     | -0.085 | -0.075 | 0.177  | 0.212  | 0.999  |
| NH4       | -0.056 | -0.041 | -0.084 | -0.011 | 0.001  |
| NO2       | .      | .      | .      | .      | .      |
| NO3       | .      | .      | .      | .      | .      |
| NO2O3     | -0.002 | -0.025 | -0.035 | -0.009 | -0.016 |
| ORGN      | -0.301 | -0.093 | -0.987 | .      | -0.009 |
| PH        | 0.105  | -0.001 | 0.256  | 0.342  | 0.109  |
| PO4       | .      | .      | .      | .      | .      |
| TKN       | 0.190  | -0.014 | 0.497  | 0.521  | 0.013  |
| TN        | 0.370  | 0.126  | 0.721  | 0.586  | 0.283  |
| TP        | -0.245 | -0.080 | -0.000 | 0.102  | 0.014  |
| TURBIDITY | 0.313  | -0.030 | 0.424  | 0.450  | -0.008 |
| UNNH4     | -0.044 | 0.011  | -0.079 | 0.225  | 0.020  |
| TNTPRATIO | 0.432  | 0.113  | 0.338  | 0.450  | -0.450 |

|           | DOSAT  | NH4    | NO2   | NO3   | NO2O3  |
|-----------|--------|--------|-------|-------|--------|
| DOSAT     | 1.000  |        |       |       |        |
| NH4       | 0.006  | 1.000  |       |       |        |
| NO2       | .      | .      | 1.000 |       |        |
| NO3       | .      | .      | .     | 1.000 |        |
| NO2O3     | -0.014 | 0.021  | .     | .     | 1.000  |
| ORGN      | 0.202  | 0.391  | .     | .     | 0.166  |
| PH        | 0.119  | -0.114 | .     | .     | 0.016  |
| PO4       | .      | .      | .     | .     | .      |
| TKN       | 0.014  | 0.094  | .     | .     | -0.035 |
| TN        | .      | .      | .     | .     | 0.147  |
| TP        | -0.003 | 0.035  | .     | .     | 0.001  |
| TURBIDITY | -0.008 | 0.133  | .     | .     | -0.031 |
| UNNH4     | 0.026  | 0.821  | .     | .     | -0.022 |
| TNTPRATIO | .      | .      | .     | .     | -0.096 |

|           | ORGN  | PH     | PO4   | TKN   | TN     |
|-----------|-------|--------|-------|-------|--------|
| ORGN      | 1.000 |        |       |       |        |
| PH        | 0.273 | 1.000  |       |       |        |
| PO4       | .     | .      | 1.000 |       |        |
| TKN       | .     | 0.343  | .     | 1.000 |        |
| TN        | .     | 0.008  | .     | 1.000 | 1.000  |
| TP        | 0.538 | -0.057 | .     | 0.178 | 0.007  |
| TURBIDITY | 0.618 | 0.325  | .     | 0.700 | -0.084 |
| UNNH4     | 0.403 | 0.168  | .     | 0.178 | .      |
| TNTPRATIO | .     | -0.219 | .     | 0.424 | 0.576  |

|           | TP     | TURBIDITY | UNNH4 | TNTPRATIO |
|-----------|--------|-----------|-------|-----------|
| TP        | 1.000  |           |       |           |
| TURBIDITY | 0.099  | 1.000     |       |           |
| UNNH4     | 0.068  | 0.292     | 1.000 |           |
| TNTPRATIO | -0.719 | 0.404     | .     | 1.000     |

Table 4. Continued. Pairwise frequency table

|           | YEAR | MONTH | CHLA | CHLAC | DO  |
|-----------|------|-------|------|-------|-----|
| YEAR      | 1111 |       |      |       |     |
| MONTH     | 1111 | 1111  |      |       |     |
| CHLA      | 659  | 659   | 659  |       |     |
| CHLAC     | 271  | 271   | 228  | 271   |     |
| DO        | 213  | 213   | 167  | 181   | 213 |
| DOSAT     | 155  | 155   | 133  | 123   | 155 |
| NH4       | 212  | 212   | 184  | 173   | 171 |
| NO2       | 1    | 1     | 0    | 0     | 0   |
| NO3       | 0    | 0     | 0    | 0     | 0   |
| NO2O3     | 240  | 240   | 180  | 192   | 198 |
| ORGN      | 24   | 24    | 3    | 0     | 14  |
| PH        | 219  | 219   | 170  | 184   | 213 |
| PO4       | 0    | 0     | 0    | 0     | 0   |
| TKN       | 220  | 220   | 181  | 197   | 188 |
| TN        | 783  | 783   | 404  | 9     | 9   |
| TP        | 918  | 918   | 590  | 197   | 203 |
| TURBIDITY | 242  | 242   | 185  | 197   | 203 |
| UNNH4     | 140  | 140   | 127  | 124   | 137 |
| TNTPRATIO | 681  | 681   | 404  | 9     | 9   |

