# FINAL

# Nutrient TMDL for Lake Weir (WBID 2790A)

## and Documentation in Support of the Development of Site-Specific Numeric Interpretations of the Narrative Nutrient Criteria

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# CHAPTER 1: INTRODUCTION

## 1.1 Purpose of Report

This report presents the total maximum daily loads (TMDLs) for nutrients for Lake Weir in the Ocklawaha River Basin. The TMDLs will constitute the site-specific numeric interpretation of the narrative nutrient criterion set forth in Paragraph 62-302.530(47)(b), Florida Administrative Code (F.A.C.), that will replace the otherwise applicable numeric nutrient criteria (NNC) in Subsection 62-302.531(2), F.A.C., for this particular water.

The lake was verified as impaired for nutrients because of elevated annual average Trophic State Index (TSI) values, and was included on the Verified List of impaired waters for the Ocklawaha Basin adopted by Secretarial Order on August 28, 2002. The nutrient impairment was confirmed in the Cycle 2 and 3 assessment periods. According to the 1999 Florida Watershed Restoration Act (FWRA) (Chapter 99-223, Laws of Florida), once a waterbody is placed on the Verified List, a TMDL must be developed. The purpose of this TMDL analysis is to establish the allowable loadings of pollutants to Lake Weir that would restore the waterbody so that it meets its applicable water quality criteria for nutrients.

## 1.2 Identification of Waterbody

Lake Weir is a 5,600-acre lake located in Marion County in central Florida, approximately 15 miles southeast of Ocala and approximately 15 miles north of Leesburg, in the Ocklawaha River Basin and the Marshall Swamp Planning Unit (**Figure 1.1**). This area is situated in the Lake Weir/Leesburg Upland Lake Region (Region 75-14), which is characterized by high elevations ranging from 75 to 125 feet with well-drained sandy soils above deeply weathered, clayey sand (Griffith *et al*. 1997). The lakes in this region are predominantly clear, acidic to neutral, and oligotrophic to mesotrophic.

Lake Weir is the largest lake in the region. The lake consists of two distinct portions: Lake Weir proper and Sunset Harbor (**Figure 1.2**). There are no major inlet streams to the lake, except a canal connecting Little Lake Weir (located west of Lake Weir) and Sunset Harbor. When water levels are higher, surface water may discharge to the Ocklawaha River over a weir structure located in the northeast corner of the lake (see **Table A-4 f**or downstream protection). The major sources of water to the lake include surface runoff from the watershed, seepage flow from ground water, and direct rainfall onto the lake.

Based on lake stage data collected for the period from 2000 to 2012, the long-term average stage of the lake was 53.1 feet National Geodetic Vertical Datum (NGVD). The elevation of the Floridan aquifer in the area of Lake Weir was 45 feet NGVD, suggesting that ground water influence on the lake may primarily come from the surficial aquifer. Long-term average annual rainfall, based on the Doppler radar converted rainfall data for the period from 2000 through 2012 provided by the St. Johns River Water Management District (SJRWMD), was 47 inches per year. The annual average air temperature, based on data collected for the period from 2000 to 2012 from a National Weather Service (NWS) weather station located (29.16 N, -82.08 W) in Ocala, was 22°C. The summer maximum temperature ranged from 35 to 38°C. The winter minimum temperature ranged from -6° to 1°C.

For assessment purposes, the Florida Department of Environmental Protection (DEP) has divided the Ocklawaha River Basin into water assessment polygons with a unique **w**ater**b**ody **id**entification (WBID) number for each watershed or stream reach. Lake Weir is WBID 2790A.  This TMDL report addresses the nutrient impairment of the lake.

## 1.3 Background

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

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

This TMDL report will be followed by the development and implementation of a restoration plan to reduce the amount of nutrients that caused the verified impairment of Lake Weir. These activities will depend heavily on the active participation of the SJRWMD, local governments, businesses, and other stakeholders. DEP will work with these organizations and individuals to undertake or continue reductions in the discharge of pollutants and achieve the established TMDLs for impaired waterbodies.

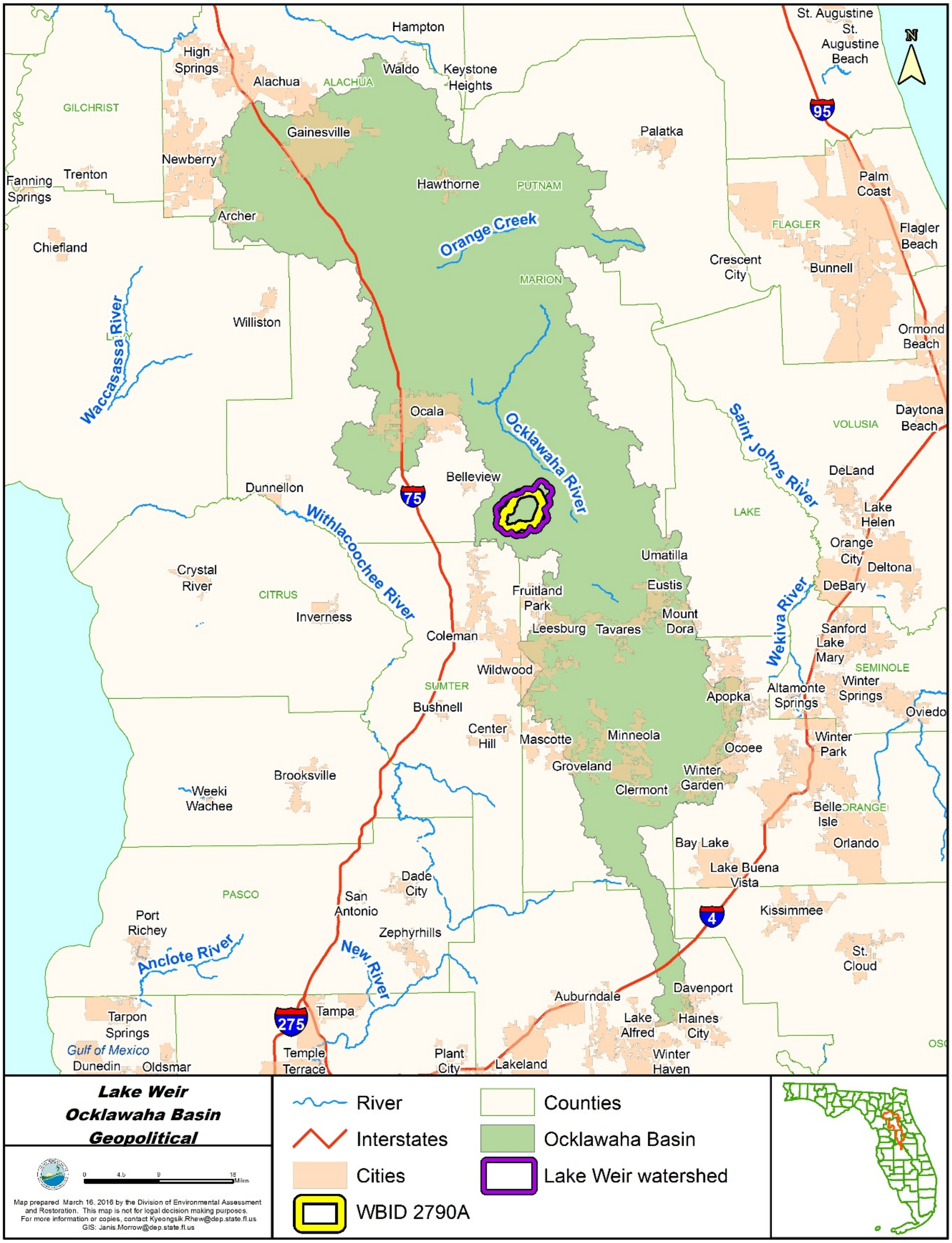


**FIGURE 1.1. LOCATION OF LAKE WEIR (WBID 2790A) IN THE OCKLAWAHA BASIN AND MAJOR GEOPOLITICAL AND HYDROLOGIC FEATURES IN THE AREA**

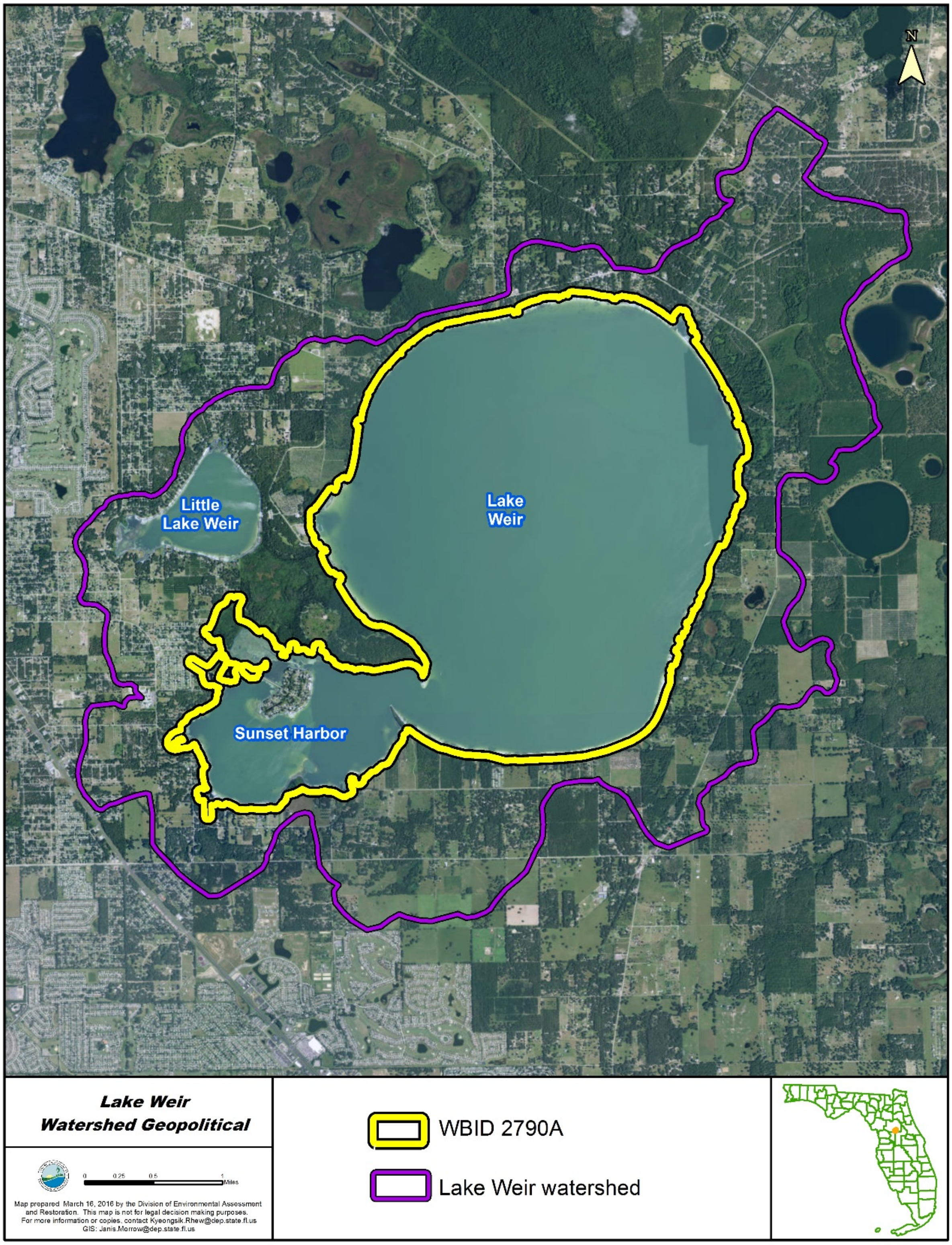


**FIGURE 1.2. DETAILED VIEW OF LAKE WEIR IN MARION COUNTY AND HYDROLOGIC FEATURES IN THE AREA**

# CHAPTER 2: DESCRIPTION OF WATER QUALITY PROBLEM

## 2.1 Statutory Requirements and Rulemaking History

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

Florida's 1998 303(d) list included 41 waterbodies in the Ocklawaha River Basin. However, the FWRA (Section 403.067, F.S.) stated that all previous Florida 303(d) lists were for planning purposes only and directed DEP to develop, and adopt by rule, a new science-based methodology to identify impaired waters. After a long rulemaking process, the Environmental Regulation Commission adopted the new methodology as Chapter 62-303, F.A.C. (Identification of Impaired Surface Waters Rule, or IWR), in April 2001. The rule was modified in 2006, 2007, 2012, and 2013. The list of waters for which impairments have been verified using the methodology in the IWR is referred to as the Verified List.

## 2.2 Information on Verified Impairment

DEP used the IWR to assess water quality impairments in the Ocklawaha River Basin (Group 1) and verified that Lake Weir was impaired for nutrients based on the fact that, in the Cycle 1 assessment (verified period for the Group 1 basins January 1, 1995, to June 30, 2002), annual average TSI values (for the equation see Gao and Gilbert 2003) exceeded 40. The nutrient impairment was confirmed in the Cycle 2 assessment (January 1, 2000, to June 30, 2007) and in the Cycle 3 assessment (January 1, 2005, to June 30, 2012) based on annual average TSI values exceeding 40 in 2005, 2006, 2007, 2008, 2009, 2011, and 2012 (**Table 2.1**). In addition, DEP assessed water quality in Lake Weir using the NNC. The results indicate that the lake does not attain the applicable lake NNC and will remain impaired for nutrients (see **Chapter 3**).

In Florida waterbodies, nitrogen and phosphorus are most often the limiting nutrients. A limiting nutrient limits plant growth (both macrophytes and algae) when it is not available in sufficient quantities. A limiting nutrient is a chemical that is necessary for plant growth, but available in quantities smaller than those needed for optimal growth of algae, represented by chlorophyll *a* (chl *a*), and macrophytes. In the past, management activities to control lake eutrophication focused on phosphorus reduction, as phosphorus was generally recognized as the limiting nutrient in freshwater systems.

Recent studies, however, have supported the reduction of both nitrogen and phosphorus as necessary to control algal growth in aquatic systems (Conley *et al*. 2009; Paerl 2009; Lewis *et al*. 2011; Paerl and Otten 2013). Furthermore, the analysis used in the development of the Florida lake NNC supports this idea, as statistically significant relationships were found between chl *a* values and both nitrogen and phosphorus concentrations (DEP 2012).

**TABLE 2.1. SUMMARY OF TSI FOR LAKE WEIR (WBID 2790A), 2000–12**

PCU = Platinum cobalt units; TN = Total nitrogen; TP = Total phosphorus
* Insufficient data

| YEAR | MEAN COLOR (PCU) | TSI THRESHOLD | CALCULATED TSI BASED ON MEASURED TN, TP, AND CHL *A* | EXCEEDANCE |
|---|---|---|---|---|
| **2000** | 26 | 40 | 31 | No |
| **2001** | 5 | 40 | 32 | No |
| **2002** | 8 | 40 | 31 | No |
| **2003** | 10 | 40 | 29 | No |
| **2004** | 16 | 40 | 32 | No |
| **2005** | 11 | 40 | 41 | Yes |
| **2006** | 9 | 40 | 45 | Yes |
| **2007** | 10 | 40 | 43 | Yes |
| **2008** | 12 | 40 | 48 | Yes |
| **2009** | 10 | 40 | 47 | Yes |
| **2010** | 5 | ID* | ID* | |
| **2011** | 5 | 40 | 48 | Yes |
| **2012** | 6 | 40 | 47 | Yes |

# CHAPTER 3. DESCRIPTION OF APPLICABLE WATER QUALITY STANDARDS AND TARGETS

## 3.1 Classification of the Waterbody and Criterion Applicable to the TMDLs

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

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

Lake Weir is a Class III waterbody, with a designated use of recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criterion applicable to the verified impairment (nutrients) for this water is the state of Florida's nutrient criterion in Paragraph 62-302.530(47)(b), F.A.C.

## 3.2 Applicable Water Quality Standards and Numeric Water Quality Target

### *3.2.1 Numeric Interpretation of the Narrative Nutrient Criterion*

The NNC for lakes were adopted on December 8, 2011, and have been effective since October 27, 2014. DEP has assessed the data for Lake Weir using the new criteria. Lake Weir does not attain the new NNC and remains on the Verified List as impaired for nutrients. The nutrient TMDLs presented in this report constitute site-specific numeric interpretations of the narrative nutrient criterion set forth in Paragraph 62-302.530(47)(b), F.A.C., that will replace the otherwise applicable NNC in Subsection 62-302.531(2), F.A.C., for this particular water. **Appendix A** summarizes the relevant TMDL information, including justification for the protection of downstream waters (pursuant to Subsection 62-302.531[4] F.A.C.), to support using the TMDL nutrient targets as the site-specific numeric interpretations of the narrative nutrient criterion.

TMDL targets and water quality criteria are generally very similar, as both measures are used to protect the designated uses of surface waters. In fact, for many non-nutrient TMDLs, the TMDL target is the applicable water quality criterion, and the TMDL identifies the load that will attain the concentration-based criteria. This is the case for some nutrient TMDLs in which the target is to attain the generally applicable NNC (for a lake, for example), and the TMDL establishes the allowable nutrient load. Under Florida's nutrient standard in Rule 62-302.531, F.A.C., the allowable load becomes the applicable NNC for the lake when the TMDL is adopted.

#### 3.2.1.1 NNC Values Adopted by the State

The adopted lake NNC include criteria for chl *a*, TN, and TP, with the specific values depending on the color and alkalinity condition of a given lake. **Table 3.1** lists the NNC for Florida lakes specified in Subparagraph 62-302.531(2)(b)1, F.A.C.

**TABLE 3.1. CHL *A*, TN, AND TP CRITERIA FOR FLORIDA LAKES (SUBPARAGRAPH 62-302.531[2][B]1, F.A.C.)**

AGM = Annual geometric mean
$CaCO_3$ = Calcium carbonate; µg/L = Micrograms per liter; mg/L = Milligrams per liter
[1] For lakes with color > 40 PCU in the West Central Nutrient Watershed Region, the maximum TP limit shall be the 0.49 mg/L TP streams threshold for the region.

| Lake Group Long-Term Geometric Mean Lake Color and Alkalinity | Lake Group AGM Chl *a* | Minimum NNC AGM TP | Minimum NNC AGM TN | Maximum NNC AGM TP | Maximum NNC AGM TN |
|---|---|---|---|---|---|
| **> 40 PCU** | 20 µg/L | 0.05 mg/L | 1.27 mg/L | 0.16 mg/L[1] | 2.23 mg/L |
| **≤ 40 PCU and > 20 mg/L $CaCO_3$** | 20 µg/L | 0.03 mg/L | 1.05 mg/L | 0.09 mg/L | 1.91 mg/L |
| **≤ 40 PCU and ≤ 20 mg/L $CaCO_3$** | 6 µg/L | 0.01 mg/L | 0.51 mg/L | 0.03 mg/L | 0.93 mg/L |

Based on Subparagraph 62-302.531(2)(b)1, if a given lake has a long-term geometric mean color greater than 40 PCU, or if the long-term geometric mean color of the lake is less than 40 PCU but the long-term geometric mean of alkalinity (represented as $CaCO_3$) of the lake is greater than 20 mg/L, the chl *a* criterion is 20 µg/L. For a lake with long-term geometric mean color less than 40 PCU and long-term geometric mean alkalinity less than 20 mg/L $CaCO_3$, the chl *a* criterion is 6 µg/L. For a lake to attain the chl *a* criterion, the AGM of chl *a* should not exceed the criterion more than once in any consecutive three-year period. These chl *a* criteria were established by taking into consideration results from paleolimnological studies, expert opinions, biological responses, user perceptions, and chl *a* concentrations in a set of carefully selected reference lakes (DEP 2012).

If there are sufficient data to calculate the AGM for chl *a* and the mean does not exceed the chl *a* target concentration for the lake type listed in **Table 3.1**, then the TN and TP target concentrations for that calendar year are the AGMs of lake TN and TP samples, subject to the minimum and maximum limits in **Table 3.1**. However, for lakes with color > 40 PCU in the West Central Nutrient Watershed Region, the maximum TP limit is the 0.49 mg/L TP streams threshold for the region. If there are insufficient data to calculate the AGM for chl *a* for a given year, or if the AGM chl *a* concentration exceeds the chl *a* target concentration specified in **Table 3.1** for the lake type, then the TN and TP criteria are the minimum values in the table.

For the purpose of Subparagraph 62-302.531(2)(b)1, F.A.C., color is assessed as true color and should be free from turbidity. Lake color and alkalinity are set at the long-term geometric mean, based on a minimum of 10 data points over at least 3 years with at least 1 data point in each year. If insufficient alkalinity data are available, the long-term geometric mean specific conductance value is used, with a value of <100 microohms/centimeter (µohms/cm) used to estimate the 20 mg/L $CaCO_3$ alkalinity concentration until alkalinity data are available.

Based on the data retrieved from IWR Database Run_49, the long-term geometric mean color for Lake Weir is 9 PCU (**Table 2.1**), which is lower than the 40 PCU value that distinguishes colored lakes from clear lakes. The long-term geometric mean of alkalinity is 14 mg/L, which is lower than the 20 mg/L threshold that distinguishes high-alkalinity lakes from low-alkalinity lakes. Lake Weir is, therefore, considered a low-color and low-alkalinity lake, and the generally applicable chl *a* criterion is 6 µg/L.

Based on Subsection 62-302.531(6), F.A.C., to calculate an AGM for TN, TP, or chl *a*, there must be at least four temporally independent samples per year, with at least one sample taken between May 1 and September 30 and at least one sample taken during the other months of the calendar year. To be treated as temporally independent, samples must be taken at least one week apart.

**Table 3.2** lists the number of corrected chl *a* samples available for Lake Weir from 2000 to 2012 and the AGM chl *a* concentrations for the years that meet the data sufficiency requirements of Subsection 62-302.531(6), F.A.C. These chl *a* data were retrieved from IWR Run_49. The table shows that sufficient data were available to calculate the chl *a* AGM for all years in the 13-year period except for 2010. Out of the 12 years with sufficient data, the AGM chl *a* concentration exceeded the 6 µg/L target in 2005, 2006, 2007, 2008, 2009, 2011, and 2012. For these years, the applicable TN and TP criteria are the minimum TN and TP concentrations listed in **Table 3.1** for low-color and low-alkalinity lakes, or 0.51 and 0.01 mg/L, respectively. In 2010, the TN and TP minimum criteria also apply because there were insufficient data to calculate chlorophyll-*a*.