|           | DOSAT | NH4 | NO2 | NO3 | NO2O3 |
|-----------|-------|-----|-----|-----|-------|
| DOSAT     | 155   |     |     |     |       |
| NH4       | 137   | 212 |     |     |       |
| NO2       | 0     | 1   | 1   |     |       |
| NO3       | 0     | 0   | 0   | 0   |       |
| NO2O3     | 140   | 207 | 1   | 0   | 240   |
| ORGN      | 14    | 24  | 0   | 0   | 24    |
| PH        | 155   | 176 | 1   | 0   | 204   |
| PO4       | 0     | 0   | 0   | 0   | 0     |
| TKN       | 130   | 188 | 1   | 0   | 215   |
| TN        | 0     | 0   | 0   | 0   | 9     |
| TP        | 145   | 212 | 1   | 0   | 240   |
| TURBIDITY | 145   | 209 | 0   | 0   | 237   |
| UNNH4     | 137   | 140 | 0   | 0   | 135   |
| TNTPRATIO | 0     | 0   | 0   | 0   | 9     |

|           | ORGN | PH  | PO4 | TKN | TN  |
|-----------|------|-----|-----|-----|-----|
| ORGN      | 24   |     |     |     |     |
| PH        | 14   | 219 |     |     |     |
| PO4       | 0    | 0   | 0   |     |     |
| TKN       | 0    | 194 | 0   | 220 |     |
| TN        | 0    | 9   | 0   | 9   | 783 |
| TP        | 24   | 209 | 0   | 220 | 681 |
| TURBIDITY | 23   | 208 | 0   | 218 | 9   |
| UNNH4     | 14   | 140 | 0   | 126 | 0   |
| TNTPRATIO | 0    | 9   | 0   | 9   | 681 |

|           | TP  | TURBIDITY | UNNH4 | TNTPRATIO |
|-----------|-----|-----------|-------|-----------|
| TP        | 918 |           |       |           |
| TURBIDITY | 242 | 242       |       |           |
| UNNH4     | 140 | 140       | 140   |           |
| TNTPRATIO | 681 | 9         | 0     | 681       |

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

| Nutrient Source                  | Lake Beauclair         |                | Lake Beauclair         |                |
|----------------------------------|------------------------|----------------|------------------------|----------------|
|                                  | Mean TP load 1991-2000 |                | Mean TN load 1991-2000 |                |
|                                  | kg/year                | %              | kg/year                | %              |
| Low density residential          | 46.5                   | 0.22%          | 510.0                  | 0.16%          |
| Medium density residential       | 42.2                   | 0.20%          | 326.7                  | 0.10%          |
| High density residential         | 0.0                    | 0.00%          | 0.0                    | 0.00%          |
| Low density commercial           | 4.1                    | 0.02%          | 47.8                   | 0.01%          |
| High density commercial          | 11.3                   | 0.05%          | 86.6                   | 0.03%          |
| Industrial                       | 7.1                    | 0.03%          | 41.8                   | 0.01%          |
| Mining                           | 0.0                    | 0.00%          | 0.0                    | 0.00%          |
| Openland/recreational            | 1.1                    | 0.01%          | 26.3                   | 0.01%          |
| Hurley muck farm                 | 771.8                  | 3.65%          | 4,399.2                | 1.35%          |
| Pasture                          | 48.2                   | 0.23%          | 333.1                  | 0.10%          |
| Cropland                         | 44.9                   | 0.21%          | 310.4                  | 0.10%          |
| Tree crops                       | 33.3                   | 0.16%          | 491.5                  | 0.15%          |
| Feeding Operations               | 0.0                    | 0.00%          | 0.0                    | 0.00%          |
| Other agriculture                | 17.5                   | 0.08%          | 110.0                  | 0.03%          |
| Forest/rangeland                 | 23.2                   | 0.11%          | 561.2                  | 0.17%          |
| Water                            | 45.4                   | 0.21%          | 1,324.1                | 0.41%          |
| Wetlands                         | 95.2                   | 0.45%          | 2,117.5                | 0.65%          |
| Septic tanks                     | 87.5                   | 0.41%          | 1,545.1                | 0.47%          |
| Precipitation                    | 58.9                   | 0.28%          | 2,107.2                | 0.65%          |
| Dry deposition                   | 82.2                   | 0.39%          | 612.5                  | 0.19%          |
| Apopka-Beauclair Canal discharge | 19,744.1               | 93.26%         | 310,783.9              | 95.33%         |
| Lake Dora discharge              | 6.8                    | 0.03%          | 278.3                  | 0.09%          |
| <b>Total</b>                     | <b>21,171.2</b>        | <b>100.00%</b> | <b>326,013.4</b>       | <b>100.00%</b> |

## 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.