**Table 3.2. Number of Corrected Chl *a* Samples Collected in Lake Weir and Calculated AGM Chl *a*, TN and TP Concentration, 2000-12**

* Insufficient data

| Year | Number of Samples Collected Each Year | At Least One Sample Collected between May and September? | AGM Chl *a* (µg/L) | AGM TN (mg/L) | AGM TP (mg/L) |
|---|---|---|---|---|---|
| **2000** | 17 | Yes | 2.58 | 0.81 | 0.013 |
| **2001** | 12 | Yes | 1.52 | 0.69 | 0.013 |
| **2002** | 14 | Yes | 1.76 | 0.72 | 0.013 |
| **2003** | 12 | Yes | 1.30 | 0.75 | 0.011 |
| **2004** | 12 | Yes | 2.44 | 0.77 | 0.011 |
| **2005** | 6 | Yes | 9.19 | 0.67 | 0.010 |
| **2006** | 10 | Yes | 9.91 | 0.78 | 0.013 |
| **2007** | 12 | Yes | 9.72 | 0.78 | 0.011 |
| **2008** | 11 | Yes | 12.65 | 0.90 | 0.014 |
| **2009** | 9 | Yes | 13.33 | 1.03 | 0.015 |
| **2010** | 3 | No | ID* | 0.99 | 0.016 |
| **2011** | 5 | Yes | 14.20 | 0.94 | 0.015 |
| **2012** | 6 | Yes | 10.95 | 1.02 | 0.017 |

### *3.2.2 TN and TP Target Concentrations Established Based on the Modeling Approach*

The site-specific TN and TP targets for this TMDL analysis were developed based on the generally applicable chl *a* criterion (6 µg/L) for clear, low-alkalinity lakes. The protectiveness of a concentration of 6 µg/L was established in the Technical Support Document for the NNC (DEP 2012) using the multiple-lines-of-evidence approach for low-color, low-alkalinity lakes in Florida. This level prevents algal blooms and ensures that no harmful phytoplankton will impair the waterbody's designated use. When these TMDLs were developed, there was no site-specific information indicating that a level of 6 µg/L was not protective of the designated use for this waterbody.

TN and TP target concentrations for Lake Weir were established using the modeling approach, which is discussed in detail in **Chapters 4** and **5** of this TMDL report.  This approach links the watershed TN and TP loading simulation to the in-lake TN and TP concentration simulation.  The watershed simulation was conducted using the Natural Resources Conservation Service 's (NRCS) curve number model for watershed runoff calculation and multiplying the runoff volume by TN and TP event mean concentrations (EMCs) to calculate the total watershed nutrient loads.  Nutrient loading directly deposited onto the lake surface from the atmosphere and nutrient loadings through ground water seepage were also estimated.

The simulated nutrient loads were then entered into a lake eutrophication model, BATHTUB, which was developed by the United States Army Corps of Engineers (USACOE) to simulate in-lake TN, TP, and chl *a* concentrations. The watershed nutrient loadings were linked to the in-lake TN, TP, and chl *a* concentrations through model calibration. The natural background TN, TP, and chl *a* concentrations of the lake were simulated by converting all human land uses in the watershed model to natural land areas (forest/rangeland area).

The TN and TP concentration targets, which are 0.68 and 0.01 mg/L, respectively, were derived based on the background condition of modeling results for the nutrient concentrations needed to achieve the chl *a* target of 6 µg/L. Using the water quality models, DEP established the nutrient loads that attain the target nutrient concentrations and chl *a* criterion. These nutrient loads are the site-specific numeric interpretations of the narrative nutrient criterion for Lake Weir.

# CHAPTER 4: ASSESSMENT OF SOURCES

## 4.1 Types of Sources

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

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

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

## 4.2 Potential Sources of Nutrients in the Lake Weir Watershed

### *4.2.1 Point Sources*

#### 4.2.1.1 Wastewater Point Sources

When this analysis was conducted, no NPDES permitted wastewater facilities were identified in the Lake Weir watershed that discharge directly to surface waters.

#### 4.2.1.2 Municipal Separate Storm Sewer System (MS4) Permittees

In the Lake Weir watershed, the stormwater collection systems owned and operated by Marion County are covered by a Phase II NPDES MS4 permit (FLR04E021). Based on Chapter 62-624, F.A.C., the MS4 permit requirements apply to urbanized area. According to Subsection 62-624.800(2), F.A.C., "Located in an urbanized area as determined by the latest Decennial Census by the U. S. Census Bureau. (If the Phase II MS4 is not located entirely within an urbanized area, only the portion that is within the urbanized area is regulated.)" The Lake Weir watershed includes urbanized areas (**Figure 4.1**). Marion County is responsible for these areas.

### *4.2.2 Nonpoint Sources*

Pollutant sources that are not NPDES wastewater or stormwater dischargers are generally considered nonpoint sources. Nonpoint sources addressed in this analysis primarily include loadings from surface runoff, ground water seepage entering the lake, and precipitation directly onto the lake surface.

In this TMDL analysis, nutrient loadings from the watershed were estimated by multiplying the runoff volume by the TN and TP EMCs. The runoff volume from the watershed was primarily estimated using the United States Department of Agriculture (USDA) NRCS curve number approach. This approach estimates runoff volume by taking into consideration the land use type, soil type, imperviousness of the watershed, and antecedent moisture condition of the soil. Curve numbers from 20 to 100 are assigned to different land use–soil combinations to represent different runoff potentials. Rainfall is the driving force of the curve number simulation.

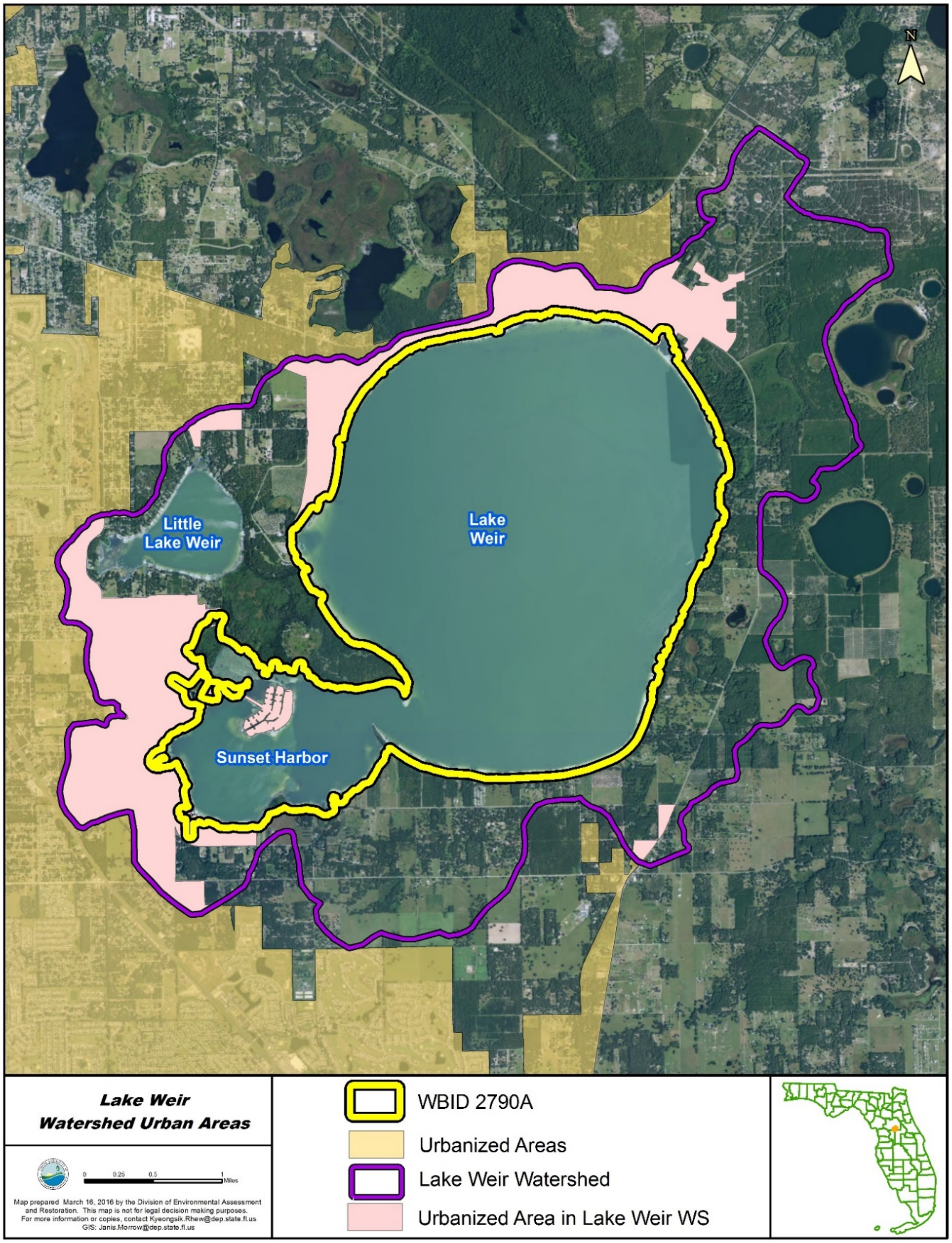


**FIGURE 4.1. URBANIZED AREAS IN THE LAKE WEIR WATERSHED (UNITED STATES CENSUS BUREAU 2010)**

The land use information included in this TMDL analysis was obtained from the SJRWMD's land use shape files. Because the watershed nutrient loading simulation covers a relatively long period from 2000 through 2012, land use geographic information system (GIS) shape files from two years were used in the loading estimation. The 2004 shape file was used for estimating annual nutrient loads for the period from 2000 through 2005, and the 2009 land use shape file was used for simulating nutrient loads for the period from 2006 through 2012. Soil hydrologic characteristics for the watershed were obtained from the NRCS 2010 Soil Survey Geographic (SSURGO) Database GIS shape file from DEP's GIS dataminer.

Possible ground water seepage into Lake Weir and septic tank loadings were simulated using the ArcNLET model developed by Florida State University (FSU) (Ye *et al*. 2015). The following sections describe in detail the methods used to estimate nutrient loadings from various nonpoint sources.

#### 4.2.2.1 Land Uses

Land use is one of most important factors in determining the nutrient loadings created in the Lake Weir watershed. Nutrients can be flushed into a receiving water through surface runoff and stormwater conveyance systems during stormwater events. Both human land use areas and natural land areas generate nutrients. However, human land use areas typically generate more nutrient loads per unit of land surface area than natural lands.

As discussed earlier, the land use information used in developing these TMDLs was obtained from the SJRWMD's 2004 and 2009 land use shape files, which define land use types based on the classification system adopted in the Florida Land Use and Cover Classification System (FLUCCS) (Florida Department of Transportation [FDOT] 1999). To estimate nutrient loads from the Lake Weir watershed, the detailed land use types defined by the Level III FLUCCS code in these shape files were aggregated based on a 15-land use classification system used by the SJRWMD in developing the pollutant load reduction goals (PLRGs) for seven major lakes in the Upper Ocklawaha River Basin (Fulton *et al*. 2004).

**Table 4.1** lists these land use types and their corresponding acreages in the Lake Weir watershed for 2004 and 2009, and the change of acreage in these land use types between 2004 and 2009. The table in **Appendix C** relates the 15 land use types to the FLUCCS code. **Figures 4.2a** and **4.2b** show the spatial distribution of different land use types in the Lake Weir watershed in 2004 and 2009, respectively.

**Table 4.1. SJRWMD's 15 Land Uses and Their Corresponding Acreage in the Lake Weir Watershed**

| SJRWMD Land Use | 2004 Acreage | 2004 % Acreage | 2009 Acreage | 2009 % Acreage | 2004/2009 Difference Acreage | 2004/2009 Difference % Difference |
|---|---|---|---|---|---|---|
| Low-Density Residential | 1,699.7 | 23.2% | 1,391.2 | 19.0% | -308.5 | -22% |
| Medium-Density Residential | 566.4 | 7.7% | 677.1 | 9.3% | 110.7 | 16% |
| High-Density Residential | 15.7 | 0.2% | 15.7 | 0.2% | 0.0 | 0% |
| Low-Density Commercial | 51.7 | 0.7% | 57.2 | 0.8% | 5.5 | 10 |
| High-Density Commercial | 33.1 | 0.5% | 29.0 | 0.4% | -4.1 | -14% |
| Industrial | 4.5 | 0.1% | 4.5 | 0.1% | 0.0 | 0 |
| Mining | 26.8 | 0.4% | 2.7 | 0.0% | -24.1 | -888% |
| Open land/Recreational | 639.9 | 8.7% | 541.8 | 7.4% | -98.0 | -18% |
| Pasture | 858.9 | 11.7% | 903.0 | 12.3% | 44.1 | 5% |
| Cropland | 59.3 | 0.8% | 154.91 | 2.1% | 95.6 | 62% |
| Tree Crops | 451.9 | 6.2% | 451.2 | 6.2% | -0.7 | 0% |
| Other Agriculture | 10.1 | 0.1% | 8.9 | 0.1% | -1.2 | -13% |
| Forest/Rangeland | 1,619.1 | 22.1% | 1,801.8 | 24.6% | 182.7 | 10% |
| Water | 444.7 | 6.1% | 448.1 | 6.1% | 3.4 | 1% |
| Wetlands | 831.3 | 11.4% | 825.9 | 11.3% | -5.4 | -1% |
| **Total** | **7,313.0** | **100.0%** | **7,313.0** | **100.0%** | | |

Based on **Table 4.1**, the total area of the Lake Weir watershed is 7,313 acres. The dominant land use type in the watershed in 2004 was low-density residential, which covered 1,700 acres and accounted for 23.2% of the total watershed area. The second largest land use type in 2004, forest/rangeland, covered 1,619 acres and accounted for 22.1% of the watershed area. The third largest land use type, pastureland, occupied 860 acres of land and accounted for 11.7% of the total watershed area. Overall, human land uses, including all the residential, commercial, industrial, and agricultural areas, occupied 4,418 acres of the watershed and accounted for 60% of the total watershed. Among these human land areas, 69% were urban lands—which include all the residential, commercial, industrial, mining, and recreational areas—and 31% were agricultural lands.

Compared with 2004, the land use pattern in the Lake Weir watershed exhibited some significant changes in 2009. The largest of these was a 309-acre decrease in low-density residential from 1,700 acres in 2004 to 1,391 acres in 2009, representing a 22% decline. At the same time, medium-density residential increased by 111 acres, from 566 to 677 acres, representing a 16% increase. The other significant changes in 2009 were a 183-acre increase in forest/rangeland, a 96-acre increase in cropland, a 98-acre decrease in open land and recreational, and a 44 acre increase in pasture.

Overall, in 2009, human land use areas occupied 4,237 acres of the watershed, accounting for 58% of the total watershed area. Among these human land use areas, 64% were urban lands and 36% were agricultural lands. However, human land use types became less dominant in 2009 than in 2004. While urban land use decreased by 399 acres, agricultural land use increased by 138 acres from 2004 to 2009.

#### 4.2.2.2 Hydrologic Soil Groups

The hydrologic characteristics of soil can significantly influence the capability of a given watershed to hold rainfall or produce surface runoff. Soils are generally classified into four major types, as follows, based on their hydrologic characteristics (Viessman *et al*. 1989):

— **Type A soil (low runoff potential):** Soils having high infiltration rates even if thoroughly wetted and consisting chiefly of deep, well-drained to excessively drained sands or gravels. These soils have a high rate of water transmission.

— **Type B soil:** Soils having moderate infiltration rates if thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well-drained to well-drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

— **Type C soil:** Soils having slow infiltration rates if thoroughly wetted and consisting chiefly of soils with a layer that impedes the downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

— **Type D soil (high runoff potential):** Soils having very slow infiltration rates if thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission.

The soil hydrologic characteristics of the Lake Weir watershed used in this TMDL analysis were based on the soil hydrologic classification included in the NRCS 2010 SSURGO GIS shape file. **Figure 4.3** shows the spatial distribution of these groups in the Lake Weir watershed. Type A soil dominates the watershed. Small amounts of A/D and B/D soils are present around the northeast to southwest of Lake Weir. Type A/D and B/D soils have Type A soil or B soil characteristics when unsaturated, but behave like Type D soils when saturated. In this TMDL analysis, A/D, B/D, and C/D soils were treated as D soils when assigning the curve number.

Soil types in some portions of the watershed were not defined in the SSURGO shape file (Soil Type X). Most are located in water or wetland areas. In this analysis, these undefined soils were all considered Type D when assigning the curve number, because soils in water and wetland areas typically show a low potential for water infiltration. **Table 4.2** shows the soil hydrologic groups in the Lake Weir watershed and their corresponding acreage.

**TABLE 4.2. ACREAGE OF HYDROLOGIC SOIL GROUPS IN THE LAKE WEIR WATERSHED**

| SOIL HYDROLOGIC GROUP | ACREAGE | % ACREAGE |
|---|---|---|
| **A** | 5,758.1 | 78.7% |
| **B** | 53.3 | 0.7% |
| **D (A/D)** | 522.1 | 7.1% |
| **D (B/D)** | 513.9 | 7.0% |
| **D (C/D)** | 4.2 | 0.1% |
| **D(X)** | 461.4 | 6.3% |
| **Total** | **7,313.0** | **100.0%** |

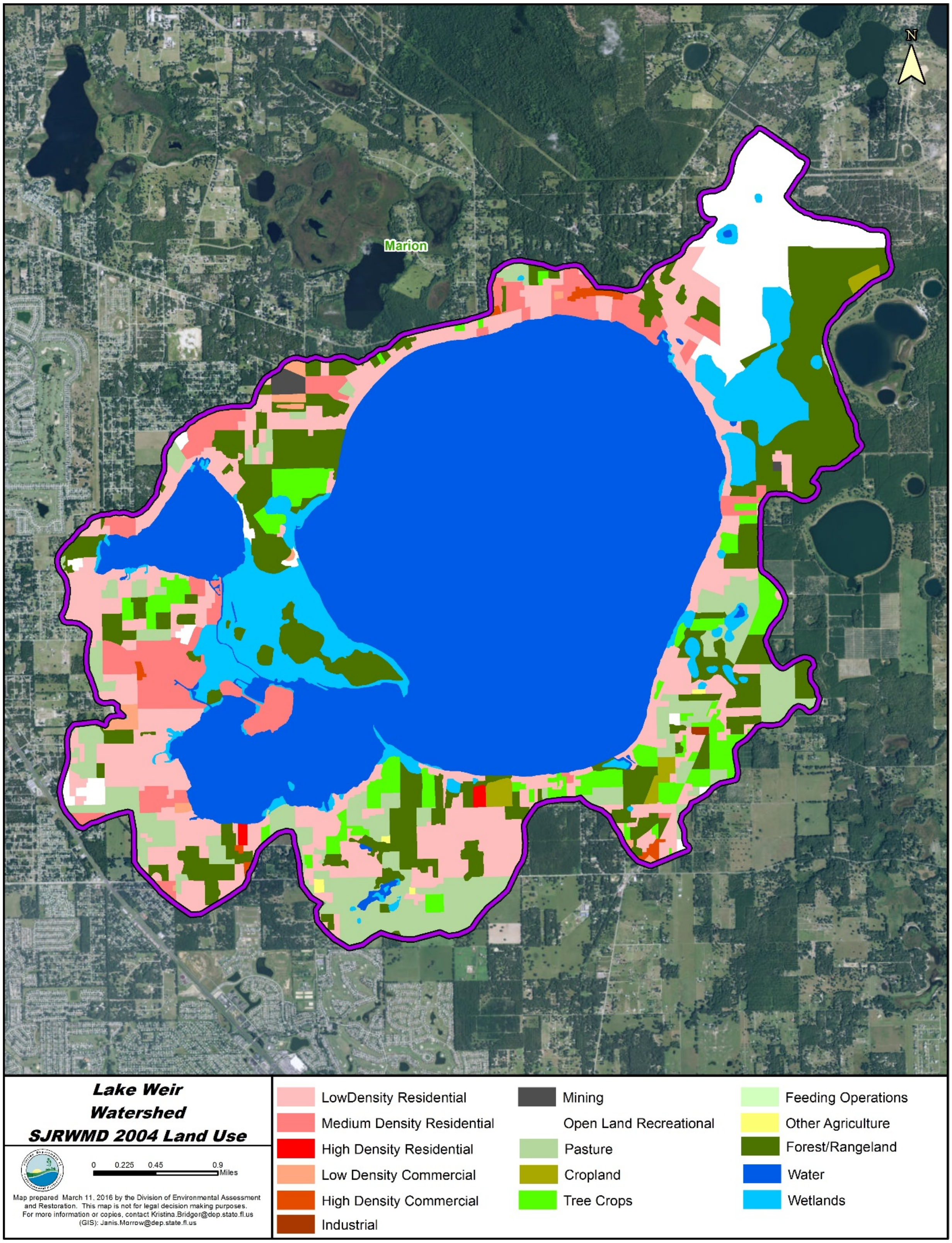


**FIGURE 4.2A. LAKE WEIR WATERSHED LAND USE SPATIAL DISTRIBUTION (2004)**

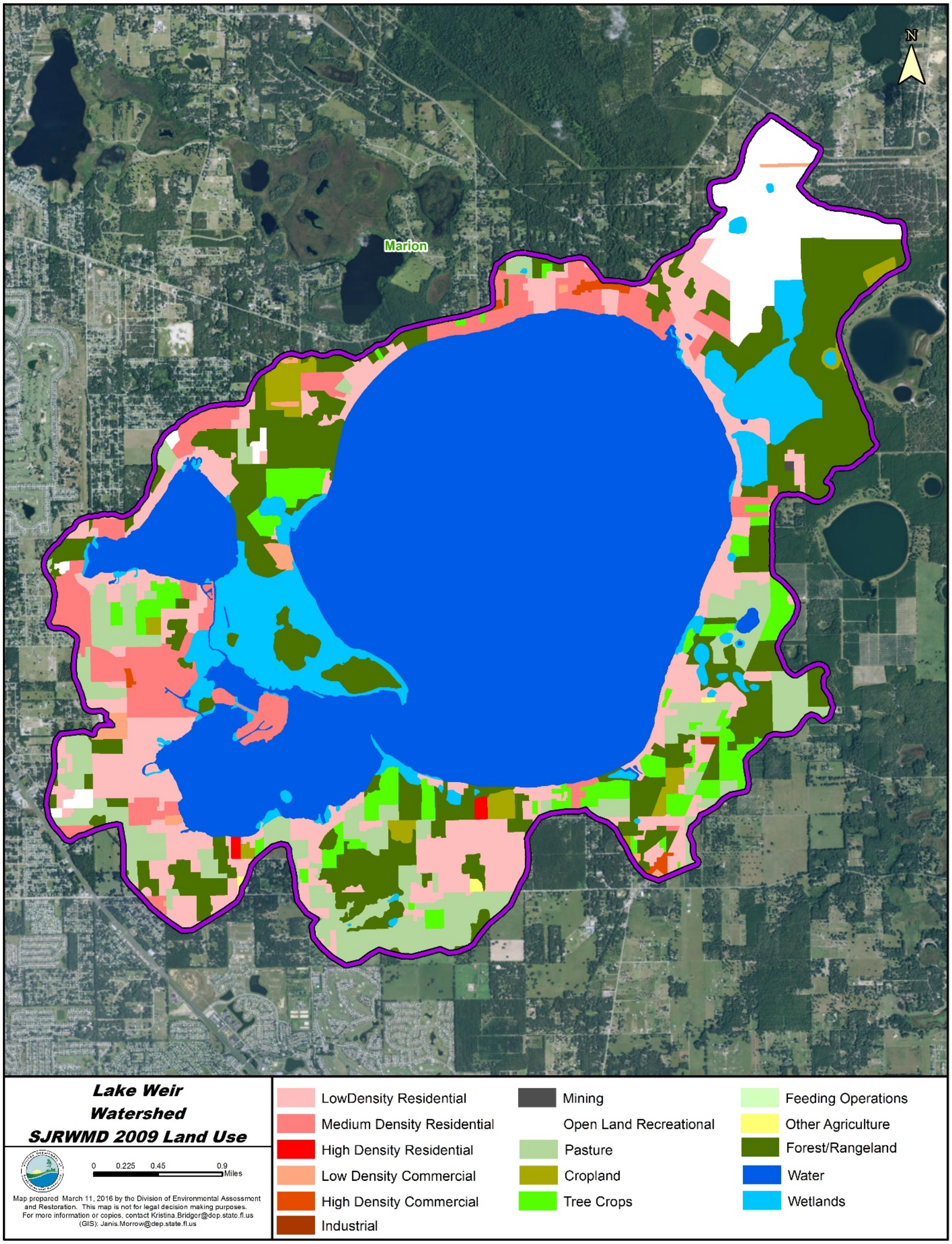


**FIGURE 4.2B. LAKE WEIR WATERSHED LAND USE SPATIAL DISTRIBUTION (2009)**

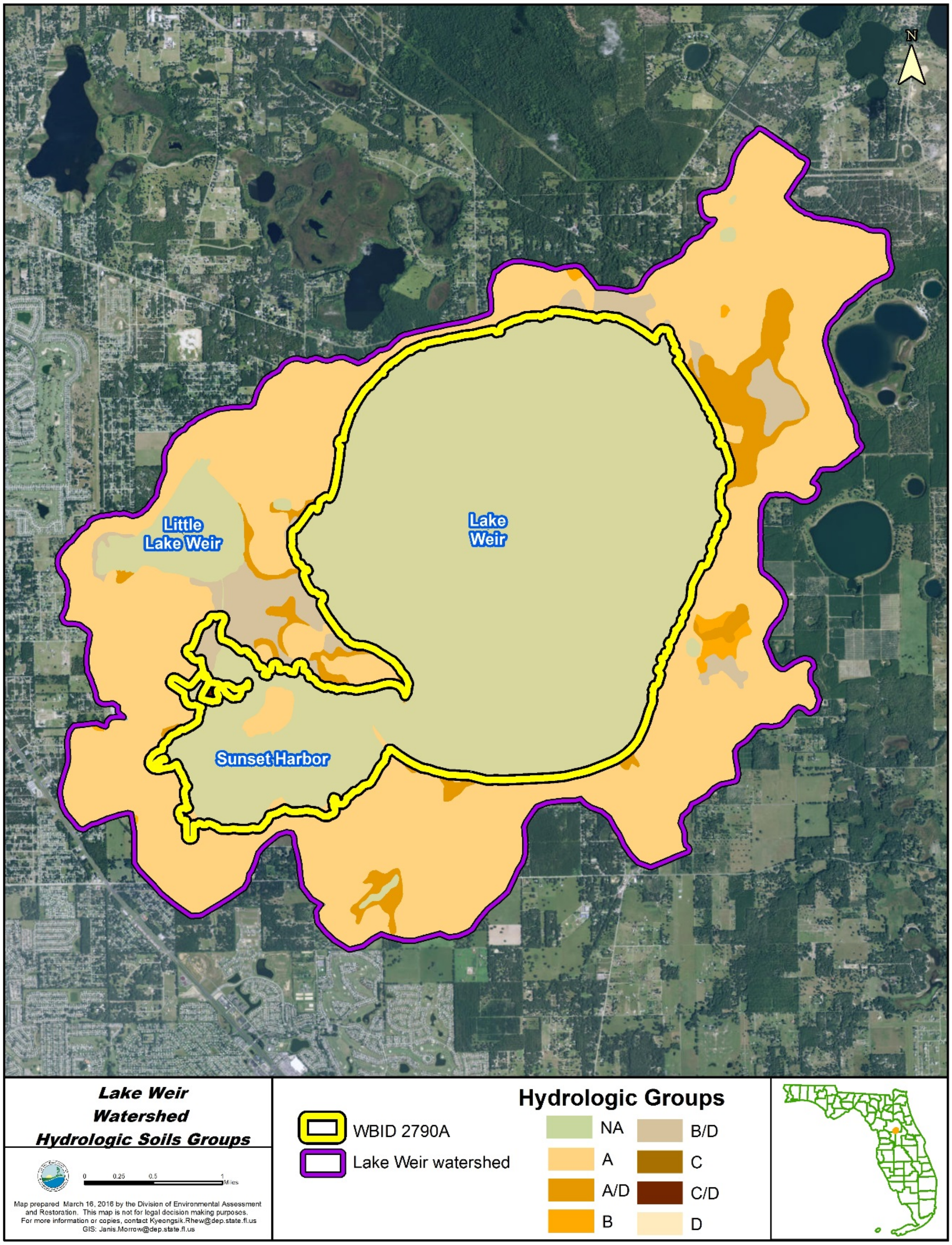


**FIGURE 4.3. LAKE WEIR WATERSHED SOIL HYDROLOGIC GROUPS (NRCS 2010)**

#### 4.2.2.3 Estimating Nonpoint Loadings from the Lake Weir Watershed

A. ESTIMATING RUNOFF VOLUME USING THE NRCS CURVE NUMBER APPROACH

Stormwater runoff from the Lake Weir watershed was estimated using the NRCS curve number approach and followed the procedure in Fulton *et al*. (2004) (**Appendix D**). The SJRWMD implemented this approach when developing the nutrient PLRGs for the Upper Ocklawaha Chain of Lakes.

The SJRWMD provided the rainfall data used in calculating the runoff coefficient and runoff volume for this TMDL analysis (Dr. R.S. Fulton, personal communication). The SJRWMD's Doppler rainfall data were created based on the measured rainfall from 75 rain gauges located in the SJRWMD area and the Next-Generation Radar (NEXRAD) data that the SJRWMD received from the NWS. Based on the SJRWMD's Doppler radar rainfall webpage, the individual radar station data are combined into a radar mosaic that completely covers the SJRWMD territory with an array of pixels. Each pixel consists of an area approximately two kilometers square. The SJRWMD combines the gauge and radar data to calculate a gauge-radar ratio and applies the ratio in a radar calibration algorithm to derive a gauge-adjusted rainfall dataset that maintains the spatial signature of the radar data while incorporating the volume estimates from the rain gauge.

For this TMDL analysis, the set of pixels for which the radar rainfall data were retrieved were defined by the Lake Weir watershed boundary. **Table 4.3** summarizes annual rainfall in the Lake Weir watershed for each year from 2000 to 2012. Annual rainfall ranged from 63.0 to 149.9 centimeters (cm) a year. The long-term average annual rainfall for the period was 120.2 cm.

**TABLE 4.3. ANNUAL RAINFALL IN THE LAKE WEIR WATERSHED, 2000–12**

| YEAR | ANNUAL RAINFALL (CM) |
|---|---|
| **2000** | 63.0 |
| **2001** | 97.3 |
| **2002** | 135.6 |
| **2003** | 124.0 |
| **2004** | 138.4 |
| **2005** | 149.9 |
| **2006** | 80.8 |
| **2007** | 128.5 |
| **2008** | 129.8 |
| **2009** | 145.5 |
| **2010** | 118.6 |
| **2011** | 121.4 |
| **2012** | 129.8 |

**Appendix D** lists the runoff coefficients for each land use–soil type combination for each year from 2000 through 2012. **Table 4.4** lists the annual runoff volume from different land use areas in the Lake Weir watershed. This ranges from 2,307 to 6,160 acre-feet (ac-ft) from 2000 through 2012. The long-term average annual runoff was 4,721 ac-ft.

Different land use areas contributed different amounts of runoff in the Lake Weir watershed. Of the long-term average annual total runoff of 4,721 ac-ft, 842 ac-ft were from urban land areas, including low-, medium-, and high-density residential areas, and low- and high-density commercial and industrial areas. This accounted for 18% of total runoff volume from the entire watershed. Natural land areas, including forest/rangeland, water, and wetlands, contributed 3,730 ac-ft, accounting for 79% of total watershed runoff. The land use area contributing the most runoff volume was wetlands, which alone contributed 2,236 ac-ft of runoff, accounting for 47% of total watershed runoff and 60% of total runoff coming from natural land areas. The runoff contribution from rural land areas, including pasture, cropland, tree crops, and other agricultural land, plus some runoff from the open land/recreational land areas, was relatively low. The total runoff volume from these areas was 148 ac-ft, accounting for 3% of total watershed runoff.  Runoff volume and nutrient loads from Little Lake Weir was estimated as water of 15 landuses.

## Table 4.4. Runoff Volume (ac-ft/yr) from the Lake Weir Watershed

| Land Use | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Low-density residential** | 154.6 | 266.1 | 386.5 | 328.0 | 408.8 | 406.8 | 176.3 | 364.2 | 448.6 | 461.5 | 248.6 | 315.5 | 310.4 |
| **Medium-density residential** | 156.6 | 252.4 | 357.4 | 317.9 | 371.0 | 387.7 | 248.1 | 437.3 | 480.8 | 515.5 | 358.4 | 398.1 | 412.6 |
| **High-density residential** | 7.3 | 11.4 | 16.0 | 14.5 | 16.5 | 17.6 | 9.5 | 15.8 | 16.5 | 18.0 | 13.8 | 14.6 | 15.5 |
| **Low-density commercial** | 38.3 | 59.8 | 83.6 | 76.2 | 85.9 | 92.1 | 55.0 | 89.7 | 92.1 | 101.4 | 80.3 | 83.9 | 89.2 |
| **High-density commercial** | 27.6 | 43.2 | 60.5 | 55.0 | 62.2 | 66.5 | 31.5 | 51.9 | 53.8 | 59.0 | 45.9 | 48.3 | 51.2 |
| **Industrial** | 4.2 | 6.5 | 9.1 | 8.3 | 9.3 | 10.0 | 5.4 | 8.7 | 8.9 | 9.8 | 7.9 | 8.2 | 8.7 |
| **Mining** | 0.5 | 1.1 | 1.7 | 1.2 | 1.9 | 1.6 | 0.1 | 0.3 | 0.4 | 0.4 | 0.1 | 0.2 | 0.2 |
| **Open land/recreational** | 10.7 | 26.6 | 43.1 | 29.5 | 49.0 | 39.8 | 16.3 | 54.3 | 82.8 | 79.4 | 20.6 | 41.7 | 35.3 |
| **Pasture** | 14.3 | 35.9 | 58.2 | 39.7 | 66.1 | 53.6 | 27.8 | 97.2 | 150.2 | 143.5 | 34.7 | 73.9 | 61.8 |
| **Cropland** | 1.0 | 2.4 | 3.8 | 2.7 | 4.3 | 3.6 | 4.6 | 15.4 | 23.4 | 22.5 | 5.9 | 11.8 | 10.1 |
| **Tree crops** | 7.6 | 18.4 | 29.6 | 20.6 | 33.5 | 27.6 | 13.6 | 45.9 | 70.1 | 67.2 | 17.2 | 35.2 | 29.7 |
| **Other agriculture** | 0.2 | 0.4 | 0.6 | 0.5 | 0.7 | 0.6 | 0.3 | 0.9 | 1.3 | 1.3 | 0.3 | 0.7 | 0.6 |
| **Forest/rangeland** | 26.8 | 68.8 | 112.1 | 75.7 | 127.8 | 102.7 | 56.5 | 204.9 | 320.1 | 304.8 | 69.8 | 154.8 | 128.0 |
| **Water** | 701 | 1,090 | 1,521 | 1,391 | 1,561 | 1,679 | 914 | 1,473 | 1,495 | 1,653 | 1,336 | 1,382 | 1,475 |
| **Wetlands** | 1,156 | 1,802 | 2,517 | 2,297 | 2,585 | 2,775 | 1,489 | 2,415 | 2,469 | 2,723 | 2,174 | 2,262 | 2,408 |
| **Total** | **2,307** | **3,686** | **5,200** | **4,657** | **5,383** | **5,665** | **3,048** | **5,274** | **5,713** | **6,160** | **4,413** | **4,831** | **5,037** |

### B. Estimating Runoff Nutrient Loads from the Lake Weir Watershed

Runoff nutrient loads from the Lake Weir watershed were calculated as the sum of nutrient loads from areas occupied by different land use types. The loads from each land use type were calculated by multiplying runoff volume from the land use area by runoff TN and TP concentrations specific to the land use type.

**Tables 4.5a** and **4.5b** list the stormwater runoff TN and TP loads from the Lake Weir watershed estimated using the procedures described in **Appendix D**. The annual runoff TP loads in the period from 2000 to 2012 reaching Lake Weir ranged from 123.2 kilograms per year (kg/yr) in 2000 to 399.6 kg/year in 2009 (**Table 4.5a**). The long-term average annual TP runoff loads for the period were 272.0 kg/yr. Different land use areas contributed different amount of runoff TP loads in the watershed. Urban land areas, including low-, medium-, and high-density residential areas, and low- and high-density commercial and industrial areas, accounted for 121.6 kg/yr, or 45% of the total runoff TP load from the entire watershed. The urban land use contributing the highest runoff TP load was medium-density residential, which alone contributed 57.5 kg/yr, accounting for 21% of the total runoff TP load from the watershed and 47% of the total runoff TP load from urban areas. Natural land areas, including forest/rangeland, water, and wetlands, contributed 114.2 kg/yr, accounting for 42% of total runoff TP loads. The runoff TP load contributed by rural land areas, including pasture, cropland, and other agricultural land, plus some runoff from open land/recreational areas, was 36.1 kg/yr, accounting for 13% of the total watershed runoff TP load. The land use area contributing the highest runoff TP load was wetlands, which alone contributed 99.5 kg/yr, accounting for 37% of the total runoff TP load from the watershed. Apparently, the urban area is the most important runoff TP contributor of the anthropogenic land uses.

The runoff TN annual loads in the period from 2000 to 2012 ranged from 2,519 kg/yr in 2000 to 7,314 kg/yr in 2009 (**Table 4.5b**). The interannual pattern is similar to that of runoff TP loads. The long-term average annual runoff TN loads from the entire watershed were 5,314 kg/yr. The highest portion of these loads came from natural land areas, which contributed 3,555 kg/yr and accounted for 67% of total runoff TN loads from the watershed. The single most important contributor of runoff TN load was wetland areas, which alone contributed 2,883 kg/yr and accounted for 54% of total watershed TN runoff loads. Urban land areas contributed 1,398 kg/yr of runoff TN, accounting for 26% of total runoff TN loads, which is a significant load contribution from the watershed. Rural areas contributed 360 kg/yr, accounting for 7% of total watershed runoff TN loads.

## Table 4.5a. Runoff TP Annual Loads (kg/yr) from the Lake Weir Watershed

| Land Use | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | Mean | % Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Low-density residential** | 18.2 | 31.3 | 45.5 | 38.3 | 47.6 | 47.7 | 21.7 | 44.7 | 55.5 | 58.2 | 30.9 | 38.7 | 38.3 | 39.7 | 14.6% |
| **Medium-density residential** | 26.4 | 42.3 | 59.9 | 53.0 | 60.9 | 64.9 | 38.8 | 66.9 | 72.5 | 80.9 | 56.1 | 60.7 | 63.8 | 57.5 | 21.1% |
| **High-density residential** | 2.5 | 3.8 | 5.3 | 4.7 | 5.2 | 5.7 | 3.0 | 4.9 | 5.0 | 6.1 | 4.5 | 4.4 | 4.9 | 4.6 | 1.7% |
| **Low-density commercial** | 3.3 | 5.1 | 7.2 | 6.5 | 7.2 | 7.9 | 4.5 | 7.3 | 7.3 | 8.5 | 6.6 | 6.6 | 7.3 | 6.6 | 2.4% |
| **High-density commercial** | 6.6 | 10.2 | 14.0 | 13.0 | 14.8 | 15.5 | 7.6 | 12.7 | 13.8 | 14.2 | 11.4 | 12.4 | 12.6 | 12.2 | 4.5% |
| **Industrial** | 0.6 | 0.8 | 1.1 | 1.1 | 1.2 | 1.2 | 0.6 | 1.1 | 1.2 | 1.2 | 1.0 | 1.0 | 1.1 | 1.0 | 0.4% |
| **Mining** | 0.0 | 0.1 | 0.2 | 0.1 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0% |
| **Open land/recreational** | 0.5 | 1.2 | 1.9 | 1.3 | 2.2 | 1.8 | 0.8 | 2.5 | 4.1 | 3.5 | 0.9 | 2.1 | 1.6 | 1.9 | 0.7% |
| **Pasture** | 5.6 | 13.9 | 22.2 | 15.0 | 25.0 | 20.2 | 10.2 | 35.5 | 55.2 | 56.2 | 13.3 | 26.6 | 23.2 | 24.8 | 9.1% |
| **Cropland** | 0.6 | 1.4 | 2.2 | 1.6 | 2.6 | 2.1 | 2.8 | 9.2 | 13.8 | 13.4 | 3.5 | 6.9 | 6.0 | 5.1 | 1.9% |
| **Tree crops** | 1.0 | 2.4 | 3.8 | 2.6 | 4.3 | 3.5 | 1.7 | 5.7 | 8.8 | 8.7 | 2.2 | 4.4 | 3.8 | 4.1 | 1.5% |
| **Other agriculture** | 0.1 | 0.2 | 0.3 | 0.2 | 0.3 | 0.3 | 0.1 | 0.4 | 0.6 | 0.6 | 0.2 | 0.3 | 0.3 | 0.3 | 0.1% |
| **Forest/rangeland** | 1.2 | 3.1 | 5.1 | 3.4 | 5.8 | 4.7 | 2.6 | 9.3 | 14.6 | 13.8 | 3.2 | 7.1 | 5.8 | 6.1 | 2.2% |
| **Water** | 4.3 | 6.9 | 9.9 | 8.9 | 9.8 | 10.9 | 6.0 | 9.6 | 9.1 | 10.5 | 8.4 | 8.5 | 9.5 | 8.6 | 3.2% |
| **Wetlands** | 52.4 | 81.0 | 113.1 | 103.1 | 115.4 | 124.8 | 66.8 | 100.6 | 104.4 | 123.7 | 97.7 | 102.6 | 107.3 | 99.5 | 36.6% |
| **Total** | **123.2** | **203.7** | **291.8** | **252.7** | **302.7** | **311.3** | **167.2** | **310.3** | **365.8** | **399.6** | **240.0** | **282.3** | **285.4** | **272.0** | **100.0%** |

### Table 4.5b. Runoff TN Annual Loads (kg/yr) from the Lake Weir Watershed

| Land Use | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | Mean | % Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Low-density residential** | 249.0 | 427.3 | 620.0 | 521.7 | 648.6 | 648.8 | 288.6 | 594.8 | 738.5 | 775.1 | 412.5 | 515.1 | 510.5 | 534.6 | 10.1% |
| **Medium-density residential** | 293.9 | 471.4 | 669.5 | 591.4 | 681.7 | 725.3 | 445.6 | 772.4 | 840.9 | 932.7 | 643.4 | 701.6 | 733.4 | 654.1 | 12.3% |
| **High-density residential** | 16.6 | 25.7 | 35.8 | 31.6 | 35.5 | 38.5 | 20.3 | 32.9 | 33.9 | 41.5 | 30.6 | 29.6 | 33.3 | 31.2 | 0.6% |
| **Low-density commercial** | 32.4 | 51.0 | 71.7 | 64.2 | 71.6 | 78.5 | 45.8 | 73.8 | 73.5 | 85.4 | 66.4 | 67.0 | 73.6 | 65.8 | 1.2% |
| **High-density commercial** | 56.0 | 86.2 | 119.4 | 110.2 | 125.5 | 131.9 | 63.8 | 106.1 | 115.6 | 118.9 | 94.6 | 104.2 | 104.7 | 102.9 | 1.9% |
| **Industrial** | 5.1 | 7.8 | 10.4 | 9.7 | 11.2 | 11.4 | 6.0 | 10.0 | 10.7 | 11.5 | 9.5 | 9.5 | 10.3 | 9.5 | 0.2% |
| **Mining** | 0.5 | 1.1 | 1.9 | 1.3 | 2.1 | 1.8 | 0.1 | 0.2 | 0.3 | 0.2 | 0.1 | 0.2 | 0.1 | 0.8 | 0.0% |
| **Open land/recreational** | 13.2 | 32.8 | 53.6 | 37.7 | 62.4 | 50.7 | 21.2 | 71.1 | 114.5 | 97.7 | 25.9 | 59.6 | 44.7 | 52.7 | 1.0% |
| **Pasture** | 42.0 | 103.8 | 166.1 | 112.0 | 186.6 | 150.9 | 76.4 | 265.2 | 412.4 | 419.9 | 99.7 | 198.6 | 173.6 | 185.2 | 3.5% |
| **Cropland** | 5.4 | 12.5 | 19.5 | 13.9 | 22.8 | 18.2 | 24.6 | 81.4 | 121.7 | 118.8 | 31.1 | 61.4 | 53.2 | 44.9 | 0.8% |
| **Tree crops** | 18.3 | 43.9 | 69.8 | 48.3 | 79.3 | 64.4 | 31.4 | 106.0 | 163.1 | 159.9 | 40.9 | 80.3 | 70.0 | 75.0 | 1.4% |
| **Other agriculture** | 0.6 | 1.3 | 2.1 | 1.5 | 2.3 | 1.9 | 0.8 | 2.7 | 4.2 | 4.3 | 1.1 | 2.1 | 1.8 | 2.1 | 0.0% |
| **Forest/rangeland** | 34.0 | 87.2 | 142.4 | 96.4 | 162.3 | 130.9 | 72.3 | 260.9 | 410.3 | 388.2 | 88.7 | 199.6 | 162.5 | 172.0 | 3.2% |
| **Water** | 249.8 | 401.1 | 572.2 | 514.0 | 570.2 | 632.1 | 348.4 | 556.8 | 524.9 | 607.6 | 486.6 | 490.0 | 549.6 | 500.2 | 9.4% |
| **Wetlands** | 1,502 | 2,323 | 3,243 | 2,957 | 3,310 | 3,578 | 1,915 | 3,082 | 3,194 | 3,552 | 2,805 | 2,941 | 3,078 | 2,883 | 54.3% |
| **Total** | **2,519** | **4,076** | **5,798** | **5,111** | **5,972** | **6,263** | **3,361** | **6,016** | **6,758** | **7,314** | **4,836** | **5,460** | **5,599** | **5,314** | **100.0%** |

#### 4.2.2.4 Estimating Septic Tank Nutrient Loadings from the Lake Weir Watershed

Septic systems generate nitrate nitrogen, which percolates through the soil and enters ground water. Nitrate in ground water tends to seep into lakes as baseflow. Therefore, lake water may receive additional nitrogen through seepage. Part of the nitrate in ground water may be degraded through denitrification under anaerobic conditions.

In this report, the amount of TN contributed by septic systems was simulated using an ArcGIS-based Nitrate Load Estimation Toolkit (ArcNLET) developed for DEP by FSU. This model requires the locations of septic tanks in the watershed to estimate nitrate loads. Marion County provided a GIS shape file for the 2,081 septic tanks in the Lake Weir watershed (**Figure 4.4**). Ye *et al*. (2015) provide detailed descriptions of how septic tank nitrogen loads were simulated using the ArcNLET model for Lake Weir.

ArcNLET currently simulates only nitrogen. TP was calculated by applying a TN:TP concentration ratio of 6.05:1. This ratio was calculated based on ground water TN and TP data collected from wells located in WBID 2790 (the Lake Weir outlet). These data were provided by DEP's Ground Water Management Section. The simulated TN and TP loads from septic effluent through seepage were 5,893 and 974 kg/yr, respectively.

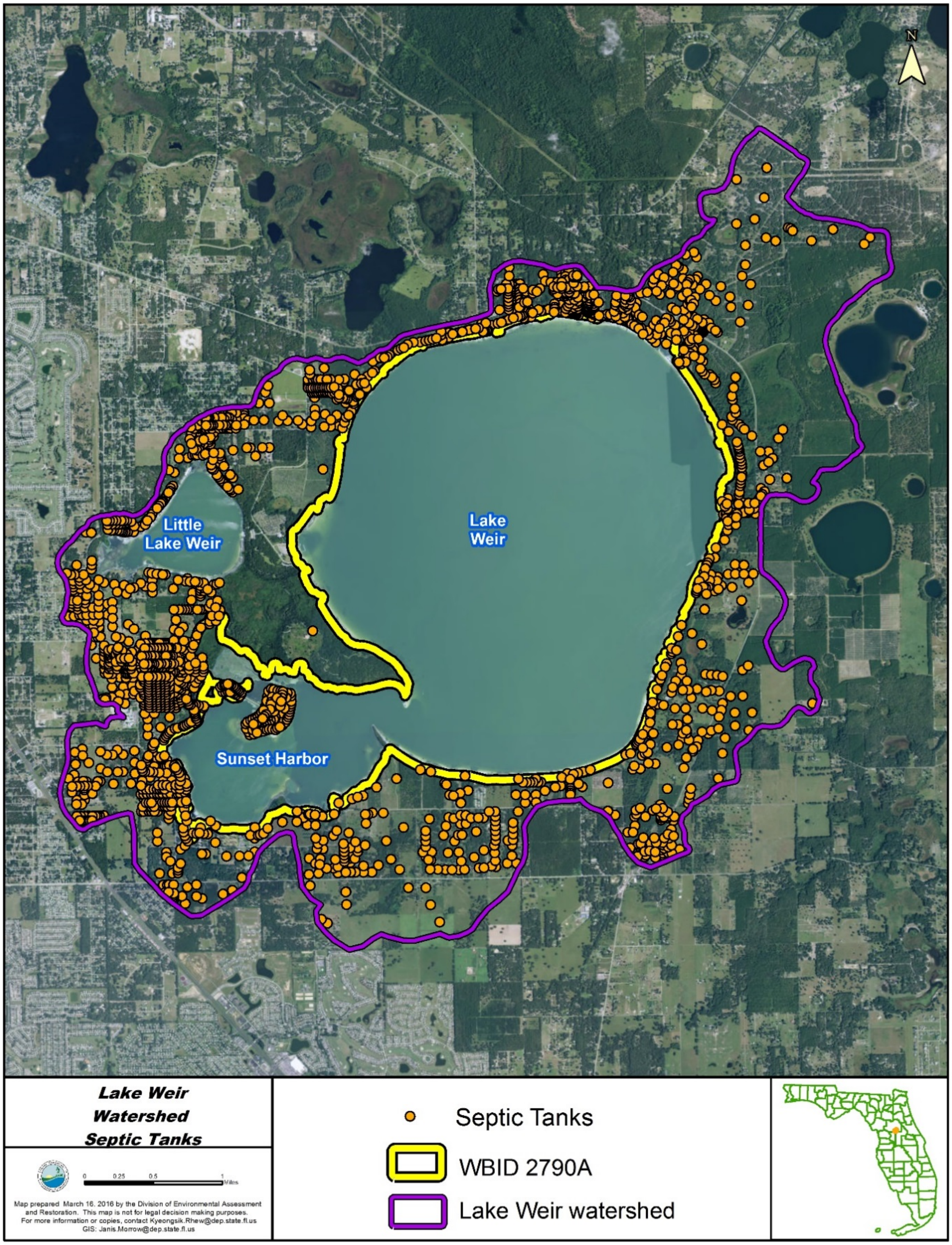


**FIGURE 4.4. LOCATION OF SEPTIC TANKS IN THE LAKE WEIR WATERSHED**

# Chapter 5: Determination of Assimilative Capacity

## 5.1 Historical Trends of TN, TP, and Chl *a* in Lake Weir

Monthly TN, TP, and chl *a* concentrations for Lake Weir from 2000 through 2012 were retrieved from IWR Run_49. **Figure 5.1** shows the locations of the individual stations where water quality data were collected. An analysis of the data indicated that the spatial variation between stations across Lake Weir was not significant. Therefore, data from all the stations in Lake Weir were pooled and treated as data collected from one station. AGM values for TN, TP, and corrected chl *a* concentrations were calculated based on all sampling data for the year (**Table 5.1**). Quarterly geometric mean values for TN, TP, and chl *a* concentrations were calculated using data sorted by quarter in the 2000–12 period. Seasonal trends for TN, TP, and chl *a* were examined using quarterly geometric mean values (**Table 5.2**).

As shown in **Table 5.1**, the long-term average AGM TN, TP, and chl *a* concentrations are 0.83 mg/L, 0.013 mg/L, and 8.3 µg/L, respectively. The long-term average TN/TP ratio is 63, indicating that algal communities in the lake may be limited by phosphorus.

The table shows that the AGMs of TN concentrations in Lake Weir ranged from 0.67 to 1.03 mg/L, averaging 0.83 mg/L during the period from 2000 through 2012. TN concentrations fluctuated throughout the period, decreasing from 2000 to 2005, increasing through 2012, and peaking in 2009 and 2012 (**Figures 5.2a** and **5.2b**). The lowest TN AGM was observed in 2005 and the highest in 2009. The AGM TP concentration ranged from 0.010 to 0.017 mg/L and averaged 0.013 mg/L (**Figures 5.3a** and **3.2b**). The trend of TP AGMs was similar to that of the TN AGMs, decreasing from 2000 and 2001 to 2005 and then increasing through 2012. The lowest TP AGM was observed in 2005 and the highest in 2012. The AGM corrected chl *a* concentration ranged from 1.3 to 17.8 µg/L and averaged 8.3 µg/L from 2000 to 2012 (**Figures 5.4a** and **5.4b**). The chl *a* concentration stayed consistently low from 2000 to 2004, increasing from 2005 to 2010, and then decreasing from 2010 to 2012. The lowest chl *a* concentration was observed in 2003 and the highest in 2010. The increase in chl *a* since 2006 is likely related to the increase of both TN and TP. In general, TN and TP showed slightly increasing trends from 2000 to 2012, and chl *a* increased more in the same period, probably because of the synergistic effect of TN and TP on phytoplankton. Although TN and TP concentrations were slightly higher in the spring and fall and chl *a* concentrations were high in the fall, there were no statistically significant differences in TN, TP, and chl *a* concentrations among seasons (**Table 5.2**).

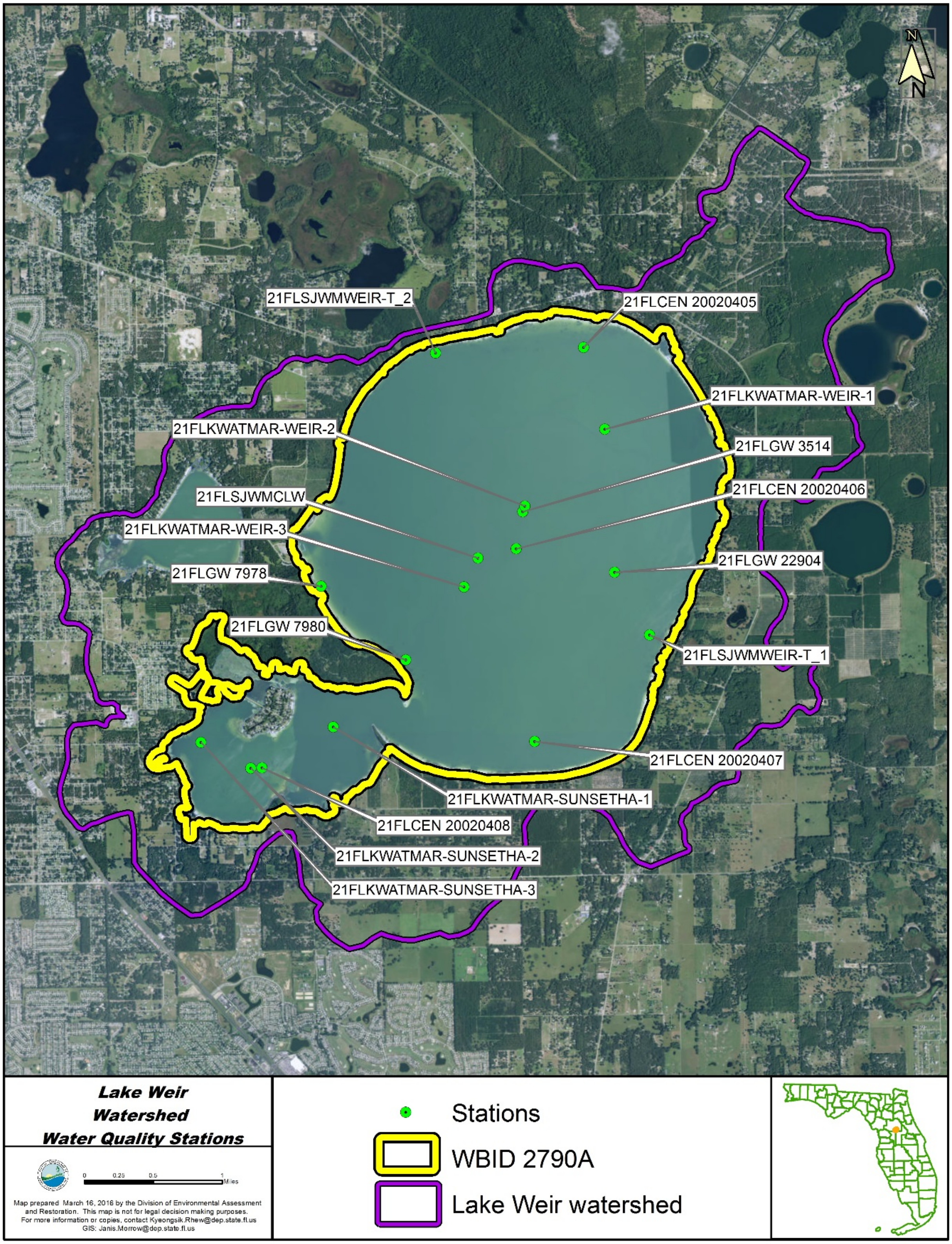


**FIGURE 5.1. LOCATIONS OF WATER QUALITY STATIONS IN LAKE WEIR**

### Table 5.1. AGMs TN, TP, and corrected Chl *a* for Lake Weir, 2000–12

| Year | TN (mg/L) | TP (mg/L) | Chl *a* (µg/L) | TN:TP Ratio |
|---|---|---|---|---|
| **2000** | 0.81 | 0.013 | 2.6 | 63 |
| **2001** | 0.69 | 0.013 | 1.5 | 51 |
| **2002** | 0.72 | 0.013 | 1.8 | 58 |
| **2003** | 0.75 | 0.011 | 1.3 | 68 |
| **2004** | 0.77 | 0.011 | 2.4 | 68 |
| **2005** | 0.67 | 0.010 | 9.2 | 64 |
| **2006** | 0.78 | 0.013 | 9.9 | 62 |
| **2007** | 0.78 | 0.011 | 9.7 | 68 |
| **2008** | 0.90 | 0.014 | 12.7 | 63 |
| **2009** | 1.03 | 0.015 | 13.3 | 70 |
| **2010** | 0.99 | 0.016 | 17.8 | 61 |
| **2011** | 0.94 | 0.015 | 14.2 | 61 |
| **2012** | 1.02 | 0.017 | 11.0 | 61 |
| **Mean** | **0.83** | **0.013** | **8.3** | **63** |

### Table 5.2. Seasonal Variation of TN, TP, and corrected Chl *a* in Lake Weir; Long-Term Mean of Quarterly Geometric Means

| Quarter (Month) | TN (mg/L) | TP (mg/L) | Chl *a* (µg/L) |
|---|---|---|---|
| **1st quarter (1,2,3)** | 0.82 | 0.013 | 7.6 |
| **2nd quarter (4,5,6)** | 0.85 | 0.014 | 7.3 |
| **3rd quarter (7,8,9)** | 0.81 | 0.013 | 7.6 |
| **4th quarter (10,11,12)** | 0.84 | 0.014 | 8.3 |
| **Mean** | **0.83** | **0.014** | **7.7** |

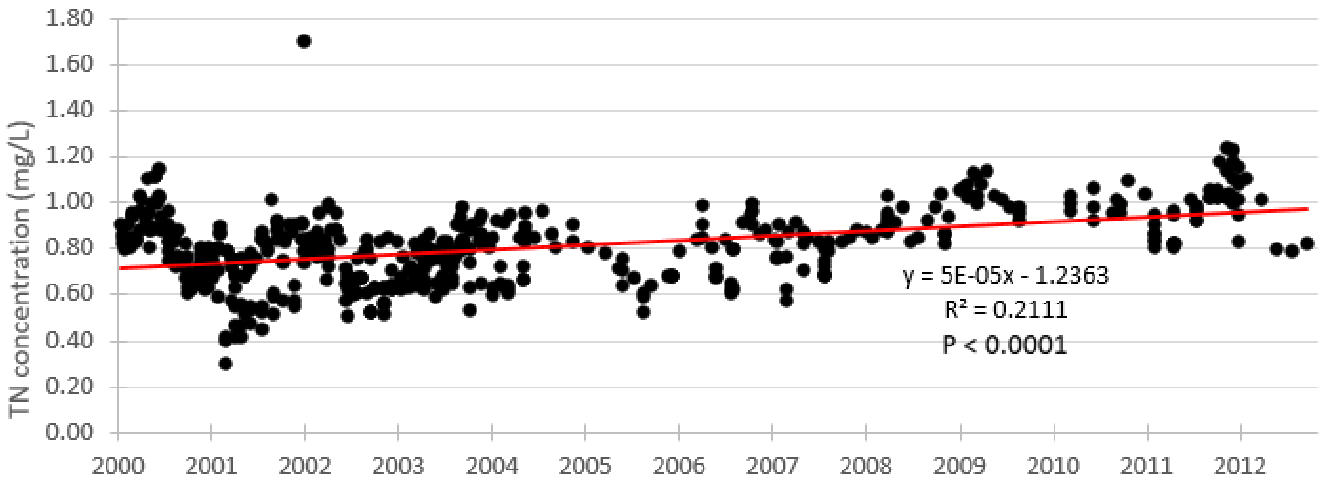


**FIGURE 5.2A. TN CONCENTRATIONS MEASURED FOR LAKE WEIR, 2000–12**

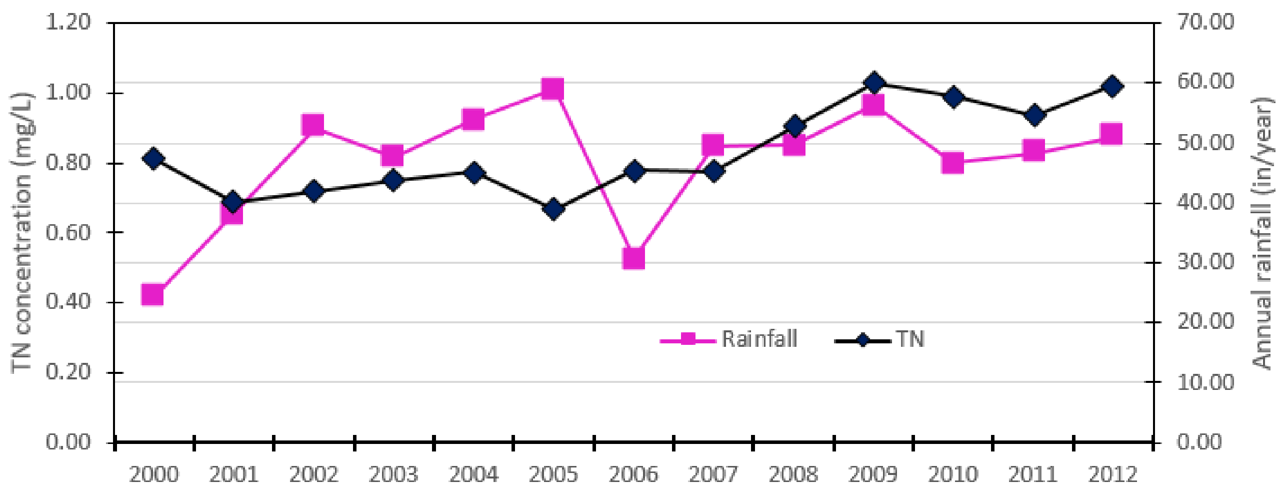


**FIGURE 5.2B. RELATIONSHIP BETWEEN ANNUAL RAINFALL AND TN AGM, 2000–12**

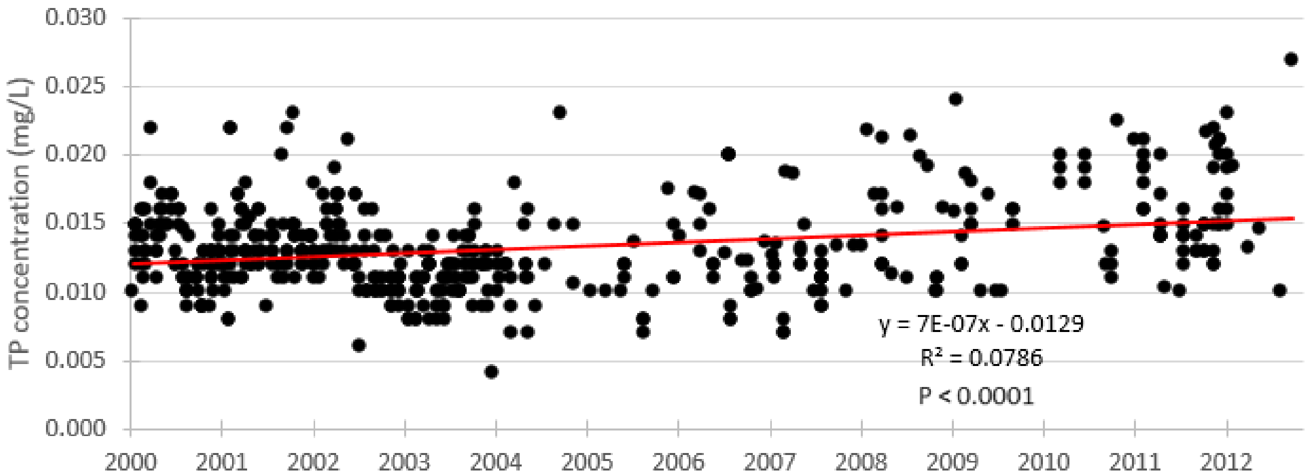


**FIGURE 5.3A. TP CONCENTRATIONS MEASURED FOR LAKE WEIR, 2000–12**

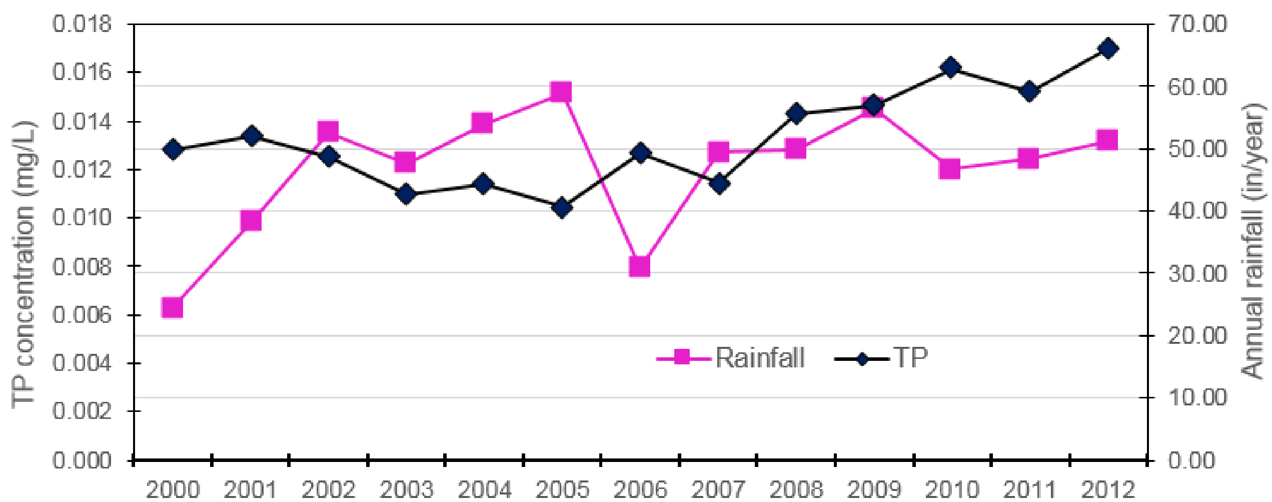


**FIGURE 5.3B. RELATIONSHIP BETWEEN ANNUAL RAINFALL AND TP AGM**

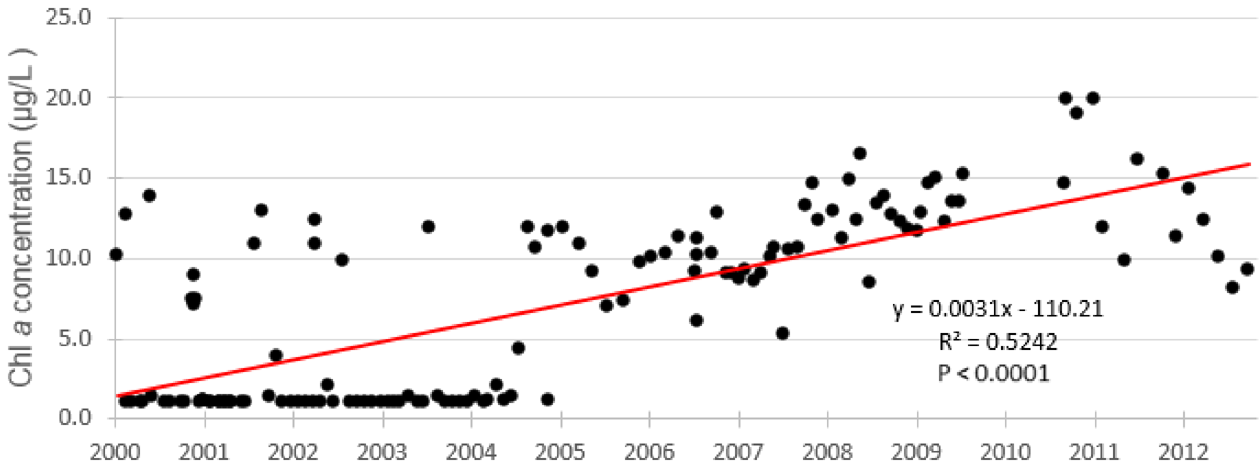


**FIGURE 5.4A. CHL *A* CONCENTRATIONS MEASURED FOR LAKE WEIR, 2000–12**

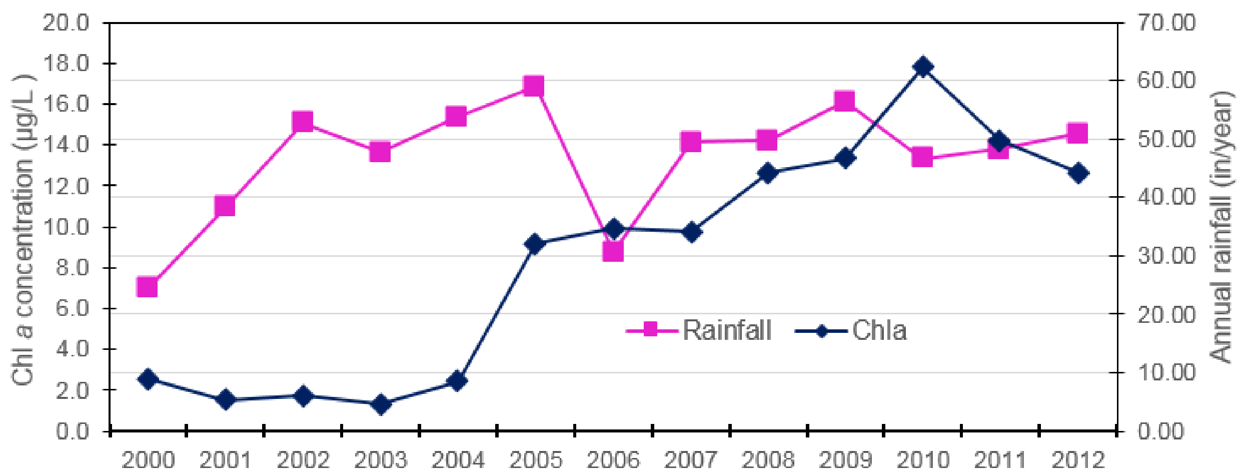


**FIGURE 5.4B. RELATIONSHIP BETWEEN ANNUAL RAINFALL AND CHL *A* AGM**

TN, TP, and chl *a* concentrations in the lake were not statistically correlated with the amount of rainfall. However, there was a general trend that when annual rainfall was high, TN, TP, and chl *a* concentrations decreased, and when annual rainfall was low, they concentrations increased.

## 5.2 Relationship between Nutrient Loadings and In-Lake Nutrient and Chl *a* Concentrations

The goal of nutrient TMDL development for Lake Weir is to identify the maximum allowable TP and TN loadings to the lake so that the lake will meet water quality standards and maintain its function and designated uses. In general, the process used for identifying water quality targets and establishing the nutrient TMDLs is divided into four main steps, as follows:

1. TP and TN loadings from the Lake Weir watershed were estimated using the curve number approach (see **Chapter 4**). Loadings from other sources, including atmospheric deposition directly onto the lake surface and input from septic tanks, were also considered in the loading estimation.

2. Loading estimates from all sources were entered into the BATHTUB model to establish the relationship between TN and TP loadings and in-lake TN, TP, and chl *a* concentrations by calibrating the model against the measured in-lake TN, TP, and chl *a* concentrations. The calibrated model was then used to predict in-lake existing TN, TP, and chl *a* concentrations.

3. All the human land uses in the watershed were then converted to natural land use in the BATHTUB model, in this case, forest/rangeland, to simulate the natural background TN, TP, and chl *a* concentrations. These natural background condition concentrations were compared with the generally applicable NNC to determine the target nutrient concentrations of TN, TP, and chl *a* for the TMDLs.

4. The TN and TP loads that achieved the target TN, TP, and chl *a* concentrations were considered the TMDLs for Lake Weir.

### *5.2.1 Lake Modeling Using the BATHTUB Model*

#### 5.2.1.1. BATHTUB Eutrophication Model

The BATHTUB model is a suite of empirically derived steady-state models developed by the United States Army Corps of Engineers (USACOE) Waterways Experimental Station. The primary function of these models is to estimate nutrient concentrations and algal biomass resulting from different patterns of nutrient loadings. The procedures for the selection of the appropriate model for a particular lake are described in the *User's Manual*. The empirical prediction of lake eutrophication using this approach typically is a two-stage procedure using the following two categories of models (Walker 2004):

- ***Nutrient balance model.*** This type of model relates in-lake nutrient concentrations to the external nutrient loadings, morphometry, and hydraulics of the lake.
- ***Eutrophication response model.*** This type of model describes relationships among eutrophication indicators in the lake, including nutrient levels, chl *a*, transparency, and hypolimnetic oxygen depletion.

**Figure 5.5** shows the scheme used by BATHTUB to relate the external loading of nutrients to in-lake nutrient concentrations and the physical, chemical, and biological responses of the lake to the level of nutrients.

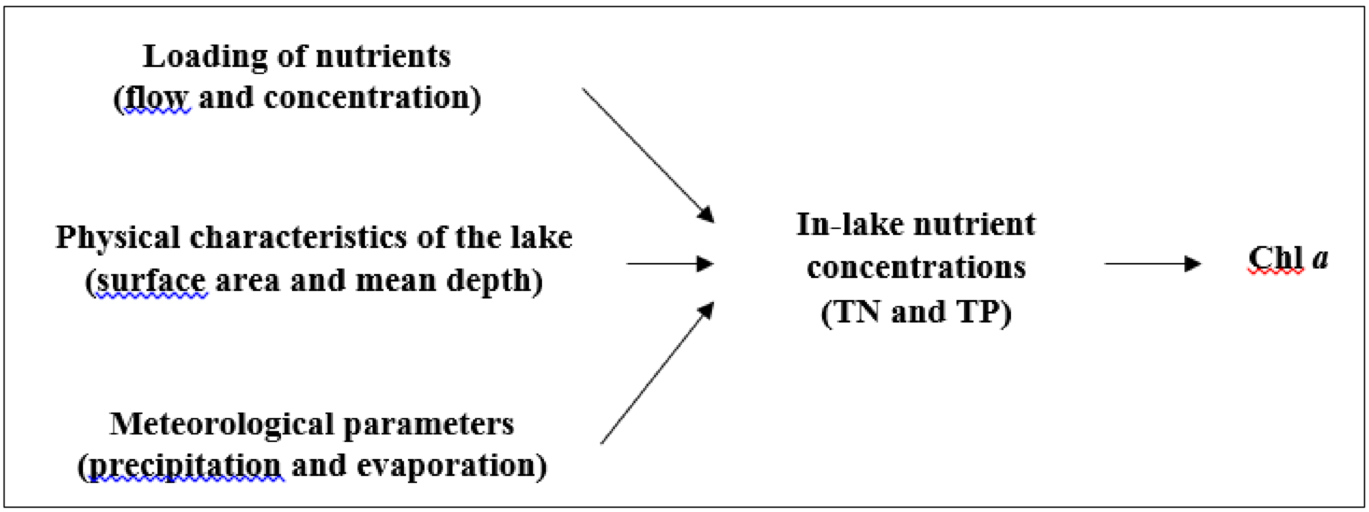


**FIGURE 5.5. BATHTUB CONCEPT SCHEME**

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

$$\text{Net accumulation} = \text{Inflow} - \text{Outflow} - \text{decay} \qquad \textbf{Equation (5.1)}$$

**Equation (5.1)** is solved by assuming that the pollutant dynamics in the lake are at a steady state, *i.e.*, the net accumulation of pollutants in the lake equals zero.

In this analysis, "inflow" included TN and TP loadings through stormwater surface runoff from various land use categories, septic seepage, ground water seepage, and atmospheric deposition directly onto the lake surface. Internal loading from sediment was not considered as a significant nutrient source. Lake Weir is relatively deep lake with narrow littoral zone and pan-shaped morphometry which minimize the sediment resuspension by wind and boating activities (Crisman 1992). Nutrient outflow was considered primarily through seepage from the lake. To address nutrient losses through processes other than seepage, BATHTUB provided several alternatives, depending on the inorganic/organic nutrient partitioning coefficient and reaction kinetics. The major pathway for TN and TP to be removed from the water column, in these simplified empirical equations, is through sedimentation to the bottom of the lake. The actual sedimentation rate is the net difference between the gross sedimentation rate and the sediment nutrient release rate.

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

One feature offered by BATHTUB is the "calibration factor." The empirical models implemented in BATHTUB are mathematical generalizations about lake behavior. When applied to data from a particular reservoir, measured data may differ from predictions by a factor of two or more. Such differences reflect data limitations (measurement or estimation errors in the average inflow and outflow concentrations), the unique features of the particular lake (Walker 2004), and unexpected processes inherent to the lake. The calibration factor offered by BATHTUB provides model users with a method to calibrate the magnitude of lake response predicted by the empirical models. The model calibrated to current conditions against measured data from the lake can then be applied to predict changes in lake conditions likely to result from specific management scenarios, under the condition that the calibration factor remains constant for all prediction scenarios.

#### 5.2.1.2 TMDL Scenario Development for Lake Weir

The TMDL of the lake was developed by evaluating the target concentrations of TN and TP for the following scenarios:

A. TN, TP, AND CHL A FOR CURRENT CONDITION

The current concentrations in Lake Weir were based on the AGMs of TN, TP, and chl *a* concentrations obtained from DEP's IWR Run_49. The calculated AGMs of TN, TP, and corrected chl *a* concentrations were used for model calibration.

B. NATURAL BACKGROUND CONCENTRATIONS

THESE ARE BASED ON THE TN, TP, AND CHL A concentrations resulting from a watershed condition in which all human land uses—including low-, medium-, and high-density residential; low- and high-density commercial; industrial; mining; open land/recreational: pasture; cropland; tree crops, and other agriculture—discharge pollutants with the same characteristics as those associated with natural land uses. In the actual modeling process, all the areas covered by human land uses were converted to forest/rangeland, and the loadings from septic tanks were completely removed. The natural background concentrations of TN, TP, and chl *a* were estimated using the model settings calibrated against the measured data.

C. MODEL SIMULATION FOR THE TARGET CONCENTRATIONS

The nutrient loadings that achieved the target TN, TP, and chl *a* concentrations were considered the TMDLs for the lake.

### *5.2.2 BATHTUB Model Calibration*

#### 5.2.2.1 Available Data and Data Use

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

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

— Coefficient of variance (CV) of all the measured data.

LAKE'S PHYSICAL CHARACTERISTICS

Lake surface area and lake water volume were calculated using a lake bathymetric chart and stage data provided by the SJRWMD. Regression equations were obtained from the relationship between contour elevation and area, and between elevation and volume. Stage data were applied to the equation to obtain lake surface area and lake water volume (**Figures 5.6** and **5.7**). Mean depth was calculated by lake volume divided by lake area. **Table 5.3** lists the lake stage, lake surface area, lake volume, mean depth, mixed layer depth, and change in lake storage of Lake Weir from 2000 through 2012.

The annual change of lake storage shown in **Table 5.3** was calculated as the difference between lake stage at the beginning (January 1) and the end (December 31) of each year. The annual average mixing depth was estimated by the following equation (Walker 2004).

$$\log(Zmix) = -0.06 + 1.36 \log(Z) - 0.47 [\log(Z)]^2$$

Where,

Z: Annual Average Mean Depth (m) **Equation (5.2)**

BATHTUB is a steady-state model; it is not usually appropriate in the systems with large year-to-year variations in lake volume, as seen in Lake Weir (**Table 5.3**). Therefore, DEP carried out a long-term simulation for the in-lake TN, TP, and chl *a* concentrations of Lake Weir instead of yearly simulations.

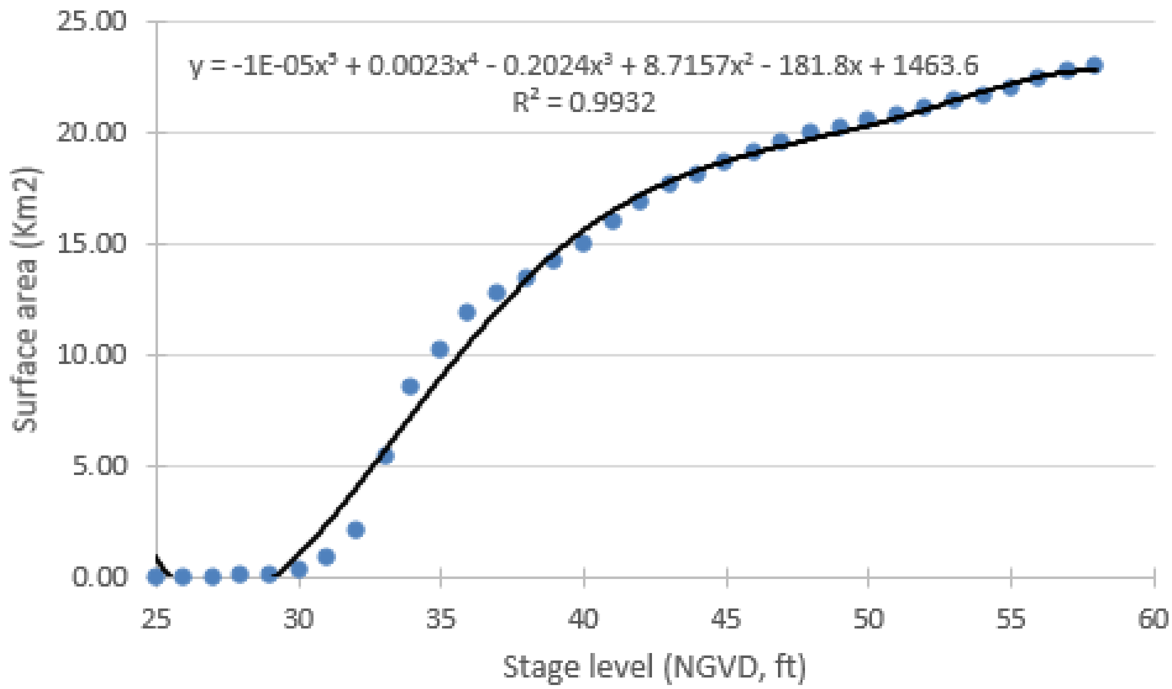


**FIGURE 5.6. CHARACTERISTIC CURVE BETWEEN LAKE STAGE AND LAKE SURFACE AREA FOR LAKE WEIR**

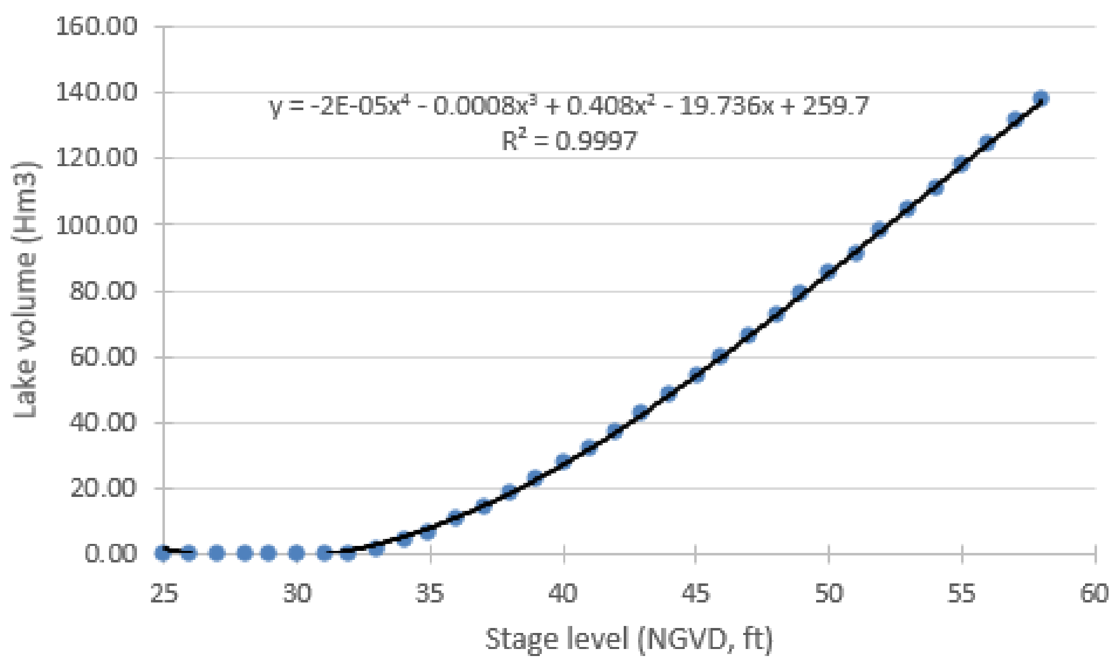


**FIGURE 5.7. CHARACTERISTIC CURVE BETWEEN LAKE STAGE AND LAKE CUMULATIVE VOLUME FOR LAKE WEIR**

**Table 5.3. Annual Lake Characteristics, Mean Depth, and CV of Lake Weir for the Modeling Period, 2000–12**

ft = Feet; $km^2$ = Square kilometer; $hm^3$ = Cubic hectometer; m = Meter

| Year | Annual Average Lake Stage NGVD (ft) | Annual Average Lake Surface ($km^2$) | Annual Average Lake Volume ($hm^3$) | Annual Average Mean Depth (m) | Estimated Annual Average Mixing Depth (m) | Annual change of Lake Storage (ft) |
|---|---|---|---|---|---|---|
| **2000** | 53.72 | 21.61 | 109 | 5.06 | 4.6 | -2.51 |
| **2001** | 52.25 | 21.19 | 100 | 4.70 | 4.4 | -0.13 |
| **2002** | 52.54 | 21.27 | 102 | 4.77 | 4.4 | 1.09 |
| **2003** | 54.18 | 21.75 | 112 | 5.16 | 4.7 | 0.87 |
| **2004** | 54.37 | 21.81 | 114 | 5.21 | 4.7 | 0.46 |
| **2005** | 55.59 | 22.23 | 122 | 5.48 | 4.9 | 1.41 |
| **2006** | 54.89 | 21.99 | 117 | 5.32 | 4.8 | -2.46 |
| **2007** | 53.29 | 21.48 | 106 | 4.95 | 4.6 | -0.40 |
| **2008** | 53.01 | 21.40 | 105 | 4.89 | 4.5 | -0.80 |
| **2009** | 52.29 | 21.20 | 100 | 4.71 | 4.4 | 0.13 |
| **2010** | 52.93 | 21.38 | 104 | 4.87 | 4.5 | -0.91 |
| **2011** | 51.75 | 21.05 | 96 | 4.58 | 4.3 | -0.76 |
| **2012** | 50.90 | 20.81 | 91 | 4.37 | 4.2 | -0.23 |
| **Mean** | **53.21** | **21.48** | **106** | **4.93** | **4.5** | **-0.33** |
| **CV** | **0.007** | **0.005** | **0.023** | **0.018** | **0.012** | **-1.024** |

### Meteorological Data

Meteorological data were provided by the SJRWMD. The daily rainfall estimates were developed from the NEXRAD Doppler rainfall coverage, which has a grid resolution of two kilometers by two kilometers. Evaporation data were obtained from the Lisbon weather station. These data are not the pan evaporation estimates reported by the weather station. Rather, they are potential evapotranspiration (PET) estimates developed in the SJRWMD Water Supply Impact Study. These estimates are based on the Hargreaves equation for water or normally saturated wetlands. **Table 5.4** lists annual rainfall and evaporation values for 2000 through 2012.

**Table 5.4. Annual Meteorological Data Used for BATHTUB Modeling, 2000-12**

| Value | Annual Rainfall (m/yr) | Annual Evaporation (m/yr) |
|---|---|---|
| **Mean** | 1.188 | 1.305 |
| **CV** | 0.059 | 0.008 |

### AREAL ATMOSPHERIC NUTRIENT LOADINGS

One source of TN and TP loading to Lake Weir is TN and TP falling directly onto the lake surface through atmospheric deposition. TN and TP concentrations of wet and dry deposition collected in Apopka, Florida, were obtained from the SJRWMD. Atmospheric wet deposition of TN and TP was calculated by multiplying the amount of precipitation directly falling on the lake surface (calculated by multiplying annual precipitation by the lake surface area) by the TN and TP concentration of rainfall. To obtain areal atmospheric wet deposition loads, the total loads were divided by the lake surface area. Areal atmospheric dry deposition loads were calculated using the following formula: (sample concentration * sample volume) / (collection bucket area * exposure time). To obtain total atmospheric loading, wet deposition values were added to dry deposition. **Table 5.5** lists the average areal atmospheric deposition rate of TN and TP loadings for the modeling period from 2000 through 2012.

**TABLE 5.5. LONG-TERM MEAN AND CV OF ANNUAL AREAL ATMOSPHERE NUTRIENT LOADINGS TO LAKE WEIR, 2000–12**

| VALUE | ANNUAL RAINFALL (IN/YR) | ANNUAL AVERAGE LAKE SURFACE ($KM^2$) | ATMOS-PHERIC TP CONC. WET (MG/L) | ATMOS-PHERIC TN CONC. WET (MG/L) | ATMOS-PHERIC TP FLUX DRY ($MG/M^2/YR$) | ATMOS-PHERIC TN FLUX DRY ($MG/M^2/YR$) | TOTAL AREAL ATMOS-PHERIC LOAD FOR TP ($MG/M^2/YR$) | TOTAL AREAL ATMOS-PHERIC LOAD FOR TN ($MG/M^2/YR$) |
|---|---|---|---|---|---|---|---|---|
| **Mean** | 46.78 | 21.48 | 0.014 | 0.580 | 22 | 178 | 38 | 858 |
| **CV** | 0.059 | 0.005 | 0.088 | 0.046 | 0.129 | 0.081 | 0.114 | 0.054 |

### MEASURED WATER QUALITY DATA (TN, TP, AND CHL *A* CONCENTRATIONS OF THE LAKE WATER)

TN, TP, and chl *a* concentrations for Lake Weir from 2000 to 2012 were retrieved for IWR Run_49. AGM values for TN, TP, and chl *a* were calculated each year, and then long-term averages of AGMs and CV were calculated. Corrected chl *a* was used for the analysis. **Table 5.6** lists the long-term average of AGMs and CV of each parameter for Lake Weir from 2000 through 2012.

**TABLE 5.6. LONG-TERM AVERAGE AGMS OF TN, TP, AND CHL *A* CONCENTRATIONS OF LAKE WEIR**

**Unit**: ppb

| VALUE | TN | TP | CHL *A* |
|---|---|---|---|
| **Mean** | 834 | 13 | 8.3 |
| **CV** | 0.042 | 0.043 | 0.191 |

### LOADING DATA (FLOW AND TN AND TP CONCENTRATIONS OF VARIOUS SOURCES IN THE WATERSHED)

BATHTUB does not allow the direct input of loading. Therefore, the data presented here are flow ($hm^3/yr$), and TN and TP concentrations (ppb) in the watershed. TN and TP concentrations presented for each source were calculated by dividing TN and TP loadings by the flow from the watershed. **Table 5.7** lists the mean and CV of the annual flow and nutrient concentrations from each major nonpoint source into Lake Weir from 2000 through 2012. Flow and TN and TP concentrations for the seepage from septic systems were calculated from the ArcNLET result.

**TABLE 5.7. LONG-TERM MEAN AND CV OF FLOW AND TN AND TP CONCENTRATIONS INTO LAKE WEIR FROM DIFFERENT LAND USE CATEGORIES, 2000–12**

| LAND USE CATEGORY | FLOW MEAN ($HM^3$/YR) | FLOW CV | TN MEAN (PPB) | TN CV | TP MEAN (PPB) | TP CV |
|---|---|---|---|---|---|---|
| **Low-density residential** | 0.406 | 0.082 | 1,318 | 0.005 | 98 | 0.008 |
| **Medium-density residential** | 0.445 | 0.076 | 1,475 | 0.007 | 130 | 0.012 |
| **High-density residential** | 0.018 | 0.062 | 1,761 | 0.011 | 260 | 0.011 |
| **Low-density commercial** | 0.097 | 0.062 | 676 | 0.006 | 67 | 0.008 |
| **High-density commercial** | 0.062 | 0.063 | 1,653 | 0.008 | 197 | 0.009 |
| **Industrial** | 0.010 | 0.059 | 950 | 0.008 | 103 | 0.008 |
| **Mining** | 0.001 | 0.252 | 690 | 0.071 | 60 | 0.128 |
| **Open land/recreational** | 0.050 | 0.150 | 1,043 | 0.013 | 37 | 0.013 |
| **Pasture** | 0.081 | 0.176 | 2,287 | 0.008 | 306 | 0.008 |
| **Cropland** | 0.011 | 0.246 | 4,246 | 0.004 | 481 | 0.004 |
| **Tree crops** | 0.039 | 0.166 | 1,905 | 0.004 | 103 | 0.004 |
| **Other agriculture** | 0.001 | 0.154 | 2,607 | 0.009 | 375 | 0.009 |
| **Forest/rangeland** | 0.166 | 0.188 | 1,033 | 0.001 | 37 | 0.001 |
| **Water** | 1.676 | 0.059 | 298 | 0.007 | 5 | 0.007 |
| **Wetlands** | 2.757 | 0.060 | 1,046 | 0.002 | 36 | 0.007 |
| **Seepage from septic system** | 0.367 | | 16,044 | | 2,651 | |
| **Ground water** | 18.25 | | 230 | | 38 | |

Because of the lack of information on ground water flow rate when these TMDLs was developed, DEP used seepage velocity (3.244 m/day) from the ArcNLET result. For the flow rate of ground water, the following equations were used.

$$\text{Flow rate of ground water} = \text{seepage velocity} \times \text{seepage area}$$

$$\text{Seepage area} = \text{Lake perimeter} \times \text{seepage depth}$$

The procedures were used to calculate general regional ground water seepage, which does not include the flow from septic tanks. The perimeter of Lake Weir measured based on the WBID shape file using ArcGIS was 30.82 km. DEP estimated seepage depth based on a literature review: “No seepage was detected >30m offshore” (Deevey 1988). Deevey estimated downward leakage from 20 Florida lakes, including Lake Weir. DEP estimated that the depth of Lake Weir at 30 m offshore would be 0.5 m based on the lake bathymetric map. TN and TP concentrations in the BATHTUB model to simulate ground water loadings were 230 ppb for TN and 38 ppb for TP from ground water samples collected from wells located in the Lake Weir outlet area (WBID 2790).

#### 5.2.2.2 Calibrating the BATHTUB Model

To calibrate the model, each source of TN and TP was designated as an independent tributary. Flow and TN and TP concentrations of the flow were defined for each tributary, as listed in **Table 5.7**.

BATHTUB provides alternative models for estimating the influence of sedimentation on in-lake TN and TP concentrations. $2^{nd}$ Order, Fixed model (Option 3 in BATHTUB) was used for TP and Bachman Flushing (Option 5 in BATHTUB) for TN because those models best predicted the observed water quality conditions in Lake Weir.

BATHTUB provides two chl *a* responding models based on the assumption of nitrogen and phosphorus co-limitation: Model 1 and 3. Model 1 assumes that algal communities are not only limited by nutrients but also by light intensity. Model 1 was selected because the lake's relatively deep water would be expected to lead to light limitation. BATHTUB allows the user to control the light limitation caused by suspended particles using the nonalgal turbidity function, which is calculated by chlorophyll and Secchi depth. The value for nonalgal turbidity used in this analysis was 0.46.

Calibration factors are applied to fit TN and TP predictions to the measured data. In this analysis, DEP adopted the calibration method, which calibrates decay rates. The calibration factors are applied to estimated sedimentation rates in computing nutrient balances. Typical calibration factors for TN and TP recommended by the BATHTUB *User's Manual* are 0.5 to 2.0 for TP and 0.33 to 3 for TN. **Table 5.8** lists the simulations for in-lake TN, TP and chl *a* concentrations with the mean of AGM (2000–12) without any calibration factors.

**TABLE 5.8. SIMULATION RESULTS FOR TN, TP, AND CHL *A* CONCENTRATION USING THE BATHTUB MODEL**

**Unit**: ppb

| VALUE | TN | TP | CHL *A* |
|---|---|---|---|
| **Measured** | 834 | 13 | 8.3 |
| **Simulated** | 642 | 15 | 5.4 |

The BATHTUB simulation underestimated TN and chl *a* concentrations by 23% and 34% less than measured results, respectively, but overestimated the TP concentration by 14%. TN and TP calibrations were primarily conducted by applying calibration factors. In this TMDL analysis, calibration factors of 0.61 for TN and 1.32 for TP were applied to the sedimentation rates to match the model simulates to measured data.

#### 5.2.2.3. BATHTUB Simulation

**Table 5.9** shows the measured and BATHTUB-simulated TN, TP, and chl *a* concentrations. The BATHTUB model was calibrated using the long-term AGMs of TN, TP, and chl *a* concentrations measured from 2000 to 2012. The model-simulated TN and TP concentrations were consistent with the measured TN and TP concentrations because those concentrations were calibrated by applying calibration factors.

**TABLE 5.9. LONG-TERM BATHTUB CALIBRATION AND SIMULATION RESULTS WITH CV**

| PARAMETER | MEASURED | CV | SIMULATED | CV |
|---|---|---|---|---|
| **TN (mg/L)** | 0.834 | 0.04 | 0.832 | 0.26 |
| **TP (mg/L)** | 0.013 | 0.04 | 0.013 | 0.21 |
| **Chl *a* (µg/L)** | 8.25 | 0.19 | 8.28 | 0.35 |

For the model-simulated chl *a* concentration, a calibration factor was also added to the model to be consistent with the measured chl *a* concentration. The long-term mean concentration of AGMs for model estimates was consistent between the measured and the simulated. The calibration factor of 1.7 was applied for the chl *a* simulation.

TN AND TP LOADINGS FROM VARIOUS SOURCES

Based on **Table 5.10**, the total annual TN loading from various sources to Lake Weir was 33,823 kg/yr. Atmospheric deposition, the largest nitrogen loading source in Lake Weir, reached 18,430 kg/yr, accounting for 55% of total loads. Surface runoff to the Lake Weir water surface was 5,314 kg/yr and represented 16% of long-term total TN loading. TN loading from ground water was 4,186 kg/yr, accounting for 12% of total TN loading. The septic load was 5,893 kg/yr, which was quantified using ArcNLET modeling and accounted for 17% of total TN loads.

According to **Table 5.11**, total TP loading from various sources to Lake Weir was 2,754 kg/yr. TP loading from atmospheric deposition represented 816 kg/yr, accounting for 30% of total TP loading. The surface runoff to Lake Weir was 272 kg/yr and represented 10% of total TP loading. The ground water loading to Lake Weir was 692 kg/yr, accounting for 25% of total TP loading. The TP load from septic effluent from ground water seepage was estimated based on the TN result from ArcNLET and the ratio of TN: TP (6.05:1) in the ground water sample from the Lake Weir outlet (WBID 2790). The septic tank TP load was 974 kg/yr and accounted for 35% of total TP loading.

**TABLE 5.10. LONG-TERM MEAN ANNUAL TN LOADING FROM DIFFERENT SOURCES INTO LAKE WEIR, 2000–12 (KG/YR)**

| VALUE | ATMOSPHERIC DEPOSITION | SURFACE RUNOFF | GROUND WATER | SEPTIC LOAD | TOTAL |
|---|---|---|---|---|---|
| **Long-Term Mean Annual** | 18,430 | 5,314 | 4,186 | 5,893 | 33,823 |
| **%** | 55% | 16% | 12% | 17% | 100% |

**TABLE 5.11. LONG-TERM MEAN ANNUAL TP LOADING FROM DIFFERENT SOURCES INTO LAKE WEIR, 2000–12 (KG/YR)**

| VALUE | ATMOSPHERIC DEPOSITION | SURFACE RUNOFF | GROUND WATER | SEPTIC LOAD | TOTAL |
|---|---|---|---|---|---|
| **Long-Term Mean Annual** | 816 | 272 | 692 | 974 | 2,754 |
| **%** | 30% | 10% | 25% | 35% | 100% |

### EVALUATING THE NATURAL BACKGROUND CONDITION OF LAKE WEIR

To avoid abating the natural background condition in setting TMDL targets, natural background TN and TP concentrations and loadings were estimated using the following procedures:

1. The loadings from septic tanks were completely removed.

2. All the human land use categories (urban and agricultural land use areas) in the watershed were converted to natural lands such as wetland or forest/rangeland. In order to allocate existing human land uses to forest/rangeland areas, **Table 5.12** was used to determine the hydrologic soil group compositions in human land use areas. Because soils with human land uses in the Lake Weir watershed are dominated by Type A (representing 94% of the total human land use areas), which is mostly considered upland soil, all human land use

types were converted to forest/rangeland when simulating the natural background condition.

3. TN and TP loadings from atmospheric direct deposition, water, wetlands, and ground water remained the same.

**TABLE 5.12. SOILS TYPE DISTRIBUTION OF HUMAN LAND USE AREAS IN THE LAKE WEIR WATERSHED**

| SOIL HYDROLOGIC GROUP | ACREAGE | % ACREAGE |
|---|---|---|
| **A** | 4,388.0 | 93.7% |
| **B** | 38.5 | 0.8% |
| **D (A/D)** | 123.3 | 2.6% |
| **D (B/D)** | 121.8 | 2.6% |
| **D(X)** | 9.8 | 0.2 |
| **Total** | **4,681.4** | **100%** |

**Table 5.13** lists the resulting TN, TP, and chl *a* concentrations. As shown in the table, after all the human land use categories were "converted" to forest/rangeland, septic loads were removed, and the TN and TP concentrations of the inflow were decreased to the level of those found in unimpacted forest/rangeland (TP = 0.037 and TN = 1.03 mg/L), the long-term average AGMs of TN, TP, and chl *a* concentrations decreased from 0.83 mg/L, 0.013 mg/L, and 8.3 µg/L to 0.68 mg/L, 0.010 mg/L, and 6.0 µg/L, respectively. This represents an 18% decrease in TN, a 23% decrease in TP, and a 27% decrease in chl *a* concentrations from the existing condition.

**TABLE 5.13. BACKGROUND CONDITION LONG-TERM AVERAGE AGM TN, TP, AND CHL *A* CONCENTRATIONS**

| VALUE | TP (MG/L) | TN (MG/L) | CHL *A* (µG/L) |
|---|---|---|---|
| **Mean** | 0.010 | 0.68 | 6.0 |
| **CV** | 0.21 | 0.26 | 0.36 |

SIMULATION OF TARGET NUTRIENT LOADS

Because the model-simulated background chl *a* concentration equals the generally applicable NNC chl *a* criterion of 6 µg/L for low-color and low-alkalinity lakes, 6 µg/L was used as the chl *a* target concentration for the Lake Weir TMDLs. As described in the previous section, the long-term average AGM TN and TP concentrations corresponding to 6 µg/L of chl *a* are 0.68 and 0.01 mg/L, respectively. The watershed TN and TP loads that allow these in-lake target concentrations to be achieved are considered the TMDLs for Lake Weir. The target loads are long-term average annual loads not to be exceeded. **Table 5.14** lists the TN and TP loadings from major sources to Lake Weir at the target conditions. **Table 5.15** shows the annual TN and TP load reductions required to achieve the water quality target, the TMDLs for TN and TP, and the long-term average annual load reductions required to achieve the TMDLs.

**TABLE 5.14. TARGET ANNUAL TN AND TP LOADINGS FROM DIFFERENT SOURCES INTO LAKE WEIR (KG/YR)**

| PARAMETER | ATMOSPHERIC DEPOSITION | GROUND WATER | SURFACE RUNOFF | TOTAL |
|---|---|---|---|---|
| **TN** | 18,430 | 4,186 | 4,816 | 27,432 |
| **TP** | 816 | 692 | 159 | 1,667 |

**TABLE 5.15. ANNUAL TN AND TP LOAD REDUCTIONS REQUIRED TO ACHIEVE THE WATER QUALITY TARGETS FOR LAKE WEIR (KG/YR)**

| PARAMETER | EXISTING LOADING | TARGET LOADING | REQUIRED LOAD REDUCTION | % REQUIRED LOAD REDUCTION |
|---|---|---|---|---|
| **TN** | 33,823 | 27,432 | 6,391 | 19% |
| **TP** | 2,754 | 1,667 | 1,087 | 39% |

# CHAPTER 6: DETERMINATION OF THE TMDL

## 6.1 Expression and Allocation of the TMDLs

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

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

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

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

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

WLAs for stormwater discharges are typically expressed as a "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 also differs from the permitting of most wastewater point sources. Because stormwater discharges cannot be centrally collected, monitored, and treated, they are not subject to the same types of effluent limitations as wastewater facilities, and instead are required to meet a performance standard of providing treatment to the "maximum extent practical" through the implementation of best management practices (BMPs).

This approach is consistent with federal regulations (40 Code of Federal Regulations § 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 TMDLs for Lake Weir are expressed in terms of kg/yr and percent reduction of TN and TP, and represent the maximum long-term annual average TN and TP loadings the lake can assimilate and maintain a balanced aquatic flora and fauna (**Table 6.1**).

Based on an EPA memorandum (2006), daily loads of TN and TP from point and nonpoint sources were also calculated. These daily loads were calculated by dividing the annual loads by 365 days/yr and are only provided in this report for informational purposes. The implementation of the TMDLs in this report should be carried out using an annual time scale.

**TABLE 6.1. TMDL COMPONENTS FOR NUTRIENTS IN LAKE WEIR (WBID 2790A)**

N/A = Not applicable
Note: The daily loading targets for TN and TP are 75.2 and 4.6 kg/day, respectively.
* The required percent reductions shown in this table represent the reduction from all sources. The needed percent reduction to each individual source type can be calculated based on the relative load contribution from each source type provided in **Chapter 5**.

| WBID | PARAMETER | WLA WASTEWATER (KG/YEAR) | WLA* STORMWATER (% REDUCTION) | LA* (% REDUCTION) | TMDL (KG/YR) | MOS |
|---|---|---|---|---|---|---|
| **2790A** | TN | N/A | 19% | 19% | 27,432 | Implicit |
| **2790A** | TP | N/A | 39% | 39% | 1,667 | Implicit |

## 6.2 Load Allocation

To achieve the load allocation (LA), current TN and TP loads require reductions of 19% and 39%, respectively. As these percent reductions are for the total loads from all sources, and any natural land uses are held harmless, the percent reductions for the anthropogenic sources may be greater. It should be noted that the LA may include loads from stormwater discharges regulated by DEP and the SJRWMD that are not part of the NPDES Stormwater Program (see **Appendix A**).

## 6.3 Wasteload Allocation

### *6.3.1 NPDES Wastewater Discharges*

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

### *6.3.2 NPDES Stormwater Discharges*

Because no information was available to DEP when this analysis was conducted regarding the boundaries and locations of all the NPDES stormwater dischargers, the exact stormwater TN and TP loadings from MS4 areas were not explicitly estimated. In the Lake Weir watershed, the stormwater collection systems owned and operated by Marion County are covered by a Phase II NPDES MS4 permit (FLR04E021). The $WLA_{NPDESStormwater}$ was set as the same percent reduction required to achieve the TMDLs as for the other conventional nonpoint sources, or 19% for TN and 39% for TP, respectively.

## 6.4 Margin of Safety

TMDLs must address uncertainty issues by incorporating an MOS into the analysis. The MOS is a required component of a TMDL and accounts for the uncertainty about the relationship between pollutant loads and the quality of the receiving waterbody (Clean Water Act, Section 303[d][1][c]). Considerable uncertainty is usually inherent in estimating nutrient loading from nonpoint sources, as well as predicting water quality response. The effectiveness of management activities (*e.g.,* stormwater management plans) in reducing loading is also subject to uncertainty. The MOS can either be implicitly accounted for by choosing conservative assumptions about loading or water quality response, or explicitly accounted for during the allocation of loadings.

Consistent with the recommendations of the Allocation Technical Advisory Committee (DEP 2001), an implicit MOS was used in the development of the Lake Weir TMDLs, because the TMDLs were based on the conservative decisions associated with a number of the modeling assumptions in determining assimilative capacity (*i.e.*, loading and water quality response) for Lake Weir.

In the past, management activities to control lake eutrophication focused on phosphorus reduction, as phosphorus was generally recognized as the limiting nutrient in freshwater systems. Recent studies, however, have supported that the reduction of both nitrogen and phosphorus is more effective in controlling algal growth in aquatic systems. Furthermore, the analysis used in the development of the Florida lake NNC supports this idea, as statistically significant relationships were found between chl *a* values and both nitrogen and phosphorus concentrations. Although the annual average TN/TP ratio for Lake Weir suggested TP limitation in Lake Weir, DEP developed both TN and TP TMDLs. Algal growth limitation by TN and TP would be different by season, environmental conditions, and algal species composition. Reducing both nitrogen and phosphorus would be more protective and also adds to the MOS.

# Chapter 7: TMDL Implementation

## 7.1 Implementation Mechanisms

Following the adoption of a TMDL, implementation takes place through various measures. The implementation of TMDLs may occur through specific requirements in NPDES wastewater and municipal separate storm sewer (MS4) permits, and, as appropriate, through local or regional water quality initiatives or basin management action plans (BMAPs).

Facilities with NPDES permits that discharge to the TMDL waterbody must respond to the permit conditions that reflect target concentrations, reductions, or wasteload allocations identified in the TMDL. NPDES permits are required for Phase I and Phase II MS4s as well as domestic and industrial wastewater facilities. MS4 Phase I permits require that the permit holder prioritize and take action to address a TMDL unless management actions are already defined in a BMAP. MS4 Phase II permit holders must also implement responsibilities defined in a BMAP.

## 7.2 BMAPs

BMAPs are discretionary and are not initiated for all TMDLs. A BMAP is a TMDL implementation tool that integrates the appropriate management strategies applicable through existing water quality protection programs. DEP or a local entity may develop a BMAP that addresses some or all of the contributing areas to the TMDL waterbody.

Section 403.067, F.S. (FWRA), provides for the development and implementation of BMAPs. BMAPs are adopted by the DEP Secretary and are legally enforceable.

BMAPs describe the management strategies that will be implemented, as well as funding strategies, project tracking mechanisms, water quality monitoring, and fair and equitable allocations of pollution reduction responsibilities to the sources in the watershed. BMAPs also identify mechanisms to address potential pollutant loading from future growth and development. The most important component of a BMAP is the list of management strategies to reduce pollution sources, as these are the activities needed to implement the TMDL. The local entities who will conduct these management strategies are identified and their responsibilities are enforceable. Management strategies may include wastewater treatment upgrades, stormwater improvements, and agricultural BMPs. Additional information about BMAPs is available on DEP's website.

## 7.3 Implementation Considerations for Lake Weir

Since a BMAP is already adopted for the Upper Chain of Lakes in the Ocklawaha River Basin to provide the conceptual plan for restoration, the BMAP for Lake Weir may be incorporated into the effort.

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# Appendices

## Appendix A: Summary of Information in Support of Site-Specific Interpretations of the Narrative Nutrient Criterion for Lake Weir

### Table A-1. Spatial Extent of the Waterbody where the Site-Specific Numeric Interpretation of the Narrative Nutrient Criterion Will Apply

| Location | Descriptive Information |
|---|---|
| **Waterbody name** | Lake Weir |
| **Waterbody type(s)** | Lake |
| **Waterbody ID (WBID)** | WBID 2790A (See **Figure 1.1**) |
| **Description** | Lake Weir is located in Marion County, Florida. The estimated average surface area of the lake is 5,600 acres, with a normal pool volume of 85,936 ac/ft and an average depth of 16.2 feet. Lake Weir receives runoff from a watershed area of 7,313 acres occupied by forest/rangeland, urban and residential, agricultural areas, and wetlands. There is no obvious inflow to the lake other than water flow from Little Lake Weir (located west of the lake) through a canal to Sunset Harbor. When the water levels are high, surface water may discharge to the Ocklawaha River over a weir structure located in the northeast corner of the lake. Lake Weir is predominantly a clear, acidic to neutral, and oligotrophic to mesotrophic lake. |
| **Specific location (latitude/longitude or river miles)** | The center of Lake Weir is located at Latitude N: 29°01’01.563,” Longitude W: - 81°56’15.019.” |
| **Map** | The general location of Lake Weir and its watershed, and land uses in the watershed, are shown in **Figures 4.2a** and **4.2b**, respectively. Watershed land uses include urban and residential (37.2%), forest/rangeland (24.6%), agriculture (20.8%), and wetlands (11.3%). |
| **Classification(s)** | Class III Freshwater |
| **Basin name (HUC-8)** | Ocklawaha River Basin (03080102) |

## Table A-2. Default NNC, Site-Specific Interpretations of the Narrative Criterion Developed as TMDL Targets, and Data Used To Develop the Site-Specific Interpretation of the Narrative Criterion

| Narrative Nutrient Criterion | Description |
|---|---|
| **NNC Summary:**<br>**Default nutrient watershed region or lake classification (if applicable) and corresponding NNC** | Lake Weir is a low-color and low-alkalinity lake, and the default NNC, expressed as AGM concentrations not to be exceeded more than once in any three-year period, are chl *a* of 6 µg/L, TN of 0.51 to 0.93 mg/L, and TP of 0.01 to 0.03 mg/L. |
| **Proposed TN, TP, chl *a*, and/or nitrate+nitrite (magnitude, duration, and frequency)** | Numeric interpretations of the narrative nutrient criterion:<br>This TMDL is only modifying the default NNC for TN and TP. (The default NNC for CHLA is not being changed as the department has no evidence that the default criterion is not protective of the designated uses of the lake.) The revised TN and TP NNC are expressed as long-term loads. Specifically, the TN load of 27,432 kg/yr and TP load of 1,667 kg/yr, are both expressed as long-term (7 year) averages of annual loads, not to be exceeded.<br><br>These loadings were derived from watershed and receiving water modeling and resulted in the default in-lake AGM chl *a* concentration of 6.0 µg/L being attained.<br><br>For the assessment purpose, the annual loads will be calculated during the Verified Period. The TMDL loads will be considered as site-specific interpretation of the narrative criterion. |
| **Period of record used to develop the numeric interpretations of the narrative nutrient criterion for TN and TP criteria** | The criteria were developed based on the application of the NRCS watershed curve number model and the receiving water BATHTUB model that simulated hydrology and water quality conditions over the 2000–12 period. The primary datasets for this period include water quality data from the IWR database (IWR_Run 49), rainfall and evapotranspiration data, and lake stage data for 2000–12 obtained from the SJRWMD. Land use data from two years were used to establish the watershed nutrient loads. For the 2000–05 model simulation period, the SJRWMD's 2004 land use was used. For the 2006–12 period, the SJRWMD's 2009 land use was used. |
| **Indicate how criteria developed are spatially and temporally representative of the waterbody or critical condition**<br><br>**Are the stations used representative of the entire extent of the WBID and where the criteria are applied? In addition, for older TMDLs, an explanation of the representativeness of the data period is needed (*e.g.*, have data or information become available since the TMDL analysis?). These details are critical to demonstrate why the resulting criteria will be protective as opposed to the otherwise applicable criteria (in cases where numeric criteria are otherwise in effect, unlike this case).** | The model simulated the 2000–12 period, which included both wet and dry years. During the model simulation period, the total annual average rainfall varied from 26.4 to 54.8 inches and averaged 46.8 inches. A comparison with the long-term average rainfall data indicated that 2000 and 2006 were dry years, while 2002, 2004, 2005, and 2009 were considered wet years.<br><br>The NWS NEXRAD rainfall data that the SJRWMD received were used as the model input for estimating nutrient loads from the watershed. These rainfall data sets have a spatial resolution of two kilometers by two kilometers, which properly represented the spatial heterogeneity of the rainfall in the targeted watershed area. The model simulated the entire watershed to evaluate how changes in watershed loads impact the lake nutrient and chl *a* concentrations.<br><br>In addition, model calibration for the Lake Weir TMDLs was based on water quality data collected across the lake. **Figure 5.1** shows the water quality sampling stations used in the Lake Weir model calibration process. These properly represent the spatial distribution of nutrient dynamics of the lake. |

## Table A-3. History of Nutrient Impairment, Quantitative Indicators of Designated Use Support, and Methodologies Used to Develop the Site-Specific Interpretation of the Narrative Criterion

| Designated Use | Description |
|---|---|
| **History of assessment of designated use support** | DEP used the IWR (Chapter 62-303, F.A.C.) to assess water quality in Lake Weir. The lake was initially verified as impaired for nutrients during the Cycle 1 assessment (verified period January 1, 1995–June 30, 2002) using the methodology in the IWR, and was included on the Cycle 1 Verified List of impaired waters for the Ocklawaha River Basin adopted by Secretarial Order on August 28, 2002. Subsequently, the nutrient impairment was confirmed in the Cycle 2 assessment (January 1, 2000–June 30, 2007) and Cycle 3 assessment (January 1, 2005–June 30, 2012), based on the fact that annual average TSI values exceeded 40 during the period from 2005 to 2012, except for 2010 because of insufficient data.<br><br>DEP also assessed water quality in Lake Weir using the adopted lake NNC. The results confirmed that Lake Weir is impaired for nutrients. Chl *a* data for Lake Weir from 2000 to 2012 were used to assess the nutrient impairment based on the NNC. Except for 2010, there were sufficient chl *a* data in all the other years to meet the data sufficiency requirements of Subsection 62-302.531(6), F.A.C., to calculate the AGM of chl *a* concentrations. In 7 out of 12 years, (2005, 2006, 2007, 2008, 2009, 2011, and 2012) the AGM of chl *a* concentration exceeded the 6 µg/L criterion, indicating that the lake is impaired for chl *a*. |
| **Basis for use support** | Lake Weir TMDL targets were established to achieve a concentration of 6 µg/L, which is consistent with the applicable chl *a* criterion for low-color and low-alkalinity lakes. This chl *a* criterion has demonstrated through the process of Florida NNC development, based on multiple lines of evidence, that it is protective of designated use for this type of lake. In addition, for Lake Weir, a 6 µg/L chl *a* concentration represents a natural background condition, which inherently is the best nutrient condition that can be expected for the lake without abating the natural condition. |
| **Summarize approach used to develop criteria and how it protects uses** | For the Lake Weir nutrient TMDLs, DEP established the TN and TP target loads to achieve a 6 µg/L chl *a* concentration target, which represents the natural background condition for Lake Weir and is consistent with the applicable chl *a* criterion for low-color and low-alkalinity lakes. These loads will also achieve in-lake TN and TP concentrations of 0.68 and 0.01 mg/L, respectively. These loading targets were established using a NRCS curve number watershed model and a receiving water BATHTUB model to quantify the relationship between watershed nutrient loads and in-lake TN, TP, and chl *a* concentration dynamics through the model calibration. The nutrient loads from anthropogenic sources such as human land use areas and septic tank loads were then removed to achieve the 6 µg/L chl *a* concentration target. The allowable loads that achieve this chl *a* target were established as the TN and TP TMDLs for Lake Weir. |
| **Discuss how the TMDL will ensure that nutrient-related parameters are attained to demonstrate that the TMDL will not negatively impact other water quality criteria. These parameters must be analyzed with the appropriate frequency and duration. If compliance with 47(a) is not indicated in the TMDL, it should be clear that further reductions may be required in the future.** | DEP notes that no other impairments were verified for Lake Weir that may be related to nutrients (such as DO or un-ionized ammonia). Reducing nutrient loads entering the lake will not negatively impact other water quality parameters in the lake. |

### Table A-4. Site Specific Interpretation of the Narrative Criterion and the Protection of Designated Use for Downstream Segments

| Downstream Protection and Monitoring | Description |
|---|---|
| Identification of Downstream Waters: List receiving waters and identify technical justification for concluding downstream waters are protected. | Lake Weir drains to Lake Weir Outlet (WBID 2786) over a weir structure located in the northeast corner of the lake when water levels are high. Lake Weir Outlet discharges to the Ocklawaha River via Marshall Swamp Drain (WBID 2778). Based on data for the period from 2000 through 2012, outflow from Lake Weir to these downstream waters is rare.<br><br>The applicable nutrient criteria for these downstream river systems are 0.12 mg/L of TP and 1.54 mg/L of TN. Since the nutrient targets for Lake Weir are 0.01 mg/L for TP and 0.68 mg/L for TN, which are both lower than the NNC applicable to the downstream water segment, the nutrient targets developed for Lake Weir are protective of downstream waters. |
| Provide summary of existing monitoring and assessment related to implementation of Paragraph 62-302.531(4), F.A.C., and trends tests in Chapter 62-303, F.A.C. | Water quality data were collected in Lake Weir by DEP, Marion County, LakeWatch, and the SJRWMD. These organizations will continue to carry out monitoring activities in Lake Weir to evaluate future water quality trends in the lake. The data collected will be used to evaluate the effect of BMPs implemented in the watershed on the lake TN and TP concentrations in subsequent water quality assessment cycles. |

## Table A-5. Public Participation and Legal Requirements of Rule Adoption

| Administrative Requirements | Descriptive Information |
|---|---|
| **Notice and comment notifications** | DEP held a public workshop on February 17, 2015, in Lady Lake, Florida, to present the first version of the draft Lake Weir TMDL report to local stakeholders. After the workshop, the public comments received by DEP resulted in a significant revision of the TMDL. DEP held the second workshop on May 27, 2015, in East Lake Weir, Florida, and the third workshop on July 19, 2016, in Lady Lake, Florida to present the revised draft Lake Weir TMDL report to local stakeholders. DEP announced the workshops through notices published in the *Florida Administrative Register (FAR)*, TMDL workshop announcements on DEP's TMDL homepage and Sharepoint website, advertisements on local newspapers, and email notices to interested parties.<br><br>Before the workshops, draft TMDL reports were provided to stakeholders for review and comments. A 30-day public comment period for the first and second workshops and a 14-day public comment period for the third one were provided to stakeholders for the workshop events. After these public comment periods ended, the public comments received by DEP were carefully reviewed to determine whether significant revisions to the TMDL were needed. So far, all public comments on the Lake Weir TMDLs have been addressed. Once DEP reaches an agreement with the EPA on the target setting language in the TMDL report, DEP will publish a Notice of Proposed Rule (NPR) to initiate the TMDL rule adoption process. |
| **Hearing requirements and adoption format used; responsiveness summary** | Following the publication of the NPR, DEP will provide a 21 day-challenge period. |
| **Official submittal to the EPA for review and GC certification** | If DEP does not receive a challenge, the certification package for the rule will be prepared by DEP's program attorney. At the same time, DEP will prepare the TMDL and site specific interpretation package for the TMDL and submit these documents to the EPA. |

# Appendix B: Background Information on Federal and State Stormwater Programs

In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of nonpoint source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as authorized in Chapter 403, F.S., was established as a technology-based program that relies on the implementation of BMPs that are designed to achieve a specific level of treatment (*i.e.*, performance standards) as set forth in Chapter 62-40, F.A.C. In 1994, the department's stormwater treatment requirements were integrated with the stormwater flood control requirements of the water management districts, along with wetland protection requirements, into the Environmental Resource Permit (ERP) regulations, as authorized under Part IV of Chapter 373, F.S.

Chapter 62-40, F.A.C., also requires the state's water management districts to establish stormwater PLRGs and adopt them as part of a Surface Water Improvement and Management (SWIM) plan, other watershed plan, or rule. Stormwater PLRGs are a major component of the load allocation part of a TMDL. To date, they have been established for Tampa Bay, Lake Thonotosassa, the Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka.

In 1987, the United States Congress established Section 402(p) as part of the federal Clean Water Act Reauthorization. This section of the law amended the scope of the federal NPDES permitting program to designate certain stormwater discharges as "point sources" of pollution. The EPA promulgated regulations and began implementing the Phase I NPDES Stormwater Program in 1990 to address, stormwater discharges associated with industrial activity, which includes eleven categories of industrial activity, construction activities disturbing five or more acres of land, and "large" and "medium" MS4s located in incorporated places and counties with populations of 100,000 or more. However, because the master drainage systems of most local governments in Florida are physically interconnected, the EPA implemented Phase I of the MS4 permitting program on a countywide basis, which brought in all cities (incorporated areas), Chapter 298 special districts; community development districts, water control districts, and FDOT throughout the 15 counties meeting the population criteria. The department received authorization to implement the NPDES Stormwater Program in 2000. The department authority to administer the program is set forth in section 403.0885 F.S.

Phase II NPDES stormwater program, promulgated in1999, addresses additional sources, including small MS4s and small construction activities disturbing between one and five acres, and urbanized area serving a minimum resident population of at least 1,000 individuals. While these urban stormwater discharges are technically referred to as "point sources" for the purpose of regulation, they are still diffuse sources of pollution that cannot be easily collected and treated by a central treatment facility, as are other point sources of pollution such as domestic and industrial wastewater discharges. It should be noted that Phase I MS4 permits issued in Florida include a reopener clause that allows permit revisions to implement TMDLs when the implementation plan is formally adopted.

# Appendix C: Lookup Table for Conversion of Land Use in This Report from the FLUCCS Code

| NUMBER | LAND USE TYPE | FLUCCS CODE |
|---|---|---|
| **1** | Low-density residential | 1100-1199 |
| **2** | Medium-density residential | 1200-1299 |
| **3** | High-density residential | 1300-1399 |
| **4** | Low-density commercial/institutional | 1700-1799, 1830, 1840, 8200-8999 |
| **5** | High-density commercial | 1400-1499, except 1480, 8100-8199 |
| **6** | Industrial | 1500-1599 |
| **7** | Mining | 1600-1699 |
| **8** | Open land/recreation | 1480, 1800,1810, 1850, 1890,1900-1999, 7000- 7999 |
| **9** | Pasture | 2110-2139, 2500 (horse farm), 2510 |
| **10** | Cropland | 2140-2169, 2600-2619 |
| **11** | Tree crops | 2200-2290, except 2240 |
| **12** | Feeding operations | 2300-2399, 2500, 2522 |
| **13** | Other agriculture | 1820, 2400-2499, 2540 |
| **14** | Forest/rangeland | 3000-3999, 4000-4999, 2240 |
| **15** | Water | 5000-5999 |
| **16** | Wetlands | 6000-6999 |
| **17** | Spray fields | |
| **18** | Muck farms and restoration areas | |
| **19** | Lakes | |

# Appendix D. Estimating Runoff Volume and Nutrient Loads for the Lake Weir Watershed

## A. The NRCS Curve Number Approach

The stormwater runoff volume for this TMDL analysis was estimated using the same spreadsheet model created by the SJRWMD. The key function of this spreadsheet model is to estimate the annual average runoff coefficient for each land use–soil type combination for each year. Once the runoff coefficient is decided, the runoff volume can be calculated as the product of rainfall, runoff coefficient, and acreage of the land use–soil type combination.

The SJRWMD's runoff volume spreadsheet model was built based on a 15-land use classification system. Each land use was associated with four soil hydrologic group (Types A, B, C, and D). This gives a total of 64 land use–soil type combinations. In order to calculate the runoff volume for the entire Lake Weir watershed and, at the same time, be able to quantify the runoff contribution from each land use area, the runoff coefficient for each land use–soil type combination needs to be estimated. The SJRWMD's runoff model achieved this goal by estimating a watershed-basin average stormwater runoff coefficient ($ASRC_{wb}$) first, and then derived the runoff coefficient for land use–soil type combination.

The NRCS curve number approach estimates the runoff volume from a given land surface using **Equation 1**.

$$Q = \frac{(P - 0.2*S)^2}{P + 0.8*S} \qquad \textbf{Equation 1}$$

Where,

$Q$ is the runoff volume (cm).

$P$ is the rainfall amount (cm).

$S$ is the potential soil storage (cm), which can be calculated using **Equation 2**.

$$S = \frac{2540}{CN} - 25.4 \qquad \textbf{Equation 2}$$

Where,

$CN$ is the curve number.

The curve number is a dimensionless value ranging from 0 to 100. It is used in the runoff equation to characterize the runoff potential for different land use–soil combinations. Specific curve numbers are assigned to different land use–soil combinations. In addition, curve numbers are also influenced by the antecedent moisture condition (AMC) of the soil. **Table D-1** lists the curve numbers used in this TMDL analysis. These numbers were cited in Suphunvorranop (1985) and were also used by the SJRWMD in developing the nutrient PLRG for the Upper Ocklawaha Chain of Lakes.

The curve numbers listed in **Table D-1** are established for the average soil AMC, which is commonly referred to as AMC II. The low and high soil AMCs are usually referred to as AMC I and AMC III, respectively. In the curve number approach, the soil AMC status is judged by comparing the total amount of rainfall a given watershed area received for the total of five days with a set of five-day threshold rainfall values in either the dormant season or the growth season. **Table D-2** lists the five-day threshold rainfall values used to determine the soil AMC for these TMDLs. **Table D-3** lists the curve numbers under the AMC I and AMC III corresponding to each curve number value under the AMC II condition.

**TABLE D-1. CURVE NUMBERS BY SOIL TYPES AND LAND USE TYPES**

| LAND USE | CN FOR SOIL GROUP A | CN FOR SOIL GROUP B | CN FOR SOIL GROUP C | CN FOR SOIL GROUP D |
|---|---|---|---|---|
| **Low-density residential** | 51 | 68 | 79 | 84 |
| **Medium-density residential** | 57 | 72 | 81 | 86 |
| **High-density residential** | 77 | 85 | 90 | 92 |
| **Low-density commercial** | 77 | 85 | 90 | 92 |
| **High-density commercial** | 89 | 92 | 94 | 95 |
| **Industrial** | 81 | 88 | 91 | 95 |
| **Mining** | 32 | 58 | 72 | 79 |
| **Open land/recreational** | 49 | 69 | 79 | 84 |
| **Pasture** | 47 | 67 | 81 | 88 |
| **Cropland** | 64 | 75 | 82 | 84 |
| **Tree crops** | 32 | 58 | 72 | 79 |
| **Other agriculture** | 59 | 74 | 82 | 86 |
| **Forest/rangeland** | 36 | 60 | 73 | 79 |
| **Water** | 98 | 98 | 98 | 98 |
| **Wetlands** | 89 | 89 | 89 | 89 |

**TABLE D-2. THRESHOLD FIVE-DAY ANTECEDENT RAINFALL VOLUME (CM) FOR AMC CLASSIFICATION**

| SOIL ANTECEDENT MOISTURE CONDITION CLASSIFICATION (AMC) | DORMANT SEASON (NOVEMBER–MARCH) | GROWTH SEASON (APRIL–OCTOBER) |
|---|---|---|
| **I** | < 1.3 | < 3.6 |
| **II** | 1.3 – 2.8 | 3.6 – 5.3 |
| **III** | > 2.8 | > 5.4 |

**TABLE D-3. RELATIONSHIP BETWEEN CURVE NUMBERS UNDER AMCS I, II, AND III**

| AMC I | AMC II | AMC III |
|---|---|---|
| 0 | 0 | 0 |
| 2 | 5 | 17 |
| 4 | 10 | 26 |
| 7 | 15 | 33 |
| 9 | 20 | 39 |
| 12 | 25 | 45 |
| 15 | 30 | 50 |
| 19 | 35 | 55 |
| 23 | 40 | 60 |
| 27 | 45 | 65 |
| 31 | 50 | 70 |
| 35 | 55 | 75 |
| 40 | 60 | 79 |
| 45 | 65 | 83 |
| 51 | 70 | 87 |
| 57 | 75 | 91 |
| 63 | 80 | 94 |
| 70 | 85 | 97 |
| 78 | 90 | 98 |
| 87 | 95 | 99 |
| 100 | 100 | 100 |

One common practice to calculate runoff volume from a given watershed using the curve number approach is to calculate the runoff from the pervious area and the impervious area, and then add the runoff volumes from these two areas to determine total watershed runoff. To apply this method, the impervious areas are usually divided into two types, directly connected impervious area (DCIA) and non-directly connected impervious area (NDCIA). The DCIA represents the areas that are directly connected to the stormwater drainage system. It is typically assumed that 90% of the rainfall that falls on the DICA will become runoff.

In contrast, the runoff created from the NDCIA area will reach the pervious area and contributes to the pervious area runoff. Therefore, NDCIA typically is not considered part of the impervious area. Instead, it is usually considered as part of the pervious area. **Table D-4** lists the percent areas occupied by DCIA, NDCIA, and pervious areas for each land use type used in developing these TMDLs. The SJRWMD used these percent area values in developing the nutrient PLRG for the Upper Ocklawaha Chain of Lakes. The values included in **Table D-4** were assembled by Camp Dresser and McKee (CDM 1994).

The total runoff from a watershed can be represented using **Equation 3**.

$$Q = Q_{Pervious} + Q_{DCIA} \qquad \textbf{Equation 3}$$

Where,

$Q$ is the total runoff from the watershed area (cm).

$Q_{Pervious}$ is the runoff from the pervious area (cm).

$Q_{DCIA}$ is the runoff from the DCIA (cm).

**TABLE D-4. LAND USE–SPECIFIC PERCENT DCIA, NDCIA, AND PERVIOUS AREAS**

| LAND USE | DCIA | NDCIA | PERVIOUS | SUM OF NDCIA AND PERVIOUS |
|---|---|---|---|---|
| **Low-density residential** | 5 | 10 | 85 | 95 |
| **Medium-density residential** | 15 | 20 | 65 | 85 |
| **High-density residential** | 25 | 40 | 35 | 75 |
| **Low-density commercial** | 40 | 40 | 20 | 60 |
| **High-density commercial** | 45 | 35 | 20 | 55 |
| **Industrial** | 50 | 30 | 20 | 50 |
| **Mining** | 1 | 1 | 98 | 99 |
| **Open land/recreational** | 1 | 1 | 98 | 99 |
| **Pasture** | 1 | 1 | 98 | 99 |
| **Cropland** | 1 | 1 | 98 | 99 |
| **Tree crops** | 1 | 1 | 98 | 99 |
| **Other agriculture** | 1 | 1 | 98 | 99 |
| **Forest/rangeland** | 1 | 1 | 98 | 99 |
| **Water** | 85 | 15 | 0 | 15 |
| **Wetland** | 75 | 0 | 25 | 25 |

This table was cited from the SJRWMD's nutrient PLRG for the Upper Ocklawaha River Basin. Data were assembled by CDM (1994).

The $Q_{DCIA}$ can be calculated using **Equation 4**.

$$Q_{DCIA} = P * 0.9 * \left(\frac{DCIA}{TotalArea}\right) \quad \textbf{Equation 4}$$

Where,

*P* is rainfall (cm).

*DCIA* is the area of DCIA.

*TotalArea* is the total watershed area.

The $Q_{Pervious}$ can be calculated using **Equation 5**.

$$Q_{Pervious} = \frac{\left(P' - 0.2 * S\right)^2}{P' + 0.8 * S} * \left(\frac{PerviousArea}{TotalArea}\right) \quad \textbf{Equation 5}$$

Where,

*P'* is adjusted rainfall (cm).

*S* is the potential soil storage of rainfall (cm).

*PerviousArea* is the acreage of the pervious area in the watershed.

The measured rainfall was adjusted in **Equation 5** to account for rain falling in the NDCIA area. It was assumed that rainfall on these areas would reach and uniformly spread out onto the pervious area. To account for the rain to the NDCIA area, the measured rainfall was adjusted using **Equation 6**.

$$P' = \frac{P * PerviousArea + P * NDCIA}{PerviousArea} \quad \textbf{Equation 6}$$

Where,

*NDCIA* is the area of the NDCIA.

**Equation 6** can be simplified to **Equation 7**.

$$P' = P * (1 + \frac{NDCIA}{PerviousArea})$$ **Equation 7**

The potential soil storage can be calculated using **Equation 8.**

$$S = \frac{2540}{CN_{Pervious}} - 25.4$$ **Equation 8**

Where,

$CN_{Pervious}$ is the curve number for the pervious area.

The $CN_{Pervious}$ can be derived from the watershed average curve number, which can be calculated using **Equation 9**.

$$CN_{Watershed} = \frac{\sum (Area * CN)}{TotalArea}$$ **Equation 9**

Where,

$CN_{Watershed}$ is the watershed average curve number.

*CN* is the land use–soil combination specific curve number listed in **Table D-1**.

*Area* is the area occupied by a specific land use–soil combination.

*TotalArea* is the total area of the entire watershed.

The $CN_{Watershed}$ can also be represented using **Equation 10**.

$$CN_{Watershed} = \frac{(CN_{DCIA} * Area_{DCIA}) + (CN_{Pervious} * Area_{Pervious})}{TotalArea}$$ **Equation 10**

Where,

$CN_{DCIA}$ is the curve number of the DCIA area.

$Area_{DCIA}$ is the acreage occupied by the DCIA area.

$Area_{Pervious}$ is the acreage of the watershed occupied by both NDCIA and pervious areas.

**Equation 10** can be rewritten to solve for $CN_{Pervious}$ as **Equation 11**.

$$CN_{Pervious} = \frac{(CN_{Watershed} * TotalArea) - (CN_{DCIA} * Area_{DCIA})}{Area_{Pervious}}$$ **Equation 11**

With all the above equations, the watershed runoff volume Q defined in **Equation 4** can be calculated. The watershed-basin average stormwater runoff coefficient ($ASRC_{wb}$) can be calculated as the quotient between the watershed runoff volume and rainfall to the watershed.

The $ASRC_{wb}$ can also be represented using **Equation 12**.

$$ASRC_{wb} = \frac{(DCIA * 0.9) + (PerviousArea * WRC_{Pervious})}{TotalArea}$$ **Equation 12**

**Equation 12** can be rewritten to solve for the weighted runoff coefficient for the pervious area (**Equation 13**).

$$WRC_{Pervious} = \frac{(ASRC_{wb} * TotalArea) - (DCIA * 0.9)}{PerviousArea}$$ **Equation 13**

When developing the nutrient PLRG for the Upper Ocklawaha Chain of Lakes, the SJRWMD assumed that D soils would have four times the runoff compared with A soils (Fulton *et al*. 2004). This assumption was made based on the typical depth to ground water and the resultant soil storage (**Table D-5**)

**TABLE D-5. GROUND WATER DEPTH AND SOIL RUNOFF POTENTIAL**

| SOIL TYPE | DEPTH TO GROUND WATER (M) | RUNOFF RATIO | SOIL TYPE COEFFICIENT |
|---|---|---|---|
| **A** | >1.2 | 1 | PRC |
| **B** | 0.9 | 2 | 2*PRC |
| **C** | 0.6 | 3 | 3*PRC |
| **D** | 0.3 | 4 | 4*PRC |

Based on this assumption, $WRC_{Pervious}$ can also be represented using **Equation 14**.

$$WRC_{Pervious} = \frac{PRC * Area_{Asoil} + 2PRC * Area_{Bsoil} + 3PRC * Area_{Csoil} + 4PRC * Area_{Dsoil}}{PerviousArea}$$ **Equation 14**

Where,

$PRC$ is the proportional runoff coefficient.

$Area_{Asoil}$ is the area occupied by A soil.

$Area_{Bsoil}$ is the area occupied by B soil.

$Area_{Csoil}$ is the area occupied by C soil.

$Area_{Dsoil}$ is the area occupied by D soil.

**Equation 14** can be rewritten to solve for PRC (**Equation 15**)

$$PRC = \frac{PerviousArea * WRC_{Pervious}}{Area_{Asoil} + 2 * Area_{Bsoil} + 3 * Area_{Csoil} + 4 * Area_{Dsoil}}$$ **Equation 15**

The final area weighted runoff coefficient for each land use–soil combination ($ASRC_{LS}$) is calculated using **Equation 16**.

$$ASRC_{LS} = \frac{(DCIA_{LS} * 0.9) + (PerviousArea_{LS} * n * PRC)}{TotalArea_{LS}}$$ **Equation 16**

Where,

$DCIA_{LS}$ is the DCIA area occupied by a specific land use–soil type combination.

$PerviousArea_{LS}$ is the pervious area (including the NDCIA area) occupied by a specific land use–soil type combination.

$n$ is the runoff ratio listed in **Table D-5**. The n values for A, B, C, and D soils are 1, 2, 3, and 4, respectively.

$TotalArea_{LS}$ is the total area occupied by a specific land use–soil type combination.

The SJRWMD provided the rainfall data used in calculating the runoff coefficient and runoff volume for these TMDLs. **Table 4.3** summarizes annual rainfall in the Lake Weir watershed for each year from 2000 to 2012. **Table D-6** lists the runoff coefficients for each land use–soil type combination for each year from 2000 to 2012. **Table 4.4** lists the annual runoff volume from different land use areas in the watershed.

## Table D-6. Runoff Coefficient for Different Land Use–Soil Type Combinations for Each Year from 2000 through 2012

NA = Not applicable because there is no such land use or soil type.

| Land Use | Soil | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Low-density residential** | A | 0.044 | 0.048 | 0.050 | 0.047 | 0.052 | 0.048 | 0.047 | 0.059 | 0.070 | 0.066 | 0.046 | 0.055 | 0.051 |
| **Low-density residential** | B | 0.043 | 0.052 | 0.055 | 0.049 | 0.058 | 0.051 | 0.049 | 0.073 | 0.096 | 0.086 | 0.046 | 0.064 | 0.057 |
| **Low-density residential** | C | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Low-density residential** | D | 0.042 | 0.059 | 0.066 | 0.053 | 0.071 | 0.057 | 0.054 | 0.100 | 0.146 | 0.128 | 0.048 | 0.084 | 0.069 |
| **Low-density residential** | X | 0.042 | 0.059 | 0.066 | 0.053 | 0.071 | 0.057 | 0.054 | 0.100 | 0.146 | 0.128 | 0.048 | 0.084 | 0.069 |
| **Medium-density residential** | A | 0.134 | 0.138 | 0.140 | 0.137 | 0.141 | 0.138 | 0.137 | 0.147 | 0.158 | 0.154 | 0.136 | 0.144 | 0.140 |
| **Medium-density residential** | B | 0.134 | 0.141 | 0.144 | 0.138 | 0.147 | 0.141 | 0.139 | 0.160 | 0.180 | 0.172 | 0.136 | 0.152 | 0.146 |
| **Medium-density residential** | C | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Medium-density residential** | D | 0.132 | 0.147 | 0.154 | 0.142 | 0.159 | 0.146 | 0.143 | 0.184 | 0.225 | 0.209 | 0.138 | 0.170 | 0.156 |
| **Medium-density residential** | X | 0.132 | 0.147 | 0.154 | 0.142 | 0.159 | 0.146 | 0.143 | 0.184 | 0.225 | 0.209 | 0.138 | 0.170 | 0.156 |
| **High-density residential** | A | 0.224 | 0.228 | 0.229 | 0.227 | 0.230 | 0.227 | 0.227 | 0.236 | 0.245 | 0.241 | 0.226 | 0.233 | 0.230 |
| **High-density residential** | B | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **High-density residential** | C | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **High-density residential** | D | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **High-density residential** | X | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Low-density commercial** | A | 0.360 | 0.362 | 0.363 | 0.361 | 0.364 | 0.362 | 0.361 | 0.369 | 0.376 | 0.373 | 0.360 | 0.366 | 0.364 |
| **Low-density commercial** | B | 0.359 | 0.364 | 0.367 | 0.362 | 0.368 | 0.364 | 0.363 | 0.377 | 0.392 | 0.386 | 0.361 | 0.372 | 0.367 |
| **Low-density commercial** | C | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Low-density commercial** | D | 0.358 | 0.369 | 0.373 | 0.365 | 0.377 | 0.368 | 0.365 | 0.395 | 0.424 | 0.412 | 0.362 | 0.384 | 0.375 |
| **Low-density commercial** | X | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **High-density commercial** | A | 0.405 | 0.407 | 0.408 | 0.406 | 0.409 | 0.407 | 0.406 | 0.413 | 0.420 | 0.417 | 0.405 | 0.411 | 0.408 |
| **High-density commercial** | B | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **High-density commercial** | C | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **High-density commercial** | D | 0.403 | 0.413 | 0.417 | 0.410 | 0.420 | 0.412 | 0.410 | 0.437 | 0.464 | 0.453 | 0.407 | 0.427 | 0.419 |
| **High-density commercial** | X | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Industrial** | A | 0.450 | 0.452 | 0.453 | 0.451 | 0.453 | 0.452 | 0.451 | 0.457 | 0.463 | 0.461 | 0.450 | 0.455 | 0.453 |
| **Industrial** | B | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Industrial** | C | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Industrial** | D | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |

| Land Use | Soil | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Industrial** | X | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Mining** | A | 0.008 | 0.013 | 0.014 | 0.011 | 0.016 | 0.012 | 0.011 | 0.023 | 0.035 | 0.031 | 0.010 | 0.019 | 0.015 |
| **Mining** | B | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Mining** | C | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Mining** | D | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Mining** | X | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Open land/recreation** | A | 0.008 | 0.013 | 0.014 | 0.011 | 0.016 | 0.012 | 0.011 | 0.023 | 0.035 | 0.031 | 0.010 | 0.019 | 0.015 |
| **Open land/recreation** | B | 0.007 | 0.016 | 0.020 | 0.013 | 0.023 | 0.015 | 0.014 | 0.038 | 0.062 | 0.052 | 0.011 | 0.029 | 0.021 |
| **Open land/recreation** | C | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Open land/recreation** | D | 0.006 | 0.023 | 0.031 | 0.017 | 0.037 | 0.022 | NA | NA | NA | NA | NA | NA | NA |
| **Open land/recreation** | X | 0.006 | 0.023 | 0.031 | 0.017 | 0.037 | 0.022 | 0.018 | 0.067 | 0.114 | 0.095 | 0.012 | 0.049 | 0.034 |
| **Pasture** | A | 0.008 | 0.013 | 0.014 | 0.011 | 0.016 | 0.012 | 0.011 | 0.023 | 0.035 | 0.031 | 0.010 | 0.019 | 0.015 |
| **Pasture** | B | 0.007 | 0.016 | 0.020 | 0.013 | 0.023 | 0.015 | 0.014 | 0.038 | 0.062 | 0.052 | 0.011 | 0.029 | 0.021 |
| **Pasture** | C | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Pasture** | D | 0.006 | 0.023 | 0.031 | 0.017 | 0.037 | 0.022 | 0.018 | 0.067 | 0.114 | 0.095 | 0.012 | 0.049 | 0.034 |
| **Pasture** | X | 0.006 | 0.023 | 0.031 | 0.017 | 0.037 | 0.022 | 0.018 | 0.067 | 0.114 | 0.095 | 0.012 | 0.049 | 0.034 |
| **Cropland** | A | 0.008 | 0.013 | 0.014 | 0.011 | 0.016 | 0.012 | 0.011 | 0.023 | 0.035 | 0.031 | 0.010 | 0.019 | 0.015 |
| **Cropland** | B | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Cropland** | C | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Cropland** | D | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Cropland** | X | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Tree Crops** | A | 0.008 | 0.013 | 0.014 | 0.011 | 0.016 | 0.012 | 0.011 | 0.023 | 0.035 | 0.031 | 0.010 | 0.019 | 0.015 |
| **Tree Crops** | B | 0.007 | 0.016 | 0.020 | 0.013 | 0.023 | 0.015 | 0.014 | 0.038 | 0.062 | 0.052 | 0.011 | 0.029 | 0.021 |
| **Tree Crops** | C | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Tree Crops** | D | 0.006 | 0.023 | 0.031 | 0.017 | 0.037 | 0.022 | 0.018 | 0.067 | 0.114 | 0.095 | 0.012 | 0.049 | 0.034 |
| **Tree Crops** | X | 0.006 | 0.023 | 0.031 | 0.017 | 0.037 | 0.022 | 0.018 | 0.067 | 0.114 | 0.095 | 0.012 | 0.049 | 0.034 |
| **Other agriculture** | A | 0.008 | 0.013 | 0.014 | 0.011 | 0.016 | 0.012 | 0.011 | 0.023 | 0.035 | 0.031 | 0.010 | 0.019 | 0.015 |
| **Other agriculture** | B | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Other agriculture** | C | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Other agriculture** | D | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Other agriculture** | X | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Forest/rangeland** | A | 0.008 | 0.013 | 0.014 | 0.011 | 0.016 | 0.012 | 0.011 | 0.023 | 0.035 | 0.031 | 0.010 | 0.019 | 0.015 |

| LAND USE | SOIL | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Forest/rangeland** | B | 0.007 | 0.016 | 0.020 | 0.013 | 0.023 | 0.015 | 0.014 | 0.038 | 0.062 | 0.052 | 0.011 | 0.029 | 0.021 |
| **Forest/rangeland** | C | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Forest/rangeland** | D | 0.006 | 0.023 | 0.031 | 0.017 | 0.037 | 0.022 | 0.018 | 0.067 | 0.114 | 0.095 | 0.012 | 0.049 | 0.034 |
| **Forest/rangeland** | X | 0.006 | 0.023 | 0.031 | 0.017 | 0.037 | 0.022 | 0.018 | 0.067 | 0.114 | 0.095 | 0.012 | 0.049 | 0.034 |
| **Water** | A | 0.765 | 0.766 | 0.766 | 0.765 | 0.766 | 0.765 | 0.765 | 0.767 | 0.769 | 0.768 | 0.765 | 0.767 | 0.766 |
| **Water** | B | NA | NA | NA | NA | NA | NA | 0.766 | 0.769 | 0.773 | 0.772 | 0.765 | 0.768 | 0.767 |
| **Water** | C | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Water** | D | 0.765 | 0.767 | 0.768 | 0.766 | 0.769 | 0.767 | 0.766 | 0.774 | 0.781 | 0.778 | 0.765 | 0.771 | 0.769 |
| **Water** | X | 0.765 | 0.767 | 0.768 | 0.766 | 0.769 | 0.767 | 0.766 | 0.774 | 0.781 | 0.778 | 0.765 | 0.771 | 0.769 |
| **Wetlands** | A | 0.675 | 0.676 | 0.676 | 0.676 | 0.677 | 0.676 | 0.676 | 0.679 | 0.682 | 0.680 | 0.675 | 0.678 | 0.677 |
| **Wetlands** | B | 0.675 | 0.677 | 0.678 | 0.676 | 0.678 | 0.677 | 0.676 | 0.682 | 0.688 | 0.686 | 0.675 | 0.680 | 0.678 |
| **Wetlands** | C | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Wetlands** | D | 0.674 | 0.679 | 0.681 | 0.677 | 0.682 | 0.678 | 0.677 | 0.690 | 0.702 | 0.697 | 0.676 | 0.685 | 0.681 |
| **Wetlands** | X | 0.674 | 0.679 | 0.681 | 0.677 | 0.682 | 0.678 | 0.677 | 0.690 | 0.702 | 0.697 | 0.676 | 0.685 | 0.681 |

### *B. Estimating Runoff Nutrient Loads*

The runoff nutrient loads from a watershed are calculated by multiplying the runoff volume from the land use area by runoff TN and TP concentrations specific to the land use type. These runoff nutrient concentrations are commonly referred to as event mean concentrations (EMCs). EMCs can be determined through stormwater studies in which both runoff volume and runoff nutrient concentrations are measured during the phases of a given stormwater event. The EMC for the stormwater event is then calculated as the mean concentration weighted for the runoff volume.

The TN and TP EMCs (**Table D-7**) used in this TMDL analysis were those used by the SJRWMD in the nutrient PLRG for the Upper Ocklawaha Chain of Lakes (Fulton *et a*l. 2004). Based on the SJRWMD's PLRG report, these EMCs were primarily cited from Dr. Harvey Harper's stormwater review report (1994). Several other published studies—including Izuno *et al*. (1991), Hendrickson and Konwinski (1998), Fonyo *et al*. 1991, Rushton and Dye (1993), and Goldstein and Ulevich (1981)—were also analyzed to supplement the numbers in the Harper (1994) report. The SJRWMD thought that the wetland EMCs included in the Harper (1994) report were measured from wetlands impacted by human activities (Fulton *et al*. 2004). Therefore, the wetland EMCs cited in the PLRG report were for the upland forest land use type included in the Harper (1994) report. The EMCs for the water land type were the natural background concentrations for the Lake Weir and Harris Chain-of-Lakes basins (Fulton *et al*. 2004).

**TABLE D-7. EMCS OF TN AND TP FOR DIFFERENT LAND USE TYPES**

| LAND USE | TP EMC (MG/L) | TN EMC (MG/L) |
|---|---|---|
| **Low-density residential** | 0.177 | 1.77 |
| **Medium-density residential** | 0.3 | 2.29 |
| **High-density residential** | 0.49 | 2.42 |
| **Low-density commercial** | 0.195 | 1.22 |
| **High-density commercial** | 0.43 | 2.83 |
| **Industrial** | 0.339 | 1.98 |
| **Mining** | 0.15 | 1.18 |
| **Pasture** | 0.387 | 2.48 |
| **Tree crops** | 0.14 | 2.05 |
| **Cropland** | 0.666 | 4.56 |
| **Other agriculture** | 0.492 | 2.83 |
| **Open land/recreational** | 0.057 | 1.25 |
| **Forest/rangeland** | 0.057 | 1.25 |
| **Wetlands** | 0.057 | 1.25 |
| **Water** | 0.013 | 0.49 |

Nutrient removal by stormwater treatment facilities in urban areas was also considered in simulating watershed nutrient loads. It was assumed that all urban construction after 1984, when Florida implemented the Stormwater Rule, had some type of stormwater treatment facilities to remove TN and TP loads at certain removal efficiencies. To identify the construction taking place after 1984, the watershed land use distribution data from 2004 and 2009 were compared with the land use distribution GIS shape file of 1988, which was the earliest land use GIS shape file available in DEP's GIS dataminer.

It was assumed that the urban land use areas included in the 1988 land use shape file did not have any stormwater treatment facilities required by the state Stormwater Rule. This assumption should be close to reality, because the 1988 land use shape file was created based on the 1987 land use aerial photography. Compared with the periods from 1984 to 2004 and 1984 to 2009, the chance of missing some urban construction taking place between 1984 and 1987 were relatively small, and therefore should not cause significant errors for nutrient load simulation. Any urban land areas that did not appear in the 1988 land use shape file but appeared in the 2004 or 2009 land use shape files were considered new construction with stormwater treatment facilities. When calculating watershed nutrient loads, the loads from these urban land use areas are subject to stormwater treatment and TN and TP removal at certain percentages. Based on studies of 13 stormwater treatment systems, it was assumed that 63% of the phosphorus load and 42% of the nitrogen load can be removed by these urban stormwater facilities (Fulton *et al*. 2004).

Another aspect of the nutrient load simulation was the effective delivery of nutrient to the receiving water after going through the overland transport process. In this TMDL analysis, all dissolved components of TN and TP were considered to reach the receiving water without any loss, while particulate fractions of TN and TP were considered subject to loss through the overland transport process. Therefore, the amount of nutrients eventually reaching the receiving water includes two components: the unattenuated dissolved fraction (T) and the particulate fraction that is attenuated through the overland transport process. The portion of the nutrients that eventually reaches the receiving water can be represented using **Equation 17**, which is a function established in the Reckhow *et al*. (1989) analyses.

$$D = (1-T) * e^{(1.01-0.34*\ln(L))} + T$$ **Equation 17**

Where,

*D* is the amount of nutrients that eventually reaches the receiving water.

*T* is the dissolved fraction of the total nutrient (TN and TP) concentrations.

*(1-T)* is the particulate fraction of the total nutrient (TN and TP) concentrations.

The exponential item of the equation represents the delivery ratio of the particulate nutrients.

*L* is the length of the overland flow path.

The percent dissolved TN and TP concentrations for the different land uses in this TMDL analysis were cited from the SJRWMD's Upper Ocklawaha Chain of Lakes PLRG report (Fulton et al. 2004). These numbers were created by comparing concentrations of TN, TP, orthophosphate ($PO_4$), total dissolved phosphorus (TDP), and total dissolved nitrogen (TDN) from several studies on stormwater runoff conducted in Florida (Hendrickson 1987; Fall and Hendrickson 1988; German 1989; Fall 1990; Dierberg 1991; Izuno *et al.* 1991; and Harper and Miracle 1993). **Table D-8** lists the percent concentration of dissolved phosphorus and nitrogen for different land uses.

The distance between the subwatershed centroid and the boundary of the lake was considered the length of the overland flow path. When estimating runoff volume and nutrient loads from the Lake Weir watershed, the watershed was divided into four subwatersheds (NE, NW, SE, and SW). Therefore, the lengths of the overland flow path were estimated as 647 m for NE, 536 m for NW, 502 m for SE, and 1,022 m for SW (Dr. R.S. Fulton, SJRWMD, personal communication).

**Tables 4.5a** and **4.5b** list the stormwater runoff TN and TP loads for the Lake Weir watershed estimated using the procedures described above.

## Table D-8. Dissolved Fraction of TN and TP Concentrations for Different Land Uses

| Land Use | % Dissolved Phosphorus | % Dissolved Nitrogen |
|---|---|---|
| **Low-density residential** | 50.1% | 75.3% |
| **Medium-density residential** | 50.1% | 75.3% |
| **High-density residential** | 50.1% | 75.3% |
| **Low-density commercial** | 41.4% | 65.7% |
| **High-density commercial** | 76.7% | 76.7% |
| **Industrial** | 76.1% | 76.1% |
| **Mining** | 46.7% | 65.7% |
| **Pasture** | 72.2% | 90.8% |
| **Tree crops** | 62.9% | 90.8% |
| **Cropland** | 60.0% | 90.8% |
| **Other agriculture** | 68.7% | 90.8% |
| **Open land/recreational** | 50.1% | 75.3% |
| **Forest/rangeland** | 50.1% | 75.3% |
| **Wetlands** | 50.7% | 77.5% |
| **Water** | 11.8% | 41.3% |

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